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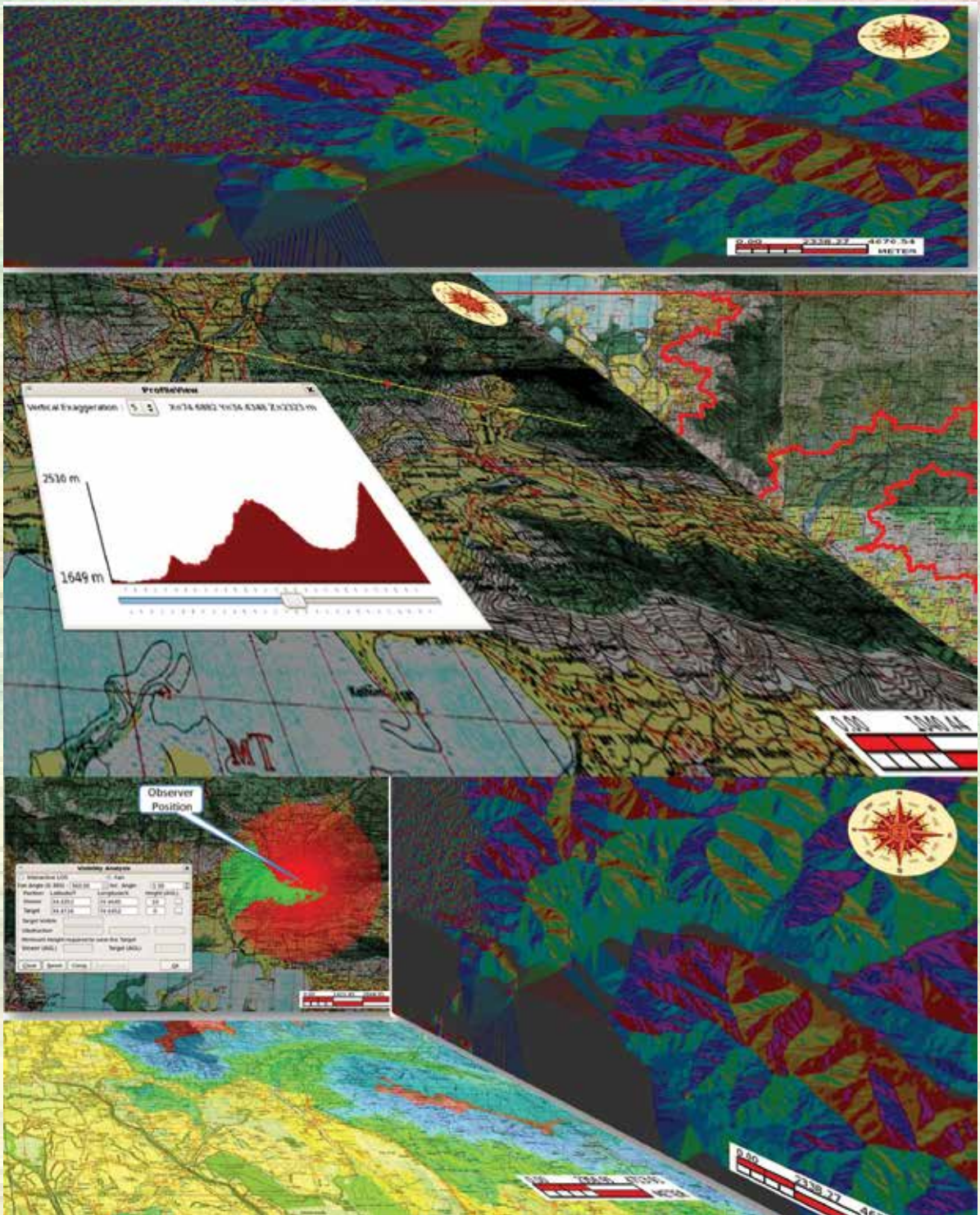
INDIGIS: AN INDIGENOUS GIS FOR DEFENCE APPLICATIONS



Technology Focus focuses on the technological achievements in the organization covering the products, processes and technologies.

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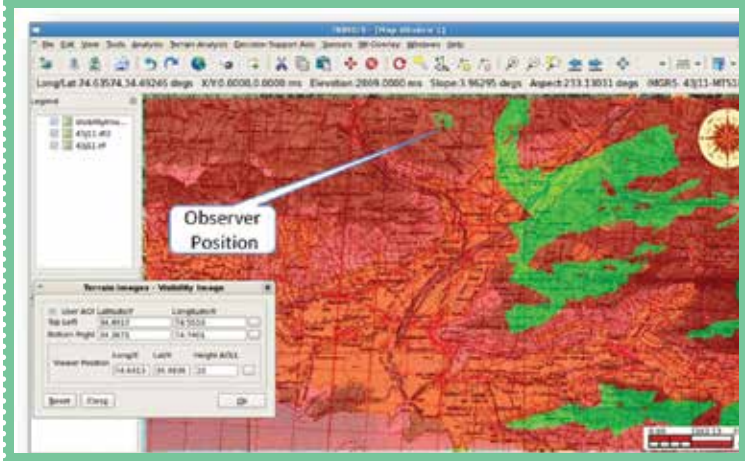

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From the Desk of Editor-in-Chief

Dear Readers…

As the law of nature, the new year brings new hopes, new dreams and new goals. Albeit last two years have been tough when the world is struggling in the quagmire of Covid-19. In the quell of the pandemic, many of us lost our near and dear ones, but life is all about moving on. So, wish you all a very happy new year. Let's take a stock of the year gone by and plan for the future. It's an immense pleasure that *Technology Focus* (TF) is entering in 30th year of continuous and successful publishing. Over the years, TF has highlighted the tireless efforts and achievements of the DRDO to its diverse readers including our Users, the Services, paramilitary forces, policymakers, S&T institutions, our partners both in academic as well as in industry, prospective buyers of Make in India defence technologies and above all budding scientists, our students.

In the year 2021, TF has covered specialised areas like DESIDOC: Knowledge Repository, Par Excellence; Netra: The Indigenous Airborne Early Warning & Control System; Futuristic Airborne Surveillance Technologies; Biomass and Bioresource: Technologies for Self-Reliance; Small Arms and Ammunition. DRDO has proved its capabilities under these areas, and the number of systems produced under these technologies have either been inducted into the Services or are under the final stage of development.

Today when I write as Editor-in-Chief of *Technology Focus*, I put on record my acknowledgment and appreciation for the exemplary team effort encompassing DRDO labs, editorial team and honest readership. The editorial team and all those involved are determined to maintain and enhance the status of the magazine and its position. I thank various DRDO laboratories for their wholehearted support in forwarding the writeups for the magazine. I invigorate and encourage DRDO scientists to come forward to submit their excellent works. Your active participation is greatly appreciated. I also thank a large number of readers who have requested printed copies. I call them all to kindly visit our link (https://drdo.gov.in/technology-focus) on the DRDO website or scan the QR code on the cover page of the magazine. In the end, I hope that DRDO laboratories would keep providing their valued contributions in 2022 also. I, on behalf of the Editorial Team, thank all the contributors, the DRDO community, and our valued readers and wish them very best wishes for 2022.

Sincerely

Dr K Nageswara Rao
Director, DESIDOC

From the Desk of Guest Editor

Dr Subrata Rakshit

Dr Narayan Panigrahi

Over the years Centre for Artificial Intelligence and Robotics (CAIR) has developed many indigenous technologies to aid in the adoption of ICT-based military systems by Services. One such critical success story is in the area of Geographic Information System (GIS). INDIGIS technology has been found useful in many user units, in systems under production by DPSUs, and in several ongoing DRDO system development projects. It is proving to be useful for visualisation, analysis and measurement pertaining to geo-spatial data in the form of digital maps. The uniqueness of INDIGIS technology is its capability to analyse and visualise spatio-temporal data in a unified way, whether the data pertains to land, sea and air in the form of terrain maps, bathymetric charts or air navigation charts. The technology has proved its robustness and scalability in visualising large scale spatial data from various sources and sensors, proving its usefulness in various DRDO projects.

The indigenous GIS system has addressed the data import-export related interoperability issues faced by Users among various COTS GIS systems, besides serving as a platform for many technology breakthrough and innovations (DRDO IPR). The subsequent CAIR projects based on this GIS technology has served to exemplify a modular approach to GIS applications, where the back-end technology, the application front end and the import-export of standard data formats can be mixed and matched to provide affordable, timely solutions with lower cost of ownership and avoidance of vendor lock-in.

Based on its usefulness for operational planning, depiction of common operating pictures and interoperability, the system has been used and retrofitted in multiple systems produced by BEL for Indian Services, and has also been exported to friendly foreign countries. Besides BEL, which is a ToT recipient of the full military version, other industries are coming forward to take ToT of a civilian variant of INDIGIS.

The mission of indigenization of GIS, spatial computing technologies and its inception has been taken up by a team of scientist under the leadership of Dr Narayan Panigrahi. It has resulted in its insertion in different systems developed by DRDO and user formations.

I am sure this homegrown technology will continue to add value in future indigenous military systems and also have a positive effect on shaping the commercial GIS offerings to MoD and GoI in years to come.

Dr Subrata Rakshit
OS & Director, CAIR

INDIGIS: AN INDIGENOUS GIS FOR DEFENCE APPLICATIONS

Indigenous GIS Mission

The Centre for Artificial Intelligence and Robotics (CAIR) has developed many Command and Control Systems (C2), Command Control and Communication Systems (C3) and Tactical Command Control Communication and Intelligence Systems (Tac C3I) Systems for various armed force users. To name a few, Artillery Command Control and Communication System (ACCCS), Battle Field Management System (BMS) and Command Information and Decision Support System (CIDSS). A common factor of all these Operation Information System (OIS) is terrain information which is available in digital form as spatial information through a Geographic Information System (GIS).

The GIS is a collaborative information system which helps in visualisation, analysis and measurement of spatio-temporal data associated with land, sea and space. Most of the GIS systems used in Tac C3I systems were COTS (Commercial Off-The-Shelve System) originating from foreign OEMs.

The COTS GIS available in market are licensed and hence have significant license cost and license-based usage restriction. Also most of the COTS GIS are, non-interoperable in the sense that, while they may import spatial data from many sources and formats, but export in only their own native formats preserving full functionality. Also most of the COTS GIS are not able to display the Indian military grid reference.

Another aspect of COTS GIS are WINTEL (Windows OS and Intel CPU) compatibility and are non-availablity in many other platforms as may be required for security or reliability considerations. In addition to these the COTS GIS were not so flexible to customise to accommodate the user specific workflow and are often subjected to the risk of technology denial. Therefore, to overcome the above pitfalls, CAIR undertook a technology demonstration project named "Development of Indigenous Geographical Information System for Military Applications". The resulting outcome of this project is the INDIGIS technology which is a platform for customisation and integration of various military applications. This technology is available in the form of a Software Development Kit (SDK) making it available to the application developers through 524 Application Programmer Interface (API) and is available in LINUX, Windows and Android OS. This indigenous GIS is available in desktop and client/server platforms.

INDIGIS Technology

After many successful customisations of COTS GIS and their delivery to Users, it was felt that most of these customisation efforts and intellectual wealth generated by the scientists in customising the COTS GIS were going futile as the core of the GIS was undergoing change or because of merger and accusation of the COTS GIS by other OEMs. Therefore, it was decided by CAIR (DRDO) to design and develop an indigenous GIS for military applications. A Technology Development (TD) project namely INDIGIS was sanctioned to this effect in 2007 which resulted in development of indigenous GIS kernel named as 'INDIGIS' which is available to the DRDO community and user community in the form of a SDK. Both as a validation and as a concrete guide, an application called INDIGIS having 136 different end user military functions was also developed as part of the TD project itself. The SDK has roughly 550 APIs, user manual, installation manual and programmer's manual. After the successful completion of the project INDIGIS was installed in various Indian Army and Indian Navy formations for couple of years and took the user feedback for its operational utility. Some of the unique functions which were

developed during 2012 to 2015 were found very useful in field exercises of Indian Army and Navy. Some of the unique functions of INDIGIS was so useful that many DRDO projects came forward to make use of the indigenous GIS in different context integrating to different systems. Looking at its usefulness and utility in various projects BEL (Bharat Electronic Limited), Bangalore, took the first ToT of INDIGIS technology in 2018. BEL successfully integrated this technology in 15 different systems under production and deployed as many as 100+ field licenses in user sites based on the unique capabilities of INDIGIS in visualization and rendering of large volume spatial data of digital data in the form of digital maps, bathymetric charts and long distance navigation charts. Besides these, INDIGIS has been designed to have many unique relevant capabilities like

⌘ Seamless visualization of land and sea maps (Topo-bathymetry surface unified datum, projection and co-ordinate system) for amphibious operation planning

⌘ Measurements of location, distance, direction, height, slope aspect, curvature of terrain surfaces in different datum and units

⌘ Simulation of 3D perspective view, fly-thru view and orthographic view of terrain

⌘ Creation and manipulation of operation overlay using (customizable) Indian military symbols and the subsequent transmission of the encoded operation overlays between nodes

⌘ Spatio-temporal query in the form of spatial query, temporal query, buffer zone analysis and iterative and cascaded query of both terrain data and operation data

⌘ Large scale visualization of sensor data and its real-time updating. Integration with GPS, INS, RADAR, LiDAR, SONAR and UAV. Depiction of UAV video overlaid of satellite image and digital maps for surveillance. Support for enabling manually assisted auto geo-coding for UAV videos that are lacking in inherent digital geo-coding telemetry data is currently being added

⌘ Support for various military maps in use by Indian armed forces

Input domain that can be processed by INDIGIS which reflects the capability of the technology at presented in Table 1.

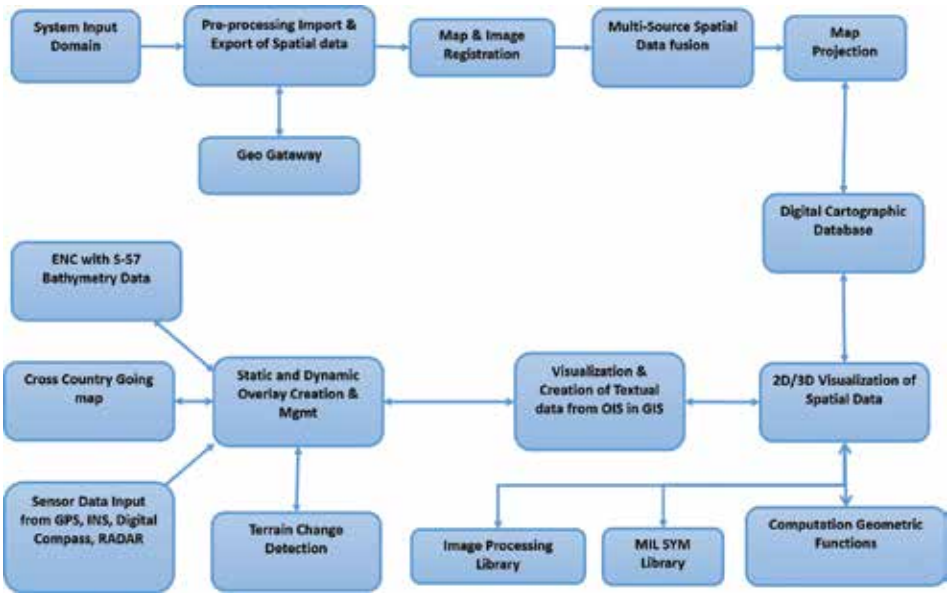
Table 1 : Input Domain of INDIGIS

Data Type	Format of the data	Sources and agencies providing the data	Utility of the data Indian Army, Navy, IAF and Tri-Services
Raster Data	TIFF, GeoTIFF, BMP, JPEG	CAMS, ADRIN, NRSC, MI-17, DIPAC, SoI	All services
Vector data	DGN, DVD, DXF, SHP	CAMS, SOI, ADMC	All Services
Satellite Image,	BIL, BIP, BSQ, GeoTIFF, TIFF	NRSC, DIPAC	All Services
Bathymetry Data	S-52, S-57,S-63	NHO, IN	Navy and Hq Tri-Services
Air Navigation Charts	LNC in GeoTIFF and Geo PDF	IAF	All Services
Digital Elevation Models, Digital Surface model	dt1, dt2, GeoTIFF, Geo PDF	CAMS, ADMC, NRSS	All Services
Indigenous data Formats	Indigenous vector, raster and overlay format	INDIGIS	All users of INDIGIS
Sensor data from GPS, DGPS, LiDAR, SONAR, RADAR, INS, CAMERA	Astrik format, CSV, NMEA	Sensors	All users and systems

Features and Capabilities

The INDIGIS is a suite of GIS components, developed indigenously by CAIR. INDIGIS component suite is a set of GIS libraries, which are customisable, scalable and data centric, and cater to the specific GIS requirements of a collaborative defence environment. The functional architecture of INDIGIS is depicted in the block diagram.

INDIGIS libraries can be customised to build Military GIS applications to facilitate in planning, executing and supporting of operations. The basic features and capabilities of the library is shown.



Functional Block Diagram of INDIGIS

Basic Features and Capabilities of INDIGIS

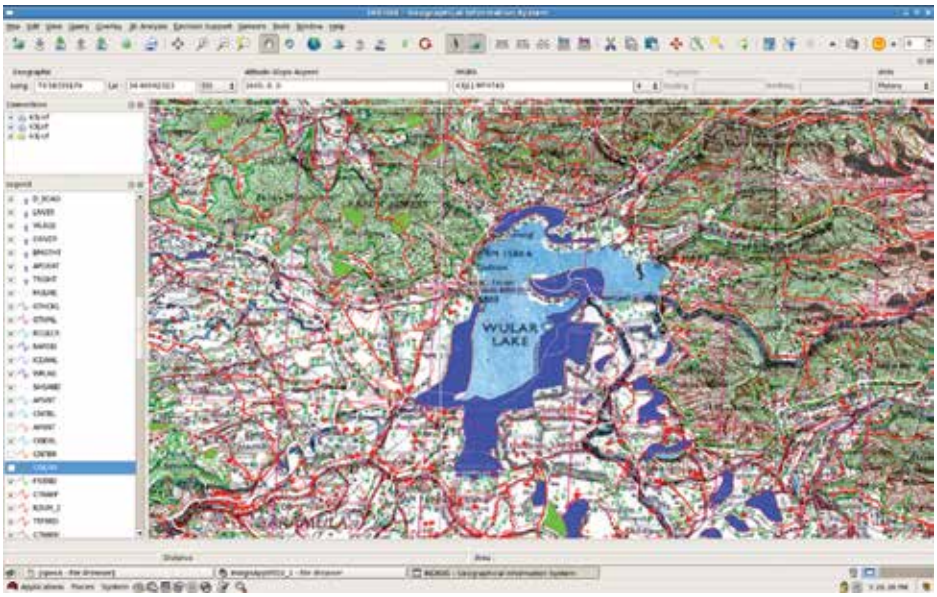
Geospatial Data Formats

INDIGIS allows the user to open map data from flat files of various standard spatial data formats. The map data can also be opened from a relational database like PostGIS. User can open multiple maps pertaining to his/her Area of Interest (AOI). Each such map will be added to the warehouse as a map connection. These maps could be of different data formats and map projections. The supported geospatial data formats are illustrated in the Table. Irrespective of the source data formats and projections, a seamless integrated multi-layer display of maps will be generated in the map window. Once the data is loaded, they can be visualised and analysed in various manner. The software allows to export the data loaded in the application to a given data format.

Map Visualization

A map window provides an interactive graphical display of map data (geographic and other objects). The feature classes belonging to vector map connections and images belonging to raster map connections are displayed on the map view area of a map window. Map window allows the User to compose the desired display of map interactively. User can display on/off map layers as needed. Also, it allows changing the display order of layers. Map window supports various ways of interacting with the map display. User can change the zoom area, view scale, orientation, etc. through map interaction operations supported by map window.

Unlike analog maps, which are static displays of geographical area in paper forms (mostly), digital maps are highly interactive. Digital map viewing allows the user to compose the map and interact with it on the fly. INDIGIS supports various map interaction functionalities like Zoom, Pan, Rotate operations in various modes as shown.

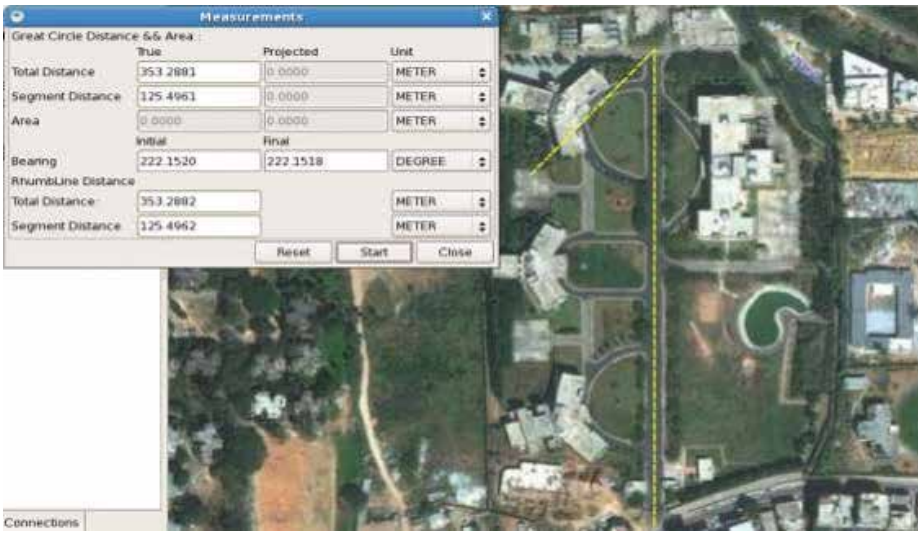


Multilayer Integrated Visualisation of Various Types of Digital Maps

Measurement

INDIGIS provides functionality for measurement such as the length/ distance, or area of a feature on a Map. In distance module, user can select the points along with the distance to be measured. After end of selection, both rhumb line and great circle distance will be displayed. Furthermore, the total distance, bearing and the segmented distance will also be calculated and displayed.

In area module, the user marks the points along which the area is to be measured. After selection, the area, perimeter and total distance will be calculated and displayed.



Distance Calculation on a Map

The distance calculation and area calculation are illustrated.

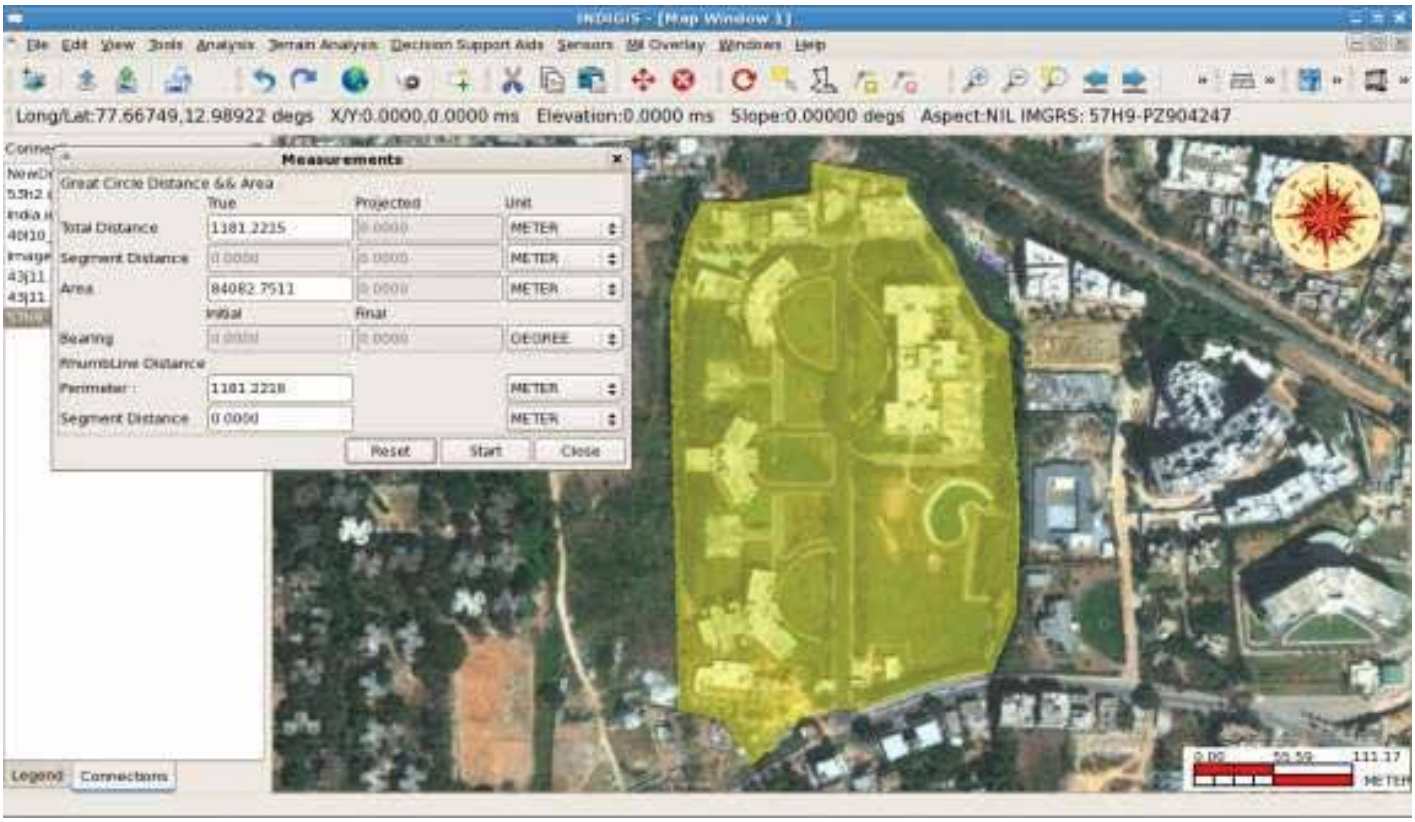
Spatial Data Analysis

INDIGIS provides various ways for the user to analyse the spatial data using queries. Broadly, a query is a request for information. Specifically, it is a request for the features that meet the conditions defined by the User and/or a request for certain information about the features. INDIGIS supports query and retrieval of spatial data using following methods:

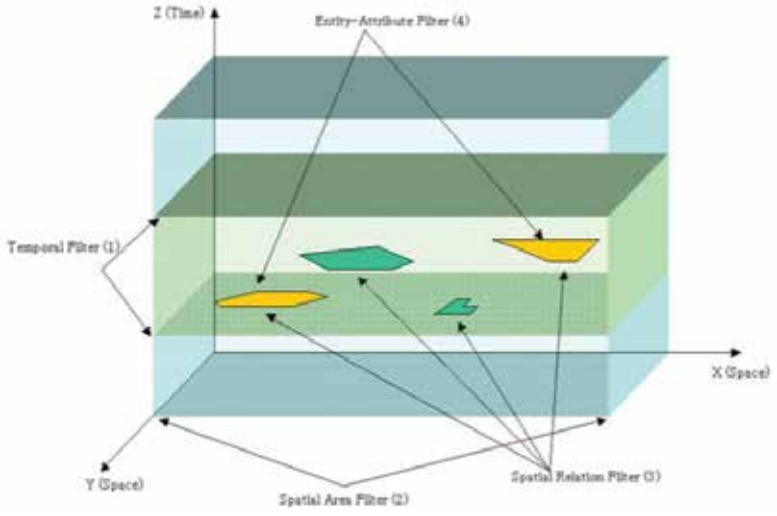
⌘ Attribute query- Filter based on values of attributes of spatial features

⌘ Spatial Query- Filter based on topological relations between spatial objects

⌘ Thematic query- Map composition based on the values of attributes of features



Area Calculation on a Map



Spatial Data Analysis

⌘ Temporal query- Viewing of spatio-temporal data based on time filters

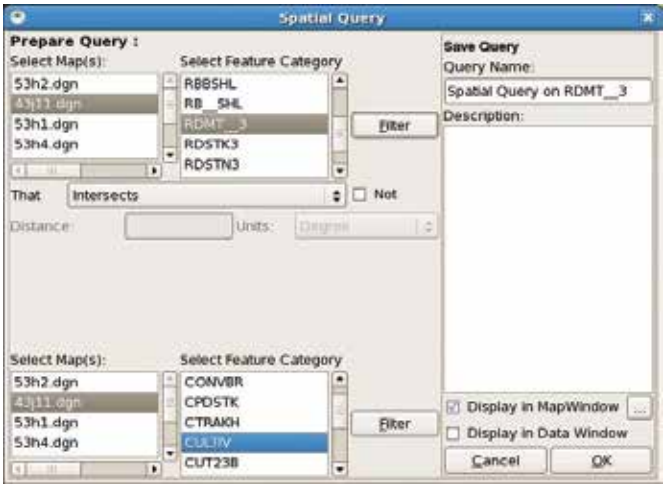
The software scans the query area for the features that meet the query conditions and then displays the results geographically in a map window and/or in tabular format in a data window. An entry for the query result is added to the legend, and its display can be manipulated through the legend properties like any other legend entry. In fact, once built, a query can be treated just like a feature layer. The structure and type of query is illustrated.

Attribute Query

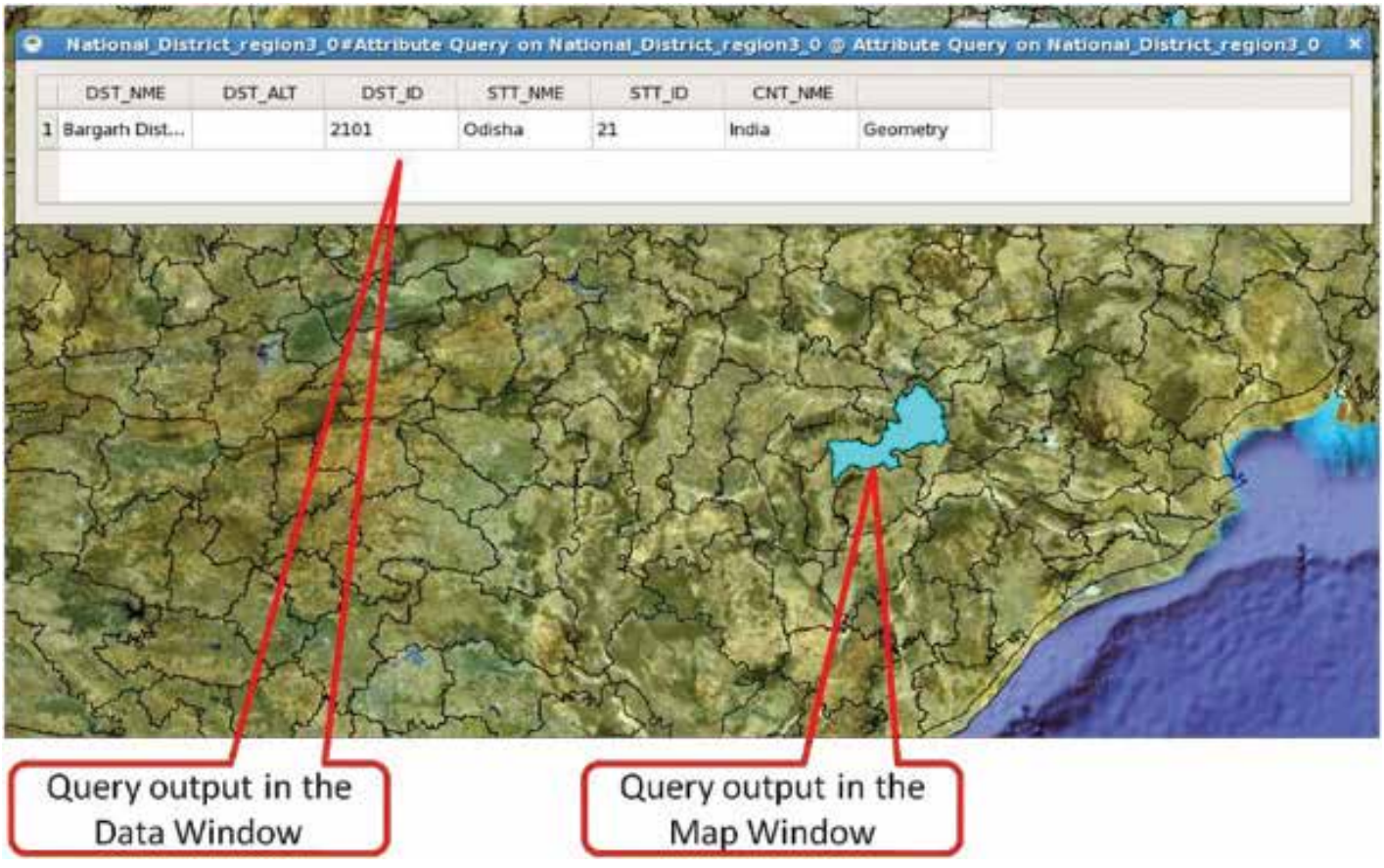
In an attribute-filter query, user identifies the features by defining an attribute filter. A filter consists of one or more expressions, each consisting of an attribute, an operator, and a value for the attribute. In a where statement, user can specify a value or a range of values for one attribute or a combination of attributes. The construction attribute query and the display of results are illustrated. For example, in attribute filter query to select all districts where population is greater than 200000, districts is the feature class, population is the attribute, greater than (>) is the operator, and 200000 is the value. The following operators in Table 2 are available for attribute queries:

Table 2 : Query Operators

=	Equals
<=	Less than or equal to
>	Greater than
>=	Greater than or equal to
<>	Not equal to
<	Less than
LIKE	Like operator for string matching in SQL
( )	Parentheses for grouping expressions
AND	Logical and between two expressions
OR	Logical and between two expressions



Attribute Query Dialog



Display of Query Result in Map Window and Data Window

Spatial Query

A spatial query defines the topological relationship between two feature classes using a spatial operator. The spatial query can be used to filter vector features based on their spatial relationship with other vector features. The construction spatial query and the display of results are shown. The following are the topological relationships (as per OGC) supported in INDIGIS.

⌘ Equal: if geometries are spatially identical

⌘ Disjoint: if the intersection of both geometries is the empty set

⌘ Touches: if the only points in common between both geometries lie in the union of their boundaries

⌘ Within: if the first geometry is completely contained into the second one

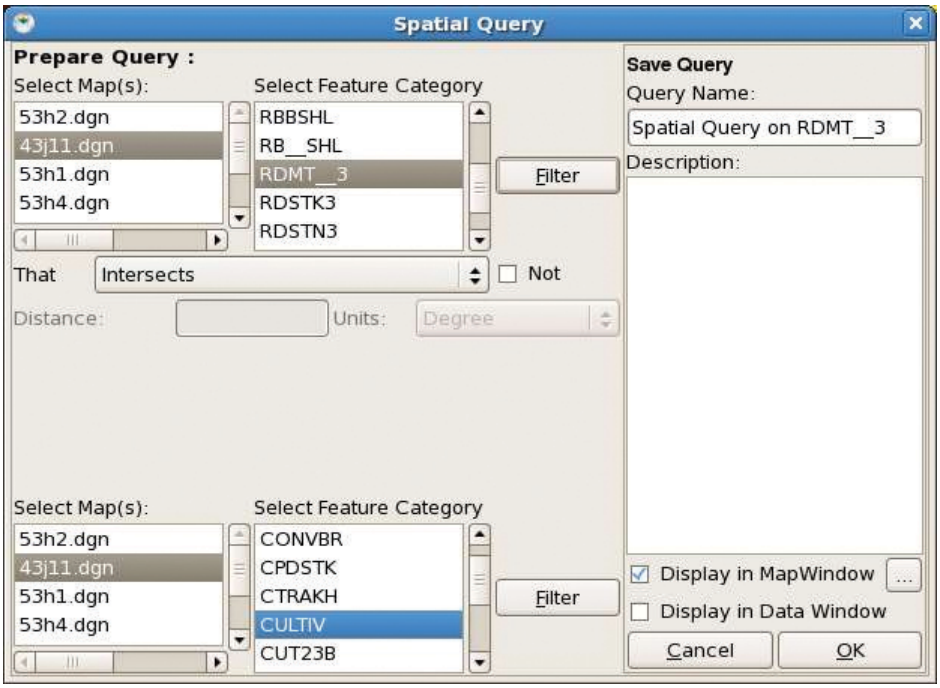
⌘ Overlaps: if the intersection of both geometries results in a value of the same dimension of both geometries and is different from both the first and the second geometry

⌘ Crosses: if the intersection of both geometries results in a value whose dimension is less than the maximum dimension of both geometries and the intersection value includes points interior to both geometries, and the intersection value is not equal to either the first or the second geometry

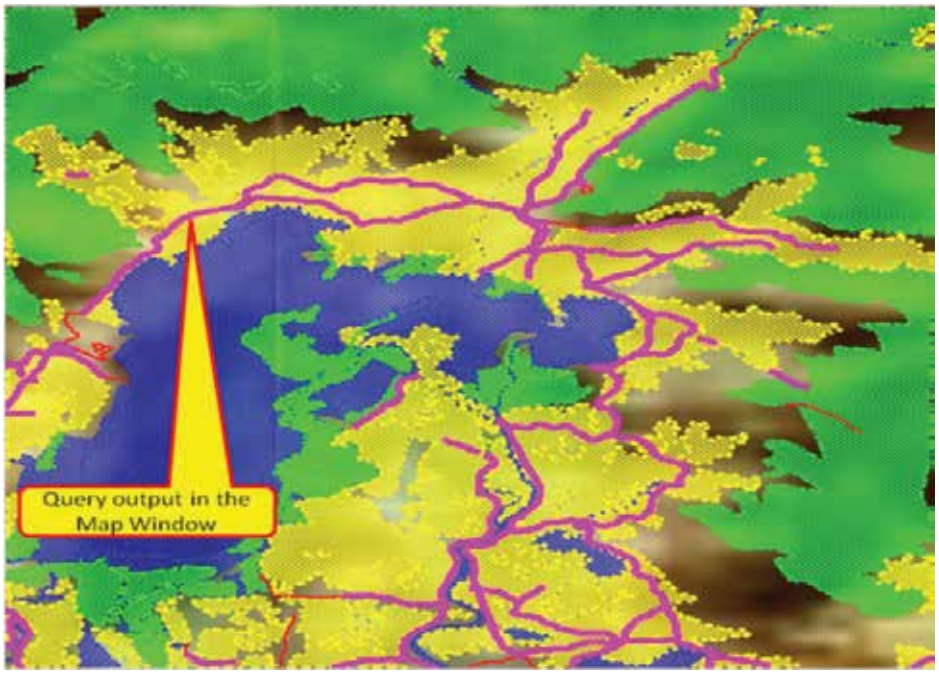
⌘ Intersects: if the intersection of both geometries is not empty

⌘ Contains: if the second geometry id completely contained into the first one

⌘ Relate: allows arbitrary comparison on the basis of a given pattern Matrix



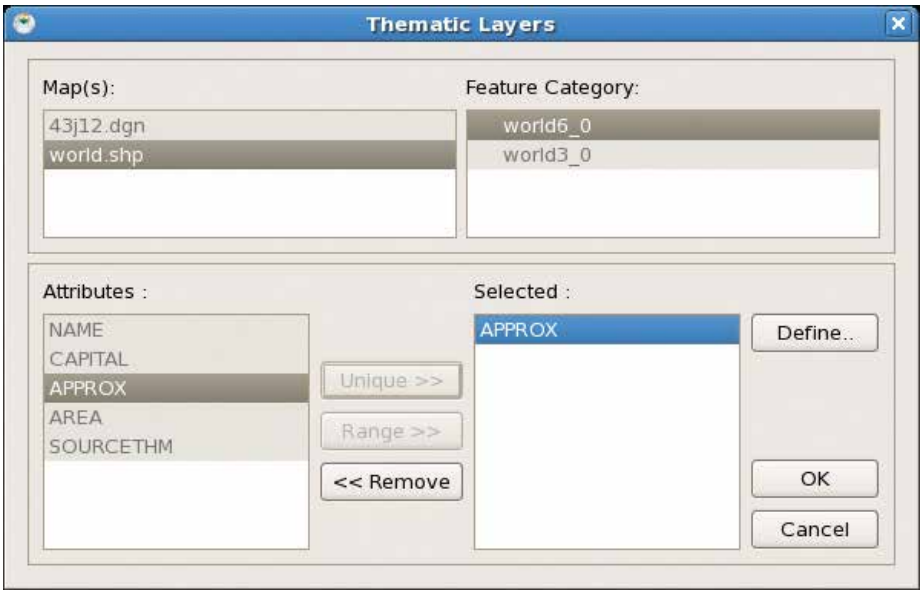
Spatial Query Dialog



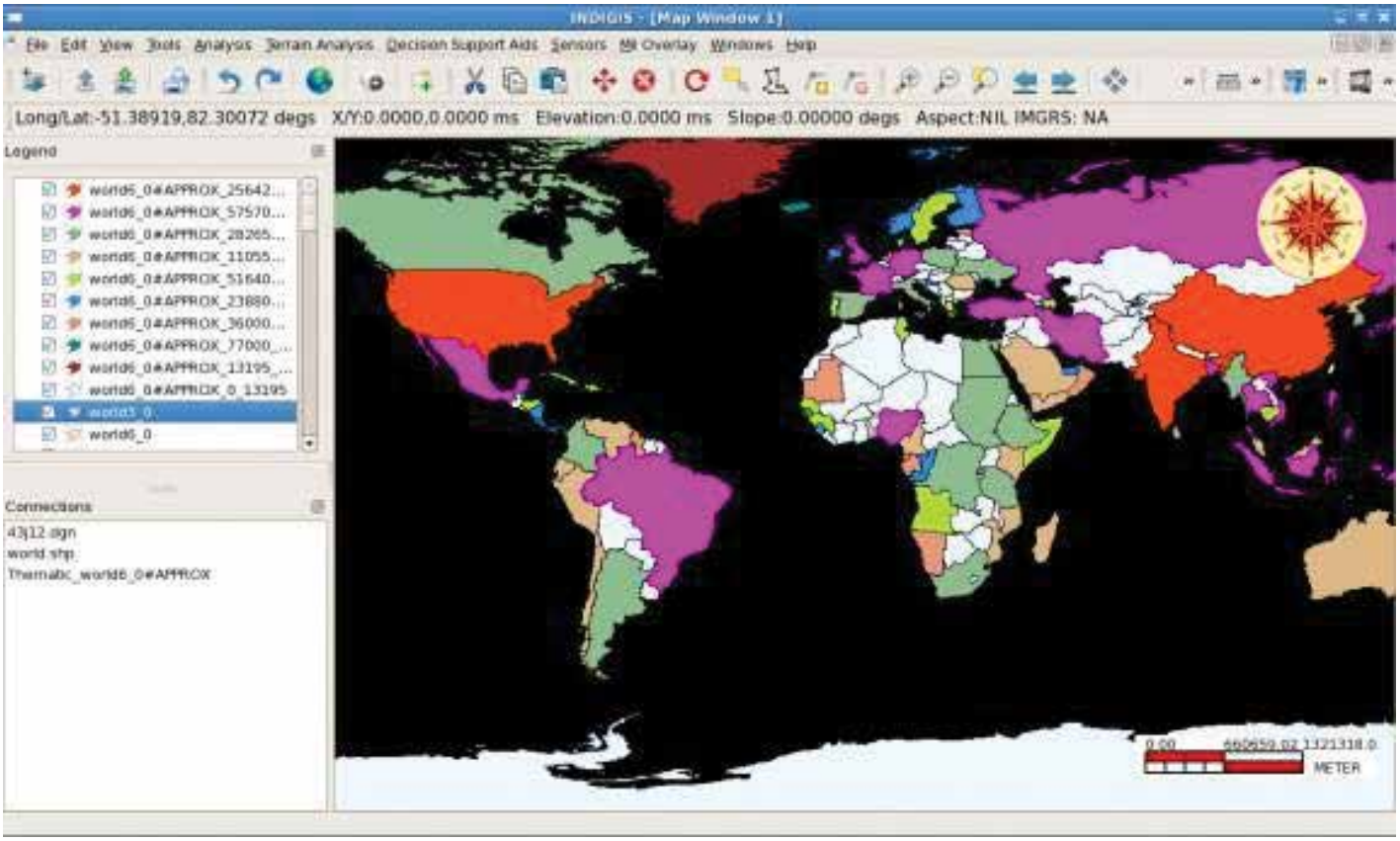
Display of Query Result on Map Window

Thematic Query

A thematic map is a map that emphasizes a particular theme or special topic such as the average rainfall in an area. Thematic query allows the User to generate map themes based on the attribute value(s) of a feature class. In a thematic layer for a feature class, the display style (normally, display colour) of individual feature objects will be decided based on the values of the attribute(s) used for theme generation. For example, a thematic map indicating the population of countries can be generated as shown. In this case, each feature object in the country feature class will be assigned a display colour-based on the value of the population attribute.



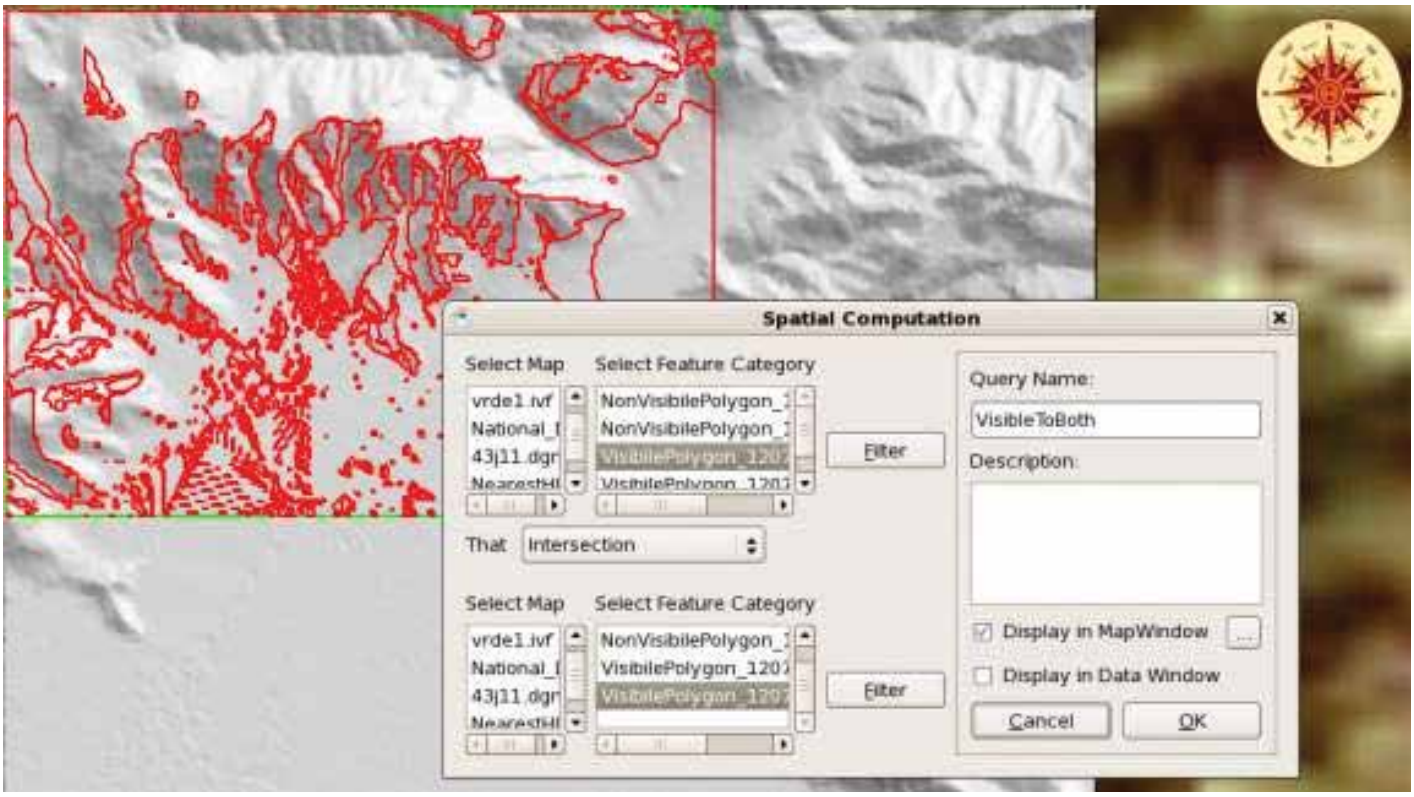
Thematic Query Dialog



Thematic Map Display

Spatial Computation

Spatial computations functionality supports spatial geometry computations between objects of two feature classes. INDIGIS supports spatial intersection, union, difference and symmetric difference operations.



Calculation and Display of Spatial Computation on Map

Terrain Analysis

Terrain Analysis functionalities are surface analysis operations that can be performed using elevation data. The INDIGIS allows cross-tile surface analysis on elevation data pertaining to different formats and coordinate systems; no need to convert the data into a common format or transform them to common coordinate system; application will perform these tasks internally transparent to the user.

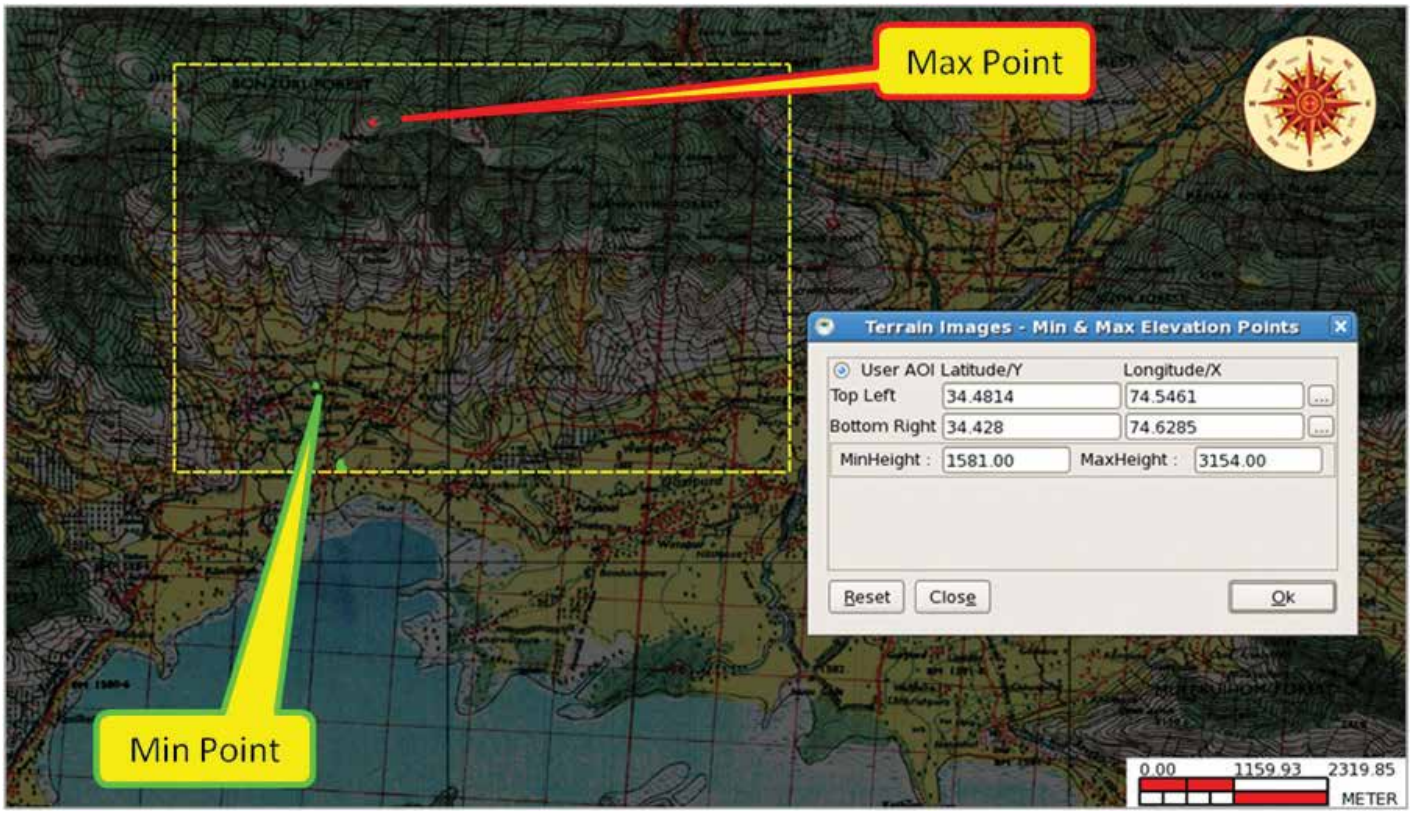
For example, if user needs to perform a visibility operation in an area that corresponds to the tile boundaries between four different elevation data tiles, user does not need to merge the files into a single dataset before running the operation - the application will merge and extract the necessary area from the elevation data behind the scenes and perform the analysis on it.

Terrain Analysis tools consist of several surface analysis functions like determining the highest and lowest points, visibility analysis, elevation profile viewing, shaded relief creation, steepest path computation, colour coded images creation: elevation/slope/aspect, terrain polygon creation-elevation/slope/aspect, cut and fill analysis, etc. For carrying out terrain analysis it is a prerequisite that elevation data of the corresponding area must be loaded in INDIGIS application. User can load elevation data in formats like DTED (dt0/dt1/dt2), DEM, SRTM HGT or IEF (INDIGIS Elevation Format).

The elevation data can be of different projection/coordinate systems (no need to transform them explicitly to a common coordinate system). The data will be dynamically projected to the coordinate system of the map window.

Highest and Lowest Point

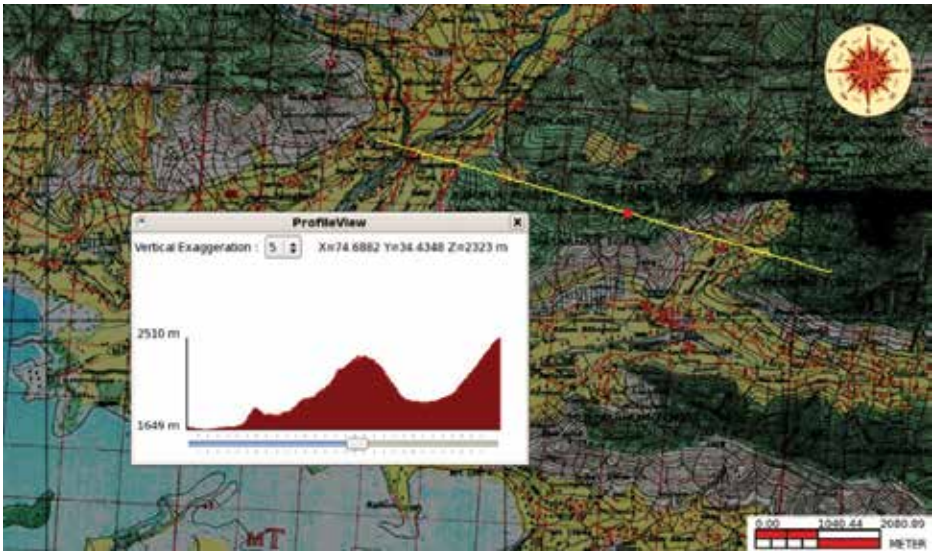
INDIGIS allows the user to locate the highest and lowest elevation points in a user-defined area.



Calculation of Highest and Lowest Point

Elevation Profile

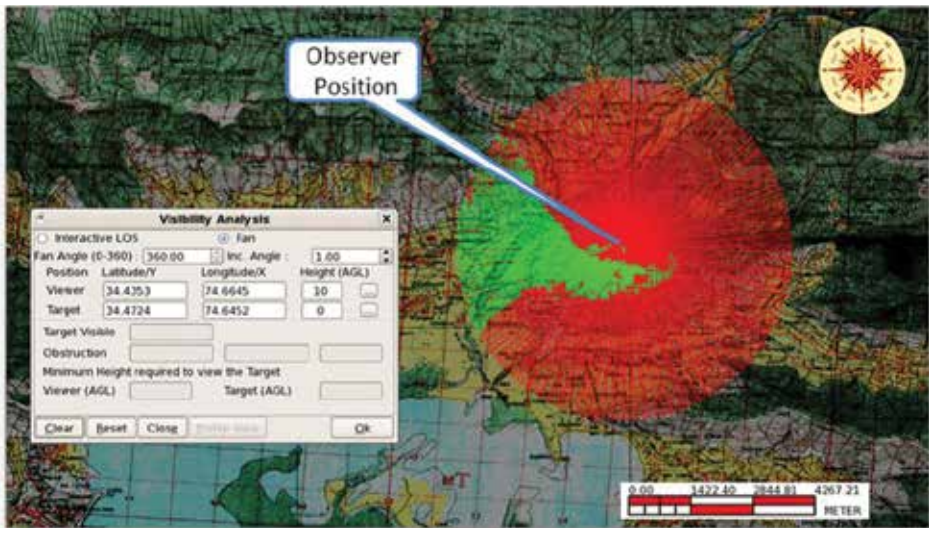
Elevation Profile view functionality allows the user to view the profile of elevations along a line marked on the map or a line or area feature selected from the vector map. User can move a slider on the profile view dialog and view the corresponding location on the line in the map with a red dot. The position and height values will be displayed on the profile view dialog are illustrated.



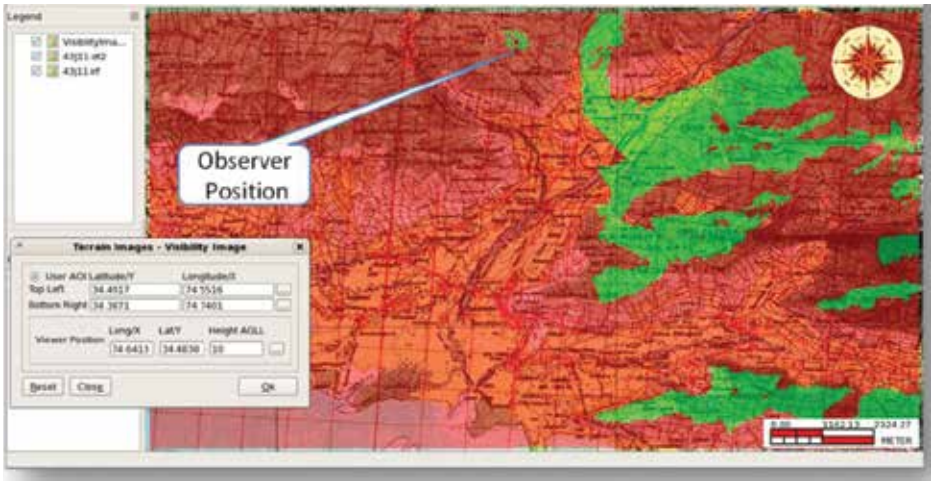
Elevation Profile

Visibility Profile

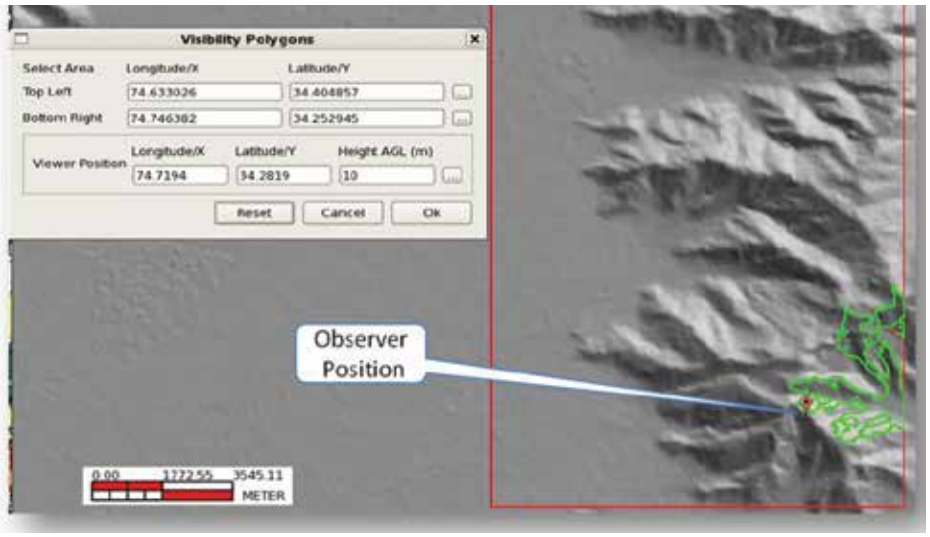
Visibility Profile functionality allows the user to identify the parts of a surface along a selected line or along a set of lines, which form a fan of given angle, that are visible or hidden from an observer.



Visibility Profile



Visibility Image



Visibility Polygon

Visibility Image

Visibility Image functionality generates a visibility image, which indicates the areas that are visible in one colour (green) and the areas that are not visible with another colour (red) to an observer located at a given location at a given height above ground level for the selected area.

Visibility Polygon

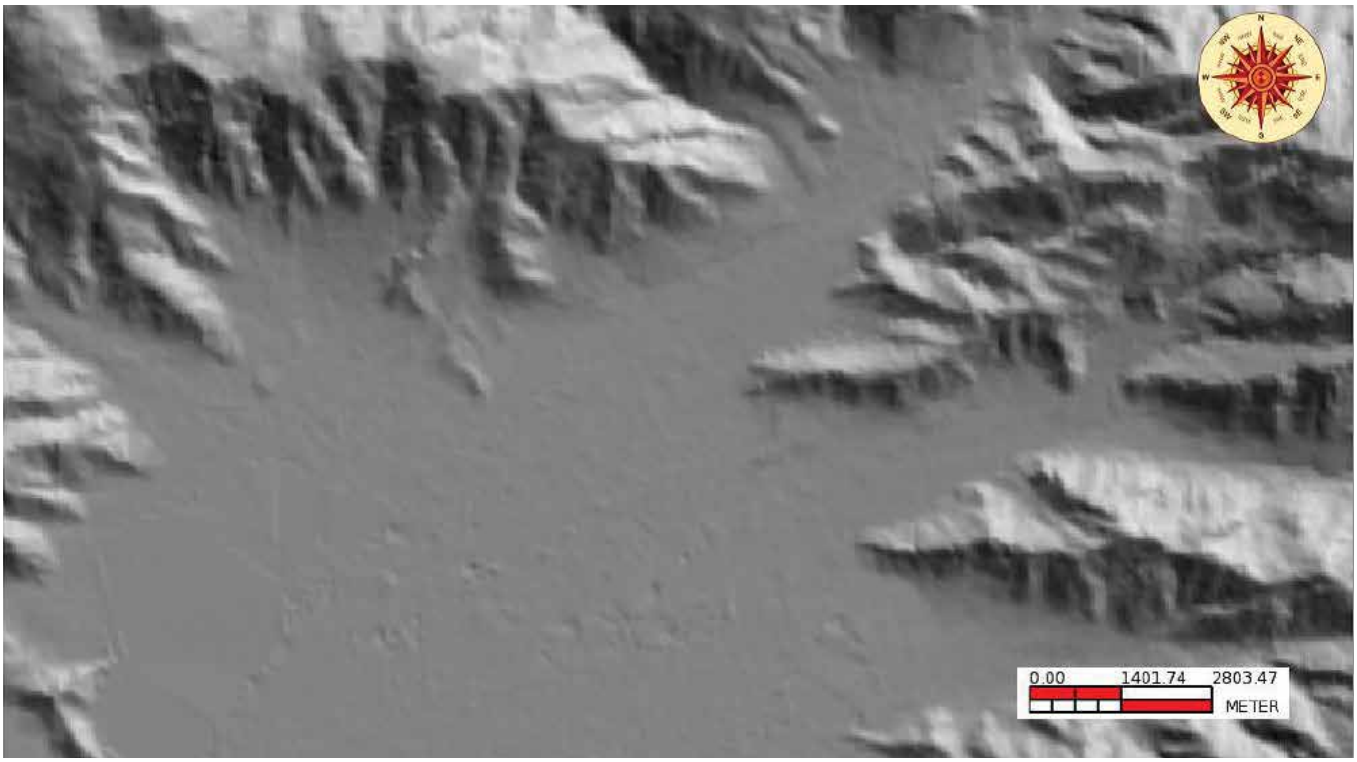
Visibility Polygon functionality generates polygons, which indicates the areas that are visible in one colour (green) and the areas that are not visible with another colour (red) to an observer located at a given location at a given height above ground level for the selected area.

Shaded Relief Image

Relief shading, also known as hill shading, involves the use of shadows to emphasize the topography of a terrain. The variation in shadowing gives the elevation a 3D effect and helps put into context how hilly or flat a geographic area is. This is a good way to get a 3-D effect without changing from a 2-D perspective. It often makes the difference between a (literally) flat, schematic-like map and a map that truly shows a picture of a landscape.

Colour Coded Image

Colour coded image creation allows the user to create and display colour coded images for terrain attributes like elevation, slope and aspect. Colour coded image, corresponding to a given elevation image, indicates the selected terrain attribute value (elevation, slope, aspect) for each pixel with a colour as per a given colour table, which

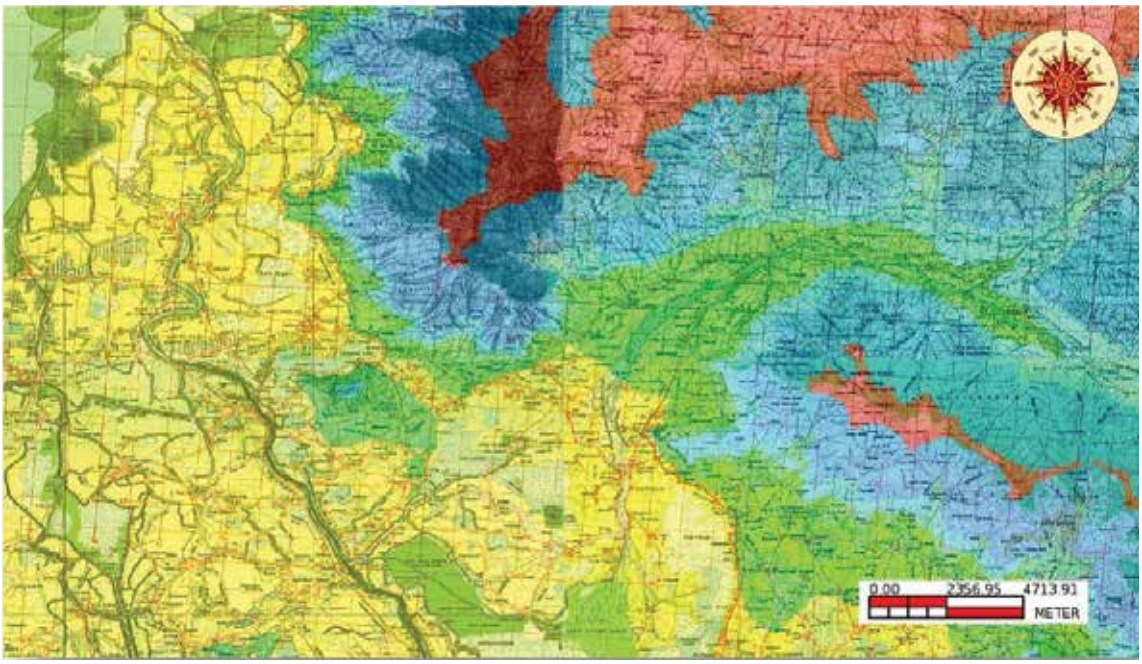


Shaded Relief Image

defines the colour maps for ranges of attribute values.

Generating Colour Coded Elevation Image

Colour coded elevation image creates an image as shown depicting the elevation ranges with various colours as per the given colour maps.



Colour Coded Elevation Image

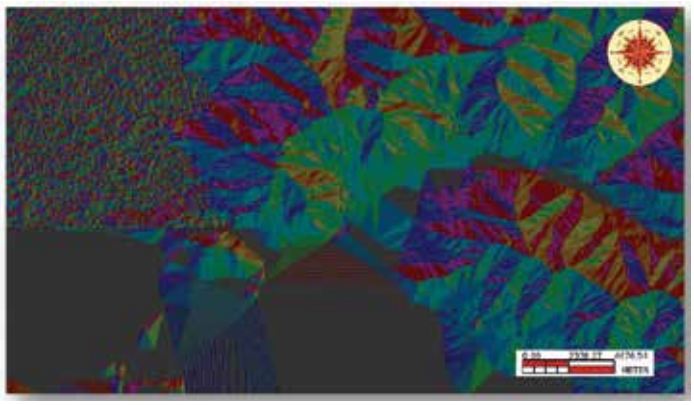
Generating Colour Coded Slope Image

Colour coded slope image creates an image as shown depicting the slope ranges with various colours as per the given colour maps.

Generating Colour Coded Aspect Image

Colour coded aspect image creates an image as shown depicting the aspect ranges with various colours as per the given colour maps.

Colour-Coded Slope Image



Colour-Coded Aspect Image

Terrain Polygons

This functionality allows the user to generate polygons corresponding to a terrain attribute (elevation, slope, aspect) from an elevation image. Terrain polygon functionality will internally generate a colour coded raster image for the selected terrain attribute and run polygonise algorithm to generate polygons (vector geometry) corresponding to a given pixel value (corresponding to the selected terrain attribute value range) from the image.

Generating Elevation Polygons

This functionality allows the user to generate polygons corresponding to a range of elevation values from an elevation image.

Generating Slope Polygons

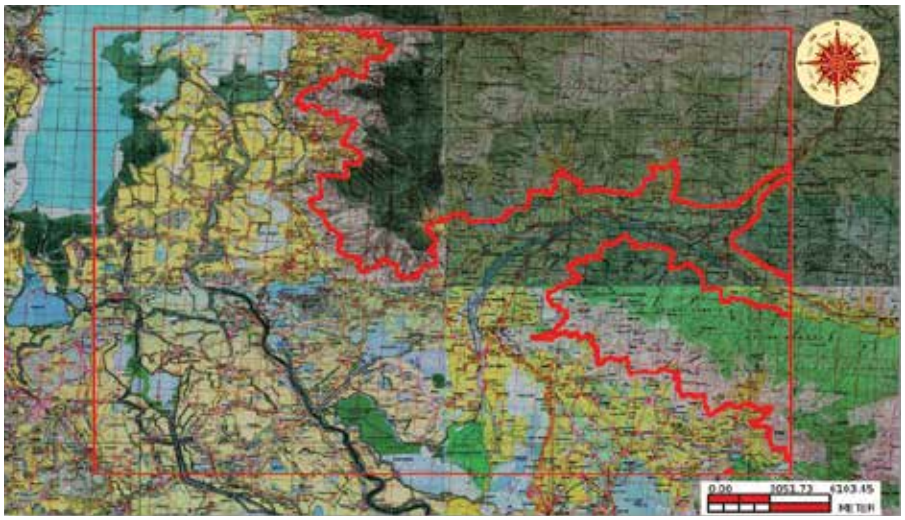
This functionality allows the user to generate polygons corresponding to a range of slope values from an elevation image as shown.

Generating Aspect Polygons

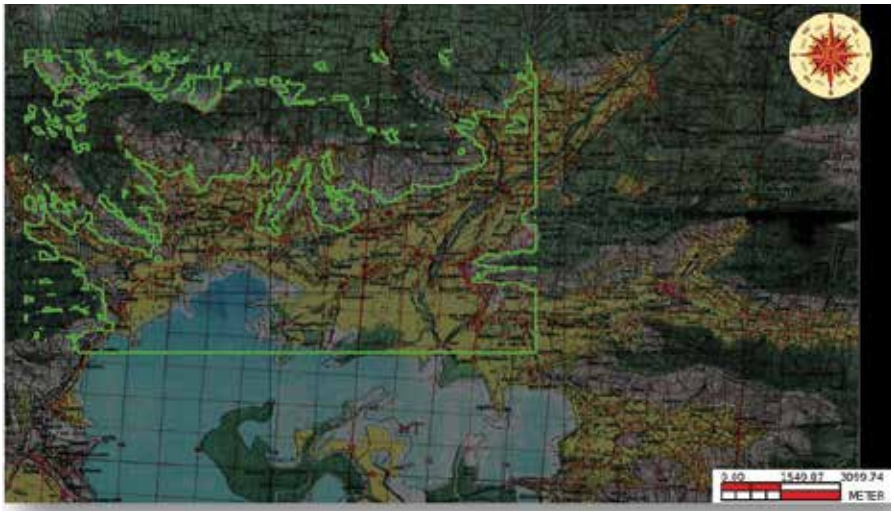
This functionality allows the user to generate polygons corresponding to a range of aspect values from an elevation image as shown.

Cut and Fill Analysis

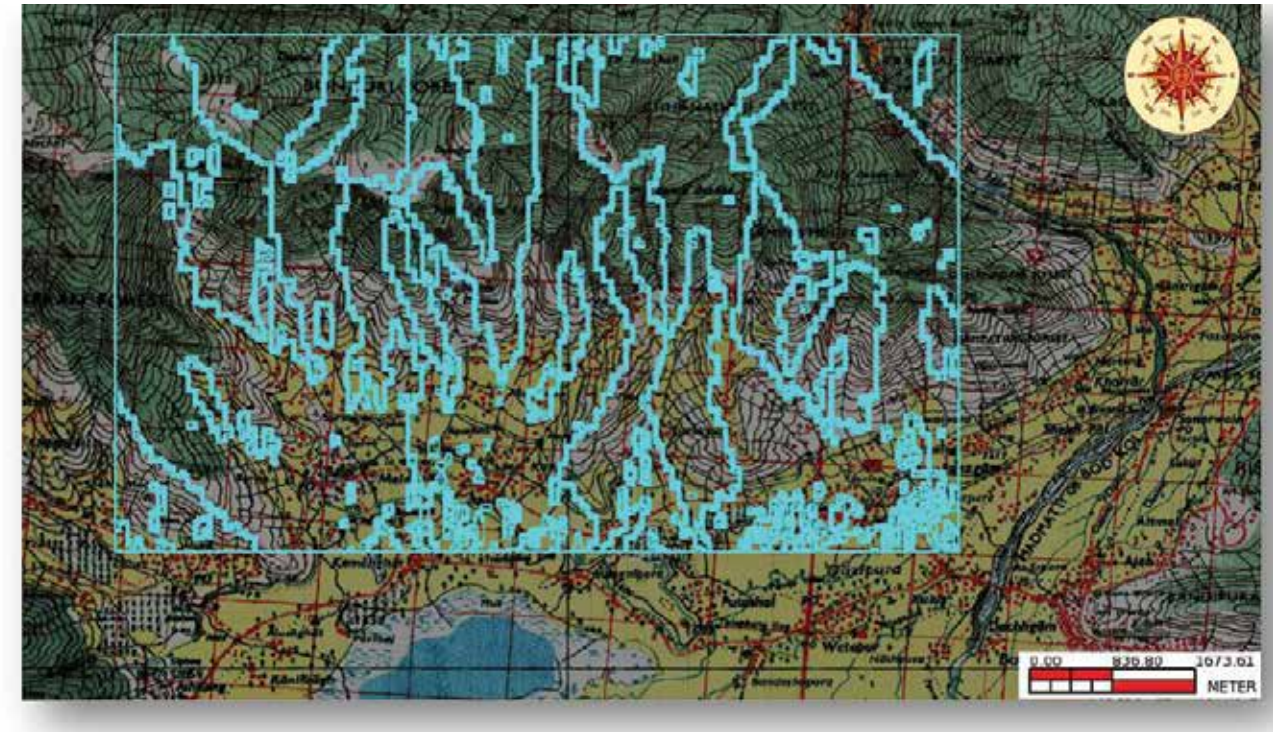
The Cut and Fill functionality summarizes the areas and volumes of change between two surfaces.



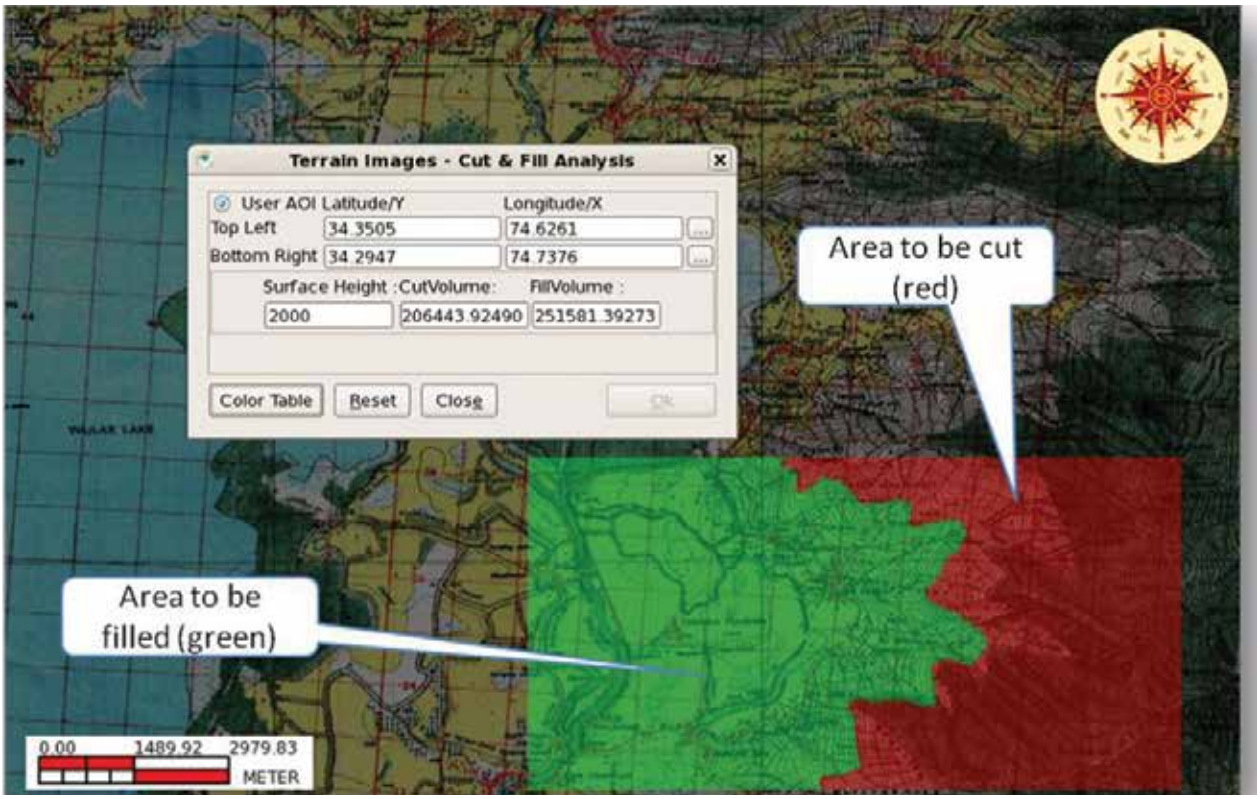
Elevation Polygon



Slope Polygon



Aspect Polygon

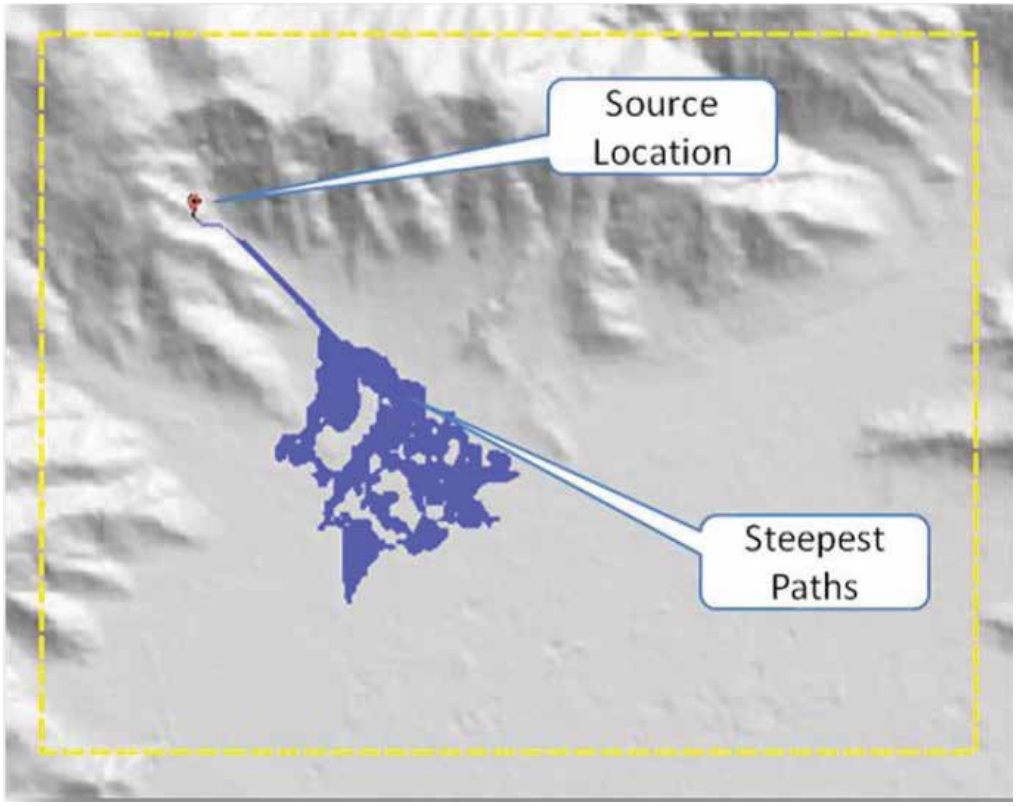


Cut and Fill Analysis

It identifies the areas and volume of the surface that have been modified by the removal or addition of surface material. This functionality can be used for estimating the cut and fill volumes and areas to make selected area flatten with given elevation level.

Steepest Path Computation

This functionality allows the user to identify the steepest path(s) from a selected location. Steepest path is the path by which a ball will roll down from a given point.

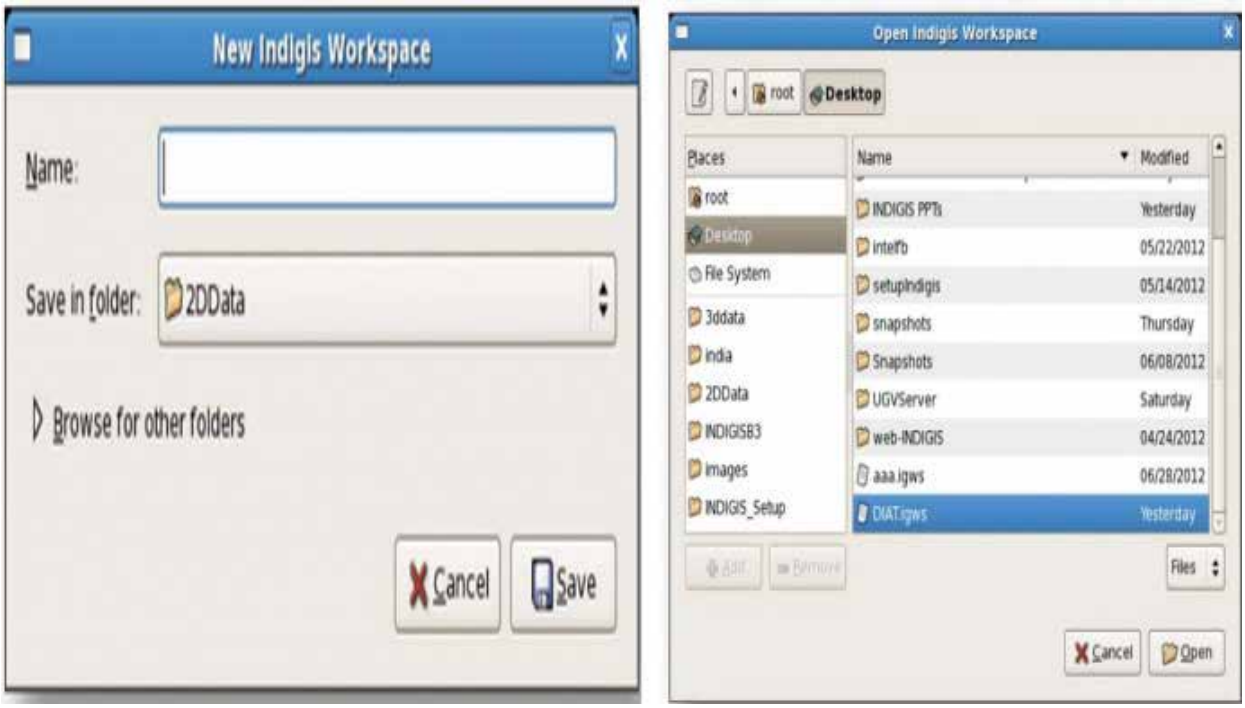


Steepest Path

Graphical User Interface

INDIGIS provides a very rich, modern and intuitive GUI-based User Interface for creation, manipulation, visualisation, analysis and storage of Geo-spatial data. It provides an established standard interfaces such as MainWindow, Toolbars, Statusbar, Dock-Widgets, Widgets, Dialogs, etc. for easy user interaction. It has work Space management functionality that allows the user to create, save and open INDIGIS work spaces. A Work space is equivalent to a user session which contains the details of data connections opened or created; on saving the work space these details will be written to a work space file. Saved work space can be opened to retrieve the session and continue the activities.

Application Main Window



Workspace Management

Way Further

There is a growing requirement of an indigenous GIS technology across different DRDO labs to realise their project objectives. Many DRDO labs have harnessed the capability and features of INDIGIS technology for different systems and projects. On realising the potential of spatio-temporal computing and visualization of INDIGIS, the labs have approached CAIR for support in developing GIS workflows for their projects. Also, INDIGIS was also evaluated from different independent Private and Govt. agencies for its export potential to different countries. The next part of this article will outline some of the key usage and inductions of INDIGIS in various DRDO projects for armed forces. Also the second phase will focus on nuances of ToT of a software technology such as INDIGIS and its potential.

The content for this issue of *Technology Focus* has been prepared by Project Team of INDIGIS, Dr Narayan Panigrahi, Sc 'G'; Rajesh M.A., Sc 'F'; Dilip Kumar Dalei, Sc 'F'; Rajesh Kumar, Sc 'E'; Shibumon Alampatta, Sc 'E'; Rakesh K.P., Sc 'C'; Vikas Kumar, TO 'A'; and Sunil Singh Rawat, TO 'A'.

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