



GIS 507/DGIS 507

M.A. /M.Sc. Geo-informatics/DGIS

**RECENT TRENDS IN GEOINFORMATICS
PART-1**

**DEPARTMENT OF REMOTE SENSING AND GIS
SCHOOL OF EARTH AND ENVIRONMENT SCIENCE
UTTARAKHAND OPEN UNIVERSITY
HALDWANI (NAINITAL)**

RECENT TRENDS IN GEOINFORMATICS PART-1



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BLOCK 1 : CLOUD COMPUTING

UNIT 1 - CLOUD COMPUTING BASICS (SAAS, PAAS, LAAS) LIKE ARC GIS CLOUD

1.1 OBJECTIVES

1.2 INTRODUCTION

1.3 CLOUD COMPUTING BASICS (SAAS, PAAS, LAAS) LIKE ARC GIS CLOUD

1.4 SUMMARY

1.5 GLOSSARY

1.6 ANSWER TO CHECK YOUR PROGRESS

1.7 REFERENCES

1.8 TERMINAL QUESTIONS

1.1 OBJECTIVES

After reading this unit you should be able to know about:

- Infrastructure-as-a-Service (IaaS) and Platform-as-a-Service (PaAS),
- Hybrid cloud and multi cloud,
- Test and development
- Big data analytics,
- Cloud storage,
- Disaster recovery,
- Data backup

1.2 INTRODUCTION

Cloud computing is on-demand access to computing resources—applications, servers (physical and virtual), data storage, development tools, networking capabilities, and more—hosted at a remote data center controlled by a cloud services provider and accessible via the internet (or CSP). The CSP charges a monthly subscription fee for these resources or bills them based on usage.

Cloud computing, when compared to traditional on-premises IT and depending on the cloud services you choose, can help you perform the following:

Reduced IT expenditures: Cloud computing allows you to offload part or all of the costs and work associated with purchasing, installing, configuring, and administering your own on-premises equipment.

Improve time-to-value and agility: Instead of waiting weeks or months for IT to reply to a request, acquire and setup supporting hardware, and install software, your company can start using corporate apps in minutes using cloud. You can also give particular individuals, such as developers and data scientists, access to applications on the cloud.

Easily and cost-effectively scale: You can scale capacity up and down in response to traffic spikes and dips in the cloud, rather of acquiring excess capacity that sits unused during dull periods. You can also use the worldwide network of your cloud provider to bring your applications closer to users all around the world.

Cloud computing also refers to the technology that enables cloud computing to function. This comprises virtualized IT infrastructure, which consists of servers, operating system software, networking, and other infrastructure that has been abstracted using special software and may be pooled and divided across physical hardware boundaries. A single hardware server, for example, can be partitioned into numerous virtual servers.

Virtualization allows cloud providers to get the most out of their data centers. Many companies, predictably, have adopted the cloud delivery model for their on-premises infrastructure in order to maximize utilization and cost savings over traditional IT infrastructure while still providing the same self-service and agility to their end-users.

Whether it's a cloud application like Google Gmail or Salesforce, streaming video like Netflix, or cloud file storage like Dropbox, if you use a computer or mobile device at home or at work, you almost definitely use some type of cloud computing every day. According to a recent survey, 92 percent of firms are already using cloud ([link is external to IBM](#)), and the majority of them want to utilize it more in the coming year.

Benefits of cloud computing

The unique properties of cloud infrastructures provide several novel technical and business benefits. The following are the key cloud computing benefits for agile teams.

1.Reduced cost

Teams that use cloud resources do not have to purchase their own hardware assets. Beyond hardware costs, cloud providers do their best to maximize and optimize hardware usage. This transforms hardware and computing resources into a commodity, and cloud providers compete to offer the lowest bottom line.

2. Increased scalability

Since cloud computing is elastic by default, organizations can scale resources on demand. Cloud computing enables auto-scaling features for teams. Cloud applications can automatically shrink and grow their infrastructure resources in response to spikes of traffic.

3. Better performance

Cloud computing offers the latest and greatest computational resources. Users can access the newest machines with extreme, multi-core CPUs designed for heavy parallel processing tasks. Additionally, major cloud providers offer cutting-edge GPU and TPU hardware machines for intense graphical, matrix, and artificial intelligence processing tasks. These cloud providers consistently update with the latest in processor technology.

Major cloud computing providers have globally distributed hardware locations that ensure high performance connections depending upon the physical connection location. Additionally, cloud providers offer global content delivery networks that cache user requests and content by location.

4. Improved execution speed

Teams that use cloud infrastructures can more rapidly execute and deliver value to their customers. Agile software teams can leverage a cloud infrastructure to rapidly spin up new virtual machines to experiment and validate unique ideas, and automate the testing and deployment phases of the pipeline.

5. Increased security

Private cloud hosting offers isolated firewalled infrastructure that improves security. In addition, cloud providers offer many security mechanisms and technologies to help build secure applications. User access control is an important security concern, and most cloud providers offer tools to limit granular user access.

6. Continuous integration and delivery

Continuous integration and continuous delivery (CI/CD) is a key practice for DevOps practitioners that helps to increase team velocity and reduce time to market. Cloud-based CI/CD, such as Bitbucket Pipelines, allows teams to automatically build, test and deploy code, without worrying about the management or maintenance of the CI infrastructure. Bitbucket Pipelines relies on Docker containers to provide isolation and reproducibility of the release pipeline. Teams can run commands similar like they might on a local machine, but with all the advantages of a fresh and reproducible setup for each build.

7. Comprehensive monitoring and incident management

Cloud deployments allow teams to connect their tools from end to end, making it easier to monitor all parts of the pipeline. Comprehensive monitoring is another key capability for organizations practicing DevOps because it allows them to address issues and incidents faster. Cloud providers share metrics about the health of the system, including application and server CPU, memory, request rate, error rate, average response time, etc. For example,

monitoring the load across many virtual machines means that teams can add more capacity (VMs) if there is an increase in demand, or teams can automate the scaling (up/down) based on those metrics to reduce human intervention and costs.

1.3 CLOUD COMPUTING BASICS (SAAS, PAAS, LAAS) LIKE ARC GIS CLOUD

In network diagrams, cloud is frequently used as a metaphor for the Internet. Cloud computing is a novel method of delivering IT services over the internet (Internet or intranet). It was not created in a single day by a "Big Bang." This revolutionary computing style is the result of technological progress, maturity, development, and advancements over the last 50 years. My blog piece on the evolution of cloud computing may be of interest to readers.

In this piece, I'll go through the fundamentals, characteristics, differentiators, and benefits of cloud computing that a newbie should be aware of.

I prefer to utilize the National Institute of Standards and Technology's definition of cloud over the many others available online (NIST). NIST claims that:

"Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction," according to Wikipedia.

It exhibits five key properties of cloud computing, three service models, and four deployment models.

The following are the five criteria that characterize cloud computing:

1. Self-service on demand. This entails automatically supplying or de-provisioning computer resources as needed without the need for human interaction. Electricity as a utility, where a consumer can turn on or off a switch on-demand to utilize as much electricity as needed, is a good parallel.

2. Network access that is available anywhere. This means that computing resources can be accessed across the network from any location using any thin or thick client (for example smartphones, tablets, laptops, personal computers and so on).

3. Pooling of resources. This implies that computing resources are pooled to satisfy customer demand, allowing resources (physical or virtual) to be dynamically assigned, reassigned, or de-allocated as needed. In most cases, customers are unaware of the precise location of computing resources. They may, however, be able to designate a place (country, city, region, and so on) for their requirement. For example, as a consumer, I might want to host my services with a cloud provider with cloud data centers located within Australia's borders.

4. Flexibility that is quick. Cloud computing gives users the appearance of boundless computer resources. Resources can be elastically provisioned or released according to demand in cloud models. My cloud-based online services, for example, should be able to withstand a sudden spike in traffic demand by elastically extending resources. When the peak has passed, any resources that are no longer needed can be released automatically.

5. Accurate service. This means that customers are only charged for the computing resources they use. This is comparable to how utilities like water and electricity work.

The three most basic cloud service models are IaAS (Infrastructure-as-a-Service), PaAS (Platform-as-a-Service), and SaAS (Software-as-a-Service), and it's not uncommon for a company to employ all three. However, there is frequently misunderstanding about the three and what each includes:

SaaS (Software as a Service) (Software-as-a-Service)

Application software that is hosted in the cloud and that you access and use via a web browser, a dedicated desktop client, or an API that connects with your desktop or mobile operating system is known as SaaS. SaaS users typically pay a monthly or annual subscription fee, while some companies may provide 'pay-as-you-go' pricing depending on your actual usage.

SaaS provides the following benefits in addition to cost savings, time-to-value, and scalability:

Automatic upgrades: With SaaS, you can take advantage of new features as soon as they are released by the provider, rather than needing to plan an on-premises upgrade.

Data loss protection: Because your application data is stored in the cloud, you will not lose data if your device crashes or malfunctions.

Most commercial software now is delivered via SaaS—there are hundreds of thousands of SaaS solutions available, ranging from very targeted industry and departmental apps to sophisticated enterprise software databases and AI (artificial intelligence) software.

PaaS (Platform as a Service) (Platform-as-a-Service)

PaaS provides software developers with an on-demand platform—hardware, a complete software stack, infrastructure, and even development tools—for running, creating, and managing applications without the cost, complexity, or inflexibility of doing so on-premises.

With PaaS, the cloud provider manages everything in their data center, including servers, networks, storage, operating system software, middleware, and databases. 'Topspin up' the servers and environments they need to operate, build, test, deploy, maintain, update, and grow applications, developers simply select from a menu.

Containers, a virtualized computation paradigm one step removed from virtual servers, are frequently used in PaaS nowadays. Containers virtualize the operating system, allowing developers to bundle a programmed with only the operating system services it requires in order for it to function on any platform without modification or middleware.

Red Hat is a software company that specializes on OpenShift is a popular PaaS based on Docker containers and Kubernetes, an open-source container orchestration that automates container-based application deployment, scaling, load balancing, and more.

IaaS stands for Infrastructure as a Service (Infrastructure-as-a-Service)

IaaS provides pay-as-you-go access to basic computing resources such as physical and virtual servers, networking, and storage over the internet. End users can scale and shrink resources as needed with IaaS, which eliminates the need for large, upfront capital expenditures, unnecessary on-premises or 'owned' infrastructure, and overbuying resources to accommodate periodic spikes in usage.

IaaS, in contrast to SaaS and PaaS (and even newer PaaS computing paradigms like containers and serverless), gives consumers the most control over cloud computing resources.

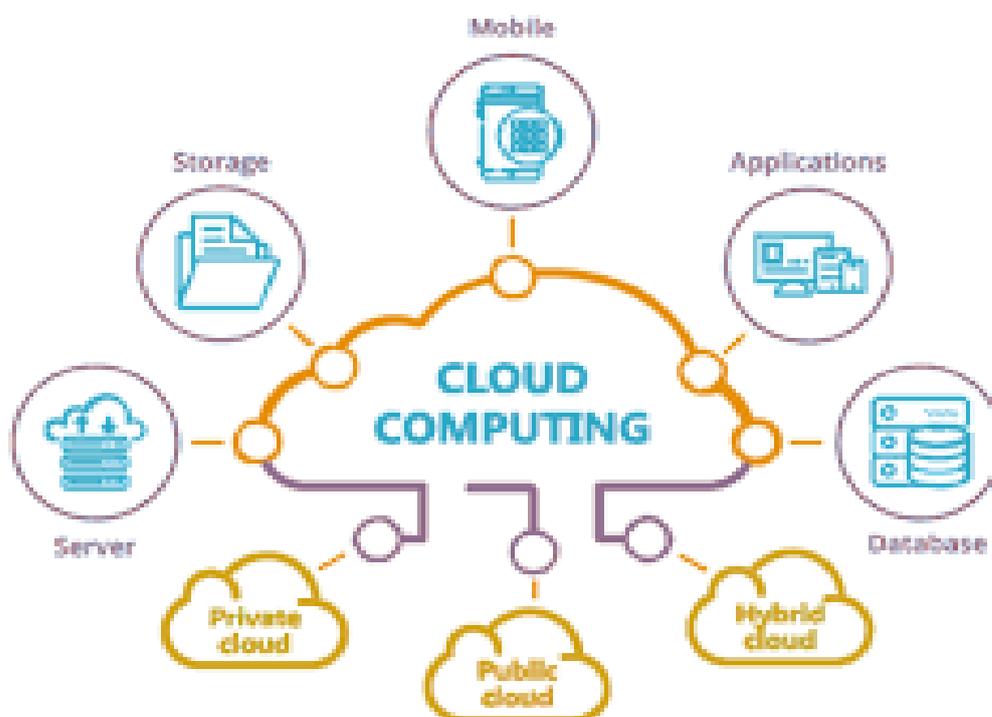
When it first appeared in the early 2010s, IaaS was the most popular cloud computing model. While the cloud model is still the most popular for many types of workloads, SaaS and PaaS are growing at a much faster rate.

Computing without a server

Serverless computing (sometimes known as just serverless) is a cloud computing approach that delegates all backend infrastructure management responsibilities to the cloud provider, allowing developers to concentrate all of their time and effort on the code and business logic particular to their applications.

Furthermore, serverless only runs application code per-request and automatically adjusts the supporting infrastructure up and down in response to the number of requests. Customers never pay for idle capacity when using serverless since they only pay for the resources consumed when the application is active.

FaaS, or Function-as-a-Service, is frequently confused with serverless computing, but it's actually a subset of the latter. FaaS enables developers to respond to specific events by executing sections of application code (called functions).



Source:https://www.google.com/imgres?imgurl=https%3A%2F%2Fmiro.medium.com%2Fmax%2F640%2F1*ngkHgQq7ij1NBNr62er3zA.png&imgrefurl=https%3A%2F%2Fmedium.com%2F%40colinbaird_51123%2Fa-primer-on-cloud-computing-9a34e90303c8&tbnid=pv8N90kRl6Z0vM&vet=12ahUKEwiBsfPkzcb0AhUyxDgGHZxdAIYQMygBegUIARDOAQ..i&docid=7goqGwTb0AoRwM&w=640&h=469&itg=1&q=image%20of%20cloud%20computing&ved=2ahUKEwiBsfPkzcb0AhUyxDgGHZxdAIYQMygBegUIARDOAQ

To describe how cloud computing works, I was given 500 words. Because the challenge was so intriguing, I had no choice but to accept it.

To appreciate the advantages of this new method of offering cloud computing resources, you must first comprehend what cloud computing is. Second, you should be familiar with the

several types of cloud services accessible, including infrastructure as a service (IaaS), platform as a service (PaAS), software as a service (SaAS), and business process as a service (BPaaS) (BPaaS). Each service builds on the one before it.

So, how does it function in practice? Starting with the Cloud Computing Reference Architecture is an excellent approach (CCRA). I don't mean to imply that the CCRA is the Holy Grail and that it should be followed to the letter at all times, but it does give you enough knowledge to come up with your own solution and understand the architecture.

The infrastructure on which the cloud will be installed is the first building block. Some people believe that the environment should be virtualized, but because the cloud is a mechanism to request resources on demand, and if you have solutions that can be provided on bare metal, why not? Different forms of cloud will be supported by the infrastructure (IaaS, PaAS, SaAS, BPaaS).

Operating System Services (OSS), which is in charge of providing the requested service, and Business System Services (BSS), which is primarily used to validate the request and prepare the invoice for the requested services, are required to provide these services. The invoice could be created using any measure (for example, the number of users, CPUs, RAM, and use hours per month). It is quite adaptable and is determined by the service provider.

Interfaces and tools for service producers and users will be required in a cloud computing environment. The Cloud Service Creator and Cloud Service Consumer components play this role.

Let's take a look at how it works in practice.

In most cases, you log in to a portal (either enterprise or public) and order services through the Cloud Service Consumer. The cloud service provider has constructed this service, which can be a simple virtual machine (VM) based on an image, some network components, an application service such as a WebApp environment, and a service such as MongoDB. It is dependent on the resource and service provider as well as the type of resources and services.

What is cloud computing and how does it work?

The supply of computer resources through the internet, such as storage, processing power, databases, networking, analytics, artificial intelligence, and software applications, is known as cloud computing (the cloud). Companies can get the computing assets they need when they need them by outsourcing these resources rather than purchasing and maintaining a physical, on-premise IT infrastructure.

This allows for more flexible resources, faster innovation, and cost savings. A cloud migration is often linked to data and IT transformation for many businesses.

Cloud computing characteristics

Prior to cloud computing, businesses had to purchase and manage their own IT infrastructure. Despite the fact that cost savings drove much of the early shift to the cloud, many firms are discovering that public, private, or hybrid cloud infrastructure offers a number of advantages. Cloud computing allows agile and DevOps teams to simplify and speed their development processes.

A list of features that describe cloud computing follows.

Self-service on demand

Users can utilize APIs provided by cloud computing providers to request additional resources or scale current resources as needed. Infrastructure as code solutions like Terraform and Ansible can help teams automate infrastructure provisioning in a simple way.

Access to a large network

When it comes to providing the best end-user experience, physical hardware location is crucial. Cloud computing is a big benefit since it allows enterprises to strategically deploy location-targeted Pooling of resources

A cloud infrastructure platform's computing resources are dynamically partitioned and allocated on demand. Cloud hardware is thoroughly tuned for maximum consumption because a cloud host's physical machines are dynamically deployed and shared among several tenants.

Quick elasticity

Users can request that their computational resources auto-scale with traffic demands, as cloud infrastructures can grow and decrease dynamically. Elasticity can occur on a per-machine basis, where an allocation of resources grows to utilize the available machine resources, or on a multi-machine basis, when an application scales to several networked machines automatically, hardware because it offers globally distributed physical hardware.

Measured Services

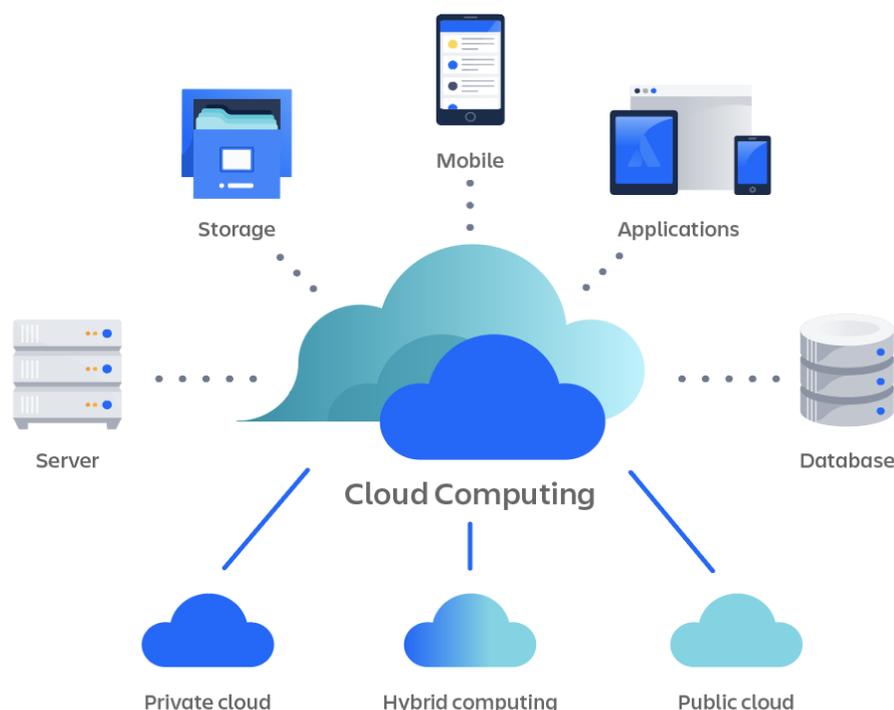
Providers of cloud infrastructure provide extensive consumption analytics that are used to explain charges. Amazon Web Services (AWS), for example, tracks usage in hourly or daily line items for each service category. Customers are charged for the exact amount of computer resources utility Service that is measured.

Providers of cloud infrastructure provide extensive consumption analytics that are used to explain charges. Amazon Web Services (AWS), for example, tracks usage in hourly or daily line items for each service category. Customers are charged for the exact amount of computer resources utilized by cloud service providers, who use a utility-style pay-as-you-go billing approach that is measured and provided by cloud service providers, who use a utility-style pay-as-you-go billing approach that is measured and provided.

Cloud computing makes advanced computing capabilities on-demand, scalable as needed, with regular updates, and without the need to purchase and maintain on-premise infrastructure. Teams become more effective and reduce time to market with cloud computing because they can quickly acquire and scale services without the significant effort required to manage traditional on-premise infrastructure.

TYPES OF CLOUD DEPLOYMENT

Cloud deployments come in a variety of shapes and sizes. Cloud installations can be divided into three categories. Each has its own set of advantages, and it's common for businesses to use more than one.



Source: (<https://wac-cdn.atlassian.com/dam/jcr:0f791cd5-c80c-4641-b10c-09c9c9b9a8b7/Cloud%20computing.png?cdnVersion=113>)

Cloud computing in the public domain

A cloud service provider, such as Amazon Web Services or Microsoft Azure, delivers computer resources — servers, storage, apps, and so on — through the internet. All hardware, software, and other supporting infrastructure is owned and operated by cloud providers.

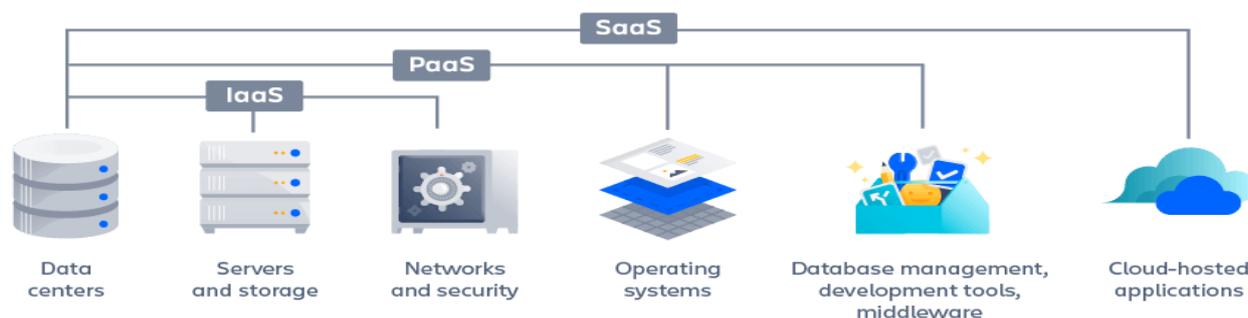
Cloud computing on a private basis

A private cloud is a set of computing resources allocated solely to a single company. It might be hosted by a cloud provider or physically located in an organization's on-site data center. By providing dedicated resources to businesses, a private cloud provides a higher level of protection and privacy than public clouds.

Customers that use a private cloud benefit from the same features as those who use a public cloud, such as self-service, scalability, and elasticity, but with more control and personalization. Furthermore, because they are hosted on private networks that are not open to public traffic, private clouds can provide a higher level of security and anonymity.

Cloud-hybrid

Hybrid clouds are a mix of private and public clouds (for example, IBM Hybrid Cloud, powered by Red Hat), linked by technology that allows data and applications to communicate with each other. Secure private clouds can house sensitive services and applications, whereas public clouds can house publicly accessible web servers and customer-facing endpoints. The majority of well-known third-party cloud providers provide a hybrid cloud model, which allows users to combine private and public clouds to meet their needs. This gives organizations more freedom in deploying their application's customized infrastructure requirements.



Source: (<https://wac-cdn.atlassian.com/dam/jcr:24991a7a-efa0-4ebc-8c2f-65d13741f535/paas-diagram.png?cdnVersion=113>)

Cloud computing's dynamic features lay the groundwork for new higher-level services. These services can help agile and DevOps teams not only complement, but also supply essential services.

As a service infrastructure

Infrastructure as a service (IaaS) is a core cloud service layer that allows businesses to rent IT infrastructure from a cloud provider, such as servers, storage, networks, and operating systems. Users can reserve and provision resources from raw physical server warehouses using IaaS. Users can also reserve pre-configured computers for specialized activities like as load balancers, databases, email servers, and distributed queues using IaaS. DevOps teams can use IaaS as the foundation for building a DevOps toolchain, which can include a variety of third-party technologies.

As a service platform

PaaS is a cloud infrastructure built on IaaS that provides resources for developing user-level tools and applications. It includes computation, network, and storage resources, as well as development tools, database management systems, and middleware. PaaS makes use of IaaS to automatically allocate resources for a language-based tech stack. Ruby On Rails, Java Spring MVC, MEAN, and JAM stacks are all popular language technology stacks. Customers that use PaaS can simply submit an artefact of their application code, which is then automatically deployed to the PaaS' infrastructure. This is a unique and powerful approach that allows teams to focus solely on their business application code, without having to worry about hosting or infrastructure. The PaaS handles infrastructure scaling and monitoring automatically to grow or shrink resources in response to observed traffic demands.

As a service (SaAS)

Software as a service (SaAS) is a subscription-based service that offers software applications via the internet on demand. The application is hosted and managed by the cloud providers, who also handle software upgrades and security patches as needed. CRM systems, webmail apps, productivity tools such as Jira and Confluence, analytics tools, monitoring tools, chat applications, and more are all examples of SaAS.

Serve as a service

FaaS (function as a service) is a cloud computing service that provides users with a platform to design, execute, and manage applications. This eliminates the requirement for developers to construct and maintain the infrastructure required to create and launch an app. Cloud

providers give cloud resources, run a block of code, produce the result, and then delete the resources used.

1.4 SUMMARY

The transmission of computing resources over the internet is known as cloud computing. Cost reductions, scalability, high performance, economies of scale, and more are all available. A cloud migration is often linked to data and IT transformation for many businesses.

The phrase "the cloud" had an esoteric ring when it first appeared in the early 2000s. It sounded like science fiction to access computing resources from somewhere other than an on-premise IT infrastructure (the sky?). The reality was far more significant, and it irrevocably altered technology and economic practices.

1.5 GLOSSARY

AWS (Amazon Web Services) - AWS (Amazon Web Services) is a set of cloud computing services offered by Amazon.com that together comprise a comprehensive cloud platform. AWS is the most popular cloud service provider, with almost 30% global market share in cloud IaAS as of 2015. It offers over three dozen cloud services spanning the IaAS, PaAS, and SaAS paradigms of cloud computing. Amazon EC2, Amazon Elastic Beanstalk, and Amazon S3 are all well-known AWS services.

API (Application Programming Interface) - An API (application programming interface) is a user interface that allows them to obtain data from another service and incorporate it into their own application. The asking application is granted limited access to the called upon application's capabilities via a set of defined requests.

BaAS (Backend-as-a-Service) – Backend as a service (BaAS) or mobile backend as a service (mBaAS) is a cloud computing model in which a vendor gives tools and services to web and mobile application developers to establish a cloud backend for their apps. Developers may connect their apps to backend cloud storage and services like user management, push alerts, and social network integration using bespoke SDKs and APIs from BaAS vendors.

Big Data: is a wide term that refers to unusual data sets that are either too vast or too complicated to be handled using regular data-processing methods.

A cloud application is one that operates on the internet.

Cloud Backup — The process of backing up data to a remote, cloud-based server is known as cloud backup.

Cloud computing is the delivery of information technology services via a network, most commonly the internet. Infrastructure, data, and software are hosted by the vendor and supplied to the user as a service, just like water or electricity is delivered by a utility company. Cloud computing has five important qualities, according to the official NIST definition: on-demand self-service resource provisioning, broad network access, resource pooling, quick elasticity, and measurable service.

Infrastructure as a service, software as a service, and platform as a service are the three basic cloud computing models.

Cloud Foundry — Developed as a joint venture between VMware and EMC, Cloud Foundry is an open-source cloud platform as a service.

Cloud Management Platform (CMP) - A cloud management platform (CMP) is a tool that allows users to manage public, private, and hybrid cloud systems in a single interface. Customers can explore and subscribe to software applications and developer services that are based on, integrate with, or augment the CSP's main product in a cloud marketplace run by a cloud service provider (CSP). Cloud marketplaces include Amazon's AWS Marketplace and Microsoft's Azure Store.

Cloud migration: is the process of moving all or part of a company's data, apps, and services from on-premise to the cloud.

Cloud native apps: Apps created exclusively for cloud platforms are known as cloud native apps.

Cloud Washing – Cloud washing is a deceptive marketing technique used to rebrand old products by connecting them to the cloud, or at least to the term cloud.

Cloud Service Provider (CSP) – A Cloud Service Provider (CSP) is a company that offers a cloud computing service, such as PaaS, IaaS, or SaaS, to individuals or other businesses.

Cloud Sourcing – Cloudsourcing is the act of replacing traditional on-premise IT operations with low-cost cloud-based services.

Cloud Storage – Cloud storage is a model of computer storage in which data is stored in facilities (often multiple facilities) managed by a hosting company (cloud service provider) and is accessed remotely by the user via a network.

Container – A container a virtualization instance in which the kernel of an operating system allows for multiple, isolated user-space instances. Unlike virtual machines (VMs), containers do not need to run a full-blown operating system (OS) image for each instance. Instead, containers are able to run separate instances of an application within a single shared OS.

Content Delivery Network (CDN) – A content delivery network (CDN) is a network of distributed services that deliver content to a user based on the user's geographic proximity to servers. CDNs allow speedy content delivery for websites with high traffic volume or large geographic reach.

Customer Relationship Management (CRM) – Customer Relationship Management (CRM) applications allow a business to manage relationships with current and future customers by providing the business with tools to manage sales, customer service, and technical support roles. SaaS CRM applications, such as Salesforce.com, are very popular.

Data Migration– The process of moving data between two or more storage systems, data formats, warehouses or servers.

Database – A database is an organized collection of data.

DevOps– An amalgamation of “development” and “operations,” DevOps is the combination of tasks performed by an organization's applications development and systems operations teams. The DevOps software development method emphasizes collaboration, communication and integration between developers and other IT personnel with the goal of streamlining software development and quality assurance.

Elasticity – In cloud computing, elasticity is a term used to reference the ability of a system to adapt to changing workload demand by provisioning and deprovisioning pooled resources so that provisioned resources match current demand as well as possible.

Enterprise Application – An enterprise application is an application (or software) that is intended for large scale use by a (large) business.

Enterprise Resource Planning (ERP) – Enterprise Resource Planning (ERP) software allows a business or organization to manage a suite of integrated applications which are used to collect, manage, and store data on a variety of business activities. ERP solutions are often offered as a service.

Extensibility- The ability of a cloud solution to add new runtime and framework support via community build packs.

Federated Database– A system in which multiple databases appear to function as a single entity. However, the databases typically involved in this kind of system exists independently of the others. Once the different databases are “combined”, one federated database is formed.

Google Cloud Platform (GCP) – Google Cloud Platform (GCP) is a comprehensive cloud platform offered by Google, Inc. that consists of both infrastructure as a service (IaaS) and platform as a service (PaAS) offering.

Guest Machine – See virtual machine

Host Machine – A host machine is a piece of physical hardware that hosts virtual machines.

Hybrid Cloud – A hybrid cloud is a cloud computing environment that is comprised of a mix of private cloud, public cloud, and on-premises solutions. In a hybrid cloud, private and public cloud infrastructures remain distinct from one another but are bound together by technology that allows data and services portability between them.

Hypervisor – A hypervisor or virtual machine monitor (VMM) is a piece of software that allows physical devices to share their resources among virtual machines (VMs) running on top of that physical hardware. The hypervisor creates, runs and manages VMs.

Infrastructure – Information technology (IT) infrastructure is a combined set of hardware and virtual resources that support an overall IT environment.

Infrastructure as a Service (IaaS) – Infrastructure as a Service (IaaS) is a model of cloud computing in which the vendor hosts virtualized computing resources, as well as network and storage resources, and provides them to the user as a service via the internet.

Integrated Development environment (IDE) – An integrated development environment (IDE) is an application that provides a programming environment for developers. An IDE typically includes a code editor, automation tools, and a debugger.

Linux – Linux is an open-source operating system, built on Unix that is used for the majority of cloud services.

Load Balancing – The process of distributing computing workloads across multiple resources, such as servers. In cloud computing, a load balancer acts as a reverse proxy and distributes application traffic to multiple servers in order to prevent any single application server from becoming a point of failure.

Managed Service Provider (MSP) – A managed services provider (MSP) is an IT services provider that provides fully outsourced network, application, and system services across a network to clients.

Microservices – Microservices or microservice architecture is a way of designing applications in which complex applications are built out of a suite of small, independently deployable services. These ‘microservices’ run their own processes and communicate with one another using lightweight mechanisms such as language-agnostic APIs. Microservices are independently deployable and scalable, and can even be written in different languages.

Microsoft Azure – Microsoft Azure, formerly known as Windows Azure, is Microsoft's cloud computing platform. Azure was originally launched as a PaaS solution but now provides both PaaS and IaaS services.

Middleware – Middleware is software that connects software components or enterprise applications.

Multi-Cloud – A multi-cloud strategy is the concurrent use of separate cloud service providers for different infrastructure, platform, or software needs. A multi-cloud approach can help prevent vendor lock-in, and may help an enterprise deal with diverse workloads and partners. However, a multi-cloud approach can complicate many processes, such as security and governance, and a Cloud management platform is recommended for this approach.

Multi-Tenancy – Multi-Tenancy is a mode of operation for software in which multiple instances of one or many applications run in a shared environment. In a cloud computing model, pooled physical and virtual resources are dynamically assigned and reassigned to tenants according to consumer demand.

On-Demand Self Service – A cloud computing service model by which a customer can provision additional cloud resources on-demand, without involving the service provider. Resources are typically provisioned through an online control panel.

On-Premise – On Premise technology is software or infrastructure that is run on computers on the premises (in the building) of the person or organization using the software or infrastructure. Microsoft Office Suite is an example of on-premise software because it needs to be installed on the computer that runs it, while Office365 is not, because it is accessed via the internet and run remotely.

Open Source – Open Source is a development model in which a product's source code is made openly available to the public. Open-source products promote collaborative community development and rapid prototyping. OpenStack and Cloud Foundry are examples of an open-source cloud computing platform.

Open Stack – OpenStack is a free, open-source cloud platform that is primarily deployed as an infrastructure as a service offering.

Personal Cloud – An example of cloud washing, Personal Cloud is a marketing term often used to describe network attached storage (NAS) devices. A NAS device is a computer connected to a network that provides data storage services to other devices on the network.

Platform – In computing, a platform is defined as a computer system that applications run on, or as a base of technologies on which other technologies (such as applications) are built.

Platform as a Service (PaAS) – Platform as a Service (PaAS) is a model of cloud computing in which a vendor provides the hardware and software tools necessary to create, deploy and manage applications at scale to the user via the internet, as a service.

Private Cloud – A private cloud is a cloud infrastructure that is provisioned for use by a single organization comprised of multiple users. A private cloud can be managed and operated by the organization, a third party, or some combination of them, and it can exist on or off premises.

Public Cloud – A public cloud is a cloud infrastructure that is hosted by cloud services provider and is made available to the public via the internet.

Resource – In computer science, a resource is any component within a computer system that is of limited availability.

Scalability – Scalability is the ability of a process, system, or framework to handle a growing workload. In other words, a scalable system is adaptable to increasing demands. The ability to scale on demand is one of the biggest advantages of cloud computing.

Service Level Agreement (SLA) – A service level agreement (SLA) is a contractual agreement between a customer and a cloud service provider (CSP) which defines the level of service, availability and performance guaranteed by the CSP.

Shared Resources – Shared Resources, also known as network resources, are computing resources that can be accessed remotely through a network, such as a Local Area Network (LAN) or the internet.

Software as a Service (SaaS) – Software as a service (SaaS), is a model of cloud computing in which applications (software) are hosted by a vendor and provided to the user as a service. SaaS applications are licensed on a subscription basis and are made available to users over a network, typically the internet.

Because SaaS applications can be accessed at any time, at anyplace, and on any platform, they have become a popular model for delivery of many business applications. A well-known example of SaaS is Microsoft's Office 365, which provides Microsoft's famous suite of productivity software— including MS Word and Excel— as a service.

Software Development Kit (SDK) – A Software development kit (SDK), also known as a developer's toolkit or devkit, is a set of development tools that aids or allows the creation of applications for a certain platform. SDKs typically include APIs, sample code, documentation, debuggers and other utilities.

Software Stack – A software stack is a group of applications that work in a specific and defined order to achieve a common goal.

User Interface (UI) – User interface (UI) is the way that the user and computer system interact.

User Experience (UX) –The nature of a user's interaction with and perception of a system.

User Space – The memory area of an operating system where application software executes.

Vendor Lock-in – Vendor lock-in is when a customer finds themselves “locked-in” or stuck with a certain cloud service provider (CSP). Vendor lock-in is characterized by extreme difficulty in moving from one cloud vendor to another, usually due to lack of standardized protocols, APIs, data structures, and service models.

Vertical Cloud – A vertical cloud is a cloud computing solution that is built or optimized for a specific business vertical such as manufacturing, financial services, or healthcare.

Virtual Desktop Infrastructure (VDI) – Virtual desktop infrastructure (VDI) is a desktop operating system hosted within a virtual machine.

Virtual Machine (VM)– A virtual machine is a software computer that runs an operating system or application environment, just as physical hardware would. The end user has the same experience on a VM as they would on dedicated hardware. Essentially, a VM is a machine within a machine. By running VMs, a hardware computer can run multiple instances of the same operating system. Applications running on separate instances cannot interfere with each other, so if one app crashes, it will not affect apps on other VMs.

1.6 ANSWER TO CHECK YOUR PROGRESS

1) What are the advantages of using cloud computing?

ANS. The advantages of using cloud computing are

- Data backup and storage of data
- Powerful server capabilities
- SaaS (Software as a service)
- Information technology sandboxing capabilities
- Increase in productivity
- Cost effective & Time saving

2) Mention platforms which are used for large scale cloud computing?

ANS. The platforms that are used for large scale cloud computing are

- Apache Hadoop

- MapReduce

3) Explain different models for deployment in cloud computing?

ANS. The different deployment models in cloud computing are

- Private Cloud
- Public Cloud
- Community Cloud
- Hybrid Cloud

4) What is the difference in cloud computing and computing for mobiles?

ANS. Mobile computing uses the same concept as cloud computing. Cloud computing becomes active with the data with the help of internet rather than individual device. It provides users with the data which they have to retrieve on demand. In mobile, the applications run on the remote server and gives user the access for storage and manage.

5) How user can gain from utility computing?

ANS. Utility computing allows the user to pay only for what they are using. It is a plug-in managed by an organization which decides what type of services has to be deployed from the cloud.

Most organizations prefer hybrid strategy.

6) For a transport in cloud how you can secure your data?

ANS. To secure your data while transporting them from one place to another, check that there is no leak with the encryption key implemented with the data you are sending.

7) What are the security aspects provided with cloud?

ANS. Identity management: It authorizes the application services

Access control: permission has to be provided to the users so that they can control the access of another user who is entering into the cloud environment.

Authentication and Authorization: Allows only the authorized and authenticated user only to access the data and applications.

8) List out different layers which define cloud architecture?

ANS. The different layers used by cloud architecture are

- CLC or Cloud Controller
- Walrus
- Cluster Controller
- SC or Storage Controller
- NC or Node Controller

9) What are system integrators in Cloud Computing?

ANS. In Cloud Computing, systems integrator provides the strategy of the complicated process used to design a cloud platform. Integrator allows to create more accurate hybrid and private cloud network, as integrators have all the knowledge about the data center creation.

10) What is “EUCALYPTUS” stands for?

ANS. “EUCALYPTUS” stands for Elastic Utility Computing Architecture for Linking Your Programs to Useful Systems”

11) Explain what is the use of “EUCALYPTUS” in cloud computing?

ANS. “Eucalyptus” is an open-source software infrastructure in cloud computing, which is used to implement clusters in cloud computing platform. It is used to build public, hybrid and private clouds. It has the ability to produce your own data center into a private cloud and allows you to use its functionality to many other organizations.

12) What is the requirement of virtualization platform in implementing cloud?

ANS. The requirement of virtualization platform in implementing cloud is to

- Manage the service level policies
- Cloud Operating System
- Virtualization platforms helps to keep the backend level and user level concepts different from each other

13) Before going for cloud computing platform what are the essential things to be taken in concern by users?

- Compliance
- Loss of data
- Data storage
- Business continuity
- Uptime
- Data integrity in cloud computing

14) Mention some open-source cloud computing platform databases?

ANS. The open-source cloud computing platform databases are

- MongoDB
- CouchDB
- LucidD

15) What are the security laws which are implemented to secure data in a cloud?

ANS. The security laws which are implemented to secure data in cloud are

Processing: Control the data that is being processed correctly and completely in an application

File: It manages and control the data being manipulated in any of the file

Output reconciliation: It controls the data which has to be reconciled from input to output

Input Validation: Control the input data

Security and Backup: It provides security and backup it also controls the security breaches logs

16) Mention the name of some large cloud providers and databases?

- Google Bigtable
- Amazon simpleDB
- Cloud based SQL

17) Explain the difference between cloud and traditional datacenters?

ANS. The cost of the traditional data center is higher due to heating and hardware/software issues. Cloud gets scaled when the demand increases. Majority of the expenses are spent on the maintenance of the data centers, while that is not the case with cloud computing

18) Explain what are the different modes of software as a service (SaAS)?

ANS. Simple multi-tenancy: In this each user has independent resources and are different from other users, it is an efficient mode.

Fine grain multi-tenancy: In this type, the resources can be shared by many but the functionality remains the same.

19) What is the use of API's in cloud services?

ANS. API's (Application Programming Interface) is very useful in cloud platforms

- It eliminates the need to write the fully fledged programs
- It provides the instructions to make communication between one or more applications
- It allows easy creation of applications and link the cloud services with other systems

20) What are the different data centers deployed for cloud computing?

ANS. Cloud computing consists of different datacenters like

- Containerized Datacenters
- Low Density Datacenters

1.7 REFERENCES

- <https://solutionsreview.com/cloud-platforms/glossary/>
- <https://www.atlassian.com/continuous-delivery/principles/cloud-computing>
- <https://www.ibm.com/cloud/blog/top-7-most-common-uses-of-cloud-computing>

1.8 TERMINAL QUESTIONS

1. What is cloud technology?
2. What do you mean by cloud delivery model?
3. What are some of the key features of cloud computing?
4. What are the different versions of cloud?
5. What are the main constituents that are part of the cloud ecosystem?
6. What are the cloud consumers in a cloud ecosystem?
7. Who are the direct customers in a cloud ecosystem?
8. Who are the cloud service providers in a cloud?

UNIT 2 - CREATE A GEO EXPLORER WEB MAP

2.1 OBJECTIVES

2.2 INTRODUCTION

2.3 CREATE A GEO EXPLORER WEB MAP

2.4 SUMMARY

2.5 GLOSSARY

2.6 ANSWER TO CHECK YOUR PROGRESS

2.7 REFERENCES

2.8 TERMINAL QUESTIONS

2.1 OBJECTIVES

After reading this unit you should be able to:

- Know about create a Geo explorer web map.

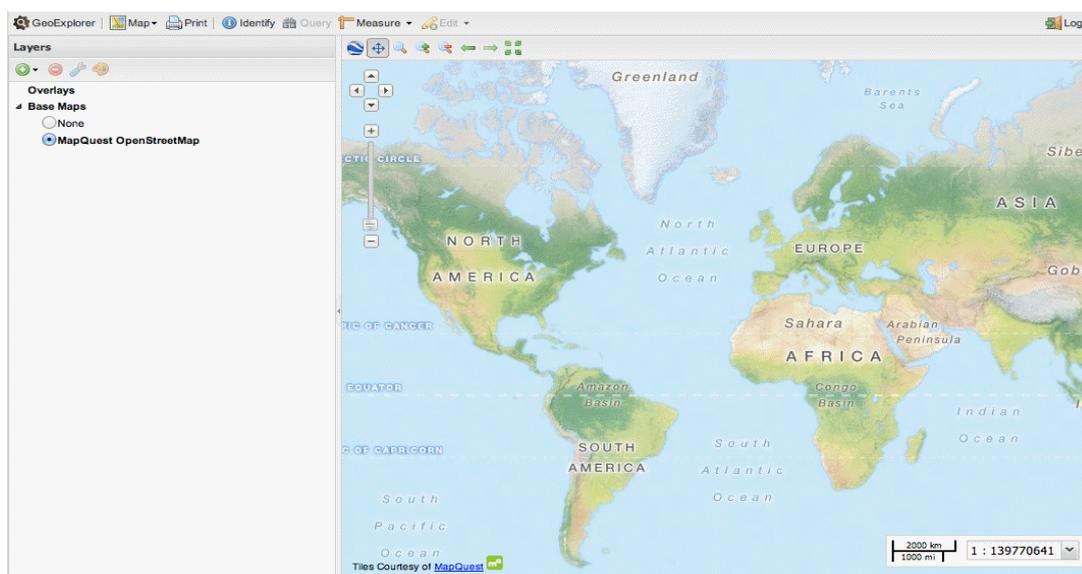
2.2 INTRODUCTION

GeoExplorer is a web application for creating and distributing maps based on the GeoExt framework. You can quickly assemble maps from GeoServer or any OGC Web Mapping Server (WMS) with GeoExplorer, and connect them with hosted maps like Google Maps and OpenStreetMap. You can also update map styling information, embed your maps on any web page, and export them as PDF files.

2.3 CREATE A GEO EXPLORER WEB MAP

This section gives you a quick overview of GeoExplorer:

Locate the GeoExplorer component on the OpenGeo Suite Dashboard and click the Launch link to start GeoExplorer.

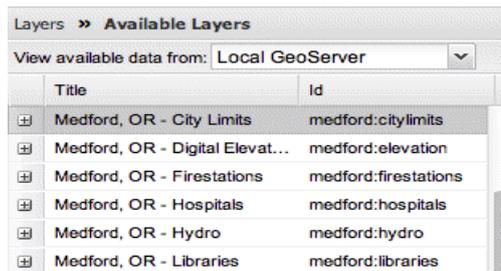


Source:

(http://www.orbital.co.ke:8080/opengeodocs/geoexplorer/_images/geoexplorer.png)

Although your local setup may change, the GeoExplorer web application is normally available at <http://localhost:8080/geoexplorer/composer>.

1. To add a new layer to the Map Window, open the Available Layers panel by clicking Add Layers and addlayer on the Layers panel toolbar.

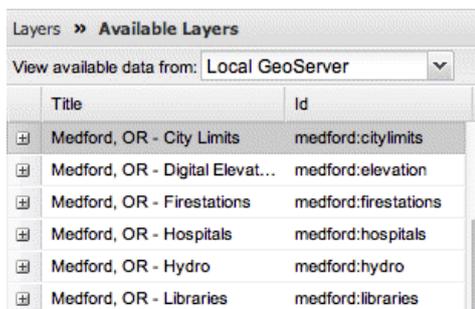


Source:http://www.orbital.co.ke:8080/opengeodocs/geoexplorer/images/panel_available_layers.png

2. Click the layer you want to add to your map in the Available Layers panel, then click Add layers at the bottom of the panel.

Note

Hold Ctrl while clicking all the layers you want to add to add multiple layers.

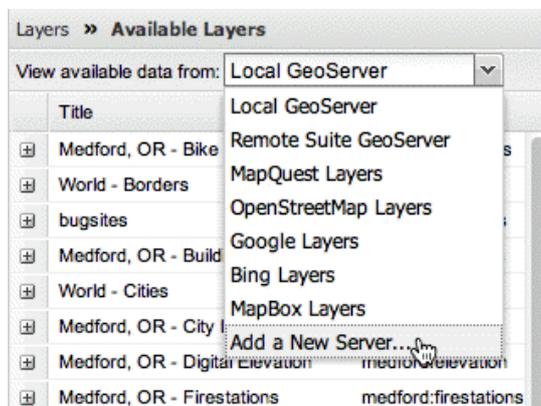


Source:http://www.orbital.co.ke:8080/opengeodocs/geoexplorer/images/panel_available_layers.png

Note

By double-clicking a layer in the Available Layers panel, you can also create a new layer.

3. In the View available data from list, select Add A New Server to add a new WMS server.



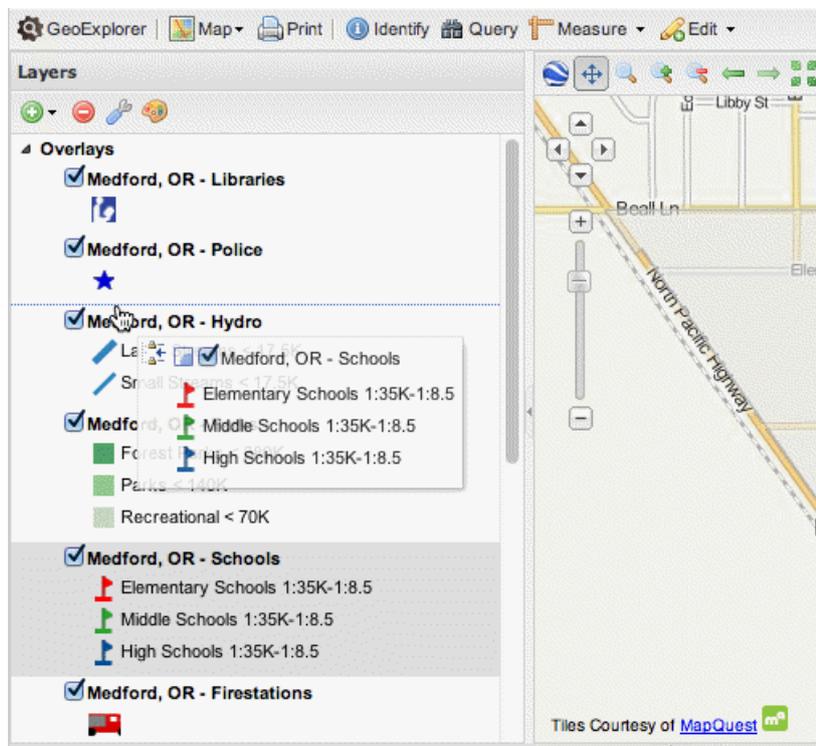
Source:http://www.orbital.co.ke:8080/opengeodocs/geoexplorer/images/add_newserver.png

http://sampleserver1.arcgisonline.com/arcgis/services/Specialty/ESRI_StateCityHighway_USA/MapServer/WMSServer is an example of a WMS URL.



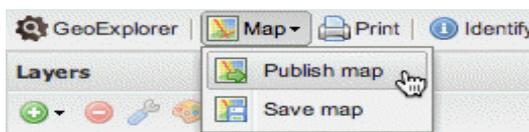
For a new WMS sever, adding the URL

4. Click the Add Server button after you've entered the URL for the new WMS server.
5. To return to the Layers window, click the Done button.
6. Click and drag a layer up or down the list of layers in the Layers panel to rearrange the layers in your map.



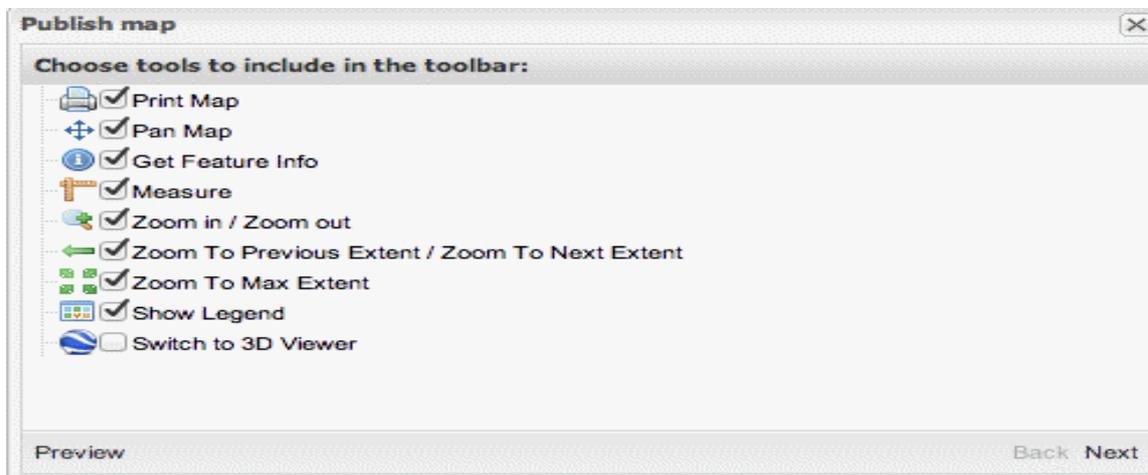
Sourcehttp://www.orbital.co.ke:8080/opengeodocs/geoexplorer/images/workspace_draftlayers.png

7. Based on the layers in your Map Window, you can also create a map application and HTML code to embed in a web page. To enter the Publish map dialogue box, click Map in the GeoExplorer toolbar, then Publish map.



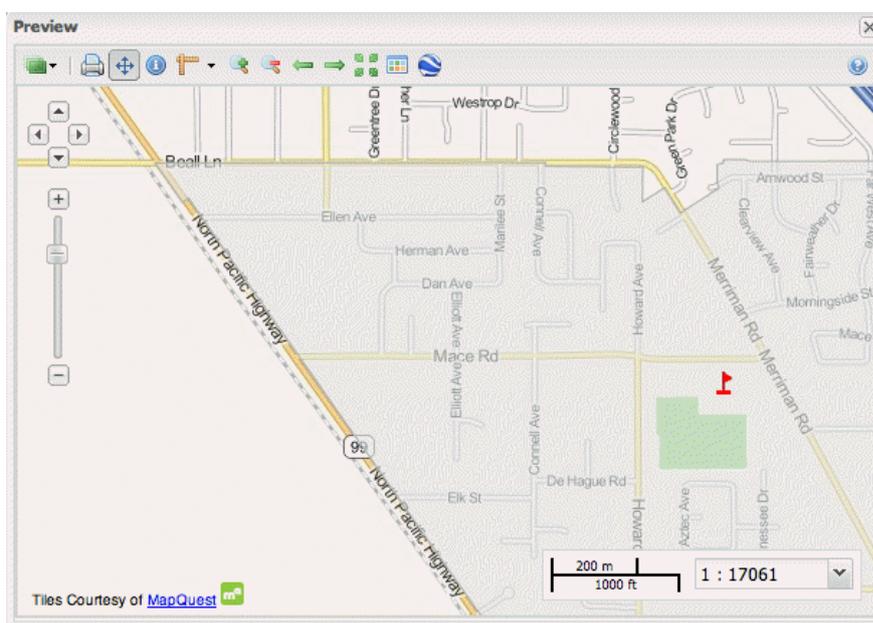
Publish Map Tool

8. Select the map tools you wish to include in your map application in the Publish map dialogue box.



Selecting the map tools

9. To build a preview of your map application, click Preview.



Previewing a map

10. To generate HTML code, click Next.



Generating HTML code

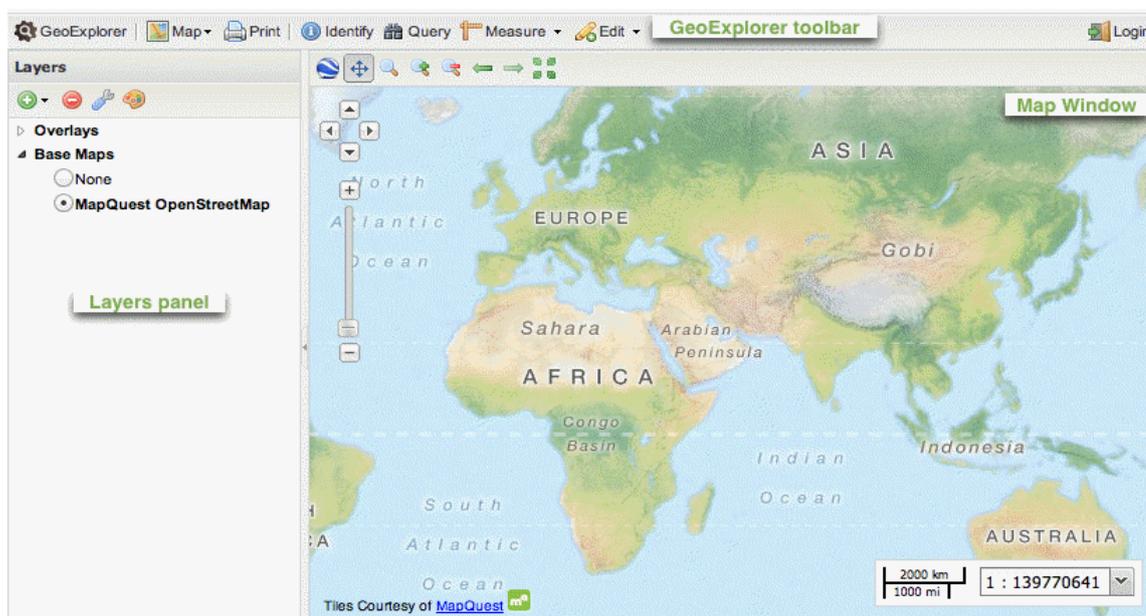
11. To view your map application, copy and paste the HTML code into your own web page.

Please see Using GeoExplorer for additional information on how to use GeoExplorer.

GeoExplorer workspace

There are three primary regions in the GeoExplorer workspace:

- Map Window is a window that displays a map.
- Toolbar for GeoExplorer—Main application toolbar
- The Layers panel shows a list of map layers and links to the Layer Properties and Layer Styles panels.



Geoexplorer workspace

Map Window

The Map Window is where any layers that have been added to GeoExplorer are displayed. The Layers panel is used to customise the Map Window's contents, while the Map Window toolbar contains display and navigation options for zooming, panning, and switching to the 3D viewer.

Map Window toolbar

The Map Window toolbar provides access to the following available tools:



Map window toolbar

Button	Name	Description
	Switch to 3D Viewer	Changes map view to 3D. Requires the Google Earth browser plugin .
	Pan map	Pan the Map Window by click and drag (enabled by default). Shift, click, and drag together zooms in to a user-defined extent.
	Zoom by dragging a box	Zoom to user-defined extent
	Zoom in	Increases the zoom level by one
	Zoom out	Decreases the zoom level by one
	Zoom to previous extent	Returns to the previous map extent
	Zoom to next extent	Returns to the next map extent (activated only after using Zoom to previous extent)
	Zoom to max extent	Zooms to the maximum extent of all layers

GeoExplorer toolbar



This provides access to the following tools:

Publish map, save map, Print, Query, Create, Modify, Login etc.

Layers panel

The Layers panel has a toolbar and a list of layers organised into two folders: Overlays and Base Maps. The visibility of individual Overlays layers can be customised as needed. Clear the check box next to layer to make it invisible. Select the check box to make the layer visible again.

Overlays

When GeoExplorer is first launched, the Overlays folder is empty. By selecting Add layers addlayer on the Layers panel toolbar, you can add layers to the list.

Note

The new layer will be added to the Overlays folder or the Base Maps folder, depending on the source of the layer. Background mapping will be added to the Base Maps folder, such as that provided by Google and OpenStreetMap.

Multiple layers can be visible in the Map Window at the same time since overlay layers are set to be transparent. Each layer's legend is produced directly from the WMS GetLegendGraphic request.

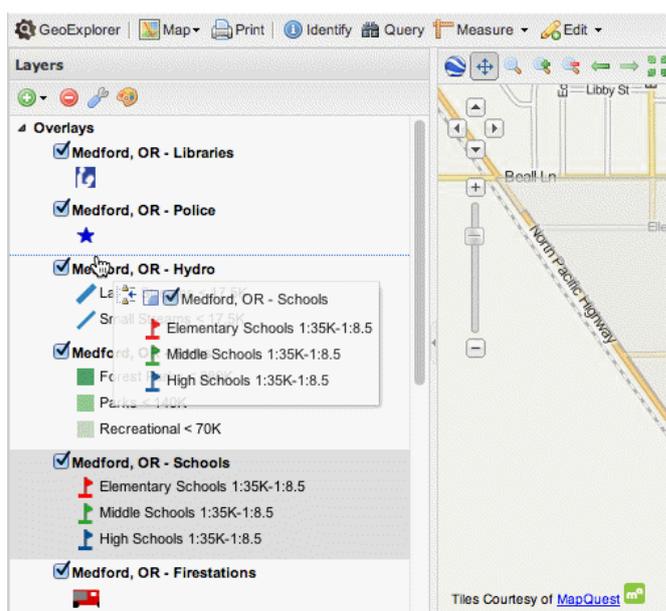
Base Maps

The base, or backdrop, layers are found in the Base Maps folder. All additional Overlays layers will be drawn on top of a base layer. Although only one base layer can be active at any given moment, the list can contain numerous base layers. Layers can also be dragged from the Base Maps folder to the Overlays folder.

Mapquest OpenStreetMap is the default base layer. It's also possible to use the Map Window with no base layer (None). You can add layers to the Base Maps folder by selecting Add layers addlayer on the Layers panel toolbar, just like you can with the Overlays list.

Layer Order

The rendering, or draw, order can be affected by reordering layers in the Layers panel. Click and drag the layers in the Overlays list in the Layers panel to reorder them. The layers will be displayed in the order that they are listed—the layer at the top of the list will appear on top of all other layers, the one below it will appear below that, and so on. All Overlays layers will be drawn beneath the selected base layer.



Reordering layers

Layer properties panel

The Layer Properties panel shows the properties of the currently chosen layer, such as the name and description of the layer, as well as the display and style settings. You can also make changes to each layer's Layer Properties as needed.

Layers style panel

The Layer Styles panel shows information about the current layer's style. The style rules are taken straight from the SLD layer. You can also make changes to the Styles for WMS layers if necessary.

Using GeoExplorer

This section describes how to use GeoExplorer to display, style and publish your data.

Layers Panel

GeoExplorer has a new feature called Adding Layers.

GeoExplorer data is being uploaded.

GeoExplorer Layer Properties: Remove Removing Layers

Layer properties can be seen and edited.

Layers of styling

The use of layer styles.

GeoExplorer Toolbar

Publish

Create a map application and publish it.

Save

a map application must be saved

Print

Make a PDF of the current map layout.

Identify

Recognize features in a specific location.

Query

You can search for features based on their attributes or the current map extent.

Measure

length or area to be measured

Make a feature

Create new functions.

Modify

Make changes to existing features

Logging in and connecting to the GeoServer.

Login

With read-only access, GeoExplorer can connect to a variety of data sources. GeoExplorer may also connect to a local GeoServer and access it with full read/write permissions. As a result, GeoExplorer can:

- Feature creation and deletion
- Make changes to existing features
- Style the map layer

GeoExplorer users must be authenticated by GeoServer before read/write access is enabled for security reasons.

Authentication:

To gain read/write access to your local GeoServer, follow these steps:

1. Make sure GeoServer is in the same servlet container as the others. If your GeoExplorer is hosted at <http://example.com/geoexplorer>, you will only be able to access a GeoServer at <http://example.com/geoserver>.
2. On the GeoExplorer toolbar, click the Login button.
3. In the Login dialogue box, type the administrator credentials for GeoServer.
4. The Login dialogue box will close if the credentials were input correctly, and you will be able to utilise the GeoExplorer features that require read/write access, such as Create and Modify.
5. Click the Logout button on the GeoExplorer toolbar to log out of GeoServer.

Add Layers:

The Overlays folder is initially empty when the GeoExplorer application is launched, thus the first step is to create layers.

1. To display the Available Layers panel and a list of available layers, click Add Layers on the Layers panel toolbar and then Add Layers.

The Available Layers panel list will default to the list of layers published by your local GeoServer instance. For each layer, the Title and Id are displayed.

2. To see a layer Abstract (summary), expand the list entry for the selected layer.

Default servers

GeoExplorer provides access to number of servers:

Server Name	Description	Notes
Local GeoServer	Local GeoServer WMS if present on the same server as GeoExplorer	Not available when using the standalone version of GeoExplorer
Remote Suite GeoServer	GeoServer WMS on OpenGeo's servers	GeoServer URL is: http://v2.suite.opengeo.org/geoserver/
MapQuest Layers	Layers published through MapQuest	Available layers: <ul style="list-style-type: none"> • MapQuest OpenStreetMap • MapQuest Imagery
OpenStreetMap Layers	Layers published through OpenStreetMap	Available layers: <ul style="list-style-type: none"> • Mapnik
Google Layers	Layers published through Google Maps	Available layers: <ul style="list-style-type: none"> • Google Roadmap • Google Satellite • Google Hybrid • Google Terrain
Bing Layers	Layers published through Bing Maps	Available layers: <ul style="list-style-type: none"> • Bing Roads • Bing Aerial • Bing Aerial with Labels
MapBox Layers	Layers published through MapBox	A number of layers are available, including Blue Marble Topography, Natural Earth imagery, and stylized base layers like Geography Class.

Connect to another WMS:

To load layers from a server that isn't already mentioned, you'll need to add it to the available servers list. Any legitimate WMS can be added.

To add a new server, open the Add New Server panel by clicking Add a New Server in the View available data from list in the Available Layers panel.

Upload data:

You can directly upload data, shapefiles (compressed into an archive file), or GeoTIFF files into a local instance of GeoServer using GeoExplorer. The data will be automatically configured and styled for use in GeoExplorer.

Warning

Shapefiles must be stored in a compressed archive file. Selecting the.shp file by itself will not function. For more information, see the section on Data Formats.

To upload data, you must first authenticate with the local GeoServer instance.

The following is the order in which the data is processed:

- Copy the file to the GeoServer data directory (subfolder named incoming)
- Unpacking the archive (if applicable)
- In GeoServer, data is loaded as a layer (with your Title and Description assigned)
- The layer's projection will be determined. If this isn't possible (for example, because the CRS ID wasn't provided when the data was uploaded), the projection information must be entered separately in GeoServer.
- For the layer, a unique style was produced.

Your new layer will appear in the Available Layers window once the upload procedure is complete. Layers can now be added to your map.

Data formats:

Shapefile or GeoTIFF data can be uploaded to the Upload layers window. If you're uploading shapefiles, you'll need to put them in an archive file first (zip, tar, gzip, or bzip). (The upload data process requires a single file, and shapefiles include a variety of files such as.shp,.shx, and.dbf files, among others.)

A GeoTIFF file (.tif) does not have to be in archive format, but it can be appended to one if file size reduction is a need.

Remove layer:

Click the layer in the Layers panel, then click Remove layer rmlayer on the Layers panel toolbar to remove it from GeoExplorer. Remove the layer by right-clicking it and selecting Remove Layer from the shortcut menu. In the same way, Base Maps and Overlays layers can be removed.

Layer Properties

Click a layer in the Layers panel, then click Layer Properties lyrprops in the Layer panel toolbar to open the Layer Properties panel. Layer Properties can also be accessed by right-clicking the layer and selecting Layer Properties from the shortcut menu.

Layer Styles

For layers produced by a WMS server that uses the SLD standard, GeoExplorer has an integrated Styles editor. To edit styles in GeoExplorer, you must first authenticate. Please read the Login section for further details.

Accessing and Using the Styles Editor

Using the Styles Editor Styles are a set of tools that allow you to change the look of your Layer styles can be added, removed, edited, and duplicated.

Rules

Layer style rules can be added, deleted, edited, and duplicated.

Identify

The Identify tool will return attribute information for any features found at a particular position in the Map Window, across all visible layers.

To use this tool, go to the GeoExplorer toolbar and select Identify.

Select a location on the map using the Identify tool. If a feature is detected at that location, the Feature Info dialogue box appears, listing the attribute information for the feature. The Feature Info dialogue box will not open if no features are discovered at that location.

Numerous levels will be listed in the Feature Info dialogue box if multiple features are located at that location. To get a list of attributes for a layer, click its name.

Query

Querying features in the presently selected layer is possible with the Query tool. The attributes of features can be queried, as well as the current map extent.

To use the Query tool, go to the GeoExplorer toolbar and select Query.

The Query and Table panels will appear underneath the Layers panel and Map Window, respectively, once the Query tool has been activated.

Measure

For a particular section of the map, the Length and Area measure tools will calculate the length in one dimension or the area in two dimensions.

Length

The Length tool will measure the distance between two points on the Map Window. The total of one or more-line segments or curves is represented by the measurement value.

Area

The Area tool estimates the area of the Map Window directly. The area of a polygon made up of one or more-line segments or curves is represented by the measurement value.

Create

You can use GeoExplorer to add new features to layers that have been published using a local instance of GeoServer. You can specify the feature's spatial information (location) as well as its attribute information.

1. To add a new feature, first pick the layer to which you wish to add features, then click Edit in the GeoExplorer toolbar, then create.
2. To add a feature to the Map Window, click a location on the map. If you're establishing a new point feature, you can do so with only one click. Trace the outline of the line or polygon feature by clicking additional places in the Map Window if you're making a line or polygon feature. You may also generate (approximate) curved lines by holding down Shift and the left mouse button while dragging the mouse.
3. To finish the feature input, double-click the last place. A dialogue box will appear, allowing you to enter attribute data for the new feature.
4. Click Save after entering the new feature's attribute values. Click Cancel to delete the newly created feature.

Modify

Existing features in layers published by a local instance of GeoServer can be Edited and Deleted using GeoExplorer.

Note

Editing features with GeoExplorer requires GeoServer authorization. Please see the Login section for additional details.

Save Map

You can save the current map setup with GeoExplorer. This setup will include the current Map Window extent, as well as a list of layers with their visibility and ordering settings intact. These settings are kept in the form of a URL, which can be saved as a bookmark.

Note

To store map configurations, GeoServer login is necessary. Please read the Login section for further details.

Click Map in the GeoExplorer toolbar and then Save map to save the current map configuration.

A URL will appear in a pop-up window. To reload the current GeoExplorer configuration at a later time, save or bookmark this URL.

Publish Map

The Publish map tool creates a map app that can be integrated in a web page. The tools that appear in the map application toolbar can be customised.

Note

To publish maps, GeoServer login is necessary. Please read the Login section for further details. To open the Publish map dialogue box, click Map in the GeoExplorer toolbar and then Publish map.

Print

You can make PDFs of the current map composition using GeoExplorer. The printing of maps can be substantially simplified using PDFs. To get started, click Print in the GeoExplorer toolbar once you've finished your map construction.

Using GeoExplorer

This section explains how to display, style, and publish your data using GeoExplorer.

Panel of Layers

GeoExplorer has a new feature called Adding Layers.

GeoExplorer data is being uploaded.

GeoExplorer Layer Properties: Remove Removing Layers

Layer properties can be seen and edited.

Layers of styling

The use of layer styles

Toolbar for GeoExplorer

Publish

Create a map application and publish it.

Save

a map application must be saved

Print

Make a PDF of the current map layout.

Identify

Recognize features in a specific location.

Query

You can search for features based on their attributes or the current map extent.

Measure

length or area to be measured

Make a feature

Create new functions.

Modify

Make changes to existing features

Logging in and connecting to the GeoServer

2.4 SUMMARY

GeoExplorer is a component of the Open Geo suite that provides a browser-based platform for viewing, editing, publishing, and performing simple spatial tasks on web GIS data. MapQuest layers, Open Street Map, Google, Bing, and MapBox layers, as well as local

GeoServer layers or any other GeoServer from a remote site, can all be loaded into GeoExplorer.

The following features are available through the GeoExplorer Portlet:

- Exploration of internal levels (preview, sorting, filtering, and multi-selection);
- Layers visualisation on a geospatial map that can be zoomed and panned;
- Visual correlation study of numerous layers on top of each other;
- One or more layers of CQL visual filter;
- retrieval of tabular spatial data from one or more layers;
- Analyze the strata of a transect;
- Visualization of the default Base Layers (TrueMarble, GEBCO, relief, and so on);
- Management of external WMS Layers;

The GeoExplorer area and the GisViewer area are the two logical components of the webapp.

Component for GeoExplorer

The GeoExplorer component provides an analytic view of all GeoNetwork layers. It has two panels: a tabular paging view of the layers and a contextual panel for layer details. The table displays a summary of layer metadata, such as the layer title, name, and url of the Geoserver where this layer is stored.

It's feasible to do the following:

- Move around the pages interactively;
- use filtering and sorting to find a specific layer;
- choose one or more layers to display in GisViewer;
- acquire details for a certain layer on demand (layer image preview, name, title, complete name, and so on).

2.5 GLOSSARY

- Contextual Query Language (CQL)- A query representation language.
- *GetCapabilities*-WMS request that returns a capabilities document, which contains a list of all WMS server layers and functionalities. GeoExplorer examines a server's capabilities document to find the layers that are available.
- *GetFeatureInfo*-WMS request for a list of properties and values for data at a certain location.
- *GetLegendGraphic*- Returns a graphic drawn in the style of a given layer via a WMS request.
- GeoExt- is a JavaScript toolbox for building interactive online maps. OpenLayers and ExtJS are used to create GeoExt. Geoext.org has more information.
- GXP- A collection of high-level application components for using GeoServer to build apps for viewing, editing, styling, and setting data. GXP is used to create GeoExplorer, while GeoExt is used to create GXP components.
- OGC-The Open Geospatial Consortium (OGC) is a standards group that develops geospatial service specifications, among other things.
- SLD- The OGC's Styled Layer Descriptor (SLD) specification is an XML-based standard for symbolising and colouring (displaying) geographic features via WMS. GeoServer employs the SLD style language.

- WMS- The OGC's Web Map Service (WMS) specification offers a web-based interface for accessing rendered map images. WMS can be used to refer to either the protocol or a server that supports it.
- WMS-C- The Web Map Service - Caching (WMS-C) concept is a WMS designed to deliver pictures that have been saved or cached.
- WFS-T-The OGC standard Web Feature Service - Transactional (WFS-T) defines away for editing geographic features.

2.6 ANSWER TO CHECK YOUR PROGRESS

1. Define Web Map Service?

2.7 REFERENCES

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2.8 TERMINAL QUESTIONS

- What is the purpose of GeoServer?
- How does GeoServer works.
- What are web GIS services?
- What is OpenGeo Information?
- How do you create a GeoExplorer web map?

UNIT 3 - CLOUD BASED DATABASES AND WEB EDITING

3.1 OBJECTIVES

3.2 INTRODUCTION

3.3 CLOUD BASED DATABASES AND WEB EDITING

3.4 SUMMARY

3.5 GLOSSARY

3.6 ANSWER TO CHECK YOUR PROGRESS

3.7 REFERENCES

3.8 TERMINAL QUESTIONS

3.1 OBJECTIVES

After reading this unit you should be able to:

- Know about cloud based databases.
- Learnt about web editing.

3.2 INTRODUCTION

A cloud database is a database that runs on a cloud computing platform and provides as-a-service access to the database. Users can run databases on the cloud themselves using a virtual machine image, or they can pay for access to a database service provided by a cloud database provider. Some of the cloud databases are SQL-based, while others use a NoSQL data format. Database services ensure the database's scalability and high availability.

3.3 CLOUD BASED DATABASES AND WEB EDITING

A database is any type of information storage, management, and retrieval system. It is a data storehouse or collection. The implementation of a database and the structure of data will impact how well an application scale. Each database type is designed to handle a particular workload. For a highly performant and cost-effective operation, matching an application with the suitable database type is critical. While a general-purpose database can handle almost any type of task, it will not scale as demand grows. This is significant for the following reasons:

- Agility is one of the promises of the cloud. That is, being able to react quickly to changes in the business environment. This is referred to as scalability, and it involves the ability to expand as needed.
- It is accomplished by breaking down tables and indexes into smaller chunks in order to manage and access data at a more granular level.
- Elasticity is another benefit of the cloud. That is, although it is excellent to be able to scale up to meet demand, elasticity enables for the inverse to occur. When demand falls, so does the scale, as well as the costs associated with it.

Benefits of a Cloud Database

You can take advantage of cloud computing benefits by running a database on the cloud. Because the database is maintained by the service provider, you can concentrate on designing your application rather than worrying about the underlying infrastructure. Storage and bandwidth are normally charged on a per-use basis, which is incredibly cost-effective, especially for start-ups and small organisations. Scalability is another significant benefit of cloud computing. It enables the application owner to simply assign more database resources in order to keep the programme running during peak hours or to remove some of the resources when they are not required. Some database providers support auto-scaling, while others need users to scale manually through an API. Almost every cloud database provider guarantees high availability (usually 99.9% or 99.99 percent uptime).

While cloud-based databases have a lot of benefits, they also have certain drawbacks. Here are some things to think about while deciding whether or not to go to the cloud.

- Lock-In of Vendors

It can be difficult to shift your infrastructure to a new cloud service provider once your company has picked one. If you wish to make modifications in the future, pay close attention to how your cloud service is built, especially any proprietary apps that the cloud platform relies on to function.

- Concerns about costs

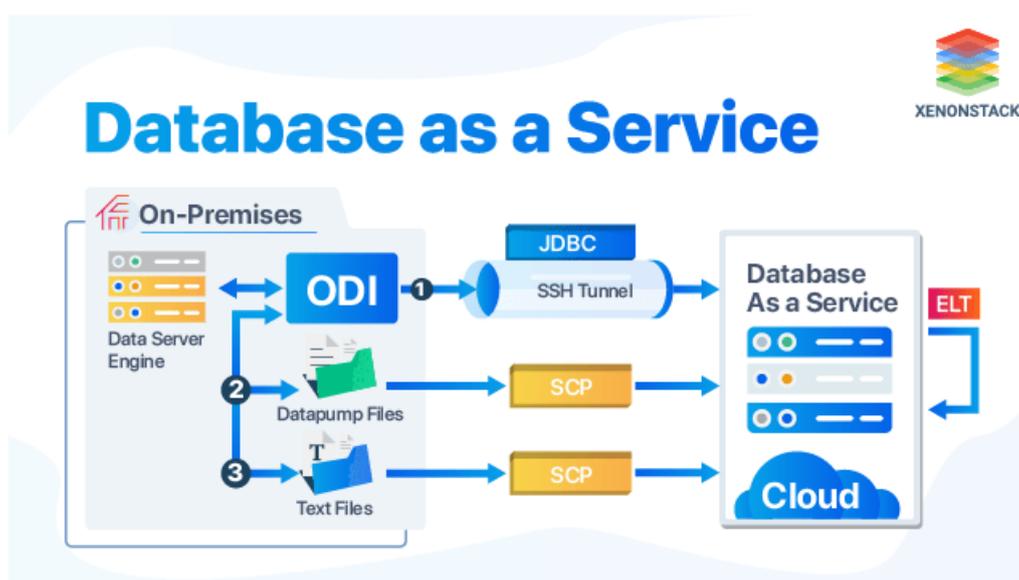
The initial cost of database hosting services may be less than the cost of increasing your company's existing servers. However, when your service requirements grow, charges can rise sometimes dramatically. One of the most appealing features of cloud database hosting is the possibility for your company to start with only the services it requires; nevertheless, don't overprovision these requirements as this may result in greater charges.

- Vulnerabilities in the system

The security of the cloud infrastructures offered by top providers is generally excellent. However, no system is completely safe from attack. The potential of a data breach is always present when sensitive data is stored online, but the risks can be reduced by adopting best practises and communicating a thorough cloud security strategy to all application developers. We all know that the majority of security breaches are caused by human mistake.

Database as a service (DBaaS) is a cloud computing managed service that allows users to access databases without the requirement for physical infrastructure, software installation, or database configuration. The service provider handles the majority of the maintenance and administrative responsibilities, allowing users to quickly benefit from the database.

Small to medium-sized firms without well-staffed IT departments will benefit from the DBaaS approach. Small and medium-sized enterprises can install applications and systems that they couldn't afford to build and run on-premises by offloading database servicing and maintenance to a DBaaS provider.



Source: <https://www.xenonstack.com/hubfs/xenonstack-database-as-a-service.png>

Tools of DBaaS

To store, manage, and access data, DBaaS uses a cloud database.

The database service and the cloud service do not have to be from the same company.

AWS, for example, can be used to provide cloud services in conjunction with a Microsoft SQL Server database. When it comes to DBaaS, the first decision to make is which database management system to choose. Most common database management systems are offered through one or more cloud service providers.

The following are some of the most popular DBMS options:

- **Oracle database:** An Oracle database is a collection of data that is viewed as if it were a single entity. A database's main goal is to store and retrieve relevant data. The key to tackling information management issues is a database server. In a multiuser environment, a server successfully manages a huge volume of data so that multiple users can access the same data at the same time. All of this is done while maintaining a high level of performance. A database server also protects against unauthorised access and offers effective recovery options in the event of a failure.
- **Microsoft SQL Server:** In corporate IT environments, Microsoft SQL Server is a relational database management system (RDBMS) that supports a wide range of transaction processing, business intelligence, and analytics applications. Along with Oracle Database and IBM's DB2, Microsoft SQL Server is one of the three market-leading database technologies. Microsoft SQL Server, like other RDBMS software, is based on SQL, a standardised programming language used by database administrators (DBAs) and other IT professionals to administer databases and query the information they contain. Transact-SQL (T-SQL), a Microsoft SQL implementation that adds a set of proprietary programming extensions to the standard language, is related to SQL Server.
- **IBM Db2:** IBM produced the Db2 series of data management tools, which includes database servers. They were designed to support the relational model at first, but were later expanded to include object-relational capabilities as well as non-relational structures such as JSON and XML. The brand name was DB/2 at first, then DB2[3][4][5] until 2017[6], when it was ultimately converted to its current form.
- **MySQL:** MySQL is a SQL (Structured Query Language)-based relational database management system. Data warehousing, e-commerce, and logging applications are just a few of the uses for the application. However, the most popular application of MySQL is as a web database. It can hold anything from a single piece of data to a whole inventory of available products for an online store.

The following step is to choose a cloud service provider. Keep in mind that not every database management system (DBMS) is supported by every cloud platform. The following are some of the most popular cloud service providers:

- **AWS:** AWS (Amazon Web Services) is Amazon's complete cloud computing platform, which comprises infrastructure as a service (IaaS), platform as a service (PaaS), and packaged software as a service (SaaS) product.

- **Microsoft Azure:** The Azure cloud platform consists of more than 200 products and cloud services that are designed to help you create innovative solutions and tackle today's challenges. Build, operate, and manage applications with the tools and frameworks of your choosing across various clouds, on-premises, and at the edge.
- **Oracle cloud:** Oracle Cloud is a cloud computing service provided by Oracle Corporation, which offers servers, storage, networking, applications, and services via a global network of Oracle Corporation-managed data centres. These services are used to create, launch, integrate, and enhance cloud-based applications.
- **Google Cloud Platform:** Google Cloud Platform is a collection of Google's public cloud computing services. The platform comprises a variety of Google-hosted services for computation, storage, and application development.

Advantages of DBaaS

The DBaaS paradigm has a number of benefits over traditional on-premises database management, including:

- Reduced management responsibilities — the DBaaS supplier assumes many of the management and administrative responsibilities.
- Physical infrastructure is no longer required because the DBaaS provider provides all of the necessary infrastructure to run the database.
- Users don't have to manage or plan for database hardware updates, resulting in lower IT expenditures.
- Increased savings — because the physical infrastructure is no longer on site, users do not need to invest in expensive hardware. Reduced construction expenditures, fewer employees, lower electrical and HVAC operating expenses, and a smaller physical space can all help you save money.

Disadvantages of DBaaS

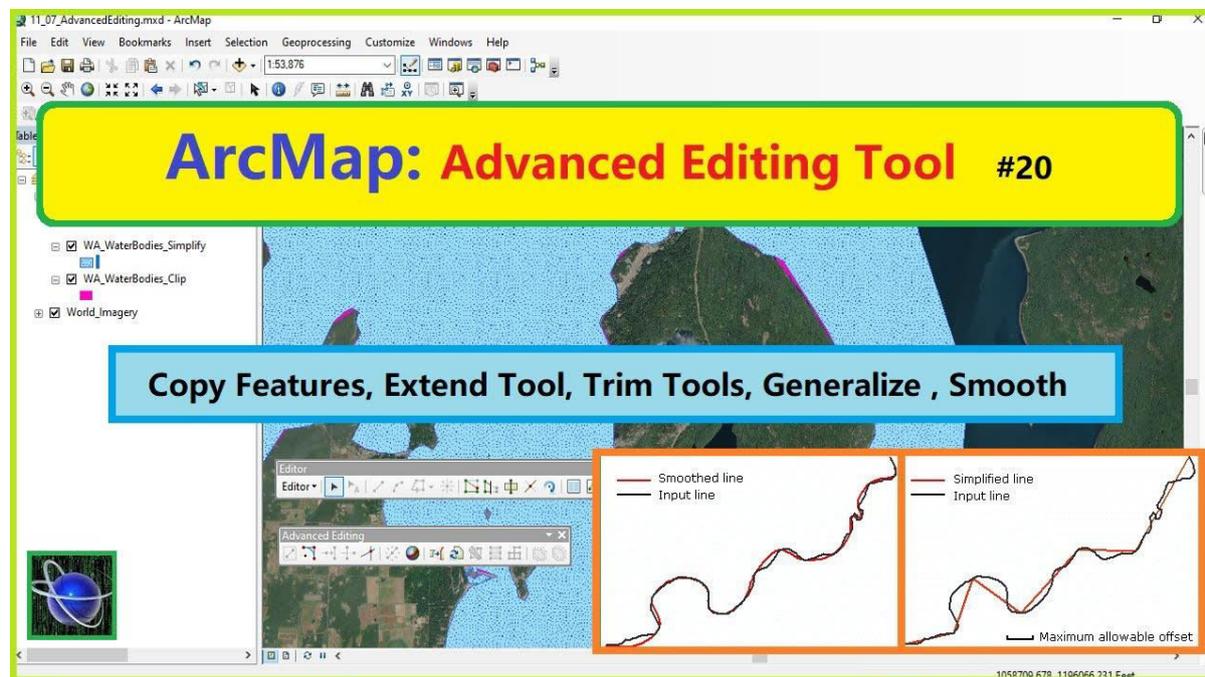
In comparison to traditional on-premises database solutions, DBaaS has some downsides mentioned below:

- When comparing DBaaS to an in-house solution, the lack of control over the IT infrastructure is usually the most important disadvantage. An organization's technicians do not have direct access to the servers and storage utilised to run the database in a provider-managed architecture.
- If an organization's internet connection goes down, or if the system goes down at the service provider's location, the organisation will be unable to access its data until the outage is resolved by the service provider.
- Security is also an issue because the service provider is in charge of it, and an organisation will have no direct control over the physical security of the servers.

Web editing

Because it can alter spatial data and geometries, the web editor is a significantly more complicated system than the web viewer. Each user can add, edit, or delete points on the map

in this fashion. HTML5 technology is used in a variety of prevalent technologies nowadays. When you're trying to reach out to users who are still using older browsers, this becomes a problem (IE8-). For this, we mostly employ SVG and VML shapes for modification. We'll be able to reduce the amount of time it takes for most users to learn how to use the web GIS editor this way.



An example of a web editor in GIS. (<https://i.ytimg.com/vi/cLj3nfcBbQg/maxresdefault.jpg>)

GIS editor's main features include:

- Points, lines, and polygons can be added, edited, and deleted.
- Editing is based on XML setting of user permissions for layers and other attributes.
- Prior to updating, new attributes are evaluated against any limitations, preventing many data problems. The option to snap different geometries to arbitrary vector layers to prevent topological anomalies is also available (duplicate points, slivers, kick-backs, spikes, etc.)
- Individual geometries can have their characteristics changed.
- Adding images to specific characteristics
- For points, you can use predefined symbols or import your own symbols (SVG or PNG).

A web editor (sometimes called an HTML editor) is a programme that lets you build web pages. Although you can write HTML code in a text editor, programmes that are specifically designed for this purpose, such as syntax highlighting, correcting syntax errors, or even allowing you to build a page using an interface without learning the fundamentals of HTML, may be more successful. In addition to allowing them, several of these programmes can manage HTML style sheets, CSS, XML, and JavaScript. In rare cases, including an FTP client to communicate with distant servers through FTP may be possible.

Text editors and visual editors are the two sorts of HTML editors. WYSIWYG editors (What You See Is What You Get) are a type of editor that lets you see exactly what you're getting.

Advantages of web editing

1.Simple to Use

One of the most significant benefits of a web-authoring application is its ease of use. With this type of tool, anyone with some basic technical knowledge can figure out how to develop a webpage; you don't need to master HTML or any other programming language to create a completely functional website. Instead, you create a webpage by just pointing and clicking.

2.Save time.

Another advantage of using this type of programme is that it can help you save a lot of time. When it comes to the elements to include in your pages, most WYSIWYG editors allow you to select from a few distinct possibilities. You create some content and decide on your page's layout and graphical aspects. It would take a lot longer to implement some of these things by hand-coding HTML.

3.Options are limited.

One of the drawbacks of using a web-authoring technology is that it restricts your design options. Typically, such tools rely on templates, with limited customization choices for the site's appearance and feel. As a result, you may be unable to develop a site that appears professional or unique. You may not be able to use Flash, video, or other typical web-design features depending on the type of programme.

4.Counting on the Program

Another issue with web-authoring software is that it makes you fully dependant on it. As a result, if the application goes inaccessible for any reason, you will be unable to construct a website. By contrast, if you know HTML, you can create webpages with any programmes you have on hand — even a simple text editor will suffice.

3.4 SUMMARY

A cloud database is one that runs on a cloud computing platform and offers database access as a service. Users can either operate databases on the cloud themselves using a virtual machine image or pay for access to a cloud database provider's database service. Some cloud databases use SQL, while others employ the NoSQL data format. Database services offer scalability and high availability of the database. Users can rent virtual machine instances for a defined amount of time on cloud systems, and these virtual machines can be used to run databases. Users can either submit their own system image with a database installed or utilise pre-built machine images that already have an efficient database installed. By running a database on the cloud, you may reap the benefits of cloud computing. You can focus on creating your application rather than worrying about the underlying infrastructure because the

database is managed by the service provider. Storage and bandwidth are typically priced on a per-use basis, making them extremely cost-effective, particularly for start-ups and small businesses. Another key advantage of cloud computing is its scalability. It allows the application owner to simply assign more database resources to keep the programme running during peak hours or delete some of the resources when they are no longer needed. A web editor (sometimes called an HTML editor) is a programme that lets you build web pages. Although you can write HTML code in a text editor, programmes that are specifically designed for this purpose, such as syntax highlighting, correcting syntax errors, or even allowing you to build a page using an interface without learning the fundamentals of HTML, may be more successful. In addition to allowing them, several of these programmes can manage HTML style sheets, CSS, XML, and JavaScript. In rare cases, including an FTP client to communicate with distant servers through FTP may be possible.

3.5 GLOSSARY

Business Intelligence (BI) Tools: Individual or combined tools with the singular task of processing vast amounts of unstructured data (from practically any source), the results of which can help businesses discover meaningful trends that can then be used for marketing, projections, and much more.

Cloud: A global network of systems and services that offer on-demand storage and computing power for end-users and businesses. This term generally serves as a metaphor for a global network of data centres available across the globe.

Cloud Bursting: A system that stands between a private and a public cloud that serves to direct overflow traffic from one to another. This is commonly used to direct traffic from a private cloud to a public cloud, when the private cloud's resources are at capacity.

Cloud Computing: A combined system of remote servers, hosted on the internet, to store, manage, and process data. Whereas the Cloud is used as a general term, Cloud computing gets more specific to describe a particular server or service, such as Linode, Google's cloud services, or AWS.

Cloud Computing Types: Generally speaking, there are only three main cloud computing types: Software as a Service (web-based applications), Infrastructure as a Service (network access to storage and computing power), and Platform as a Service (tools for developers to build on).

Cloud Service Provider: Any company that provides a cloud platform. These platforms are generally offered for free, but can also include tiered-pricing models.

Cloud Storage: A network-based service that allows users to store data on remote servers. Cloud storage solutions offer real-time (or near-real-time) syncing solutions to multiple platforms and devices.

Computer Grids: A collection of computers, networked together, that combine the sum total of their resources to be able to process and perform large tasks. Typically these types of systems are used for analysing vast data sets. When combined with Cloud computing, these grids allow clients to pay only for usage, thereby saving companies significant money (when compared to building in-house Computer grids).

Database Sharding: The ability to divide a vast database into smaller databases, which can be analysed and managed more easily across a network of servers.

DevOps: When software development and IT operations are combined together, with the help of automation, such that building, testing, and releasing software is faster and more reliable. The idea of DevOps is founded on a culture of collaboration between teams.

Elastic Computing: When computer resources (such as processing, memory, and storage) can be provisioned on the fly to meet the ever-changing demands of a business. This is done such that neither capacity planning or engineering for peak usage is a concern.

Hybrid Cloud: A combination of public and private clouds, networked together in such a way that data and applications can be shared between them. Hybrid clouds offer businesses greater flexibility for scaling and deployment.

Infrastructure as a Service (IaaS): A form of cloud computing that delivers virtualized computing resources (i.e. hardware, storage, service, data center space, network equipment, software) over the internet. These resources are typically used to support enterprise operations.

Middleware: Provides services to software applications beyond what is offered by the operating system. Any piece of software that exists between the kernel and end-user applications is considered Middleware. This type of software allows data to flow from one application to another.

NoSQL: A type of non-relational database that provides a mechanism for the storage and retrieving of data based on models other than standard relational databases (such as MySQL). NoSQL databases are capable of handling massive volumes of unstructured and changing data. These types of databases scale well beyond relational databases, which is why they are often the choice of Big Data.

Platform as a Service (PaaS): A cloud computing model where a third-party delivers hardware and software, primarily focused on software development, over the internet. Typically, these platforms are virtual operating systems, like Linux, which make for outstanding development environments.

Private Cloud: A cloud computing environment that is only offered for specific users or clients. These can be either on-premises or over the internet clouds that are not available for general, widespread usage.

Public Cloud: A cloud computing environment offered to the public, whose services are available either for free or for purchase.

Serverless Computing: A cloud computing model in which a cloud provider both provisions and dynamically manages the allocation of resources. Pricing for Serverless computing is based on the amount of resources consumed by an application. This type of service enables developers to focus more on their software and less on the development environment.

Software as a Service (SaaS): A method of delivering centrally hosted applications over the internet, via a subscription, by a third-party host. These are sometimes referred to as web-based software, on-demand software, or hosted software.

Virtual Machine: The emulating of a computer system, such that a single piece of hardware can deploy and manage a number of host environments, by providing the functionality of physical hardware.

Virtualization: Creating a virtual computing environment (aka a virtual machine), instead of running each environment on its own, unique hardware. With enough resources (CPU, RAM, Storage) a single system can host numerous guests, thereby saving businesses money while helping them become more agile.

3.6 ANSWER TO CHECK YOUR PROGRESS

1. Define PaaS.
2. Define IaaS.
3. Define Hybrid cloud.

3.7 REFERENCES

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3.8 TERMINAL QUESTIONS

1. What is cloud databases used for?
2. What are the advantages and disadvantages of cloud database?
3. Differentiate between SQL and NoSQL databases.

BLOCK 2 : 3D GIS

UNIT 4 - 3D GIS TECHNOLOGY

4.1 OBJECTIVES

4.2 INTRODUCTION

4.3 3D GIS TECHNOLOGY

4.4 SUMMARY

4.5 GLOSSARY

4.6 ANSWER TO CHECK YOUR PROGRESS

4.7 REFERENCES

4.8 TERMINAL QUESTIONS

4.1 OBJECTIVES

After reading this unit you will be able to:

- Explain 3D GIS Technology.
- Explain its uses and 3D Tools.

4.2 INTRODUCTION

3D GIS maps depict objects in greater detail by adding another dimension. 3D technology in GIS maps is explanatory illustrations that represent the scale of real-world objects. 3D models assist appearance, survey in a large number of different domains. For instance, 3D maps can show the height of a hotel or a mountain and not just its location. The 3D tools have to be used along with 2D GIS and then imagined in a 3D setting. There was a time when more than one software was needed in order to view objects on the streets and different places in a city. Modern Geographic Information System (GIS) has changed the dynamics of Geographic and Earth Science. With the development of digital medium, modern GIS interface lets its operators not only envisage and evaluate, but also manage geographical facts and figures.

Over the years, GIS has made a significant impact in creating mapping as an essential tool to solve problems. Conventionally, GIS information was based on a two-dimensional recording, which apparently limited its usage in most applications. Incorporating 3D technology in GIS customizes the whole experience, making it more personal and enabling detailed visualization. Let us look at some of the uses of 3D GIS.

There are two basic types of 3D GIS data: feature data and surface data.

1. **3D feature data:** Feature data represents discrete objects, and the 3D information for each object is stored in the feature's geometry. Three-dimensional feature data can support potentially many different z-values for each x,y location. For example, a vertical line has an upper vertex and a lower vertex, each with the same 2D coordinate, but each having different z-values. Another example of 3D feature data would be a 3D multipatch building, whose roof, interior floors, and foundation would all contain different z-values for the same 2D coordinate. Other 3D feature data, such as an aircraft's 3D position or a walking trail up a mountain, would only have a single z-value for each x,y location.

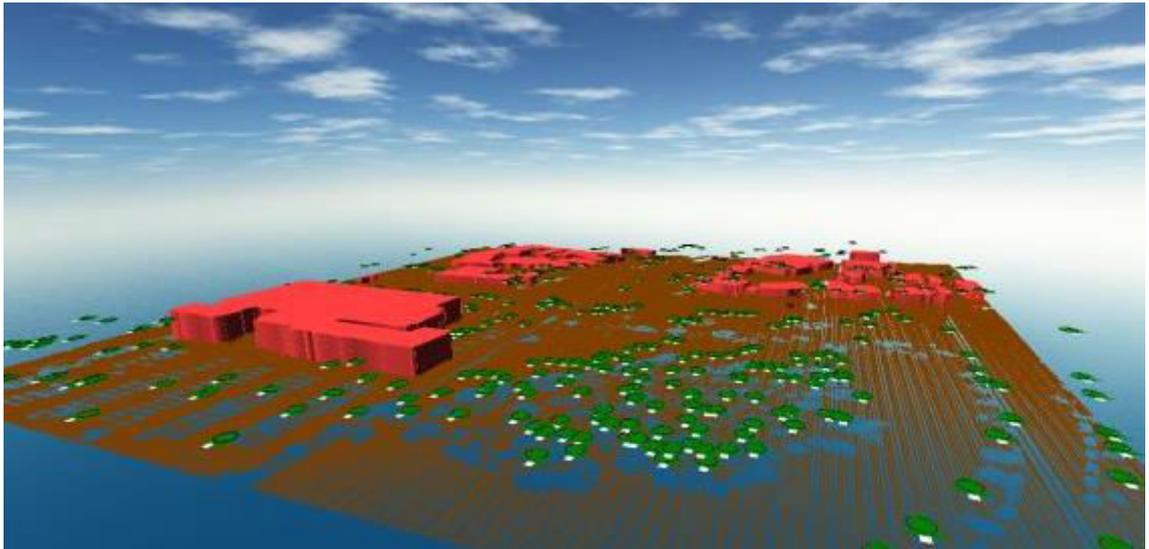


Figure 4.1: 3D Feature Data

2. **Surface data:** Surface data represents height values over an area, and the 3D information for each location within that area can be either stored as cell values or deduced from a triangulated network of 3D faces. Surface data is sometimes referred to as 2.5D data because it supports only a single z-value for each x,y location. For example, the height above sea level for the surface of the earth will only return a single value.

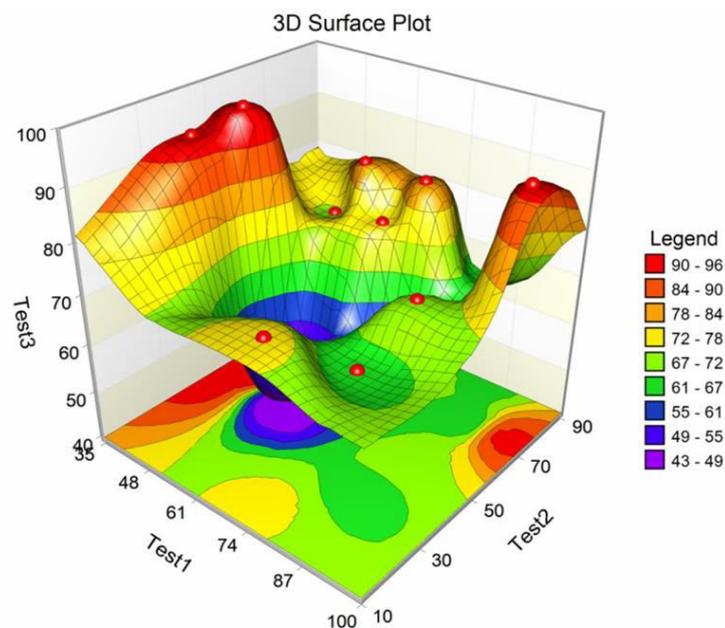


Figure 4.2: 3D Surface Data

4.3 3D GIS TECHNOLOGY

The 3D Analyst is an extension that adds support for 3D shapes, surface modeling, and real-time perspective viewing. With it, you can create and visualize spatial data using a third dimension to provide insight, reveal trends, and solve problems.

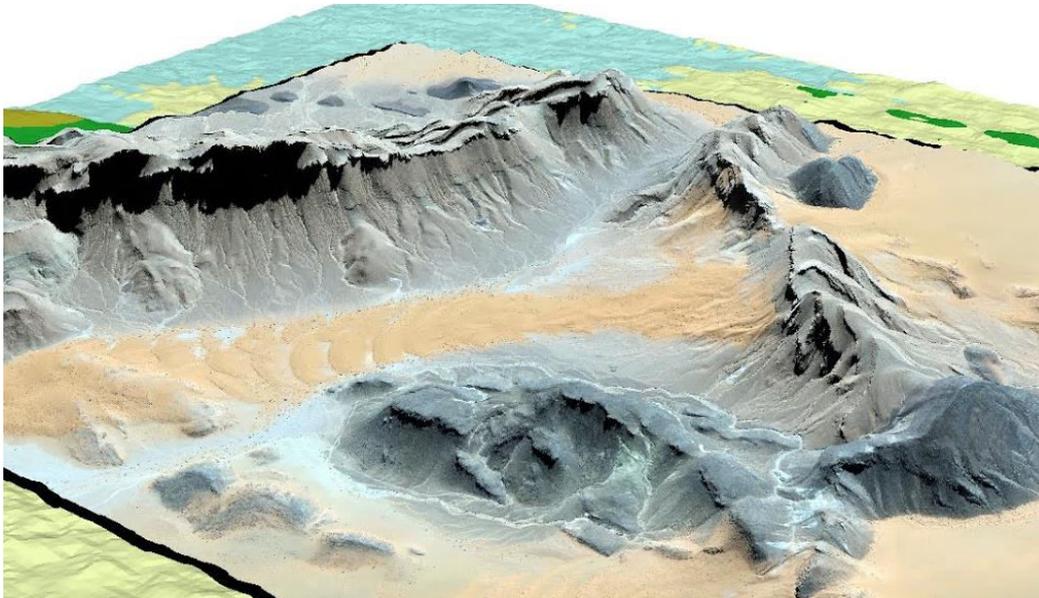


Figure 4.3: 3D GIS Technology

3D GIS, some problems and related issues in 3D GIS software development are reviewed and discussed. 3D GIS should be able to model, represent, manage, manipulate, analyze and support decisions based upon information associated with three-dimensional phenomena. The definition of 3D GIS is very much the same as for 2D system. In GIS, 2D systems are common, widely used and able to handle most of the GIS tasks efficiently. The same kind of system, however, may not be able to handle 3D data if more advanced 3D applications are demanded such as representing the full length, width and nature of a borehole. 3D GIS very much needs to generate information from such 3D data. Such a system is not just a simple extension by another dimension (i.e. the third dimension) on to 2D GIS. Adding this third dimension into existing 2D GIS needs a thorough investigation of many aspects of GIS including a different concept of modelling, representations and aspects of data structuring. Existing GIS packages are widely used and understood for handling, storing, manipulating and analyzing 2D spatial data.

3D GIS IN MARKET

There are few systems available in the market that can be categorized as systems that attempts to provide a solution for 3D representation and analysis. Four systems are chosen for detailed consideration, because they constitute a large share of the GIS market and provide some 3D data

processing functions. The systems are the 3D Analyst of ArcView (see ESRI Inc.), Imagine Virtual GIS (ERDAS Inc., <http://www.erdas.com>), GeoMedia Terrain (Intergraph Inc., <http://www.integrgraph.com>) and PAMAP GIS Topographer (PCIGEOMATICS, <http://www.pcigeomatics.com>).

3D GIS IN RESEARCH

The research in 3D GIS is intensive and covers all aspects of the collecting, storing and analyzing real world phenomena. Among all, 3D analysis and the issues related (topological models, frameworks for representing spatial relationships, 3D visualization) are mostly in the focus of investigations. Topological model: The topological model is closely related to the representation of spatial relationships, which are the fundament of a large group of operations to be performed in GIS, e.g. inclusion, adjacency, equality, direction, intersection, connectivity, and their appropriate description and maintenance is inevitable. Several 3D models have already been reported in the literature. Each of the models has strong and weak points for representing spatial objects. Carlson 1987 proposed a model called the simplicial complex. The simplex is the simplest representation of a cell. 0-simples is a point, 1-simples is the straight line between two points, 2- simplex is the triangle composed by three 1-simplexes and 3- simplex is the tetrahedron composed by three 2-simplexes. The author uses the simplexes to denote spatial objects of node, line, surface, and volume. The model can be extended to ndimensions. Molenaar 1992 presents a 3D topological model called 3D Formal Vector Data Structure (3DFDS). The model maintains nodes, arcs, edges and faces that are used to describe four types of features named points, lines, surfaces and bodies. Compare to the simplex approach, 3DFDS has less restrictions to the objects, e.g. the 2-cell (face) can have arbitrary number of 1-cells. Furthermore, some spatial relationships are explicitly stored, i.e. face-body. The model belongs to the group of Boundary representations (B-reps). Cambray 1993 proposes CAD models for 3D objects combined with DTM as a way to create 3D GIS that is a combination of Constructive Solid Geometry (CSG) and B-rep. Pigot 1995, developed a 3D topological model based on 0,1,2, 3 cell, which maintains an explicit description of relationships between cells. Work by Pilouk 1996 focussed on the use of TIN data structure and relational database for 2D and 2.5D spatial data. He proposes an integrated data model for 3D GIS (i.e. TIN and 3D FDS), which produced a practical approach to the problem. Moreover, the author develops the Tetrahedron Network (TEN) data structure that is based on simplexes. The structure assures strict consistency check, built on the generalised Euler's Equality. De la Losa 1998 and Pfund 2001 propose object-oriented models similar to Molenaar's one but they have include several more explicitly stored spatial relationships. For example, De la Losa maintains the relationship arc-faces as strict ordering of faces is introduced.

Zlatanova 2000 discusses some aspects of the data structuring and 3D visualisation with respect to data query over the Web. The proposed data structure lacks the 1-cell in order to improve the performance of the system. Abdul-Rahman 2000 focuses on the object-oriented TIN (2D and 3D) based GIS. The conceptual and the logical model are developed based on the Molenaar's data model. The consensus on a 3D topological model is not achieved yet. Formalism for detecting spatial relationships: OpenGIS consortium has adopted two frameworks to detect spatial relationships known as Egenhofer operators and Clementini operators based on the 9-intersection model (see Egenhofer and Herring, 1992, Clementini and Di Felice 1994). Although the topology is considered the most appropriate mechanism to describe spatial relationships, the study on other mathematical frameworks continues. Billen et al 2002 propose another framework (i.e. the Dimensional model) for representing spatial relationships, built up in affine space and convexity properties of the constructing elements (named dimensional elements). The Dimensional model allows larger variations in grouping spatial relationships compare to the 9-intersection model. Data Presentation: Advances in the area of computer graphics have made visual media a major ingredient of the current interface in the communication and interaction with computers. Therefore the research related to the visualisation of real world 3D data is mostly "shifted" to the computer graphics society. Many viewers and browsers as stand-alone applications and plug-ins have been developed to quickly visualise and navigate through 3D models for a variety of applications. New algorithms and implementations are reported daily. The design criteria, however, are fast rendering techniques based on internal structures rather than utilization of database representations. TerraExplorer (SkyLine, 2002), the current leader for visualizing large 3D textured data from real world and the first software with acceptable performance, also requires restructuring of data. Another significant area of 3D GIS research is devoted to Web applications. The Web has already shown a great potential in improving accessibility to 2D spatial information (raster or vector maps) hosted in different computer systems over the Internet. 3D data were even not transferable over the Web until five years ago. The first attempt to disseminate and explore 3D data, i.e. VRML, appeared to be rather "heavy" for encoding real geo-data due to the lack of a successful compression concept. Despite the drawbacks, the language became a tool for research visualization. Researchers could concentrate on data structuring and analysis and leave the rendering issues to browsers offered freely on Internet. The research on spatial query and 3D visualization utilizing VRML has resulted in a few prototype systems (see Coors and Jung 1998, Lindenbeck and Ulmer 1998, Zlatanova2000). GeoVRML (VRML extended with geo-nodes) and Geographic Modelling language (GML) are another promising opportunities for representing 3D data on the Web. Based on XML concepts, GML provides larger freedom, flexibility and operability than VRML.

USES OF 3D GIS TECHNOLOGY

- 1) **City Planning:** Cities have a way of growing to encompass previously under- or undeveloped areas in a process often called urbanization or urban sprawl. There are many reasons behind urban sprawl, including a desire to build improved infrastructure, affordable land or tax rates, or overcrowding inside the city. Urban sprawl can have a major impact on people who decide to leave the city as well as those who remain. For example, as residents move farther away from the city center, infrastructure such as roads or public transportation systems must accommodate their commutes, and traffic can lead to higher rates of air pollution. To minimize the negative impacts of urban sprawl and increased development, it is important for city planners to carefully determine the best way to grow urban areas. Urban development needs to take into consideration today's requirements, potential changes in demand and the long-term effects of building upward and outward.

3D GIS software can help city planners visualize what their proposed changes will look like and predict the outcomes for current residents and future generations. One example was the 2012 revitalization of the Mülheim Süd district in Cologne, Germany, located on the Rhine River. The project set out to make the district, which included a mix of residential, commercial and industrial buildings, more environmentally friendly over the course of two decades. A 3D model spotlighted building information, aerial photos, energy performance, air pollution, lidar elevation data, noise and traffic. The wide range of integrated information allowed architects, planning engineers and others to collaborate effectively. As the district develops further, the 3D model will help future planners with energy and environmental modeling and guide public participation initiatives.

- 2) **Building Information Modeling:** Building information modeling (BIM) is a technology that generates digital representations of facilities and relevant processes. BIM has given facilities managers the ability to closely review structures, beginning with the construction planning phase. Used in conjunction with 3D GIS data, BIM can help create robust building management plans and allow for more detailed analysis. For example, before breaking ground on a construction project, stakeholders can review findings from GIS and BIM to draw conclusions about environmental impact, sustainability, disaster readiness and how to optimize the use of assets and space. BIM and 3D GIS can also come together to support the preservation and restoration of historical buildings. An effort to digitally record cultural heritage sites in Dublin, Ireland, drew on Historic Building Information Modeling (HBIM) and 3D GIS to document and analyze selected locations.

One project focused on restoring buildings along Henrietta Street, which dates its earliest construction to 1730. By the 21st century, the street was lined with buildings in serious need of care. HBIM technology made it possible to map the extent of the damage and visualize what the area looked like when new. Researchers employed GIS tools to note attributes of individual buildings like the years of construction and address information. In the process, they developed a store of information that could be used to generate in-depth visualizations or guide tourists.

- 3) **Coastal Modeling and Analysis:** A nation's coastline is a crucial gateway for imports and exports, and about 40 percent of the world's population lives within 60 miles of a coast. But these areas also pose numerous challenges for development. It's critical for planners to understand the factors that affect construction and maintenance for shipping ports, fisheries, mineral mining operations and wilderness preservation areas. Responsible coastal development must be informed by underwater topography, local vegetation and predictions for the long-term environmental impact.

Resource planning systems that draw on GIS can provide insights into the economic, environmental and cultural results of activities along the coast. The right data makes all the difference in sustainably performing operations like construction or excavation. When preparing for the extraction of resources on the coastline, organizations benefit from synthesizing information like:

- Findings from 3D GIS mapping that suggest the likely outcomes of dredging material in the water
- Lidar topographical surveys
- Data sets from past extraction activities
- Trends in coastal change

- 4) **Wind Farm Assessment:** Planning a wind farm requires a detailed analysis of an environment and the potential effects of the structures. By using 3D GIS modeling, planners and other stakeholders can get a better idea of the impact from wind farm development on wildlife and people. For example, when assessing possible wind farm locations in two dimensions, a bird's migratory path might make a location seem inaccessible. However, reviewing that same space using 3D GIS data, may reveal that the elevation of birds' flight paths and the height of the wind farm are compatible. In Switzerland, developers wanted to find a way to accurately determine the noise that would be generated from the installation of a new wind farm. A team developing a visual-acoustic simulation tool decided to study Mont Crosin in

the Canton of Bern, Switzerland, which is home to 16 wind turbines. The researcher's analyzed recordings taken on days with varying wind and weather conditions and wind speed measurements taken with a 3D ultrasonic anemometer. They generated 3D models representing vegetation, infrastructure and the wind turbines themselves. The data allowed planners to predict the noise and environmental impact that would be produced by the proposed wind farm.

3D ANALYSIS TOOLS

3D analysis has been a growing trend in GIS because it's a better representation of the real world. It's not only for a pretty picture. For some types of problems, 3D analysis is sometimes the only way you can solve them. There has also been an explosion in 3D data types that's driving this demand. For example, **LiDAR**, **BIM**, UAV, textured meshes, **photogrammetry**, boreholes, **IoT**, **augmented reality**, **inSAR**, **space-time cubes** and **indoor mapping** are examples of 3D data.

1) 3D Geometric Analysis

These 3D tools perform overlay and proximity analysis in 3D based on the geometry of the features.

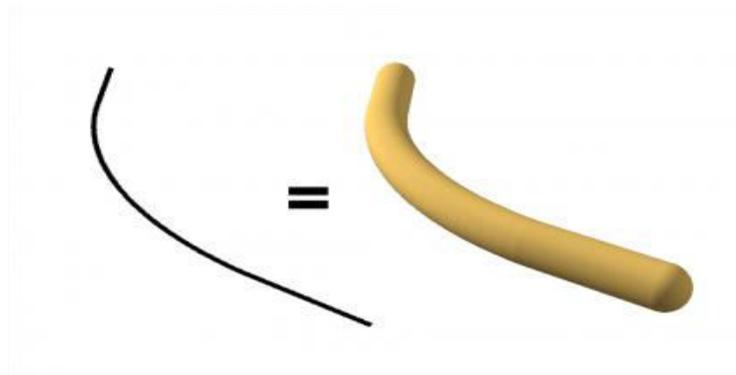


Figure 4.4: 3D Geometric Analysis

2) Visibility and Point of Observation

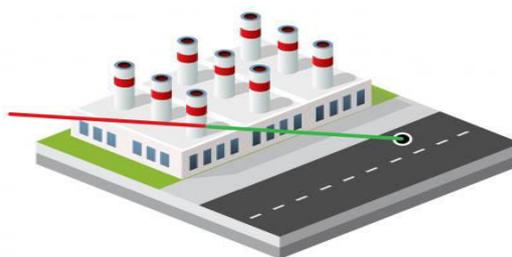


Figure 4.5: 3D Line of Sight

This group of 3D tools focuses on what's visible from an observer's point of view. These tools are common in military, city planning and identifies obstruction and non-obstruction parts of a straight line from an observer. It evaluates the amount of shadow and impact for the proposed building in an urban setting.

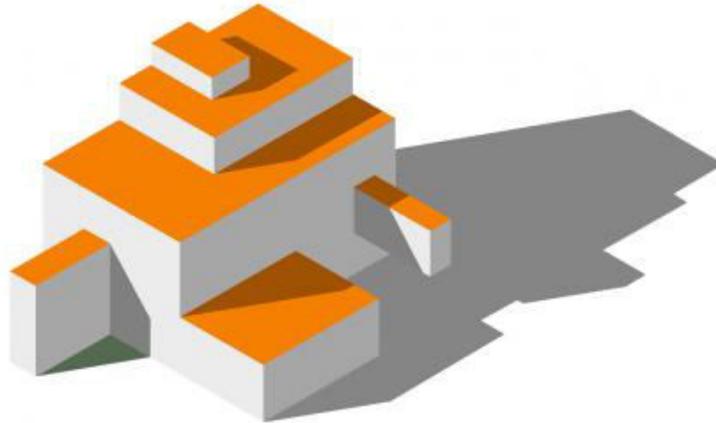


Figure 4.6: Shadow Analysis

Displays visible and obstructed areas like a 3D fan pointing towards from an observer's point of view.

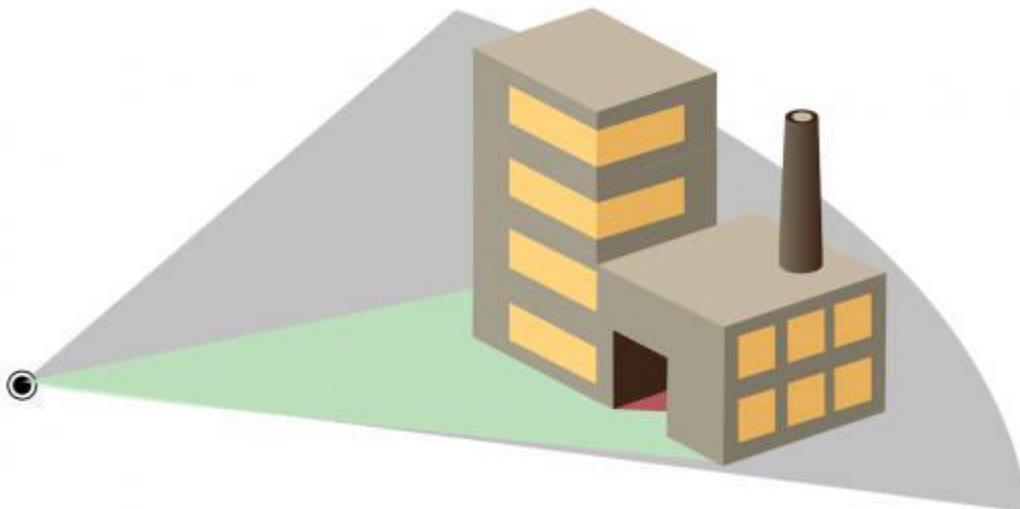


Figure 4.7: 3D Skyline

3) Surface and Area Calculation

This group of 3D analysis tools focuses on measurements of surfaces and volumes.

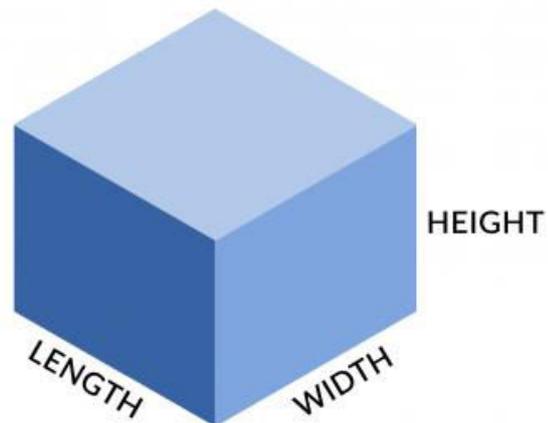


Figure 4.8: 3D Surface and Area Calculation

4) 3D Interpolation

Interpolates surface estimates unknown values by adding a third dimension in its analysis such as **kriging**, **IDW** and spline.

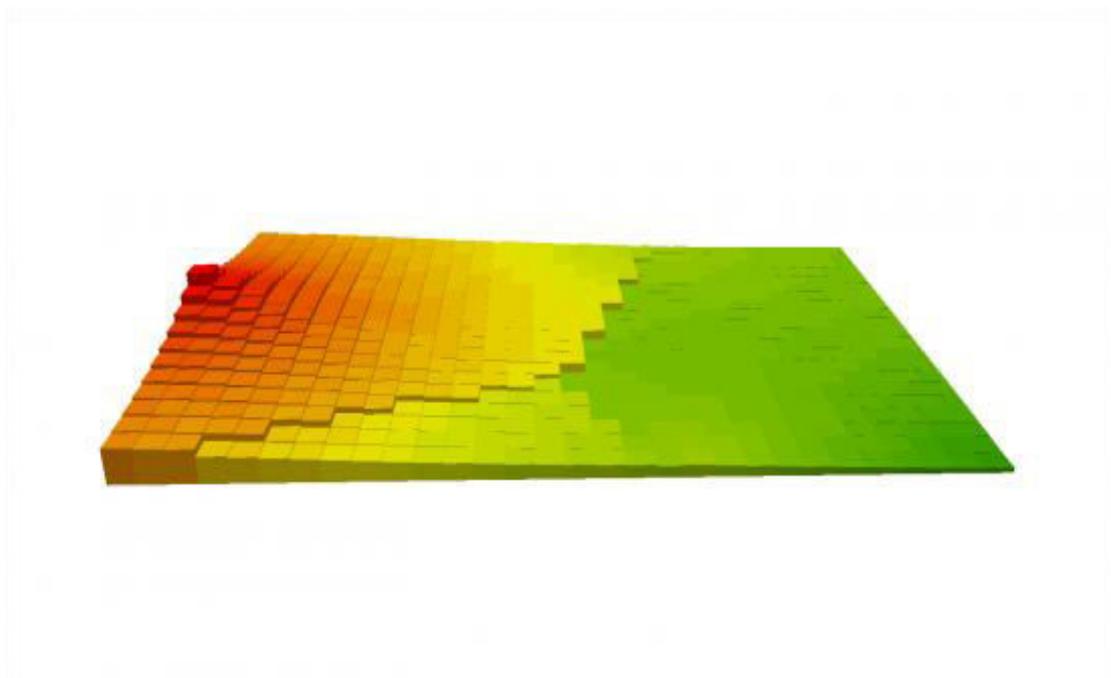


Figure 4.9: 3D Interpolation

4.4 SUMMARY

Although, quite significant number of works devoted to 3D data structuring, the research is concentrated around few basic ideas, as the level of explicitly described spatial relationships varies. Each suggested structure exhibits efficiency and deficiency with respect to a particular applications and operations to be performed. Still 3D GIS functionality to be addresses: 3D buffering, 3D shortest route, 3D inter-visibilitys are some of the most appealing for research. Integration of object-oriented approaches with the 3D GIS raises research topics at a database level toward standard object descriptors and operations. 3D visualization within 3D GIS requires appropriate means to visualize 3D spatial analysis, tools to effortlessly explore and navigate through large models in real time. Observations on the demand for 3D City models show user preferences for photo true texturing. Trading photo-true texture brings up necessities to store parameters for mapping onto the geometry.

4.5 GLOSSARY

1. **3D:** 3D GIS maps **depict objects in greater detail by adding another dimension (z).**
2. **3D Data:** 3D data capture is **the process of gathering information from the real world,** with x, y, and z coordinates, and making it digital.
3. **3D Technology:** The 3D Analyst is an extension that **adds support for 3D shapes,** surface modeling, and real-time perspective viewing.
4. **Surface Analysis:** Surface analysis will **depict surface conditions plotted from reported data or generated by computer models.** Surface analyst in GIS generated the contour, slope, aspect, and hill shade maps.
5. **3D Software:** 3-D software is a **type of computer graphics software** that enables the design, development and production of 3-D graphics and animations. 3-D software allows users to visualize, design and control an object, environment or any graphical element within a three-dimensional scope.
6. **Spatial Analyst:** Spatial Analyst is the extension ArcGIS uses to conduct analyses with raster data. 3D Analyst and ArcScene **allow users to display and work with three-dimensional (x, y, z) data.**

4.6 ANSWER TO CHECK YOUR PROGRESS

1. Define 3D software.
2. Define 3D data.
3. Define 3D technology.

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4.8 TERMINAL QUESTIONS

1. Explain 3D GIS in details.
2. Describe uses and tools of 3D GIS with suitable examples.

UNIT 5 - MODELING IN 3D GIS

5.1 OBJECTIVES

5.2 INTRODUCTION

5.3 MODELING IN 3D GIS

5.4 SUMMARY

5.5 GLOSSARY

5.6 ANSWER TO CHECK YOUR PROGRESS

5.7 REFERENCES

5.8 TERMINAL QUESTIONS

5.1 OBJECTIVES

After reading this unit you will be able to know about:

1. Data Modelling in 3D GIS
2. What is Terrain Modelling and Digital Elevation Modelling?
3. Visualization of 3D Data.
4. Application of 3D Application.

5.2 INTRODUCTION

What is Data Modeling?

A model is a mathematical or visual representation of a physical object and its associated events. The characteristics of the physical object are represented using data and their behaviour emulated through suitable mathematical equations. Geo-spatial objects are modeled using the spatio-temporal data pertaining to them and the various operations that can be performed on them to extract different aspects of geo-spatial information. In order to perfectly model geo-spatial objects the following key aspects of the terrain surface are preserved viz.

1. The physical representation of the object in terms of point, line or polygon
2. The inter se distance, direction and orientation of the object with respect to its surrounding objects.
3. The overall position, length, perimeter, surface area, volume and shape of the object.
4. The graphical and symbolic representation of the terrain object, which will give a visual representation to the objects in terms of shape, colour, style, pattern etc.
5. The scale, horizontal and vertical datum, projection parameters and the coordinate system associated with the geo-spatial data.
6. How the data is stored or organized in the memory and how it is accessed using logical data structure. Suitable spatial file formats which is the outcome of the spatial data organization and data structure that can hold the data while computation is also preserved.
7. The temporal behaviour of the spatial features i.e. the behaviour of the object with respect to time e.g. change in shape, attribute pattern etc.

5.3 MODELING IN 3D GIS

Modeling spatial data involves storing it into different data structure. Data structure imparts syntax to the spatial data. The operations that can be performed to manipulate and extract information from the data structures are well-defined in terms of algorithms in computing science. In other words, storing spatial data into a data structure means imparting syntax to the spatial data (Frank 1992). A GIS aims at processing, managing and analyzing spatiotemporal data. The capability of any information system in general and GIS in particular largely rely on the design of its data model. A data model presents the conceptual core of an information system. It defines the data object types, relationship among data structures, operations that can be performed and the rules to maintain database integrity (Date 1995). A rigorous data model must anticipate the spatio-temporal queries and analytical methods to be performed in the GIS. Information regarding temporal constructs must be represented by data objects defined in the data model of a GIS. Because of the temporal analytical capability, many GIS systems are called temporal GIS.

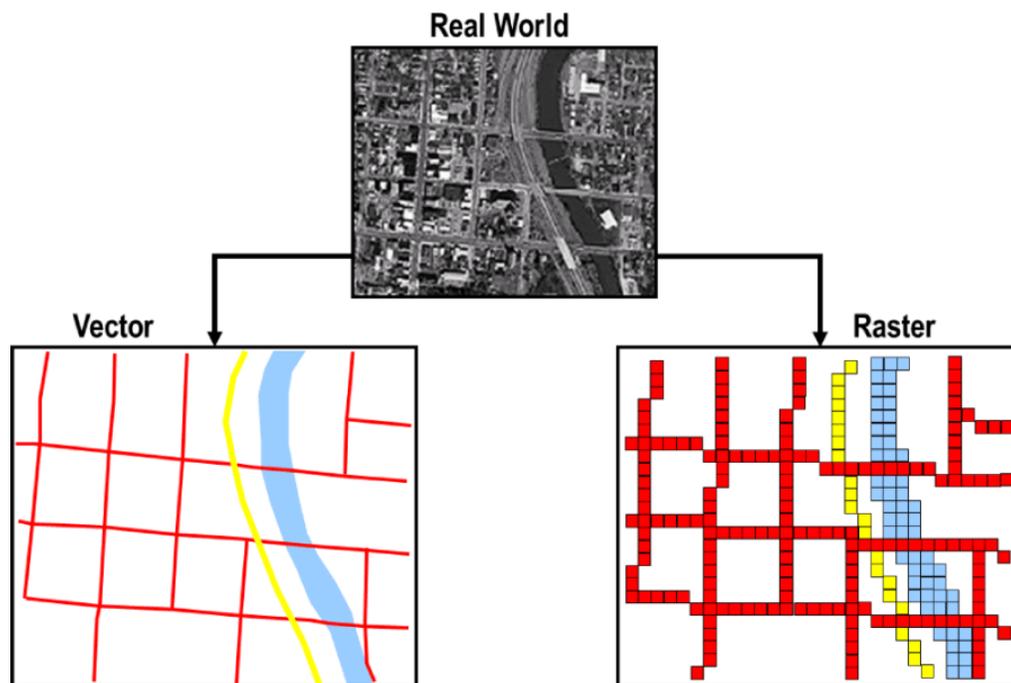


Figure 5.1: Data Modelling in GIS

Geo-Spatial Data Modeling

Earth surface, which is generally referred to as ‘terrain surface’, contains numerous features both natural and man-made. The frequency and occurrences of these features differ in different regions (e.g. coastal,

mountainous, desert etc.) arid time. In a way, the occurrence of a particular feature on terrain depends on both space and time and hence is a spatial and temporal phenomenon. Modeling terrain features involves giving a uniform definition so as to describe the complete attributes of every feature i.e. its spatial occurrences, its spatial and temporal relationship with its surrounding features, its appearance etc. To represent the feature symbolically so as to uniquely visualize and identify it in a physical container viz, a paper map or digital map or an elevation model etc also forms a part of the spatial modeling known as cartography.

Modeling of earth features in terms of spatial, temporal and attribute data and quantifying them as digital information is an important prerequisite for processing GIS data. The organization and storage of these digital information guides the kind of data structure needed to hold them and the type of algorithm to be applied for retrieval, processing and display by the GIS. Saving the digital information in various data formats so as to retrieve, modify and update for different purposes is quite intriguing and poses lots of challenge in designing GIS systems (Frank 1992). For the purpose of making maps, the earth surface is divided into various zones with each zone having uniform spheroid or ellipsoid parameters. Each zone is further sub-divided into sub-zones and a mosaic of squares known as grid or graticule. Each square is surveyed (locating of features relative to each other) using location information with respect to an origin of the graticule. The surveyed terrain feature is modeled keeping in view its usage (e.g. preparation of paper map, printing of paper map, creation of thematic map, topological analysis of earth features, viewing of terrain model etc). Depending on different usage of the geo-spatial data, modeling differs and hence the way the data is being organized, stored and further analyzed.

The most important geo-spatial data models prevailing are vector, raster or DEM (digital elevation model) (Carter 1988). Table, lists some aspects that have to be considered while modeling terrain features for different usages. As can be seen in the table, all modeling considerations are not applicable to all sets of geo-spatial data.

Vector data model envisages the object as a set of coordinates (x, y, z). These data are stored along with the associated datum parameters and are assigned with different colour, style, line type and width to represent them uniquely in a digital display or paper container. The raster data is a digital image displayed in the form of a matrix of the pixels representing the patch of earth. Each pixel is encoded as red, green, blue and intensity modeling the optical characteristic of the object. The digital terrain elevation data models the earth surface as a grid of square patches. Each patch is assigned the average

height of the patch from mean sea level. Hence DEM is essentially a matrix of height values with a header containing the meta-data regarding the terrain it represents.

Table 5.1: Spatial data model and their modeling considerations

Spatial data model	Modeling considerations
Vector model	<p>(x, y, z) coordinates: for retrieval of location information</p> <p>Colour, style, line type/pattern, symbology and symbol size:</p> <p>To impart a unique visualization to the feature</p> <p>Major category, minor category, sub-sub category: For thematic composition of maps, categorization of features into major and minor categories; to create thematic and operational maps</p> <p>To archive, query, organize, save, update, and retrieve from digital data</p> <p>For measurements of earth features e.g. area, distance, perimeter and volume</p> <p>For analysis e.g. to compute shortest path, optimum path, surface area, cross country mobility condition etc</p> <p>Preparation of paper map for printing</p>
Raster model	For printing and visualization of maps in digital display
DEM (digital elevation model)	<p>(x, y, z) coordinate for location in 3D-space, for a 3D-perspective view of terrain surface, fly through and walk through visualization</p> <p>To compute optical and radio line of sight</p> <p>To compute elevation value for visualization of terrain surface</p>

Each of these models has its strength and weakness. A comparison of the prime spatial data models with different aspects brings out the strengths and weakness of the models for different applications. It gives the builder of spatial information resource a general idea as to what types of modeling criteria to choose for building different applications.

Beside these primary terrain data models, there are many secondary or derived models. These are specific to applications which make use of them. Some prominent secondary spatial data models are contour models, grid models and TIN models. A contour model is used for terrain surface visualization. A grid model, which is a derived form of a raster model, is used for modeling digital terrain elevation and visualization of surface. The triangular irregular network (TIN) model is used for realization of

spatial query such as point in an area or space, range query etc. Each of these models can be derived from one another through highly optimized and established algorithms.

Raster vs Vector Data Model

One of the most important debates among geo-spatial community is the raster vs. vector model argument. A typical GIS user is always concerned about what advantage, disadvantage he or she gets by adapting a particular spatial data model functionally. It is because a particular set of functions, which is applicable over vector model, may not be applicable to raster model and vice versa. Table 5.2 gives a comparison between the vector and raster model of geo-spatial data with different perspectives, which will set to rest some of these concerns.

Table 5.2: Raster vs. vector data model

Property/ perspective	Raster	Vector
Spatial feature representation	Grid of pixels or cells Point = A single cell Line = A series of connected cells Area = A region of contiguous cells	Series of coordinates Node = Single coordinate Line = Two coordinates Polygon = Series of line segments with the first and last coordinate the same
Coordinate representation	Location of each cell is identified by the grid's origin plus the relative horizontal and vertical distance of the cell from the origin	The basic unit of representing geo-spatial information in the vector model is the coordinate. The coordinates are a pair or triplet of numbers expressing the distance from a set of orthogonal axis e.g. 2D/ 3D and rectangular or polar coordinate system. The data are represented in the form of (x y, z) or (easting, northing, altitude) or (range, bearing, phi) or (latitude, longitude, altitude)
Explicit attribute	The attribute of each cell are expressed using red (R), green (G), blue (B) and	Attributes of each object are attached as a record stored in RDBMS. Hence each object has a link to a record in the RDBMS

Property/ perspective	Raster	Vector
	intensity (I) values which are the spectral measures corresponding to the patch of earth	
Spatial resolution	The resolution is expressed as the minimum linear distance! dimension of the smallest feature, which can be identified in the image. High resolution means smaller dimension of the pixel. Low resolution means larger cell dimension and less information content	The resolution of vector data is expressed in the form of a scale. The scale is a ratio of the distance of two points on the digital map to the actual ground distance, Higher the scale, lower is the precession. Lower the scale, higher is the precession. 2 cm on a digital map = 2 km on the ground implies that the scale of the map is 1:50,000
Data structure used	Matrix or a 2-dimension array of values storing the R, G B and I per pixels organized as bytes per pixels, pixels per rows and rows per segments and number of interconnected segments as image files	The data structure used to store a vector representation is an array, quad tree and RB tree.
Operations and functions that can be applied	A convoluting matrix can be used to the entire image matrix, which apply the average value to the value of the center cell, or the median value, or apply a dominance rule etc.	Topologies i.e. the relative positioning of spatial objects are easy to represent in a vector model. One can prepare a TIN (triangular irregular network of nodes) and thus the following operations can be applied in vector data: Line–line intersection Point inside triangle/polygon

Property/ perspective	Raster	Vector
	Sometimes the value of each cell is checked for a threshold to apply binary rules such as zero or one thus making a binary image.	
	The outcomes are edge prominent images; noise removed images; binary images; grey-valued images,	Compute the convex hull of the object To find the nearest location of a particular object etc.

Figure 5.2: shows the visual results of a geographical space using both vector and raster data model.

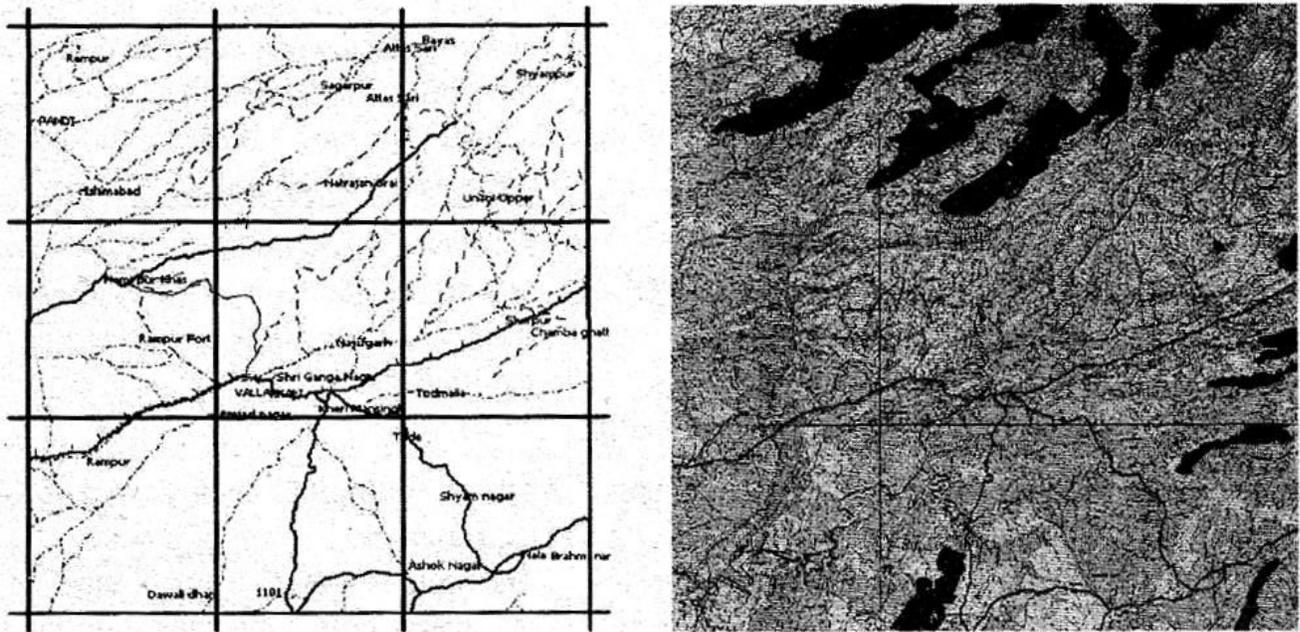


Figure 5.2: Vector and Raster representation of the same geographical area

3D VISUALIZATION AND MODELLING

3D terrain visualization is a prime function in many applications and information systems such as GIS, virtual reality, scientific visualization, and remote sensing. Viewing the terrain surface as it is in the digital display has enthused many researchers and user communities due to various reasons. To name a few, a battle commander needs to view a fly through model of the red (enemy) land to have a general appreciation of the terrain, to study the topography and to observe enemy deployment-A pilot may like to have a first-hand experience of flying to a destination along a particular air route before actually commencing the flight.

One can obtain a general appreciation of the terrain by visualizing the 3D terrain with different information layers laid on top of a model e.g. a satellite image, a topographic map or a shaded relief map. Further, different temporal conditions such as daylight, night time, fog, cloud and other meteorological conditions can be simulated on the terrain for realistic visualization of the terrain. Hence of late, 3D terrain viewing and analysis or simulation of a fly through along a terrain has become an integral part of any GIS software.

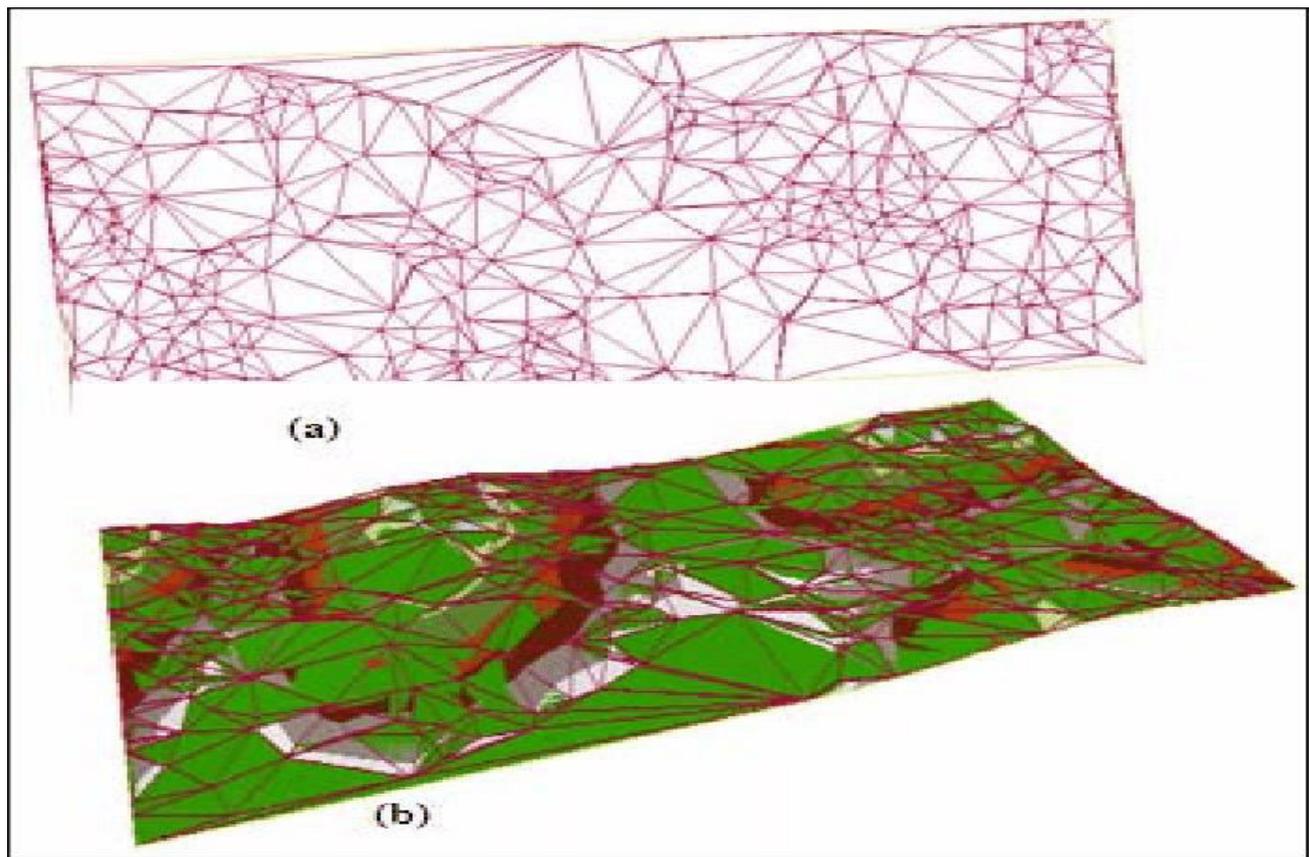


Figure 5.3: Terrain 3D Modelling

Terrain surfaces are usually modeled in GIS using grid of raster cells or triangular irregular networks (TINs). The derivatives discussed in this chapter may be calculated using either of the models, but emphasis is given more on raster maps. The most commonly calculated surface derivatives are slope and aspect. Because slope estimates in coordinate systems using latitude and longitude are not interpretable, the derivatives are measured using ground distance units like meters, feet, or miles.

When to model GIS data in 3D

Since 3D GIS data can be more difficult to create and maintain than 2D data, modeling your data in three dimensions should only be done when the extra effort will add value to your work. While some GIS features, such as aircraft locations or underground wells, naturally lend themselves to being modeled in 3D, other data can be just as effective in 2D as in 3D. For example, having a road network modeled in 3D might seem useful for investigating gradients, but the additional effort to maintain z-values might outweigh the benefits.

These are some important considerations when deciding to model your data in 3D:

- GIS data does not have to be modeled in 3D to be displayed inside a 3D view.
- Height values from a surface can easily be added to 2D objects, when you need them, through the use of geoprocessing tools.
- If the source of your z-values is a surface, consider how often that underlying surface changes.

The more it changes, the less useful it will be to store z-values for features generated against it.

If you decide to model some or all of your data in three dimensions, the most important decision will be the units of the z-values. A solid understanding of what your z-values represent will be critical when you start editing and maintaining them. A general rule to follow whenever possible is that the z-units should match your x,y units. For example, if your data is in a (meter-based) UTM zone, you should also model your z-values as meters. This will help you interact with the data in an intuitive way, such as when you measure 3D distances or move objects in x, y, and z.

What is Digital Terrain Modeling?

In general the first question that comes to the mind of a beginner is: 'What is digital terrain modeling?' A terrain model is a scaled down visual representation of the terrain surface as a solid model or a computer model displayed in a digital display environment. Creation of a terrain model involves the collection of terrain data, organization of data and finally representation of the data on computer screen

or through a solid model. A digital representation of the terrain is often called a digital terrain model (DTM) or a digital elevation model (DEM) and the data is called digital terrain elevation data (DTED) (US Geological Survey 1987).

In a DTM the representation of the terrain is done in the form of a grid of height values which corresponds to the average height of the patch of earth under consideration from the mean sea level. This grid of height values or matrix of values divides the patch of earth under consideration into a matrix of square elements. The average height of the square elements of the earth is assigned the height value of the grid point as depicted in Fig. 5.4. Obtaining the height at each and every point of the grid and associating them with the patch of earth is done using various methods e.g. from ortho-photos, from satellite images, from shaded relief maps, from surveyed spot heights, trig, heights and contours. Different formats of elevation models can be obtained depending on the way height values are organized. The most popular elevation models are DTED, DEM and triangular irregular network (TIN) (Cavendish 1974). Among the DEM models, there are many popular data formats that are in practice e.g. USGS DEM/DTED, National Marine Engineers Association (NMEA) format etc. In general, the data files are organized into two parts: (1) the header and (2) the body. The header contains the meta-data regarding the actual height matrix and the body constitutes of the height profile as a regular grid.

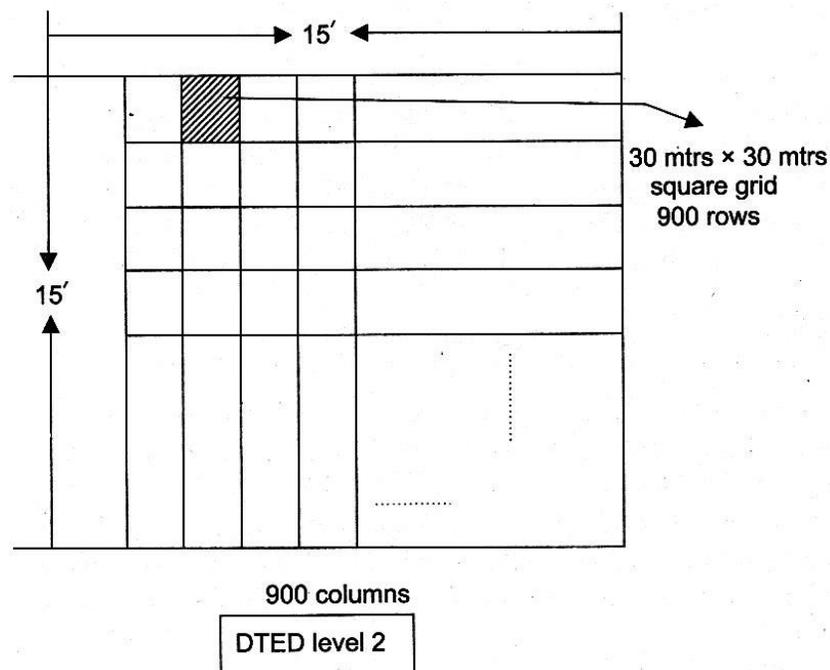


Figure 5.4: DTED Matrix of 15' x 15' Area

The evolving spatial modeling techniques and algorithms combined with easy availability of DEM data has made applications of DEM popular. Different applications of DEM in both military and civilian applications are increasing day by day. The importance of DEM can be emphasized from emerging applications such as fly through and walk through simulation, scientific visualization, study of terrain change, etc. Here are some reasons why digital elevation models are important. This is a candidate list and is not exhaustive.

1. DEM combines the following data and information to give a comprehensive visualization of the terrain as it is: the current state of a landscape typically captured in a GIS i.e. the digitized contours, trig, heights (triangle heights), the spot heights surveyed as benchmark heights of the terrain surface and height of the earth surface obtained from GPS.
2. It helps to visualize and plan the future use of the terrain surface and schedules of human activities such as establishment of new human settlements, vital installations, landscape modeling and possibility of landslides and disasters.
3. DEM helps to understand and gain knowledge about how natural processes can get affected because of changing terrain.
4. It helps to produce time-series data regarding the potential future of the landscape. Fly through and walk through simulations can be conducted for visualization of unknown territories where direct human reconnaissance is not advisable or will risk human life.

Generation of DEM

The choice of sources of data and capturing techniques used for collection of terrain data are critical for the quality of the resulting DTM. DTM data mainly consists of observations of terrain elevation, shape of the terrain surface (i.e. structural features such as drainage channels, ridges, peaks and other terrain surface discontinuity) and spot heights or trig. heights obtained from ground survey (Cole et al. 1990; Zhang and Montgomery 1994).

DEM data is directly or indirectly obtained from the following sources

1. Ground survey
2. Photogrammetric data capture (manual, semi-automatic, automatic mode)
3. Digitized cartographic data sources etc.

In addition to the above traditional sources, different sources are used to obtain DEM data for different terrains. Some of the popular techniques of DEM data collection are RADAR (radio detection and

ranging) used for mountainous terrain, LASER (light amplification by stimulated emission of radiation) altimetry used by UAV and airborne platforms, LiDAR (light detection and ranging) for mapping city profiles and SONAR (sound navigation and ranging) for aquatic terrain. These techniques' help in measurement of undulation in terrain surface using stereoscopy.

DEM data are obtained after processing satellite scans or UAV (unrtianned aerial vehicles which help in aerial surveys) scanned images, interpolated heights from ground survey contours, spot heights and trig, heights. Aerial survey through photogrammetry technique is a mechanism of ortho-photo generation and aero-triangulation from which height of ground objects are computed. Of late, ground survey using GPS and DGPS gives the nascent profile of the earth surface in terms of location and height from MSL.

Figure depicts how an aerial photo of an undulated earth surface is captured using an airplane. The photograph obtained through this sort of an aerial platform has a disadvantage in that it does not capture the height of the terrain. But there will be a shift of objects in the photograph, which has considerable height above mean sea level due to relief of the terrain. This is known as displacement due to relief. This phenomenon of relief displacement in ortho-photo is exploited to measure the height of the object on earth. To obtain the height of the ground, two oblique photographs of the same area is taken from two different perspective points using the same camera and from the same height as depicted in Figure.

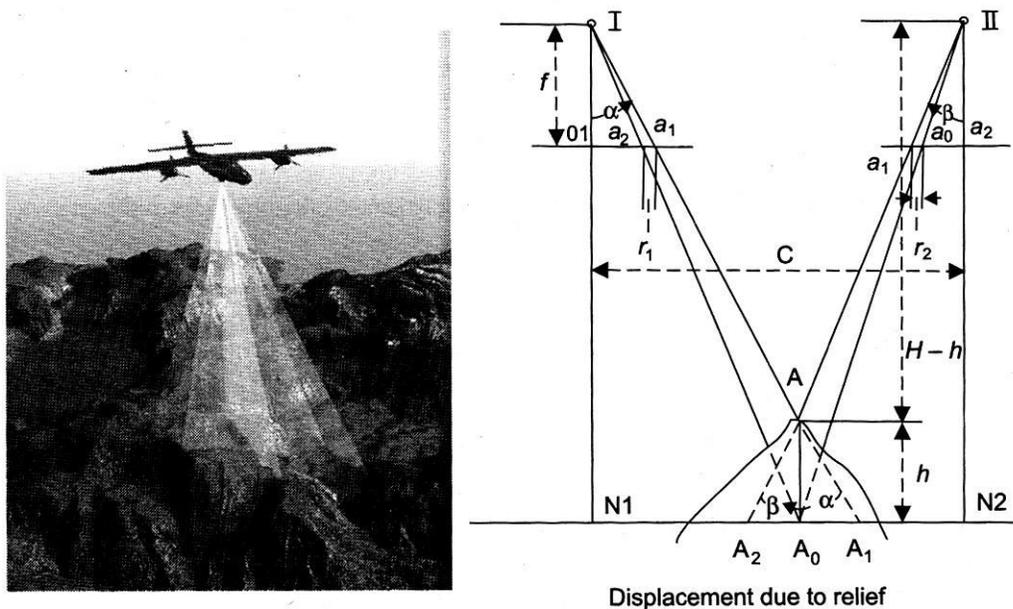


Figure 5.5: Capturing an aerial photograph of an undulated terrain surface; Computing displacement due to relief of ground from the aerial stereo-photo

These are called stereo pair of photographs. Because of the relief of the ground, although the photographs are taken from the same height, the object will appear to have been displaced from its original position. The height of the terrain object is then computed using this relative shift observed from the pair of stereo-photos (equation).

In Figure, vertical photographs of the irregular terrain surface is taken from two different perspective points I and II with the same camera of focal length f at an altitude of $(H - h)$ above the point A. Rays from A toward the perspective center I pierce the focal plane at point a_1 . Had point A been at an elevation $h = 0$, that is, either at sea level or in some other reference plane, the rays would have been reflected from point A_0 and would have pierced the focal plane of the camera at I at point a_0 . The distance $r_1 = a_1a_0$ on the photograph I is the displacement of the image point of A due to relief h above the datum surface. Similarly on photograph II the displacement $r_2 = a_2a_0$ due to relief is recorded from the same camera. From using geometry one can establish

$$O_1a_1lf = \tan \alpha$$

Where, O_1a_1 is the distance on the photograph from the principal point to the picture location of A and α is the angle of the ray IA from the vertical. From Fig. 5.1(b) using similarity of triangles one can establish

$$r_1 / A_0A_1 = f/H$$

Substituting $A_0A_1 = h \tan \alpha$ in the above equation one can compute the displacement due to relief r_1

$$\text{Hence } r_1 = hf \tan \alpha / H$$

The scale of the photograph is the ratio of the actual distance of the object from the camera to its focal length. Hence substituting scale $S = H/f$ of the photograph in equation (5.1)

$$r_1 = h / S \tan \alpha$$

Using the same principle in stereo photo II, the relief r_2 can be computed. The height of the terrain h can be computed more accurately using the differential relief obtained by the pair of ortho-photos as given by equation (5.3)

$$r = r_2 - r_1 = h(\tan \alpha_2 - \tan \alpha_1) / S$$

Therefore, given relief displacement r , scale factor S and perspective angles α_1 and α_2 of the imaging instrument one can compute h , the height or relief of the terrain using equation (5.3)

Collection of DEM

Various survey and data collecting agencies over the years have collected digital elevation data using a number of different production strategies such as manual profiling from photogrammetric stereo-models; stereo-model digitizing of contours; digitizing topographic map contour plates; converting hypsographic and hydrographic tagged vector files; and performing auto-correlation via automated photogrammetric systems. Of these techniques, the derivation of DEMs from vector hypsographic and hydrographic data produces the most accurate model, and is the preferred method in use.

One important source of DTED data is the Internet. The Shuttle Radar Topography Mission (SRTM) successfully collected interferometric synthetic aperture radar (IFSAR) data over 80 percent of the landmass of the earth between 60 degrees north and 56 degrees south latitudes in February 2000. The mission was co-sponsored by the National Aeronautics and Space Administration (NASA) and the National Geospatial Intelligence Agency (NGA) of USA. NASA's Jet Propulsion Laboratory (JPL) performed preliminary processing of SRTM data and forwarded partially finished data directly to NGA for their contractors to finish it. Subsequently these data were made available to different US agencies and are now available through the Internet for the general public.

Input Domain of DEM

Visualization of DEM varies according to the data contents, visualization techniques used and requirement or purpose of the model. Generally the input domain of a DEM constitutes the following components.

1. The surveyed contours (iso-heights)
2. The spot heights or heights obtained from GPS/DGPS
3. The triangle heights or trig, heights
4. The randomly sampled heights from MSL for a set of surveyed points of the earth surface
5. Grid of height values representing the statistical height of a patch of earth
6. The satellite image of the area or image taken from UAV
7. The almanac data of the area with respect to time
8. The layer-wise vector data

Process Flow of 3D Analysis

The block diagram in Figure, depicts the process flow of how 3D processing is carried out on the digital terrain elevation data (DTED) obtained from various sources. Steps 1-4 explain the process.

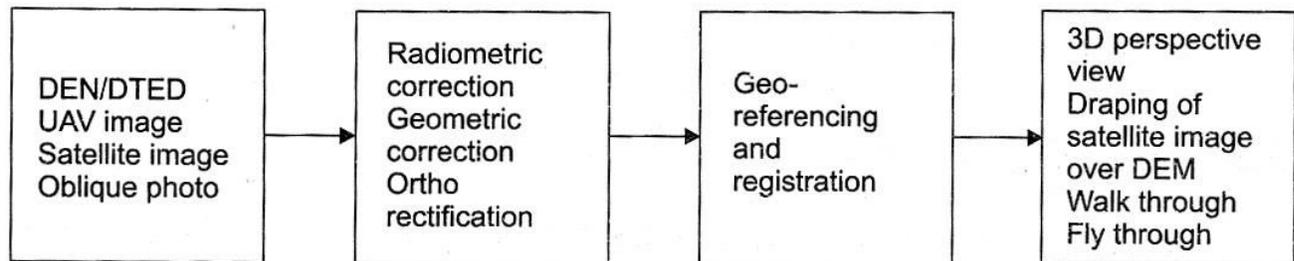


Figure 5.6: Process Flow of 3D Processing

- STEP 1** The height data are obtained through various sources such as surveyed spot heights, triangle heights, surveyed contours and heights obtained from GPS and DGPS.
- STEP 2** A regular grid of known resolution, i.e. a grid of known rows, columns and inter se distance between rows and columns is imposed on the above data so as to obtain a uniform grid of height values from these scattered data using interpolation. Usually a bilinear interpolation is used to obtain a uniform array of heights from the above data. Sometimes an irregular grid e.g. Delaunay triangulation is constructed from the scattered data to obtain a unique triangular irregular network (TIN) of height values.
- STEP 3** Finally the TIN or the grid is geo-coded and geo-referenced i.e. the upper left and lower right corner boundary of the data is assigned the actual geographical coordinates (latitude, longitude) pertaining to the ground. This defines the physical boundary of the data representing the terrain profile. Thus the coordinate readout will read the true (latitude, longitude and height) from MSL or (easting, northing and altitude) from MSL at every point.
- Finally the following visual analysis can be performed on the DEM.
- STEP 4** 3D perspective transformation is applied to the data with respect to the viewer's eye point to visualize a 3D perspective of the terrain.

A shaded relief map is generated for different azimuths and elevation of the sun depicting the relative height of the terrain due to the shade generated from the sunlight. A colour code is applied to different

ranges of heights to generate a colour-coded view of the terrain profile. A terrain irregular view and a wire frame model gives different views of terrain undulation.

Draping of the satellite image or scanned photo of the area is done over the DEM to give a realistic view of the terrain. Simulation of daylight, twilight or almanac condition over the terrain gives a realistic visualization of the terrain surface.

The followings can be computed using DEM data. These are known as the DEM derivatives.

1. Slope at each point on the terrain
2. Rate of change of slope
3. Direction of the slope from the north
4. The height from mean sea level
5. The minimum and maximum height of a particular area
6. The profile of the land; cross-section of a designated path (path profile)
7. Linear distance taking into account the undulated surface between two points
8. The perimeter and surface area of a closed area
9. The volume of a piece of land

DEM Derivatives

Sets of information that can be derived from DEM after processing are known as DEM derivatives (Guth 1995; Burrough 1986). Depending upon different processing methods, different results are obtained from the DEM data. Some significant and commonly used information derived from DTM are the height from MSL, the slope, aspect and curvature. These derivatives have already been discussed in Chapter 4 where terrain surface was modeled as a discrete matrix of heights. In this chapter, the height at a terrain location will be modeled as a continuous function of the location, i.e. height is a function given by $h = f(x, y)$ which perfectly models a raster image of a terrain surface..

1) Slope

Slope measures the steepness of the surface at any particular location. It is often measured in degrees or in percent rise. A flat region has a slope equal to zero. The steeper the surface, the higher is the slope. Slope is an important variable for many analyses; here are just a few:

- To generate drainage patterns on digital elevation models (DEMs)
- For environmental modeling
- For selection of suitable site for staging, installation of equipments etc.

- For generation of cross-country movement models

A map obtained by the derivative of DEM data using neighbourhood operations is known as a slope map. A slope map gives the rate of change of the height of the cell under consideration with respect to its adjacent cells. It gives a measure, of the steepness of an area of the earth's surface. Slope is usually measured in degrees or percent. The slope value assigned to each cell reflects the overall slope based on the relationship between that cell and its neighbours.

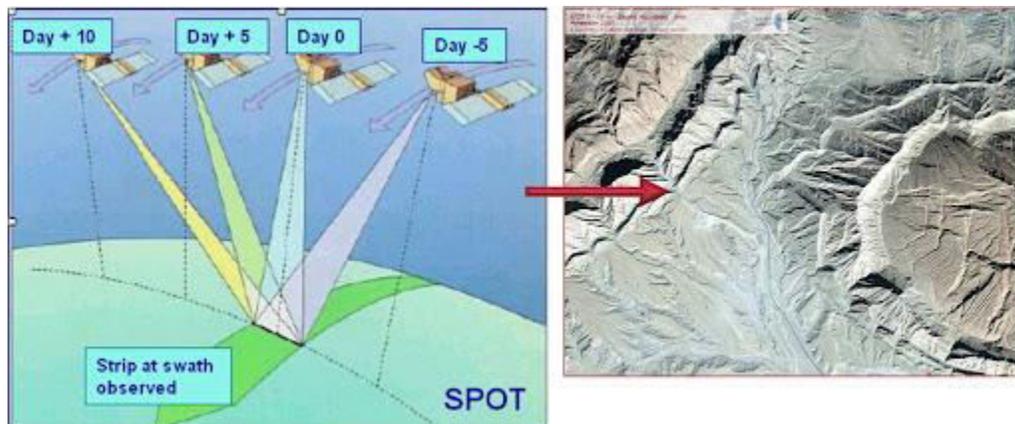


Figure 5.7: Slope

2) Aspect

Aspect measures the direction of the steepest slope for a location on the surface. It is usually measured in degrees, where 0 degrees is due north, 90 degrees is due east, 180 degrees is due south, and 270 degrees is due west. Note that zero and 360 degrees are equivalent.

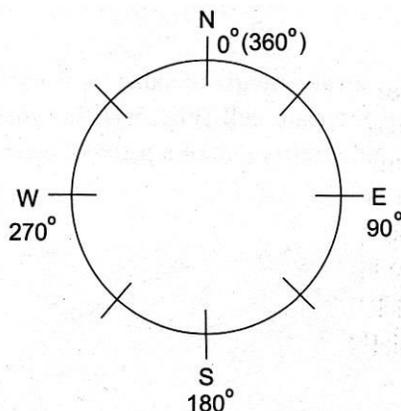


Figure 5.8: Aspect: The orientation of slope measured in degrees from north

A map where each cell is assigned a value of its orientation in the form of an angle is known as an aspect map. An aspect map tells us the direction to which the surface cells are oriented with respect to the terrain normal. Generating and interpreting maps of aspect can be tricky, since the scale ‘wraps’ around from 359 to 0 degrees.

3) **Curvature Map**

Curvature gives the rate of change of slope. In a curvature map each cell carries the value of rate of change of the slope i.e. curvature of the landform. Oeomorphology uses curvature maps for landform analysis (concave/convex) to study the ageing of terrain surface or for change detection of the terrain surface. The age of the terrain surface can also be gauged from the curvature. If the height is given, the slope, aspect and curvature of a patch of terrain can be computed using the following formulae. In this, the terrain height is given modeled as a continuous function of the location (x, y) i.e. $h = f(x, y)$.

The second order derivative of the DTM grid (i.e. the first derivative of the slope) gives the curvature of the DTM. The curvature describes the convex, concave or plane nature of the surface

In case of a DEM, the height of the terrain surface is given as a matrix of values with each value of the matrix element representing the height of a terrain cell (Fig. 5.4). In other words, in DEM, height is not a continuous function but a discrete value of a patch of earth.

A	B	C
D	E	F
G	H	I

Grid of DTM with cell designated alphabetically

Hence the computation for slope, aspect and curvature is done differently (equation (5.4)). In Fig, let us consider Z_a to be the elevation for cell A, Z_b the elevation for cell B, and so on. Then, the algorithm for finding the slope in cell E is given in the steps below.

STEP 1 Calculate the east—west gradient (dz/dr) and north—south gradient (dz/dy) for cell E:

.....

STEP 2 Calculate the slope at E from the partial gradients using equation (5.4)

.....

Note that dz/dx and dz/dy are equivalent to rise/east—west run and rise/north—south run, respectively. The aspect and curvature of a DEM can be computed using the values of east—west gradient and north—south gradient substituted in equations (5.2). and (5.3) respectively.

Processing and Visualizations of 3D Data

There are various ways of visualizing the 3D surface of the terrain using GIS—3D perspective view, an orthogonal view, a perspective view with a colour-coded relief map draped on the undulated terrain and a satellite image draped on top of the terrain surface. All these give a static view of the undulated terrain. On the other hand, simulations such as a fly through the terrain at a specified height and a walk through the terrain give a dynamic visualization of the terrain surface. Figures show a specimen of each of these types of visualization possible through a modern GIS system.

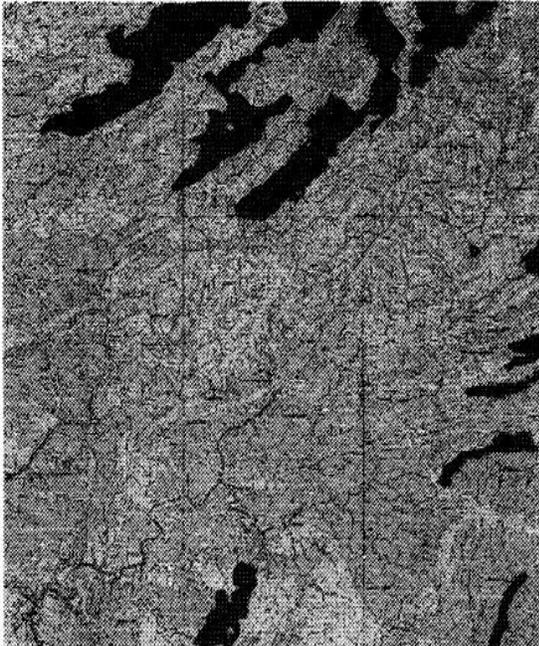


Figure 5.9: Raster Image/Scanned Image of the Map

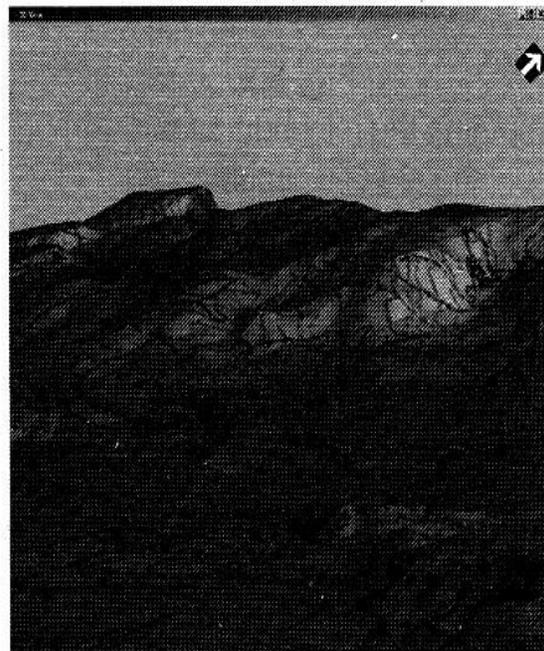


Figure 5.10: 3D Perspective view of DEM with raster image and vector layer draped on it

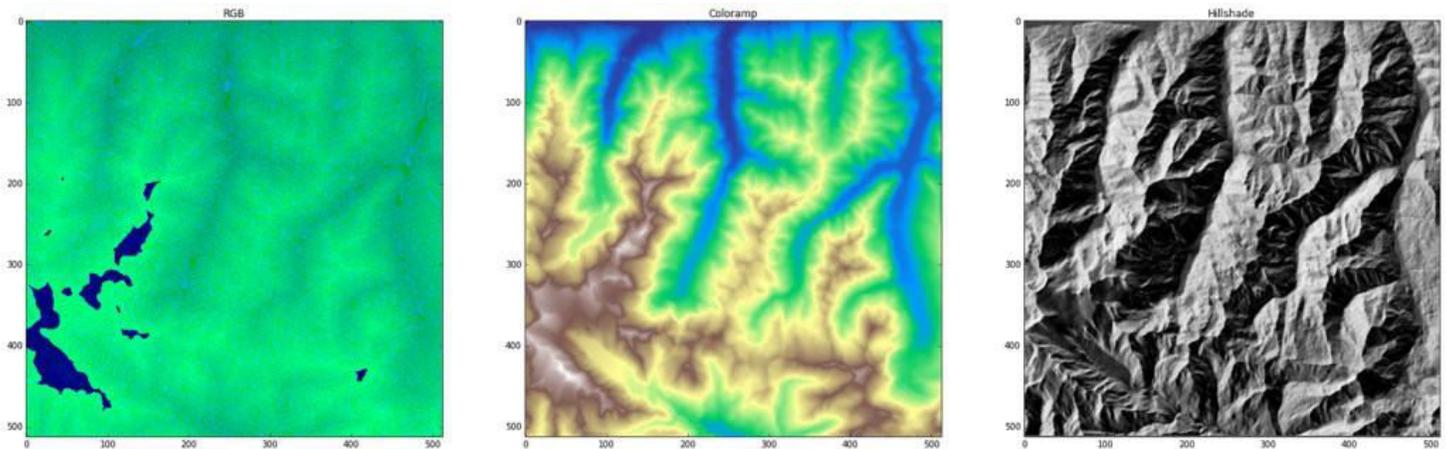


Figure 5.11: Relief and Elevation Map

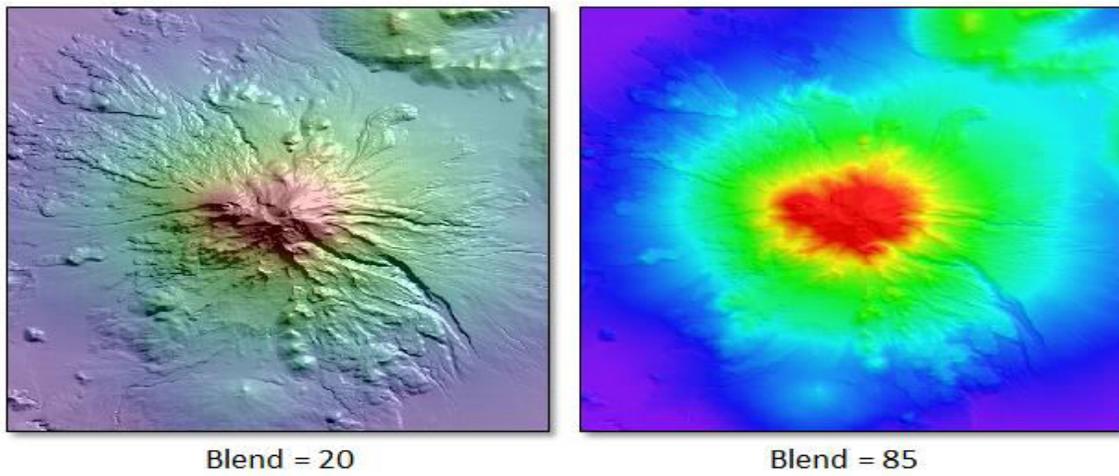


Figure 5.12: Topographic Shading

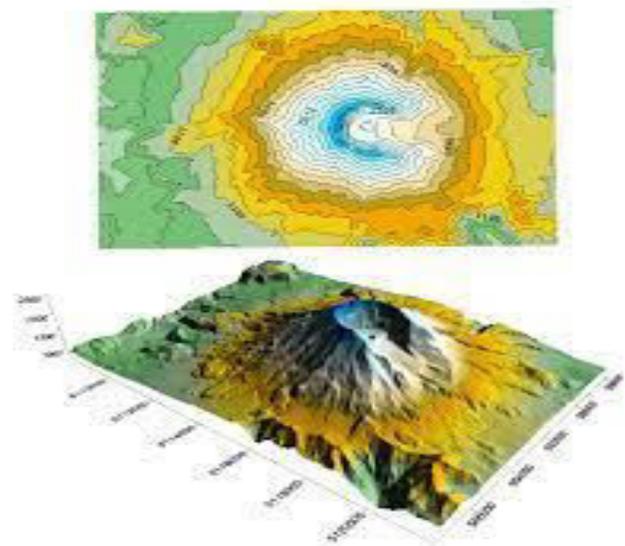


Figure 5.13: Surface Mapping

Applications of DEM

DEM provides a forum for formalized thinking about how the landscape is working (Zhang et al. 1994). Users are already making decisions based on conceptual models prepared using DEM. It helps users to formally analyze, improve, and combine formalized conceptual models and geo-spatial data from various sensors and sources and identify the relative importance of the collection of different data.

Various applications use DEM for generation of three-dimensional graphics displaying terrain slope, aspect (direction of slope), and terrain profiles between selected points. DEMs have been mostly used in combination with digital raster graphics (DRG5), digital line graphs (DLGs), and digital ortho-photo quadrangles (DOQs) to enhance the visual information. They are also used for data extraction, revision purposes and to create aesthetically pleasing and dramatic hybrid digital images. Non-graphic applications such as terrain modeling and gravity data modeling used for searching for energy resources, calculating the volume of water reservoirs, and determining landslide probability have also been developed using DEM extensively.

- 1. Oil and Gas:** DEM is used for locating oil wells and planning routes and pipelines for transport of oil and gas. In telecommunications, DTED data is used to plan installation of telecom infrastructures such as trans-receivers and antennas for wireless networks supporting propagation models integrated with clutter models. In land use study, environment engineering, study of erosion and forestry, hydrology and drainage, DTED is used extensively. Slope derivatives of DEM can be used to generate attractive hill-shaded maps with different sun-angles. One such sample output of a GIS using DEM data, computing the shades generated due to slope, is depicted in Figure.

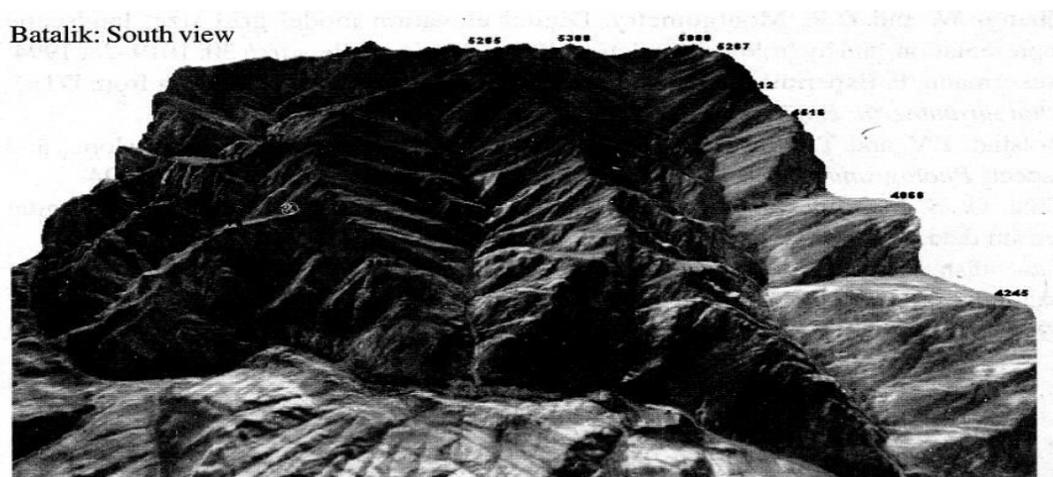


Figure 5.14: Hill Shade

5.4 SUMMARY

The major 3D progress is observed in the area of data presentation. All traditional GIS vendors provide extended tools for 3D navigation, animation and exploration. However, many of these systems still are lacking full 3D geometry. OpenGIS specifications seem to have been adopted rapidly by DBMS, CAD, and GIS developers. In this order of thoughts, the understanding for GIS is changing. Instead of a monolith, desktop, individual system, GIS is becoming an integration of strong database management (ensuring data consistency and user control) and powerful editing and visualization environments (inheriting advanced computer graphics achievements). At present, only the first step is made, i.e. the implementations focus mostly on the geometry. 2D topological representations and operations are intensively in the process of implementation. The third dimension with respect to topological issues is still in the hands of the researchers. The case studies clearly showed the benefits of a standardized spatial data structuring as well as revealed the very early stage of the integration. The large number of specialized settings, the application dependent feature-geometry linkage, the limited semantic hierarchy, the spatial operators utilizing only X, Y values, are some of the issues that need further improvement. Although, there are quite a significant number of works devoted to 3D data structuring, the research is concentrated around a few basic ideas, as the level of explicitly described spatial relationships varies. Each suggested data structure exhibits efficiency and deficiency with respect to particular applications and operations to be performed. Still 3D GIS functionality needs to be addressed: 3D buffering, 3D shortest route, 3D inter-visibilitys are some of the most appealing for research. Integration of object-oriented approaches with the 3D GIS raises research topics at a database level toward standard object descriptors and operations. 3D visualization within 3D GIS requires appropriate means to visualize 3D spatial analysis tools to effortlessly explore and navigate through large models in real time. Observations on the demand for 3D City models show user preferences for photo-true texturing. Trading photo-true texture brings up necessities to store parameters for mapping onto the geometry.

5.5 GLOSSARY

- Visualization: The representation of an object, situation, or set of information as a chart or other image.
- Navigation: is the art and science of determining the position of a ship, plane or other vehicle, and guiding it to a specific destination.

5.6 ANSWER TO CHECK YOUR PROGRESS

1. Define Digital Elevation Model.
2. Define 3D GIS.

5.7 REFERENCES

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5.8 TERMINAL QUESTIONS

1. What do you understand by data modelling in GIS? Explain with examples.
2. Briefly explain the stages of data processing cycle.
3. What do you understand by remote sensing data products?
4. What are various remote sensing data formats?

UNIT 6 - FUTURE VISION OF 3D GIS

6.1 OBJECTIVES

6.2 INTRODUCTION

6.3 FUTURE VISION OF 3D GIS

6.4 SUMMARY

6.5 GLOSSARY

6.6 ANSWER TO CHECK YOUR PROGRESS

6.7 REFERENCES

6.8 TERMINAL QUESTIONS

6.1 OBJECTIVES

After reading this unit you will be able to:

- Explain recent trends of 3D GIS
- explain future development in 3D GIS

6.2 INTRODUCTION

The need for 3D information is rapidly increasing. Currently, many human activities make steps toward the third dimension, i.e. urban planning, cadastre, environmental monitoring, telecommunications, public rescue operations, landscape planning, transportation monitoring, real estate market, hydrographical activities, utility management, military applications. Practically, the area of interest grows significantly when 3D functionality is offered on the market. Moreover, the role of geo-information in all kinds of business processes is getting quite transparent. Terms such as “location-specific information” and “location-based services” become a part of the daily business language to denote the link between the virtual world of information (transactions, events, and internet communication) and the real world of information - customers, inventory, shipping and the like. Most business transactions rely on information systems to operate successfully, as the Geoinformation (location-specific information) is critical for many of them (see Sonnen and Morris, 2000). Once the developments in 3D GIS provide a compatible functionality and performance, the spatial information services will evolve into the third dimension.

6.3 FUTURE VISION OF 3D GIS

Currently, a variety of software is capable of handling a wide range of spatial problems, beginning with approaches for describing spatial objects to quite complex analysis and 3D visualization. However, an increasing number of applications need more advanced tools for representing and analyzing the 3D world. Among all types of systems dealing with spatial information, GIS has proven to be the most sophisticated system that operates with the largest scope of objects (spatial and semantic), relationships and provide means to analyze them. However, what is the status of 3D GIS? It is the aim of this paper to find the answer by analyzing both available software and efforts of researchers. An overview of several software packages and 3D case studies performed in Oracle and Microstation is given to provide knowledge about the 3D functionality offered by commercial systems.



Figure 6.1

Traditionally, GIS system should be able to maintain information about spatial phenomena and provide means to analyze it and thus gain knowledge of the surrounding world. In general, consensus on the demanded functionality of GIS was achieved years ago. The tasks or the functions of a GIS are specified as follows (see Raper and Maguire, 1992): 1) data capture, 2) data structuring, 3) data manipulation, 4) data analysis, and 5) data presentation. Indeed, 3D GIS aim at providing the same functionality as 2D GIS. Unfortunately, such 3D systems are still not available on the market. A variety of different software (i.e. 2D GIS, DBMS and CAD) is employed to maintain the objects of interest and extract the required information. Due to the deficiencies of all the systems to handle 3D objects, the data are often spread between several systems. For example, one system is used for data storage and another for 3D visualization. This situation often faces inconsistency problems, which leads to extra time, efforts and money to find the appropriate solution.

The most significant achievements in the 3D research area concerning key issues of 3D GIS, i.e. 3D structuring and 3D topology are summarized to portray the current research status. At the end, some of the issues and problems involved in developing such a system are presented and recommendations on directions for further research are made.

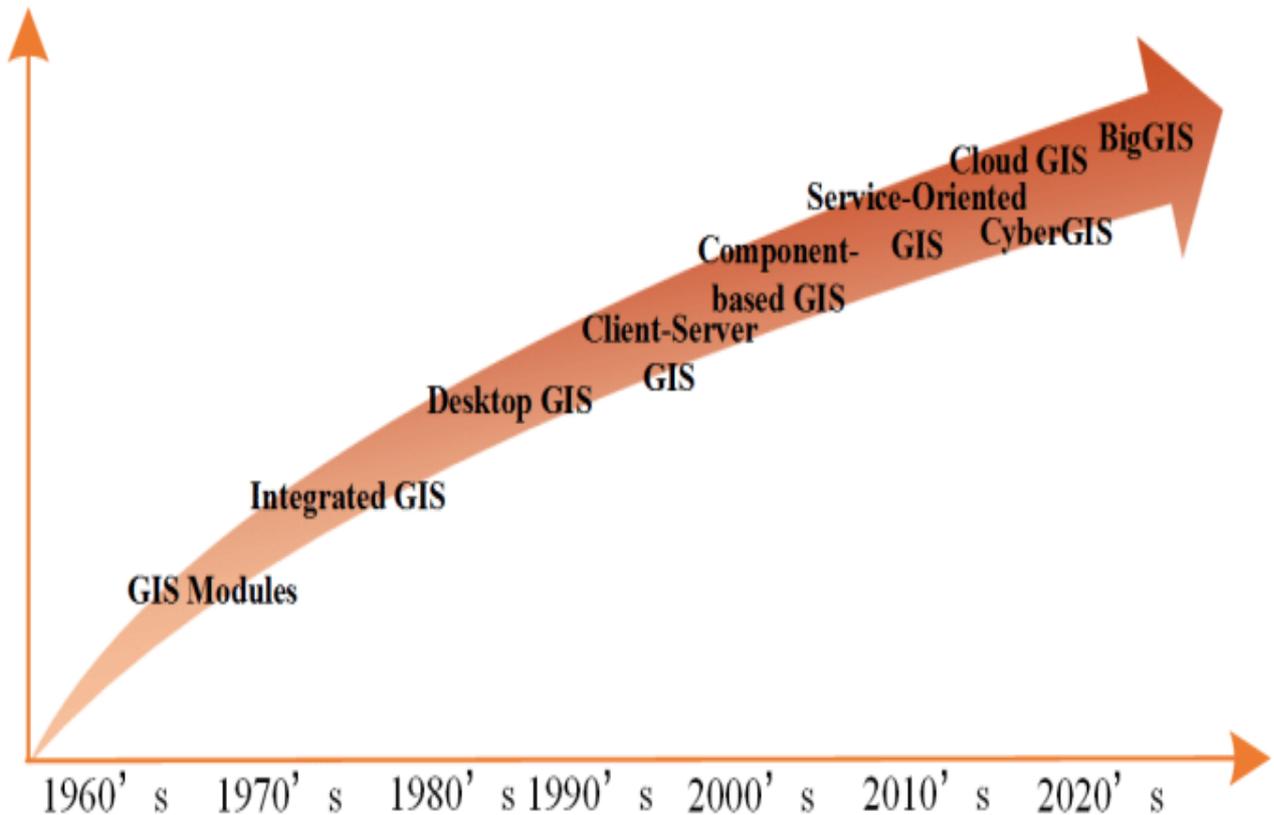
TRENDS IN GIS

Figure 6.2: Trends in GIS Technology

In the 1960s, computer based GIS concepts began to be explored in North America and today numerous and considerable technological and methodological developments have taken place in the field of GIS. The main advancements are a result of the use of computing techniques and this would continue to affect the future advancements also. Some of the important developments in GIS methodology are listed below:

- GIS has evolved from the earlier use in mainframe computers to personal computers to now in mobile devices, facilitating the growth of GIS usage and research
- Application of computer based technology to handle numerical census data for deriving useful information
- Introduction of topological data structures to store and analyze map data
- Relational database technology becoming standard and integral part of GIS for handling spatial/spatial data with the development of spatial database management systems (SDBMS)
- standardization of data quality norms and accuracy standards
- Developments in the field of object orientation in system and database design

- Advent of internet and subsequent developments of GIS tools in World Wide Web leading to development of new internet protocols, easy to use interfaces (browsers), tools and programming languages, Web GIS, OPEN GIS, etc.
- Evolution of GIS from a mere powerful spatial technological tool to a spatial science • it was earlier required to have all the parts at one place for any GIS implementation; whereas its now possible to access data and software remotely and implement • its applications have expanded from mapping and resource management to utilities, market analysis, location based service and data browsing • use of GIS has now opened up for general public from the earlier restricted use in only government sectors • focus has changed from earlier system centric approach to service oriented approach.

As you have studied in the previous section about recent trends in the field of remote sensing, there are many developments taking place in the field of GIS. We will now study about recent trends and developments in GIS in the following subsections.

TRENDS IN GEOINFORMATICS EDUCATION

You have studied in the previous sections of this unit about the recent trends and developments taking place in various components of the Geoinformatics. The recent trends and developments have brought markable changes in structure and format of University curricula and also in delivery mechanisms of Geoinformatics related educational programs. This revolution is necessary to keep pace with the latest technologies and to develop knowledgeable and skilled manpower in different employment sectors. Some of the developments and trends observed currently at Indian and global levels are listed below:

- Training and education in Geoinformatics were earlier restricted too few selected disciplines and were later included in many other disciplines. It has now been realized that multidisciplinary education in information technologies, management, and space technology can increase employment opportunities
- Earlier, there were only few institutes and universities, which were offering educational and training programmes related to Geoinformatics. Now many universities and institutes are offering such programmes
- The range of programmes being offered vary from appreciation level (from few days to few weeks duration) to certificate levels (from few weeks to few months duration) to diploma (of few months) to masters (from ~one year to ~three years) to doctoral levels

- In comparison to the past, there are many choices one can make with regards to the level of programmes, depending upon the preference of learners with regard to location of institute, cost of programme, level and mode of programme, etc.
- Focus has shifted from just developing professional and technical skills of learners to expose learners to modern tools and technologies and also to update their knowledge in specific application areas and domains
- Education and training is now also being imparted by adopting other modes, such as open and distance learning including e-Learning with interactive lecture/education materials and hands on exercises along with the use of internet medium to conduct online test and examinations. The use of e-Learning enables enrollment of working professionals as their time and possibility of attending courses are limited
- Due to the above efforts, Geoinformatics technicians and professionals are comparatively more readily available in the market in comparison to the past.

LiDAR Processing: After the basemaps were created, the next step was to create 3D models for both sites in Savannah and Atlanta. These models were intended to display the existing buildings, trees, and accurate terrains to represent the landforms. This was done by extracting 3D features from LiDAR point cloud data (Figure 1). For the site in Savannah, the LiDAR data was acquired from Department of Architecture in Savannah College of Arts and Design (SCAD). 8 LiDAR tiles were obtained in the .las file format (version 1.1). They were commissioned in 2009, each covering an area of 5,000 ft by 5,000 ft with a point spacing of 1.5 ft. These tiles had been classified into 5 classes: unassigned; ground; building; noise; water. For the site in Atlanta, the LiDAR tiles were downloaded from the website USGS Earth Explorer. 2 tiles were obtained in the .las file format (version 1.0). The tiles were created in 2006, each covering an area of 5,300 ft by 5,300 ft with a point spacing of 4.6 ft. Since these two LiDAR tiles were not classified, the first step was therefore to reclassify them. ArcGIS Pro was used to process this step. The reclassification was performed by applying the following two methods: classify building and classify by height. After this step, the class used Esri's Local Government 3D Basemaps tools to process all LiDAR tiles for both two cities to extract buildings and trees in 3D. This step also produced digital terrain models (DTM) in the .tiff file format to represent the bare ground terrain for both two sites.

Cloud-based GIS: In addition to relying on online open data sources to acquire GIS data, the class also took advantage of Esri's cloud-based platform, ArcGIS Online, for the following activities and purposes: 1) Data and content sharing: An online user group was created to include all the students as well as the instructor of the class to enable sharing of GIS data, processed map layer and scene

layer packages, and maps and 3D scenes that were generated by the class. 2) Data processing and analysis: the class also used some of the analysis capabilities offered by the platform to perform some basic analysis, such as walkability analysis and hot-spot analysis. 3) Map and web scene generation: the class used this online platform to generate maps and 3D web scenes, which included detailed streetscapes, buildings, spatial analysis, and to visualize and explore urban structures and design solutions. 4) Project presentations: the class used the template provided by the online platform to create story maps to present project outcomes. Each story map contains multiple forms of media, including static images, text narratives, interactive maps and 3D scenes that reveal urban structures of the two sites. These story maps were made available to the general public online through the Internet.

VR Development: The class also tested the potential of using virtual reality as a way to study urban form and explore urban design solutions. Their 3D CityEngine models were exported as .fbx files (Autodesk), which were then imported into Unity, a game development platform, or game engine, to be further converted into virtual reality scenes. Unity allows additional lighting effects and environment rendering options to enhance the appearance of the models. It also enables virtual reality settings that allow a user to use a typical game controller, such as Xbox controller, to walk around 3D scenes generated by the City Engine models. During the class final review meeting, a computer was set up to allow guest critics to experience the virtual reality scenes in person and offer comments for students' design projects

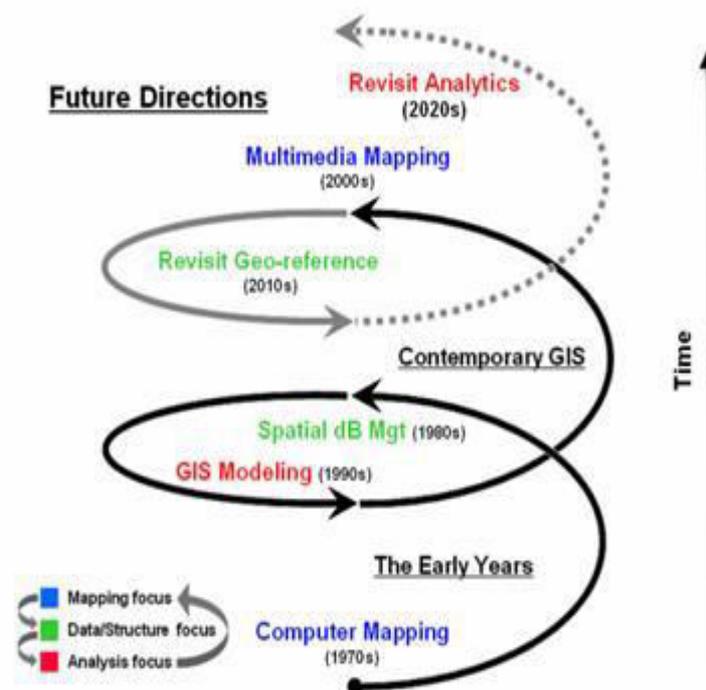


Figure 6.3: Future Directions and Development in 3D GIS

GIS DEVELOPMENT CIRCLE

GIS is centered on *Multimedia Mapping* (mapping focus) which brings us full circle to our beginnings. While advances in virtual reality and 3D visualization can “knock-your-socks-off” they represent incremental progress in visualizing maps that exploit dramatic computer hardware/software advances. The truly geospatial innovation awaits the next re-focusing on data/structure and analysis. The bulk of the current state of geospatial analysis relies on “*static coincidence modeling*” using a stack of geo-registered map layers. But the frontier of GIS research is shifting focus to “*dynamic flows modeling*” that tracks movement over space and time in three-dimensional geographic space. But a wholesale revamping of data structure is needed to make this leap. The impact of the next decade’s evolution will be huge and shake the very core of GIS—the Cartesian coordinate system itself ...a spatial referencing concept introduced by mathematician Rene Descartes 400 years ago.

The current 2D square for geographic referencing is fine for “static coincidence” analysis over relatively small land areas, but woefully lacking for “dynamic 3D flows.” It is likely that Descartes’ 2D squares will be replaced by hexagons (like the patches forming a soccer ball) that better represent our curved earth’s surface ...and the 3D cubes replaced by nesting polyhedrals for a consistent and seamless representation of three-dimensional geographic space. This change in referencing extends the current six-sides of a cube for flow modeling to the twelve-sides (facets) of a polyhedral—radically changing our algorithms as well as our historical perspective of mapping (see April 2007 Beyond Mapping column for more discussion).

FUTURE VISION OF GIS

You have studied in previous sections, about the trends and advancement in different components of Geoinformatics viz. remote sensing, GIS, photogrammetry, GPS and Geoinformatics education. The technologies utilized in Geoinformatics are advancing at an extraordinary rate due to changes in user needs and advances in computing technologies, which is continuously increasing its potential to utilize it in different sectors. The advancement in technology and applications is further expected to grow and have a major impact on our daily lives. Some of the important points related to future trends and developments in the field of geoinformatics are given below:

- launch of more sophisticated and specialized application specific sensors with reduced size, weight and cost
- improved methodologies and techniques for faster and more accurate geoinformation retrieval
- GIS is expected to be interoperable, fully web based and become more dynamic and maps to become interactive
- further improvement in availability, reliability, usability, accuracy and interoperability of GNSS
- development of receiver independent GPS software
- methods to improve usability of

GNSS in situations such as indoor, underwater, inside tunnel, etc. • improved new methodologies and techniques for faster and reliable geospatial data acquisition, storage, processing, transfer and retrieval, and also for remote sensing, GIS and GPS data integration • development of innovative data fusion approaches to synthesize and analyze extensive and diverse data sets and to create new information products • developments of new methods and approaches for much wider applications of Geoinformatics to make it become part of daily life • Open Geospatial Consortium (OGC) is expected to grow faster and richer, and with it the use of open source Geoinformatics software • newer or improved educational models for Geoinformatics education to fulfill the demands of changing education, industry and market scenario • greater role of Geoinformatics to facilitate multidisciplinary research to enhance our understanding of the Earth system processes for its sustainable management. However, the growth and trends may be affected by the many issues. Some of the issues are mentioned here: • geospatial data, which were earlier either absent or lacking, are now available from numerous sources at larger volumes and faster rates however, at times the quality data is absent and if available, it is either in incompatible formats or there is ownership issue. It also requires regular updating and maintenance. Further, the available data is liable to be misused. • many mainstream IT companies have now entered in the GIS related business bringing along with them overwhelming and excessive information about their products and capabilities resulting into creating confusion among the ordinary users. • Newer and improved methods for improving interoperability at different levels are required.

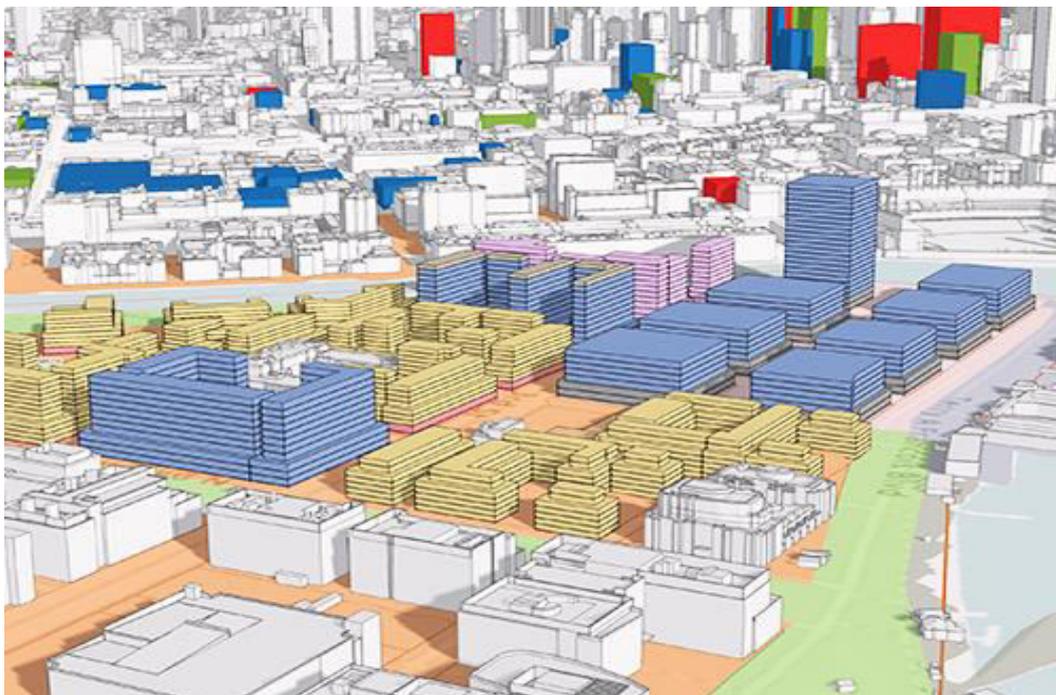


Figure 6.4: Future 3D Analysis

6.4 SUMMARY

Compared with 2D GIS, 3D GIS depicts the objective world in a more realistic way, which shows geospatial phenomena to users by 3D modeling technology. It not only expresses the relationships between spatial objects in the plane but also describes and expresses the vertical relationship between them. In addition, carrying out 3D spatial analysis for spatial objects is the unique functions of 3D GIS (Tan, 2003). With the development and application of computer hardware and software as well as 3D GIS technology, if integrate the real estate mass appraisal model with 3D GIS, on the one hand make full use of 3D GIS spatial data management capabilities, 3D spatial visualization skills and 3D spatial analysis capabilities, in the other using the assessment model for the real estate mass appraisal, that will undoubtedly have a strong advantage. Firstly, this paper use 3D modeling technology to generate refined 3D model of the buildings, and then through carrying out the landscape analysis and sunshine analysis for a large number of real estate data, extract the quantitative information which have a significant impact on the real estate price, such as landscape visibility and lighting length. Compared to the previous valuation results, it's more convenient for appraisers to make the right judgments and could greatly improves the efficiency and accuracy of the valuation.

On the other hand, GIS in its advanced stage, and day-to-day utility, like 3D GIS, Web GIS, Mobile GIS, LBS, Enterprise GIS, and GIS customization have been briefly elaborated to give the learner a flavor for the subject with some practical applications to try out as part of their on-going project. Global Positioning System (GPS) provides reliable positioning and navigation services on a worldwide basis at any point of time. GPS has undergone many notable developments in this field. There are many issues and challenges in the field of Geoinformatics. It is high time that mankind should make use of sustainable space technologies to the very survival and to take it forward to our future generations. You have also learnt about potential applications of space technologies through integrated approach, such as GIS & RS in combination with GPS.

This class project offered an opportunity to explore the possibilities to use new geospatial tools and visualization media to study urban form and its related topics. These tools and media, including 3D procedural modeling with GIS, LiDAR remote sensing, cloud-based GIS platform, and virtual reality, represent four of the many major development trends in the geospatial technology industry and its related fields. This project reveals potential advantages of these geospatial and visualization tools for the study of urban form, including: 1) quick 3D form extraction from LiDAR; 2) urban structure exploration with 3D procedural modeling; 3) easy access to accurate terrain elevation data

and global satellite imagery; 4) easy data sharing and presentation over the Internet through cloud-based platform; and 5) a new way to experience urban spaces through virtual reality.

However, noticeable disadvantages or issues still present and hinder the adaption of these tools, including:

- 1) proprietary software license;
- 2) limited data availability and unreliable quality;
- 3) inconsistent data schema;
- 4) multiple software programs and platforms with a steep learning curve; and
- 5) high cost of hardware devices.

Though an in-depth evaluation on the exact effectiveness of these software tools or media for the study of urban form is out of scope for this paper, which can certainly be an important next-step for advancing this particular practice, this project allowed for a quick glimpse of the current development trends in the GIS world. As these digital tools are becoming more and more advanced, we researchers, scholars, or designers interested in understanding the dynamics of city building processes should explore new methods and establish new workflows to utilize these tools to advance our work.

6.5 GLOSSARY

1. Future : The time that will come after the present.
2. GIS : Global Positioning System

6.6 ANSWER TO CHECK YOUR PROGRESS

1. How Web Mapping is useful during natural disaster?

6.7 REFERENCES

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6.8 TERMINAL QUESTION

1. Discuss in brief some of the notable developments in remote sensing satellites.
2. If you are living in a metro city then you know that traffic congestion is the biggest transportation issues facing cities. If you have won a project to use the high resolution satellite imagery and GIS to identify the bottleneck areas and come out with a comprehensive traffic management plan. Here, you have a task to prepare entire road network, bridges, median, traffic island, signals, pedestrian crossing, accident spots, bus terminal, bus stops, etc. How do you plan to do this?
3. Government is on a massive drive against encroachment of settlements on lakes and rivers. In this connection, they are planning a demolition drive based on the individual house level details overlaid on high resolution satellite imagery. Here, how would you differentiate the buildings which are legal and illegal? Apply your real world knowledge and demonstrate.

BLOCK 3 : RS BASED GEODETICS SURVEYS

UNIT 7 - CONCEPT OF GEODESY

7.1 OBJECTIVES

7.2 INTRODUCTION

7.3 CONCEPT OF GEODESY

7.4 SUMMARY

7.5 GLOSSARY

7.6 ANSWER TO CHECK YOUR PROGRESS

7.7 REFERENCES

7.8 TERMINAL QUESTIONS

7.1 OBJECTIVES

After reading this unit you will be able to:

- Define geodesy.
- Understand the concept of Geoid, Datum & Spheroid.

7.2 INTRODUCTION

Geodesy, the study of the size and shape of the earth, has undergone a major revolution since start of the space age which the launch sputnik in 1957. The meaning of word Geodesy is:

Geo - Earth

Desy - The study of

The study of the Earth is called geodesy.”Geodesy is the science of the measurement and mapping of the Earth’s surface”.

Geodesy is the science of surveying and depicting the earth’s surface. Its purpose is to determine the shape of the earth (referred to as the geoid) and its gravity field, and any changes that take place.

In this unit, we'll take a look at Geodesy, a mathematical discipline with three branches and many uses. At the end, you should have a good understanding of this world affecting discipline.

7.3 CONCEPT OF GEODESY

What is Geodesy?

Geodesy is an applied mathematics discipline used to understand various aspects of the Earth. In particular, it looks at:

- **Shape** - the geometric object it resembles in both general and specific terms. In general terms, we know it's a sphere, but in specific terms, mountains and valleys skew that representation.
- **Orientation** - the relative position of key features, like the magnetic poles, in relation to other things in the solar system and galaxy.
- **Gravity Field** - the effects of gravity as we move away from the surface, whether it is constant over the entire surface, and other factors.

According to the Geodetic Glossary (NGS 2009), geodesy can be defined as “The science concerned with determining the size and shape of the Earth” or “The science that locates positions on the Earth and determines the Earth’s gravity field.” It might be hard to see anything too interesting or exciting in these definitions. After all, generally speaking, the Earth is round, a fact known at least since the time of the ancient Greeks. The earliest known definitive work on this was done by Aristarchus of Samos (ca. 310-230 B.C.E.), an astronomer who worked out a geometric method to determine ratios of the distance between

the Sun and the Earth with the distance between the Moon and the Earth, a method that required knowing that all three bodies were round (Ma or 1998, p. 63). But what is not obvious from the definition of geodesy is that much modern technology is possible only due to geodesy. For example, without modern geodesy, navigation might still be done with ancient methods (e.g., don't lose sight of the shore) and high-accuracy maps of moderate or larger regions could not exist. Perhaps surprisingly, geodesy plays a central role in wide variety of cutting-edge sciences, such as geophysics, astronomy, and climatology. The Earth's warming due to climate change is expected to produce rising sea levels in many places, and sea level rise cannot be observed and monitored without geodesy. The observable change in sea level is due to a combination of a change in the ocean's mean surface level and any subsidence of the shore. Geodesy is necessary to tease these two apart. Global warming is also generally reducing the size of ice sheets and glaciers as well as dramatically increasing how quickly they move. Space-age positioning methods make it possible to determine not only the location of an ice sheet, but also its velocity, shape, and size. Geodesy is also a key component of geophysics by making it possible to observe tectonic plate motion, for example. Geodesy is usually subdivided into geometrical geodesy, physical geodesy, and satellite geodesy, although additional subdivisions are recognized as well. Geometrical geodesy is concerned with describing locations in terms of geometry. Consequently, coordinate systems are one of the primary products of geometrical geodesy. Physical geodesy is concerned with determining the Earth's gravity field, which is necessary for establishing heights. Satellite geodesy is concerned with using orbiting satellites to obtain data for geodetic purposes. To understand the role of geodesy, it might be useful to look at how maps are often drawn. A map is an abstract, scaled, two-dimensional image of some region typically on the Earth's surface, showing the features of interest in their correct relative locations, sizes, and orientations. According to this definition, a globe is not a map because it is not two-dimensional. Neither are directions to the neighborhood gas station drawn on a napkin for a friend. Although entirely adequate for its purpose, such a rendering is a sketch, not a map, because, while schematically correct, it is not an accurate rendition of the features. Maps are drawn essentially the same way whether they are drawn on paper or on a computer screen. The process begins with someone determining positions for all the features of interest. A position is (usually) a pair or triplet of numbers, called coordinates. A location is a place in the real world, whose spatial placement is described by a position. A coordinate system specifies how coordinates are assigned to locations. In order to draw, say, a building on a map, we need to determine the positions of its defining points, like its corners. Linear coordinates, such as the familiar x , y , z , are descriptions of off sets from some point of reference, called an origin, each in the direction of its axis. Suppose one corner of the building was found to be 150.25 meters (m) east, 95.51 m north, and 10.59 m above the origin. The coordinates are $x=150.25$, $y=95.51$ and $z=10.59$, and the position is written (150.25, 95.51, 10.59). After the positions have been determined, appropriately scaled

symbols of the locations can be drawn on the paper to produce a map (see section 3.5.1 on page 28). The building's edges can then be drawn by "connecting the dots." This example used a Cartesian coordinate system. Cartesian coordinate systems have an origin at the intersection of several straight lines, the axes that are mutually perpendicular. Linear coordinates are distances as opposed to locations on a number line. Some might ask, "Don't numbers on a number line always represent distances?" The answer is "not necessarily." In a Cartesian coordinate system they represent distances, but in other types of coordinate systems they do not. To illustrate this point, think about street addresses. Street addresses are really just symbols, same as numbers on a number line. They don't necessarily mean anything spatial. In Tokyo, street addresses were assigned sequentially in time, not in space, so an address in Tokyo indicates when the building was built but not where it is located! In contrast, a Cartesian coordinate represents a linear distance from an origin in a specified direction. Geodesy uses many types of coordinate systems, including ones whose coordinates are angles, such as latitude and longitude, rather than linear distances. However, regardless of whether a coordinate is an angle or a linear distance, it is always a separation from an origin in a particular direction. But where do coordinates come from? What coordinate system are they in? Is there more than one coordinate system of a particular type? In the above example with the building, we assumed that it was possible to determine in what direction the building's corner lay from the origin. But how is that possible? Who decides in what direction is north and, once that has been decided, how do we determine other directions for ourselves? By now you may have guessed that geodesy provides the answers to these questions. Some of the primary products of geometrical geodesy are coordinate systems within which realistic geospatial coordinates can be derived.

What is Geodesy used for?

As you might imagine, the information gathered has a number of uses. Some notable ones include:

- Map Shorelines - Geodesy can help determine the physical boundary between a land mass, and the water it meets. This can be difficult with water levels rising and falling. You see examples of this in the maps we use.
- Determine Land Boundaries - at a macro level, this use comes into play between countries and provinces/states. At a micro level, it determines the property lines for home and your neighbor's.
- Improve Transportation - Geodesy contributes to things like route determination, shortest routes, traffic patterns, and such. You see this in trip planning software, and in services like taxis and buses.

- Increase Navigational Safety - this use affects navigation, especially in areas where landmarks are at a minimum, like over water. You see this in things like cargo ship and cruise line navigation.

Why we learn about geodesy?

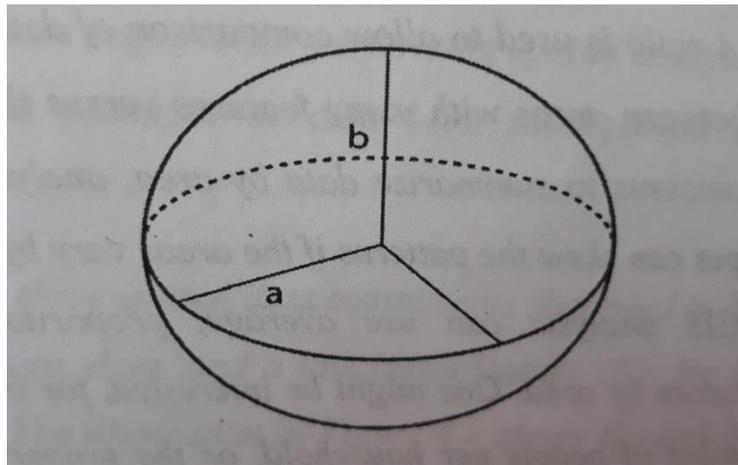
The GIS revolution created a new generation of cartographers who often are expert computer users but not necessarily trained in the concepts underlying spatial data or the processes by which spatial data are created. This can lead to confusion and errors. Furthermore, GIS analyses always depend upon map projections of the latitude and longitude data from which they were compiled. All map projections distort one or more of length, area, shape and direction, so any analysis that ignores these distortions is less accurate than it could be because, with the knowledge of geodesy, these distortions can be computed and then either eliminated or reduced to negligible levels. Geomatics need to understand that all geospatial data contain error, either from their measurement or from distortions introduced by geospatial manipulations. There are many kinds of geospatial coordinate systems and many kinds of map projections. Geospatial data that refer to different coordinate systems cannot be mixed together in a meaningful way any more than temperatures in degrees Fahrenheit can be used with temperatures in degrees Celsius. Spatial data are routinely collected in many different coordinate systems, and using them together in a naïve way results in unrealistic maps. Knowledge of geodesy and cartography is necessary to solve this problem correctly. There are tools to transform the data so that they are all in the same coordinate system. With these tools and the proper knowledge, the geomaticist is free to mix and match data with an understanding of the compromises and trade-offs inherent in each decision made along the way. In extreme cases, ignorance of these distortions and other geodetic topics could lead to maps that could endanger public safety. It's entirely possible, for example, to depict a fire hydrant in the wrong place on a map by not using the proper units for its position. Such a mistake might hinder firefighters in locating the hydrant in an emergency. Gunther Greulich, past president of the American Congress on Surveying and Mapping, stated somewhat facetiously that, "Geography without geodesy is a felony," which underlines the importance of geodesy for all practitioners of geomatics.

Concepts of Geoid , Datum , Spheroid

The earth as a Sphere. In this calculation the earth is viewed as being an evenly round 'ball'. This is called a Sphere. From an imaginary centre of the Earth, calculations are made from the centre of the Earth to the surface of the Earth.

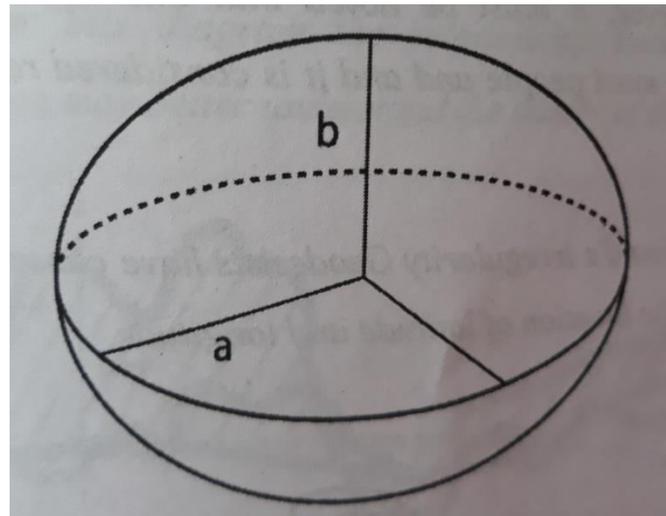
In this diagram the distances from the centre of the Earth to the Equator and the Geographic /True North Pole (indicated by 'a' and 'b') are the same value.

Figure 7.1(a) Distances from the center of the Earth



The Earth as an Ellipsoid (or Spheroid). However, the Earth is not evenly round – it is in fact wider around the Equator than it is between the North and South Poles. This is called Ellipsoids (or Spheroids). All Ellipsoids/Spheroids are ‘wider’ than they are ‘tall’.

Figure 7.1(b) Distances from the center of the Earth

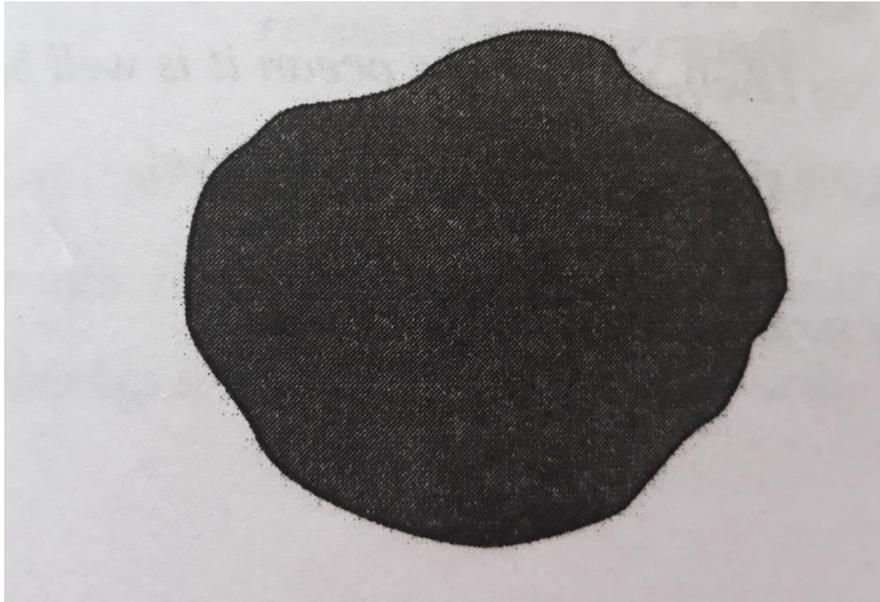


The use of the terms Ellipsoid and Spheroid can be very confusing as they are used interchangeably within the geodetic community.

A Spheroid is simply an Ellipsoid which is as wide as it is long (i.e. evenly round and close in shape to that of a sphere). All other Ellipsoids are longer than they are wide (i.e. shaped more like an Australian Rules football).

In Australia, most datums refer to the Australian National Spheroid.

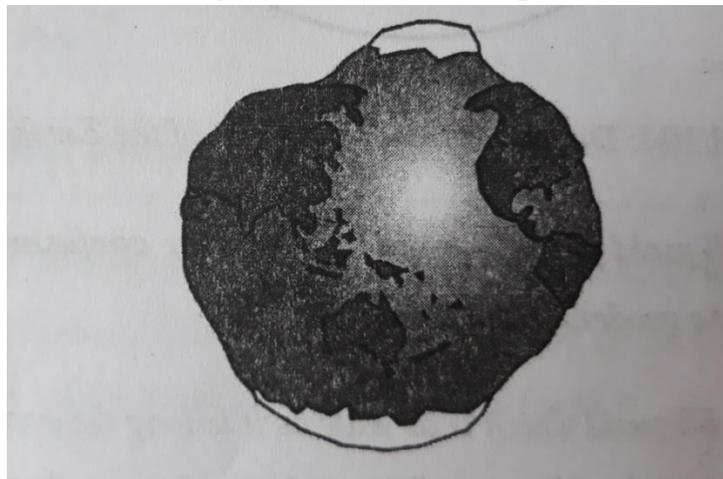
Figure 7.2 (a) The Earth as a Geoid



However, this is also a very simplistic concept. The Earth in reality is a very misshapen object. This is called a Geoid. The Earth's Geoid is a surface which is complex to accurately describe mathematically. But it can be identified by measuring gravity.

The Earth's Geoid is regarded as being equal to Mean Sea Level. Over open oceans the Geoid and Mean Sea Level are approximately the same, but in continental areas they can differ significantly. However, it must be noted that this difference it is not of any practical consequences for most people and it is considered reasonable that they are regarded as the same. Because of the Earth's Geoid's irregularity Geodesists have chosen to use Ellipsoids (or Spheroids) to calculate the locations of latitude and longitude.

Figure 7.2 (b) Earth's Shape



The Earth's True Shape – Its Terrain of course the Earth isn't just ocean (Mean Sea Level). Much of the land masses are well above the sea level (eg Mount Everest is over 8,000 meters above Mean Sea Level), while in the ocean it is well below sea level (eg the Mariana Trench is over 10,000 meters below Mean Sea Level).

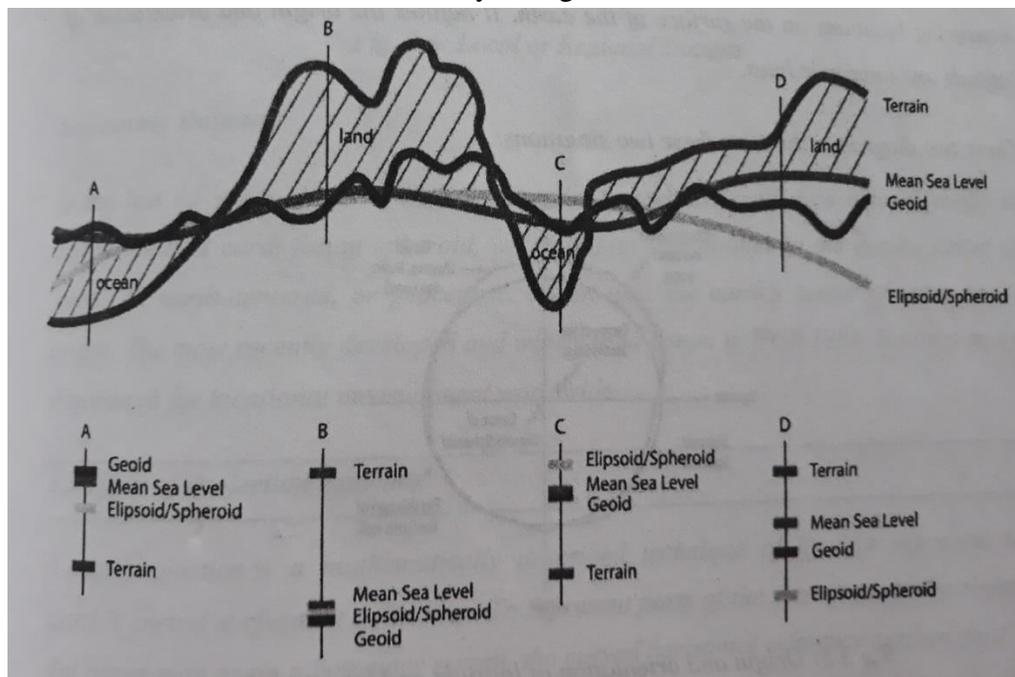
In summary – there are four surfaces the geodesists study:

- 1 Ellipsoid/Spheroid
- 2 Geoid
- 3 Mean Sea Level
- 4 Terrains

It is important to recognize the relationship between these four surfaces is not always the same. Rather, as this diagram indicates, they 'wobble' around each other.

(Please note that for this diagram the relationship between these four has been exaggerated so that you may better understand the nature of this 'wobbling'.

Figure 7.3 Four examples (A, B, C and D) have been chosen to describe how these relationships may change.

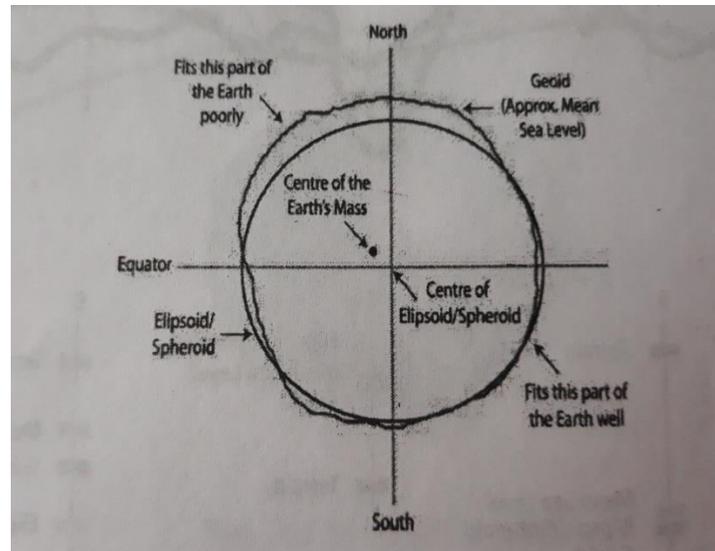


A and C show the Earth's terrain as being below Mean Sea Level- this is equivalent to an area of ocean. Note how the Geoid and Mean Sea Level are very close to the same value, but their relationships to the Ellipsoid/ Spheroid varies. B and D show the Earth's terrain as being above Mean Sea Level- this is equivalent to an area of land. It is worth noting that the differences between the Geoid and Mean Sea Level are much greater than in the ocean examples. And similarly their relationship to the Ellipsoid/ Spheroid varies.

With an understanding of these four geometric shapes and their relationships to each other it is possible to better understand Datums.

While a spheroid approximates the shape of the Earth, a datum defines the position of the spheroid relative to the center of the earth. A datum provides a frame of reference for measuring locations on the surface of the Earth. It defines the origin and orientation of latitude and longitude lines. These two diagrams illustrate these two situations.

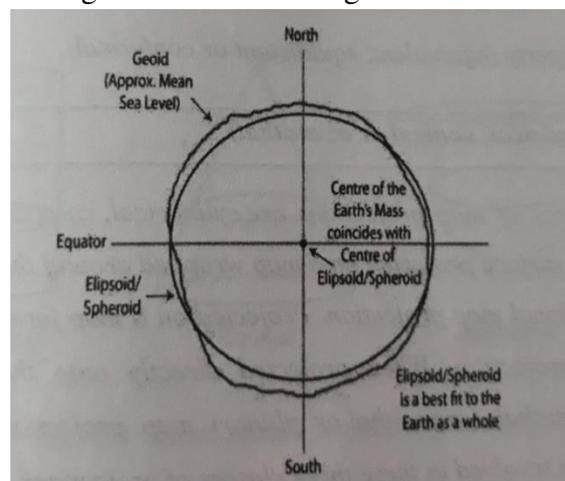
Figure 7.4 Origin and orientation of longitude and longitude lines



Local or Regional Datums

A local datum aligns its spheroid to closely fit the earth's surface in a particular area. A point on the surface of the spheroid is matched to particular positions on the surface of the earth. This point is known as the origin point of the datum. The coordinates of the origin point are fixed, and all other points are calculated from it.

Figure 7.5 Local or Regional Datums



Geocentric Datums

In the last 15 years, satellite data has provided geodesists with new measurements to define the best earth- fitting spheroid, which relates coordinates to the earth's center of mass. An earth – centered, or geocentric, datum uses the earth's center of mass as the origin. The most recently developed and widely used datum is WGS 1984. It serves as the framework for locational measurement worldwide.

Coordinate systems are very well described in unit 14.

7.4 SUMMARY

In this unit, overview of Geodesy, the earth shape & size have been discussed. The unit begins with the description of Geodesy. Next, the Geodic, Datum and Spheroid are explained. The types of Datum have also been discussed. The coordinate systems have been discussed in unit 14.

7.5 GLOSSARY

- 1. Datum** - A reference for position on the surface of the Earth. In surveying, a datum is a reference system for computing or correlating the result of surveys. There are two principal types of datum's: vertical and horizontal. A vertical datum is a level of surface to which heights are referred. The horizontal datum is used as a reference for position.
- 2. Ellipsoid / Spheroid** - A mathematical figure that approximates the shape of the Earth in form and size, and which is used as a reference surface for geodetic surveys. Used interchangeably with Spheroid.
- 3. Mean Sea Level** - The average level of the ocean's surface, calculated as the arithmetical mean of hourly tide levels taken over an extended period and used as the standard for determining terrestrial and atmospheric elevations and ocean depths.
- 4. Terrains** - An area of land, when considering its natural features.

7.6 ANSWER TO CHECK YOUR PROGRESS

- 1-What is the meaning of Geodesy?
- 2-What is the meaning of Ellipsoid?
- 3-What is local datum?
- 4-What is geocentric datum?

7.7 REFERENCES

Entire content of this unit is for the purpose of the academic uses for learners. References from where this entire material has been taken are as follows:

- 1-<https://www.slideshare.net/KutubuddinANSARI/basic-of-geodesy>
- 2-<https://www.slideshare.net/AmitMishra387/shape-size-and-motions-of-the-earth-1>

- 3-https://esripress.esri.com/storage/esripress/images/320/geodesy_ch01.pdf
- 4-<https://pubs.geoscienceworld.org/ssa/srl/article-abstract/69/1/52/142281/Introduction-to-5-5-Geodesy-The-History-and-Concept-of?redirectedFrom=fulltext>
- 5-<https://www.swisstopo.admin.ch/en/knowledge-facts/surveying-geodesy.html>
- 6-<https://study.com/academy/lesson/geodesy-definition-branches.html>
- 7-<https://www.yourdictionary.com/mean-sea-level>
- 8-<https://dictionary.cambridge.org/dictionary/english/terrain>

7.8 TERMINAL QUESTIONS

- 1- Give diagram with difference between Spheroid and Geoid.
- 2-What is datum? Explain types of datum with examples.

UNIT 8 – NEAR FIELD AND FAR FIELD GEODETIC SURVEYS

8.1 OBJECTIVES

8.2 INTRODUCTION

8.3 NEAR FIELD AND FAR FIELD GEODETIC SURVEYS

8.4 SUMMARY

8.5 GLOSSARY

8.6 ANSWER TO CHECK YOUR PROGRESS

8.7 REFERENCES

8.8 TERMINAL QUESTIONS

8.1 OBJECTIVES

After studying this unit,

- You should be able to familiarise yourself with various type of linear measuring devices, and
- Choose a suitable measuring device according to the precision required.

8.2 INTRODUCTION

Baseline Measurement or Base lining as it is shortly called is the process of establishing the starting point of any process/metric, from which the improvement or impact of any change measure is calculated. It is used to gauge how effective an improvement or change initiative is. Distance measurement is usually regarded as the most fundamental of surveying observations. In traditional ground surveys, although many angles might be read, the length of at least one line has to be measured to supplement the angles in locating points. In-plane surveying, the distance between two points means the horizontal distance. When the points are at different elevations, the distance is the horizontal length between vertical lines in the points. Lengths of lines could be specified in different units. In the USA, the foot, decimally divided, is usually used through the meter is becoming more and more common. Geodetic surveys and lots of highway surveys use the meter. In machine and architectural function, and on some construction projects, the unit is a foot divided into inches and fractions of an inch. In surveying, the most commonly employed units are such as length, area, volume, and angle. Surveyors are concerned with the measurement of vertical and horizontal distances and angles and, even more recently, with direct positioning. These, then, are used in a variety of combinations in traversing, triangulation, trilateration, mixed-mode operations, mapping, layout staking, levelling, etc.

8.3 NEAR FIELD AND FAR FIELD GEODETIC SURVEYS

8.3.1 Types of liner measurement surveying

- 1 Direct Measurements.
- 2 Measurements by Optical Means
- 3 Electra-Magnetic Methods

In the case direct measurements, distances are measured on the ground with the help of a chain or tape or any other instrument. In the optical methods, observations are taken through a telescope, and calculations are done for the distances, such as in tachometer or triangulation. In the electro-magnetic methods, distances are measured with instruments that rely on propagation, reflection, and subsequent reception of either radio wave. Light waves or infrared waves.

1 Direct Measurements

Measuring the distance directly as Pacing, Measurement with Passometer, Measurement with Pedometer, Measurement by Odometer and Speedometer, Changing

- **Pacing:** Measurements of distances by pacing are chiefly confined to the preliminary surveys and explorations where a surveyor is called upon to do a rough survey as quickly as possible.

Figure 8.1 Pacing



Source: Google

It may also be used to roughly check the distances measured by other means. The method consists of counting the number of paces between the two points of a line. The length of the line can then be computed by knowing the average length of the pace. The length of pace varies with the individual, & also with the nature of the ground, the slope of the country, and the speed of pacing. A length of pace, more nearly that of one's natural step, is preferable. The length of one's natural step may be determined by walking on the fairly level ground over various lines of known lengths. One can soon learn to pace distances along with level, unobstructed ground with a degree of accuracy equivalent approximately to 1 in 100. However, pacing over rough ground or on slopes may be difficult.

- **Measurement with Passometer:** Passometer is an instrument shaped like a watch that is carried either in the pocket or is attached to one leg.

Figure 8.2 Passometer

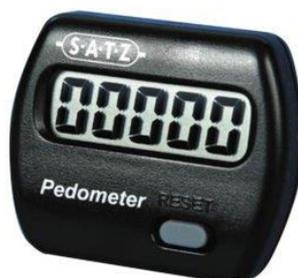


Source: Google

When the person wearing the Passometer walks, it counts the number of paces the person has moved. Then by multiplying the number of paces with the average pace length, the distance between the two end stations can be determined.

- **Measurement with Pedometer:** A pedometer is a device similar to the passometer except that, adjusted to the length of the pace of the person carrying it. It registers the total distance covered by any number of paces.

Figure 8.3 Pedometer



Source: Google

- **Measurement by Odometer and Speedometer:** The odometer is an instrument for registering the number of revolutions of a wheel. The well-known speedometer works on this principle.

Figure 8.4 Odometer



Source: Google

The odometer is fitted to a wheel that is rolled along the line whose length is required. The number of revolutions registered by the odometer can then be multiplied by the circumference of the wheel to get the distance. Since the instrument registers the length of the surface actually passed over, its readings obtained on the undulating ground are inaccurate. If the route is smooth, the speedometer of an automobile can be used to measure the distance approximately.

- **Chaining :** Chaining is a term that is used to denote measuring distance either with the help of a chain or a tape and is the most accurate method of making direct measurements. For work of ordinary precision, a chain can be used, but for higher precision, a tape or special bar can be used. The distances determined by chaining form the basis of all surveying. No matter how accurately angles may be measured, the survey can be no more precise than the chaining.

2 Measurements by Optical Means

In this method, observations are taken through a telescope, and calculations are done for distances such as in tachometer (stadia) or in triangulation. Tachometer (stadia is the common term in the USA) is a surveying method utilized to quickly determine the horizontal distance to, and elevation of, a point. Stadia observations are accessed by sighting through a telescope equipped with two or more horizontal cross wires in a spacing that is known the apparent intercepted length between the bottom and top wires is read onto a graduated rod held vertically in the desired stage. The space from the telescope to a rod is seen by proportional relationships in similar triangles. Accuracy of 1/500 of this distance is achieved with reasonable care.

Instruments used in the tachometer: It's only a transit theodolite fitted Using a stadia diaphragm along with an analytic lens. As per below figure shows the different forms of stadia diaphragm commonly used For short distances, ordinary levelling staves are used. The levelling staff is normally 4 m long and can be folded into three parts. The graduations are so marked a minimum reading of 0.005 or 0.001 m, could be taken. For long sights, as specially designed graduated rod is utilized, which is called a stadia rod? It's also 4 m long, and could possibly be telescopic or brushed. The graduations are comparatively clear and daring, and the minimum reading Which Can Be taken is 0.001 m.

3 Electra-magnetic Methods

In the case of electronic methods, the distances are measured with instruments that are based on propagation, reflection, and subsequent reception of either radio or light waves. The instruments used under the electronic methods are Geodimeter, Tellurometer, and Decca Navigator, etc. The main instrument for surveyors on site today is the 'total station.' It is an instrument that combines the angle measurements that could be obtained with a traditional theodolite with electronic distance measurements.

Taping distance, with its associated problems, has been rendered obsolete for all base-line measurement. The distance can now be measured easily, quickly, and with great accuracy, regardless of terrain conditions.

Figure 8.5 Instruments used for Digital Measurement



Source: Google

For engineering surveys, total stations with automatic data logging are now standard equipment on site. A typical measurement of distance takes between 1.5 and 3 s. Automatic repeated measurements may be utilized to improve reliability in tough atmospheric conditions. Tracking modes, for the setting from distance, repeat the measurement several times a second. Total stations with their inbuilt EDM enable: Traversing over great distances, with much greater control of swing errors. The inclusion of the many more measured distances into control networks, rendering classical triangulation outdated. This results in a much greater control scale error. Setting-out and photogrammetric control, over the large areas, by polar coordinates from a single baseline.

8.3.2 Direct measurement methods

Direct measurement is obtaining the measurement directly which means measuring the length directly using simple equipments and there is no need to solve hard quotations. In the direct methods the distance is actually measured during field using a chain or tape. The following instruments are used while chaining.

- 1) Chains
 - 2) Tapes
 - 3) Arrows
 - 4) Ranging rods and offset rods
 - 5) Pegs
 - 6) Plumb-bob
- 1) **Chain:** The chain is composed of 100 or 150 pieces of galvanized mild steel wire called links, joined together with oval rings and handles at both ends. The end of each link are bent into a loop and connected together by means of three oval rings. The ends of chain are provided with brass handles for easy handling. The length of chain is measured from one handle to other handle.
 - 2) **Arrows:** They are also called as marking or chaining pins and are used to mark the end of chain during the process of chaining. They are made up of good quality hardened and tempered steel wire of 4mm in diameter. The arrows are made 400 mm in length. The one pointed part of an arrow is inserted into ground and the other is attached with ring.
 - 3) **Ranging rods or offset Rods:** They are round poles made up of wood or metal. These rods are used to range intermediate points of a survey and to set out straight lines on the field when the surveying length is long. The only difference between ranging rods and poles is the length. Ranging rods and offset rods are commonly occurs in 3m length but the ranging poles are available up to 8m length. The rods possess a metal point at its bottom and the rod or pole is painted with red & white or black & white successive combination. When the survey lines are too lengthy a flag with red/white/yellow colour will be attached to the top of the pole for easy identification.
 - 4) **Pegs:** The pegs are made up with wood and they used to mark the survey positions or terminals. The size of the pegs (40 to 60 cm) depends on the type of survey work they

are used for and the type of soil they have to be driven in. Although the pegs are driven into the ground 1/5th of its part should be visible on the ground surface.

- 5) **Plumb-Bob:** A string suspended with a weight at the bottom will be both vertical and perpendicular to any level plane through which it passes. The plumb consists of a specially designed weight and coarse string or special threads. At one end of the string the weight is affixed. Precisely machined and balanced bobs have pointed tips, and can be made of brass, steel, or other materials, including plastic.
- 6) **Tapes:** Tapes are used for more accurate measurements. The tapes are classified based on the materials of which they are made of such as: Cloth or linen tape, Fiber tape, Metallic tape, Steel tape and Invar tape.

Figure 8.6 Instruments used for Direct Measurement



Source: Google

8.3.3 Non- precision measuring methods

Non-precision instruments are limited to the measurement of parts to a visible line graduation on the instrument used. There are several non-precision measuring devices. They are used where high measurement accuracy is not required. This section describes some of the non-precision measuring devices.

- 1) **Steel Rule:** It is the simplest and most common measuring instruments in inspection. The principle behind steel rule is of comparing an unknown length to the one previously calibrated. The rule must be graduated uniformly throughout its length. Rules are made in 150, 300, 500 and 1000 mm length. There are rules that have got some attachment and special features with them to make their use more versatile. They may be made in folded form so that they can be kept in pockets. The degree of accuracy when measurements are made by a steel rule depends upon the quality of the rule, and the skill of the user in estimating part of a millimetre.

- 2) **Calipers:** Calipers are used for measurement of the parts, which cannot be measured directly with the scale. Thus, they are accessories to scales. The calipers consist of two legs hinged at top, and the ends of legs span part to be inspected. This span is maintained and transferred to the scale. Calipers are of two types: spring type and firm joint type. Spring Type As the name explains, the two legs are attached with spring in this type of calipers. The working ends of each leg of a spring calipers should be identical in shape and have contact points equally distant from the fulcrum. The cross-section of the legs is either rectangular or circular in shape. The calipers are adjusted to set dimensions by means of either a knurled solid nut or a knurled quick action release nut operating in a finely threaded adjusting screw. The top portion of the legs are located in a flanged fulcrum roller and held in position by a spring in order to maintain the alignment of the working ends. The spring provides sufficient tension to hold the legs rigid at all points of the adjustment. A separate washer under the nut minimizes the friction between the adjusting nut and the leg.

Figure 8.7 Caliper



Source: Google

- 3) **Divider:** A divider is similar in construction to a caliper except that both legs are straight with sharp hardened points at the end as shown in Figure below. These are used for scribing arcs and circles and general layout work. The distance between the fulcrum roller centre and the extreme working end of one of legs is known as the nominal size Dividers are available in the sizes of 100, 200, 300 mm. In practice, one point is placed in the centre position and the circle or arc may then be scribed on the job with the other point. A steel scale must be used with this instrument.

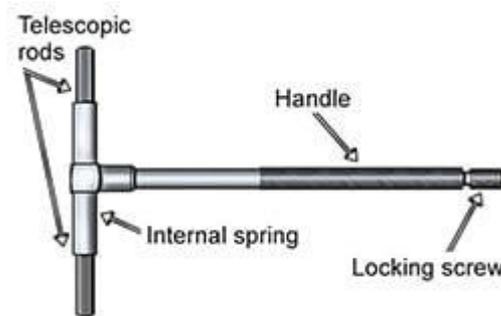
Figure 8.8 Divide



Source: Google

- 4) **Telescopic Gauge:** The telescopic gauge shown in Figure below is used for the measurement of internal diameter of a hole during machining operation. It consists of a handle and two plungers, one telescopic into the other and both under spring tension. Ends of the plungers have spherical contacts. The plunger can be locked in position by turning a knurled screw at the end of the handle. To measure the diameter of a hole, the plungers are first compressed and locked in position. Next, the plunger end is inserted in the hole and allowed to expand the opposite edges. Finally, they are locked in place, taken out of the hole, and measured by an outside micrometer.

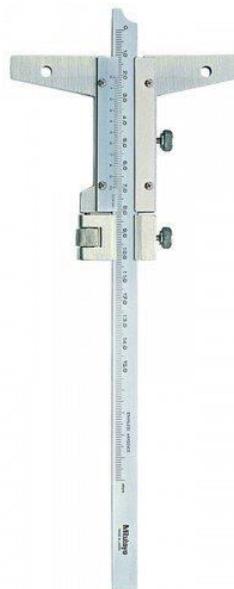
Figure 8.9 Telescopic Gauge



Source: Google

- 5) **Depth Gauge:** This tool is used to measure the depth of blind holes, grooves, slots, the heights of shoulders in holes and dimensions of similar character. This is essentially a narrow steel rule to which a sliding head is clamped at the right angles to the rule as shown in Figure 8.10. The head forms a convenient marker in places where the rule must be held in a distance from the point being measured.

Figure 8.10 Depth Gauge



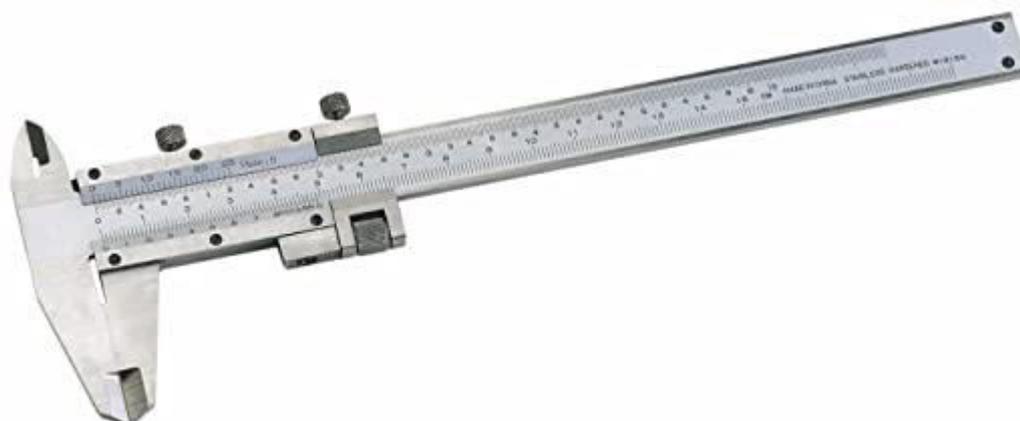
Source: Google

2.3.4 Precision measuring instruments

Since modern production processes is concerned with interchangeable products, precise dimensional control is required in industry. Precision measurement instruments use different techniques and phenomena to measure distance with accuracy. We will discuss some of the precision measuring instruments in this section.

- 1) **Vernier Calipers:** Vernier calipers are precision measuring instruments that give an accuracy of 0.1 mm to 0.01 mm. The main scale carries the fixed graduations, one of two measuring jaws, a vernier head having a vernier scale engraved on. The vernier head carries the other jaw and slides on main scale. The vernier head can be locked to the main scale by the knurled screw attached to its head. Enlarged diagram of the metric vernier scale is shown in Figure below.

Figure 2.11 Vernier Caliper



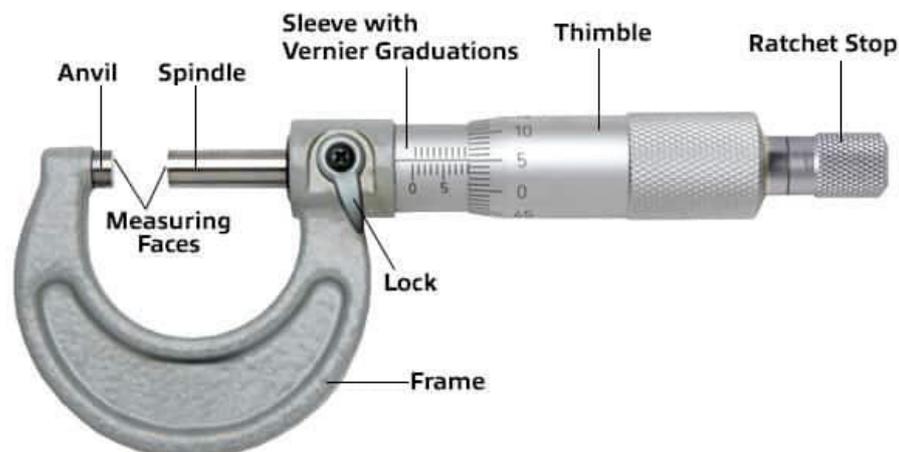
Source: Google

The caliper is placed on the object to be measured and the fine adjustment screw is adjusted until the jaws tightly fit against the Workpiece. There are vernier calipers that incorporate arrangements for measurement of internal dimensions and depth. The vernier calipers are designed to measure both internal and external dimensions. The lower jaws of a vernier scale are used for external measurement and the upper jaws for the measurement of internal dimensions. The rectangular rod carried by the movable jaw is used for the measurement of depth.

- 2) **Micrometers:** Micrometer is one of the most widely used precision instruments. It is primarily used to measure external dimensions like diameters of shafts, thickness of parts etc. to an accuracy of 0.01 mm. The essential parts of the instruments shown in Figure, consist of
 - (a) Frame
 - (b) Anvil and spindle
 - (c) Screwed spindle
 - (d) Graduated sleeve or barrel
 - (e) Thimble

- (f) Ratchet or friction stop
- (g) Spindle clamp

Figure 2.12 Parts of Micrometer



Source: Google

The frame is made of steel, malleable cast iron or light alloy. The anvil shall protrude from the frame for a distance of at least 3-mm in order to permit the attachment of measuring wire support. The spindle does the actual measuring and possesses the threads of 0.5 mm pitch. The barrel has datum and fixed graduations. The thimble is a tubular cover fastened with the spindle. The beveled edge of the spindle is divided into 50 equal parts, every fifth being numbered. The ratchet is a small extension to the thimble. It slips when the pressure on the screw exceeds a certain amount. It produces uniform reading and prevents damage or distortion of the instruments. The spindle clamp is used to lock the instrument at any desired setting.

The following are the various types of micrometers.

- a) **Inside Micrometer Caliper:** The measuring tips of inside micrometer are constituted by jaws with contact surface, which are hardened and ground to a radius. Unlike the conventional micrometer, an inside micrometer does not have any U-shape frame and spindle. One of the jaws is held stationary at the end and second one move by the movement of the thimble. A locknut is provided to check the movement of the movable jaw. This facilitates the inspection of small internal dimension.
- b) **Inside Micrometer:** The inside micrometer is intended for internal measurement to an accuracy of 0.001 mm. In principle, it is similar to an external micrometer and is used for measuring holes with a diameter over 50 cm. It consists of: (a) measuring unit (b) extension rod with or without spacing collar, and (c) handle. When the micrometer screw is turned in the barrel, the distance between the measuring faces of the micrometer can vary from 50 to 63 mm. To measure the holes with a diameter over 63 mm, the micrometer is

fitted with extension rods. The extension rods of the sizes 13, 25, 50, 100, 150, 200 and 600 mm are in common use.

- c) **Stick Micrometers:** Stick micrometers are used for measurement of longer internals length. A series of extension rods will permit continuous range of measurement up to the required length. It is connected with a 150 mm or 300 mm micrometer unit fitted with a micrometer of 25 mm range and having rounded terminal faces. Screw joints are used for joining the end-piece, extension rod and the measuring unit. The extension rod is generally hollow and has minimum external diameter of 0.005 mm. Figure 5.14±14 mm. The accuracy of this instruments is in order of shows the parts of a stick micrometer.
- d) **Screw Thread Micrometer Caliper:** The shape of a Screw thread Micrometer is more or less like an ordinary micrometer with the difference that it is equipped with a pointed spindle and a double V-anvil, both correctly shaped to contact the screw thread of the work to be gauged. The angle of the V-anvil and the conical point at the end of the spindle correspond to the included angle of the profile of the thread. The extreme point of the cone is rounded so that it will not bear on the root diameter at the bottom of the thread, and similarly clearance is provided at the bottom of the groove in the V-anvil so that it will not bear on the thread crest. The spindle point of such a micrometer can be applied to the thread of any pitch provided the form or included angle is always same.
- e) **V-anvil Micrometer Caliper:** This is a special purpose micrometer used for checking out-of-roundness condition in centreless grinding and machining operations, odd-fluted taps, milling cutters, reamers etc. Use of special fixtures is eliminated in this type of micrometer. The V equals 60 degrees and the tip of the Vee coincides with axis of spindle. The zero reading of micrometer starts from a point where the two sides of the V meet.
- f) **Blade Type Micrometer:** It is ideally suited for fast and accurate measurement of circular formed tools, diameters and depth of all types of narrow grooves, slots, keyways, recesses etc. It has non-rotating spindle which advances to contact the work without rotation.
- g) **Bench Micrometer:** A bench micrometer is a high precision micrometer with an anvil retractor device for repeated measurement. The worktable is adjustable and the indicator cans m. The Anvil pressure is adjustable and linear friction transferµmeasure up to 1 mechanism is used between anvil and indicator for high accuracy.
- h) **Groove Micrometer:** It is used for measuring grooves, recesses and shoulders located inside a bore. Standard discs with diameter 12.7 mm and 6.35 mm are used to measure the locations inside a small bore. It is also capable of measuring an edge of a land and groove.
- i) **Digital Micrometer:** Digital micrometer is capable of giving direct reading up to 0.001 mm. The spindle thread is hardened, ground and lapped in this type of

micrometers. The positive locking clamp ensures locking of spindle at any desired setting. Operation is very simple with push button controls for “Zero” reset and indication “hold”.

- 3) **Height Gauge:** This also uses the same principle of vernier caliper and is used especially for the measurement of height. It is equipped with a special base block, sliding jaw assembly and a removable clamp. The upper and lower surfaces of the measuring jaws are parallel to the base, which make possible to measure both over and under surfaces. A scribing attachment in place of measuring jaw can be used for scribing lines at certain distance above the surface. Specification of a vernier height gauge is made by specifying the range of measurement, type of scale required and any particular requirement in regard to the type of vernier desired.

Figure 2.13 Height Gauge



Source: Google

- 4) **Slip Gauges:** Slip gauges are rectangular blocks of steel having a cross-section of about 30 by 10 mm. The essential purpose of slip gauges is to make available end standards of specific lengths by temporarily combining several individual elements, each representing a standard dimension, into a single gauge bar. The combination is made by pressing the faces into contact and then imparting a small twisting motion while maintaining the contact pressure. This is called wringing. Wringing occurs due to molecular adhesion between the mating surface. It is also used for the verification and graduation of measuring apparatus and for direct measurement of linear dimensions of industrial components. For this purpose, control geometry of form such as flatness and parallelism of the surfaces and squareness of the gauging surfaces are essential. According to accuracy, the slip gauges can be graded into three categories, i.e. Grade 0, Grade I and Grade II. Generally, two sets of slip gauges are available

2.3.5 Electrical measuring devices

Electrical measuring devices give the most precise value of measurement among all the instruments discussed above. They use electrical transducers that transform a variety of physical quantities and phenomena into electrical signals. We will discuss some of the widely used electric devices in linear measurement in the following sections.

- 1) **Strain Gauge:** The most widely used pressure and force sensitive transducer is the strain gauge. The principle of the strain gauge is based on the resistive properties of electrical conductors. When a metal conductor is stretched or compressed, its resistance changes because of the fact that both length and diameter of the conductor change. These effects, called piezo-resistive effect, can be used for measurement of several variables like strain and associated stress in experimental stress analysis, and small dimensional changes.
- 2) **Potentiometer:** A potentiometer consists of a resistive elements provided with a sliding contact. This sliding contact may move either in linear or rotational direction and accordingly the corresponding potentiometer is called a linear or rotary potentiometer respectively. Figure shows the diagram for translational, single turn rotational and multi-turn helix potentiometer
- 3) **Linear Variable Differential Transformer (LVDT):** LVDT is high-resolution contact transducer. As Figure below illustrates, it is connected with three coils, one primary and two secondary. A magnetic core sits within the coil. If an alternating current is imposed on the primary coil, a voltage will be induced across the secondary coil. The magnitude of that voltage is a linear function of the position of the magnetic core. LVDTs come in various sizes. The resolution of an LVDT is excellent, easily able to measure displacement below 0.001 inch. Since this is an analog device, the limits of resolution are usually governed by the resolution of the A/D converters. LVDT use alternating currents. Therefore, a requirement exists to transform the output voltage to DC before it is applied to the A/D converter. Manufacturers of LVDT serve this requirement with instrumentation packages that provide the required DC operation voltage. It is apparent that the LVDT has an advantage over the potentiometer as a position measurement device. Since its core does not touch the coil, there is no mechanical wear that would result in deterioration of performance over time. On the other hand, it is a more expensive transducer. It is justifiable primarily where very high and repeatable accuracy is required.

2.3.6 Comparators

Comparators are the instruments calibrated by means of end standards to measure unknown dimensions. The purpose of a comparator is to detect and display the small differences between the unknown linear dimensions and the length of the standard. The difference in lengths is detected as a displacement of a sensing probe. The important and essential function of the instruments is to magnify or amplify the small input displacement so that it is displayed on an analog scale. Comparators are classified on the basis of type of the amplification method used. Accordingly comparators are of following types or hybrid thereof. (a) Mechanical comparators, (b) Optical Comparators. (c) Pneumatic comparators, (d) Electrical comparators.

- 1) **Mechanical Comparators:** Conventional mechanical methods to obtain magnification are not suitable in construction of mechanical comparators as it causes backlash and friction. Also they require a large input force. Let us understand the mechanical comparators by studying a reed comparator which is strictly a mechanical

comparator. A spindle attached to the movable member is in contact with the component to be measured. Movable member moves through a distance x , in response to displacement with respect to fixed member. The movable member is constrained by flexure strips or reeds R_1 , to move relative to the fixed member. The pointer is attached to reeds R_2 . A small input displacement produces a large angular movement, x , of the pointer on account of their orientation relative to the motion. The scale is calibrated by means of gauge blocks and indicate the difference in displacement of the fixed and movable elements. There is no friction and the hysteresis effect is minimized by using suitable steel for the reeds. Comparators of this type have sensitivities of the order of 3 mm/scale division. There are many other systems which are used for $\sim 10 \times 0.25$ mechanical comparators. However, there is a limit to magnification that can be achieved with purely a mechanical comparator.

- 2) **Optical Comparators:** Optical comparators are based on the principle of projection of image. A simple optical comparator for measurement of linear dimension is shown in Figure. The arrangement consists of mechanical system which causes a plane reflector to tilt about an axis so that the image of an index is projected on scale on the inner surface of a ground glass screen. The actual difference x between the two dimensions is amplified by a lever of a pivoted mirror. The reflected ray is deflected to give an angular displacement from the original line and gives a reading of X on the scale. The θ through an angle 2 main advantage of an optical comparator is that it is capable of giving higher degree of magnification due to reduction of moving members and better wear resistance qualities.
- 3) **Pneumatic Comparators:** Pneumatic comparators are the widely used precision instruments which use the principle of obstructed nozzle.
- 4) **Electrical Comparators:** Electrical comparators are used as a means of detecting and amplifying small movements of a work contacting elements. It may use any of the following transducers for magnification. They are (a) strain gauges, (b) variable inductance transducers, and (c) variable capacitance transducers. The transducer converts the displacement into a corresponding change in current and a meter recorder connected in the circuit to indicate the electrical change calibrated to show in terms of displacement. Generally, an amplifier is used to provide the requisite sensitivity and to match the characteristics of different parts of the circuit. There are different types of electrical comparators. One of them, called an electro limit gauge, is used to check or measure the outside diameter of a roll. The object to be checked is placed on the anvil under overhanging gauging spindle. Movement of the spindle for its deviation from a standard dimension unbalances an electric circuit. The displacement is magnified electrically and shown on the dial meter.

2.3.7 Common instrument error in measurement

- 1) **Length other than standard:** Tape manufacturers do not guarantee 100 ft steel tapes to be exactly 100.00 ft. An error due to the incorrect length occurs every time the tape is used.

- 2) **Temperature other than standard**: Steel tapes are standardized at 68° F (20° C). A temperature higher or lower will change the length of the tape. Temperature of the tape can be quite different from the air temperature measured.
- 3) **Tension**: If tension is greater than standard the tape will stretch. If less than standard tension is applied the tape will be shorter than standard.
- 4) **Sag**: A tape not supported along its entire length will sag. By applying correct tension the sag can be reduced.
- 5) **Poor alignment**: This error occurs when one end of the tape is off-line or there is an obstruction in-line. The actual distance will be less than the measured distance.
- 6) **Faulty marking**: This error is random as the result of incorrect placement of chaining pins. Careful placement of chaining pins and then checking the measurement will reduce errors.
- 7) **Incorrect reading or interpolation**: The error occurs when reading or noting the measurement clearly or in a hurry. Careful reading and using a small scale to determine the last figure will reduce errors.

2.4 SUMMARY

In this unit, linear measuring devices and comparators have been discussed. The unit begins with the description of non-precision measuring devices like scale (ruler), caliper, divider and telescopic gauge. Next, precision measuring devices, viz. vernier caliper, micrometer, height gauges and slip gauges are explained. The principles of electrical measuring devices like strain gauges, LVDTs, potentiometers have also been discussed. The four basic types of comparator viz. mechanical, optical, pneumatic and electrical are discussed.

2.5 GLOSSARY

- 1) **Vernier Constant**: It is defined as the difference between one small division of the vernier scale and one small division of the main scale.
- 2) **Least Count**: It is the minimum distance that can be measured by a vernier caliper or a micrometer accurately.
- 3) **Wringing**: It is the process of combining two slip gauges by application of pressure normal to the surface to be joined with sliding motion of one surface over the other.
- 4) **Transducer**: A transducer is a device which, when actuated, transform energy from one form to another.
- 5) **Piezo-resistive Effect**: It is defined as the phenomenon due to which resistivity of a conductor changes when it is subjected to strain.
- 6) **Gauge Factor**: The gauge factor of a strain gauge is the ratio of relative change in resistance to the relative change in length.
- 7) **Backlash**: It is the lack of motion or lost motion of the spindle when the rotation of thimble is changed in direction.
- 8) **Measuring Range**: It is the total travel of the measuring spindle for a given micrometer.

- 9) **Cumulative Error:** It is the deviation of measurement from the nominal dimension determined at any optional point of the measuring range. It includes the effect of all possible individual errors such as errors of the thread, errors of measuring faces etc. It can be determined by using slip gauges.
- 10) **Linear measurement:** The measuring accuracy of line graduated instruments depends on the original accuracy of line graduations. Excessive thickness or poor definition of graduated lines affects the accuracy of readings captured from the instrument.

2.6 ANSWER TO CHECK YOUR PROGRESS

- 1- Define direct measurement.
- 2-What is Pasing?
- 3-What is Passometer?
- 4-What is Speedometer?
- 5-What is chaining?
- 6-What is Calipers?
- 7-What is Telescopic Gauge?

2.7 REFERENCES

- American Congress on Surveying and Mapping 1978. *Metric practice guide for surveying and mapping*, 12 pages, A.C.S.M., 210 Little Falls Street, Falls Church, Virginia 220.
- ASPLUND, E. C. 1971 A review of self reducing, double image tacheometers. *Survey Review* (Jan.).
- BAUER, S. A. 1949 The use of geodetic control in surveying practice. *Surveying and Mapping* 9(3), 187–191. Falls Church, VA.

2.8 TERMINAL QUESTIONS

- 1) Describe different types of caliper for measuring the linear dimensions.
- 2) List various types of micrometers. Describe screw thread micrometer caliper.
- 3) List the slip gauges to be wrung together to produce an overall dimension of 93.458 mm using both normal and special set of slip gauges without any protection slips.
- 4) What are the advantages of electrical comparators over mechanical comparators?
- 5) Explain direct methods of linear measurement with suitable illustration.

UNIT 9 - OPTICAL THEODOLITES AND MEASUREMENT OF ANGLES

9.1 OBJECTIVES

9.2 INTRODUCTION

9.3 OPTICAL THEODOLITES, MEASUREMENT OF ANGLES

9.4 SUMMARY

9.5 GLOSSARY

9.6 ANSWER TO CHECK YOUR PROGRESS

9.7 REFERENCES

9.8 TERMINAL QUESTIONS

9.1 OBJECTIVES

After studying this unit, you should be able to

- describe the details of theodolite and its components.
- explain various operations and adjustments of theodolite.
- describe methods and procedures used for measurement of horizontal and vertical angles.

9.2 INTRODUCTION

If survey exercise is required to be accurate and elaborate, e.g. for triangulation and precise measurement of horizontal and vertical angles, the instrument used is theodolite. It is a very delicate and sensitive instrument and requires careful handling. The prime objectives of theodolite survey are to

1. establish control points of survey accurately so that the subsequent details can be filled in as and when required by other methods,
2. conduct theodolite traversing by measurement of linear distances (tacheometry), horizontal, and vertical angles,
3. laying out of important projects, e.g. dams, canals, highways and rail routes, centre line of pipelines, power lines etc., and
4. laying out the curves both horizontal and vertical. In addition to these, theodolite is also used in trigonometric levelling and field astronomy.

9.3 OPTICAL THEODOLITES, MEASUREMENT OF ANGLES

9.3.1 Theodolite surveying

The system of surveying in which the angles are measured with the help of a theodolite, is called Theodolite surveying. The theodolite is the most intricate and accurate instrument used for measurement of horizontal and vertical angles. It consists of telescope by means of which distant objects can be sighted. The telescope has two distinct motions on in the horizontal plane and the other in the vertical plane. The Theodolite is a most accurate surveying instrument mainly used for:

- Measuring horizontal and vertical angles.
- Locating points on a line.
- Prolonging survey lines.
- Finding difference of level.
- Setting out grades
- Ranging curves
- Tacheometric Survey

9.3.2 Classification of theodolites

Theodolites may be classified as;

1. Transit Theodolite: A theodolite is called a transit theodolite when its telescope can be transited i.e revolved through a complete revolution about its horizontal axis in the vertical plane, whereas in a-
2. Non-Transit type, the telescope cannot be transited. They are inferior in utility and have now become *obsolete*.
 - Vernier Theodolite: For reading the graduated circle if verniers are used ,the theodolite is called as a Vernier Theodolite.
 - Whereas, if a *micrometer* is provided to read the graduated circle the same is called as a Micrometer Theodolite. Vernier type theodolites are commonly used .

Figure 9.1 Types of Theodolites

TYPE OF THEODOLITE

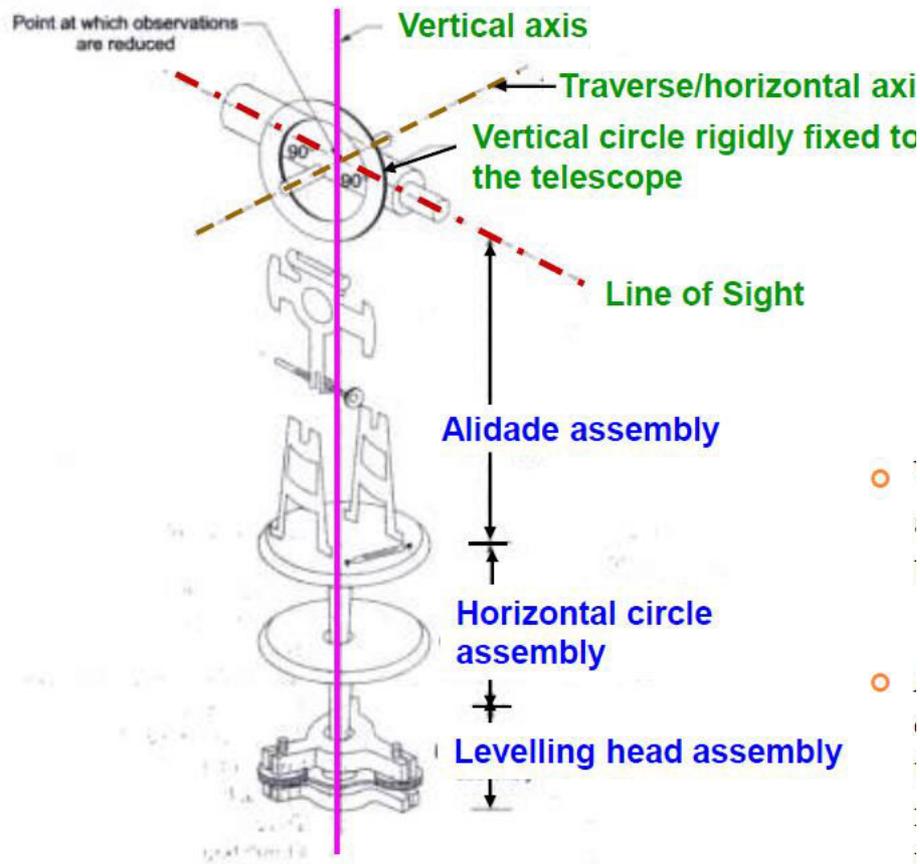


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9.3.3 Instrument and its components

The basic components of a theodolite can be telescope, main body frame by which rotation of telescope about horizontal and vertical axis can be regulated, and tripod to support and level the main body.

Figure 9.2 The Three Assemblies of Theodolite



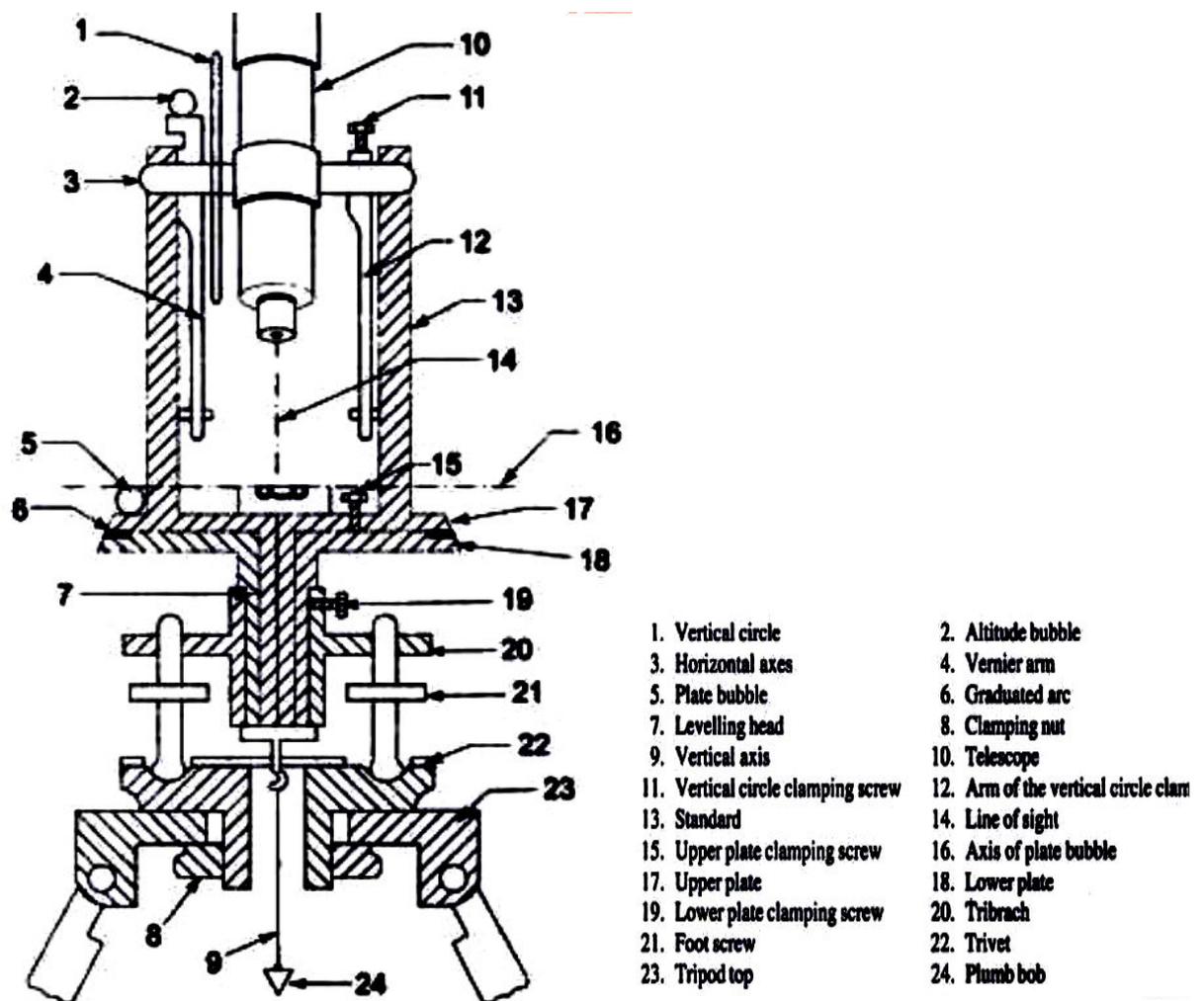
Source: Google

The theodolite in which the telescope can rotate through 360° about the horizontal axis is termed a transit theodolite. The other type, e.g. plane or non-transit theodolite in which rotation about only vertical axis is possible, have become obsolete.

1. **Telescope:** It is an integral part and is mounted on the spindle known as horizontal axis or turn on axis. Telescope is either internal or external focusing type.
2. **The leveling head:** It may consist of circular plates called as upper and lower Parallel plates. The lower parallel plate has a central aperture through which a plumb bob may be suspended. The upper parallel plate or tribranch is supported by means of four or three leveling screws by which the instrument may be leveled.
3. **To lower plate or screw plate:** It carries horizontal circle at its leveled screw. It carries a lower clamp screw and tangent screw with the help of which it can be fixed accurately in any desired position.
4. **The upper plate or vernier plate:** It is attached to inner axis and carries two vernier and at two extremities diametrically opposite.
5. **Compass:** The compass box may be either of circular form or of a rough type. The former is mounted on the vernier plate between the standards while the latter is attached to the underside of the scale or lower plate or screwed to one of the standards. Modern theodolite is fitted with a compass of the tubular type and it is screwed to one of the standards.

6. **Vertical circle:** The vertical circle is rigidly attached to the telescope and moves with it. It is silvered and it is usually divided into four quadrants.
7. **Index bar or T-frame:** The index bar is T shaped and centered on horizontal axis of the telescope in front of the vertical axis. It carries two vernier of the extremities of its horizontal arms or limbs called the index arm. The vertical leg called the clip or clipping screws at its lower extremity. The index arm and the clipping arm are together known as T-frame.

Figure 9.3 Main Parts of Theodolites



Source: Google

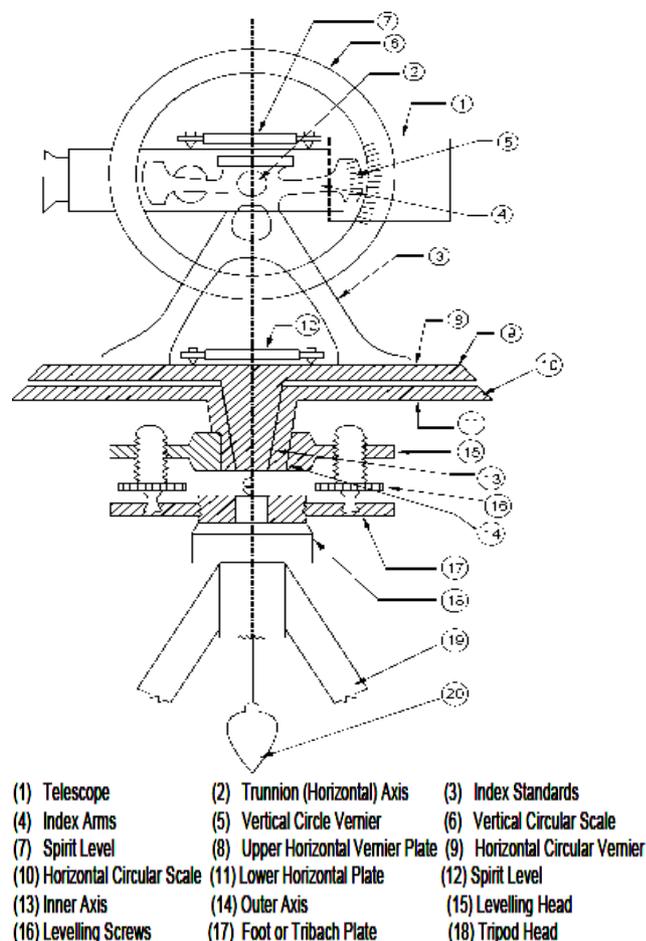
8. **Clamps and tangent screws:** There are two clamps and associated tangent screws with the plate. These screws facilitate the motion of the instruments in horizontal plane. Lower clamp screw locks or releases the lower plate. When this screw is unlocked both upper and lower plates move together. The associated lower tangent screw allows small motion of the plate in locked position. The upper clamp screw locks or releases the upper vernier plate. When this clamp is released the lower plate

does not move but the upper vernier plate moves with the instrument. This causes the change in the reading. The upper tangent screw allows the fine adjustment.

9. **Vertical circle clamp and tangent screw:** Clamping the vertical circle restrict the movement of telescope in vertical plane.
10. **Altitude level:** A highly sensitive bubble is used for levelling particularly when taking the vertical angle observations.
11. **Plumb bob:** To center the instrument exactly over a station mark, a plumb bob is suspended from the hook fitted to the bottom of the central vertical axis.

9.3.4 Main body frame

Figure 9.4 Theodolite: Essential Parts



Source: Google

The basic components of a theodolite, apart from telescope [1], are as described below. The telescope rotates in a vertical plane about the horizontal axis [2]. This is supported on a sturdy two index standards carrying the bearings at top [3]. The index standards also contain index arms [4] inscribed with two vertical circle verniers [5] at the ends. The index standards are mounted on trunnion axis to facilitate adjustments but are not fixed to it. The verniers are used along with vertical circular scale [6] which is graduated in degree and its parts and is attached to the telescope. The readings in these scales should be zero and 180° respectively

against the two vernier zeros, when the line of collimation is horizontal. Sensitive levels are attached to the main frame. One or a combination of two spirit levels [7] is attached either at the top of the telescope or to the top of one of the index arms or one spirit level at each location.

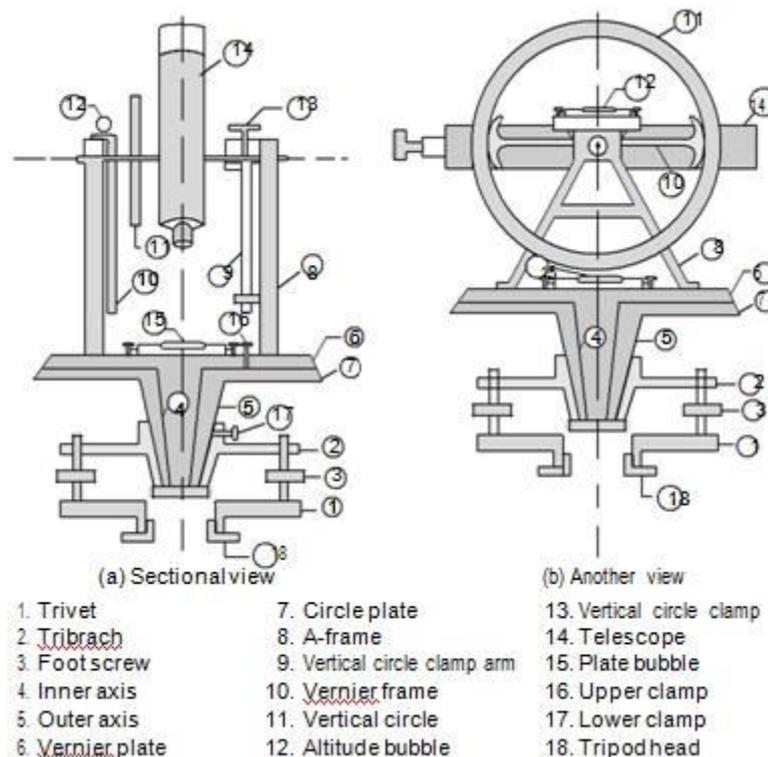
Theodolite Surveying: The index standards [3] are supported on upper horizontal circular vernier plate [8] which carries the horizontal circle vernier [9] provided at opposite ends of the diameter of the upper plate. The angular movement of horizontal line of collimation is measured in conjunction with horizontal circular plate scale [10] inscribed on the lower horizontal plate [11] which also carries another set of sensitive spirit levels [12]. The entire assembly is mounted on concentric tapered axes. Upper plate [11] is cast monolithically with inner axis [13] which rotates in the outer axis [14] cast integrally with lower plate. The free, smooth and frictionless rotation is achieved by the use of the tapered bearing cast monolithically with levelling head [15]. The levelling head usually have three arms, each arm provided with a tapped hole to accommodate threaded levelling screws [16] which are manipulated by attached milled discs [16a]. The base of each levelling screw is usually enlarged to a ball to fit in a socket provided in a tribach (foot) plate [17]. The foot plate is also provided with a threaded hole to make it fit in the tripod head [18]. In recent, instruments are provided with three small projections with foot plate which fit into slots on the tripod head. The tripod legs [10] are then provided to be connected to the tripod head by pins to allow their free inwards/outwards movement. The plumb bob [20] is attached to the levelling head by a cord and hooks, at the centre of the underside to centre the telescope at instrument station.

9.3.5 Refinements

Many refined versions of these basic twenty components of the theodolite are developed to increase the accuracy of the instrument and reducing the manual operations/labour involved. Some important refinements are as follows:

- **Adjusting Screws:** These are provided on diaphragm, spirit levels, and trunnion axis to adjust the relevant component. Clip screws are provided to control the position of the index arm vernier relative to the index frame scale. This facilitates setting of the vertical scale reading to zero when the line of collimation is horizontal.
- **Clamp and Tangent Screws:** Clamp and Tangent screws are provided to control the motion of vertical circle, horizontal circle and the lower plate. These enable a slow and steady circular motion of the telescope with precision. Ordinary adjustments are made to bring the line of sight close to the desired mark. The clamp screw is then tightened to partially fix the movement of line of sight, which can then be moved only slowly, steadily and with precision only by turning the tangent screw. The tightening of clamping screw presses the pad [5] against the outer axis locking it to the casting [3]. Turning the tangent screw then only will cause the outer axis to move relative to inner axis.

Figure 9.5 Theodolite Screws and Clamps



Source: Google

- **Adjustable Head:** This is attached to the levelling head which can be moved slowly and precisely relative to it horizontally to enable the instrument to move horizontally with the adjustable head. Approximate centering of theodolite over the station is achieved by manipulation of tripod legs. Adjustable head is then used to precisely and accurately move the instrument exactly over the station.
- **Direct Reading Telescope:** In place of vernier, the readings are directly read either by eye or with the aid of low power micrometer microscopes.
- **Optical System Theodolite:** It is observed that very fine lines on scales can be etched on glass rather than on brass or silver. Since light can pass through glass and can be reflected/refracted by a system of lenses and prisms, almost along any desired path to be able to observe the scale readings by an attached micrometer microscope. Kern of Switzerland manufactured an optical theodolite which can directly measure up to one second of arc. Optical plummet is also developed which can be used with optical system theodolites to accurately centre the instrument over survey station by providing a right angled prism at the junction of two circular passages at the instrument base. One passage coincides with the vertical axis and is orthogonal with the other passage, provided with cross wires inscribed on the surface of a glass window fixed at the end of the passage. The surveyor, thus, can look apparently downwards along the vertical axis and accurately centre the instrument by manipulating the adjustable head without the use of a plumb bob.

9.3.6 Operating and adjusting the instrument

After knowing the components of a theodolite and getting acquainted with its construction, a surveyor must get herself/himself familiar with its working. By regular working with the theodolite, systematically and methodically, certain labour saving techniques can be developed and time spent on its operations greatly reduced. Manufacturers of quality theodolites ensure that the instrument is perfectly in order, properly adjusted and ready to use. However, it could be disturbed during handling and transportation. Instruments, which are already in use, can definitely be affected due to wear and tear. The surveyor must therefore also get a knowledge and practice of temporary and permanent adjustments required for working of instrument with precision. Some operating requirements will be definitely there, where adjustments are not possible in field and require servicing/repair by the manufacturer. However, most of the setting and adjusting required for regular operation of theodolite can be done by surveyor. These are described below in brief.

9.9.1 Setting of the Theodolite: Operations required to be undertaken at each survey stations, before measurements of levels, angles or bearings, are termed temporary adjustments or setting of the theodolite. There are principally three steps in setting up the instrument at a station, i.e. three temporary adjustments, e.g.

- setting up the theodolite over a station,
- levelling of the instrument, and
- parallax elimination.

The step-by-step procedure will be as follows.

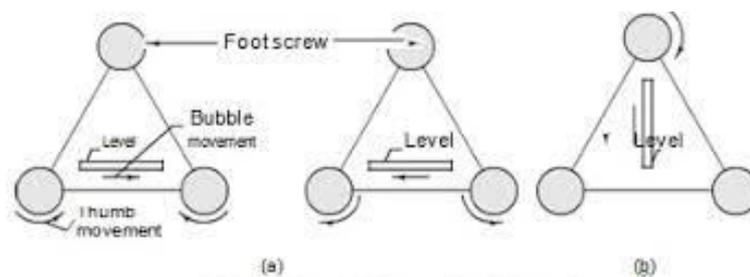
- a. Erect the tripod with its shoes pushed well into the ground after approximately centering it over the station with the help of plumb bob. The tripod head can be approximately levelled by placing a spirit level on the tripod head and centering the bubble, when tripod is centered over the station.
- b. The positioning of the instrument in the box is carefully noted so that it can be put back in the box properly after the work is finished at the station, without any difficulty. Once the surveyor gets acquainted with the instrument after multiple use, this process becomes routine.
- c. Release all the clamp screws of the theodolite before lifting it from the box to avoid any damage which might occur to instrument accidentally during lifting.
- d. Lift the instrument carefully from its casing, holding it at the base and index frame. Never hold the theodolite by levelling screws while removing the theodolite from the box or placing it in it.
- e. Screw the base plate in the tripod head which is already approximately centred at survey station. The instrument is firmly and carefully supported during this operation.
- f. The wing nuts of the tripod head are tightened.
- g. The instrument is then carefully levelled and centred accurately by plumb bob or optical plummet if provided. This levelling and centering operation is repeated till no further adjustment is needed.

The operations of levelling and centering are basics for any measurement of angles or distances by theodolite. Hence, these are discussed in detail in the following sub-section.

9.3.6.1 Levelling: This operation is performed to ensure that trunnion axis is horizontal, i.e. the horizontal plates of the instrument are lying in the horizontal plane. This is essential to ensure that measurements at one station can be correlated with readings at other stations. Any error in this operation, however small it may be, will influence the accuracy of measurements. Most of the instruments, currently manufactured and employed, have three levelling screws provided at the apex of an equilateral triangle. Step-by-step levelling process is as follows:

- (a) Rotate the upper plate until the axis of the spirit level is parallel to the line joining a set of two levelling screw. Rotate levelling screws 'a' and 'b' in opposite direction as shown in Figure 9.6 until the bubble is in the centre of spirit level.

Figure 9.6 Levelling of Theodolites



Source: Google

- (b) Rotate the telescope horizontally by right angle and bring the bubble back to centre of its run by rotating the third levelling screw 'c' as shown in Figure 9.6.
- (c) The process of steps (a) and (b) is repeated until the bubble remains central in both the positions.
- (d) Rotate the telescope by 180° and repeat steps (a) and (b). If the instrument is in good condition bubble should remain stationary in its central position.
- (e) It is very important to note that
- Never handle the tripod either during levelling or making observations.
 - The theodolite is handled absolutely minimal only just sufficient to make the observations.

9.3.7 Centering the theodolite

The vertical axis of the theodolite shall pass through the ground station. This is ensured by accurately centering the instrument at a station with the help of a plum bob or, if provided, with optical plummet. It may be noted that initial positioning of the tripod and approximately centering and levelling of tripod head greatly reduces the effect and time needed for subsequent accurate centering and levelling of the theodolite. The centering clip is released and the instrument is moved on its levelling head until the vertical axis passes through the ground station. The process is repeated until the requirements of levelling and centering are

simultaneously satisfied. The amount of care, time and effort used in the procedure will greatly depend upon the degree of precision and accuracy desired. The following terms should be well understood when manipulating a transit theodolite :

- 1) **Theodolite Surveying Transiting:** Transiting (also termed as plunging or reversing) is the process of turning the telescope over its supporting axis (horizontal axis) through 180° in a vertical plane, thus bringing it upside down and making it point exactly in the opposite direction.
- 2) **Face Left:** When the vertical circle of the instrument is on the left of the observer while taking a reading, the position is called face left.
- 3) **Face Right:** When the vertical circle of the instrument is on the right of the observer, the position is called face right.
- 4) **Face Left (FL) Observation:** It is an observation of an angle (horizontal or vertical) made with the *face* of the vertical circle on the left of the observer.
- 5) **Face Right (FR) Observation:** An observation made with the *face* of the vertical circle on the right of the observer is called a face right observation.
- 6) **Swinging the Telescope:** It means turning the telescope in a horizontal plane. A swing is called right or left, accordingly as the telescope is rotated clockwise or counter clockwise.
- 7) **Telescope Normal:** It implies *bubble up* and the *face* of the vertical circle left. It is also called *Telescope Direct*.
- 8) **Telescope Inverted:** It means *bubble down* and the *face* of the vertical circle right. It is also called *Telescope Reversed*.
- 9) **Changing Face:** It is the operation of bringing the vertical circle to the right of the observer, if originally it is to the left, and vice-versa.

9.3.8 Removing the parallax

While recording the observations by telescope of the theodolite, it should be ensured that there shall not be any apparent movement between the image and the cross hairs when the eye is moved from one side of eyepiece to the other. This exercise is termed as elimination of parallax and ensures that the image produced by the object glass is in the same vertical plane as the image of the cross wires viewed through the eyepiece.

The procedure followed for removing the parallax can be described as follows in a step-wise method.

- 1) Eyepiece is focused against a light coloured background until the cross hairs image is clear, sharp and distinct.
- 2) Observe a staff and focus the telescope screw until the staff image is also sharp, clear and distinct.
- 3) Move the eye across the eyepiece to check whether the parallax has been eliminated. Any parallax still remaining can be eliminated by a small movement of focusing screw.

9.3.9 Method and procedures

Once the theodolite has been set, centered and levelled at a ground station and parallax is eliminated, it is a simple exercise to carry out the four major operations given below:

- (a) Measurement of horizontal angles,
- (b) Measurement of vertical angles,

- (c) To set out a horizontal angle, and
- (d) To set out a vertical angle.

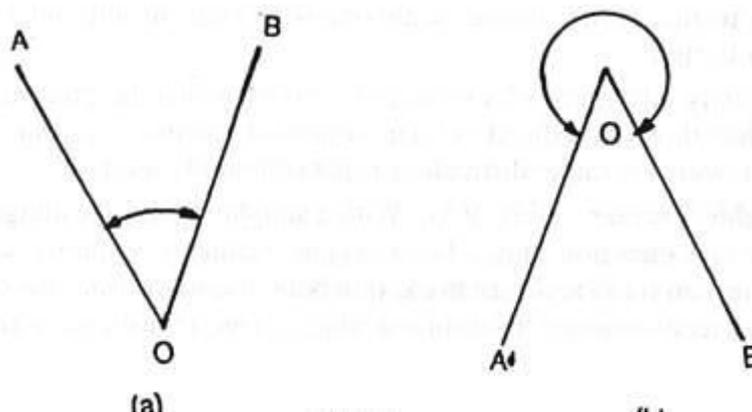
The basic procedures normally followed in each of these operations can be described and detailed. However, it is a relatively simple matter to arrive at the best routine to be followed by individual surveyor, assisted by the basic standard procedures described here. It is essential that surveyor ensures in advance the provision of suitable station signals. Vertical ranging rods with metal shoes pushed well in the ground can be conveniently sighted from distances up to 700 meters or so. If the longer sights are necessary, special signals may be required. Specifically designed survey books are developed to note all the readings and observations, neatly, correctly and systematically. Each page of the survey note book may also carry the space for surveyors name, job name, work description, instrument particulars, weather details, the observation date etc. All or any information which can be considered as relevant must be recorded at prescribed place. It is always better to collect too much information rather than too little.

9.3.10 Measurement of horizontal angles

9.3.10.1 Horizontal Angle: To measure the horizontal angle AOB, following step by step procedure may be adopted.

- 1) Set, centre and level the instrument at instrument station *O*.

Figure 9.7 Horizontal Angle



- 2) Release the clamps and rotate the horizontal plates in opposite directions until the vernier and scale zeros almost coincide. With micrometer theodolites, set the micrometer and horizontal scale readings close to zero.
- 3) Clamp the horizontal plate movements and bring the scale and vernier zeros to coincide using upper plate tangent screw. Release the lower plate clamp so that the plates now can rotate together.
- 4) Sight the left hand signal (*A* in figure 9.7). It may be noted that subtraction of one observation from the other, to obtain the included angle, is easy if the rotation of instrument is clockwise. However, this is not essential. Any signal may be sighted.

However, it is desirable that whichever direction is chosen, it must be followed throughout the operation.

- 5) Clamp the vertical and horizontal movements and remove the parallax. The cross hairs are set to bisect the signal with the help of lower plate and the vertical circle tangent screws. This ensures that zero of the horizontal scale is pointing to the signal. In an adjusted theodolite, the reading of the other horizontal scale will be exactly 180° .
- 6) Upper plate and vertical motion clamp screws are released and the telescope is rotated until the second signal (*B* on the right hand side in Figure 9.7) is sighted.
- 7) Clamp screws are tightened and telescope is focused on the signal *B*. The cross hairs are set to intersect the new signal using vertical circle and upper plate tangent screws.
- 8) The horizontal angle is observed and entered in the field note book at appropriate place.
- 9) The relative positions of the telescope and vertical scale are noted. These positions are then reversed by turning the telescope through 180° vertically and 180° horizontally. The vertical turning of telescope by 180° is termed transiting the telescope. The complete operation may be called changing the face.
- 10) Repeat steps (b) to (h) at the other facing.
- 11) The mean value of the angle will give the actual value of the angle. This system of reversal assists in eliminating the errors in instrument's permanent adjustments.

9.3.10.2 Measurement of Horizontal Angle by Repetition

For better accuracy and precision, the method of repetition is used. It is claimed that by method of repetition following errors are either eliminated or minimized.

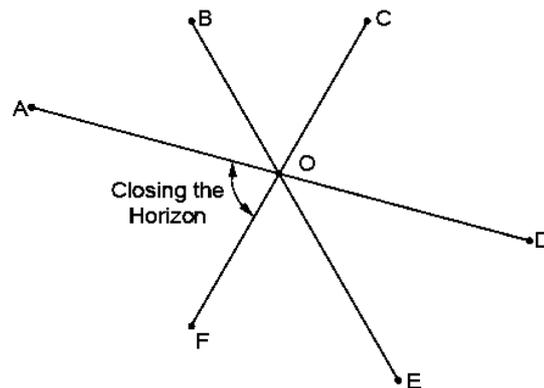
- 1) Any error due to eccentricity of the centres and verniers are eliminated by reading both verniers and averaging the readings.
- 2) Any error due to misadjustment between horizontal axis of instrument and line of collimation is minimised by face left and face right observations (face changing).
- 3) Any error of graduation is minimized by measuring the angle on different parts of the circle scale.

The method of repetition consists of adding the angle mechanically several times and then dividing the accumulated reading by number of repetitions. The angles are measured several times by clamping the vernier each time at the previous reading when the back sight is taken. Half the repetitions are done with face left position and half with face right position.

9.3.10.3 Measurement of Horizontal Angle by Reiteration

Like repetition, reiteration is another method of measuring the horizontal angle precisely. This method is preferred when several angles are required to be measured at one instrument station (Figure 9.8).

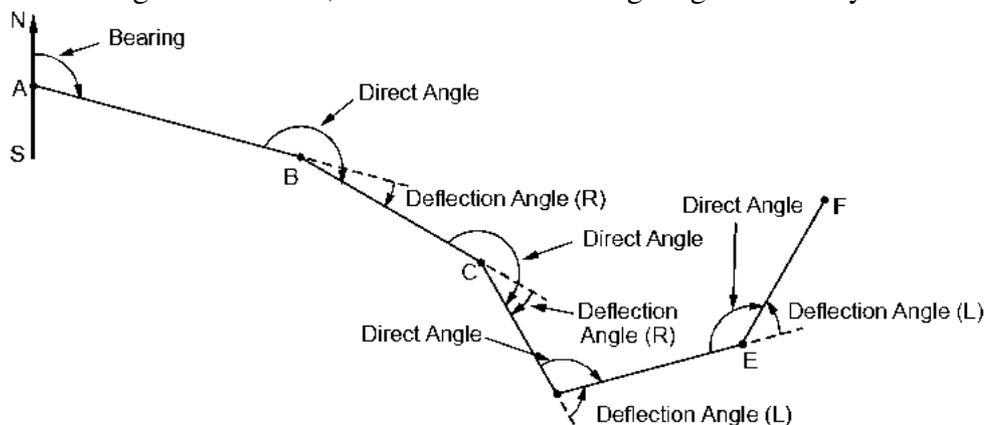
Figure 9.8 Several Angles at a Station



Several angles, e.g. AOB , BOC , COD , DOE and EOF are measured successively by the usual method. Finally, the angle between the last and the first station (i.e. F and A) angle FOA , is measured. This is called *closing the horizon*. If all the observations are recorded correctly the final reading of the leading vernier should be the same as its initial reading. Any error in this observation is equally and proportionately distributed among all the measured angles at this instrument station. If the discrepancy is large, all the readings taken at this stations are rejected and the new set of readings taken. It may be noted that the entire set of readings are first taken with face left setting and then repeated with face right setting. The average of the two sets is regarded as true readings.

9.3.10.4 Direct Angles: The angles measured clockwise from the preceding lines are called the direct angles (Figure 9.9). These are also termed *azimuths* from back lines.

Figure 9.9 Direct, Deflection and Bearing Angle of Survey Line



The theodolite is set at station B and back sighted on the preceding station on A with leading vernier set to zero. Unclamp the upper plate and turn the instrument clockwise to bisect the forward station C . Record the angle taking observation on both verniers. Change face and again take the back sight on A without disturbing the vernier setting. Loosen the upper plate, turn the telescope to bisect C once again and read the verniers. The average of the four vernier readings will give the true value of the direct angle ABC .

9.3.10.5 Deflection Angles: The angle made by the survey line with the extension of the preceding line is termed as deflection angle (Figure 9.9). This is equal to the difference between the included angle and 180° and are described as right (*R*) or left (*L*) depending upon whether these are measured clockwise or counter clockwise from the extension of the preceding line.

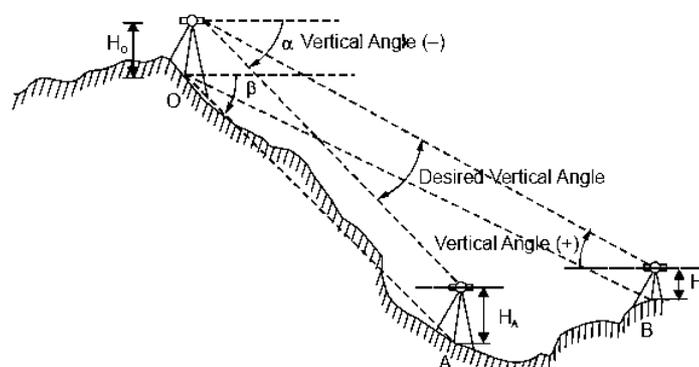
Magnetic Bearing of a Line: Most of the modern theodolites are provided with a magnetic compass as an attached accessories. Angles measured with reference to N-S line at a station are termed bearings or magnetic bearings of the survey lines.

- The theodolite is set at station (station *A* in Figure 9.9).
- Set the leading vernier to zero of the circular scale. Unclamp the lower plate and release the magnetic needle of the attached compass.
- Rotate telescope about outer axis until magnetic needle (N-S axis) synchronizes with N-S graduation in the circular box compass. Clamp the lower plate and manipulate the lower tangent screw to bring zero graduation into exact coincidence with the N-end of the needle. Leading vernier reads zero in this position and the theodolite is oriented along magnetic meridian.
- Loosen the upper plate. Turn the instrument and bisect the next station on survey line (Station *B* in Figure 9.9) exactly by using the upper clamp and its tangent screw.
- Change the face and repeat the process. The average of the two observations will be the true bearing of the survey line.

9.3.10.6 Measurement of Vertical Angles

Vertical angle is the angle between the horizontal and the inclined line of sight *OA* (Figure 9.10). The vertical angle can also be measured between the lines of sight *OA* and *OB* (Figure 9.10). The vertical angle of line of sight and horizontal (α) and between horizontal and line joining ground at stations *O* and *A* (β) can be related by considering height of instruments at stations *O* and *A*.

Figure 9.10 Vertical Angle



It could be an angle of elevation (+ angle) or an angle of depression (– angle) depending whether the observed station is above or below the horizontal plane at the reference station. The step-by-step process employed is listed below:

- (a) The instrument is set, centered and levelled at the instrument station, O , the lower plate is clamped.
- (b) The vertical scale and vernier is set to zero by vertical circle clamp and tangent screw.
- (c) Sight the lower station (A in Figure 9.10).
- (d) Remove the parallax and focus the telescope. The cross hairs are set to bisect the intersection of the signal and the ground using the upper plate and the vertical circle, clamp and tangent screws. The vertical circle verniers and micrometer readings are recorded.
- (e) Release the clamp screws and the upper plate.
- (f) Sight the upper signal (B in Figure 9.8). Repeat step (d) at this station.
- (g) Repeat step (a) to (d) at the reverse facing.
- (h) The mean value of the angle (difference in the readings at two stations) is the true value of the desired vertical angle.

Angle with Horizontal

Many times the vertical angle between signal, i.e. line of sight of station with the horizontal is desired. In this case, the line of collimation is made horizontal by bringing the altitude level to the centre of its run by means of clip screws. The vertical vernier reading is set to zero when line of collimation is horizontal. This step is carried out in place of step (c), sighting the lower station. The rest of the steps repeated as described above. If more than one angle is required to be measured, care should be exercised to rotate the telescope both horizontally and vertically in one direction only.

9.3.10.7 Setting out a Horizontal Angle

It is required to set off a horizontal angle α (say) with reference to a survey line OA . The following step wise process may be adopted:

- a. Setting the instrument at O , carry out the steps (a) to (k) of Section 3.13.6, the process of measuring the horizontal angle.
- b. Clamp the lower plate and rotate the upper plate until the leading vernier is nearly indicating the required angular reading α .
- c. Clamp the upper plate and turn the upper plate tangent screw until the horizontal scale reading exactly indicates the value of required angle α .

9.3.10.8 Setting out a Vertical Angle

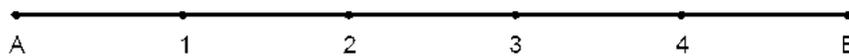
- a. The steps (a) to (d) of measuring vertical angle as described in Section 3.13.6 are carried out.
- b. The vertical angle to be set (β) is added algebraically to the angle between the line of sight to the first station and the horizontal.
- c. Release the vertical circle clamp and rotate the telescope in vertical plane until the vertical scale reading is approximately equal to angle as obtained in step (b) above.
- d. Clamp the vertical circle and set the vertical scale vernier reading exactly equal to the required angle β using vertical scale tangent screw. The intersection of the obtained line of sight with ground is marked by a ranging rod.

9.3.11 General application

The theodolite is a very versatile and precise instrument and can be used for a variety of purposes in addition to measuring and setting horizontal and vertical angles. Some of these can be discussed in brief as follow:

- 1) **Compass:** The theodolites are usually provided with a magnetic compass as an accessory. Hence, it can be used for measurement of bearings of the survey lines as described in above Section.
- 2) **As a Level:** levelling is the most direct method of comparing the relative altitudes of the ground features. The principal requirements are a horizontal line of sight and a graduated measuring staff. The dumpy level was used to provide the line of sight. The line of sight in horizontal plane can also be provided by the theodolite as indicated in the procedure of setting and measuring the vertical angles by theodolite, earlier in this unit. The line of collimation is made horizontal by bringing the altitude level to the centre of its run by means of clip screw. The vernier reading and vertical scale readings are set exactly at zero in this position with the help of vertical clamp and vertical tangent screws. These are then clamped. The theodolite in this setting can then be used as a level for direct levelling. Theodolites can also be used for trigonometric levelling, employed to determine large differences in altitudes particularly when direct levelling is not possible or when levels are required of one or more stations that are not readily accessible and depends only upon the possibility of placing ranging rods/staffs at the stations.
- 3) **Lining-In:** The procedure of ranging, that is, establishing of points on a given straight line is called *lining-in*. Let end points *A* and *B*, along a survey line *AB*, are visible from each other and it is required to establish intermediate points 1, 2, 3, 4 etc. along this line. Following procedure may be employed.

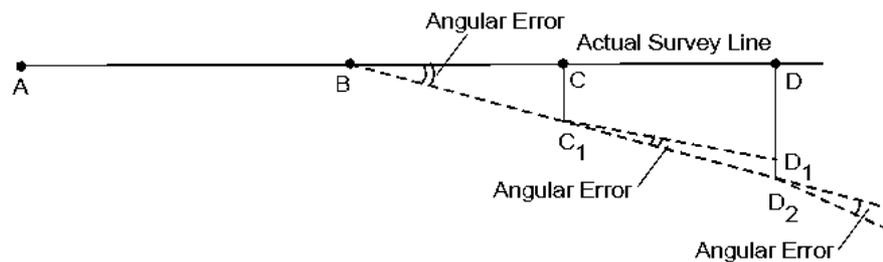
Figure 9.11 Lining-In



- a) Set, centre and level the instrument over one end station, say *A*, of the survey line *AB*.
- b) Clamp the lower plate and rotate the telescope until ranging rod at station *B* is sighted. Clamp the upper plate and bisect exactly the ranging rod *B* with the help of horizontal scale tangent screw.
- c) Approximately direct the flag man and intermediate station, say 1 to lie along line *AB*.
- d) Exactly bisect the ranging rod at 1, by directing the flag man to place the rod exactly along *AB*, while viewing through the telescope.
- e) For accurate surveying, intermediate points are established by double sighting, first with left facing telescope position and then with right facing.

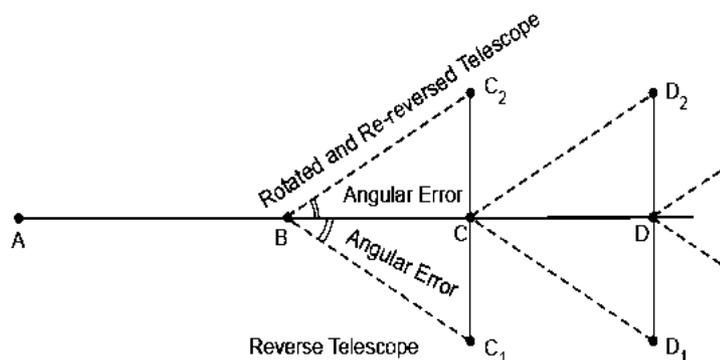
- 4) **Prolonging a Straight Line:** In place of fixing the intermediate stations as described in Lining-in, the survey line AB may be required to be extended (Figure 9.12). The procedure similar to Lining-in can be used.

Figure 3.12 Prolonging of Line



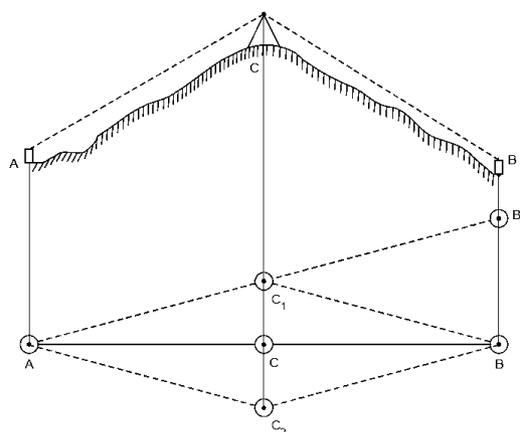
- The theodolite may be set, centered and levelled at station A or station B . If station A is selected as instrument station, ranging rod is placed at station B and fore sight is taken by sighting and bisecting the ranging rod at B . The instrument locked in this position is then used to direct the flagman at C to move right or left to place ranging rod exactly along the line of sight, thus establishing station C .
- The instrument is then shifted to B and rod C is bisected similarly to establish line BC . Extend the line BC to D as in step (b) above.
- The process is continued until final station is reached.
- If station B is selected as first instrument station, direction AB is fixed by setting theodolite at B and back sighting and bisecting the ranging rod at A .
- Clamp both upper and lower plate motions, transit the telescope and set new point C along AB extension.
- Move the theodolite to C , back sight station B , transit the theodolite and establish station D along BC extension.
- Continue the process until final station is reached.
- For more accurate work, the method of double sighting or double reversing is used in the following manner : (i) Station B is selected as instrument station and the instrument is set, centered and levelled.
- Back sight is taken at station A , transit the telescope and establish the next station (say C_1) along AB .
- Lower plate is unclamped and telescope rotated keeping its inverted position, and back sighted on A .
- Transit the telescope and set a new point (say C_2) in line of AB . If the instrument is in adjustment point C_1 and C_2 (Figure 3.13) will coincide. Normally the point C_2 will be on one side of the true line and equally distant from it as the point C_1 on the other side. True value of C will be exactly at midway between $C_1 C_2$.

Figure 9.13 Double Reversing



- l) If the double reversing is not carried out, angular error, however small, will cause deviation of survey line from its true alignment. This deviation will be added cumulatively as the line is extended causing grave errors as shown in Figure 9.13.
- m) Repeat the process until last station is reached.
- 5) **Balancing-In:** In many real life situations, the end stations are not intervisible (Figure 9.14) but both are visible from some intermediate point, say C, along the line AB. It is required to locate and establish this intermediate point. The procedure adopted is termed balancing-in and briefly outlined in the following steps :

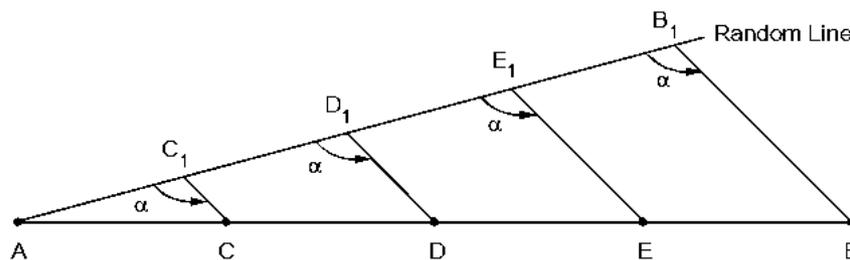
Figure 9.14 Balancing



- a) Select a station C1, as nearly as possible, by visual observation and other considerations, along the survey line AB. Set up and level the theodolite at this station.
- b) The end station A is back sighted. The telescope face is reversed and point BB1 is located along the line of sight.

- c) Distance BB_1 is measured or estimated. For this the distance CC_1 is either measured or estimated using similar triangle principle.
- d) Move the theodolite to position C by estimated distance CC_1 .
- e) The steps (b) to (d) is repeated until the line of sight fixed on back sighting A , bisect station B exactly. The station C is the required station.
- f) The location of station C is then checked by double reversing. A perfectly adjusted instrument will give only one position of C , otherwise another station C_2 will be obtained (Figure 9.14). The real station position C will be at the centre of line $C_1 C_2$.
- 6) **Random Line:** In the previous case, end stations A and B were not intervisible, but they were visible from some intermediate point C . It may so happen that these end stations may not be simultaneously visible from any intermediate station also. Under these special conditions, the intermediate points C, D, E etc. can be established by following procedure:

Figure 9.15 Random Line



- a) A straight line AB termed as random line or trial line is established. The point BB_1 is so selected that it is visible from B and is as close to as possible, and is visible from A . This is done by any method described earlier.
- b) The instrument is set at BB_1 and angle $BB_1 A$ (α) is measured (Figure 9.15). Also measure AB and AB_1 .

Intermediate station C on survey line AB is located by setting the instrument at C_1 on AB_1 . Distance AC_1 is obtained from equation

$$AC_1 = \frac{AB_1}{AB} \times AC.$$

Lay off angle $AC_1 C$ equal to α and set the point C at a distance $CC_1 = \frac{BB_1}{AB_1} \times AC_1$. Point C will then be the desired point on survey line AB .

Similarly, other intermediate points, e.g. D, E , etc. can be located.

9.3.12 Traversing

The simple and basic principle of traversing or traverse surveying is that if it is possible to measure the distance and angles between successive survey stations, their relative positions can be plotted on the drawing board and the survey map can be produced. A traverse is

needed whenever a rigidly determined framework is required for a survey, e.g. to plot the outlines of small and large lands measuring the details from the traverse lines. The distance can be measured with a chain, tape, tacheometric measurements or by one of the recently developed electronic methods of measurements. The angle can be measured by compass or theodolites. If the first and the last stations coincide, the traverse is known as closed traverse. Otherwise it is an open traverse. The process of traverse survey consists of following steps :

- (a) Reconnaissance,
- (b) Selection, marking and referencing of stations,
- (c) Running the survey lines by distance and angular measurements,
- (d) Picking up the details by taking offsets from the survey lines,
- (e) Recording the readings in the field book and making the field notes, and

9.3.13 Uses of theodolites

- Mapping application and in the construction industry.
- Measurement of horizontal and vertical angles.
- Measurement of magnetic bearing of lines.
- Locating points on line.
- Prolonging survey lines.
- Determining difference in elevation.
- Setting out curves.
- Aligning tunnels,
- Mining work etc.

9.4 SUMMARY

Theodolite is an instrument used to measure horizontal and vertical angles. Because of its variety of uses, such as the measurement of horizontal and vertical angles, prolonging a straight line, measurement of bearings, measurement of horizontal and vertical distances and to determine the direction of true north, it is sometimes referred to as universal instrument. Depending upon the facilities provided for reading of observations, the theodolites may be classified as simple vernier theodolite, micrometer theodolite, optical (glass arc) theodolite and electronic theodolite. A modern theodolite is compact, light in weight, simple in design and can be used roughly. All the movable parts and scales are fully enclosed and are virtually dust and moisture proof.

9.5 GLOSARRY

1. **Face Right:** When the vertical circle of a theodolite is on right of the observer, the position is called face right and observation made is called face right observation.
2. **Face Left:** When the vertical circle of a theodolite is on left of the observer, the position is called face left and observation made is called face left observation. By taking the mean of both face readings, the collimation error is eliminated.
3. **Telescope Normal:** The telescope is said to be normal or direct when its vertical circle is to the left of the observer and bubble is up.

4. **Telescope Inverted:** The telescope is said to be inverted when its vertical circle is to the right of the observer and the bubble is down.
5. **Changing face:** Revolve the telescope by 180° in vertical plane about horizontal axis. Again revolve the telescope in horizontal plane about vertical axis.

9.6 ANSWER TO CHECK YOUR PROGRESS

- 1-What is Transit Theodolite?
- 2-What is Telescope?
- 3-What is levelling?
- 4-What is Centering?
- 5-What are Direct Angles?

9.7 REFERENCES

1. Volland, C., I.U.M Centre the Villeurbanne, 2001.
2. Dennison, K, Thedolite presentation, 2000.
3. Mitchell, M., Jolley, J., Survey Methods Overview, 2009.

9.8 TERMINAL QUESTIONS

1. Define theodolite. And explain its major parts with suitable diagram.
2. Explain the basic principle of traversing and the process of traverse survey.
3. Describe the temporary adjustments of a theodolite. Explain how you would measure the following with theodolite.
 - (i) Horizontal angle,
 - (ii) Vertical angle, and
 - (iii) Bearing of a line.
4. Explain the terms used in theodolite surveying 'lining-in' and 'balancing-in'. Also explain 'random line'.
5. What are the major applications of theodolites?

UNIT 10 - DIRECT AND REVERSE GEODETIC PROBLEM, THEODOLITE MOVES AND HORIZONTAL PICTURE

10.1 OBJECTIVES

10.2 INTRODUCTION

***10.3 DIRECT AND REVERSE GEODETIC PROBLEM,
THEODOLITIC MOVES & HORIZONTAL PICTURE***

10.4 SUMMARY

10.5 GLOSSARY

10.6 ANSWER TO CHECK YOUR PROGRESS

10.7 REFERENCES

10.8 TERMINAL QUESTIONS

10.1 OBJECTIVES

After studying this unit, you should be able to:

- Explain the different types of errors possible in theodolite surveying and adjustment done for removal of errors.

10.2 INTRODUCTION

A theodolite is a precision optical instrument for measuring angles between designated visible points in the horizontal and vertical planes. The traditional use has been for land surveying, but they are also used extensively for building and infrastructure construction, and some specialized applications such as meteorology and rocket launching. It consists of a moveable telescope mounted so it can rotate around horizontal and vertical axes and provide angular readouts. These indicate the orientation of the telescope, and are used to relate the first point sighted through the telescope to subsequent sightings of other points from the same theodolite position. These angles can be measured with great accuracy, typically to milliradian or seconds of arc. From these readings a plan can be drawn, or objects can be positioned in accordance with an existing plan. The modern theodolite has evolved into what is known as a total station where angles and distances are measured electronically, and are read directly to computer memory. In a transit theodolite, the telescope is short enough to rotate through the zenith, otherwise for non-transit instruments vertical (or altitude), rotation is restricted to a limited arc. The optical level is sometimes mistaken for a theodolite, but it does not measure vertical angles, and is used only for levelling on a horizontal plane.

Figure 10.1 Surveying Instrument: Theodolite



Source:Google

10.3 DIRECT AND REVERSE GEODETIC PROBLEM, THEODOLITIC MOVES & HORIZONTAL PICTURE

10.3.1 Geodetic problems

In geometric geodesy, two standard problems exist—the first (direct or forward) and the second (inverse or reverse). Given a point (in terms of its coordinates) and the direction (azimuth) and distance from that point to a second point, determine (the coordinates of) that second point. First (direct or forward) geodetic problem; given a point (in terms of its coordinates) and the direction (azimuth) and distance from that point to a second point, determine (the coordinates of) that second point. Second (inverse or reverse) geodetic problem; given two points, determine the azimuth and length of the line (straight line, arc or geodesic) that connects them.

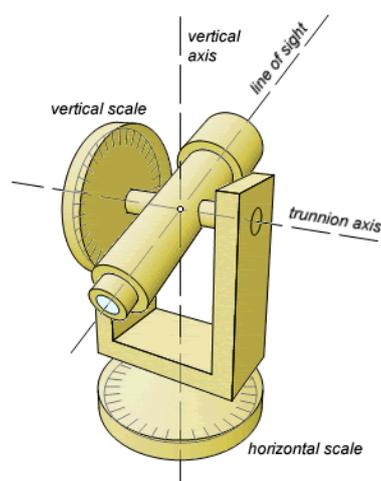
In plane geometry (valid for small areas on Earth's surface), the solutions to both problems reduce to simple trigonometry. On a sphere, however, the solution is significantly more complex, because in the inverse problem the azimuths will differ between the two end points of the connecting great circle, arc.

On the ellipsoid of revolution, geodesics may be written in terms of elliptic integrals, which are usually evaluated in terms of a series expansion—see, for example, Vincent's formulae. In the general case, the solution is called the geodesic for the surface considered. The differential equations for the geodesic can be solved numerically.

10.3.2 Errors in theodolite

To obtain results with high degree of accuracy it is necessary that measurements should be checked for errors whenever possible. The sources of errors in a theodolite survey can be classified as:

Figure 10.2 Working and Axis of Theodolite



Source:Google

1. **Instrumental Errors:** Instrumental errors are caused by lack of adjustments or wear and tear during continuous use. Instrumental error should never be used as an excuse during survey as the instrument shall always be checked and adjusted before commencement of survey process.
2. **Personal Errors:** Personal errors are through lack of care and attention on part of the surveyors. These can be numerous, e.g. sighting the wrong signal, inaccurate bisection of the signal, careless levelling and centering of the instrument and errors in recording the observations in field book.
3. **Natural Errors:** Natural errors are due to wind, rain, temperature etc. and are easy to be guarded against. It is impossible to obtain accurate readings in strong winds and/or in heavy rains. Heat may produce haze and shimmer or rapid changes in refraction near the ground.
4. **Computational Errors:** Computation errors will arise from failure to tabulate results properly, carelessness in handwriting and recording observations, incorrect use of log tables, or calculator, or incorrect data entry in computers, copying figures incorrectly and putting the figures in wrong columns. These errors can be avoided only by taking great care during computations and cross checking the computations.
5. **Drawing Board Errors:** Drawing board errors or errors in plotting the survey maps may occur if the coordinate network is not constructed carefully or not accurately set out on drawings or if proper material and method is not used for drawings. These errors are minimized in recent times by using computer aided plotting and drafting.

10.3.3 Instrumental errors

A new or recently adjusted instrument should perform smoothly without any error or problem. The requirements of error free and smooth operations can be listed as follows.

- a) The moving components of theodolite shall move only along the circular path relative to each other without any back lash, whip or looseness.
- b) The trunnion or horizontal axis shall be normal to the optical axis of the telescope and the vertical circle.
- c) The horizontal plates, upper and lower, should be perpendicular to vertical axis. The trunnion axis should be horizontal when horizontal plates lie in a horizontal plane.
- d) The geometric centres of the vertical circle and horizontal axis should coincide. So also the geometric centres of axis of horizontal plates and vertical axis of the theodolite.
- e) The two verniers of the theodolites should be diametrically opposite to each other.
- f) The optical axis of the telescope should coincide with the line of collimation and both should be parallel to axis of the telescope spirit level and normal to trunnion axis.
- g) The vertical circle readings along with its vernier shall be zero when line of collimation is horizontal. In this position, the index frame spirit level bubble shall be central.

h) The vertical axis and the trunnion axis shall be mutually perpendicular.

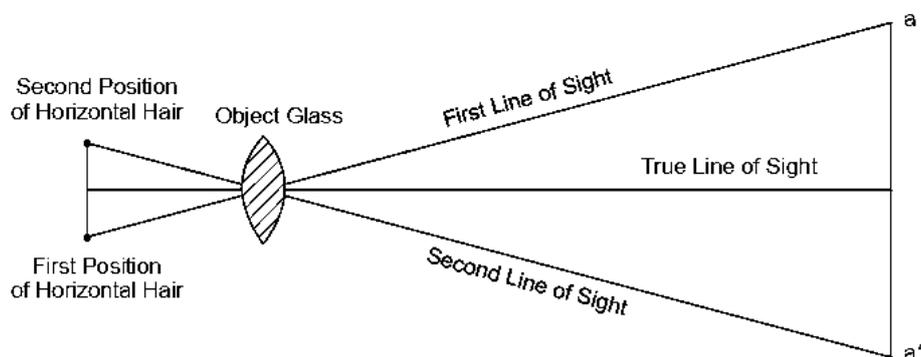
First five requirements of the instrument require complex, expensive and expert attention for testing and adjustment. The instrument is required to be repaired at frequent and regular intervals by a competent instrument repairer or by the manufacturer itself, if required. However, requirement from (f) onwards can be established by the surveyor in the field and adjusted before the start of the survey. These testing and adjustments are based on the principle of reversal, i.e. the telescope is transited (turned vertically through 180°) and then turned horizontally through 180° .

10.3.3.1 Horizontal Plate Spirit Level Test: This is conducted to ensure that the horizontal plate spirit level has its bubble in central position when vertical axis is vertical. The horizontal plates will be truly horizontal in this position. Horizontality of both upper and lower plates is an essential requirement for relating the results from different stations. To test the theodolite it is set, centred and levelled at a station, with lower plate clamped. The telescope is rotated through 180° in horizontal plane. The horizontal plate spirit level bubble should remain central during this operation. If not, following adjustment process is carried out.

- (a) The axis of the telescope is brought parallel to a line joining two levelling screws.
- (b) Using vertical circle clamp and its tangent screws, the bubble is brought in its central position. If the spirit level is fixed on the index arm, one has to use levelling screws for centralization.
- (c) The telescope is rotated through 90° and this bubble is again centralized using levelling screws. The process of (b) and (c) is continued until the bubble remains central in this quadrant.
- (d) Rotate the telescope through 180° . Any run of the bubble is returned half way of its run using levelling screws.
- (e) The bubble is centralized now using tangent screws if it is mounted on telescope and with clip screws if it is on index arm.
- (f) The process from (a) to (e) is iterated until no further adjustment is required.

10.3.3.2 Line of Collimation: The optical axis of the telescope and line of collimation of theodolite should be coincident. This ensures that line of sight is normal to trunnion axis. If this adjustment is not proper, observational errors, as shown in Figures 10.3.

Figure 10.3 Line of Collimation



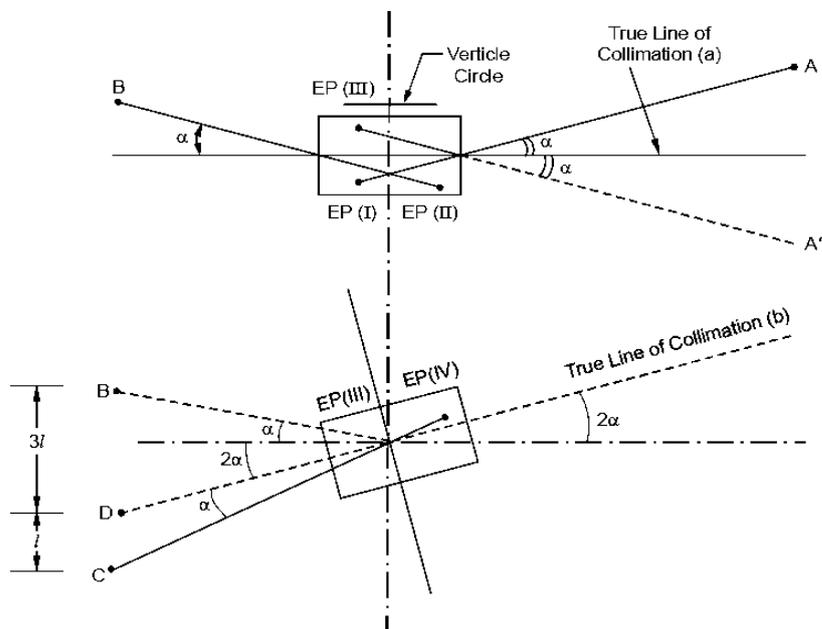
There are four types of maladjustment possible as given below:

- (a) Horizontal hair: angular displacement.
 - (b) Vertical hair: angular displacement.
 - (c) Horizontal hair: lateral displacement.
 - (d) Vertical hair: lateral displacement.
- (a) **Horizontal Hair: Angular Displacement:** Set the theodolite at a station and level it. Clamp vertical motion and sight the staff at both sides of the field of view, using upper plate tangent screws. In the perfectly adjusted instrument, both the readings will be same. If not, adjust the instrument as described below. Loosen the capstan headed screws of the diaphragm and rotate the diaphragm till both the readings are same.
 - (b) **Vertical Hair: Angular Displacement:** In modern instruments, hair lines are etched on glass hence testing and adjustment for horizontal hair angular displacement will also ensure meeting of this requirement. However it is better to carry out the vertical hair test. A fine plumb line is hung at a distance from instrument. Check the vertical hair against this plumb line. If the horizontal hair is tested and adjusted for any angular displacement as described above and still, the vertical hair and plumb line do not coincide throughout the length, discard the diaphragm and fit the new diaphragm in the instrument.
 - (c) **Horizontal Hair: Lateral Displacement** The adjustment error is shown in Figure below. Set, centre and level the instrument at a station. Place a staff at a sufficient distance from it (say a few hundred meters). Clamp all the screws and note the staff reading (a in Figure 10.4) and vertical angle. The telescope is then reversed, i.e. rotated through 180° both horizontally and vertically. It is now set to same vertical angle as above. The staff reading in this setting will be a' . If a and a' do not coincide, error in adjustment is indicated. Slacken the diaphragm screw and move the horizontal hair vertically to intercept the staff reading at $(a + a')/2$. Tighten the diaphragm screw and repeat the test till a and a' coincide.
 - (d) **Vertical Hair: Lateral Displacement:** The effect of error in this adjustment is exhibited in Figure below. The instrument is set and levelled and clamp horizontal motion. Place a ranging rod roughly at 100 m from theodolite.

Figure 10.4 Line of Collimation Adjustment (Vertical Hair)

Test

The effect of error in this adjustment is exhibited in Figure 6.18.

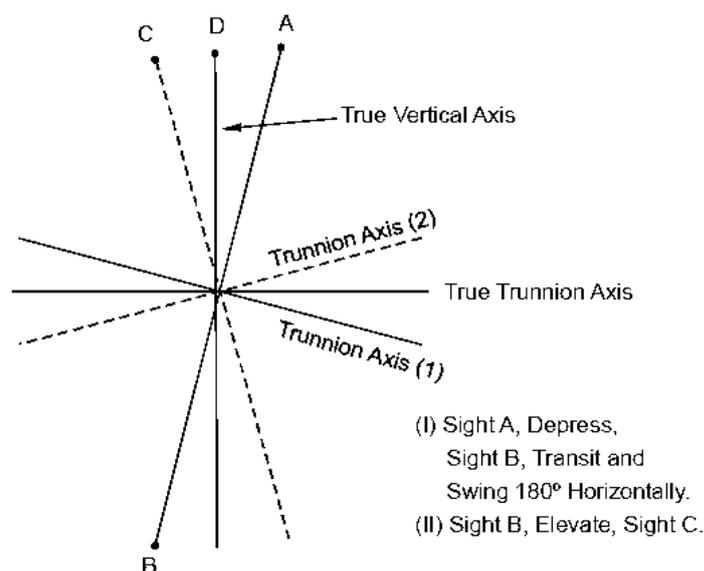


(i) Sight A (ii) Transit to Sight B (iii) Swing Through 180° Sight A (iv) Transit to Sight C
Numbers (i) to (iv) Indicate Successive Positions of Vertical Cross Hair. EP Indicates Eye Piece

Transit the theodolite and place another ranging rod *B* on the line of sight roughly at the same distance (100 m). Place a measuring staff in horizontal position on ground at right angle to line of sight at ranging rod *B*. The reading of intercept of vertical hair at *B* is recorded. Rotate the telescope by 180° and sight *A* transit the telescope sight the staff and note the intercept *C* of staff by vertical hair. Here *C* shall coincide with *B* in an adjusted theodolite. If not, following adjustments are carried out.

- (a) Compute the difference in intercept *CB*.
 - (b) Loosen the diaphragm screws and move the vertical hair laterally until staff intercept *D* is such that $CD = CB/4$.
 - (c) Repeat the process until no adjustment is required. Once all the four tests and adjustments are carried out as above, the process as described in Section 6.6.1 is iterated until no further adjustment is required in any of the above four sources of error.
- (e) **Horizontal Axis:** When vertical axis of the theodolite is truly vertical, the trunnion axis or horizontal axis of the instrument shall be truly horizontal. If this adjustment is not proper, the transit of the telescope will not trace out a vertical plane (Figure 10.5).

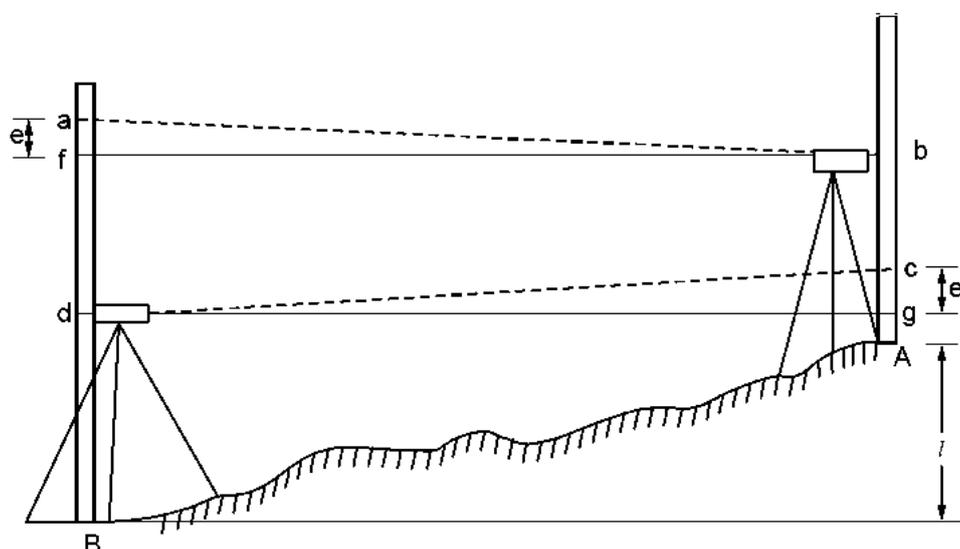
Figure 10.5 Horizontal Axis Adjustments



Set, centre and level the instrument. Sight a well defined object *A* at a sufficient elevation. Clamp horizontal motion, depress the telescope and sight a point *B* on ground close to station of instrument. Change the face of telescope and sight *B* again. Clamp the horizontal motion and elevate the telescope equal to depressing of it previously. Sight *C*, which should be same as *A*. If *A* is not bisected exactly in this position, adjustment is required. The line of sight is moved in a position midway between imaginary object *C* and object *A*. Repeat the process until *C* coincides with *A*.

- (f) **Telescope Spirit Level:** When the line of collimation of instrument is horizontal, the bubble of the spirit level; shall be central. The modern telescopes are not provided with this level, hence in most of the cases this testing and adjustment is not needed.

Figure 10.6 Spirit Level Test



A line AB is marked on ground which is nearly level. Set the instrument on AB as near to A as possible and level it. Set the vertical circle reading to zero. Read the staff held at B (say reading a). Read the staff held at A (say reading b). Setup the theodolite near B on line AB and read the staff at A (reading c) and at B (reading d). If the instrument is in adjustment, $(a - b)$ shall be equal to $(d - c)$. If not, adjustment is indicated (Figure 10.6).

- (g) **Index Error Test:** The index arm spirit level bubble should be central when the line of collimation is horizontal and vertical circle reading is zero. It may be noted here that it is not essential that adjustment of telescope spirit level and index arm spirit level shall be perfect in a real life situation. However, it is more convenient and desirable if these adjustments are correct.

The instrument is erected and leveled using horizontal plate spirit levels only. Set the vertical circle reading to zero using the clamp and tangent screws. The index arm spirit level bubble is centralized using the clip screws. Place staff nearly at 100 m from theodolite and record the reading.

Transit the telescope and set the vertical scale reading again to zero using tangent screws. Rotate the instrument 180° horizontally and re-level the horizontal plate levels using only the levelling screws. Staff reading shall be same in this setting otherwise adjust the instrument.

The telescope cross hairs are set to intersect the mean staff reading using clip screws and centralize the bubble of index arm level using the adjusting screws of this level. Repeat the adjustment until no further action is required.

Once all adjustments are carried out as detailed in Section, it may be possible that one of the adjustment above have disturbed another adjustment. It is, therefore, necessary that the entire sequence of these tests and adjustment is iterated several times until no further readjustment is warranted.

10.3.4 Personal errors

As discussed earlier, these errors occur due to carelessness or lapses on the part of surveyors. Although every effort should be made to reduce the errors of observation and measurement to minimum, errors do occur even when the most stringent precautions are taken. Hence, it is almost impossible to determine the exact measure of any quantity. Effort, therefore, shall be made to determine the sources and magnitude of these errors. The errors of observations can be subdivided into three major categories.

- **Blunders:** These occur due to wrongly counting the number of tape/chain lengths in a distance measurements, misreading or wrong recording a staff reading.
- **Systematic Errors:** These occur under the same conditions and have the similar magnitude. Mainly these are instrumental errors, e.g. length of a tape or chain. Equipment are required to be repaired and maintained at desired level of accuracy and also making allowances for them.
- **Accidental Errors:** These are beyond the control of surveyor. Errors in observation could be

- 1) Errors in manipulation like inaccurate centering, inaccurate levelling, slip or play in instruments, wrong handling of equipment etc., or
- 2) Errors in sighting and reading, e.g. inaccurate bisection of the object/signals, non-verticality of ranging rod or levelling staff etc., displacement of stations due to shifting of pegs or ranging rods, parallax, mistakes in setting and reading the vernier and mistakes due to inaccurate or wrong recording of measurements.

As pointed out earlier, these errors can be minimized by training and retraining the observers, strict adherence to prescribed procedures, checking and cross checking by other surveyors wherever possible. Taking multiple readings of the same object and repeating observations whenever possible is highly desirable, though costly and time consuming. The advantage is that these errors are as likely to be positive as negative and the law of probability can be applied to obtain the most probable value of the quantity. A detailed treatment of the theory of errors is beyond the scope of present.

10.3.5 Natural errors

Natural errors are caused by:

- (a) wind producing vibration of the instruments,
- (b) high temperature producing irregular refraction,
- (c) the sun shining on the instrument,
- (d) unequal expansion of the various parts of the instrument,
- (e) unequal settlement of the tripod, and
- (f) bad visibility.

Accurate work cannot be done in high wind or on hot sunny days. Precise work is usually done under the most favourable atmospheric conditions.

10.3.6 Temporary adjustments of theodolite

1. **Centering**: This involves setting the theodolite exactly over the station mark or on the station peg. It is done by the following steps.
 - The plumb bob is suspended from a small hook attached to the vertical axis of the theodolite.
 - The instrument is placed over the station mark with the telescope at a convenient height and with the tripod legs set well apart.
 - Two legs of the tripod are set firmly into the ground and the third leg is moved radially to bring the plumb bob exactly over the station mark. Then the third leg is also pushed into the ground.
 - If the instrument has a shifting head, the instrument is roughly centered over the station mark and then by means of the shifting head, the plumb bob is brought exactly over the station mark.

2. **Levelling:** Having centered and approximately leveled the instrument is accurately leveled with reference to the plate level by means of levelling (or foot) screws. So that the vertical axis is made truly vertical, to lead the instrument. (a) Loosen all the clamps and turn the instrument about either of its axis until the longer plate level is parallel to the pair of foot screws, the other plate level will then be parallel to the line joining the third screw and the midpoint of the line joining the first pair. (b) Bring the long bubble to the center of its run by turning both screws equally either both inwards or both outwards. (c) Similarly bring to the other bubble to the center of its run by turning third leveling screw or the other pair of leveling screws. (d) Repeat the process until finally both bubbles are exactly centered. If the vertical angles are to be measured the instrument should be levelled with reference to the altitude level fixed on the index arm. To do this,
- First level the instrument by the plate levels. Then turn the telescope. So that the altitude level is parallel to the line joining a pair of foot screws. Bring the bubble to the center of its run by means of these screws.
 - Turn the telescope through 90° and bring the bubble exactly to the mid position by the third leveling screw. Repeat until the bubble remains central in these two positions.
3. **Focussing:** This is done in two steps. 1) Focussing the eyepiece for distinct vision of the cross hairs at diaphragm. 2) Focussing the object glass for bringing the center of the object on the plane of the diagram.
- Focussing the eyepiece: Point the telescope towards the sky or hold a sheet of white paper in front of the object glass, and move the eyepiece in and out until the cross hairs are seen quite distinctly and clearly (appear sharp and black)
 - Focussing the object glass: There will be an apparent movement of the image relatively to the cross hairs when the observer moves his eyes. The apparent movement being called the parallax. To eliminate it, direct the telescope towards the object and turn the telescope towards the object and turn the focusing screw until the image appears clear and sharp.

10.4 SUMMARY

Theodolite is an instrument used to measure horizontal and vertical angles. Because of its variety of uses, such as the measurement of horizontal and vertical angles, prolonging a straight line, measurement of bearings, measurement of horizontal and vertical distances and to determine the direction of true north, it is sometimes referred to as universal instrument. Depending upon the facilities provided for reading of observations, the theodolites may be classified as simple vernier theodolite, micrometer theodolite, optical (glass arc) theodolite and electronic theodolite. A modern theodolite is compact, light in weight, simple in design and can be used roughly. All the movable parts and scales are fully enclosed and are virtually dust and moisture proof.

10.5 GLOSSARY

1. **Uses of Theodolite:** A theodolite is a precision instrument used for measuring angles both horizontally and vertically. Theodolites can rotate along their horizontal axis as well as their vertical axis. Theodolites have a lot in common with transits. A transit is a surveying instrument that also takes accurate angular measurements.
2. **Measurement of Theodolite:** A precision optical instrument for measuring angles between designated visible points in the horizontal and vertical planes.
3. **Principal of Theodolite:** The principles of the theodolite are that a beam of light travels in a straight line, and that when you know the length of one side of a triangle and the angles of the corners as measured by reflecting beams of light then you can precisely map features on the ground both horizontally and vertically.
4. **Types of Surveying:**
 - Land surveying (also known as Cadastral Surveying),
 - Engineering surveying,
 - Mining surveying,
 - Hydrographic (Bathymetric) surveying,
 - Geodetic surveying,
 - Aerial (Photogrammetry and remote sensing),
 - Topographic (Detail/Tachymetry),
 - Notes.
5. **Tools used in Surveying:** The main surveying instruments in use around the world are the theodolite, measuring tape, total station, 3D scanners, GPS/GNSS, level and rod. Most instruments screw onto a tripod when in use. Tape measures are often used for measurement of smaller distances.

10.6 ANSWER TO CHECK YOUR PROGRESS

- 1-What are Instrumental errors?
- 2-What are Natural errors?
- 3-What are Personal errors?

10.7 REFERENCES

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10.8 TERMINAL QUESTIONS

1. Describe importance of surveying and application of theodolite.
2. Enlist the sources of errors in a theodolite survey. Explain personal errors that may occur during survey.
3. Define the following terms: Line of collimation, axis of telescope, horizontal axis, bubble line, Principle focus of a lens, compound lens and magnification.

BLOCK 4 : GPS BASED RS SURVEYS APPLICATION POTENTIAL OF GPS

UNIT 11 – FUNDAMENTALS OF GLOBAL POSITIONING SYSTEM

11.1 OBJECTIVES

11.2 INTRODUCTION

11.3 FUNDAMENTALS OF GLOBAL POSITIONING SYSTEM

11.4 SUMMARY

11.5 GLOSSARY

11.6 ANSWER TO CHECK YOUR PROGRESS

11.7 REFERENCES

11.8 TERMINAL QUESTIONS

11.1 OBJECTIVES

After reading this unit you will be able to understand the following:

- Concept of Global Positioning System.
- History of GPS.
- Components of a GPS instrumentation.

11.2 INTRODUCTION

Global Positioning System (GPS) technology is a great boon to anyone who has the need to navigate either great or small distances. This wonderful navigation technology was actually first available for government use back in the late 1970s. In the past ten years or so years, it has been made available to the general public in the form of handheld receivers that use this satellite technology provided by the US government.

GPS formally known as the NAVSTAR (Navigation Satellite Timing and Ranging) Global Positioning System originally was developed for the military. Because of its popular navigation capabilities and because you can access GPS technology using small inexpensive equipment, the government mad the system available for civilian use. The USA owns GPS technology and the department of defense maintains it. The first satellite was placed in orbit on 22 February 1978, and there are currently 28 operational satellites orbiting the Earth at a height of 20,180 km on 6 different orbital planes. There orbits are inclined at 55^0 to the equator, ensuring that at least 4 satellites are in radio communication with any point on the planet. Each satellite orbits the earth in approximately 12 hours and has four atomic clocks on board. During the development of the GPS system, particular emphasis was placed on the following three aspects:

- 1- It has to provide users with the capability of determining position, speed and time, whether it motion or at rest.
- 2- It had to have a continuous, global, 3- dimensional positioning capability with a high degree of accuracy, irrespective of the weather.
- 3- It had to offer potential for civilian use.

GPS had also demonstrated a significance benefit to the civilian community who are applying GPS to a rapidly expanding number of applications. What attracts us to GPS is:

- 1- The relatively high positioning accuracies, from tens of meters down to the millimeter level.
- 2- The capability of determining velocity and time, to an accuracy commensurate with position.
- 3- The signals are available to users anywhere on the globe: in the air, on the ground, or at sea.
- 4- It is a positioning system with no user charges that simply requires the use of relatively low cost hardware.

- 5- It is an all-weather system, available 24 hours a day.
- 6- The position information is in three dimensions, that is, vertical as well as horizontal information is provided.

Using the Global Position System (GPS, a process used to establish a position at any point on the globe) the following two values can be determined anywhere on Earth:

- 1- One's exact location (longitude, latitude and height co-ordinates) accurate to within a range of 20 m to approximately 1 mm.
- 2- The precise time (Universal Time Coordinated, UTC) accurate to within a range of 60ns to approximately 5ns.

Speed and direction of travel (course) can be derived from these co-ordinates as well as the time. The coordinates and time values are determined by 28 satellites orbiting the Earth

11.3 INTRODUCTION TO GLOBAL POSITIONING SYSTEM

11.3.1 History of GPS

In 1951, Dr. Ivan Getting designed a three-dimensional, position-finding system based on time difference of arrival of radio signals. Shortly after the launch of Sputnik scientists confirmed that Doppler distortion could be used to calculate ephemerides, and, conversely, if a satellites position were know, the position of a receiver on earth could be determined. Within two years of the launch of Sputnik the first of five low-altitude "Transit" satellites for global navigation was launched. In 1967, the first of three "Timation" satellites demonstrated that highly accurate clocks could be carried in space. In parallel with these efforts, the 621B program was developing many of the characteristics of today's GPS system. In 1973 these parallel efforts were brought together into the NAVSTAR-Global Positioning System, managed by a joint program office headed by then-colonel Dr. Brad Parkinson at the United States Air Force Space and Missile Systems Organization. This office developed the GPS architecture and initiated the development of the first satellites, the worldwide control segment and ten types of user equipment. Today, it continues to sustain the system as the Global Positioning System Directorate of the Space and Missile Systems Center. All performance parameters for the system were verified during ground testing by 1978. Ten development satellites were launched successfully between 1978 and 1985 and the initial ground segment that would provide the critical uploads to the satellites was also developed. The initial constellation of 24 operational satellites was deployed between 1989 and 1994 and the system was declared "fully operational" in 1995. It has been sustained at that level or higher ever since.

Table 11.1 History of GPS

1973	Decision to develop a satellite navigation system based on the systems TRANSIT, TIMATION und 621B of the U.S. Air Force and the U.S. Navy.
1974 - 1979	System tests
1977	First receiver tests are performed even before the first satellites are stationed in the orbit. Transmitters are installed on the earth's surface called Pseudolites (Pseudo satellites)
1978 - 1985	A total of 11 Block I satellites are launched in this period.
1979	Decision to expand the GPS system. Thereupon the resources are considerably shortened and the program is restructured. At first only 18 satellites should be operated. 1988 the number of satellites is again raised to 24, as the functionality is not satisfying with only 18 satellites.
1980	Launching of the first Block I satellite carrying sensors to detect atomic explosions. This satellite is meant to control the abidance of the agreement of 1963 between the USA and the Soviet Union to refrain from any nuclear tests on the earth, submarine or in space.
1980- 1982	The financial situation of the project is critical, as the usefulness of the system is questioned again and again by the sponsors.
1983	When a civilian airplane of the Korean Airline (Flight 007) was shot down after it had gone lost over Sovjet territory, it was decided to allow the civilian use of the GPS system.
1986	The accident of the space shuttle "Challenger" means a drawback for the GPS program, as the space shuttles were supposed to transport Block II GPS satellites to their orbit. Finally the operators of the program revert to the Delta rockets intended for the transportation in the first place.
1989	The first Block II satellite was installed and activated.
1990 - 1991	Temporal deactivation of the selective availability (SA) during the Gulf

Source: (Global Positioning System (GPS), 2008)

Usage of GPS includes a whole set of functions like personal navigation, aircraft navigation, vessel navigation, offshore survey, fleet tracking, dredging control, land surveying, civil engineering, Geographical Information System (GIS) and mapping and deformation analysis (NRSC, 2015).

11.3.2 Concept of GPS

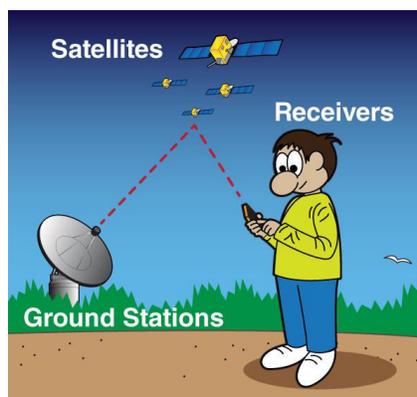
Global Positioning System (GPS) tells you where you are on earth. 5 questions are simultaneously answered on this topic GPS.

1. “Where I am?”
2. “Where I am going?”
3. “Where are you?”
4. “What’s the best way to get there?”
5. “When will I get there?”

No matter where are you, any time, any weather GPS is the only system that can show your exact position on Earth.

GPS is a system and made of three parts: satellites, ground stations, and receivers. Satellites are works like the stars in constellations—we know where they are supposed to be at any given time. Radar’s are used by ground stations to make sure that where they actually are. A receiver that you may find in your mobile, parents car or in smart watch etc is constantly catching signals from satellites. The receiver figures out how far away they are from some of them. Once the distance is calculated by receiver from four or more satellites, your exact position is known. Presto! From miles up in space your location on the ground can be determined with incredible precision! They can usually determine where you are within a few yards of your actual location. Where you are within few inches can be figure out by more high-tech receivers. The ancient sailors of history would be flabbergasted by the speed and ease of pinpointing your location today.

Figure 11.1The Global Positioning System (GPS) is made up of satellites, ground stations, and receivers.

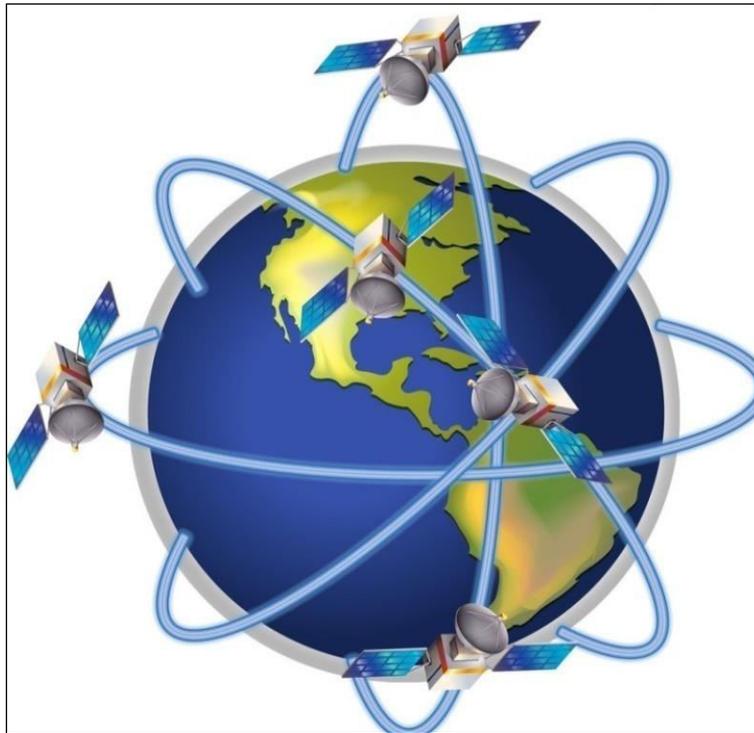


<https://spaceplace.nasa.gov/gps/en>

Generating GPS signal transit time 28 satellites inclined at 55° to the equator orbit the Earth every 11 hours and 58 minutes at a height of 20,180 km on 6 different orbital planes. Each one of these satellites has up to four atomic clocks on board. Atomic clocks are currently the most precise instruments known, losing a maximum of one second every 30,000 to 1,000,000 years. In order to make them even more accurate, they are regularly adjusted or synchronized from

various control points on Earth. Each satellite transmits its exact position and its precise on board clock time to Earth at a frequency of 1575.42 MHz these signals are transmitted at the speed of light (300,000 km/s) and therefore require approximately 67.3 ms to reach a position on the Earth's surface located directly below the satellite. The signals require a further 3.33 us for each excess kilometer of travel. If you wish to establish your position on land (or at sea or in the air), all you require is an accurate clock. By comparing the arrival time of the satellite signal with the on board clock time the moment the signal was emitted, it is possible to determine the transit time of that signal.

Figure 11.2 Global Positioning Systems



Source: blueringmedia

The working/operation of Global positioning system is based on the 'trilateration' mathematical principle. The position is determined from the distance measurements to satellites. From the figure, the four satellites are used to determine the position of the receiver on the earth. The target location is confirmed by the 4th satellite. And three satellites are used to trace the location place. A fourth satellite is used to confirm the target location of each of those space vehicles. Global positioning system consists of satellite, control station and monitor station and receiver. The GPS receiver takes the information from the satellite and uses the method of triangulation to determine a user's exact position.

11.3.3 How does GPS works

Three distinct parts make up the Global Positioning System. The first segment of the system consists of 24 satellites, orbiting 20,000 km above the Earth in 12 hour circular orbits. This means that it takes each satellite 12 hours to make a complete circle around the Earth. In order to make sure that they can be detected from anywhere on the Earth's surface, the satellites are divided into six groups of four. Each group is assigned a different path to follow. This creates six orbital planes which completely surround the Earth.

11.3.4 Basic concept of GPS receiver and its components

The main components of a GPS receiver are:-

1. Antenna with pre-amplifier
2. RF section with signal identification and signal processing
3. Micro-processor for receiver control, data sampling and data processing
4. Precision oscillator-Power supply
5. User interface, command and display panel
6. Memory, data storage

- **Antenna**

Sensitive antenna of the GPS receiver detects the electromagnetic wave signal transmitted by GPS satellites and converts the wave energy to electric current] amplifies the signal strength and sends them to receiver electronics. Types of GPS Antenna

Mono pole or dipole

Quadrifilar helix (Volute)

Spiral helix-Micro strip (patch)

Choke ring

Micro strip antennas are most frequently used because of its added advantage for airborne application, materialization of GPS receiver and easy construction. However, for geodetic needs, antennas are designed to receive both carrier frequencies L1 and L2. Also they are protected against multipath by extra ground planes or by using choke rings. A choke ring consists of strips of conductor which are concentric with the vertical axis of the antenna and connected to the ground plate which in turns reduces the multipath effect.

- **RF Section with Signal Identification and Processing**

The incoming GPS signals are down converted to a lower frequency in the RS section and processed within one or more channels. Receiver channel is the primary electronic unit of a GPS receiver. A receiver may have one or more channels. In the parallel channel concept each channel is continuously tracking one particular satellite. A minimum of four parallel channels is required to determine position and time. Modern receivers contain up to 12channels for each frequency.

In the sequencing channel concept the channel switches from satellite to satellite at regular interval. A single channel receiver takes at least four times of 30 seconds to establish first position fix, though some receiver types have a dedicated channel for reading the data signal. Now days in most of the cases fast sequencing channels with a switching rate of about one-second per satellite are used.

In multiplexing channel, sequencing at a very high speed between different satellites is achieved using one or both frequencies. The switching rate is synchronous with the navigation message of 50 bps or 20 milliseconds per bit. A complete sequence with four satellites is completed by 20 millisecond or after 40 millisecond for dual frequency receivers. The navigation message is continuous; hence first fix is achieved after about 30 seconds. Though continuous tracking parallel channels are cheap and give good overall performance, GPS receivers based on multiplexing technology will soon be available at a cheaper price due to electronic boom.

- **Microprocessor**

To control the operation of a GPS receiver, a microprocessor is essential for acquiring the signals, processing of the signal and the decoding of the broadcast message. Additional capabilities of computation of on-line position and velocity, conversion into a given local datum or the determination of waypoint information are also required. In future more and more user relevant software will be resident on miniaturized memory chips.

- **Precision Oscillator**

A reference frequency in the receiver is generated by the precision oscillator. Normally, less expensive, low performance quartz oscillator is used in receivers since the precise clock information is obtained from the GPS satellites and the user clock error can be eliminated through double differencing technique when all participating receivers observe at exactly the same epoch. For navigation with two or three satellites only an external high precision oscillator is used.

- **Power Supply**

First generation GPS receivers consumed very high power, but modern receivers are designed to consume as little energy as possible. Most receivers have an internal rechargeable Nickel-Cadmium battery in addition to an external power input. Caution of low battery signal prompts the user to ensure adequate arrangement of power supply.

- **Memory Capacity**

For post processing purposes all data have to be stored on internal or external memory devices. Post processing is essential for multi station techniques applicable to geodetic and surveying problems. GPS observation for pseudo ranges, phase data, time and navigation message data have to be recorded. Based on sampling rate, it amount to about 1.5 Mbytes of

data per hour for six satellites and 1 second data for dual frequency receivers. Modern receivers have internal memories of 5 Mbytes or more. Some receivers store the data on magnetic tape or on a floppy disk or hard-disk using external microcomputer connected through RS-232 port.

Most modern receivers have a keypad and a display for communication between the user and the receivers. The keypad is used to enter commands, external data like station number or antenna height or to select a menu operation. The display indicates computed coordinates, visible satellites, data quality indices and other suitable information. Current operation software packages are menu driven and very user friendly.

11.4 SUMMARY

In this unit we have discussed the concept and technology of Global Positioning System. The key components essential for a global positioning system to function has also been discussed. We also learned about how does GPS works?

11.5 GLOSSARY

- GPS- Global Positioning System
- Signal- Information conveyed via an electric current or electromagnetic wave.
- Receivers- A device or apparatus that receives electrical signals, waves.

11.6 ANSWER TO CHECK YOUR PROGRESS

1. Why do we need a GPS?
2. Explain components of GPS.

11.7 REFERENCES

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- 2-<https://spaceplace.nasa.gov/gps/en/>
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- 5-https://www.aiaa.org/docs/default-source/uploadedfiles/about-aiaa/press-room/videos/iaf-60th-6-anniv-gps-nomination.pdf?sfvrsn=9bc64bfa_0
- 7-https://www.globalguideline.com/interview_questions/Answer.php?a=How Does GPS Work

11.8 TERMINAL QUESTIONS

- 1-How does GPS works?
- 2-How many satellites are needed by a GPS in a 3D space?
- 3-Explain basic concepts of GPS receiver and its components.

UNIT 12 - COMPONENTS / SEGMENTS OF GLOBAL POSITIONING SYSTEM

12.1 OBJECTIVES

12.2 INTRODUCTION

12.3 COMPONENTS / SEGMENTS OF GLOBAL POSITIONING SYSTEM

12.4 SUMMARY

12.5 GLOSSARY

12.6 ANSWER TO CHECK YOUR PROGRESS

12.7 REFERENCES

12.8 TERMINAL QUESTIONS

12.1 OBJECTIVES

By the end of this unit you will be able to understand the following:

- Components of Global Positioning System.
- Different applications of GPS.

12.2 INTRODUCTION

The Navstar Global Positioning System (GPS) is a satellite based all weather-space based navigation system that provides instantaneous position, time and velocity information of any object anywhere on earth in a common reference system. This service of navigation is being owned by United States and controlled by U.S. Department of Defense (DoD) with management performed by US Air force and guidance from the DoD positioning/Navigation executive committee. The primary purpose of introducing GPS was to utilize it for Military ones but later the US congress directed DoD to promote it for civil use. Since then GPS is now being used in day today navigation.

GPS basically uses pseudo ranges derived from broadcast satellite signal. These ranges are derived from either from measuring the travel time of the signal and by multiplying it by its velocity or by measuring the phase of the signal. In both the cases clock of the satellites are fully employed.

GPS is a utility awaiting application that provides position accuracies from 100 meters to 5 to 10 meters. In order to attain higher accuracies, a set of greater infrastructure with much greater cost is required, which may provide accuracy up to sub meter or a meter and at times sub- centimeter. The accuracy of GPS depends on how GPS satellites broadcast their signals in space with certain accuracy, but what we receive depends on additional factors, including satellite geometry, signal blockage by obstacles like high raised buildings and mountains, atmospheric conditions, and receiver design features/quality (US, 2015).

Usage of GPS includes a whole set of functions like personal navigation, aircraft navigation, vessel navigation, offshore survey, fleet tracking, dredging control, land surveying, civil engineering, Geographical Information System (GIS) and mapping and deformation analysis (NRSC, 2015).

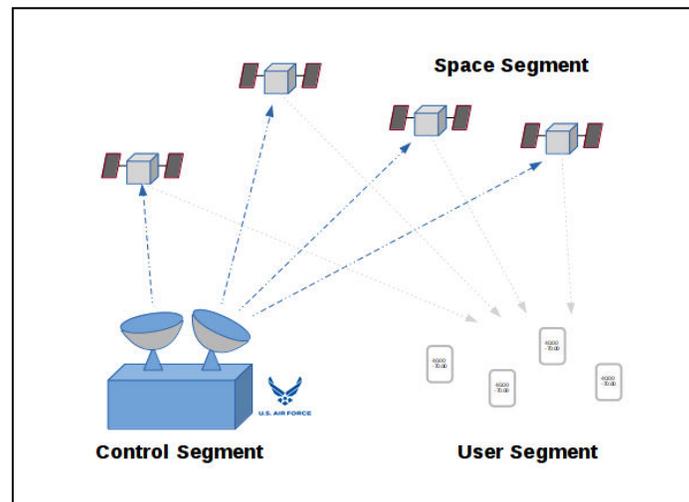
12.3 COMPONENTS / SEGMENTS OF GLOBAL POSITIONING SYSTEM

There are three main components of GPS. They play a very important role in the functioning of the GPS

1. The control segment
2. The user segment

3. The space segment

Figure 12.1 Segments of GPS



Source: (Minn, 2000)

12.3.1 The Control Segment

The control segment comprises of five monitoring ground stations located at Falcon Air Force base, Colorado Springs, Hawaii, Ascension Island, Diego Garcia and Kwajalein. These stations act as the major controller of the satellite signals every time the satellite passes overhead them. Here the pseudo-ranges are tracked using the ionosphere and meteorological data. They measure the distance in every 1.5 second whenever the satellites passes overhead. The main task of the ground station is to track the satellites for orbit and clock determination and prediction modeling, time synchronization of the satellite, and upload of the data message of the satellite (Bernhard Hofmann-Wellenho et al, 1992). Apart from this there are three uplink stations (collocated at the Ascension Island, Diego Garcia and Kwajalein monitor stations) where the information is returned and transmitted to the satellite.

12.3.2 The Space Segment

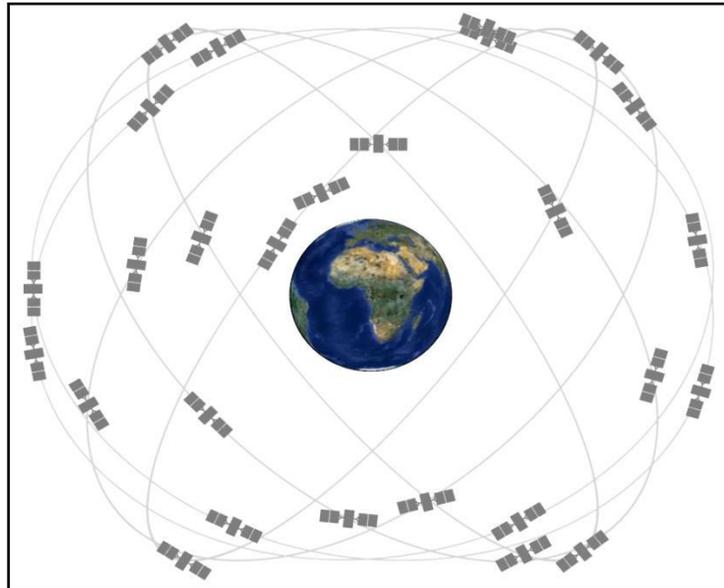
The space segment of Global Positioning system consists of a constellation of 24 satellites each weighing more than 850 kilograms. They are placed in such a manner that there are 4 satellites in each orbit. There are 6 orbits altogether with an altitude of 20,185 kilometers from the surface of the earth. Out of all the 24 satellites, only 21 are functional and the remaining 3 are kept as active spares only if any of the satellites among the 21 becomes dysfunctional.

The following are the specifications of GPS Constellation:

- 24 satellites with a minimum of 21 operation 98% of the time
- 6 orbital planes
- 55 degrees of inclination

- 20,200 km above the earth surface
- 11 hours, 58 minutes of orbital period
- Visible for approximately 5 hours above the horizon

Figure 12.2 Constellation of active GPS satellite



Source: <https://www.gps.gov/systems/gps/space/>

12.3.3 The User Segment

The navigating receiver or system can be called user segment. For instance, any vehicle carrying the GPS receiver to compute its position and velocity at a given point of time from the satellite information with respect to their position, time of transmission of message between the satellite and the receiver (Panda, 2016). A receiver is often described by its number of channels, signifying how many satellites it can monitor simultaneously. Originally it is limited to four or five channels, but it has typically increased over years 2007. Now, the receivers can have between 12 and 20 channels.

There are basically two types of services available to a GPS user- the SPS and the PPS.

SPS- Standard Positioning Service is the positioning accuracy that is provided by GPS measurements based on the single L1 frequency C/A code.

PPS- Prescribe Positioning Service is the highest level of dynamic positioning accuracy that is provided by the GPS measurements based on the dual frequency P-code. A user segment may also include a surveyor using instruments installed with GPS receivers in order to compute latitude, longitude, altitude and the survey time.

Figure 12.3 GPS Receiver used for Navigation

Source: <https://www.presco.in/gps-device.html>

12.4 SUMMARY

GPS is a fantastic tool of the 21st century offering many functions. However, received information is not always reliable, and it would have been interesting to see in which cases it is not. Furthermore, the space segment is completely controlled by the American Army which enables them to completely remove the satellite cover in certain countries in the event of a war. In order to avoid the absence of navigation during the war scenario many countries have launched their own navigation system. India in 2013 launched Indian Regional Navigation Satellite System (IRNSS). The operational name for this navigation system is Navik. The satellite system in this covers the entire country and area extending 1500 kilometers around it. Similarly, GLONASS a navigation system administered by Russia was first launched in 1982, second in the world providing global coverage.

The future of GPS appears to be virtually unlimited; technological fantasies abound. The system provides a novel, unique, and instantly available address for every square yard on the surface of the planet—a new international standard for locations and distances. To the computers of the world, at least, our locations may be defined not by a street address, a city, and a state, but by a longitude and latitude.

12.5 GLOSSARY

1. **Navigation** - The process or activity of accurately ascertaining one's position and planning and following a route.
2. **Pseudo ranges** - The pseudorange is an approximation of the distance between a satellite and a GNSS receiver.
3. **Constellation** - A group of stars forming a recognizable pattern that is traditionally named after its apparent form or identified with a mythological figure.

12.6 ANSWER TO CHECK YOUR PROGRESS

1. What is GPS?
2. Name three components of GPS.
3. Write Specifications of Space Segment.

12.7 REFERENCES

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12.8 TERMINAL QUESTIONS

1. Write a short note on GPS.
2. Name all the segments of GPS and their specifications.

UNIT 13 - COORDINATE SYSTEM

13.1 OBJECTIVES

13.2 INTRODUCTION

13.3 COORDINATE SYSTEM

13.4 SUMMARY

13.5 GLOSSARY

13.6 ANSWER TO CHECK YOUR PROGRESS

13.7 REFERENCES

13.8 TERMINAL QUESTIONS

13.1 OBJECTIVES

By the end of this unit you will be able to:

- Understand about the need of coordinate system.
- Explain various coordinate systems used for marking or reading position of a given location on the surface of earth.

13.2 INTRODUCTION

A system used to identify the position of a point in a given space with reference to the origin is called as the coordinate system. Most of the coordinate systems use one, two or three numbers to represent the distance between the point and a fixed reference point called as “origin”. The numbers used to present the position are referred as the “coordinates” and the system is known as coordinate system. We are much familiar with the widely used Cartesian coordinate system used to represent position of a point in a two dimensional space which can be represented by putting two measuring scales perpendicular to each other where the starting points (zero) of each scale meets (Figure 13.1). The meeting points of zero of both the measuring scales is used as reference point and noted as origin (marked as 0, 0). All other space with reference to this origin are presented by measuring distance towards right (shown by positive sign) or left (shown by negative sign) and upward (shown by positive sign) or downward (shown by negative sign). However, this type of coordinate system is not well suited to represent a position on the curved surface of the Earth. We are going to understand in this module about various coordinate systems that could be used to represent the position of a point, line or any feature on the surface of earth.

13.3 COORDINATE SYSTEM

As we have understood that a coordinate system is a system used for referring position of a point in a given space. The most frequently used and the simplest system for referring position in a two dimensional space is by using a Cartesian coordinate system (Figure 13.1). However, this is well suited for two linear measurements and not appropriate for locating position on the curved surface. As we know that earth forms a curved surface and there for locating a position on the earth we need to use spherical coordinate system that uses two curved measurement scales with reference to the center of the earth (considered as origin) named as the **latitude** and the **longitude**. This kind of coordinate system when referring position on the earth surface by using latitude and longitude is called as the **geographic coordinate system (GCS)** (Figure 13.2). However, the position on the surface of earth can be represented by other coordinate systems also. There are more than hundreds of other coordinate systems used around the world to locate position on the surface of earth such as: 1. Cartesian coordinate system, 2. Cylindrical coordinate system, 3. Spherical coordinate system, 4. Parabolic cylindrical coordinate system, 5. Conical coordinate system, 6. Prolatespheroidal coordinate system, 7. Oblate spheroidal coordinate System, 8. Ellipsoidal coordinate system.

It was during the seventeenth century, when Rene Descartes, a French mathematician introduced method to describe position of a point in a plane and to honour him this system was named after him as the Cartesian system. Descartes introduced the idea of placing two lines perpendicular to each other on a plane for locating a point with reference to these two lines (Fig. 13.1). One line is the horizontal line referred as the “x” axis and the second vertical line perpendicular to x axis is referred as the “y” axis. The lines intersecting each other are referred as the origin (0, 0) and all the locations of the plane are marked with reference to this origin. Any position on the right side and above the origin is referred as positive x and positive y value, respectively; whereas, any position left to the origin and below the origin is referred to as negative x and negative y value, respectively (Fig. 13.1). The axes (x and y) divide the plane into four parts called as the Quadrants (one fourth parts) and are numbered as I, II, III and IV in anticlockwise direction from OX (Fig. 13.1). In this system, the plane is referred as the Cartesian or Coordinate plane and the lines are referred as coordinate axes (singular is axis). The distance of a point from y axis is called as the **abscissa** (or x coordinate) and the distance of a point from x axis is called as the **ordinate** (or y axis). Thus, we can see that the position of a point “P” in figure 13.1 can be denoted easily as 4, 4. We will now learn one by one the most widely used coordinate systems.

Consider the position of point “P” presented in figure 13.1 for locating a point in a plane. The position can be represented either as x,y or the r,θ, considering the origin at point 0,0 (O). Here the point “O” is the reference for both the coordinate system and we can see that the point “P” can be marked without changing the reference point. Similarly, while representing the position of a point on the surface of the earth, it can be presented in more than one way and with different coordinate systems. In all of these coordinate systems the reference points may or may not be the same. However, we can always change one reference system into another where the reference used is called as the “**Datum**”. The process of converting one datum into another is referred as the “**transformation**”. A datum acts as a reference for representing other quantities. A datum may represent any numerical or geometric quantity and this could be horizontal or vertical. A given datum is based on a specific spheroid. For the GCS the center of the earth is referred as the origin and the positions on the surface of earth are marked with reference to this. The moment we say center of the earth; it comes to our mind where the center of the earth is? With different consideration and assumptions center of earth may be considered at different position and thus different datum. Now suppose the reference is made considering earth as a sphere, the system is referred to as the spherical coordinate system and when the earth is considered as an ellipsoid the Ellipsoidal coordinate system and so on. But, the question arises what is the exact shape of the earth and which is the reference point of origin (i.e. the center of the earth)? And which coordinate system to be used for referring a position on the surface of the earth? This requires understanding of the different coordinate system used worldwide. We will discuss this in this unit with reference to the most widely used coordinate systems.

In general, a complete representation of a coordinate system for locating position of a point on the earth will primarily require three information, viz., 1. The location of the origin 2. The projection used to represent earth (a three dimensional feature) on a flat piece of paper (a two dimensional object), and 3. The units used for measuring distance from the origin. Here, we see a new term “**Projection**”. Projection is the scientific way of representing three dimensional features on two dimensional planes. Here, the earth is a three dimensional feature while we generally use a flat piece of paper (or a map) to place earth surface over it. The surface may be the administrative units (e.g. countries, states, districts, villages, etc.) or its cover (e.g. forest, grassland, agriculture, water, bare land, etc.). Here, the paper used is a two dimensional space. So, the concept of projection has evolved for representing any three dimensional representations on a two dimensional surface. The detail discussion on projection will follow in section 13.3.2.

Figure 13.1 Cartesian coordinate system

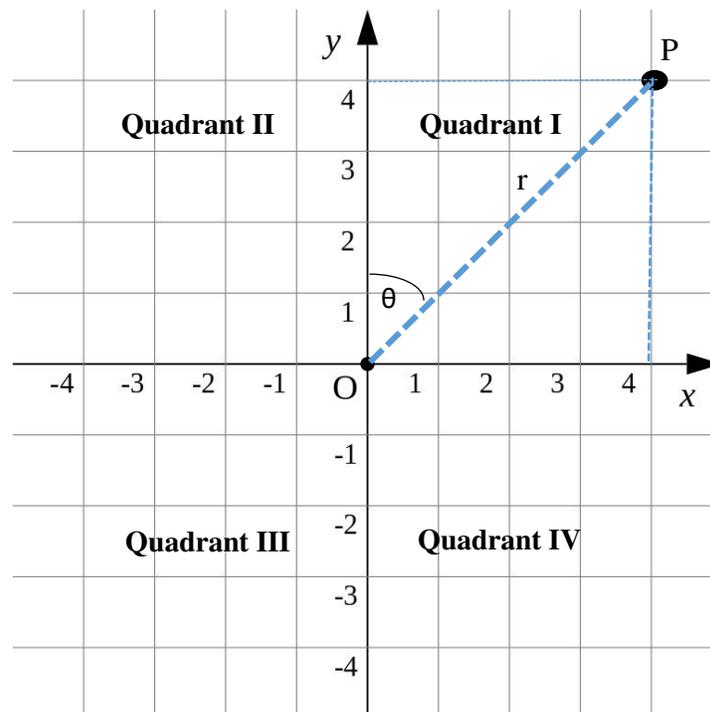
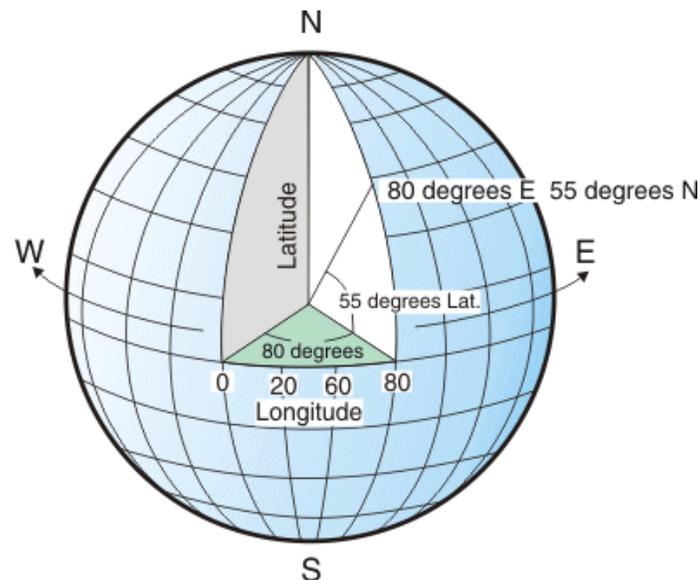


Figure 13.2 Geographic coordinate system

In geographic information system (GIS), we use two broader categories of coordinate systems. The first one that uses three dimensional spherical earth surfaces to locate position of a point while the second one uses just two dimensional space with some projection system. Thus, in majority of the GIS software the coordinate system is categorized into two groups as: 1. Geographic coordinate system (GCS), and 2. Projected coordinate system. In the GCS we will simply need information of parameters to represent shape and the reference point (origin) of the earth while the projected system will need additional parameters of projections.

13.3.1 Geographic coordinate system (GCS)

For referring the position of a point on the surface of the earth the foremost requirement is to consider the shape and size of the earth which decided the reference point of measurement i.e. the datum. In GCS, we primarily need to define a datum, the angular unit of measurement latitude and longitude and the prime meridian. The latitude and the longitude are the angular measurement of a point on the surface of the earth from the center of the earth (origin) measured in degree. Latitude is the angle made in north or south direction from the equatorial plane denoted by " ϕ " (*phi*) and the longitude is the angle made in east or west direction from the Greenwich meridian denoted by " λ " (*lambda*). The GCS uses spherical or the ellipsoidal coordinate system in which the earth is divided into set of north-south and east-west lines. The north-south lines are the lines joining north and south poles and are lines of equal longitude also called as "*meridians*", whereas, the east-west lines are the parallel lines on the upper and lower side of the equator having equal latitude and referred as "*parallels*". These lines of latitude and longitude encompassing each other forming a network of grids referred as "*graticules*". The equator is the central line between the north and South Pole that divides the earth into two

hemispheres. The upper one – northern and the lower one - southern hemisphere. The line of equator is the zero-degree latitude. Whereas, the Greenwich line (prime meridian) is referred as the line of zero-degree longitude. For most of the GCS the prime meridian line is the line that passes through Greenwich, England referred as Greenwich meridian. The equator is the largest and the only latitude which is as large as the meridian. Because, as we move upward or downward from the equator, the size of the circle reduces on a spherical representation of earth and finally converges into a single point at north ($+90^\circ$) and south pole (-90°). Therefore, the equator together with all the meridians are also referred as the *great circles*.

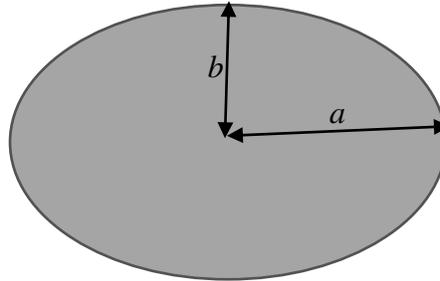
The origin of the graticules (0,0) is the intersection point of equator and prime meridian thus any point above equator (toward north pole) and to the right of the prime meridian (towards east of prime meridian) is assigned a positive value while the points located below equator (towards south pole) and left of the prime meridian (towards west of prime meridian) is assigned a negative value with their corresponding degree. Thus we can see that the latitudes measured with reference to the equator ranges between $+90^\circ$ at the North Pole and -90° at the South Pole. The values of latitude are accordingly suffixed with “N” (e.g. 60°N) to represent a position towards north of the equator and S (e.g. 60°S) to represent position towards south of the equator. Similarly, a position eastwards of the prime meridian is suffixed by “E” (e.g. 78°E) and the position westward of prime meridian is suffixed by “W” (e.g. 110°W). The values of the longitude vary between -180° in west to $+180^\circ$ in east. India lies on the eastern side of the prime meridian and above the equator, hence all the longitude carry positive values suffixed by “E” whereas its latitudes are denoted with positive sign suffixed by “N”. Thus, if someone wishes to mark a location of point on surface of the earth it could be done by using latitude and the longitude, however if we need to represent elevation we will need a third dimension.

The representation of latitude and longitude as degree can also be done by separating degrees into minutes and seconds. Where, one degree has 60 minutes and one minute has 60 seconds. The representation is much often done as degree decimal (DD) for showing values only as degree up to a given decimal point; or as degree minute (DM) showing values in degree and decimal part of the degree as its corresponding minute value; or the degree minute second (DMS) where the values are denoted into degree, minute and seconds. For example, 60.5 (DD) can be written either as 60 degree 30 minutes (DM) (as 0.5 degree = 30 minutes) or as 60 degrees, 30 minutes and 0 seconds (DMS).

The shape of the Earth is approximation of a sphere with radius 6371 km for which a three dimensional spherical coordinates could be used that relates to the spherical shape of the Earth. Thus, in a spherical coordinate system the consideration of the shape and size of the earth is important. While considering earth as a spheroid, the two important parameters are; 1. The *semi-major axis* (a), and 2. The *semi-minor axis* (b) (Figure 13.3). a is the distance between the center

of the spheroid and the equator whereas b is the distance between the center of the spheroid and the poles of the spheroid (i.e. north or South Pole).

Figure 13.3 Semi-major (a) and semi-minor (b) axis of a spheroid



With the help of axis related parameters (a and b), other parameters could be derived which are usually used while defining a spheroid. The other parameters are:

- *Flattening* (f) = $\frac{(a-b)}{a} = 1/298$
- *Eccentricity* (e^2) = $\frac{a^2 - b^2}{a^2}$

These parameters are in a way related to each other and could be expressed as:

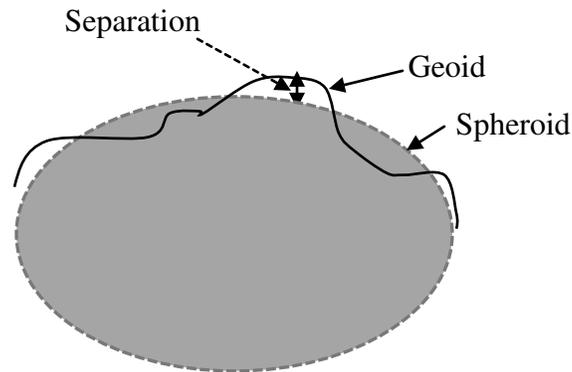
$$e^2 = 2f - f^2$$

$1 - f = \sqrt{1 - e^2} = \frac{b}{a}$, thus, we can see that a spheroid could be defined by any of the two parameters such as a and b , a and e , or a and f as these are related to each other as explained above. A coordinate system defined with respect to this spherical parameters of the earth in the form of latitude, longitude and height is often referred as “Geodetic coordinates”. This geodetic coordinate system is the basis of all mapping systems. The distinction between the spherical coordinate system and the spheroidal coordinate system is based on the consideration which we make for the shape and size of the earth and the parameters defining the shape and size. In the mapping system generally we refer Geographic coordinate system with reference to the spheroidal model of the earth defined by latitude and longitude.

As of now we have learnt that the spheroid is a good approximation of the earth’s shape, however, this is not an exact representation. The shape of the earth is decided by its surface which is perpendicular to the direction of the gravity defined as the “equipotential surface”. As the force and direction of the gravity is bound to vary due to the variation in the density of the material of the earth, therefore this equipotential surface tends to be irregular. The true shape of the earth is called as the “geoid” and this represents the equipotential surface that corresponds most closely to the mean sea level. For general purpose usually the geoid and the mean surface level are considered to be synonymous although both differ. The spheroid is approximation of

the geoid and they vary across the earth. The height of the geoid above spheroid surface is referred as “separation” and this could be positive or negative (Figure 13.4). An exclusive branch of science where people study about the shape, size, gravitational and magnetic field of the earth is called as the “geodesy.

Figure 13.4 Representation of a geoid and spheroid surface, and separation



13.3.2 Projected coordinate system (PCS)

The term projection is referred for the representation of a three dimensional object (e.g. earth) over a flat two dimensional space (e.g. piece of paper, map, computer screen). Thus, a map, which is two dimensional representations of a three dimensional earth surface, involves projection system for the representation of earth surface. The earth surface is curved while we represent them over a flat piece of paper as a map. We can see that if we wish to transform spherical maps (that better represents the earth) over a flat paper there would obviously be distortion in the actual shape, area, distance or direction. Consider the example of peeling off of the orange cover and trying to spread the cover over a flat surface there would be distortion in the shape. However, if we are interested in preserving the shape or area of a specific part for relatively small portion, it could be done. Likewise, while representing earth’s surface over a flat piece of paper we are often interested in preserving the actual shape or area of a country (or any other administrative unit like state, district, village etc.) thus we may need a projection system that better preserves the shape, size or other spatial variables of our interest. Thus all of the projection systems differ when we wish to preserve any spatial variations. Some may be accurate for just selective spatial variation and accordingly we select the projection system. All of the projection systems have their own advantages and disadvantages. There is no any single projection system that can maintain all of the spatial variation of shape, area, distance, direction, etc.

Projections are one of the spatial configuration or the mathematical transformation used for fitting a part of the earth (i.e. a three dimensional surface) onto a flat view (i.e. a two dimensional

surface). To understand projection, simply imagine a bulb placed inside a globe and consider that the globe surface is semi-transparent, now imagine about the surface features being projected over a flat surface near the globe is a type of projection (Figure 13.4). Based upon the type of surface upon which you are considering the light to fall, the projection can broadly be grouped into cylindrical, conical or the planar projection (Figure 13.5 – 13.7). While making a flat map using projection it involves progressive steps of considering earth as geoid, geoid as ellipsoid, ellipsoid as reference sphere, and reference sphere to plane.

Figure 13.5 A representation of projection over a flat plane surface

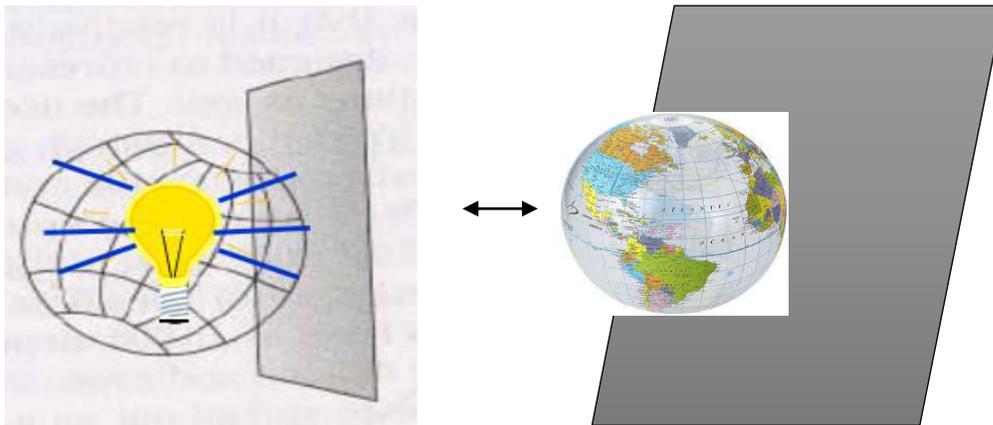


Figure 13.5 A representation of cylindrical projection

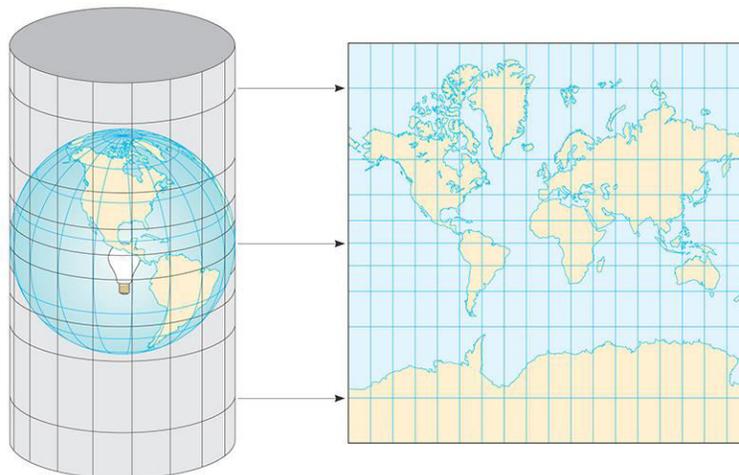
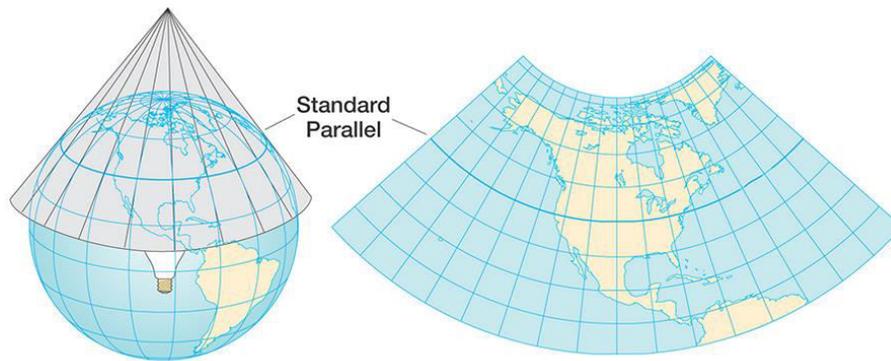
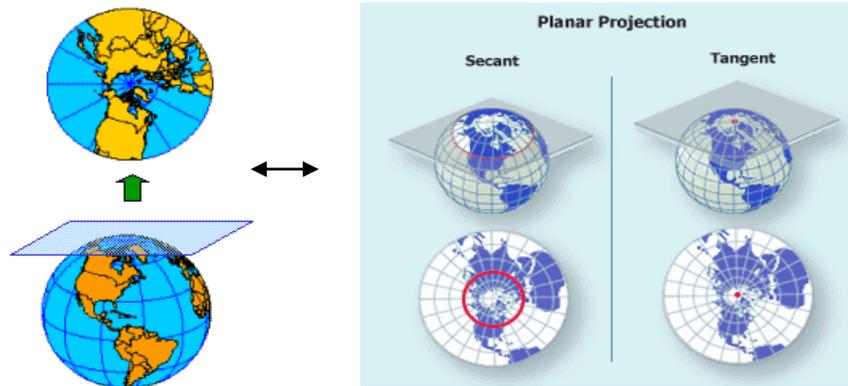
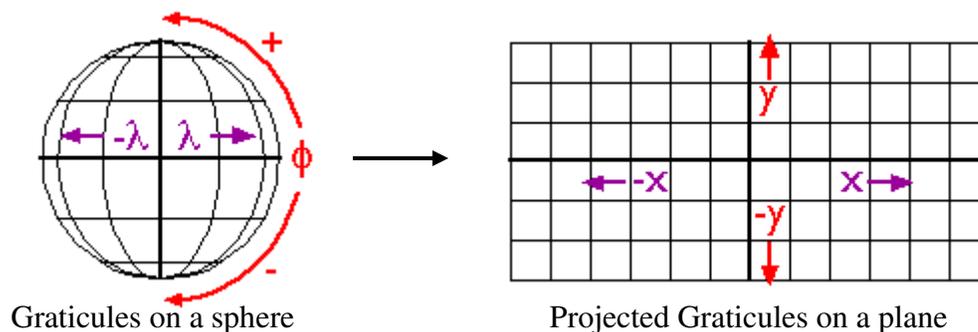


Figure 13.6: A representation of conical projection**Figure 13.7:** A representation of planar projection (<http://geokov.com/education/map-projection.aspx>)

Conversion of geographical coordinate system into a projected coordinate system is done by mathematical transformation which is dependent upon the parameters that defines the shape, size and datum of the earth. A simplified representation of transformation from GCS to PCS is shown in Figure 13.8

Figure 13.8 Transformation from a geographical to a projected coordinated system

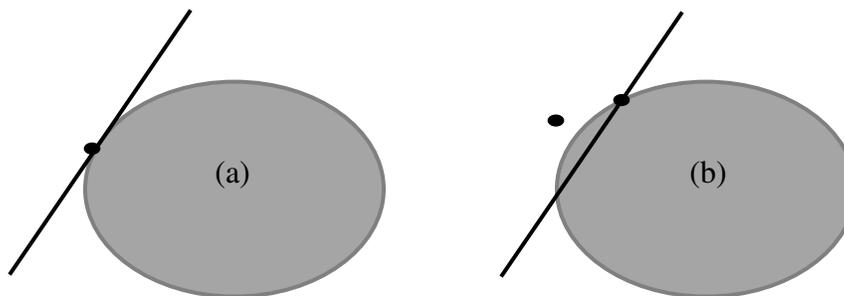
Map projections are usually categorized on the basis of either of the followings:

- i. Class (cylindrical, conical or azimuthal),
- ii. Points of contact (tangent or secant),
- iii. Aspect (normal, transverse or oblique), and
- iv. Distortion property (equivalent, equidistant or conformal).

On the basis of class which takes into account the type of surface being considered for the projection we have already seen the three classes, viz., cylindrical, conical and planar or azimuthal projection. Projections onto the mapping plane is also referred as the azimuthal or zenithal map projection.

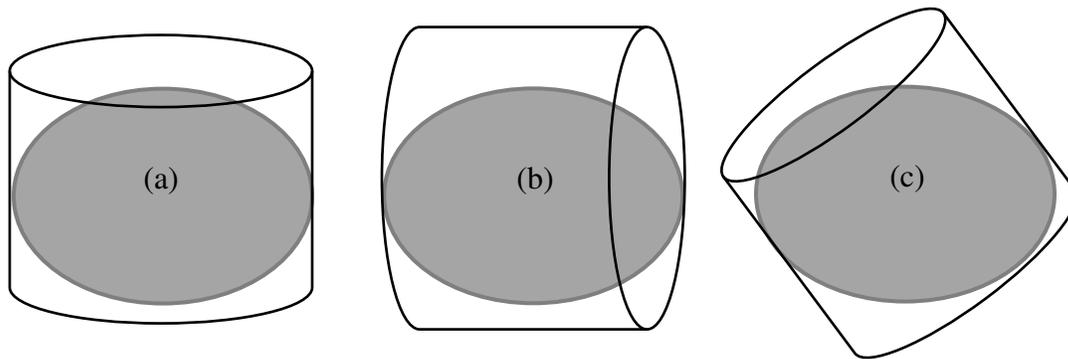
On the basis of whether the lines of projection are tangent or the secant the projection could be tangent or the secant. A tangent is a line when it touches at only one point of the circle while a secant is the lines that touch at two points of the circle (Figure 13.9). The points where the line touches the sphere is the location where is no distortion while as we move away from these points distortion tends to increase. At the points of contacts, the features represented in a map are the actual representation of the features without having any distortion in its shape, size, direction, distance or the scale. So we can see that all of the three classes of cylindrical, conical and azimuthal/planar projections could be using either of the type of tangent or the secant lines and accordingly they could be tangent or secant projections.

Figure 13.9 Projection on the basis of point of contacts of line; (a) tangent, and (2) secant



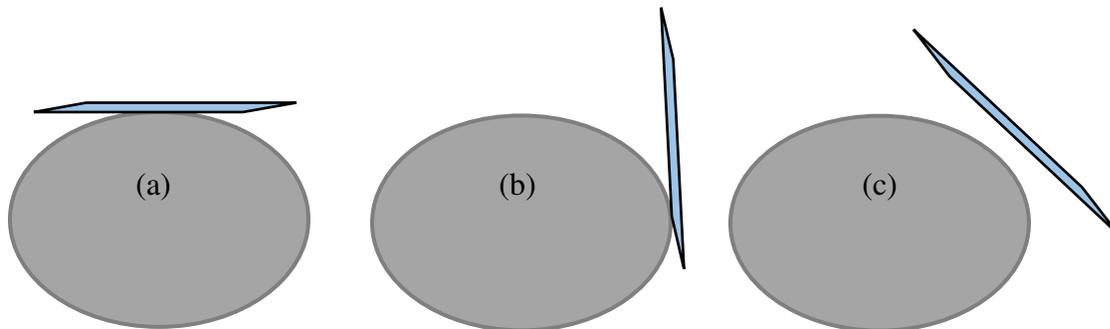
Now moving to the next categorization on the basis of aspect the projection could be normal, transverse or the oblique. To understand this, first consider if a globe is placed before you how in different ways you could look on the globe. It can be viewed in either of the ways like viewing straightly to it or viewing it from side or viewing with some viewing angles or viewing it from the top. All of these points of viewing are referred to as “aspect”, accordingly the projections could be grouped as normal, transverse or the oblique, depending on the aspect (Figure 13.10).

Figure 13.10 Projection on the basis of aspect; (a) normal, (b) transverse, and (c) oblique



Similarly, on the basis of the projection planes touching at poles, equator or any other lines the projections could be grouped as polar, equatorial or simply oblique (Figure 7.11).

Figure 13.11 Projection on the basis of planes touching the part of earth; (a) polar, (b) equatorial, and (c) oblique



While considering any projection system for its use one should be aware about the limitations of the projection. It depends upon the type of uses and the kind of distortion one is ready to accept. For example, few projections may preserve shape but there would be distortion in the size while the other projection may preserve the size but not the shape. So, while selecting any projection system the key selection criteria is the consideration of factors (shape, size, direction, distance or scale) which we wish to present most accurately in a map. While using various spatial layers in a GIS environment one should be using one common projection system for all the layers to accurately present the location at same point in all of the layers. In some GIS software by default it transforms all the GIS layers into one common projection system, for the visualization purpose. Now can you think what will happen if all the layers are not shown in the same projection system? The location of a point which you are investigating will be shown at different

location on the computer screen if all the layers are having different projections in spite of the fact that the location in each of the respective layers is shown accurately.

As a general rule of thumb one may consider following points:

- Distortion of the area, shape, direction, etc. will be more as we move away from the origin of the projection towards the edges.
- For tropical areas use of cylindrical projections is better for preserving the distortion
- For temperate regions one may select conic projections
- For polar region one should be using azimuthal (also known as planar) projections

Some of the important map projections used widely:

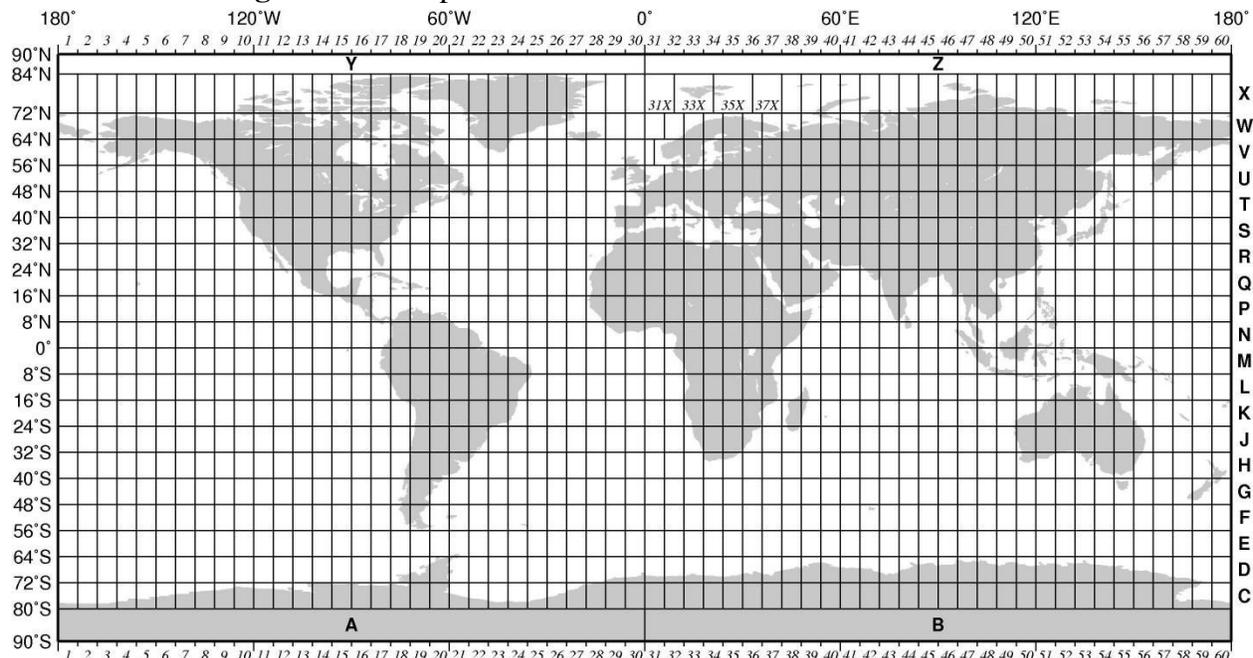
- **Mercator projection**
- **Universal transverse Mercator – UTM**
- **Lambert conformal conic (LCC)**

Mercator Projection: It is a type of cylindrical projection in which spacing of the parallels increases slowly towards the poles. Scale towards the north-south and east-west direction increases with a same rate. So, the scale around any point in both the directions is same. In this projection the latitudes and the longitudes crosses at a right angle and the shape of the area within a grid is preserved up to great extent although the area is not preserved. It's a type of conformal projection in which the local shape is preserved.

Universal transverse Mercator (UTM): It is one of the kinds of Mercator projection where the projection is made using transversely placed cylinder over the globe whereas the Mercator uses upright cylinder. So we can say UTM is a class of cylindrical transverse Mercator projection. In UTM, the entire globe is divided into 60 parts (i.e. zones) thus one zone has an east-west extent of 6° . As the globe represents a total 360° and if you divide this into 60 parts the one part will have 6° . Consider the globe as an orange and peel off the orange equally into 60 parts and place them by flattening each part on a plane surface what one part will represent is the UTM zone. In UTM projection, each of the 60 zones is projected onto a plane separately, this minimizes scale distortion within each zone. The longitude/meridian at the center of each zone is called the central meridian. UTM zones are numbered from 1 to 60 starting from 180° west longitudes of the GMT/international date line and the numbering increases towards east. Thus suppose in India if a place is located at 78°E , it means that it falls after the 30 zones in the western side of the GMT and then the 13th zone at the east side of the GMT ($78^\circ/6^\circ = 13$), making 43rd zone (i.e. 30 zone in west of GMT + 13 zones in east of GMT). The Polar Regions are excluded in UTM. The places lying at position higher than 84° North and 80° south are excluded from the UTM. The numbering of the zones starts from C which is for the 72° - 80° south zone and is marked as C-X omitting the use of O. The north-south extent of the UTM zones is limited between 80° south to 84° North. The division along north-south direction is at 8° except for the zone X which is of 12° .

This makes a total 20 latitude bands along north-south direction (Figure 13.12). The coordinates in UTM are expressed in “m” for the 60 zones and 20 latitude bands.

Figure 13.12 Representation of UTM zones and latitude bands.



One of the most widely coordinate system is WGS84 where the projection is based on considering earth as an ellipsoid with consideration of parameters defined by ellipsoid WGS84. This projection is based on ellipsoid WGS84, which defines the coordinate system that is also called WGS 84. The global positioning system (GPS) uses WGS84 coordinate system.

After understanding the coordinate systems and the projections, different types of projection, now let us discuss some important terms associated with the cartography such as scale factor, datum, transformation of the datum, important parameters of datum transformation, Indian map series.

Scale factor

Features on a spherical surface undergo distortion when projected onto a plane. For the exact measurement using projected maps the information of distortion is essential. One will have to multiply with the scale factor to the measurement on the map to derive the actual length. The scale factor here is different than the scale which we use to represent how much time the information has been compressed while making maps that is usually represented as 1:50,000 (i.e. ratio of distance on map to the ground). The scale factor in projection is represented by symbol “*k*” and it is ratio between the distances on the projection to the distance on the sphere.

$$k = \frac{\text{distance on the projection}}{\text{distance on the sphere}} \text{ where, } k \text{ is scale factor.}$$

Datum

A datum is a mathematical model of the earth used in mapping. A datum is represented by parameters that defines the shape, size and the orientation of ellipsoid (earth) in space. A datum is selected to define the best possible representation of the true shape and size of the earth. The earth for convenience of mathematical calculations is represented as a spheroid. The spheroid that has its origin matching with the center of the gravitation of the earth is referred as the “geoid”. This is essentially required for the satellite reference system for worldwide application and the reference system used for this purpose is referred as the datum. A datum having its origin at the center of the earth is said to be *geocentric*(Iliffe 2000). The reference helps in the computation of satellite orbits. After the advent of satellite geodesy several global geocentric datum has evolved among them World Geodetic System 1984 (WGS84) is the most widely accepted and used globally. A spheroid is not a datum as many countries may use same spheroid but different datum as they may use different point of origin of the reference system. A local datum used by individual country is designed to approximate the geoid in the region more closely than the global datum used for matching a wider region. Therefore, each regional or local datum has a point of origin which is represented by an offset from the center of the earth. The offsets are represented by ΔX , ΔY , and ΔZ which can be used for transforming the datum to other coordinates. A simple transformation of coordinates from a local to WGS82 can be done by:

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix}_{WGS84} = \begin{pmatrix} X \\ Y \\ Z \end{pmatrix} + \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}_{local}$$

There are the methods which uses various parameters for the transformation of one datum into another and are represented mathematically, some of them most widely used are the Molodensky formulae, Bursa Wolf method, Molodensky Badekas method.

Survey of India topographic map series

The survey of India (SOI) is the nodal agency of India for the development of topographic maps. The SOI has the old and the new series of maps. The old series uses the Everest as local datum and polyconic projection. These maps were printed on the scales of 1:250,000; 1:50,000 and 1:25,000. However, after the implementation of National Mapping Policy, 2005 on 19 May, 2005 production of topographical maps on Polyconic projection and Everest datum (Old layout) has been replaced with Open Series Maps (OSM) and Defense Series Maps (DSM) on 1:250,000; 1:50,000 and 1:25,000 scales. The OSM uses WGS-84 datum and UTM projection, prepared on 1:250,000; 1:50,000 and 1:25,000 scales for the use of general public for supporting development activities in the country. They do not contain grid and classified information; therefore, they are kept under unrestricted category. As per restriction policies of Ministry of Defense (MOD), OSM maps classified as Frozen, Top Secret, Secret are not to be published, hence no data/map for such sheets is available for supply. Data/Maps/Digital elevation for restricted OSM topo-sheets are supplied through data supply forms i.e. O.57(a) and O.57(b) to

Government agencies only. The OSM maps with international boundary are published with Ministry of External Affairs (MEA) clearance for the international boundary only, hence OSM maps/data for un-cleared topo-sheets are available for supply after MEA clearance only. The numbering of the maps by SOI is presented in Figures 13.13 and 13.14.

Figure 13.13 Representation of the numbering of survey of India topographic maps for scales 1:250,000 and 1:50,000.

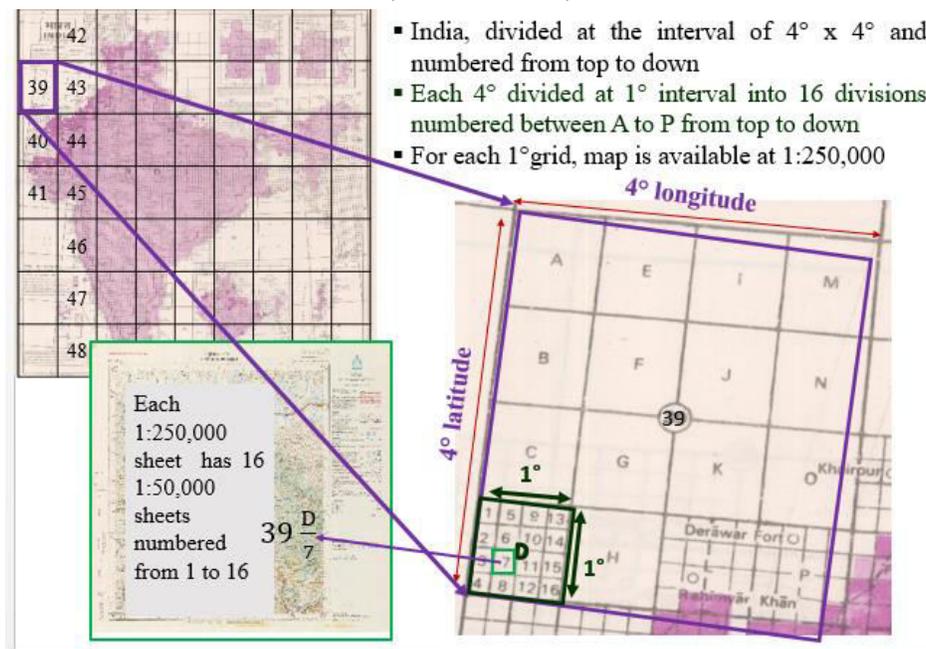
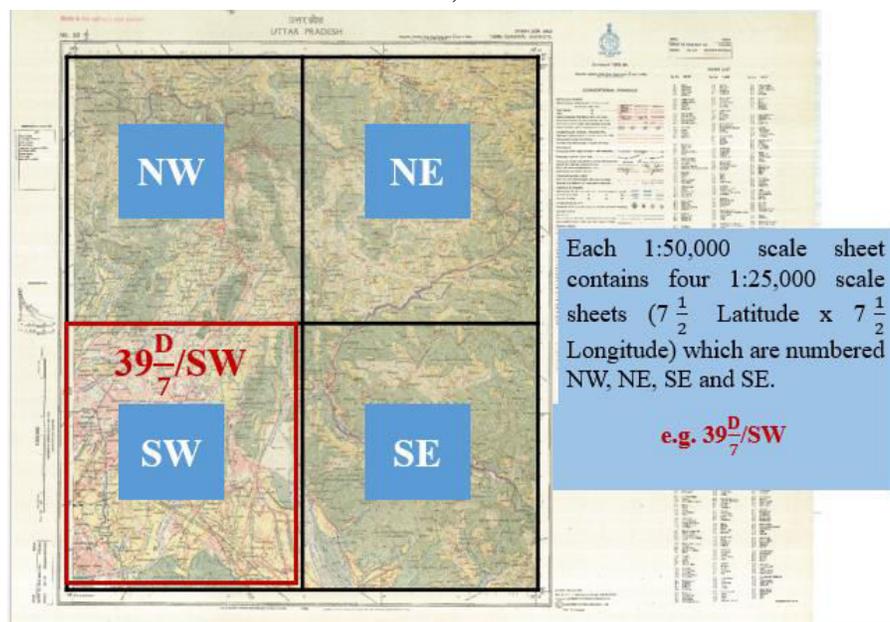


Figure 13.14 Representation of the numbering of survey of India topographic maps for scale 1:25,000.



13.4 SUMMARY

In this section we have learnt about the coordinate systems for locating the object in a given space, the use of different coordinate systems, the major grouping of the coordinate system into geographic coordinate systems (GCS) and the projected coordinate systems (PCS). The coordinates used for locating the position of an object on the earth could be done either by GCS or the PCS. The GCS uses a three dimensional shape of the earth to locate the position with reference to the origin which usually coincides with the center of the earth. The use of latitude and longitude is among the GCS. Different conventions may use different shape and size of the earth thus there are different GCS. Whereas, a method used for the representation of the location of object on earth on a two dimensional piece of paper, computer or map is referred as the PCS. There are various kinds of PCS on the basis of the surface upon which the earth is projected such as the cylindrical, conical or the planar (also referred as azimuthal) projections. Further the PCS can be grouped on the basis of orientation of the planes of projected surface and it could be normal, transverse or the oblique projections. The projection planes when it touches at just one point as tangent it is referred as the tangential while the one that touches at two points of the sphere as secant is referred as secant projections. All the projections have its own merits and demerits and the use of a specific projection is dependent upon the individual based on the purpose one intends to use the map. The projection involves the distortion of one or the combination of components in terms of its shape, size, direction, distance and scale and accordingly one can select projection to preserve one or more component which might be more important for the use. Some of the most widely used projected coordinate system are Mercator, Universal transverse Mercator and Lambert conformal conic projections. The old series of Survey of India topographic maps uses polyconic projection and Everest as the datum while the new series maps uses UTM projections with WGS84 datum.

13.5 GLOSSARY

Abscissa: The distance of a point from y axis (also referred as x coordinate).

Cartography: The art and science of representing a geographical area, usually on a flat surface such as a map. Also called as the art and science of making maps for representing earth's surface features.

Coordinate system: A system used for referring position of a point in a given space.

Datum: set of parameters defining a coordinate system, and a set of control points whose geometric relationships are known, either through measurement or calculation: origin, direction of axis, reference point for elevations.

Geographic coordinate system: A kind of coordinate system when referring position on the earth surface by using latitude and longitude.

Graticules: A network of grids formed by the lines of latitude and longitude encompassing each other.

Great circle: Equator and all the meridians.

Latitude: Angle made in north or south direction from the equatorial plane denoted by “ ϕ ” (phi).

Longitude: Angle made in east or west direction from the Greenwich meridian denoted by “ λ ” (lambda).

Meridian: An imaginary north-south line drawn on the earth joining north and south poles having same longitude.

Northern hemisphere: The portion of the earth above equator.

Origin: Location of reference point from where the position of an object is measured.

Ordinate: The distance of a point from x axis (also referred as y coordinate).

Parallels: An imaginary east-west line drawn on the upper and lower side of the equator having equal latitude.

Projection: A scientific way of representing three dimensional features on two dimensional plane.

Scale: Ratio between the distances on a map to the distance on the ground.

Scale factor: A ratio between the distances on a projection to the distance on a sphere.

Southern hemisphere: The portion of the earth below the equator.

Transformation: The process of converting one datum into another.

13.6 ANSWER TO CHECK YOUR PROGRESS

1. Represent 23.15° N and 78.45° E as degree, minute and seconds.
2. Represent 78 degree, 30 minute and 30 second as degree decimal value.
3. What will be the UTM zone and latitude bands for a point located at 23.15° N and 78.45° E.
4. Old series of survey of India topographic maps uses which projection system?
5. What is the datum used in the old series of survey of India maps?
6. The open series map of survey of India uses which projection system?
7. What is the reference datum used by the open series maps of survey of India?
8. What is the extent of coverage of the UTM projection along north-south direction?
9. A distance of 5 cm measured on a map of scale 1:50,000 would actually represent how much km on earth?
10. A UTM system has how many zones?

13.7 REFERENCES

1. Iliffe J (2000) Datums and map projections for remote sensing, GIS, and surveying. Whittles Publishing, Scotland, UK

13.8 TERMINAL QUESTIONS

1. What do you mean by a coordinate system? Explain any one coordinate system with a neat diagram.
2. What do you mean by projection? Explain any one projected coordinate system with neat diagram.
3. Explain about the shape of the earth used for the coordinate systems. What is the difference between a spheroid and a geoid?
4. Explain Universal Transverse Mercator (UTM) projection system. Show the various zones and latitude bands with the help of a neat diagram.
5. What do you understand by a datum? Explain any one datum.