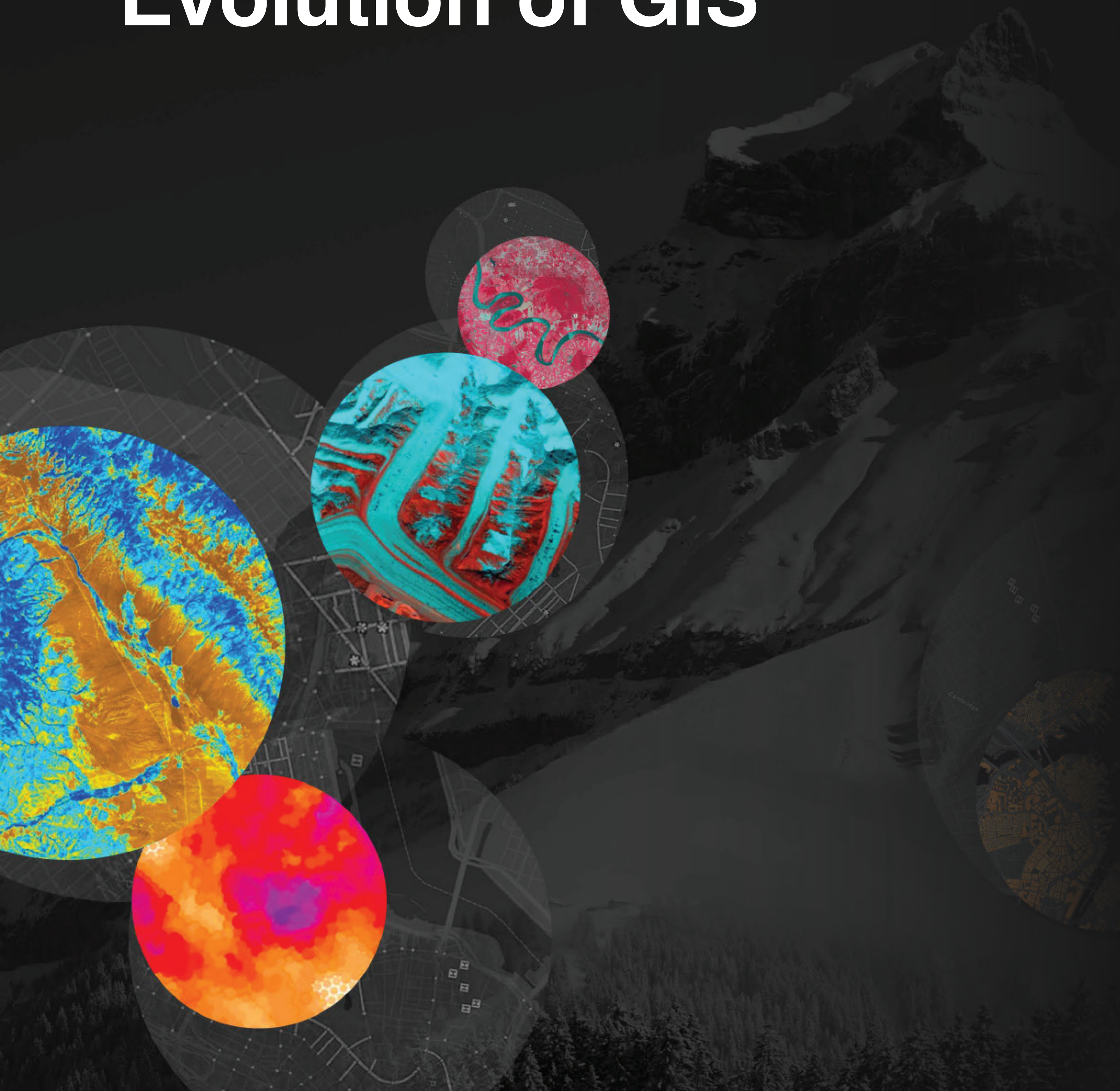
COVER STORY

Evolution of GIS



Geography often referred to as “the world discipline” has been the strongest “bridge” between the economies, natural resources, people, communities, environment and their interactions in space and time. Geographical thinking is deep-rooted in humans and subconsciously we harness it to think and do things. “We’re often unaware of how much spatial thinking we do because it is so ingrained in us. We move through the world so easily that it seems we do it without attention or effort, almost unconsciously.” says Jack Dangermond, Founder and President of Esri.

Human Cognition (the mental action or process of acquiring knowledge and understanding through thought, experience, and the senses) consists of a) objects, events, processes, background environment and b) their acquisition, storage and retrieval and manipulation. As human brain gathers visual information about an object, it also gathers information about its surroundings, and associates the two. Every time we think of “what”, invariably context of “where” follows. This is how the human brain is wired. Every piece of information is processed by human brain in space and time to contextualize and help us take decisions in everyday life.

Early humans are known to have depicted geographic information symbolically on flat surfaces (stones, bones, rocks, etc) in the form of patterns and pictures. With times information got better organized, different mediums of communication came into use and became popular as “maps”. First recorded use of geographic information dates to prehistoric times (2.5 million years ago to 1,200 B.C. - Stone Age, Bronze Age, and Iron Age). Through ages humans have relied on geographic information for wide range of activities including military superiority, navigation, and administration. Over time the applications of maps evolved into every aspect of human life.

It was in 1960’s, when computers revolutionized the way geographic information could be used. The first “Geographic Information System (GIS)” built in 1963, was used for storing, analyzing, and manipulating land information in a map-based environment. Over time, with advances in computing and communication technologies GIS has become a powerful and versatile tool with enhanced capabilities and diverse applications. While continuing to be based on basic principles of cartography, today’s GIS can integrate diverse disciplines and technologies such as Remote sensing, Positioning, Surveying, Photogrammetry, Analytics, Modeling, Data Science, Artificial Intelligence, Machine Learning and Deep Learning. Cutting across the sectors these advanced capabilities on a unified GIS platform provide numerous benefits to the stakeholders.

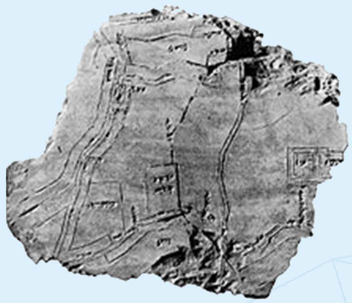
From times when map making was a tedious, time consuming affair and had to be carried out by experts, today’s GIS gives people the ability to create their own digital maps to help solve real-world problems. From data processing tool in the past, today’s GIS has graduated into a means for data sharing and collaboration, inspiring a vision that is now rapidly becoming a reality—a continuous, overlapping, and interoperable database of the world, about virtually all subjects.

The word “map” is believed to have originated from the medieval Latin ”Mappa mundi”, wherein “mappa” meant napkin or cloth and “mundi” the world. “Map” became a shortened term referring to a two-dimensional representation of the surface of the world.

Past

Cartography

While cartography continues to be foundation of today's GIS, its history is very fascinating. The earliest surviving maps are cave paintings and etchings on tusk and stone, followed by extensive maps produced by ancient Babylon, Greece and Rome, China, and India.

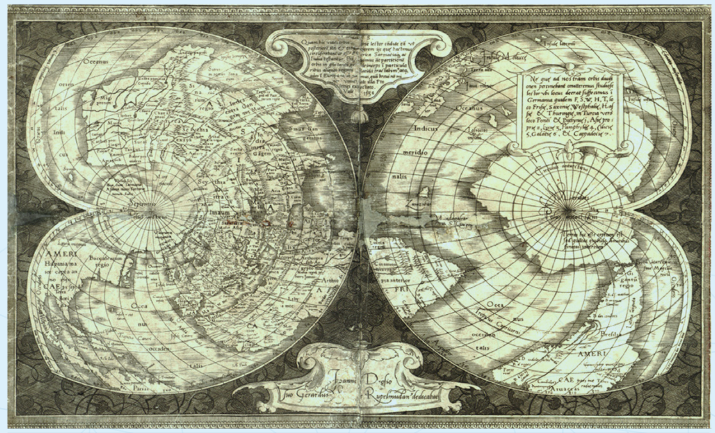


Clay tablet with map of the Babylonian city of Nippur (ca. 1400 BC) Image Courtesy

Cave painting and rock carvings used simple visual elements that may have aided in recognizing landscape features, such as hills or dwellings. A map-like representation of a mountain, river, valleys and routes around Pavlov in the Czech Republic, carved on a mammoth tusk, has been dated to 25,000 BC, making it possibly the oldest known map of all time. Maps in Ancient Babylonia were made by using accurate surveying techniques. Oldest preserved maps on Babylonian clay tablets date to 2300 BC.
Early maps depicted small areas and were pictorial in nature. They had no rules to how they were oriented and relationship between the features on the maps were often not accurate. The Greeks are credited with map making based on mathematical principles. Using surveying techniques, they measured positions of various objects by calculating the distance and angles between each point. The earliest Greek known to have made a map of the world was Anaximander in 6th Century BC, assuming that the earth was cylindrical.
While Eratosthenes was the first person to assume earth as spherical in shape, Ptolemy (90-168), a Hellenized Egyptian, developed the depiction of the spherical earth on a map by using perspective projection. He suggested precise methods for fixing the position of geographic features on its surface using a coordinate system with parallels of latitude and meridians of longitude. Ptolemy's eight-volume atlas Geographia is a prototype of modern mapping and GIS. For the first time the practice of orienting maps so that north is at the top and east to the right of the map started with Ptolemy, which has become a default standard today.

First World Map

It was 16th century when Gerardus Mercator born as Geert de Kremer (1512-1594) a leading Flemish cartographer published the first world map in 1538, usually referred to as "Orbis Imago". He used a double-heart-shaped projection which resulted in maps of greatly increased accuracy. Mercator's navigational charts enabled compass bearings to be plotted in straight lines on charts and clarified longitude and latitude measurements. Mercator's world maps flattened the spherical planet with latitude and longitude lines drawn in straight grid, to make it easier to display.



World Map 1538, By Mercator, Image Source Wikipedia.

Thematic Maps

Ability to handle thematic maps / layers have proved to a big differentiator of GIS technology. Interestingly, idea of portraying different layers of data on a series of base maps, and relating things geographically, has been around much longer than computers. Maps of the Battle of Yorktown, 1782 (American Revolution) drawn by Louis-Alexandre Berthier (1753-1815), Minister of War and chief of staff to Napoleon, have used overlays to show troop movements.

Louis-Alexandre Berthier map showing position of the American and French Armies in Kings Ferry, Peak's Hill, Crompond and Hunts Tavern from September 17 to October 20, 1782. Map shows roads, bridges, houses, some industries, creeks, rivers, and relief.

In 1838 "Atlas to Accompany the Second report of the Railway Commissioners, Ireland" by Irish Railway Commission, showed population, traffic flow, geology and topography superimposed on the same base map.
Origin of modern-day thematic representation of map layers can be attributed to Photozincography (sometimes referred

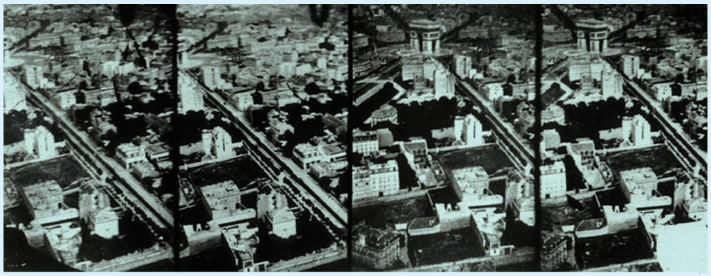
to as heliozincography, also known commercially as zinco). First developed by a British army officer, Sir Henry James FRS (1803–1877) in the mid-nineteenth century, this process allowed maps to be split into different thematic layers. While the use of layers much later became one of the main typical features of a contemporary GIS. This method proved invaluable when it was used to create maps by Ordnance Survey of Great Britain in the 1850's.

Positioning (GNSS)

One of the invisible technological components that has made significant contribution to development of GIS applications is precise positioning using Global navigation satellite systems (GNSS). GNSS aids in determination of location, navigation, tracking, mapping, and timing, relying upon real-time satellite signals.
Ground-based radio navigation systems, such as LORAN (1942) and the Decca Navigator (1945), were used during World War II. These learnings were applied to space and The Soviet Union launched Sputnik 1 satellite in 1957. American scientists tracked Sputnik's radio pulses using the Doppler effect, which led to development of Navy Navigation Satellite System, known as "Transit". Transit became the first satellite-based geo-positioning system in 1960 and was used primarily by the US Navy in 1964. For better accuracy, scientists developed accurate time reference for a ranging signal which led to development of the Navstar-Global Positioning System (GPS) by United States (launched in 1973). The Soviet Union developed their own satellite navigation system "Parus" in 1974. While these were initially developed for military uses, they were made accessible to civil applications in 1983. These were followed by many other systems over years including GLONASS (Russia), Galileo (EU), BeiDou (China), QZSS (Japan) and The Indian Regional Navigation Satellite System (IRNSS) operationally known as NavIC. As on 1st September 2021, there are about 150 navigation and positioning satellites in earth's orbit.

Remote Sensing

With ground-based surveys being time consuming and expensive, remote sensing technologies became a very viable alternative and soon became main source for rapid information acquisition.
Remote Sensing of earth started with aerial photography. Early platforms used for acquisition of aerial photos included balloons, pigeons and kites. The first aerial photograph was taken in 1858 by Felix Tournachon (1820-1910), known as Nadar, from a tethered balloon over the Bièvre Valley in France. Light aircrafts were widely for aerial photography in the first world war during 1914–1918. This was followed by development of new format cameras, development of photogrammetric hardware (analog stereoplotters), digital photpgrammetry and use of aerial photographs in non-military applications as time passed.
Satellite remote sensing started in 1960's with meteorological applications being the first ones. In early 70's the first satellite ERTS-1 Earth Resources Technology Satellite (later renamed as Landsat in 1975) specifically designed to collect data of the Earth's surface and its resources was developed and launched by United States.



Aerial Photographs of Paris from a balloon by Nadar, 1838, Image Source Wikimedia

Since then, many countries have launched earth observation satellites including India's IRS constellation (IRS-1A was first launched in 1988). Landsat program continues to be operational even today with Landsat 9 being the latest launch in September 2021. As per Union of Concerned Scientists (UCS), there are about 4550 operational satellites currently in earth's orbit, of which 1028 are Earth Observation satellites as on 1st September 2021.

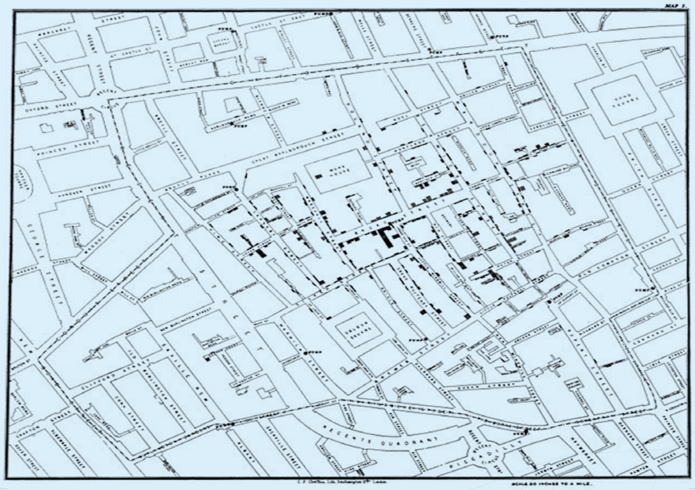
Landsat 1 (ERTS 1)

Over the decades, satellite remote sensing has witnessed rapid developments that transformed the GIS application landscape. These include higher spatial/temporal resolutions and stereo pairs providing finer details with improved accuracies suitable for most of the civil applications. Optical and radar systems, hyperspectral sensors, and thermal sensors also came into use to address specific challenges.

Early Spatial Analysis

Spatial analysis has been the most intriguing and remarkable aspect of GIS critical to solving complex problems. First known instances of spatial analysis are reported from the field of epidemiology. In 1834 French economist, statistician, and demographer Louis-François Benoiston de Châteauneuf (1776-1856), as head of a French commission, issued "Rapport sur la marche et les effets du choléra-morbus dans Paris- Year 1982". This work contained map outlining 48 districts of Paris, using color gradients, to provide a visual representation for the number of reported deaths due to cholera. In 1854, John Snow (1813-1858), an English epidemiologist and physician, determined the source of a cholera outbreak in London using spatial analysis.
As the time progressed ability of GIS to aid in spatial analysis with power to visualize and explore contextual information became widely popular for extracting knowledge and

insights for decision support. In recent times ability of GIS to integrate with non-spatial data and leverage advanced technologies have further amplified the benefits for users.



Original map made by John Snow in 1854. Cholera cases are highlighted in black, showing the clusters of cholera cases (indicated by stacked rectangles) in the London epidemic of 1854. The map was created in order to better understand the pattern of cholera spread in the 1854. Image Source

Birth of Geographic Information System (GIS)

Technological and conceptual advancements in the last half of the twentieth century brought by advent of computers, development of faster mathematical and computational algorithms, and the earth observation satellites contributed to paradigm shift in the way geographic information could be harnessed.

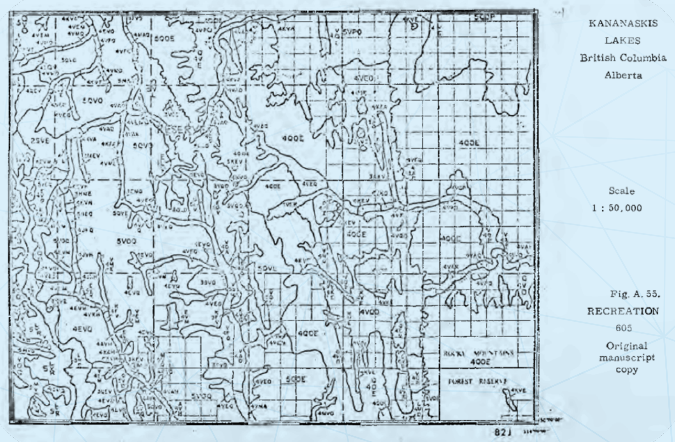
Dr Roger Tomlinson (1933-2014)
Image Courtesy Wikipedia

Computer hardware development spurred by nuclear weapon research led to general-purpose computer "mapping" applications by the early 1960s. With development of new sources, use of geographic information proliferated and complexities led to automation for better organization, presentation and management of geographic data and information, and thus Geographic Information System (GIS) was born.

The first known automated mapping application was produced by Swedish meteorologists and British biologists in 1957. It was in 1963 when the term Geographic Information System (GIS) was coined by Dr Roger Tomlinson (1933-2014) who developed Canada Geographic Information System (CGIS) for Canada Land Inventory.

CGIS was an improvement over "computer mapping" applications as it provided capabilities for overlay, measurement, and digitizing/scanning. It supported a national coordinate system that spanned the continent, coded lines as arcs having a true embedded topology and it stored the attribute and locational information in separate files. Dr.Tomlinson promoted use of overlays for spatial analysis of convergent geographic data.

Other notable developments in the early days of GIS which have left a significant impact on modern day GIS are development of theoretical aspects of spatial data handling by Howard T Fisher (1903-1979) of Laboratory for Computer Graphics and Spatial Analysis at the Harvard Graduate School of Design in 1964. By the 1970s distributed seminal software code and systems based on these concepts became source for subsequent commercial development of GIS worldwide.



Graphic Output of The Canada Geographic Information System (CGIS) from Dr. Roger Tomlinson's PhD Thesis. Source, UCL http://discovery.ucl.ac.uk/1563584/

Introduction of map overlay method by Ian L. McHarg (1920 – 2001), a Scottish landscape architect and writer on regional planning using natural systems in his book "Design By Nature" (1969), highlighted on how to break down a region into its appropriate uses. He also introduced a street network into the US Census Bureau's DIME (Dual Independent Map Encoding) System. The file format developed for storing the DIME-encoded data was known as Geographic Base Files (GBF), which was replaced with Topologically Integrated Geographic Encoding and Referencing (TIGER) in 1990.

Waldo Tobler (1930-2018), an American-Swiss geographer and cartographer coined the term analytical cartography in 1975 to reflect the combination of mapping and analysis. He asserted that "everything is related to everything else, but near things are more related than distant things" (1970). Known as Tobler's First Law of Geography, this has proven to be immensely important in the development of geographic information science.

Commercial GIS Software

Encouraged with these developments and recognizing future potential of the technology for civilian applications, late 1960's saw a flurry of activity in commercial GIS software development.

In 1969, Jack Dangermond, then member of the Harvard Lab and his wife Laura founded Environmental Systems Research Institute, Inc. (Esri). Esri applied computer mapping and spatial analysis to help land use planners and land resource managers make informed decisions. Esri's early work demonstrated the value of GIS for problem solving. Esri's Arc/INFO was first released in 1982 which laid the foundation for today's ArcGIS.

Jack and Laura Dangermond

By the late 1970s two public domain GIS systems (MOSS and GRASS GIS) were also in development and eventually launched in 1979 and 1984 respectively.

In due course of time M&S Computing (later Intergraph and now Hexagon) along with Bentley Systems Incorporated, CARIS (Computer Aided Resource Information System), MapInfo Corporation (later Pitney Bowes and now Precisely) and ERDAS (Earth Resource Data Analysis System) (Later Leica Geosystems and Now Hexagon) released other notable commercial GIS software incorporating many of the CGIS features, combining the first generation approach to separation of spatial and attribute information with a second generation approach to organizing attribute data into database structures.

By the end of the 20th century, the rapid growth in various systems had been consolidated and standardized on relatively few platforms. Business landscape too changed with mergers and acquisitions in the industry bringing in consolidation of complementary technologies and capabilities. With proliferation of internet and faster networks, "desktop GIS" graduated to "internet GIS" making anywhere, anytime access possible.

Data compression and management technologies paved way for easy and quick access to the geospatial datasets which inherently were large in sizes and were cumbersome to deal with. With cloud taking over in recent times, increasingly geospatial data and mapping applications are switching over to the cloud offering GIS as SaaS (Software as a Service) and PaaS (Platform As a Service) empowering users to leverage the GIS technologies at their convenience.

Present

From 1960's to 2020's, rapid technological advances transformed the way geographic information is being collected, processed, analyzed, and disseminated over times. Cutting across industry verticals, from direct productivity benefits and cost savings, modern GIS technologies are force multipliers for economic growth and play a critical role in sustainable development of resources.

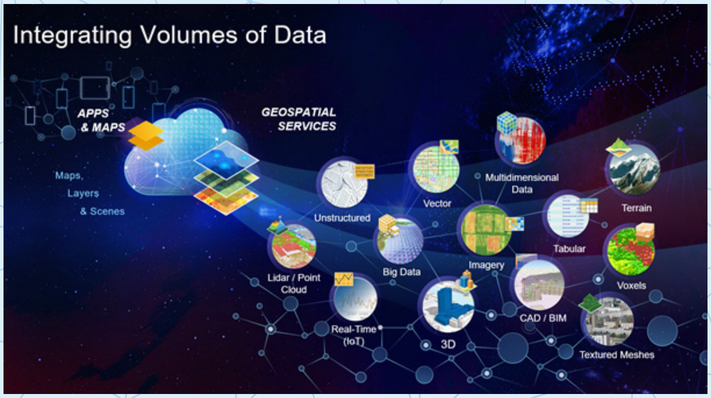
While continuing to be based on the principles of traditional cartography, modern day GIS allows us to much more than just visualizing maps. Jack refers to GIS in its digital manifestation of geography, going beyond just the science (2015). He says "It provides us a framework and a process for applying geography. It brings together observational science and measurement and integrates it with modeling and prediction, analysis, and interpretation so that we can understand things".

With increasing awareness on benefits of GIS, easy availability of location information has fueled geo-enablement across the sectors. Use of GIS which started with land information management in 1963, today finds an important place in governance, politics, urban development, rural development, agriculture, infrastructure development, natural resource management, disaster management, mining, power, telecom, oil & gas, and water management, planetary sciences, social empowerment and so on.

Diverse technological advances have also played a major role in providing these widespread benefits and adoption. With advanced communication infrastructures faster connectivity and data exchange became easier. Proliferation of location intelligent devices flooded the landscape with "real-time" geoinformation which brought to fore numerous applications for user convenience and decision support. This "real-time" data and "actionable" intelligence are being leveraged by businesses and consumers for informed decisions.

Digital transformation initiatives in recent decades started focusing on establishing linkages to exploit data and insights through interconnections and interdependencies. By integrating diverse data and knowledge, spatially and temporally in a unified environment, organizations are able to harness the "Science of where" better than ever. With their unique ability to integrate data about everything—and provide intuitive understanding through maps, GIS technologies have become an essential tool for organizations.

With cloud technologies and easy to use Platform-as-a Service (PaaS), access to GIS has become much easier, faster, and cheaper. Relieved of expensive computing infrastructure and storage, organizations are now able to churn out enhanced value from their GIS investments from very first hour. With faster computing available at lower costs, by processing and integrating ever increasing volumes of geo-data from satellites, LiDAR, and other IoT sensors, along with crowdsourced data, organizations are now able to rapidly transform data into actionable intelligence for informed decisions.



Governments and businesses are using geographic information to strengthen governance, improve business operations and provide services to citizens and consumers. Geo-information driven experiences like maps, routing apps, location information, etc using mobile phones are transforming consumer landscape rapidly. Consumer behavior and expectations are being reshaped towards personalized experiences based on their location.

Mobile GIS tools now play a vital role in democratizing geo-information and empowering stakeholders with real-time information for informed decisions and risk mitigation.

Continued advancements in data storage and parallel and distributed computing are making solving problems at the intersection of machine learning (ML) and GIS increasingly possible. This focus on innovation empowers users to take advantage of the latest advances in technology and computing, while still focusing on solving problems in a fundamentally spatial way. Advanced GIS capabilities like spatial modelling and predictive analysis using artificial intelligence, machine learning and big data provide enhanced situational awareness for accurate forecast of likely scenarios to mitigate, plan and respond, including the impact of changing economic, demographic, and climatic conditions. Spatially simulated models provide decision-makers with interactive tools for understanding the physical systems and judging how actions on the ground can affect the overall ecosystems.

"Geo-Hub's" are revolutionizing open access of the authoritative geospatial data, fostering collaboration, and sharing among governments, scientists, NGOs, communities, and other stakeholders for informed decisions through data driven insights. Fostering spatial thinking, "Story Maps" are redefining the way we communicate intuitively and spread awareness to a larger audience.

Today's GIS gives people the ability to create their own digital map layers to help solve real-world problems. GIS has also evolved into a means for data sharing and collaboration, inspiring a vision that is now rapidly becoming a reality—a continuous, overlapping, and interoperable GIS database of the world, about virtually all subjects. Today, hundreds of thousands of organizations are sharing their work and creating billions of maps every day to tell stories and reveal patterns, trends, and relationships about everything.

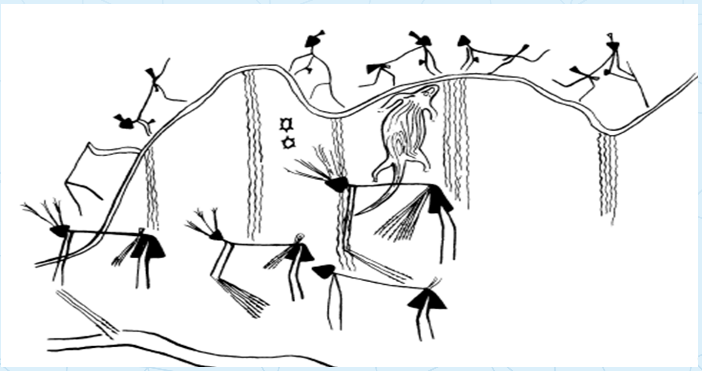
Indian Context

Early cartography in India is known to have used paintings and poetry for description of locations. Cave paintings from Mesolithic sandstone caves in Madhya Pradesh show geometric designs, which could be purely decorative but might also be, in some cases, cartographic elements, symbolic plans of huts, depicted in both ground plan and elevation.

Evidence of modern-map making can be traced to the Brahmand Purana of 500 B.C. to 700 A.D. Sulva Sutra (science of mensuration) and in the Arth Shastra of Chanakya written in the 3rd century B.C refer to the art of surveying and techniques of mensuration.

Bhavabhuti, a 8th century scholar described paintings in his work "Uttara Rama Charita" which minutely describe a habitation and its surroundings. In the 9th century, Islamic geographers under Abbasid Caliph Al-Ma'mun improved on Ptolemy's work and described the Indian Ocean as an open body of water instead of a land-locked sea. The Iranian geographers Abū Muhammad al-Hasan al-Hamdānī and Habash al-Hasib al-Marwazi set the Prime Meridian of their maps at Ujjain, a centre of Indian astronomy. Revenue maps and land survey systems were known to have started during Mughal emperor Sher Shah Suri's regime during 1540-45. Shershah (1472-1545) is credited to have introduced systematic survey and measurement of the entire cultivable land of his empire and fixe the land-tax on just and fair principles.

Modern cartographic traditions were officially employed by the British Survey of India. Major James Rennell (1742-1830) the first Surveyor General of Bengal (1767-1777) carried out the first

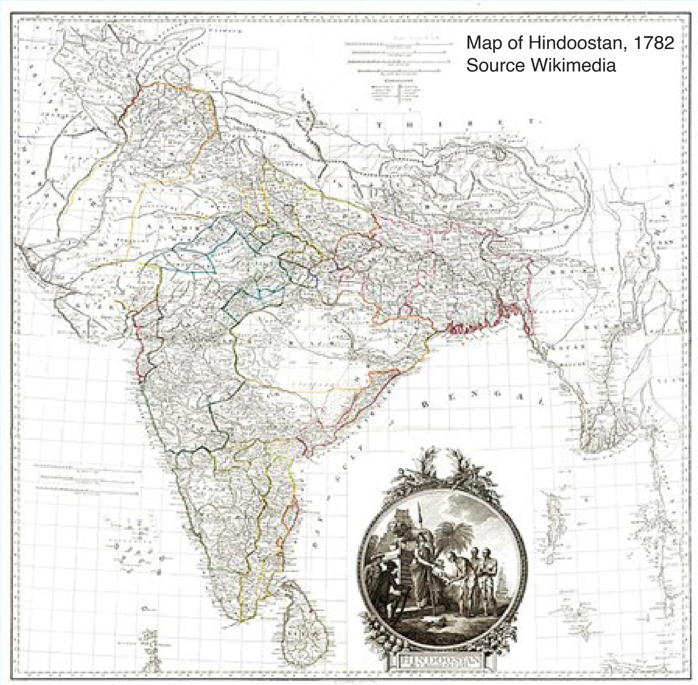


Cave paintings from Mesolithic sandstone caves in Madhya Source - Introduction to South Asian Cartography, Joseph E. Schwartzberg

comprehensive geographical survey of much of India at a greater detail. He is most known for his Bengal Atlas of 1779 and Memoir of a Map of Hindoostan (1782). His survey led to The Great Trigonometrical Survey (GTS) of India which began in 1802 and continued throughout most of the 19th century which is referred to as most advanced mapping carried in the world at that time. Other nations, including Britain, were not mapped to the extent that India was.

First known aerial photography in India was carried out in 1920 when large-scale aerial photographs of Agra city were acquired. In 1923-24 Air Survey Party of the Survey of India took up aerial survey of Irrawaddy Delta forests (now in Maynmar). Post independence aerial photography in the country continued predominantly for military applications.

Like other parts of the world, the modern map making techniques in India, too employed digitization, photographic surveys, and printing. This was followed by use of remote sensing data including aerial photographs and Satellite imageries. IRS-1A, the first of the series of indigenous remote sensing satellites, was launched in 1988. IRS-P5 (CARTOSAT-1) launched in 2005 was equipped with high resolution panchromatic equipment to enable it for cartographic purposes for the first time.



Map of Hindoostan, 1782
Source Wikimedia

GIS in India

Adoption of GIS in India started in late 1980's with Natural Resources Data Management System (NRDMS), National Natural Resources Management System (NNRMS), and National Natural Resources Management System (NNRMS). This was followed by Urban Mapping Scheme (UMS) which involved base map preparation using aerial photographs for 53 towns as pilot scheme, which was continued under National Urban Information System (NUIS) scheme in tenth five year plan.

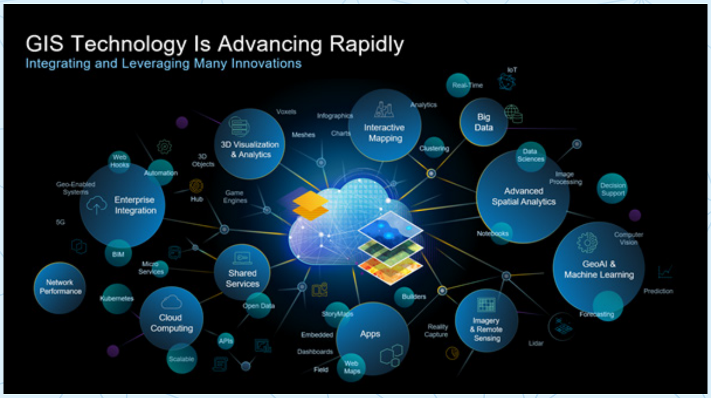
1990's saw increase in adoption of GIS by governments in diverse application areas along with private enterprises embracing GIS. Indian Defence, India Census, Integrated Mission for Sustainable Development, National (Natural) Resources Management System (NRIS), adopted GIS during this period. In the private sector CESC and Reliance Infocomm, commenced deployment of electric GIS and Telecom GIS respectively. Satellite imageries were used extensively for generating telecom propagation models for planning by the private telecom industry.

It was 2000's when use of GIS became prominent in governance. Many government schemes were formulated with GIS as integral component of the implementation plan. These include Restructured Accelerated Power Development and Reforms Programme (R-APDRP), The Digital India Land Record Modernization Programme (DILRMP), previously known as the National Land Record Modernization Programme (NLRMP), The Jawaharlal Nehru National Urban Renewal Mission (JNNURM), Integrated Watershed Management Program (IWMP), and many others. This was the decade which also saw massive geospatial infrastructure deployment in the country. These include National Forest Information System (NFIS), BharatMaps-Multi-Layer Geographical Information System (GIS) for Planning - NICMAPS, National Urban Information System (NUIS), National Spatial Data Infrastructure (NSDI), and other state geospatial infrastructures.

2010's can be termed as decade of mass adoption with use of GIS spreading across the economic activity in the country. There was a surge of GIS deployment in the country for addressing various challenges covering infrastructure, water resource management, rural development, urban development, public safety, healthcare, agriculture, environment and natural resource management and disaster management. This decade also saw strengthening of geospatial infrastructure in terms of Continuously Operating Reference Station (CORS) networks being deployed in the country along with further expansion of GIS based decision support systems and state spatial data infrastructures.

Future

Over last six decades use of geospatial information has grown exponentially. From being a niche technology, GIS is getting subsumed into enterprise architectures. Blurring the lines, with its unmatched capabilities, GIS is becoming integral component of enterprise IT architectures and fueling geo-enablement of digital transformation initiatives.



Changing Business Dynamics

With changing market and consumer dynamics businesses are being challenged constantly to adapt and align themselves to stay ahead. With explosion of data they are also challenged to efficiently and cost effectively mine the data for insights and decision support. Increasingly there is a realization that 80% of data generated today has a context of geographic location attached, which can be effectively harnessed for improving business operations and providing better services to customers. In times when data is being termed as "new oil", this underutilization of location has been one of the major misses of recent digital transformation initiatives. With proliferation of location information and rich experiences they provide, businesses are forced to take

cognizance of the fast changing consumer behavior with a strong desire for location rich personalized experiences.
Post first wave of the COVID 19 pandemic, there is also an increased awareness that contextualized data and analytics offer a huge potential to deal with disruptive changes and radical uncertainties in a better way. Along with climate change and sustainability concerns, governments across the world are also faced with increasing population, urbanization and demand for natural resources which need to be addressed on war-footing.

Drivers

With 2000's setting stage for geo-enabled transformations, explosion of location rich data and advanced capabilities of GIS technologies are expected to be primary drivers for future growth. Increasing reliance on data and insights, improved awareness and past experiences are expected to drive governments and organizations to move up the geospatial value chain to realize higher potential from GIS technologies to address the complex challenges they are faced with.

As per the UNGGIM's Future Trends in Geospatial Information Management: The Five to Ten Year Vision, Third Edition, the view of 'everything happens somewhere' will drive many of the changes in the global economy as geospatial enters the mainstream. The next five to ten years will see an unprecedented change in the way in which geospatial information will shape and be shaped by the global economy.

Technology

Technologically, the next frontier in IT services will be driven by the nexus of cloud, edge, 5G, artificial intelligence (AI), the Internet of Things (IoT) and data and analytics, according to Gartner' s report "Tech Providers 2025". The report urges leaders to embrace this nexus to enable solutions for emerging use cases such as smart cities, drones, connected and autonomous vehicles, remote healthcare, and smart retail.

Gartner predicts that from "Big Data" the thrust is shifting to "Small Data" and AI solutions around them will be way forward for better agility and resilience. These call for contextualized analytics with deep AI/machine learning (ML) capabilities to deliver location specific experiences. Given how these are closely liked with geographies and cultures, context of location is expected to be a gamechanger in these transformation initiatives. Newer opportunities to capitalize on the geo-information using spatial modeling and analytics, artificial intelligence, machine learning and deep learning are waiting to be exploited.

Blockchain technology is expected to test waters in the geospatial industry in coming years. Leading the efforts, European Space Agency (ESA) has identified priorities relevant to block chain solutions for the EO community. The outcomes of this program will be eagerly awaited by the geospatial industry.

Applications

Geoinformation driven experiences through mobiles have been transforming geospatial landscape rapidly. Consumer behaviour is being reshaped towards instantly gratifying personalized experiences which are creating demand for new products and services. Consumers are changing the narrative and will expect products that offer dynamic, proactive and even prescriptive, location specific personalized experiences. Be it gaming or navigating, virtual terrains are here to transform the future interactions.

Powered by multiple devices live streaming location, physical "analog" objects are being complemented by intelligent "digital twins". Opportunities for creating "digital cities" and "virtual terrain models" for an immersive experience and their applications throw open new opportunities for businesses to access the metaverse in multiple ways. Once realized, metaverse will be a new way of people interacting with their environment and potentially transform every aspect of business in coming years.

With more and more earth observation sensors such as satellites, UAV's, high altitude, or vehicle-based sensors providing a greater variety and flexibility to acquire application/project specific data at desired spatial resolutions and temporal frequency, customers will be able to make optimized choices for their specific requirements.

Emerging cloud based geospatial data/content management tools and capabilities are expected to revolutionize capture, maintenance, and management, helping organizations to focus on harnessing the geospatial data for their requirements while taking away the burden of managing the infrastructure and associated challenges.

Continued developments in image recognition and feature extraction, coupled with reduced storage costs, are fostering faster data capture and geo-spatial content creation. While offering cost arbitrage these automated capabilities are expected to free up time-consuming and resource-intensive tasks benefitting organizations with faster turnaround times, better operational efficiencies, and enhanced cost savings.
As the web-based service infrastructures gain popularity, a new wave of customized GIS tools that can be rapidly configured and deployed by users themselves are likely to emerge. While at the same time, creation and management of virtual geospatial data center's and delivering Data-as-a-Service (DaaS) itself is an opportunity waiting to be exploited.
Given the rapidly deteriorating global climate and its impact on the businesses and society, adopting to climate change will be a critical challenge for leading governments and businesses alike. This will be critical for steering economic, environmental, and social progress sustainability.
Geospatial information combined with socio-economic and other statistical data will continue to provide critical inputs for addressing the complex challenges of climate change while supporting in policy preparation, monitoring, and evaluation.