MULTIPLE APPLICATIONS OF GEOSPATIAL ANALYTICS

ARVIND PANDEY

INTRODUCTION

Geospatial information in the present era is driving not only our cars but our entire day-to-day living. The constant evolution of this technology and its integration into other utilities is taking centre-stage. Geospatial data consists of earth features, their locations and characteristics, and may include imagery, Global Positioning System (GPS) coordinates, addresses and other traditional data, i.e. photos, maps, charts, etc. In this article, the endeavour is to familiarise the reader with geospatial data, and its fusion with other domain data riding on the Geographical Information System (GIS) platform and its applications.

Major applications of geospatial analytics are of dual use in which similar data sets are utilised for national security (military and non-military) and environmental applications. Several geospatial analysis applications related to the military and internal security such as intelligence preparation of the battlefield, integrated air defence picture, common operational picture for joint operations, precision targeting and bomb damage assessment,border surveillance and movement control, surveillance of disputed border areas, security census of big and important events, coastal surveillance and navigation are some areas which utilise this technology.

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The need of the hour is information in real-time, population density analysis of the affected areas, adjacent environment (with details of water bodies and low lying areas), sensitive civil and military installations, satellite imagery annotating the real-time picture of the affected sites, highlighting community structures and healthcare facilities, location of the first responder on site agencies, crowdsourced information, social media inputs, and so on. This holistic elaboration defines the capabilities of geospatial analytics.

In this article, environmental applications, along with business and cyber applications are dealt with in detail. The relationship with Artificial Intelligence (AI) and the emerging geospatial activities will also be discussed.

GEOSPATIAL ANALYTICS

Geospatial technology[1] by itself is limited in its ability to provide solutions for the queries that demand additional knowledge and relationships between multiple geographic entities. For instance, availability of erstwhile geographical maps and imagery of flood affected areas cannot fully support the disaster support response. The need of the hour is information in real-time, population density analysis of the affected areas, adjacent environment (with details of water bodies and low lying areas), sensitive civil and military installations, satellite imagery annotating the real-time picture of the affected sites, highlighting community structures and healthcare facilities, location of the first responder on site agencies, crowdsourced information, social media inputs, and so on. This holistic elaboration defines the capabilities of geospatial analytics and its applications.[2]

Geospatial analytics can enable the following critical activities:[3]

1. M J de Smith, M F Goodchild and P A Longley, *Geospatial Analysis: A Comprehensive Guide to Principles, Techniques and Software Tools (UK:* The Winchelsea Press), http://www.spatialanalysisonline.com/HTML/index.html. Accessed on July 26, 2018.
2. Geoint Capabilities, chap -3, Geoint basic doctrine; https://fas.org/irp/agency/nga/doctrine.pdf. Accessed on April 2, 2018.
3. "The Future of GEOINT, Dold an Groopman", *Geospatial Information Science*, vol 20, issue 2, 2017; https://www.tandfonline.com/doi/full/10.1080/10095020.2017.1337318. Accessed on April 3, 2018.

- Formation of a common platform for multiple civil/military agencies to share geospatial information.
- Facilitate Intelligence Preparation of the Battlefield (IPB) and provide battlefield transparency.
- Mapping of men and material movements across time, space and terrain for military tactical planning.
- Analysing business advantages from trade insights (financial and trade secrets of business, decisions about establishing new infrastructure).

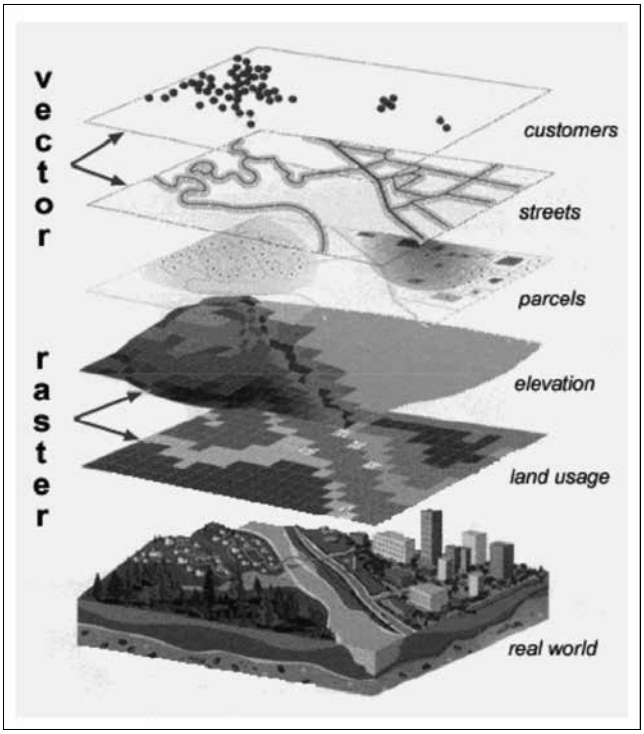
The value addition for digital geospatial analytics products is achieved by adding more layers of information to meet a stakeholder's needs. Each layer has the capability to provide additional details and intelligence information to the desired end product.

- Managing production of significant national strategic assets (defence installations, power plants, refineries, etc.).
- Activation of disaster support operations and planning logistics support for disaster response and other humanitarian assistance.
- Assistance in town planning, humanitarian missions, military and cyber surveillance, internal security and precision targeting in war.
- Forecasting to help avert dangers, counter conflicts and predict opportunities or adapt to shifting conditions.
- Application in the use of multiple sensor technology and multiple types of geospatial data for visualisation and fructification of neutralisation missions. For instance, geospatial analytics applied towards identification of probable terrorist activities close to the Line of Actual Control/ International Boundary (LAC/IB), data mined from geotagged messages, human geography mapping, aerial and satellite image of the terrain, persistent drone surveillance and location tracking of cell phone devices enables real-time mapping and analysis of terrorist movements across time and space.[4]

4 Sangeeta Deogawanka, "Geointelligence—Empowering Geospatial with Intelligence", April 26, 2015, GIS lounge; https://www.gislounge.com/geointelligence-empowering-geospatial-with-intelligence. Accessed on April 2, 2018.

Information Layering Through GIS: The value addition for digital geospatial analytics products is achieved by adding more layers of information to meet a stakeholder's needs. Each layer has the capability to provide additional details and intelligence information to the desired end product. This layering process allows the stakeholders to continually change or update the product to meet the growing needs and changing circumstances. GIS is used to facilitate the layering process. The data sets used are in vector /raster formats[5] which are engaged by geospatial tools in the form of various layers. A descriptive image of the layering process is reproduced in Fig 1 below which clearly brings out the ingredients and the final product.

Fig 1: Process for Analysing Geospatial Information.[6]



5. Vector and raster are types of geospatial data sets. Vector data is made up of point, lines and polygons. It has vertices and paths for description. Examples of this could be borders, land parcels and streets. Raster data is made up of pixels or grids. Examples of this could be satellite or aerial imagery and elevation data.
6. Figure by http://cherokeecountyiowa.com/offices/gis/index.htm. Accessed on July 26, 2018.

GIS and Geospatial Analysis:[7] GIS is a computer-based system which is involved in the acquisition, storage, management, transformation, visualisation, and analysis of information that pertains to a particular location on the earth's surface. Geospatial analysis involves extraction of information and knowledge from spatial and non-spatial data sets from the GIS through the application of a wide range of analytical techniques, including visualisation and data exploration. With the creation of *Google Earth* and similar services, both GIS and geospatial analysis are updating the geo-technology and internet to support location-based services. Technological improvements in elevation data such as the Digital Surface Model (DSM)[8] and Digital Terrain Model (DTM)[9] force the commercial suppliers to upgrade the geospatial tools. GIS is offered as a web service and several competitors are delivering solutions with standards of the Open Geospatial Consortium (OGC).[10] Worldwide research in geospatial analysis is involving both human and physical phenomena, increasingly supported by massive quantities of data.[11]An example of this could be air pollution analysis, which, in the present context, is actively being geovisualised. Geospatial analytics is a tradecraft which utilises special abilities interlinked to art/science for comprehension.

Geospatial Analytics: Art or Science? The analyst community perceives that there are multiple views for explaining geospatial analysis. One view is that intuition, experience, and subjective judgment are the keys to analysis.

7. Otto Huisman and Rolf A de By. "Principles of GIS". https://webapps.itc.utwente.nl/librarywww/papers_2009/general/principlesgis.pdf. Accessed on March 7, 2018.
8. A Digital Elevation Model, or DEM, is a representation of the terrain (bare earth) with elevations at regularly spaced intervals. A Digital Surface Model (DSM) also contains elevations at regularly spaced intervals; however, the elevations represent the first reflected surface detected by the sensor. These first returns may be reflected by bare ground or by surface features such as trees and structures.
9. A digital elevation model is a 3D representation of the terrain elevations found on the earth's surface. DEMs are generated from variably-spaced Lidar ground points, or they can be created using a raster grid. A Digital Terrain Model (DTM) is a DEM in which terrain data has been further enhanced with break-lines, creating greater accuracy as it contains additional information defining terrain in areas where Lidar data alone is unable to do the job effectively.
10. The Open Geospatial Consortium (OGC) is an international not for profit organisation committed to making quality open standards for the global geospatial community. These standards are made through a consensus process and are freely available for anyone to use to improve sharing of the world's geospatial data.
11. *The Future of Geospatial Intelligence*, vol 20, 2017; https://www.tandfonline.com/doi/full/10.1080/10095020.2017.1337318. Accessed on March 8, 2018.

According to this thought process, analysis is an art and non-quantitative methods are followed for the final product. The other view is that quantitative data and analysis using tools such as GIS are most relevant. In this case, intelligence analysis is science-like, and quantitative methods as applied in spatial analysis are followed. For understanding these points of view, the definition in terms of the *Merriam-Webster Collegiate Dictionary*, tenth edition, is used:

- *Art - the conscious use of skill and creative imagination in the production of anaesthetic objects.*
- *Science-knowledge or a system of knowledge covering general truths or the operation of general laws, especially as obtained and tested through the scientific method.*

Experience says that integrative geospatial data tools, such as those found in GIS, act as primary aids to intuition and experience-based analysis. In this domain, there is no certain dividing line between art and science. Some geospatial analytics practitioners contend that there is no dividing line at all and a pure scientific approach to geospatial analysis is impossible. Therefore, a subtle combination of art and science is preferably worked out as a tradecraft.

Remote Sensing Capabilities: Geospatial analytics amalgamates a broad range of evolving and emerging remote sensing capabilities, including traditional imagery systems, sources associated with land-based and hydrographic surveying and imagery derived fusion systems. With technological advancements and a growing range of collection platforms and sources, it improves the access to earth observables and increases the ability to conduct persistent surveillance to obtain broad area coverage.

Airborne Imagery Platforms*:* Airborne imagery collection platforms, including Unmanned Aerial Vehicles (UAVs) with varying altitude, speed and sensing capabilities, provide persistent and responsive coverage of high-interest ground areas. Worldwide, high-endurance UAVs are dramatically improving the ability to conduct persistent surveillance of high-interest targets and support time-critical actions. Merging manned and unmanned imaging capability is an emerging aspect which has been used in some conflicts by the North Atlantic Treaty Organisation (NATO) forces. In the Indian context, a wide range of airborne sensors and platforms is operated by governmental as well as civil agencies for achieving the desired tasks.

Commercial Imagery*:* The commercial imagery industry is an important emerging data source for generation of geospatial analytics. This helps in providing data sets to the users with no or limited capability in the field. It is now accepted that with growing capacity in both satellite and airborne imagery collection, commercial providers are able to produce a greater share of the data needed to support high resolution imagery needs for geospatial applications. Digital Globe and other such companies provide imagery as well as geospatial analytics applications for utilisation in the open domain. The high resolution commercial imagery provides an important advantage in joint operations and in internal security, as it can be shared with all the stake holders without compromising the capabilities and operating characteristics of reconnaissance systems. The availability of commercial data with crowd-sourcing[12] is becoming a boon to mankind.

GEOANALYTICS APPLICATIONS

With the availability of imagery data sets, geospatial information and other domain data sets, it is essential to visualise the applications supported by this technology. Several geospatial analysis applications related to military and internal security are:

- Intelligence preparation of the battlefield, integrated air defence picture: these applications use sensor specific data from surveillance platforms and a fused picture is generated.
- Common operational picture for joint operations, precision targeting and bomb damage assessment: these applications use a fused picture and prepare the data for utilisation by the joint forces as well as for targeting and battle damage assessment.

12. Crowdsourcing data collection consists of building data sets with the help of a large group of people. It is a process through which a task, problem or project is solved and completed through a group of unofficial and geographically dispersed participants.

The National Remote Sensing Centre (NRSC), Hyderabad—a part of the Indian Space Research Organisation (ISRO) – is the nodal agency for all geospatial related tasks. The NRSC Data Centre (NDC) is responsible for dissemination of all geospatial data to the users.

- Border surveillance and movement control, and surveillance of disputed border areas.
- Security census of big and important events.
- Coastal surveillance and navigation: these applications utilise data from all the sensors for national security purposes.

ENVIRONMENTAL APPLICATIONS

The geospatial analytics applications in day-to-day life are enumerated below, with details in the Indian context. The National Remote Sensing Centre (NRSC), Hyderabad—a part of the Indian Space Research Organisation (ISRO)—is the nodal agency for all geospatial related tasks. The NRSC Data Centre (NDC) is responsible for dissemination of all geospatial data to the users. These applications are growing at a fast pace, clearly defining the success of their technological utilisation and adaptability. Apart from attempts at the national level, regional remote sensing centres are applying and adapting to this technology; thereafter, depending upon the area of utilisation, different applications are developed. The major areas of work are in the fields of the following resources:[13]

- Agriculture.
- Water resources.
- Urban and infrastructure planning.
- Geosciences and ground water.
- Forestry.
- Disaster management support.

13. "Applications in Earth Observations", https://www.isro.gov.in/applications. Accessed on July 26, 2018.

The earth observation applications enumerated above have been derived from the ISRO and NRSC domains and the important characteristics are discussed hereafter.

Agriculture: Agriculture is the strength of the Indian economy and the crucial sector for ensuring food security. Timely availability of information on agriculture is vital for taking informed decisions on food security issues. India is amongst the few countries in the world that uses space technology and land-based observations for generating regular updates on crop production statistics and providing inputs to achieve sustainable agriculture. Satellite-based optical, infra-red and radar imagery[14] are used widely in monitoring agriculture. Radar imagery is especially used during the monsoon season. Hyper-spectral imaging tools have provided the requisite information which multi-spectral tools could not provide.[15] Continuous monitoring and extensive utilisation of geospatial tools with different crop models and the on-ground observation network enables timely crop production forecasts and drought assessment and monitoring.[16]

Continuous monitoring and extensive utilisation of geospatial tools with different crop models and the on-ground observation network enables timely crop production forecasts and drought assessment and monitoring.

The following primary areas are interdependent on geospatial analysis:

- Utilisation of space technology to provide crop forecasts and assessment of a drought situation.
- National agricultural drought assessment and monitoring.
- National agricultural land-use mapping.

14. Optical, infrared imagery utilises a certain portion of the Electromagnetic (EM) spectrum for imaging. Radar imagery uses a certain portion of the EM spectrum of radar which is used to create two-dimensional images, typically of landscapes. Increased usage of satellite-derived Synthetic Aperture Radar (SAR) data has occurred during the last few years.
15. Multispectral and hyperspectral imagery gives the power to see as humans (red, green and blue).The main difference between multispectral and hyperspectral is the **number of bands** and **how narrow the bands are.** Multispectral imagery generally refers to **3 to 10 bands**. Hyperspectral imagery consists of much narrower bands (10-20 nm). A hyperspectral image could have **hundreds or thousands of bands**.
16. Hyperspectral Remote Sensing; http://www.csr.utexas.edu/projects/rs/hrs/hyper.html;. Accessed on Apr 15, 2018.

Satellite images, with embedded information of spatial, temporal and spectral characteristics, help in extraction of information about the historical aspect of land-use/ land-cover, enhancement of existing infrastructure, terrain characteristics, etc. The analysed information forms an integral part in facilitating infrastructure planning, monitoring and management in a timely and cost-effective manner.

Water Resources: Water is a key driver of economic and social development and one of the fundamental elements in sustaining the integrity of the natural environment. Water, being an indispensable constituent for all life supporting processes, its assessment, conservation, development and management are of great concern for all those who manage, facilitate the availability (of water) and its utilisation. It is the major renewable resource amongst the various natural resources

The following primary areas are interdependent on geospatial analysis:

- Irrigation infrastructure monitoring and performance assessment.
- Glacial lakes/water bodies monitoring.
- Watershed management.

Urban and Regional Infrastructure Planning: Infrastructure forms an integral part of the growth and development of any region. Satellite images, with embedded information of spatial, temporal and spectral characteristics, help in extraction of information about the historical aspect of land-use/land-cover, enhancement of existing infrastructure, terrain characteristics, etc. The analysed information forms an integral part in facilitating infrastructure planning, monitoring and management in a timely and cost-effective manner.

The following primary areas are interdependent on geospatial analysis:

- Imagery data provides the necessary information on topography, vegetation cover, and water bodies, etc., which are vital for infrastructure planning.

- Urban and regional planning, route alignment (road, rail, oil/gas pipeline, etc.), site suitability analysis (hydroelectric project, new township), etc.
- Smart cities planning and development can be greatly enabled by geospatial analysis.

Geosciences and Ground Water: Satellite images offer a wide variety of applications in the field of earth sciences, e.g. geological and geomorphological mapping, hydrogeology, mineral exploration, monitoring of mining activity, geohazards, etc. The geosciences group at NRSC is the pioneer in this field.

Remote sensing as a tool has facilitated a systematic and hierarchical approach of forest resources assessment and its monitoring, using sensors of different spatial and spectral capabilities. It has also helped in the characterisation, quantification and monitoring of different natural habitats/eco-systems.

The following primary areas are interdependent on geospatial analysis:

- Ground water prospects mapping.
- Coal fire mapping.
- Mineral exploration.

Forestry: Forests are the natural resource which provide mankind with numerous benefits in both goods and services. The task of managing forest data can be a daunting one without the utilisation of the proper spatial tool. Space technology has immense influence in the decision-making processes, especially in areas like forest resource management. Remote sensing as a tool has facilitated a systematic and hierarchical approach of forest resources assessment and its monitoring, using sensors of different spatial and spectral capabilities. It has also helped in the characterisation, quantification and monitoring—including specific efforts towards understanding the structure, composition and function – of different natural habitats/eco-systems.

The following primary areas are interdependent on geospatial analysis:

- Forest cover assessment.
- Vegetation type mapping.
- Biodiversity assessment.

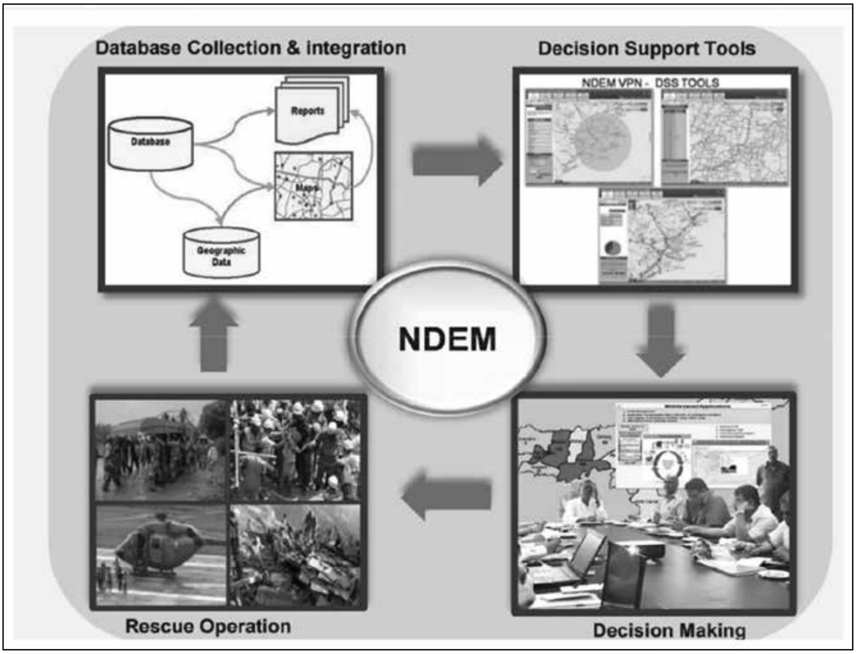
Disaster Management:[17] Disaster management falls under the dual applications of geospatial analytics domain, and the data provided by the NRSC is taken as the base data for any immediate and long-term assistance. A Decision Support Centre (DSC) has been established at NRSC which monitors five types of natural disasters, viz. floods, cyclones, forest fires, earthquakes and landslides, and acquires satellite/aerial data on the affected regions. The data of the affected area is analysed and assessments, along with value added products, are disseminated to the Ministry of Home Affairs (MHA) and nodal ministries. The armed forces are a part of the support system, based on air, land and sea requirements. The National Disaster Response Force (NDRF) is the specialised force structure available as the first responder. The National Disaster Management Authority (NDMA) is the agency responsible for the overall coordination and administration.

A GIS based database termed as the National Database for Emergency Management (NDEM)[18] has also been established for disaster management in the country. The data base provides all necessary geo-information for enabling GIS tools at all levels. This is also hosted on ISRO's *BHUVAN* platform. A descriptive image of the process involved is depicted in Fig 2.

The database has layered geoinformation with high resolution satellite imagery for visualisation and analysis, and also contains specific disaster layers for analysis of all natural disasters.

17. DSC, ISRO; https://nrsc.gov.in/ISRO_DMSP. Accessed on April 15, 2018.
18. Data base, NDEM; https://nrsc.gov.in/NDEM. Accessed on April 15, 2018.

Fig 2: NDEM Operational Loop[19]



APPLICATIONS IN DAY-TO-DAY LIFE

Artificial Intelligence (AI)[20] is **intelligence** displayed by **machines**, in contrast with the Natural Intelligence (NI) displayed by humans and other animals. In geographical contexts, AI and big data solutions always follow the same pattern. The first step is to import information from various sources. This dataset is then used to build a multi-layer model for applying geospatial tools.

Analysis based on geoprocessing involves the use of tools like the "spatial join" operation[21] which enriches a model by appending information from different layers. If this process is applied to road safety, then, by analysing

19. Ibid.
20. Demetrio Barragán, director at Strategy Big Data, director of the management programme in Big Data, and professor at IE Business School, and Pedro Torres, chief marketing officer at Esri Spain; February 23, 2018; https://www.ie.edu/corporate-relations/insights/location-analytics-big-data-and-artificial-intelligence-the-genesis-of-the-new-data-scientist/. Accessed on June 21, 2018.
21. A spatial join is a GIS operation that affixes data from one feature layer's attribute table to another from a spatial perspective. Spatial joins begin by selecting a target feature and comparing it spatially to other feature layers.

and correlating data—human, natural, and climatic factors, type of road, etc.—it is possible to create a map that minimises the risk of accidents at a particular spot and improves our understanding of the environment. Such a map can be used to predict accidents and optimise resource management, for example, by dispatching ambulances to the most dangerous areas. The most common AI applications in our day-to-day life are Amazon's A*lexa*, Apple Inc's S*iri* and Microsoft's C*ortana*.

The dependence on AI in the geospatial domain is increasing day by day and to proceed further in the Indian context, the National AI Task Force[22] on Defence submitted its report on June 30, 2018, to the Ministry of Defence. The report identifies applications in the military and non-military areas. Development of expertise and products for defence, cyber, nuclear and biological warfare by public sector units, in conjunction with private entities, has also found mention in the report.

Business Intelligence: Business Intelligence (BI)[23] focusses on the strategies and technologies used by enterprises for the data analysis of business information. The common tools involved are data processing, data mining and predictive analysis. This technology is designed to process large amounts of structured and unstructured data to ascertain the development of existing and new business opportunities, as explained below.

BI and Spatial Analytics:[24] Businesses are now focussing on the 'where' of things, the integration of spatial analysis and BI is helping companies to make more informed decisions, thus, leading to better outcomes. Organisations today are collecting data at every level of their business and in volumes that in the past were unimaginable. Datasets are stored in different database systems or in files with distinctive formats, all reflecting the business process, application, programme software, or information type dependencies. It is an accepted fact now that most of the data has a spatial component. Traditionally,

22. "AI Task Force Hands Over Final Report to RM"; http://pib.nic.in/newsite/PrintRelease.aspx?relid=180322. Accessed on July 20, 2018.
23. Shimonti Paul, "BI and Spatial Analytics: A Collaboration We Can't Do Without", September 20, 2017; https://www.geospatialworld.net/article/business-intelligence-spatial-analytics/. Accessed on June 20, 2018.
24. Ibid.

such data would be presented to the user in the form of long reports, either with graphs and pie charts, or in a spreadsheet format.

Spatial Analytics and Traditional Methods*:* Humans think visually, therefore, spatially. In the traditional methods, the ways to represent information proved to be helpful, however, they have been limited in capabilities when it comes to performing a quick analysis and comparison of data. Ordinarily, maps represent spatial relationships and spatial visualisation for an area or region.

Scope of Spatial Analysis: With businesses now focussing on the 'where' of things—where products are shipped, where product inventories are stacked in stores, where products are advertised, or where products are consumed, etc.—every business transaction has a geographic dimension and is, thus, becoming essential for spatial analytics. A study carried out by Dresner Advisory Services in 2017[25] reveals that among 30 technologies and initiatives consisting of facets varying from strategic to business intelligence, spatial/locational intelligence ranks 20th.

Pitney Bowes, a location intelligence solutions provider,[26] identifies that social media companies like Facebook and Twitter utilise location-based data and this data is also utilised by bigger entities like Google and Bing to process that geoinformation, so that they can do a better job of servicing their clients. Location intelligence, along with business intelligence, truly amplifies technology.

Advantages to Industries:[27] With the success of integration, more and more industries are adopting the new technology. The following are the major sectors that are engaging spatial analytics to the BI domain.

Energy: Enabling the energy industry to discover generation and usage patterns and identify gaps in the shortest possible time.

Transport and logistics companies: For identification of fastest transportation routes, optimising warehousing processes and stock flows

25. Embedded Business Intelligence Market Study, 2017 Edition, https://www.microstrategy.com/getmedia/8cbce43f-22fe-4bb4-bcd4-9515ca7a8e15/Wisdom-of-Crowds-Embedded-Business-Intelligence-Market-Study-by-Dresner.pdf. Accessed on June 20, 2018.
26. Pitney Bowes, "GIS Solutions", http://www.pbinsight.co.in/. Accessed on June 20, 2018.
27. Paul, n. 23.

Like private enterprises, governments are also actively incorporating spatial analysis into decision-making processes. This integration is helping them in achieving speed, accuracy, and cost-effectiveness in information dissemination, urban planning, and service delivery.

based on the consumption rates of particular products by locality.

Real estate and commercial developments: Real estate is really about the location and, thus, focusses more on this field. Geospatial insight helps in determination of optimum sites for development and further planning, construction and maintenance of projects.

Telecommunications: It enables the industry to assess the strength of the current infrastructure and helps in understanding which locations will provide the best network coverage at the lowest price possible.

Retail and wholesale industry: It is helping the industry gain invaluable insights in stock delivery, store management, inventory management, marketing and sales along with physical store-level details.

Insurance companies: The companies analyse location-based data, such as crime rates, weather patterns, etc., for enabling them to identify high or low risk cases and develop marketing strategies and policies.

Finance and banking sector: The financial sector is using location data and analytics of customers to carry out customer segmentation and profiling which helps in the development of more successful marketing and sales campaigns and helps identify and actively retain and pursue profitable customers.

Airports and airlines: Globally, airlines use spatial analytics to track flight operations more closely and accurately. Airport, meteorological, and fleet data is monitored in real-time, and the operations crew re-route flight paths to optimise fuel and staff costs. The technology also provides the ability to geolocate any flight at any point of time.

Education: This sector is utilising geoinformation of student data to enable higher education institutions to develop more effective marketing campaigns and better understand where to put facilities. This will also provide basic trained personnel in the domain for further utilisation.

Like private enterprises, governments are also actively incorporating spatial analysis into decision-making processes. This integration is helping them in achieving speed, accuracy, and cost-effectiveness in information dissemination, urban planning, and service delivery. It is now established that in the times to come, industries will benefit from emerging technologies like visual analytics, geospatial intelligence fusion, crowdsourcing and forecasting.

The relationship of cyber information with human geography defines the path taken by a GEOINT analyst. The analyst's role is to discover, describe, explain, and interpret geographic and cyber information in order to generate cyber geo-intelligence products.

GEOSPATIAL INTELLIGENCE AND CYBER SPACE[28] (CYBER GEO-INTELLIGENCE)

Geospatial Intelligence (GEOINT) and cyber space are interwoven and are equally applicable in the military and non-military arenas. This can also be classified as a dual use domain.

In the US Army's *"Cyberspace Operations Concept Capability Plan 2016-2028"*, cyber space has been categorised as one of five domains of warfare amongst the other domains (air, land, maritime, and space). Most importantly, cyber space nodes are physically present in all the other domains. It is possible that activities in cyber space may affect activities in the other domains, and activities in the other domains can also create effects in, and through, cyber space. The technology ensures an exponential increase in the volume, variety, and velocity of the available data for geointelligence extraction.

The relationship of cyber information with human geography defines the path taken by a GEOINT analyst. The analyst's role is to discover, describe,

28. GEOINT and Cyber Space, psu; https://www.e-education.psu.edu/geog479/node/4. Accessed on July 12, 2018.

explain, and interpret geographic and cyber information in order to generate cyber geointelligence products.

For this task, the analyst scans and analyses the internet. Geospatial tools like distance and neighbourhood are used for analysing data flow between cyber entities.

The analysis of an open source requires an approach which sieves through a massive amount of data from the social media or other sources to create finished information. There is a common practice of analysts, often using multiple sources of information to create actionable intelligence. Some developed countries clandestinely monitor the internet for keeping an eye on the usage. To link cyber information with geography, a working model has been taken into consideration.

Classic models of the cyber domain state that cyber space can be described as comprising three layers, i.e. the physical, logical, and social. With an aim to identify the relationship with the geospatial environment, the element of geospatial location is tagged in the operational loop. Therefore, for ascertaining the information flow within the loop, these three layers have been embedded with five mutually supporting components, i.e. geographic, physical network, logical network, cyber persona, and persona. The Information Technology (IT) infrastructures and data embedded within these layers define cyber space as two distinct environments, i.e. information and operational.

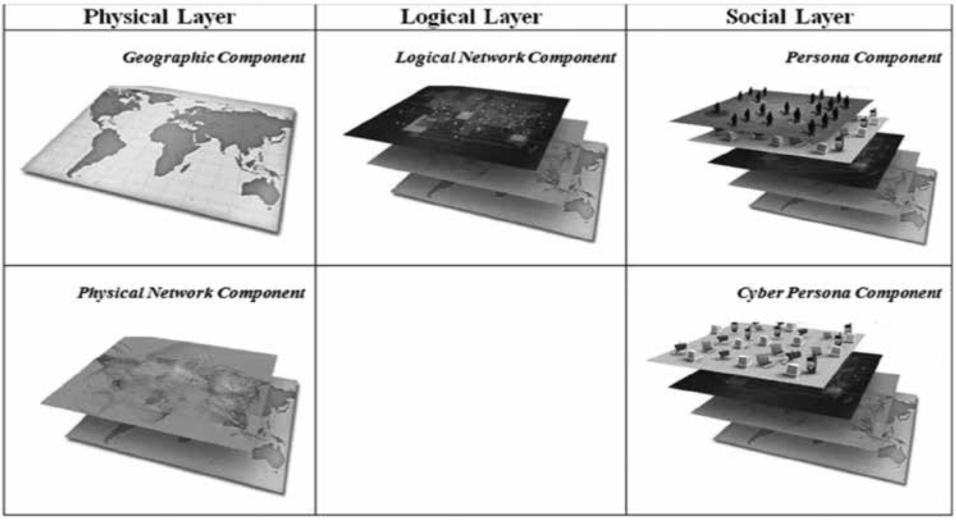
The relationship between all the layers is depicted in Fig 3.

The **physical network layer**[29] includes both geographic and physical network components. The geographic component consists of the geographical location of the cyber elements of the network. The geospatial signature of the entity defines the physical presence of the subject and subsequent identification of the network. The physical network component consists of the actual equipment associated with the physical infrastructure (wired, wireless, and optical) and the inter-connectivity that supports the transfer of the code and data on the networks and nodes. These components may

29. Layers of Cyber Space, FM 3-38, Cyber Electromagnetic Activities, February 2014. Accessed on July 18, 2018.

include any connector, system and other networked device where data is created, manipulated, processed, and stored.

Fig 3: Three Layers of Cyber Space (physical, logical, social) and Five Components (geographic, physical network, logical network, cyber persona, persona).



Source: The United States Army's Cyberspace Operations Concept Capability Plan 2016-2028, TRADOC Pamphlet 525-7-8.pdf and FM 3-38.

The **logical network layer** consists of the components of the cyber network which, although interconnected with each other, are distant from the physical network. The example may be of entities in the physical layer which are logically related to one another to form broader entities in cyber space that are not tied to a specific node, path, or individual. Another example could be of similar websites hosted on servers in multiple physical locations where content can be accessed through a single uniform resource locator or web address.

The **social layer** includes a cyber persona layer and a persona layer which are distant from the logical network, and it uses the domain of the logical network layer to form a digital signature of an individual or entity in cyber space. The persona layer consists of the individuals who actually operate the network and, therefore, have digital signatures that can be identified and attributed for any activity. These signatures may include various operational elements like Internet Protocol (IP) addresses, social networking IDs, e-mail IDs and cell phone numbers. Cyber personas have important attributes in terms of fixing responsibility and targeting the source of a cyber space threat. It may happen that a single persona may have links to multiple entities of cyber personas, therefore, significant intelligence collection and analysis capabilities may be required for attribution.

Activities by the US National Geospatial Agency (NGA):[30] The US NGA supports its cyber community by providing imagery information to the cyber warriors. Experts defending the United States from a cyber attack utilise a new geospatial tool by being able to visualise the facility from where the digital activity is taking place.

The NGA has in the past provided a variety of value-added geospatial products to customers throughout the defence and intelligence communities. The NGA is of the view that the agency can help provide information about a potential location of cyber activity. The NGA helps find that site and it can also provide imagery products for efforts against cyber criminals. Bringing the location information to visualisation is the most useful activity for cyber warriors.

When a location where malicious cyber activity might be occurring is seen , it enables much better understanding of what might be going on at that site. The NGA is of the opinion that if the cyber community finds that some malicious activity is taking place, then, with the help of GIS tools, this geolocation can be identified. The issue of precise identification of the geolocation required a constant surveillance on the suspects and the information has to be correlated with other inputs. Stakeholders would have to approach the NGA with intelligence on potential cyber target areas, and the agency would need to incorporate this information to narrow down the location.

Customers usually request a simple description of the potential target—its appearance, its location and any other distinguishing features. This description could be very revealing—for example, a set of microwave dishes

30. Robert K. Ackerman, "Intelligence Generates a Cyber Picture", *Signal Magazine*, June 1, 2014, https://www.afcea.org/content/intelligence-generates-cyber-picture. Accessed on July 20, 2018.

on a building's roof could tip off analysts that a structure is more than just an innocuous building. In some cases, stakeholders ask the NGA to identify a specific location. It's an iterative process and is performed in collaboration and it sometimes helps the agency to narrow down to the target.

Geoanalytic tools are applied by the NGA to investigate cyber geo-intelligence missions, along with other areas of collection for fusion. The agency's partnership with the National Security Agency (NSA) and the US Cyber Command assures that the NGA strives to develop this tradecraft.

Cyber Threat Intelligence Assessment:[31] The ingredients of geospatial information come in the form of feed from several sources. An insight to this is being provided by several cyber threat assessment sites which are operating and providing assessment services the world over, the important ones being Norse, Kaspersky, Fire eye, Fortinet and Checkpoint. Norsecorp IPViking claims to be providing geolocation assessments for the users. Questions are asked about whether these provide real-time data or not. As originator and target information is being provided, this leads to geolocating the cyber activity and enhances the situational and spatial awareness. There are several activities which go unnoticed but in the case of any suspicion, the inputs are to be correlated, fused and analysed.

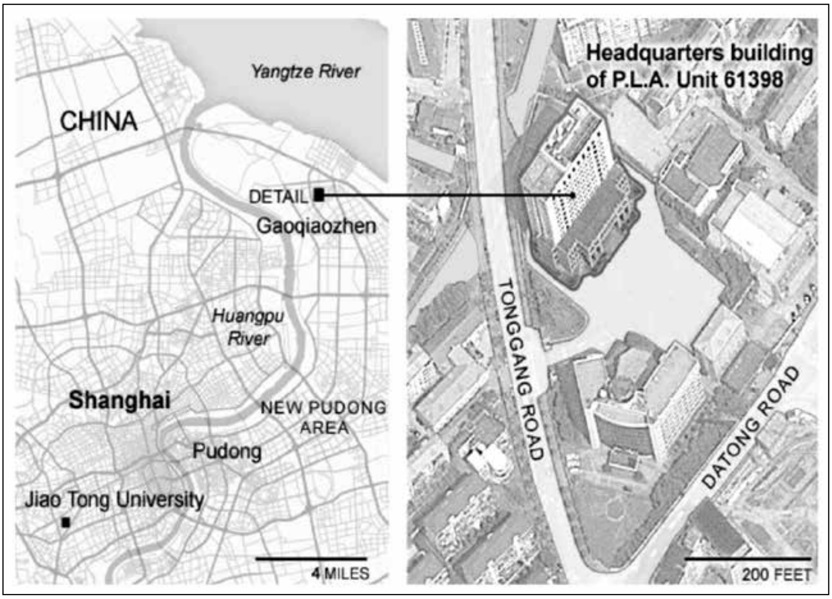
Norsecorp is said to monitor all internet traffic routing through its honeypots[32] and is able to identify most of the data. However, the threat assessment in terms of commercial and military use is required to be ascertained at each decision level.

Great Firewall of China (GFW) and Geolocation of China's Cyber Unit: The "Golden Shield Project", popularly known as the "Great Firewall of China (GFW)", launched in 2003, provides security at Internet Service Provider (ISP) level and ensures verified interaction between the global internet and the Chinese internet.[33] GFW is also said to be more liberal towards traffic inside China and operates mostly for traffic being tested at the Chinese

31. Real Time Visibility, IP Viking; http://map.norsecorp.com/#/. Accessed on July 24 , 2018.
32. In computer terminology, a **honeypot** is a computer security mechanism set to detect, deflect, or, in some manner, counteract attempts at unauthorised use of information systems.
33. R Bu, "The Great Firewall of China", 2015; http://campus.murraystate.edu/academic/faculty/wlyle/540/2013/Bu.pdf. Accessed on July 24, 2018.

borders. The structure of China's internet is different from that of other countries, and it is said that the accuracy in geolocating the IP addresses is subject to certain restrictions by the GFW but the efforts put into this field by researchers are encouraging. By various mapping techniques and fusion of information, it has been possible for researchers in the USA to pin-point the location of activities of a cyber unit of the People's Liberation Army (PLA) which has continuously been carrying out cyber activities against the USA. The location, as analysed, is shown in Fig 4.

Fig 4: the Location Intelligence: Unit 61398[34]



Mandiant, a computer research consultancy firm, brought out in a report in 2013 that Unit 61398 was actively involved in cyber operations against the global network. It suggested that the cyber unit was operating out of a nondescript 12-storey white tower off Datong Road in the Pudong New area of Shanghai. The report claimed that the cyber unit represented one group of actors in a "long-running and extensive cyber espionage campaign"

34. Source: Mandiant APT1 Report; https://www.fireeye.com/content/dam/fireeye-www/services/pdfs/mandiant-apt1-report.pdf. Accessed on July 24, 2018.

that Mandiant contended could only be sustained with "direct government support." Based on the size of this facility, Mandiant speculated that the unit employed hundreds and possibly as many as 2,000 people.[35]

Fire eye[36] (of which Mandiant is a part now) has denied using a technology named as *hack back* in which the investigators turn on the web cams of the hackers during the process. However, Mandiant continues to stand by its report on Unit 61398.

EMERGING AREAS OF GEOSPATIAL ANALYTICS

Geospatial Fusion[37]

Geospatial fusion is achieved by combining geographic information from multiple sources which may belong to various sensors, networks, databases and documents. Fusion is performed to evaluate spatial or spatiotemporal phenomena for purposes such as tracking, prediction or reconstruction of an environment. For example, a situational assessment of a major flood may fuse imagery data from airborne or satellite sensors, social media, news and reports from observers on the ground. In the present era of technological advancement, fusion is important because assessments of a phenomenon from multiple sources of information are likely to be better than those from a single source. In the military context, fusion is the most important part of warfare as it provides the necessary real-time inputs to decision-makers in the field.

CROWDSOURCING[38]

The term crowdsourcing is defined in the 2011 *Merriam-Webster Dictionary* as "the practice of obtaining needed services, ideas, or content by soliciting contributions from a large group of people and especially from the online

35. Ibid.
36. https://www.itnews.com.au/news/fireeye-denies-hack-back-against-chinas-unit-61398-495612. Accessed on July 30, 2018.
37. National Academies Press, catalogue; https://www.nap.edu/catalog/18265/future-us-workforce-for-geospatial-intelligence. Accessed on March 7, 2018.
38. Crowdsourced GEOINT data, Penn State University; https://www.e-education.psu.edu/emsc100s/node/828. Accessed on March 7, 2018.

The application of visual analytics tools is used to extract inferences from huge, variable, and often contradictory geospatial data and other information so as to ensure that human intervention is limited and does not affect the analysis.

community rather than from traditional employees or suppliers." Crowdsourcing is related to participatory sensing, which shares the same principle of collecting data from a set of users working collaboratively.[39]The two terms (crowdsourcing/participatory sensing) are often used interchangeably, but the preferred term implies not only data collection but also other types of group activities, such as utilising professionals' work. Spatial information provided by crowdsourcing is generally referred to as volunteered geographic information. As the information is collected by volunteers, there is a huge challenge of accuracy, credibility, and reliability. With the increasing use of crowdsourced data, issues of data quality, purity and uncertainty will increase in importance. An example of this can be found in Digital Globe (a commercial imagery provider) providing its imagery for the search of the missing MH 370 flight. Tomnod, an analytics company, ran a campaign for the search of the flight in the open domain and approximately 60,000 counts were received.[40]

VISUAL ANALYTICS

Visual analytics is the science of analytic reasoning, facilitated by interactive visual interfaces integrated with computational power and database capacity. Analytical reasoning is essential to the analyst's task of drawing conclusions from a dissimilar set of evidence and assumptions. The application of visual analytics tools is used to extract inferences from huge, variable, and often contradictory geospatial data and other information so as to ensure that human intervention is limited and does not affect the analysis. Effective utilisation of the powerful human perception system for visual analysis tasks

39. Crowdsourcing; https://www.digitalglobe.com/products/crowdsourcing. Accessed on March 7, 2018.
40. MH 370, Search; http://blog.digitalglobe.com/crowd/flightmh370possibledebris/. Accessed on March 10, 2018.

requires the applicability of the appropriate human-computer interface. An example of this could be analysis of movement of people and objects on a large scale through the use of GPS.[41] The application is presently widely used by different search engines like Google maps.

Geospatial data in the present times is an essential ingredient without which no geospatial application can be performed. The data, whether structured or unstructured, provides ample time, space and tools to analyse and arrive at an informed and structured decision.

FORECASTING[42]

Forecasting is a technique that uses observations, knowledge about the processes involved, and analytical skills to anticipate outcomes, trends, or future behaviours. Geospatial and predictive modelling tools are engaged for predictions and anticipatory intelligence. Predictions and anticipatory intelligence estimate what may happen, along with the odds of it happening (such as predicting reallocation of forces in the case of a changed operational scenario). Geospatial modelling may provide a hot spot analysis for events taking place on a regular basis. An example of this is obtaining data regarding smart city development.

In the geospatial domain, it is important to understand that forecasting addresses the concerns regarding what, where, when, and how events will unfold and how processes will evolve in space and time. The ability to forecast is in the core of many scientific disciplines. Geospatial events and processes are a result of real-time communication amongst the human natural artistic behaviour and scientific environments as well as social and cultural systems across global, regional, and local scales.

CONCLUSION

Geospatial data in the present times is an essential ingredient without which no geospatial application can be performed. The data, whether structured

41. Information Visualisation, Visual Analytics Applications, p. 169; https://link.springer.com/chapter/10.1007/978-3-540-70956-5_7. Accessed on March 10, 2018.
42. Future work force for geospatial intelligence, n. 31.

or unstructured, provides ample time, space and tools to analyse and arrive at an informed and structured decision. GIS is the backbone of all such applications, and along with the analyst's capability, the technology is able to derive fused results for all the stakeholders and decision makers.

The applications discussed such as cyber, business, environmental areas, infrastructure development and disaster mitigation mostly cover the civil domain; however, some of these could be of dual use. The easy availability of commercial imagery, GPS data, business domain data and OGC compliant GIS makes the task goal-oriented. In the future, it is perceived that most of the businesses will actively utilise geospatial data driven by artificial intelligence for better competition and business prospects. Applications in support of military stakeholders in the external and internal security environments demand interdependent data sets for various fused products which can be utilised by different users in an integrated environment. The expertise in the military context also needs to be developed on the lines of the NRSC, which has proven its worth at the national level.

In the Indian context, the academia, industry and research institutes play a vital role as the applications are still at a nascent stage and the integration requires a holistic approach towards capacity building and development of this technology.