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National GIS in India: Setting Agenda

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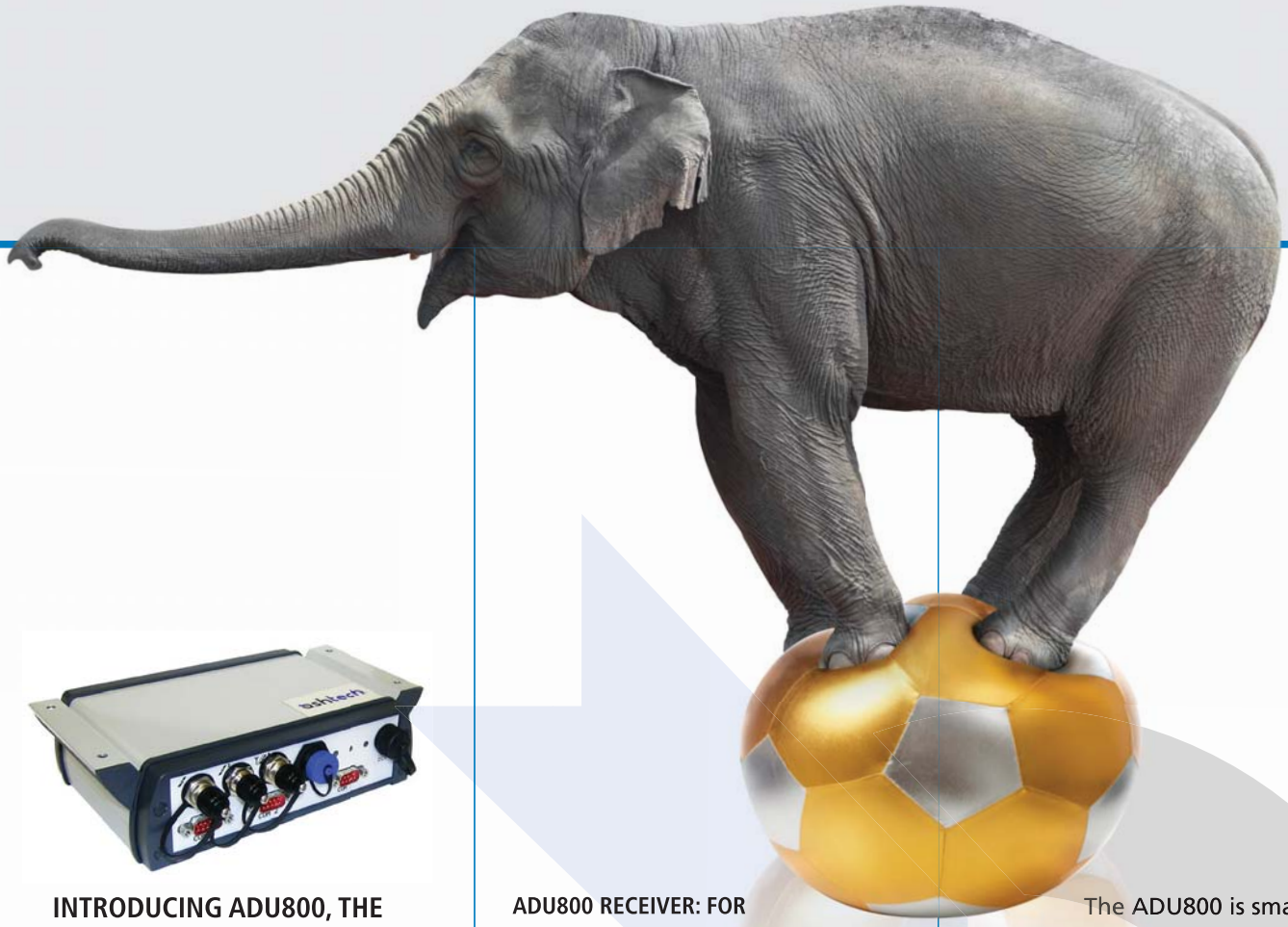

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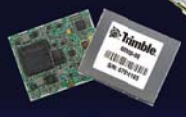

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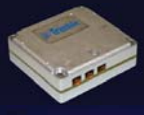

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Columns

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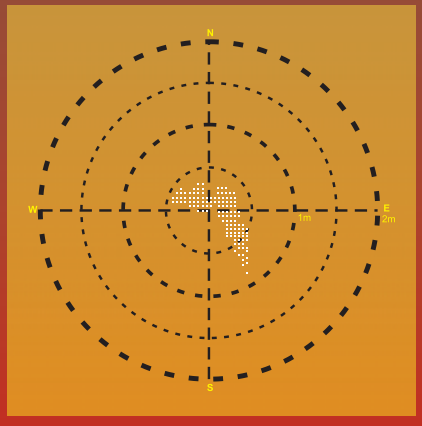

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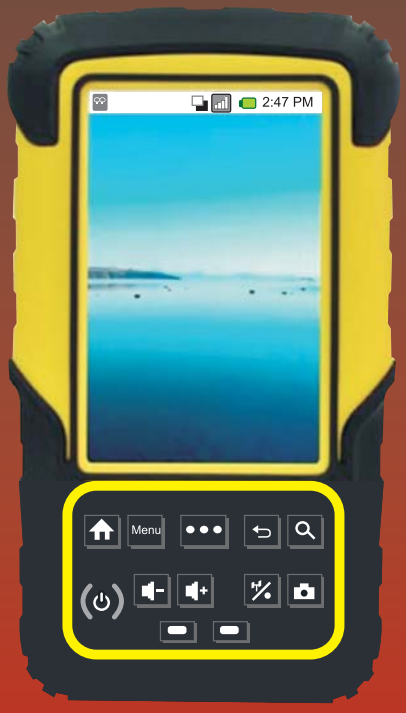

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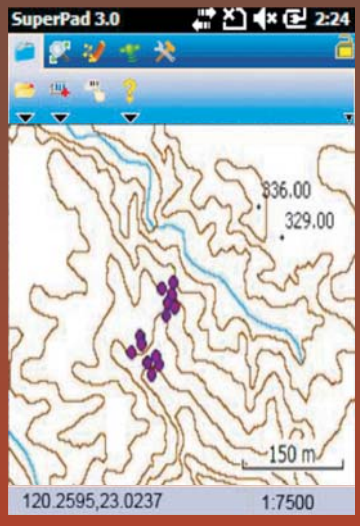

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Making Sense in the Sky

Andrea Hildebrand, Co-founder, senseFly, Switzerland highlights the benefits of its drones offering comprehensive mapping system

What are the key features of senseFly drones?

senseFly drones were developed to offer end users a comprehensive mapping system that is both easy to use and portable without the need to be an experienced pilot. With our systems being the lightest in the industry at less than 700 grams and compact enough to fit into a single hand luggage case transportation is not a problem even to remote launch sites.

Our hand launched systems are fully automated from mission planning to flight and landing making them simple to use, while also offering live monitoring via a tablet or laptop where users can track the entire mission and make adjustments to the flight plan, when and if required.

How different is the eBee from the Swinglet CAM?

The eBee is not only an improvement on the swinglet CAM but a whole new system. Designed as a modulated system with removable wings the eBee's camera and sensors are all fully enclosed within the body of the unit. The eBee can fly in much stronger winds then it predecessor (45km/h compared to 25km/h). Another advantage of the eBee is it utilizes reverse thrust technology, which enables the drone to slow down on descent enabling it to land in a softer, more controlled manner in either linear or circular modes. It also boasts a new ground proximity sensor, which senses the ground on landing for increased accuracy as well as in-flight safety to avoid collision with the ground.

At what altitudes can the Swinglet CAM and the eBee operate?

Although senseFly drones can easily operate up to 1000m above ground, most projects are completed between 90 & 150m, due to both resolution accuracies and flight regulations. Being constantly in search of a new challenge our team has tested absolute altitude at up to 3000m in the Swiss Alps.

In case of high wind speed or drop in battery charge, how will the users manage to operate it back to safety?

A lot of emphasis has been placed on safety within senseFly and our systems have been designed with this in mind. We want to make sure our end users feel comfortable and safe using our products and as a result we have automated to a large degree our fail safe procedures. When wind conditions become too strong, low GPS or low battery is experienced for example, the user will automatically be notified and the unit will return home without any user input being required. Other safety protocols such as a buffer zone and loss of radio link add additional protection as well.

Can both the drones be repaired in case of damage?

At senseFly we realize the importance of keeping the client working whenever possible and so our technical service team are on hand to assist end users in completing minor repairs in the field where possible. In association with our ever expanding distributor network we have developed fully authorized service centers in a number of countries which have the ability to carry out required service repairs in addition to our own repair center in Lausanne, Switzerland.

The eBee system has been designed for longevity, as we understand the importance of return on investment for the end user. To achieve this the eBee has been designed for optimum protection of its critical parts, in addition to this minor repairs and replacement of the most exposed parts such as the wings and underbody are easy to carry out.

Could you describe the role of eMotion2 and Postflight Terra software?

eMotion 2 is our quick to learn and easy to use, intuitive ground station software allowing you to plan, simulate, monitor and control the trajectory of the eBee both before and during flight.

Postflight Terra 3D-EB is a professional photogrammetry software that runs on your desktop computer or laptop and processes aerial imagery into 2D maps and 3D models with centimeter accuracy with just a couple of clicks.

What kind of authorization is required for using the drones? Are there special permission required in certain countries?

Authorization requirements are dependent on the country of use with most countries now adopting some form of UAV or UAS specific regulations. Some countries for example required operators to complete an authorized training course, which our distributors advise and guide our customers through. In others, for example, Switzerland, the only regulation is to keep it in the line of sight while flying. At senseFly, we believe it would make sense to differentiate the regulations depending on the weight and structure of drones. Drones, which are very light and small, like ours, do not present the same danger as larger, heavier systems do.

You have supported several humanitarian projects with your excellent technology. Could you please mention some of them for benefit our readers.

We recently supported Drone Adventures (Drone Adventures is a young non-profit organization based in Lausanne, Switzerland. Their goal is to promote the great potential of drones in civilian applications, focusing on conservation, humanitarian, cultural and search and rescue domains.) who completed a mission in Haiti in collaboration with the International Organization for Migration (IOM) and the Humanitarian Open Street Map Team (HOT). They used three eBee drones to map ten different sites for a total coverage of approximately 45km2, all done in just 1 week.

The resulting data allowed 3D terrain models to be created, which enabled them to perform water-flow simulations. This will be used in the planning of infrastructures whilst mitigating against flooding and to protect dense urban encampments near dangerous riverbeds. Several shantytowns were also mapped allowing them to count the tent locations and to help organize the population census as well as distribute aid.

On top of this, 2D and 3D maps of the University of Limonade situated in the north of the country were also accomplished. These maps will help to promote this brand new university, which should play a significant role in the economic and social development of the country.

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Dymaxion SAS, Colombia, a young Colombian company focusing on development of services, software and web applications for engineering projects.

Outdoor mobile field robot navigation

This paper proposes a low-cost field robot capable of short-range field navigation, obstacle avoidance, color identification and spraying. Multiple micro-electro-mechanical sensors (MEMs) and multiple micro-controllers using a multi-layer fuzzy logic decision scheme were integrated to guarantee the autonomy of the mobile robot. We present here the first part of the paper

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The automation of agriculture has become a significant concern due to the benefits of increased productivity and enhanced operational safety developed in 1997 [1]. In recent years, with the on-going development of mechatronic techniques, traditional manual work has been replaced by automated tools, such as the harvester, mower, and sprayer [2]. However, more specialized farming work still requires human manipulation of farming machinery. Thus, several techniques for applying guidance and radio navigation systems in agriculture have been investigated [3-6]. In addition, numerous studies have addressed the topic of intelligent robots for greenhouse use, and the robotics industry has produced a wide variety of remarkable robots [7-10]. The development of a gardening robot with an autonomous navigation system is now regarded as an important advance in precision agriculture, as well as a promising alternative to the dwindling farm-labor force [11-13].

However, the outdoor environment provides very different circumstances from those encountered in the laboratory [14]. Natural environments are inherently unstructured; the ground may be hazardous due to uneven pavement, ramps, hidden rocks, branches and potholes, making safe passage almost impossible. Overcoming these difficulties requires accurate data related to position and attitude in order to ensure the effective application of a mobile robot in an garden or greenhouse setting [15].

The integration of an IMU with a RTK GPS can compensate for positioning errors associated with machinery attitude, and may provide more accurate navigational information for many field operations, such as sowing, tilling, planting, cultivating, weeding and harvesting. [4, 16-17]. These devices are sealed from the environment, which makes them more robust under harsh environmental conditions. Noguchi *et al.* proposed an agricultural navigation system comprised of an RTK GPS in conjunction with an inertial measurement unit [16].

The Kalman filters method is most commonly used in integrated navigation. Kalman filters offer a sound theoretical framework for the fusion of multi-sensor data, in which the position of the mobile robot is tracked at all times. Literature on the integration of IMU and/or other sensors, with or without a GPS/DGPS receiver, is widely available [17, 22-25]. These integrated systems are capable of enhancing positional accuracy; more importantly, they offer reliable short-term positioning information should the GPS suffer a signal outage. Although Kalman filter-based navigation techniques are effective to achieve high-precision positioning, the application field, environmental conditions, system complexity, and cost of hardware/software development should all be considered to achieve the required positioning accuracy at a low development cost. In addition, the integration of received sensor data within one controller is vulnerable to the following problems:

1) The program design of internal system requires extra attention. If the sensor data can not be received,

idling occurs in the system and fails to function properly;
2) The use of single controller to achieve autonomous navigation will require the main core controller to execute every function in the system program, which takes long computation time to calculate. Thus, it will degrade the overall performance of the system. The use of more advanced signal processor will require more cost; and
3) Although such techniques are indeed capable of reducing positional errors resulting from robot movement, both system complexity and the cost of the robots are increased.

The fuzzy logic concept began with the 1965 proposal of the fuzzy set theory by Lotfi Zadeh [26-27]. This approach addresses the imprecise nature of control issues within all physical systems. In recent years, fuzzy logic and expert system have been widely adopted in smart control systems, crop management, energy management, and finances, etc. [28-30]. Nevertheless, traditional fuzzy expert systems have to solve the problem of converting more complex problems into more complex expressions of expert knowledge. More the number of input variables and membership functions, more are the number of fuzzy logic rules. Thus, typical single-layer fuzzy inference systems are insufficient for complicated systems with a large number of input variables. It is shown that multi-layer fuzzy inference can reduce the number of fuzzy rules [31]. Kuo *et al*. established a three-layer parallel fuzzy inference model to shorten the time of inference calculation in the fuzzy controller [32]. The improved fuzzy neural network is able to conduct distributed processing.

Nowadays, many literatures focus on obstacle avoidance and autonomous navigation by using fuzzy-based control method for mobile robot [33-42]. Among them, some scholars use the sliding mode controller to serve as motion controller, or the position error and angular error to serve as input variables of fuzzy controller. After the fuzzy inference process, the output signal of fuzzy controller is used to drive the two servo motors, which results in obstacle avoidance and navigation for mobile robot. However, these fuzzy-based techniques are only employed in indoor environment or simulation. Only a part of literatures use ultrasonic sensor or other sensors (such as compass, odometer, etc.) for mobile robot navigation. Meanwhile, uniform sensors are often utilized in fuzzy controller. None of them use the sensor integration method to improve the navigation performance for mobile robot.

The development of micro-mechanics (MEM) sensors has expanded the potential of design techniques used for automated machinery; the most noteworthy of these are intelligent mechanical systems. That is, with respect to the current low-cost GPS receiver with precision ranging between 5 to 10 meters, some range sensors, in combination with short-distance positioning techniques and GPS receivers, may be employed to achieve high-precision positioning. Some research results regarding mobile robots have been applied to many fields of agriculture [43-47]. These methods utilized the MEM sensors to assist the robot in navigating autonomously, picking fruit or spraying safely, reducing the labor of farmers.

Dead-reckoning sensors are inexpensive and dependable. They work by adopting a simple mathematical procedure to determine the current location of a mobile robot as it advances, at a specified velocity and over a given length of time, from a previously known position along a pre-determined course. The simplest form of dead reckoning is termed odometry and is based on the integration of information related to incremental motion over time, which results in an unbounded accumulation of errors [48-49]. To be more specific, orientation errors result in considerable errors in lateral position, which increase proportionally with the distance travelled.

Laser-based sensors have a relatively long-to-short range and high resolution [50], and are used in the dual functions of simultaneous location and mapping (SLAM) and obstacle avoidance [51]. An electronic compass (EC) is a magnetometer that detects the magnetic field of the earth. ECs are typically employed to supplement other sensors. Benson, *et al.* [52] adopted an EC with GPS to guide a robot along straight lines. Thus, this research focuses on short-distance detection techniques, using low-cost sensors and controllers to meet short-range navigational demands. All sensors incorporated into the structure of the proposed mobile robot were controlled using multiple controllers embedded board.

To ensure safety for the moving vehicle, the proposed vehicle is equipped with a laser range finder to avoid collision. The accelerometer, gyroscopes, and electronics compass are adopted to effectively correct the error of vehicle moving path. The Hall-rotary wheel encoders can be combined with GPS to serve as an elementary dead reckoning in order to accomplish vehicle safe navigation through multi-layer fuzzy decision scheme. The proposed platform is designed to receive the multiple sensor data and integrated in multiple micro-controllers based on embedded concept.

Methodology

This section provides a dynamic mathematics model of a mobile robot, the design of the sensor-fusion scheme, and each of the devices required for the mobile robot to accomplish its tasks.

Kinematics Model of the Mobile Robot

In this paper, the speed difference between the wheels is utilized to control the moving direction of the mobile robot. An idler wheel is used to assist the robot in its movement. The kinematics model of the mobile robot is shown as follows [53][54]:

$$\dot{x}_k = \cos\theta_k^G \cdot (V_R + V_L)/2 = \cos\theta_k^G u_s \quad (1)$$

$$\dot{y}_k = \sin\theta_k^G \cdot (V_R + V_L)/2 = \sin\theta_k^G u_s \quad (2)$$

$$\dot{\theta}_k^G = \left|(V_R - V_L)/D\right| = u_p \quad (3)$$

where $\dot{x}_k$ and $\dot{y}_k$ are the speeds of the mobile robot moving in the $\{X_b, Y_b\}$ body-frame to a specific kth time point (x_k, y_k) and a specific orientation

Photo: Hermod Halse

NORWEGIAN EXTREME ARTIST, ESKIL RONNINGSBAKKEN, DURING A ONE-HANDED HANDSTAND AT THE DISTINCTIVE NEEDLE PEAK, BLADET, NORWAY, 2010.

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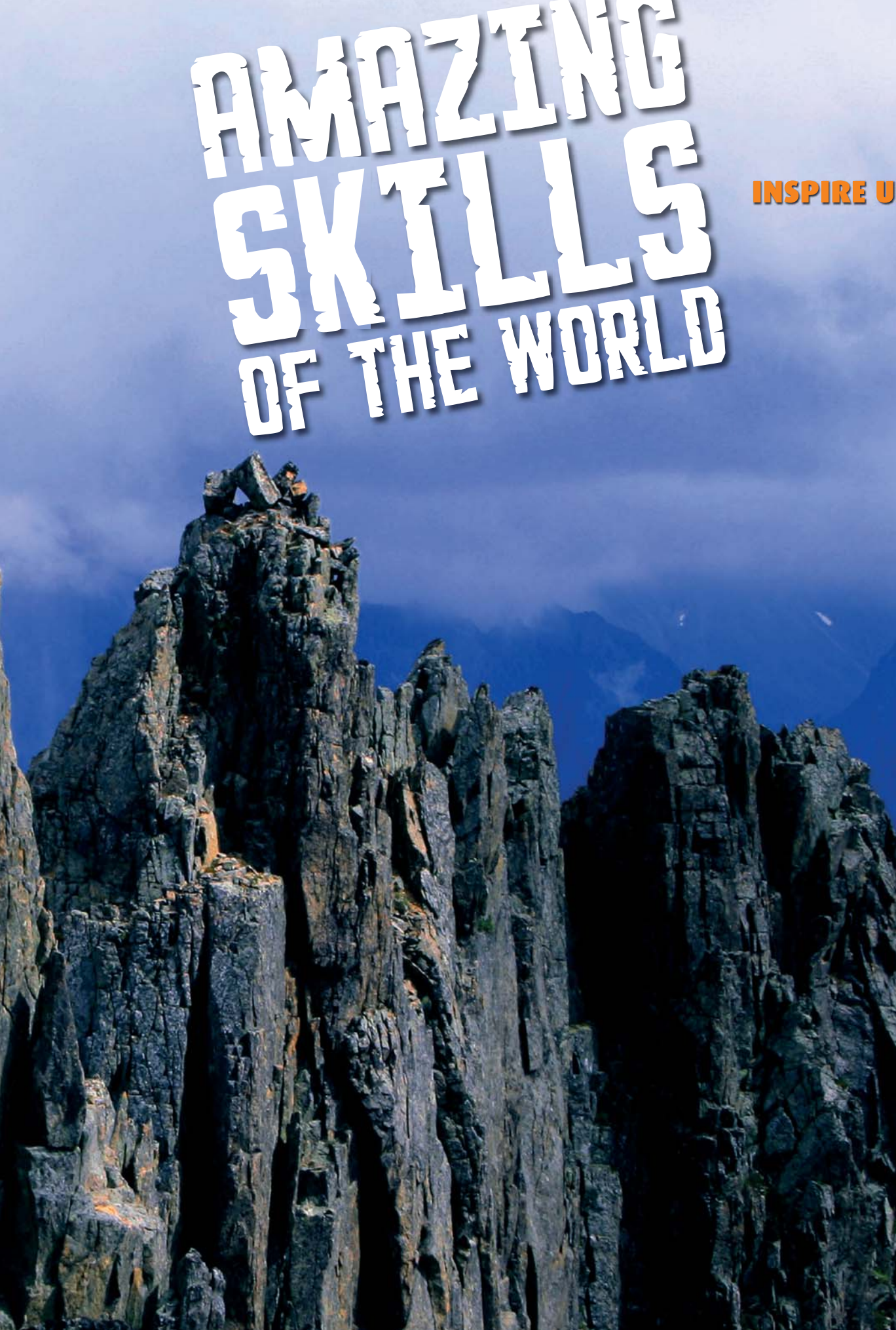

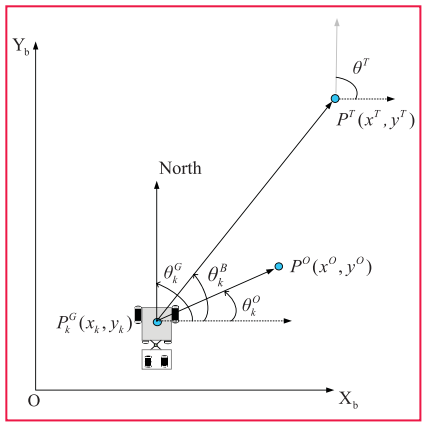

Figure 1: Navigation coordinate system

θ_k^G. The value u_s denotes the straight-line speed of the robot. The values V_R and V_L depict the linear velocities of its right and left wheels, respectively. The value u_p is the angular velocity of the mobile robot, and D is the distance between the two wheels. The robot coordinate system is shown in Figure 1.

Assume the target position to be $P^T(x^T, y^T)$, the final steering angle to be θ^T, and the obstacle position to be $P^O(x^O, y^O)$. The value L_k denotes the distance between the positions of the robot and its target. The angle θ_k^{Te} is the difference between the final angle θ_k^T and the target angle θ_k^B, and the error angle θ_k^{Ge} is the difference between the current robot angle θ_k^G and the target angle θ_k^B. The value d_k depicts the distance between the positions of robot and obstacle, and the direction angle of the obstacle θ_k^{Oe} is the difference between θ_k^G and θ_k^O.

$$d_k^T = \sqrt{(x^T - x_k)^2 + (y^T - y_k)^2} \quad (4)$$

$$d_k^O = \sqrt{(x^O - x_k)^2 + (y^O - y_k)^2} \quad (5)$$

$$\theta_k^{Te} = \theta^T - \theta_k^B \quad (6)$$

$$\theta_k^{Ge} = \theta_k^B - \theta_k^G \quad (7)$$

$$\theta_k^{Oe} = \theta_k^G - \theta_k^O \quad (8)$$

where $\theta_k^B = \tan^{-1}[(y^T - y_k)/(x^T - x_k)]$ and $\theta_k^O = arctan[(y^O - y_k)/(x^O - x_k)]$. The mobile robot can reach the target position if the values L_k, θ_k^{Te}, and θ_k^{Ge} satisfy the conditions $\lim_{k\to\infty} L_k \to 0$, $\lim_{k\to\infty} \theta_k^{Te} \to 0$, and $\lim_{k\to\infty} \theta_k^{Ge} \to 0$. In addition, the value d_k and θ_k^{Oe} should be considered in the process of controller design in the presence of an obstacle. Thus, these parameters (L_k, d_k, θ_k^{Te}, θ_k^{Ge}, and θ_k^{Oe}) are used to calculate the values V_R and V_L, and to satisfy the above condition.

Multi-layer fuzzy logic controller

The proposed scheme combines the multi-layer fuzzy controller with sensor modules, controller modules, and spraying module to form a sensor-fusion system for robot navigation, obstacle avoidance, and spraying. The system diagram is displayed in Figure 2.

The sensor signals from the electronic compass and gyroscope were used to calculate the avoidance and traveling angles within the system. The location and moving distance of the robot were calculated using an accelerometer and an odometer. Static initial location information was received via the GPS receiver. The distance between obstacle and robot was detected and calculated using a laser rangefinder. The behaviors of path planning and obstacle avoidance were determined using four controllers: Target-tracking was performed by the first fuzzy controller (FLC #1); the second and third fuzzy controllers (FLC #2 and FLC #3, respectively) were designed to perform obstacle avoidance and decision making for the mobile robot; Finally, the speeds of the right and left wheels of the mobile robot were controlled via the fourth fuzzy controller (FLC #4). Meanwhile, the T/H and color sensors were used to find the crop target and to perform the spraying work.

The design of a fuzzy controller depends on human experience, and does not entail excessive reliance on the mathematical model, which makes it a good method for intelligent control application [31]. However, the more complex the system, the greater is the fuzziness of the rules within the fuzzy controller [32]. In this paper, the multi-layer fuzzy logic controller consisted of

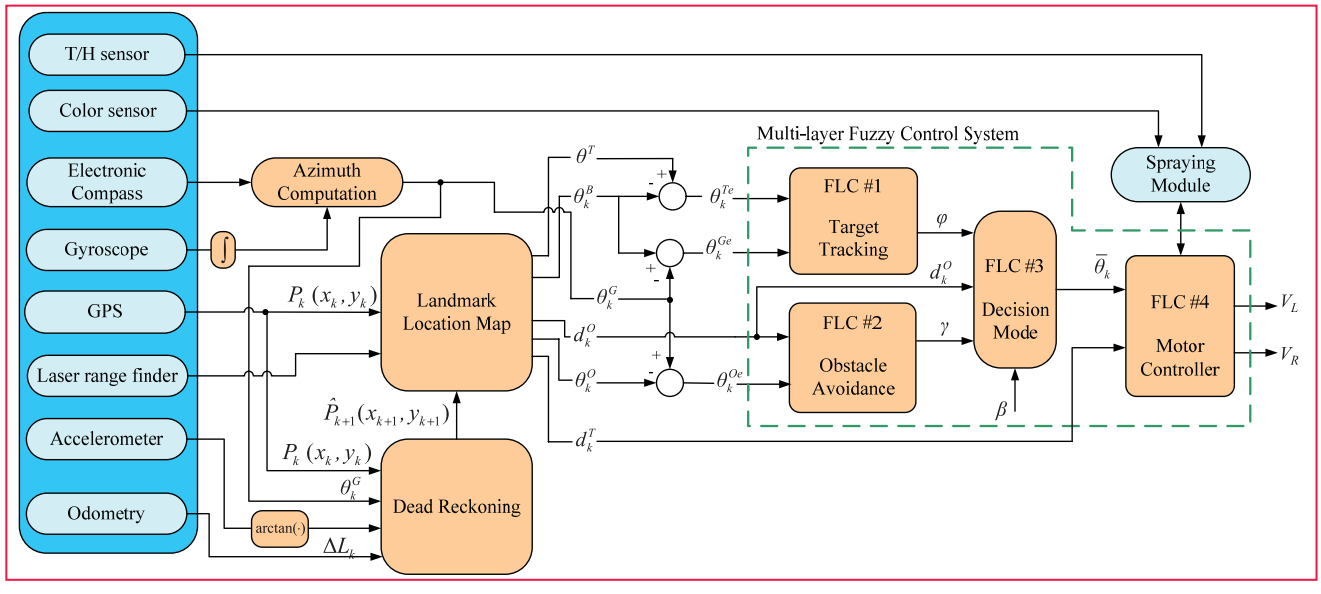

Figure 2: The structure of the sensor fusion system

four sub-fuzzy controllers. The benefit of using this structure was to avoid increased input variables, which result in increased dependence on fuzzy inference rules. This method may effectively reduce the complexity and cost of the system.

The design process for each controller resembled that of the traditional fuzzy controller. The design steps were as follows [53-54]:

1.) Define the number of input/output variables and linguistic labels;
2.) Select the strategies for "fuzzification";
3.) Design the fuzzy rule table;
4.) Establish the fuzzy inference engine; and
5.) Select the method of defuzzification. In the proposed system, there were five input variables and two output variables to be selected. The value of input/output in the physical domain must be transferred to a fuzzy domain and then to fuzzification through a fuzzy membership function. Triangular and trapezoidal shapes were selected as those membership functions. The linguistic labels of the fuzzy domain in each fuzzy subset of input variables and output variables may be declared as: POSITIVE BIG (PB), POSITIVE MEDIUM (PM), POSITIVE SMALL (PS), ZERO (ZE), NEGATIVE SMALL (NS), NEGATIVE MEDIUM (NM), NEGATIVE BIG (NB), VERY SMALL (VS), SMALL (S), MEDIUM (M), BIG (B) and VERY BIG (VB). The next step is to design the fuzzy rule table. The inference rules in this study were established in accordance with the order of development of the input and output variables and the linguistic labels. The rules were expressed in the form of "*If…and…then…*". For example, the qth rule in the first fuzzy logic controller (FLC #1) might look something like the following:

Rule q: *If* θ_k^{Ge} is NM *and* θ_k^{Te} is PB, *then* φ is NB (9)

Regarding the fuzzy inference, the "and" was considered as a minimum operator. In other words, the linguistic rule was calculated through dot operator and minimum (min) operation [55]. Finally, the defuzzification process involved finding a physical value from these fuzzy sets. In this paper, the bisector was utilized to serve as a defuzzification operation [54]. The design process of the proposed scheme is demonstrated below. In Figure 2, the variables θ_k^{Te} and θ_k^{Ge} serve as inputs of FLC #1, which may estimate the output variable of FLC #1 (rotation angle φ) based on the position, current direction angle, target angle and final angle of the robot (the memberships of the input and output variables and the fuzzy rule table are shown in Figure 2 and Table 1, respectively.).

Next, the input variable d_k and θ_k^{Oe} are used for the obstacle-avoidance controller (FLC #2) and for the calculation of the compensation angle γ, which can correct the moving path of the robot (the memberships of the input and output variables

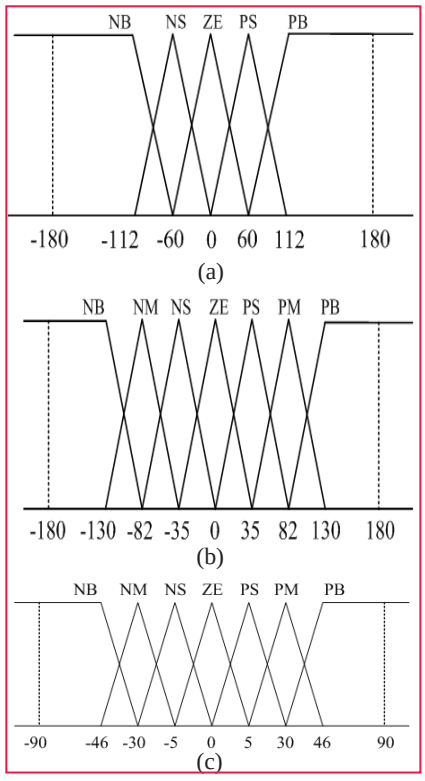

Figure 3: Membership function of fuzzy controller (FLC #1); (a) The membership function (θ_k^{Te}); (b) The membership function (θ_k^{Ge}); (c) The membership function (φ)

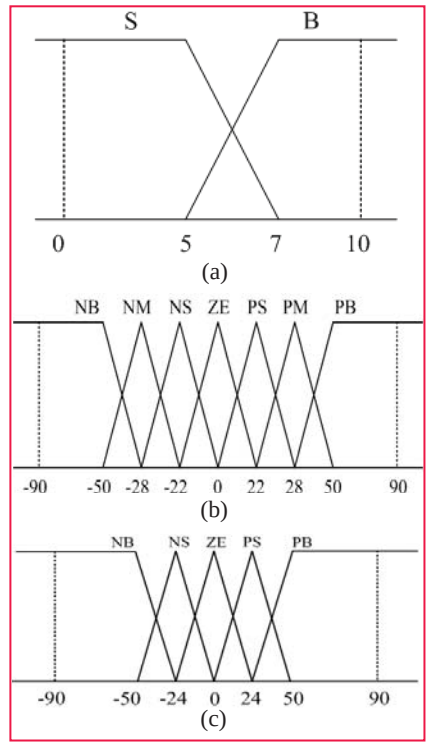

Figure 4. The membership function of obstacle avoidance controller; (a) The membership function of input variable d_k^O; (b) The membership function of input variable θ_k^{Oe}; (c) The membership function of output variable γ

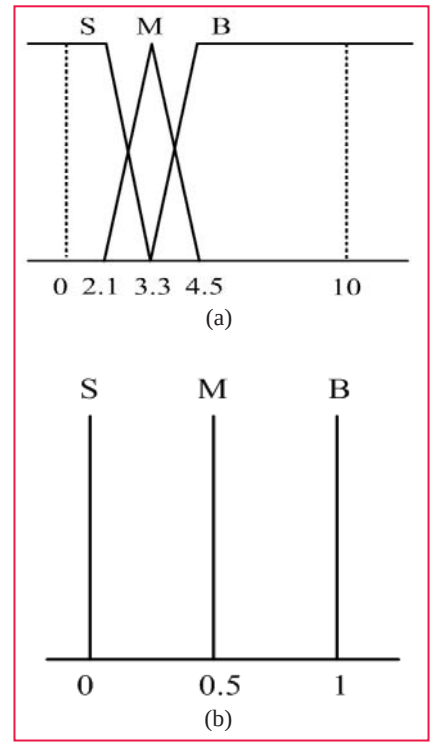

Figure 5. Membership function of decision-mode controller (FLC #3); (a) The membership function of input variable d_k^O; (b) The membership function of input variance β

and the fuzzy rule table are shown in Figure 4 and Table 2, respectively.).

Finally, the values d_k^O, φ and γ are sent to the decision-mode controller (FLC #3). The weight β is calculated based on d_k, which is the distance between robot and obstacle. Then, the final angle can be obtained by (10):

$$\bar{\theta}_k = \beta\varphi + (1-\beta)\gamma \quad (10)$$

The value $\bar{\theta}_k$ depicts the final steering angle of the robot. In addition, the greater the value θ_k^{Oe}, the larger the β. Then, the target-tracking mode is performed. Otherwise, the obstacle avoidance mode is executed (again, the memberships of the input and output variables and fuzzy rule table for the obstacle avoidance controller are shown in Figure 5 and Table 3, respectively.).

Next, the variables $\bar{\theta}_k$ and d_k^T serve as inputs for the motion-controller (FLC #4), where the output variables are V_R and V_L (the memberships of the input and output variables and fuzzy rule tables for the motor controller are shown in Figure 6 and Table 4-5, respectively.)

The value d_k^T may be obtained through a landmark location map or dead reckoning algorithm (see the following section).

Table 1. The fuzzy rule table (φ)

φ		θ_k^{Ge}						
		NB	NM	NS	ZE	PS	PM	PB
θ_k^{Te}	NB	NM	NS	PM	PM	PM	PB	PB
	NS	NM	NS	PS	PS	PS	PM	PB
	ZE	NB	NM	NS	ZE	PS	PM	PB
	PS	NB	NM	NS	NS	NS	PS	PM
	PB	NB	NB	NM	NM	NM	PS	PM

Table 2. The fuzzy rule table (γ)

γ		θ_k^{Oe}						
		NB	NM	NS	ZE	PS	PM	PB
d_k^O	S	ZE	NS	NB	NS	PB	PS	ZE
	B	ZE	ZE	ZE	ZE	ZE	ZE	ZE

Dead reckoning

A dead-reckoning algorithm can be

Table 3. The fuzzy rule table for FLC #3

d_k^O	S	M	B
β	S	M	B

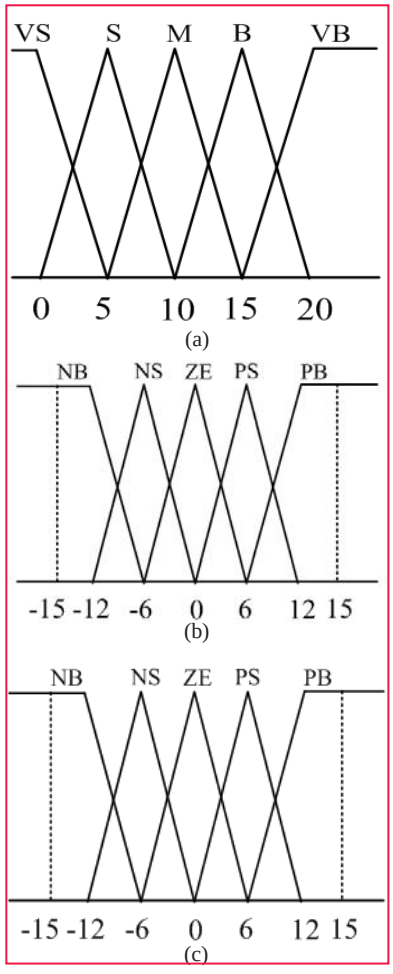

Figure 6. Membership of fuzzy controller 4 (FLC #4); (a) The membership function of input variable d_k^T; (b) The membership function of input variable $\overline{\theta}_k$; (c) The membership function of output variable V_R and V_L)

used to calculate the location of a robot [56]. The odometer served as a displacement sensor for dead reckoning. A three-axis accelerometer and a single-axis gyroscope were used to measure the static and dynamic tilt angles, respectively. Under this structure, the static location information for the robot was received by the GPS receiver and then the position of robot could be estimated through the sensor information from the odometer, gyroscope and accelerometer. The adoption of dead reckoning was performed through a reference point $P_k\,(x_k,y_k)$ with the position known *a priori* in which the following position $\hat{P}_{k+1}(x_{k+1}, y_{k+1})$ is determined by the following equations:

$$x_{k+1} = x_k + \Delta x \qquad (11)$$

Table 4. The fuzzy rule table (V_R).

V_R		$\overline{\theta}_k$				
		NB	NS	ZE	PS	PB
d_k^T	VS	NB	NM	ZE	PM	PB
	S	NB	ZE	PM	PM	PB
	M	NB	ZE	PM	PB	PB
	B	NB	PM	PB	PB	PB
	VB	NB	PM	PB	PB	PB

Table 5. The fuzzy rule table (V_L).

V_L		$\overline{\theta}_k$				
		NB	NS	ZE	PS	PB
d_k^T	VS	PB	PM	ZE	NM	NB
	S	PB	PM	PM	NM	NB
	M	PB	PM	PM	ZE	NB
	B	PB	PB	PB	ZE	NB
	VB	PB	PB	PB	PM	NB

$$\overline{\theta}_k = \beta\varphi + (1-\beta)\gamma \qquad (12)$$

Where x_{k+1} and y_{k+1} indicate the two-dimensional location of the (k+1) th position P_{k+1}. In (11) and (12), the values $\Delta x = \Delta L_k \sin\theta_k$ and $\Delta y = \Delta L_k \cos\theta_k$ represent the distance the robot moves along the x- and y-axes, respectively, where the constant ΔL_k denotes the moving distance and can be calculated through displacement information from the odometer. The value θ_k can be obtained through sensor information from the single-axis gyroscope, electronic compass, and 3-axis accelerometer as shown in the following equation:

$$\theta_k = (1-\alpha)\cdot \arctan\left(\frac{\hat{a}_{Y_b}}{\hat{a}_{X_b}}\right) + \alpha\theta_k^G \qquad (13)$$

Where $\hat{a}_{X_b}$ and $\hat{a}_{Y_b}$ are the normalized acceleration vector of X_b -direction and Y_b -direction, respectively. These acceleration values (m/s^2) in the range of $+/-\ 2g$ after the application of the zero-g offset and scale-factor calibration parameters to the accelerometer raw data. The constant α is between 0 and 1. The distance d_k^T (which may be calculated by (4)) and the value $\overline{\theta}_k$ in (10) is sent to FLC #4, which results in the output values V_R and V_L. Finally, the output values of motion controller can determine the moving direction of the robot.

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The concluding part of the paper will be published in the next issue where the hardware and software design process and experimental results, including performance analysis and a comparison of different type of navigation methods will be discussed.

"Access to cadastral data on mobile devices is now out of the box"

Brent A Jones, PE, PLS , Global Manager , Cadastre/Land Records, Esri shares his views on trends and challenges in cadastre

What are the technological advances in cadastre?

There have been many technological advances in cadastre, particularly with the workflows of how parcel data is managed and published. It's obvious that data collection via satellite imagery, total station, and GPS have all advanced, but lesser seen is the management of this data, particularly maintaining all aspects of parcel data, which include history and maintaining data integrity. The parcel fabric is a new data structure purpose built to manage parcel data. This model enforces survey methods and properly handles parcel data, ensuring a new standard for data integrity. It also allows the use of what data a cadastral agency has and provides new tools for improving data quality employed with standardized workflows designed for production efficiency. The parcel fabric incorporates old and new record measurements, enabling the incremental improvement of data quality over time.

Public data access is another area where there have been recent significant technological advances. Publishing cadastral data via web services enables the use of this data in web browsers; other applications; and, importantly, mobile devices. Access to cadastral data on mobile devices is now out of the box.

Cadastral technology is headed for modular, configured solutions operating on a common platform, using standard data models, and leveraging cloud capabilities. It is very costly to develop and maintain custom solutions. Commercial off-the-Shelf (COTS) solutions give cadastral agencies the ability to configure software to their organization's requirements while realizing the benefits of supported commercial solutions.

Given the poor state of the land records are in many countries, is it really difficult to incorporate modern technology in cadastral systems?

Successful cadastral systems that started with very poor land records have been built around the world. Success depends on high-level commitment to the endeavor, changing the culture in the organization, and building a system of sustainability. It's not difficult, but it takes sustained commitment. Even with modern cadastral systems, the effort of sustaining the systems is a challenge. Many IT managers in all areas of government are working to implement COTS that can be sustained. When large custom cadastral systems need updating, it is costly. Managing a COTS solution is much easier and less expensive to maintain with the added benefit of new capabilities with new releases.

> When the return on investment (ROI) is part of the equation, affordability rarely is a factor. Good cadastral systems return manyfold their cost in economic benefit.

GIS can provide a powerful backend support to any cadastral system. Do you think that users are ready to use it given the fact that still in several countries, land records are still maintained in traditional way?

GIS is the platform technology for cadastral systems, from collecting and managing data to producing cadastral products and sharing data within government and with the public. With new cloud GIS technologies, it is becoming easier to implement cadastral systems. Some organizations implement GIS-based cadastral systems that mimic the traditional process but use new technology. This gives a good foundation to update and modernize. Some more progressive organizations build a completely new process and system. The most important parameter is leadership and to have a champion to follow through to ensure the system is properly implemented, personnel adequately trained, and the resources are in place to sustain the system.

Is affordability of the technology is also one of the factors?

When the return on investment (ROI) is part of the equation, affordability rarely is a factor. Good cadastral systems return manyfold their cost in economic benefit. In fact, many people, including Hernando de Soto, author of *The Mystery of Capital*, believe that a successful cadastral system is a necessary precondition to a successful economy. When dealing with custom systems, the cost of developing and maintaining them is certainly a factor in success, but with the new capabilities of GIS technology and the use of standard data models like Land Administration Data Model (LADM), ISO International Standard 19152, the cost and complexity are considerably less.

Is lack of capacity another factor in some countries?

The lack of capacity is certainly a factor in developing economies. We are working to address this. We have recently made freely available the book *Land Administration for Sustainable Development* from Esri Press in e-book format at http://esriurl.com/SusDev. Along with this book, which is currently being translated into Spanish and French, the Centre for Spatial Data Infrastructures and Land Administration is developing land administration GIS exercises based on LADM to complement the book. With other contributions from the authors, we will have a complete curriculum in land administration and GIS that we will freely distribute.

How do you see the application of such technology in conflict management at local levels related to land?

Many conflicts over land occur when information about ownership and location is not available. Developing property ownership information and making it easy to find, use, and share are key to avoiding conflicts. GIS-based cadastral systems have the core technology to collect and manage ownership information, and they have the core technology to share information in many ways—automated map generation, web maps, and maps on mobile devices are some of the ways that data can be published. Public access to current, authoritative cadastral data is key to avoiding land conflicts.

> The most important parameter is leadership and to have a champion to follow through to ensure the system is properly implemented, personnel adequately trained, and the resources are in place to sustain the system.

How do you look at 3D cadastre? Is it an oversold concept?

Societies have been working with 3D property rights for a long time—underground utilities, mineral rights, submerged lands, etc., so as a concept, managing 3D cadastre is sound. Some of the concern comes in when dealing with 3D in dwelling/condominium-type units and how to manage that data with technology. For a developing economy, developing a sound cadastre is not exclusive of 3D, and LADM allows the inclusion of the third dimension, but perhaps focusing on this for a developing economy may not be as productive as getting a solid two-dimensional cadastre in place but leaving the provision for 3D when the demand is there. For highly developed economies with high-rise complexes, such as Singapore and Hong Kong, 3D cadastre is a necessity and core to the continued development and management of their cadastre infrastructure.

What could be the role of technology providers to encourage the effective implementation of modern cadastral systems?

There are several roles of technology providers to the cadastral industry. First is to provide a platform that helps cadastral organizations work more efficiently and meet ongoing changing needs. We do this by working with many organizations around the world to understand and develop best practices and build solutions around these practices leveraging new technologies. This delivers to the cadastral organization solutions that the technology provider tested and then built into core technology. This helps minimize costly software customization. For example, in the United States, there are over 3,000 organizations (primarily counties) that maintain parcel data. We have spent years studying workflows, common challenges, and common outputs. As a result, we developed a solution (ArcGIS for Land Records) that meets these needs and provides efficient workflows for common tasks. This allows local governments to use COTS technology that costs less and requires much less ongoing IT support than customized solutions. Additionally, organizations can take advantage of new core technology releases by using COTS technology and avoiding being locked into a particular software version because of extensive customization.

Technology providers also play a key leadership role in developing new solutions that respond to both the needs of cadastral agencies and new technologies as they become available. A good example of this is the challenge of maintaining IT infrastructure, publishing data, and the cloud. Building a GIS environment in the cloud enables cadastral agencies to publish data for public access, share internally, minimize IT infrastructure investment and maintenance, and deliver new capabilities for cadastral data to be consumed on mobile devices such as smartphones and tablets. We understood the need, developed the capabilities on new technology, and delivered solutions and new capabilities.

NATIONAL GIS: Setting agenda

Dr Mukund Rao identifies Top 10 Actions required for National GIS in India

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The need is to draft a small, dedicated, committed, technically excellent and empowered team of experts and charge them with the responsibility of organising National GIS

The significance of National GIS

I think the time is just right for National GIS **(National GIS Vision Document, (2011) http://moes.gov.in/national_gis.pdf)** First, as a nation we are witnessing tremendous progress and will economically grow manifold in the coming 5-10 years. With such high growth, society will demand very high efficiency in governance and quality services and government will have to depend upon very efficient and guaranteed methods of nation-building and bringing equity in quality of life for people with efficiency, transparency, speed and compassion. Immense amount of Analytics will be called for. Support information systems have to be READY-TO-USE and not "get organised" in a project and take months to get results. Governance will have to be anticipative and futuristic and be "one step ahead" of the people's demand. This is where GIS becomes extremely important and most relevant. GIS could easily address the multifarious issues of ready GIS-data availability, spatial analytics, multi-parameter visualisation, what-if and scenario simulations – all of which will have to be the drivers for determining best development options, integrated approach to spatial planning and bringing scientific rationale to development and governance – at the same time being transparent with scientific GIS-Ready data and participative for citizens.

The second aspect is to see what is happening in the GIS eco-system today in India. Even though the nation has a history of Survey & Mapping, years of Imaging and many years of GIS activities, the usage of images/maps/GIS has yet to be impacting and meaningful. An organisational "responsibility" focus is essential for National GIS – which will bring the much-needed thrust to GIS activities with a mandate for making easily available/accessible upto-date, seamless, nation-wide GIS-Ready data and allowing any number of GIS Decision Support System (DSS) applications for governance, citizens and enterprises. The visualisation of Indian National GIS Organisation (INGO) is something unique. It is only this mandated organisational focus that will make National GIS activities continuous, service-oriented activity – thus, very much ensuring the responsibility and accountability for National GIS.

The challenges before National GIS

The biggest challenge is already behind us – that is getting the concept debated/discussed and endorsed. This has happened very efficiently – thanks to Planning Commission efforts. Almost all ministries (in centre and states), GIS industries, GIS academia etc have been consulted and a wide-range of discussions have happened. These led to the Vision document for National GIS in September, 2011. Even after the Vision has been published, Indian government has undertaken various consultation exercises for financial and programmatic strengthening. So, now the issue is not whether "National GIS is required" BUT "when National GIS will become operational".

The policy needs

National GIS will need innovative policy instruments – quite different from what is available today in the five individual policies. Thanks to a study sponsored by Government of India, we have conducted a study in National Institute of Advanced Studies (NIAS), Bangalore where we have analytically determined a holistic GI Policy that not only aims to institutionalize National GIS BUT also visualises a larger, vibrant GIS eco-system development by

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which national GI excellence, industry participation, academic thrust in GIS and nation's commitment to citizen for GIS is propounded. After a national-level workshop, wide-range of consultation, questionnaire-survey and our own analysis, we have prepared a comprehensive first-of-kind policy report which includes a draft of the National GI Policy (Perspectives for a National GI Policy (Including a National GI Policy draft) (2012) - http://www.nias.res.in/docs/R11-2012-GI-Policy.pdf). The report has already been submitted to Government and would become major input for approval, sanctions and further eco-system positioning for National GIS.

Top 10 actions for National GIS

Technically, one challenge is organising the National GIS Asset – that is seamless, nation-wide and is GIS-Ready. Now, user demand is "driving" National GIS (and thus will contain what users want) rather than the spectrum of data generators providing "what they have". One still does not have a National Spatial Framework in India that "marries" the image, the administrative boundaries and geographic frame into one common, accurate and authoritative framework. This has to be organised for the first time in digital GIS domain for India. Similarly, bringing in myriad sets of survey data, available maps, tabular development data to be geo-tagged and linked, cadastral data etc is a challenge – a voluminous challenge. Designing and developing an updation cycle and creating a "GIS warehouse" for the GIS Asset will be essential.

Creating an environment for GIS Applications – many for the government (and thus regulated access), some for citizens (and thus in public domain), many customized and published by citizens/enterprises (maybe in commercial domain) etc and managing them is something that India will be doing for the first time – there is a learning-curve here. Establishing the infrastructure and systems is not a difficulty and can be easily done – but what will be more challenging is to make all these elements "work together" and establish an operational framework by which GIS Data and GIS App services become a reality, as envisioned.

There would be critical policy, access and licensing issues that would have to be positioned. Of course, keeping the "total system" chugging along and making National GIS embed into the nation's information and governance regime (so that it comes to be "embedded") will be a long-term challenge. But it is because there are many of these challenges – though looking "mind-boggling", that is driving many in India and motivating many GIS experts to contribute/participate and make this GIS eco-system a reality.

> National GIS is an "over-arching system cutting across existing systems" and thus complexity is "core embedded" in its inherent character – after all, integrating human, technological, social, cultural, competitive and temporal dimensions is a difficult task but not impossible.

I think the TOP 10 actions I would recommend are as follows:

#1. Prepare the National Spatial Foundation (NSF) Dataset. I think I would start with this immediately as this is the most crucial piece for National GIS. I believe that if we have to develop an authoritative and responsible National GIS Asset then we must plan, design and develop the NSF with utmost professional and determined finesse. Just like when you construct a building, the foundation is crux and critical – if one gets the foundation in error then the building does not have longevity and intended use. Let me explain this to your readers. In a National GIS system, unlike when one develops a project GIS, India has to be correctly and as-accurately represented so that every inch of India is reflected correctly – in terms of its coordinates, distances, area etc. This is easily done by geographic referencing all information (like in an Atlas the coordinate grid does). While this looks easily doable – the complexity comes in when different "primary source" data are put together. In India, all information (maps or tabular) are referenced on 4 basic platforms – either on a satellite/aerial image (which is processed and supplied by NRSC); or, on a SOI OSM reference (which is supplied by SOI); or, from a survey instrument like GPS/TS etc; or, on an administrative frame of villages/taluk/district/state (which generally is from Census or states). Thus, in any GIS (and also in National GIS) the features/layers are all based on one of these 4 referential primary source. Now, if one does not have the spatial geometry across these 4 sources standardized/referenced then the GIS Asset can have across-errors that would compound to differences in coordinates for the same feature referenced – thus, locations of features, distances and area measurements would come out differently – leading to user confusion. We have seen this happen in earlier GIS projects – but when National GIS service is accessed by citizens, government and other users then they would be "confused" and soon dis-enchantment can happen. To avoid this, the key is NSF where a "one-time effort" is made to standardize the reference of Image-based coordinates; SOI OSM based coordinates and GPS/TS based coordinates. They key here would be to use the best-accurate Indian administrative boundary frame from SOI OSM, the best-resolution image frame for India (which is corrected using GPS based GCPs) and

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"marry" these 2 together to create the foundation – so that this foundation can easily assimilate the features coming out from satellite images or features of SOI OSMs and also survey data – and the administrative frame too. This way the NSF will become the basic frame for any GIS data – and should form the base of all Image, OSM and survey activity – so that any GIS data emanating from these follow the same spatial reference. I also feel that this NSF (which will be a set of features in GIS Ready form with additional metadata on National Tie Points) AS A TEMPLATE should be freely and easily available to anybody to use – thereby ensuring that other GIS data can also be ingest into National GIS.

#2. Define, parametrise and document National GIS Standards. The task of preparing the National GIS Standards - a suite of technical standards and protocols for National GIS need to be immediately taken up (actually, this can be right away initiated) that will allow easy GI data creation and organisation – especially guidelines for surveying, mapping and GIS database organisation, publishing GI in National GIS and ingest guidelines, access to National GIS, , QA/QC standards for GI, publishing protocols for GIS applications on National GIS DSS service, sharing of credits/ value for GI and applications and other related procedures required for GI generation, sharing and usage in the larger context of National GIS. These standards procedures and protocols should ultimately enable government, private and individuals to "contribute" to GIS Asset, provide effective GIS applications services and also for easy usage/access to National GIS data and GIS Applications.

#3. Gather, prepare and organise the presently available GIS features for whole nation – atleast the basic layers that can be either extracted from SOI OSMs OR extractable/ updateable from latest satellite images - like administrative boundaries upto villages, roads, rail, drainages, landuse/landcover, city-boundaries, water bodies, terrain etc. In my assessment, almost 20-25 features of the 41+ features of National GIS can be easily organised in this manner. Of course, a key element will be to reformat these layers into GIS Readiness and then adjust these on the NSF – thereby creating the first level of National GIS Asset.

#4. Collate and organise the 2011 Census data (and also past 2001, 1991, 1981 census data) on village level to National GIS village layer – so that host of census data can be "virtually converted" to map views. Of course, this task looks easy but will be challenging when past census referencing is done – especially to see and view changes. Similarly, any other attribute data that are on an administrative frame and available with ministries/agencies etc can also be considered and included. This action, if done properly, can become the first

Karnataka-GIS

When we completed the visioning of National GIS, many of us felt that this may be seen as addressing national needs and questions regarding how states should look at their GIS requirement would be relevant. At the same time, we also realised that the success of the National GIS will be "exponential" if states needs of GIS are also met – after all states are mechanisms for delivering governance and are "more closer" for delivery to citizens. So, thanks to the Government of Karnataka, we took up a task-force study to "logically drill-down" a GIS system for state requirements. We conducted state-level discussions and workshops and stake-holder/user meetings and determined that state needs of GIS would need much more than what would be in National GIS – in fact, we clearly documented the state-GIS needs for different sectors and citizen interfaces as a design-input. That is how the vision document of Karnataka-GIS and the User Needs Assessment report for Karnataka-GIS have come to fore **(Reference: Karnataka State GIS Vision Document (2013) – http://karunadu.gov.in/ksac/documents/KGS-VISION%20 DOCUMENT.pdf; GIS User Needs and Stakeholder consultation report for the state of Karnataka (2013) - http://karunadu.gov.in/ksac/documents/KGIS-STAKEHOLDER-BOOK.pdf).** Now with the vision of National GIS and Karnataka-GIS, we understand what it will mean to develop state systems – and how the dove-tailing to National GIS would happen. Now, we see a GIS Systems of Systems – meeting state/ central government needs, citizen needs and also enterprise's needs.

What I see is that many states already have some key elements for National GIS – especially in terms of GIS data. If these can be aligned and structured to NSF and organised state-wide then we shall pieces of National GIS getting organised – what needs to be done is to technically GIS-stitch them into a nation-wide GIS Asset. Further, if State-GIS are organised, they not only achieve some key goals of National GIS but also trigger a set of GIS Apps at state-level – which we have documented are very different apps than what is visualized in National GIS for central ministries. Thus, (State)Karnataka-GIS can become first-rate vehicle for quickly and systematically organising an aligned GIS that manifests as National GIS. This has now been formally presented to DST to bring in the coupled alignment of Karnataka-GIS and National GIS – and this has been well-appreciated. When the Karnataka-GIS was presented to DST, we gathered that other states are also being primed to think to align their GIS tasks and make the contributions to and participate in National GIS. I am sure that the "sum" of all state-GIS must mesh into National GIS achievement – apart from taking GIS within state governance.

simple GIS Application base and enable geo-tagged attribute data applications for many agencies/citizens etc.

#5. Source GIS ready data from public and private sources – especially POIs and other map data. Crowd-sourcing of GIS data needs to be built-in and allow citizens to engage and provide GIS data on the platform. After careful vetting and converting to NSF, these data can also become a part of National GIS Asset. A large volume of data in this nature is available and should get onto the platform.

#6. Merge #2, #3 and #4 (ensured that these are on #1) and organise the National GIS Asset Version 1.0.

#7. Initiate a consultation process across government ministries/ states/industries/citizens/academia etc to identify key GIS Data and Application services with functional detailing – as this will depend on GIS Asset availability (which would be just what is available from SOI OSM maps and satellite images) and also time required. However, maybe 10-15 key GIS Applications – few ministries; few citizens Apps need to be taken up on priority basis and development of the Application DSS taken up. At the same time, the development of National GIS Data service can be standardized and developed. Some key GIS Applications I feel are critical would be for Planning Commission to monitor the sanctions/progress/ status of each and every 12th Plan project/schemes on National GIS; for NDMA and others to "force ensure" Emergency Management Plan formulations; for Urban Development Ministry to undertake City-Development reviews based on National GIS; monitoring of MNREGA works using GIS on National GIS Platform; water availability and demand analysis across the country; Key Village/Taluk development indicators development with comparative analysis etc. I also feel that a National GIS Dashboard at key decision-makers (say, if PMO and Cabinet could call on National GIS to review and visualise decisions OR Planning Commission henceforth reviews Plan proposals only if they are "put on" National GIS OR situational awareness visualisation is done on National GIS in case of disasters) would help a lot and this must be worked on. If the benefits of National GIS are amply worked on and visualised by key decision-makers then I think success would be more profoundly achieved. But this will require a lot of hard work.

> Design a protocol for private enterprise GIS Data ingests and GIS Applications services so that a clear role and path for private enterprise-driven GIS services emerge

#8. Design a protocol for private enterprise GIS Data ingests and GIS Applications services so that a clear role and path for private enterprise-driven GIS services emerge. National GIS must consult industries and experts to make this protocol and enable private enterprise to also "ride" on the platform and offer services.

#9. Organise a state-of-art and robust National GIS Platform – the system on which the National GIS will operate. Here, caution is required to size and scope it correctly to ensure performance and reliability and security of GIS data and applications. Best experts in the country must be involved to design and architecture this Platform – which requires good backbone of servers, storage and networking to be efficient and robust.

> If we have to develop an authoritative and responsible National GIS Asset then we must plan, design and develop the National Spatial Foundation NSF Dataset with utmost professional and determined finesse

#10. Work on adoption of National GI Policy – which should aim at building a long-term road-map for India to be at fore-front of GI and also for assured/mandated GI services for the country. Of course, implementing National GIS can be the vehicle for the policy implementation and a short-term goal and focus. The National GI Policy enunciated in the NIAS study needs to be taken up for vigorous consultation and strategy-development – moreso within government and also outside. With more debate and discussion, the GI Policy text can be refined and improved and can then be taken up for adoption in India – through an act of legislation.

Of course, the above 10 actions that I list are "high-level" – in the sense, each of these would have a range of sub-actions that need definition. In addition, apart from these TOP 10 actions, planning for the full-scale National GIS Asset and covering wide range of Apps must also start right away – these would take time and must be well-planned. There would be many other actions of linking with States; creating eco-system that helps National GIS; keeping the GIS Asset updated; operations of National GIS etc that would required addressing. Thus, I visualise that there would hundreds of actions required for National GIS to ultimately operational and successful.

Based on my own experiences in the GIS scene in India, I feel that there is one very critical action – to me this will impact how actions unfurl in coming times. The need is to draft a small, dedicated, committed, technically excellent and empowered team of experts and charge them with the responsibility of organising National GIS. This team must first architecture the whole National GIS system elements and network with existing agencies/ organisations to draw on national strengths already available BUT align each of these to the common goal. The Standards and Protocols must be properly defined and documented – further debated and firmed up. A sound preparatory and design activities will help in effective implementation as per planned tasks.
In my view, this is the most critical and most important task that needs to be done and is top of all. The nimble and highly agile team must make it their mission to "give all" for National GIS – for they will have to cross and overcome many, many challenges – technological, bureaucratic, administrative, organisational and even cultural variations that may look "obstructing" but have to be unfurled out to achieve the goal. There would be many organisations involved as data generators, users, administrators, monitors etc – they have each to be made to see the same goals and success; there would be intricate procedures to be followed – transparency has to be maintained at high order BUT speed also will have to be maintained; there would be motivational issues of people/individuals but "smoothing out rough edges" will be called for; and many other challenges. The team must realise that implementing National GIS will be a class-room in "techno-management skills" and a learning experience (I feel that such an experience nations like India can only provide). A single individual will be least important but the "sum of all individuals" will only make success. So, dedicatedly this team must move on – only with one aim to make National GIS operational.

National GIS is an "over-arching system cutting across existing systems" and thus complexity is "core embedded" in its inherent character – after all, integrating human, technological, social, cultural, competitive and temporal dimensions is a difficult task but not impossible.

Schedule, budget and official approvals

As I know from publicly available information, the National GIS is part of Indian 12th 5-Year Plan (draft of which is available at http://planningcommission.gov.in/plans/planrel/12thplan/welcome.html) – thus official approvals are already there. I am told that specific programmatic approvals are in process of being obtained – I really hope that we now take the major step of initiating and launching National GIS. Similarly, for Karnataka-GIS, I think the state Government of Karnataka would also obtain its state programmatic and financial approvals and implement, in tandem with National GIS, the Karnataka-GIS.

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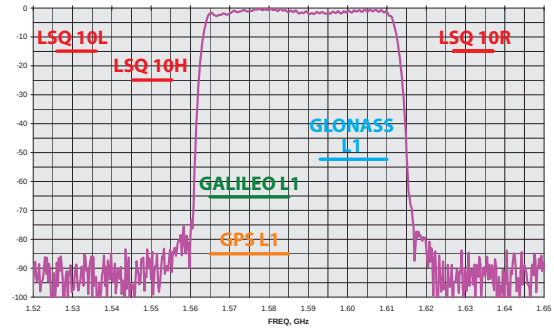

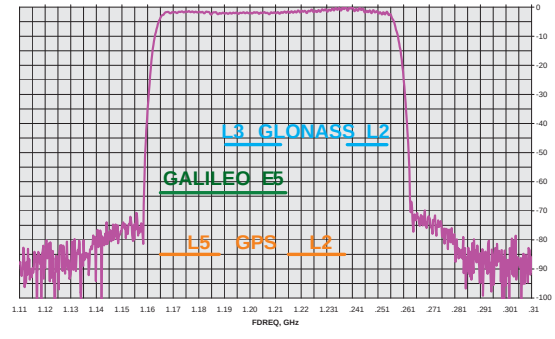

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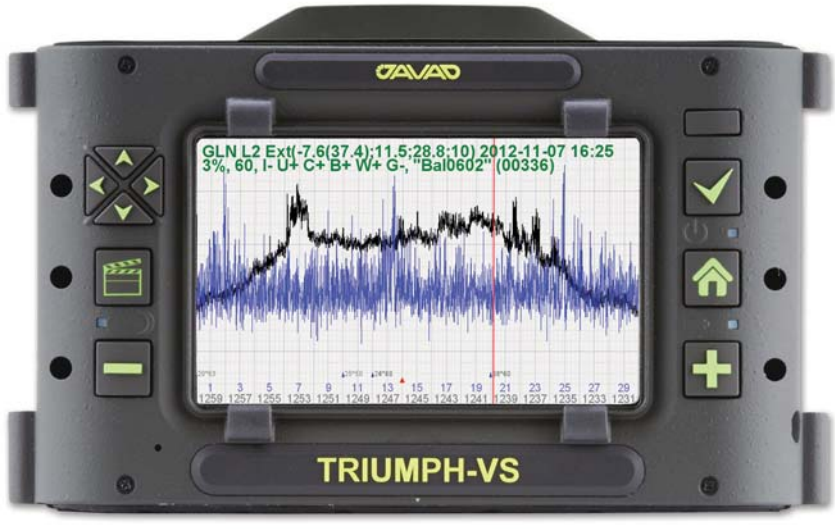

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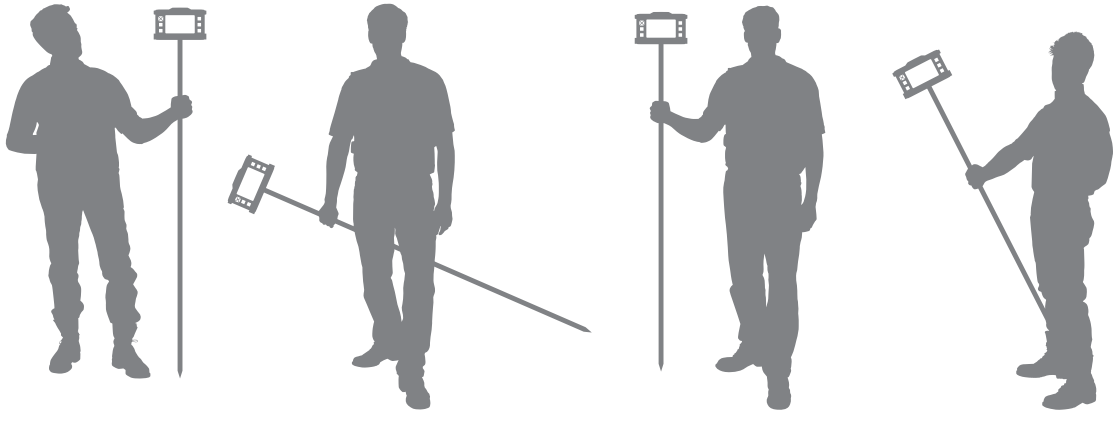

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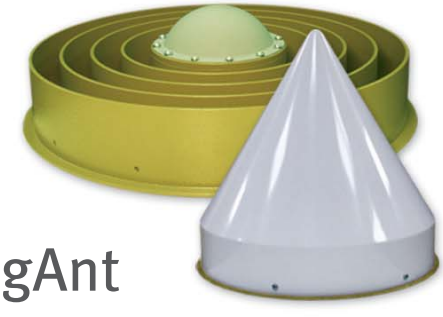

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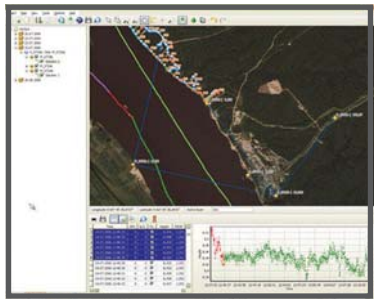

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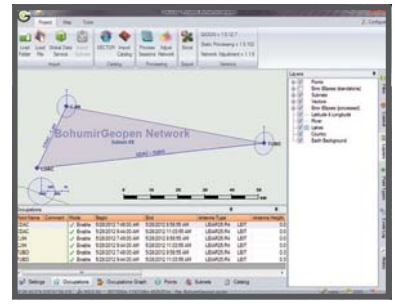

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3D Cadastral complexities in dense urban areas

The current paper aims to study the multi-stakeholding urban area locations in Delhi and around where (infrastructural) changes are creating the complex land management situations for the authorities involved

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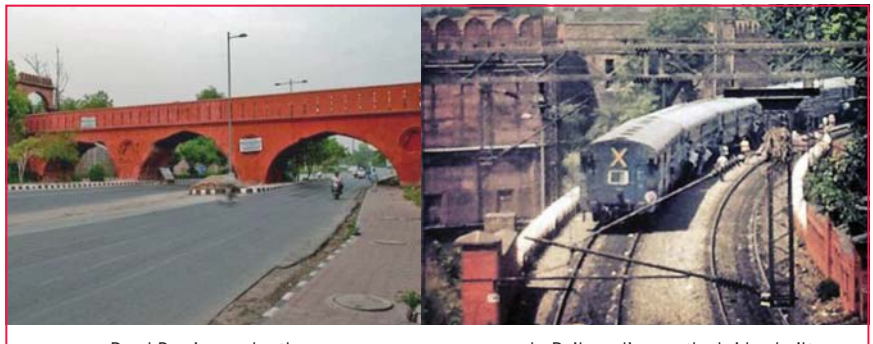
Cities in developing countries are expanding rapidly and consuming every possible space available. The growth is not only in their physical expansion but also the increased urban population. The space consumption is again not only horizontal but also vertically underground and upwards covering the skyline of the city (Godard, 2004). Delhi, being a metro city and also the capital of India, is not an exception to this phenomenon.

Property information systems based on 2D maps have served land administration and property management well for hundreds of years. However, most of the developed world (including Australia) and many developing countries now give ownership titles in buildings in three dimensions (3D) using the same 2D maps developed for traditional broad acre development on vacant land (CSDILA, 2012).

The paper aims to study the multi-stakeholding urban area locations where 3D (infrastructural) developments are creating more and more complex land management situations for the authorities involved. We are presenting some cases in brief to highlight the different aspects of complexities while focusing on a particular case study of multi-infrastructure (utility) networks in one single area, where we have tried to understand the current administrative situation as well as spatial dimensions involved from Land Administration Domain Model context.



a: Road Passing under the older Bridge; Source: Around the Red Fort, 2011

b: Railway line on the bridge built by colonial British rulers; Source: An Alternate View-Red Fort, Delhi, 2012

Figure 1: 3D space usage at bridges connecting Red fort and Salimgarh Fort

Land management and cadastral arrangements

Cadastral systems in India were designed initially to earn revenue through collection of taxes on property. The cadastral systems support the legal ownership of the land, depiction of legal and topographical aspects including area and parcel boundaries. In India, the basic unit of the cadastral record is the land parcel, which is known as plot. The plots are registered in the name of the owner defining plot boundaries. Maintenance of land records with ownership; assessment of tax on the property and tax collection is the responsibility of district authorities. Each state is adopting their own methods of cadastral surveys, and emphasis is given to the legal aspects which are connected with rights. There is no concept of licensing and registration of cadastral surveyors in India. In fact, the government surveyors of state/center are carrying out all the cadastral surveys. Private sectors are now being involved for generating GIS and LIS for better management of land resources (Country Report, 2003).

For several decades after Independence, Delhi has three municipalities: New Delhi Municipal Council (NDMC), Delhi Cantonment Board (DCB) and Municipal Corporation of Delhi (MCD) having their separate jurisdictions in Delhi. Recently in 2011-12, the Municipal Corporation of Delhi

was divided into three parts: North, South and East Delhi Corporations (MCD Online, 2013; Directorate General Defence Estates, 2013; New Delhi Municipal Council, 2013). Municipal organizations including MCD, NDMC and DCB are executing agencies which provide basic civic amenities to the city like roads and waste management. These organizations have different jurisdictions covering the entire city. Only the Delhi Development Authority (DDA) is a land development authority.

DDA takes the land from the Delhi Revenue Department or private parties whenever any land has to be developed or upgraded like a settlement. DDA has a role of planning (master plans, zonal plans) and initial development agency for the new areas while these executing agencies maintain these developed areas. There is no central registry of land in Delhi. Agricultural holdings are recorded, but urbanized land is not subject to any central registration system. In general, records of land held by governmental agencies are maintained by each individual agency, Delhi does have a long-standing system of *deed* registration. In accordance with the Registration Act, 1908 (Department of Land Records, 2013), the Delhi Government's Registrar of Assurances is required to register most types of property transactions, although there are some exceptions. One important exemption is that changes of ownership through simple inheritance, and equitable mortgages need not be registered. Sale by power of attorney allows sales without registration, incentives to avoid fees and taxes (USAID, 2007; Rabenhorst, 2008).

Current Tenure Characteristics in Delhi are (Rabenhorst, 2008):

- Freehold land (Old Delhi; pre-1947 titles; more recent colonies; leasehold conversions)
- Leasehold land (owned by development authorities)
- Apartment – sale deed and use rights; chain of title remains with developer (it should be noted that these use rights related to an apartment units imply 3D spaces, but these are currently not explicitly represented in 3D)
- Informal settlements – 10m+ people, over 70%
  - Types: squatters, relocation settlements, unauthorized colonies, rural and urban villages
  - All income levels
  - No title requested or obtained
  - No building permit requested or obtained
  - Risk of demolition
  - Nature of tenure constrains water and electricity supply and service

Delhi – A capital city always

It has a long history of being the centre of political activities even before the 15th century. When Muslim invaders settled down in India after permanent invasion in early 15th century, they gradually settled down in Delhi (Krishna, V. B., 1980). At that time, the city was mostly limited to the northern part of Delhi on the banks of the river Yamuna.

This part of today's Delhi is called 'Shahjahanabad' or now popularly known as old city or the walled city. Some 3D usage examples from Mughal era and British times in the old Delhi city parts are still functional. One classic example is the Salimgarh Fort Bridge. Mughal Emperor Shahjahan built the Red fort in 1639 AD in Old Delhi. Close to this fort along the north-eastern part, there was an old fort called Salimgarh, built by Islam Shah Suri in 1546 AD. The river Yamuna once flowed between these two forts. The two forts are connected to each other by two masonry bridges (Comprehensive Conservation Management Plan, 2009**)**. Today, the river does not flow here anymore. Now a road (Delhi Ring Road) passes under it with traffic in both directions. The second bridge was built by colonial British rulers on which they constructed a railway line from old Delhi railway station going towards the other side of Yamuna river (Figure 1). It is still functional and all types of trains pass through it (Around the Red Fort, 2011; An Alternate View-Red Fort, Delhi, 2012).

After gaining independence in 1947, Delhi rapidly began taking shape of a metro city with many urban developments, including 3D spatial aspects in design, such as large multi-storey academic and office buildings (sometimes parlay above the road or other public spaces) and offices (Architecture of Delhi, 2013). In 1991, the Indian government adopted the liberalization concept for the nation's economy (Panagariya, A., 2001; UNCTAD, 2012). Delhi still remained a union territory that was governed by the central government. All the civic bodies were functioning under the central government. By mid-1990s, it was decided to conduct elections for constituting a state-level government. However, certain important land management related bodies remained outside the scope of the Delhi government. This included Municipal Corporation of Delhi (MCD), New Delhi Municipal Council (NDMC), Delhi Cantonment Board (DCB) and Delhi Development Authority (DDA).

By the start of the 21st century, Delhi had started growing rapidly in terms of population and infrastructure development and the amount of 3D solutions continuously increased. A big urban area/sub-city started taking shape in west Delhi just behind the international airport. This was targeted to provide housing to approximately 1 million middle class families (DDA, 2013; Architecture of Delhi, 2013). The Metro rail started operating in this decade and changed the entire landscape of Delhi by providing a mass transport system with high quality service. Its tracks were laid down on surface, above surface on the pillars and under surface through tunnels.

A remarkable change in early 2000 was the fact that most of the plot-owning landlords started making basements while initiating constructions on the plot. The immediate satellite towns of Gurgaon, which because of Information Technology companies' dominance is called cyber city, and Noida started feeling the pressure of demand for residential apartments and offices (Figure 2, Figure 5). Agricultural lands have been acquired by neighbouring provincial governments and sold to private developers. The builders have created or dug out the base for new high rise buildings in several hectares.

Figure 2 shows Delhi with its utility networks of roads along with green spaces, natural drainages and settlement pockets. Metro train routes are also reaching satellite towns of Gurgaon in south, Noida and Ghaziabad in the east.

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This rapid expansion in Delhi and immediate neighbouring cities of Noida and Gurgaon came as a life-style changing shock to the traditionally agricultural communities of these cities. It was also a shock for the land administration of these cities that were not ready to deal with this rapidly changing land market and especially the 3D aspects hereof. The major player in the case of Gurgaon is Haryana Urban Development Authority (HUDA). The bureaucratic setup in the authority was still riddled with the inefficiency of paper work. Even after 20 years of this change, civic amenities are not up to the mark of a high value urban area. In Noida, the inefficiency of the authority together with political motives led to a large scale riot in 2009-2010-2011 when the government was accused of bias in following the land acquisition procedures (India Today, 2011; Indian Express, October 2009; Headlines India,2011; Indian Express, December 2009), The Hindu, 2009).

Multi-stakeholding developments in urban scenario

The 3D urban (infrastructure) development has affected many aspects of an average Delhi resident's life. It has changed the way they travel to their office, the access to cooking gas, the water they receive in the flat, telephone and internet access. To provide these amenities, multiple government and private agencies have consumed the space of Delhi in different layers, above and below the Earth surface. The result is a situation in which the space (related to the same unit of surface land) is under control of different agencies with their user rights. In other words, many stakeholders in the form of civic amenity providing agencies become involved in the same place. This requires organizational level of coordination on a much higher scale than ever before because of the complexities of land management to lay down the service networks. Utility networks for different facilities are competing for the vertical and horizontal space. Different laws and directives need to be in place to ensure proper planning and construction of these networks without interfering with the operational functionality of other networks. To have proper laws and directives, there is a need to understand the spatial topology of these networks, their relation to surrounding land use and the mandates of the agencies responsible for them. Spatial dimensions involve understanding the space requirements in three dimensions and how the interaction of the networks takes place in the defined space.

Land administration domain model

Land administration is a large field; the LADM international standard (ISO, 2012) is concerned with the representation of *parties (natural and non-natural persons), spatial units (including survey and geometrical/ topological representations) and their relationships via RRRs; rights, restrictions and responsibilities (and the grouping into basic administrative units)*. In LADM, the basic administrative unit class serves the purpose of defining the bundle of RRR that apply to a given spatial unit, or a group of spatial units (Hespanha, 2012). In countries following the British common law tradition, this usually translates for the registration of a freehold right, together with optional appurtenances (minor rights) or encumbrances (restrictions).

The LADM is capable of handling more than one type of registry, besides the commonly referred Land Registry (essentially registering private property RRR's), for instance a Spatial Planning Government Portal, storing several types of public regulations and their associated spatial units. The LADM provides a *reference model* which will serve at least two important goals:

(1) Avoiding reinventing, and re-implementing the same functionality, over and over again, but providing an extensible basis for the development, and refinement of efficient, and effective land administration system development, based on a Model Driven Architecture (MDA), and

(2) Enabling involved parties, both within one country, and between different countries, to communicate, based on the shared vocabulary (that is, an *ontology*), implied by the model.

Within the LADM, classical cadastral concepts as 'parcel' and 'boundary' (Lemmen et al, 2010; Thompson and van Oosterom, 2012) have been extended to be able to include spatial representations of overlapping tenures or claims and also multi-dimensional objects (3D and 2D/3D, combined with temporal dimensions). The spatial units may have a 3D representation, and a provision is made for a mixture of 2D and 3D spatial units to co-exist. A level is a collection of spatial units with a geometric or thematic coherence. The concept of level is related to the notion of 'legal independence' from Cadastre 2014. This allows for the flexible introduction of spatial data from different sources and accuracies, including utility networks, buildings and other 3D spatial units, such as mining claims, or construction works. The LADM introduces concepts such as 'boundary face string' (LA_BoundaryFaceString) and 'boundary face' (LA_BoundaryFace) and partially unbounded primitives. Spatial profiles and the different spatial representations are used to demonstrate the flexibility of spatial representations of this domain model.

Three dimensional complexities in urban space – Case studies from Delhi and neighbourhood

To show the various kinds of land complexities which involve different spatial dimensions, some cases from Delhi and its surroundings will be presented.

Figure 2: Delhi map with Satellite towns; Source: Google Maps

Case 1: Basement Coverage and Adjoining Property

Due to building collapse incidents in congested areas of Chandni Mahal, Old Delhi and Uttam Nagar, West Delhi in 2011, the Municipal Corporation of Delhi (MCD) came up with a new regulation that makes it mandatory for builders constructing a basement to leave a buffer zone of 2 meter on all sides of the building being constructed. This has been done to make sure the adjoining buildings remain safe. According to MCD officials, the new rule is in accordance with Master Plan 2001(Page 159, Table 8 [4], Control for Building/Building within use premises-specific premises residential plot-plotted housing, Foot Note No. IV) in which there is a clause that reads, "Basement up to ground floor level is required to leave 2 meter distance from adjoining property and is not counted towards Floor Area Ratio."

Spatial Dimensions

2D surface plot with rights granted to build underground basement structure which implies the 3rd dimension. The term "basement up to ground floor level" indicates a 3D space from the floor of the basement up to its ceiling which could be the ground floor level. Two meter distance to be left considers the geometrical connectivity of 2D surface plot to adjoining plots in 3rd spatial dimension also (complete vertical columns).

LADM spatial unit context

The upper face boundary is defined by ground floor coverage and the lower face boundary defined by the basement floor. The term "basement up to ground floor level" includes vertical boundary–faces to catch the 3rd dimension in its entirety. This case can also be modelled in its spatial and temporal dimensions considering a succession of different spatial units combining 2D and 3D geometric primitives. In a first instant, it defined a buffer zone as a building restriction, using an internal (closed) boundary face string, which lies 2 meter inside the property boundary face string. These are both implemented through 2D primitives, but represent unbounded vertical faces, forming thus an unbounded (above and below) ring around a space where building can occur.

When construction is about to begin (in which new Legal Space Building Units, LA_LegalSpaceBuildingUnit in LADM terminology, will be created), the basement volume can be defined by setting two horizontal boundary faces for the basement floor and the ground floor/basement ceiling. These two faces are 3D primitives which will touch the building outline boundary face string, thus forming liminal space (at the opposite side of the face string). When referring to the building outline, it must be kept in mind that the spatial unit delimits the legal space of the building and not necessarily its physical boundaries. Applying the operation as defined in ISO 19152 IS Annex B (ISO, 2012) will generate the vertical boundary faces required to close the volume representing the basement legal space (Figure 3). In the end, there are thus three spatial units:

A. Property Parcel (2D representation, implying a 3D column);
B. Buffer zone restriction (2D representation, implying a 3D column);
C. Basement volume (3D representation).

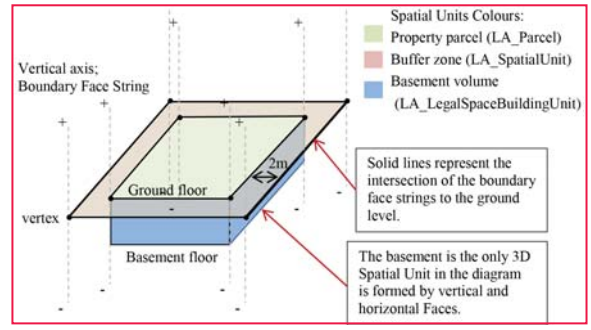

Figure 3: A basement coverage and adjoining property; schematic geometry of corresponding LADM objects.

Case 2: high rise apartments made on stilt basis for cooperative group housing societies

The following text is based on an actual conveyance deed of a flat owner in a stilt basis society building (Figure 4). The Registry/ Conveyance Deed of individual owner of a building unit (in a flat /apartment complex on stilts) with Delhi Development Authority (DDA) states that the vendor (DDA) accepts and reserves unto himself all mines and minerals of whatever nature lying in or under the said property. It gives full liberty together at all times for the vendor, its agents and workmen to enter upon all or any part of the property to search for, win, make merchantable and carry away the said mines and minerals. The mentioned elements could be under or upon the said property or any adjoining land of the vendor. The vendor can lay down the surface of all or any part of the said property and any buildings under or hereafter to be erected thereon making fair compensation to the purchaser for damage done unto him thereby, subject to the payment of land revenue or other imposition payable or which may become lawfully payable in respect of the said property and to all public rights or easement affecting the same.

Spatial dimensions

The authority gives the rights to the individual flat owner, under the deed for which the owner pays registration fees, for the 2D surface or on the unit in a multi-floor residential building to live without paying rent for the property to the authority. This means the individual flat owner is allowed to hold the right to live and to own the unit in 3rd spatial dimension towards upwards. However, the owner needs to keep paying annual property tax to the municipal corporation. On the other hand, the Delhi Development Authority is making clear its rights on the mineral resources present in 3rd spatial dimension under the surface. Interestingly, it doesn't mention anything about groundwater resource present in the same spatial dimension. In practice, the Cooperative Group Housing Society managements are allowed to do boring for groundwater extraction to provide drinking water to society residents.

LADM spatial unit context

If the mineral resources are at ground level, its exploration, together with the

Figure 4: Stilt Based Multi-Floor Society Apartments in Delhi

required easements, could mean that any building would be at stake, and the required space returns to the state through an expropriation. This should be avoided by a (cheaper) surface geological mapping to clarify matters beforehand. If the mineral resources are below ground, the best course of action would be defining a 3D Parcel belonging to the State (which can then make a lease or concession). Apart from this 3D Parcel, there should be a 3D Parcel representing the upper unbounded space of the Housing Society. Also in this case there are at least three spatial units, as follows:

A. Housing Society Property Parcel (3D upper half of infinite column);
B. Individual building units (3D within Housing Society Property);
C. Mining Property (3D lower half of infinite column).

In addition, there should be some topologic constraints, in that the mining easements should intersect both the property parcel boundary and the mineral deposit.

Case 3: High groundwater disposal from the large construction sites (including basement)

Knowing the subsurface components like soil composition in different vertical profiles, groundwater flows and volume or other minerals is important before initiating the construction. This can help to avoid the unforeseen problems in completing the construction process. As per Times of India, February 19, 2012, in a bid to conserve groundwater, the Noida Authority decided to initiate legal action against private developers wasting the precious resource during construction work. From now on, developers will have to submit affidavits assuring that they will minimize the wastage of groundwater before seeking permission for construction.

The decision came after a meeting of Noida Authority, State Pollution Control Board and Environment Pollution Control Authority (EPCA). Taking cognizance of a recent incident whereby a private developer had been blatantly wasting groundwater resources by pumping it out in a sewage drain for almost a year while digging for the construction of a mall in Sector 18 to make the terrain dry and suitable to construct the basement, Chairperson, EPCA directed the Authority to ensure that the work is halted. The Authority was also told to take appropriate action against the builder.

The Authority has now served notices to all developers who have been carrying out massive construction work, directing them to submit affidavits and details of reusing the groundwater.

While individuals who construct a floor or two for residential use can be spared, builders constructing high-rises must submit the affidavits. All cases of violations have been submitted to the Central Ground Water Commission. A related situation exists in case of cyber city Gurgaon, adjacent to Delhi, in the state of Haryana, where the Urban Development Authority cannot give license for construction to builders and developers until they submit an building/ construction request in which it becomes clear that they will not use the groundwater for construction work. As per July 16, 2012 Hindustan Times, the High court of Punjab and Haryana state had given this order while listening to the petition submitted by the Resident Welfare Associations of the neighbourhood. The associations had written in the petition that some big builders, while digging foundations for the large sites, were using the groundwater from the foundation for the construction and some were selling this groundwater through tankers to urban settlements in Delhi. On the other hand, due to falling groundwater levels, the borewell works done by resident societies in the neighbourhood were not getting any water.

It is worth noting to consider the natural water availability in the cases of Noida and Gurgaon (Figure 5). The Noida extension construction areas fall between two rivers namely, Yamuna and Hindon. This means plenty of groundwater available at relatively low depth at least for the near future. This also means that developers in Noida can get easy water supply at cheap rates even in case of groundwater usage ban which keeps the construction costs lower. On the other hand, Gurgaon which is 15-20 km away from Yamuna

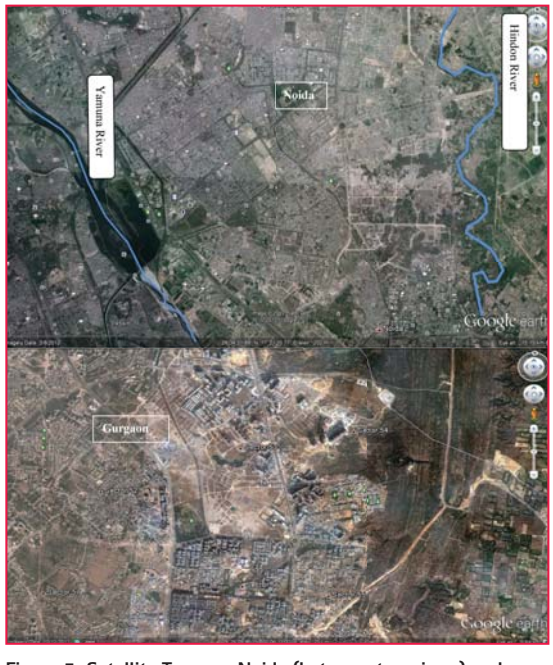

Figure 5: Satellite Towns – Noida (between two rivers) and Gurgaon (No surface water source visible); Source: Google Earth

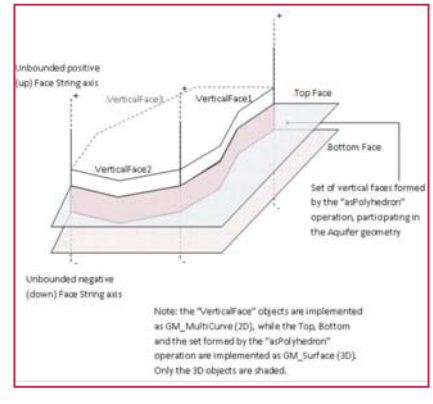

Figure 6: Groundwater Spatial Unit within the area of a large construction site

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Table 1: Utility Networks at Dhaula Kuan

S.No.	Utility Network	Spatial Dimensions in Z	Operating Agency
1	Sewerage Line	Below Drinking Water Line at Subsurface Level (.... meters in depth) -z	Delhi Jal Board (Water Board) under Delhi State govt.
2	Drinking Water Line	Subsurface Level (-1.35 meters in depth) –z	Delhi Jal Board (Water Board) under Delhi State govt.
3	Internet Optical Fiber Line/ Telephone Lines	Subsurface Level (.... meters in depth) –z	Reliance (Private Concessionaire) & Mahanagar Telephone Nigam Ltd. (Government of India Telephone agency)
4	Electricity Lines	Subsurface Level (-1.1, -0.6, -0.56, -0.45 meters in depth) –z	BSES, (Private Concessionaire)
5	Cooking Gas Pipe Line	Subsurface Level (.... meters in depth) –z	Indraprastha Gas Ltd., (Company promoted by public sector gas and petroleum agencies)
6	Surface Road	Surface Level (0 meters in depth) z	Public Works Department, National Highway Authority India, NDMC, DCB, North Delhi Municipal Corporation
7	City Train Track	Surface Level (0 meters in depth) z	Ministry of Railways
8	Vehicle Flyover	Above Surface Level (Approx. 5.5 -6 meters in height) +z	Public Works Department
9	Airport Express Metro Track on Pillars	Above Surface Level (Approx. 12-15 meters in height) +z	Reliance Pvt. Ltd, (Private Concessionaire)
10	Delhi Metro Track	Above Surface Level (Approx. 15+ meters in height) +z	Delhi Metro Rail Corporation (company with equal participation of Government of India and Government of National Capital Territory of Delhi).

has almost no surface water supply. About 80% water supply for different purposes is coming from groundwater extraction. Rainfall is less than 600 mm annually. This means developers find it economically attractive to use any groundwater they get while digging the foundation. Any kind of ban on groundwater usage is now going to increase the construction cost, although this will help to keep the groundwater stable in the shared aquifers.

Spatial dimensions

2D surface plot with rights granted to build underground basement structure which implies the 3rd spatial dimension. The groundwater occurrence and related regulations increases the complexity of 3rd spatial dimension lateral extent. The geometrical connectivity of 2D surface plot in 3rd spatial dimension to adjoining and non-adjoining plots in the context of groundwater as a dynamic resource type needs to be considered.

LADM Spatial Unit Context:

In this case, a simple face boundary derived from boundary face strings (2D primitives) would not be sufficient. Boundaries in all spatial dimensions need to be made up of 3D primitives, which will help to build the adjoining boundary faces with 3D geometry and topology maintained as in geological models (Ghawana et al., 2010, 2012). The 3D geometry and topology will ensure correct volume calculations of groundwater for each stakeholder in case of a shared aquifer. Based on these 3D primitives, Upper face boundary can be defined by ground floor coverage. Lower face boundary defined by foundation floor. Vertical boundary–faces with their 3D geometry will help to catch the 3rd dimension in its entirety.

In the case of groundwater, one important topological requirement would be the maintenance of surface (not horizontal, but along the flow) connectivity, especially if there is a groundwater stream flowing under the property ground surface. There could be defined a building restriction area at the surface for areas with high recharge potential, or a limitation in depth for the basement, due to a valuable deep aquifer which can still be recharged by sub-horizontal flows. This last restriction can be a simple 3D boundary face, which generates a layered representation within the property boundary face strings.

The example in Figure 6 shows a private property spatial unit (the large construction site), represented by the set of boundary face strings named 'VerticalFace1' to 3. The groundwater spatial unit is derived then through the definition of top and bottom face strings (3D primitives), together with the set of vertical face strings (also 3D primitives) determined by the 'as Polyhedron' operation as presented in (Lemmen et. al, 2010).

Case 4: Dhaula Kuan – Multiple (utility) networks and vertical space claims

Dhaula Kuan is an interesting location from the perspective of land management complexities involved in actual situations. It is a major traffic intersection receiving traffic from all directions of Delhi. From land use point of view, it is interesting to see that it has a golf course for army personnel in Delhi Cantonment, a forest area called central ridge area, and it has two biggest five star hotels. Multiple (transport) networks are passing through this area: Surface Roads, vehicle flyover and loops, city train track and Airport Express Metro Link in addition to the utility networks for sewer, drinking water, electricity, etc. The situation is going to be more complex when the ordinary metro track construction will begin soon. It is not clear whether it will be above surface on pillars, on surface or underground, but under the third phase of Delhi Metro, a corridor will cross this path (Figure 7 and 8).

(a)Year 2000 – A simple roundabout

(b)Year 2004 – A flyover for vehicles constructed

(c) Year 2008- All the road loops completed

(d)Year 2009 – Work begin for Airport Metro Express line under PPP model, concessionaire: Reliance Pvt. Ltd.

(e) Year 2010 – Airport Express Metro Track Completed

Figure 7: Dhaula Kuan infrastructural changes over the years; Source: Google Earth

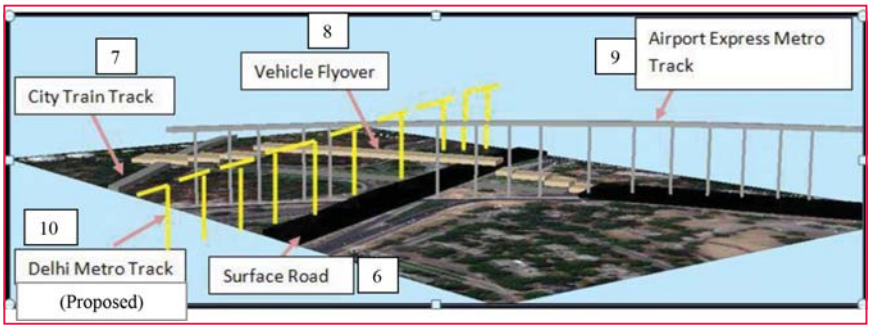

Figure 8: 3D view of Dhaula Kuan surface and above surface utility networks

Administrative aspects

At Dhaula Kuan, we find various agencies at work including NDMC towards Hotel Area. After MCD division, the area towards north side with the central ridge forest comes under the jurisdiction of North Delhi Municipal Corporation. Delhi Cantonment Board (DCB) takes care of the area inside Delhi Cantonment and that includes the golf course next to Dhaula Kuan Point. All the forest area, called Central Ridge, around this point comes under the forest department of Delhi government. There are many other executing agencies like Public Works Department (PWD), Delhi Metro Rail Corporation (DMRC), Land and Development Office of Indian government and Revenue Department of Delhi Government. PWD maintains the road infrastructure (surface road and flyover) up to the flyover end points on both sides and the loops. After the end of the flyover towards the western side, there is a traffic light which has one road going straight to the west (National Highway 8) and one taking a right turn, goes inside the Delhi Cantonment Area (General Carriappa Road). National Highway 8 after this traffic light comes under the National Highway Authority of India (NHAI) while the General Carriappa Road, after this traffic light, is maintained by DCB. On the eastern side of the flyover, after it ends, the roads are maintained by the NDMC. North Delhi Municipal Corporation is responsible for the maintenance of the ridge road going through the central ridge forest towards the north-eastern side. Under the Airport Metro express pillars, the ownership of the buffer zone of approximately 2 meter remains with governmental company DMRC. DMRC need not to take any permission for any kind of infrastructure work in this buffer zone from other executing agencies (Figure 7 and 8).

Spatial dimensions

The complexity of spatial dimensions for different utility networks at Dhaula Kuan point is significant from the perspective of coordination between the various agencies involved. This coordination is important for the maintenance and thus for the smooth functioning of these networks. Table 1 lists the various utility networks which claims spatial space share in vertical dimensions also. It also mentions their approximate depth/height as well as the operating agencies which could be governmental, semi-autonomous governmental or private concessionaire agencies. Figure 9 shows the agencies having ownership/responsible for the maintenance of the utility networks which are on surface/above surface.

LADM Spatial Unit Context

The situation depicted in this case is obviously complex and involves a substantial number of different types of

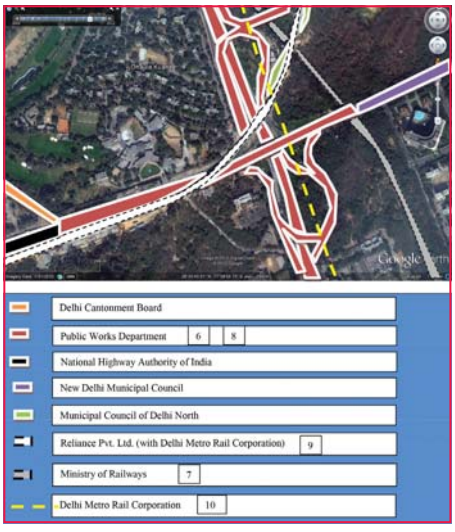

Figure 9: Dhaula Kuan Surface & Above Surface Utility Networks and Maintenance Agencies; Source: Google Earth; Note: These areas (with specific RRRs) overlap the other areas (with other RRRs) as depicted in Fig. 8, so really a complex 3D situation

spatial units, which combine 2D, 3D and liminal representations. For the sake of simplicity, the following description is omitting the administrative subdivisions within the area, although LADM can be used for this purpose as well (Figure 10).

A first level of analysis concerns the delimitation of spatial units belonging to two basic forms of property: Public Domain and Private Property. This should form the basic partition of (2D) space, leaving no gaps or overlaps at this level, and is naturally best represented by boundary face strings following a 2D Topologic spatial profile (ISO TC211, 2011, Annex E). As already seen, these spatial units are in fact representing an unbounded vertical space, both above and below ground. In a second level of analysis, there should come all the spatial units which consider administrative servitudes and easements (also with 3D descriptions), whenever the ownership (public or private) differs from the one in the first level (the basic partition). This is the case with all the referred utility networks, where a specialized type of spatial units (LA_LegalSpaceUtilityNetwork) shall be considered. These should be represented by 3D spatial units, defining elongated prisms which carve out parts from the unbounded space defined by the spatial units in the basic level.

Giving the traditional mandate of Land Registries, the situation should be carefully examined to see which spatial units are currently being registered, so as to consider possible modifications to the legal framework. This should consider particularly the spatial relationships between units in the public and private domains. The above description, considering just two levels of analysis, can be in fact more complex in reality, through the consideration of true 3D parcels representing a different ownership from the basic level (2D) parcels. In this case, it would be possible to consider a different level of easements (or administrative servitudes) which would be contained within these 3D parcels.

As an example for the specific case above, the situation of a vehicle flyover forming a 3D Parcel (owned by a Public Party) could be considered where an easement for a Gas Pipe is included and is registered with a different owner. This would form a 3D spatial unit that should be contained within the volume of the 3D Parcel.

In this example, it should also be considered administrative servitudes imposed in any basic level public property parcel (2D) which is crossed by the vehicle flyover.

Conclusion and recommendations

Dense urban spaces in developing countries are facing new challenges of land management on technical and institutional coordination level. Delhi and its immediate neighbourhood cities are going through a transformation process for land administration and their cadastral systems. There is an imperative need on land management related organisations and other stakeholders level to understand this rapidly changing scenario of land as a valuable commodity and also as a scarce resource. Cadastral systems need to be designed and supported from three dimensional spatial perspective and contributing for a continuously updated registration system(s).

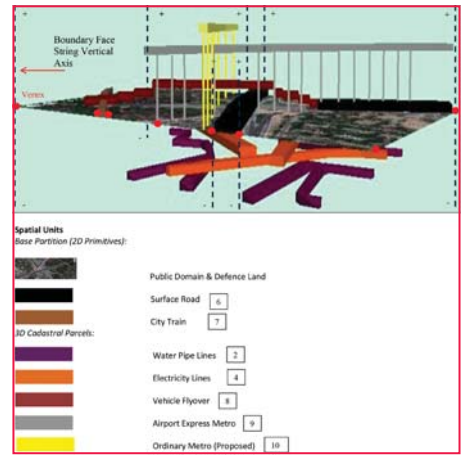

Figure 10: Spatial partition and above ground properties at Dhaula Kuan intersection; schematic geometry of corresponding LADM objects.

It is important to focus on determining the right type of data primitives so that to generate meaningful information in LADM Context or other generic spatial perspectives. As seen in these cases, underground and above ground structures need to keep a topological relationship with earth surface in between. In this paper, the focus has been kept on the support which the Spatial Unit package of LADM and its related modelling patterns can provide, in the context of particularly complex land administration cases in and around Delhi metropolis. A logical follow up, concerning a possible prototype implementation of a 3D cadastral system, should study the implications brought by considering the remaining packages of LADM (Legal and Administrative). A first version of such a system could be built upon the data already gathered for Case 4 at Dhaula Kuan.

Future work also includes implementing the Spatial Unit model. For this an integrated TIN/TEN model is proposed, which represents the surface (2D) objects in a TIN and volumetric objects (3D) as TENs, which will be placed on top or below the TIN. It is also presumed that all 3D features are connected to the earth surface (Peninga, 2008). Such an integrated model can easily handle large data sets while maintaining 2D and 3D topological relationships.

The complete paper with detailed references can be accessed at www.mycoordinates.org

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GIS in pipeline route selection

This paper identifies some of the factors responsible for the relatively limited use of GIS in route selection. Limitations of GIS in multi-criteria and multi-participant decision-making tasks, such as pipeline route selection are discussed and efforts that are being made to overcome these challenges are highlighted

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Burgeoning energy needs in the 21st century are driving demands for more petroleum products. These needs were hitherto met by using pipes to transport required energy products over long distances within countries and across borders, from their sources to respective destinations (Chai et al, 2006; Yildirim et al, 2007; Dubey, 2009). However, increase in global population has triggered an increase in demand for essential products such as natural gas, crude oil and finished petroleum products, etc. For instance, regional and global demand on the Persian Gulf's hydrocarbon reserves has increased dramatically in the last decade (Degermenci, 2001). Other regions are also experiencing similar demands for their petroleum resources and existing pipelines are rather insufficient to efficiently transport the huge volume of required energy resources. Moreover, many of the existing pipeline systems are old and face the risk of failure sooner than later. It is also generally considered risky to depend solely on single, ageing pipe networks/routes for product transportation (Nord Stream, 2012). Thus, it is imperative to develop new pipeline routes in-order to augment existing ageing ones. According to Smith (2012), planned pipeline construction, which is to be completed in 2012 increased by 6.7% when compared with the previous year's figure. Relying on data from the world's pipeline operating companies, it was projected that 8,887 miles of pipelines will be installed in 2012.

Pipeline route planning and selection

Route selection is a foremost and crucial step in the overall pipeline design and construction process (Feldman et al, 1995; Yildirim et al, 2007). Proper pipeline route selection is a strategic component of a company's pipe laying activities when laying new pipelines or expanding the existing pipeline network. Selection of an appropriate pipeline route is perhaps the single most important element in the development of transmission lines (Khene, 1997; Degermenci, 2001). The pipeline route selection process focuses on achieving the optimal location for a pipeline. Optimization of route selection brings about risks and cost reduction, as well as a better decision making process. The selected route can significantly affect the success or failure of a project. The importance of selecting an appropriate route is evident when the increased pipe length and higher cost of an unnecessarily longer, meandering route is considered (Wilburn et al, 1995).

Reports from two European Union (EU) commissioned studies on pipeline transportation out of Caspian Sea producing areas concluded that such pipeline systems are technically, economically, and environmentally feasible but depend critically on route selection (Degermenci, 2001). These findings further underscore the significance of proper route planning and selection in any pipe installation project. It is thus essential to endeavor to always identify routes which are technically feasible, are constructible at reasonable costs, cause minimum damage to the environment, and create minimum resistance from the public (Feizlmayr et al, 1999). Basically, critical issues affecting route selection are a societal risk, have an environmental impact, and require engineering and operational efficiency. Other route selection considerations include physical, political, economic,

and regulatory concerns (Carpenter et al, 1984; Ryder, 1987; Feldman et al, 1995; Montemurro et al, 1998).

Pipeline route planning and selection is usually a complex task involving simultaneous consideration of several factors. It is more complicated than simply laying pipes from the oil source to the final destination. Natural and man-made barriers along probable routes have to be considered and the likely influences of these barriers on the pipes after installation are also taken into account. Accurate determination of the impact of these factors on pipeline routes is usually a tedious task requiring a skilled and dedicated approach (Oil and Gas, 1993). Generally, pipeline route selection procedures are implemented using two techniques: Traditional route selection process and GIS-based (automated) route selection process.

Traditional route selection process

Traditional routing procedures usually begin with a start to end (source to destination) plan. A large area within the start and end points is identified and detailed data within this whole area is acquired. Typical data sources include maps, field surveys, aerial photographs, or other sources that provide information on routing obstacles which must be overcome. If the proposed route presents insurmountable physical obstacles, environmental constraints or other barriers, a new route must be explored and the data collection process begins again (Oil and Gas, 1993; Humber, 2004; Berry et al, 2004). The manual method is characterized by small scale paper maps, hand delineation, and manual topographic map overlay (Jankowski, 1995; Price, 2009). There is limited use of technology in this process and feasible results obtained from the data acquisition process serve as a preliminary pipeline corridor on which decisions are based. The core strength of the traditional route selection method lies in its reliance on experts' experiences, interpretations, and judgments in selecting the final pipeline route (Jankowski, 1995; Matori et al, 2009). However, the process has been criticized for its inaccuracies and resources wastage (Feldman et al., 1995; Humber, 2004). It is claimed that this manual procedure is usually tedious, time consuming, and lacks details (price, 2011). It is further argued that it lacks a defendable, documented procedure that clearly demonstrates the constitution of a best route (Matori et al., 2009).

Pipeline route planning and selection is usually a complex task involving simultaneous consideration of several factors. It is more complicated than simply laying pipes from the oil source to the final destination

GIS-based route selection process

Finding an optimal pipeline route using GIS can be accomplished using a least cost path (LCP) algorithm. The LCP method for determining the optimal pipeline route between the product source and destination is an established GIS technique (Husdal, 2001; Humber, 2004; Berry et al., 2004). Four parameters are required for a least cost path analysis - source raster, cost raster, cost distance measures, and an algorithm for deriving the least accumulative cost path (Chang, 2010). Finding the least accumulative cost path is an iterative process based on Dijkstra's algorithm (Chang, 2010). In 1959, Dijkstra developed what is arguably today's most popular shortest path algorithm. It is also probably the most widely used (Husdal, 2001). The iterative process starts by activating cells adjacent to the source cell and by computing costs to the cells. The cell with the lowest cost distance is chosen from the active cell list, and its value is assigned to the output raster. Subsequently, cells adjacent to the primary cell are activated and included in the active cell list. Whenever a cell is reactivated, its accumulative cost has to be computed again. The lowest accumulative cost is then assigned to the reactivated cell. The process will be repeated until all the output raster cells are assigned with their least accumulative costs to the source cell (Chang, 2010). A remarkable feature of Dijkstra's algorithm is that it guarantees the optimal solution to a shortest path or least cost path problem.

Benefits of GIS-based route selection are well documented in existing literatures (Humber, 2004). GIS least cost path (LCP) analysis has been effectively used to determine suitable oil and gas pipeline routes in several real-life projects (Feldman et al.,1995; Montemurro et al.,1998; Dupuis et al., 2004; Iqbal et al., 2006; Yildirim et al., 2007). A GIS-based route selection process has the potential to reduce project costs by about 15 %-30% (Delavar, 2003; Humber, 2004; Exprodat, 2012). When properly used, GIS techniques are faster, better, and more efficient than traditional/manual techniques (Price, 2009 and 2011).

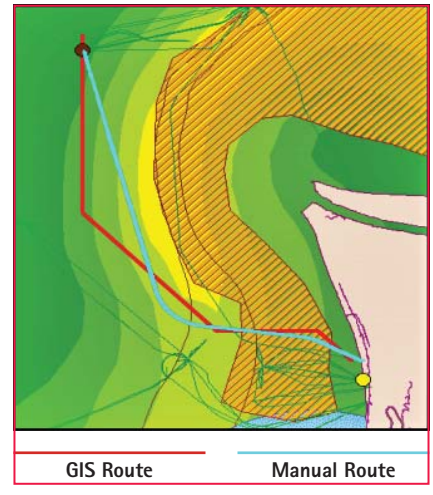

Figure 1: Comparison of GIS generated route and manually generated route (Adapted from: Matori et al., 2009)

In a comparison of a GIS-generated pipeline route and a manually generated route shown in figure 1 above, Matori et al., (2009) concluded that the GIS-developed route facilitated greater reduction in pipeline construction cost.

In spite of its efficacy and cost effectiveness, the use of GIS in route selection and utility mapping by companies and consultants is still limited. There is a reluctance to shift from the traditional method and holistically adopt GIS techniques and analysis (Scott et al, 1998; Humber, 2004).

Challenges of GIS-based route selection

One reason GIS remains under-utilized in pipeline route selection projects is 'project panic', which is an intense fear experienced by project personnel who are skeptical of procedural change or a shift from the status quo (Humber, 2004). They are comfortable with the way things were done in the past and are satisfied with results from previous projects utilizing manual route selection methods. To this group of people, adopting a GIS-based route selection process could be a costly gamble.

Another growing concern in recent times is the reliability of GIS, especially when dealing with multi-participant and multi-criteria problems like pipeline route selection. A lot of researchers have expressed concerns that GIS is a limited tool in spatial decision-aid domain. This is primarily attributed to its lack of more powerful analytical tools which makes it challenging to reliably deal with spatial problems involving several diverse groups with conflicting objectives/criteria (Janssen and Rietveld 1990; Carver 1991; Fischer and Nijkamp 1993; Laaribi et al., 1996; Malczewski 1999; Chakhar et al, 2003). It is argued that decision makers' preferences, represented by criteria weights are not accurately represented by current GIS (Chakhar et al, 2003). This limitation fuels the skepticism of companies and consultants who are originally not keen on utilizing the technology.

Current trend

In order to overcome the limitations identified in previous section, continuous efforts are being made to integrate GIS with other analytical tools to produce robust decision support systems (DSS) capable of effectively solving multi-criteria and multi-participant problems like pipeline route selection (Chakhar et al, 2003). Specifically, Multi Criteria Decision Making (MCDM) tools have been successfully used for various applications since the 1960s and many of these tools are working well with GIS too. Though, MCDM is divided into two broad groups: Multi Attribute Decision making (MADM) and Multi Objective Decision making (MODM), MADM tools are more commonly integrated with GIS (Malczewski, 2006). While GIS is a powerful tool for managing spatially referenced data, MADM tools offer powerful techniques for modeling spatial problems (Chakhar et al, 2003). Collectively, they form very powerful decision-making tools capable of solving complex decision problems (Jankowski, 1995; Malczewski, 2006).

Lin (2006) listed major types of MADM techniques as shown in Table 1.

Table 1: Overview of MADM Techniques (Adapted from Lin, 2006)

MADM Technique	Description
Dominance	An alternative is dominated if there is another alternative which excels in at least one attribute and equals it in others.
Maximin	The overall performance of an alternative is determined by its weakest or poorest attribute (Pessimistic attitude).
Maximax	The overall performance of an alternative is determined by its best attribute (Optimistic attitude).
Conjunctive	An alternative is accepted if each attribute meets a set of preset minimal acceptable levels or standards. If at least one attribute doesn't meet the set, it is unacceptable. The minimal acceptable levels for each attribute are used to screen out unacceptable alternatives.
Disjunctive	An alternative is accepted if it scores sufficiently high on at least one attribute. If no attribute meets a set of preset minimal acceptable levels or standards, it is unacceptable. Desirable levels for each attribute are used to select alternative which exceed or equal those levels in any one attribute.
Lexicographic	Uses the most important attribute to evaluate and rank the alternatives from best (most preferred) to worst. If there is a tie for some of the alternatives (performance values of alternatives are equal), use the second important attribute for these alternatives, that is, to compare the alternatives by the order of the importance of the attributes.
Elimination	Alternatives are compared one attribute each time and eliminated from consideration if they do not pass a yes-no or minimum acceptable level. Alternatives are eliminated that do not satisfy some minimum acceptable level or standard, and it continues until all alternatives except one have been eliminated.
SAW	The overall score of an alternative is computed as the weighted sum of the attribute values.
Weighted product	The overall score of an alternative is computed as the weighted product of the attribute values.
TOPSIS	The chosen alternative should have the minimal distance from the positive-ideal solution and the maximal distance from the negative- ideal solution.
ELECTRE	The concept of an outranking relationship is used.
Median ranking	Adds all attribute ranks (ranks from each attribute) and ranks them in ascending order. If there is a tie for some alternatives (performance values of alternatives are equal), the median value of the ranks of them is used.
AHP	To construct the decision problem into a hierarchical structure – Pair-wise comparison matrices are used to evaluate the importance among attributes and alternatives.

So far, GIS and some of the MADM methods have been effectively combined to solve real-world pipeline route selection problems. Nonis et al (2007); Wan et al (2011)) have successfully integrated GIS-MADM for the determination of optimal pipeline routes.

Summary and conclusion

Development of new oil and gas pipeline routes in coming years is inevitable and selection of an optimal route is crucial to the success of any pipeline routing project. An optimal route will minimize economic loss and negative socio-environmental impacts, in addition to enhancing the pipes' sustainability and prolonging its lifespan. Empirical evidences suggest that GIS-based route selection is more efficient than manual route selection. However, the use of GIS for this purpose is relatively low. Many researchers have argued that GIS has limitations when dealing with multiple criteria and multiple participant related projects like pipeline route selection. Consequently, it is recommended to integrate GIS with other analytical tools for optimal performance.

GIS and MADM have complementary features and GIS-MADM integration has the potential to tremendously enhance group decision-making processes like route selection. So far, not all MADM techniques can be properly integrated with commonly available GIS softwares. For future research, it is necessary to develop platforms that will support the integration of GIS with virtually all the established MADM techniques. This will provide project managers and other pipeline routing stakeholders the opportunity to choose suitable GIS-MADM methods from the wide range, on a project–by-project basis.

GIS and MADM have complementary features and GIS-MADM integration has the potential to tremendously enhance group decision-making processes like route selection

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New Zealand opens up mapping information to developers

Mapping information showing the locations of publicly accessible land across New Zealand has been released by the New Zealand Walking Access Commission (NZWAC) to enable researchers, government agencies and app developers embark on their own mapping projects.

The mapping information released includes locations of public reserves, conservation land, Crown land, legal roads, marginal strips and esplanade strips. Developers wanting to use the information can plug into the map feed on the Commission's website, on the new GIS Data page. *www.futuregov.asia*

G8 leaders sign Open Data Charter

Leaders from Canada, France, Germany, Italy, Japan, Russia, USA and UK met at Lough Erne in Northern Ireland for the G8 Summit 17-18 June. They signed an Open Data Charter, putting open data firmly at the forefront of international efforts to drive economic growth and use transparency to improve accountability.

The Open Data Charter sets out 5 strategic principles that all G8 members will act on. These include an expectation that all government data will be published openly by default, alongside principles to increase the quality, quantity and re-use of the data that is released.

G8 members have also identified 14 high-value areas – from education to transport, and from health to crime and justice – from which they will release data. These will help unlock the economic potential of open data, support innovation and provide greater accountability. *http://epsiplatform.eu/*

Spatial Planning Bill could soon become law in South Africa

According to minutes circulated, the Spatial Planning and Land Use Management Bill (B14B-2012) was endorsed by the National Council of Provinces (NCOP), paving the way for

municipalities to become the primary regulators of land use. Once in force, the Bill is expected to transform South Africa's spatial planning and land use management systems so that they promote social and economic inclusion, provide for the sustainable and efficient use of land and redress spatial inequity. *www.legalbrief.co.za*

Authorities allow Google Street View into Israel

After months of consultations with Israeli security officials, Google has launched its popular Street View service in the country's three largest cities. The new Street View provides images of ordinary life, contested areas and religious sites in the Holy Land. Due to security issues, areas around several sensitive sites, such as the military headquarters in Tel Aviv and the prime minister's residence in Jerusalem, are blurred out. *www.guardian.co.tt/*

WWF and Thailand government launch TREEMAPS

The Department of National Parks, Wildlife and Plant Conservation (DNP) and WWF-Thailand formally launched on June 6th the joint project, TREEMAPS - Tracking Reductions in Carbon Emissions through Enhanced Monitoring and Project Support - which aims to establish Thailand's first forest carbon basemap and monitoring system, as well as establishing a sub-national REDD+ project.

TREEMAPS' overriding objective is for Thailand to develop the capacity at the national level - and, in one region, at the sub-national level - to measure and monitor change in forest carbon and to take advantage of the full range of emerging forest carbon financing and benefit opportunities. Data will be collected from three sources: satellite imagery, on-the-ground surveys and through the use of groundbreaking LiDAR technology. *http://wwf.panda.org/*

NGO maps out indigenous community territories in Indonesia

A group of NGOs — the JKPP; the community and ecological-based Society for Legal Reform (HuMa); Sawit Watch; the Consortium for Agrarian Reform (KPA); the Consortium in Support of a Community Forest System (KpSHK); and the Mining Advocacy Network (JATAM) — established a website geodata-cso.org to document and track land conflicts in Indonesia.

As of now, around 222 reports of land conflicts have been documented on the Geodata website. *www.thejakartapost.com*

Crowd-Sourcing the Nation: USGS seeking more volunteers

The mapping crowd-sourcing program, known as The National Map Corps (TNMCorps), encourages citizens to collect structures data by adding new features and/or correcting existing data within The National Map database. Structures being mapped in the project include schools, hospitals, post offices, police stations and other important public buildings.

The 16 recently added states needing help with structures are: Alabama, Arizona, California, Connecticut, Florida, Illinois, Louisiana, Massachusetts, Mississippi, Nebraska, Nevada, New Hampshire, Rhode Island, South Dakota, Vermont, and Wyoming, bringing the total number of states available for updating to 35.

The final release of states by the end of the year will open up the entire country for volunteer structures enhancement.

Preliminary results of the effort have been very promising. As part of the project pilot, The National Map Corps had 143 volunteers who improved data for more than 6,400 structures in Colorado. The quality of the volunteer data collected met the USGS standards for position, attribution, and completeness. *www.USGS.gov*

In China, 'Danger Maps' highlight pollution, toxic waste, abuse, other risks

As pollution concerns rise in China, Liu Chunlei is boosting environmental awareness among the nation's 564 million Internet users with help from the charitable arm of Alibaba Group Holding. Danger Maps, a website Liu started last year, allows people to look up sites such as toxic-waste treatment facilities, oil refineries and power plants. Liu has plotted about 6,000 pollution sources based on government data and user input on Baidu Map, China's equivalent of Google Maps. Inspired by "crowd-mapping" efforts in Kenya and Japan, the site taps the knowledge of China's masses to draw attention to environmental risks in a nation where public information is often scattered and incomplete. Now, Liu is expanding his site by letting users add information to maps with other themes such as missing people and child abuse. *www.northjersey.com*

WB to conduct mapping of renewable energy sources

The government of Pakistan has requested the support of the World Bank and the Renewable Energy Resource Mapping Initiative of Energy Sector Management Assistance Programme (ESMAP) to help improve the country's knowledge and awareness of solar, wind and biomass energy resources. According to the World Bank, the project, approved last month, would be launched in the second half of 2013 and would focus on resource mapping and spatial planning, including ground-based data collection, data analysis, GIS mapping, strategic environmental assessment, and policy integration. *http://x.dawn.com/*

ROLTA India to establish National NAVTEX Network

Rolta India has bagged a contract from a subordinate office under the Ministry of Shipping, Road Transport & Highways, Government of India that provides general aids to marine

Galileo update

SSTL... Payloads packed off for Galileo

Surrey Satellite Technology Ltd. (SSTL) has successfully completed the delivery of the payloads for the first four Full Operational Capability (FOC) satellites of GALILEO to prime contractor OHB System AG. The payloads were shipped to OHB in Bremen, Germany for integration of the payload to platform and the start of the satellite integration and test activities. The delivery of these four navigation payloads is part of an on-going contract, awarded to the OHB-SSTL consortium in 2010 for the first 14 Galileo FOC satellites. SSTL is continuing work on the payloads for the next ten FOC satellites, with the next five payloads already in production at its advanced technical facility, The Kepler Building. In addition to these 14, SSTL and prime contractor OHB were awarded the contract for a further eight Galileo satellites in 2012. *www.satnews.com*

European Patent Office awards best patented GNSS related innovation

With the development and extension of the European satellite navigation system Galileo the protection of innovative technologies and applications is becoming more and more important for Europe's inventors. In 2012, the European Patent Office (EPO) granted 104 patents in the field of satellite navigation technologies (source: EPO).

For the first time the EPO will award a prize within the ESNC 2013 to the best GNSS application innovation that has been granted a European patent. "We want to support inventors to gain recognition while helping them to protect ideas and to encourage innovation. The ESNC is a fantastic opportunity for us to seek out promising patented GNSS related innovation. Our prize will recognise the best patented innovation based on its high economic potential, strong technological impact, and outstanding benefits for today's society." says Oswald Schröder, Principal Director Communications and Spokesperson at EPO.

The winner of the ESNC EPO Best Patented Innovation Prize will be shortlisted and presented to the jury tasked with compiling a list of 15 total finalists (in five different categories) for the prestigious European Inventor Award 2014. If nominated, the winner will be included in a Europe-wide publicity campaign and get dedicated marketing support including integration in high-ranking media partnerships, e.g. with CNN, Financial Times, or Les Echos. In addition, the winner and two runners-up will receive an economic study (valued at approx. EUR 5,000) on the market potential of their patent in the corresponding field of technology. *www.galileo-masters.eu*

navigation along the Indian coast to set up 'National NAVTEX Network'. Rolta will establish NAVTEX (Navigational Telex) network which will offer improved safety and security for maritime traffic in coastal waters of India. It will also be able to provide coverage upto 250 nautical miles (460 km) from the Indian coast line and will transmit maritime navigational and metrological warnings and forecasts, as well as urgent marine safety information to ships at sea in Indian waters. *www.tendersinfo.com/*

Survey of India to share expertise with Thailand

Survey of India is all set to share its expertise in surveying and urban mapping with geo-informatics experts from Thailand in the coming months. An MoU was signed between the Survey of India and Geo-Informatics and Space Technology Development Agency of Thailand, as part of 'Indo-Thai Geo Spatial Cooperation' initiative during PM's recent visit to Thailand.

According to the agreement, the SoI will map a town measuring about 100 square kilometer to demonstrate its expertise in urban survey and mapping. The treaty will allow five experts from the GISTDA to visit the Indian Institute of Surveying and Mapping (IISM) which is the SoI's training wing. Training will be imparted every year until the expertise is transferred. *http://articles.timesofindia.indiatimes.com/*

Astrium's Cloud Services will support Landgate

Landgate (Western Australia's Land Information Authority) has contracted through Geospatial Intelligence Pty Ltd, an Astrium Services' reseller, the SPOTMaps coverage of Western Australia (2.6 million km²) with multi-year hosting and streaming. Landgate intends to use SPOTMaps imagery as the base level dataset for SLICP, a platform that allows multiple government agencies to share spatial information for environmental mapping, cadastre, infrastructure, engineering, agricultural and emergency services. *www.astrium-geo.com*

Uttarakhand government, ignored NRSA report

Accusing the Uttarakhand government in India of sleeping over a report of National Remote Sensing Agency, noted environmentalist and Magsaysay awardee Chandi Prasad Bhatt said had the government taken the report seriously "destruction in and around Kedarnath shrine would have been much less horrific".

"The scale of destruction at the Himalayan shrine could have been far less if the state government had paid adequate attention to the report of National Remote Sensing Agency, whose scientists had identified the natural calamity prone areas of Uttarakhand and neighbouring Himachal Pradesh way back in 2001," the Magsasay awardee said.

The report, termed as 'Hazard Zonation Mapping', was prepared by arond 100 distinguished scientists from country's leading research institutes at the initiative of the Indian government and was submitted to the state government in 2001. *www.business-standard.com*

MoEF releases draft policy on forest clearances

The ministry of environment and forests (MoEF), India has released a draft policy on inspection, verification, monitoring and overall procedure relating to the grant of forest clearances.

The draft policy envisages establishment of an independent, remote-sensing, satellite-based monitoring system to detect encroachment and unauthorised changes in the approved land use plan, illegal mining on forest land after expiry of the approver under the Forest (Conservation) Act and the progress of concurrent/final reclamation/rehabilitation of mined-out area in mining project. Besides, it will detect damage to flora and fauna in the adjoining forests and maintenance of minimum ecological flow in hydel/irrigation and river valley projects. *www.business-standard.com*

Indian navigation satellite set to fly on July 1

Indian Space Research Organisation replaced a faulty component in the PSLV-C22 rocket and rescheduled the flight of the IRNSS-1A satellite, India's first regional navigation satellite, on it for 11:43 p.m. on July 1, according to an informed ISRO official. It forms the country's new and third category of multi-use spacecraft-navigation along with the older communication and remote-sensing (or earth observation) satellites. It will offer motion and location information over the sub-continent just as the popular U.S. Global Positioning System, or GPS, has done across the world for several years. ISRO says data from the indigenous system will be superior to information coming from GPS. *www.thehindu.com*

Shanghai to invest in satellite navigation system

Shanghai will invest 190 million yuan (US$30.65 million) to build infrastructure for China's homegrown Beidou Navigation Satellite System that can be used for everything from monitoring vehicles transporting hazardous materials to locating people. The city government said that in the next 18 months it will create the infrastructure needed to track 50,000 objects or people.

Beidou began providing services such as positioning, navigation, timing and short messages for China and surrounding areas to users in the Asia-Pacific region last December, said Ran Chengqi, director of the China Satellite Navigation Office. *http://english.eastday.com/*

Russia set to launch four satellites

Russia has plans to launch four more GLONASS satellites by this year-end, the Aerospace Defence Forces head said. "Three GLONASS satellites are scheduled to be launched on board of a Proton carrier rocket in July from the Baikonur space centre and another one is planned to be launched in December from the Plesetsk space centre," Maj. Gen. Alexander Golovko said. *http://zeenews.india.com/*

Russian vice prime ministers get new roles

Russian Vice Prime Minister Dmitry Rogozin, responsible for national defense, will now work on military cooperation with other countries and the development of the GLONASS navigation system.*http://vestnikkavkaza.net/*

Africa to use GPS and phones to help map neglected diseases

Countries in Sub-Saharan Africa will begin using the latest technologies to map and collect data on the distribution of neglected tropical diseases (NTDs) later this year. Officers running national NTD control programmes will be trained to use the latest mapping tools — including GIS, GPS and smart phones to create maps and collect data, to help with 'practical control' of diseases that continue to afflict millions of people on the continent. Despite being some of the easiest diseases to treat, NTDs continued to ravage populations across Africa. The five most common NTDs on the continent will be targeted: intestinal worms, trachoma, elephantiasis (lymphatic filariasis), river blindness and bilharzia. *http://africanbrains.net/*

Mapping tribal's rights in India using GIS/GPS

The state government has procured the Forest Dwellers Land Mapping System developed by the Madhya Pradesh government, India to utilize it for mapping areas claimed by tribals under the Forest Rights Act (FRA). The department of tribal welfare has already purchased 20 units of GPS-enabled personal digital assistant (PDA) from the MP government and is in the process of inking a MoU with the forest department of the central Indian state for purchasing the customized software for the purpose. *http://articles.timesofindia.indiatimes.com/*

GPS in autos still a distant dream in Delhi

Three years ago when the Delhi Government in India increased the auto-rickshaw fares, it had included a component

that would help the auto owners to meet the cost of installation of a GPS system in their vehicles. But till date the system has not become operational. The GPS was meant to be installed in all the auto-rickshaws and was expected to provide real time data on the location of autos across the city through a server operated by the Delhi Integrated Multi-Modal Transit System (DIMTS).

"As of June 14, GPS has already been installed in 20,423 auto-rickshaws. These are all new vehicles and the signals from them are being received at the Control Room," said a DIMTS spokesperson. But beyond this, the system is yet to function. So even if some passenger were to use the emergency button on the auto, it would only send an alert to the Control Room but there would be no action on it. *www.thehindu.com/*

Cut in GPS Budget by House Committee in USA

The House Appropriations Committee in the US has made a series of cuts to GPS programs that, if agreed to by the Senate, suggest an overall slowdown in the pace of GPS modernization. The biggest cut came in the GPS Block III satellite program where committee members slashed $44.167 million or 60 percent from advance procurement for the 9th and 10th spacecraft. If approved by the Senate, the reduction in the total FY14 budget for nearer-term and advanced satellite procurement would drop spending from $477.598 million down to $433.431 million. That is a far cry from the $492.910 million requested and approved for FY13.

The reason given for the advanced procurement squeeze was that the money was requested "ahead of need," according to a draft of the report that accompanies the appropriations bill. GPS program managers are currently looking at a wide range of changes aimed at substantially reducing the constellation's overall cost. They have already revised upward by an average of two years their estimates of the useful life of the current operational satellites — thereby enabling the program to slow replacement of the aging spacecraft already on orbit.

Nokia HERE Maps

Nokia has announced some details on the HERE Venue Maps available for Nokia Lumia devices and Bing Maps. It now features 49,000 buildings in 45 countries. This doesn't only include shopping malls, but also stadiums, theme parks, historic streets, or other outdoor spaces, such as Carnaby Village and golf clubs. Nokia claims to create precise Venue Maps by not only collecting floor plans, but by also physically visiting venues to ensure that our data is more accurate than those from competitors. *http://wmpoweruser.com/*

43% of UAE mobile customers using LBS

While mobile penetration stands at 92 per cent across the Mena region, 43 per cent of mobile users in the UAE currently utilise location based services (LBS), a report said.

More than 53 per cent of UAE customers who don't yet use LBS are interested in doing so, added the annual Mobile Life Study by TNS, one of the world's largest custom market research organisations pointing out that LBS and Quick Response (QR) codes look to be the next mobile growth feature. *www.tradearabia.com*

Google acquires Waze' App

Google finalized its acquisition of the crowdsourced navigation and traffic app Waze, which is a free app that uses the input of trusted community members to update maps in real time to help other users avoid delays and congestion. *www.wired.com*

Webtech Wireless announces navigation partnership with ALK Technologies

Webtech Wireless Inc has releaseed of its MDT 3100 In-Cab mobile data terminal, version 2.5 with new capabilities enabling enhanced truck navigation. In partnership with ALK Technologies, a global leader in GeoLogistics(TM) and navigation software, Webtech Wireless is offering ALK Technologies' CoPilot(R) Truck(TM) in-cab navigation solution as part of the MDT 3100 and Quadrant Manager.

Ideal for any size of fleet, this release provides a safer alternative for trucking companies than purchasing off-the-shelf consumer GPS navigation systems, because it provides truck-specific on-board navigation. *www.webtechwireless.com*

Maxis launches location-based ad service

Malaysian communications provider Maxis has launched a location-based advertising a service for brands and advertisers to reach out to Maxis myDeals customers. The service, which can be time based as well, enables advertisers to select the demographic profile of their target customers and apply it to a destination to deliver their message or promotional offer. Maxis and Hotlink customers who are members of myDeals will be able to get these customised offers each time they walk into a specific location where Maxis' location-based advertising is available. Once the system detects their presence, an SMS will be sent with the featured promotional offer. The service is available in over fifteen participating shopping destinations and will be expanded to over 25 destinations throughout Malaysia this year. *www.telecompaper.com*

LBS can become $2-5 bn sector in 3 years: COAI

Location-based services sector has potential to achieve $2-5 billion size in the next two to three years provided some issues related to application, devices, IP rights and privacy are addressed, industry body Cellular Operators Association of India (COAI) said.

"As of today location-based services (LBS) is less than half a billion industry but it has potential to grow anywhere between $2-5 billion in the next 2 to 3 years ... can add a good 10-20 per cent of revenue to

telecom industry over the period," COAI Director General Rajan S Mathews said on sidelines of a Ficci event in Delhi recently. He further said, mobile operators right now are not structured to sell LBS as there is shortage of specialised people who know logistics which is hampering growth of the services. *http://articles.economictimes.indiatimes.com/*

Portugal Telecom selects Intersec's IGLOO LBS Solution

IGLOO is a network enabler which consolidates real-time intelligence from the mobile operator's network including subscriber location information on a mass scale. Residing in the operator network, IGLOO anonymously aggregates and manages subscriber and location information to enable the creation of location-based services. *www.intersec.com*

Trusted Positioning Launches MEMS-based Indoor Location Software

Canada-based Trusted Positioning has released their Trusted Portable Navigator (T-PN), software for indoor location based on MEMS sensors. It integrates on any platform including Android, Windows, QNX, BB10, Linux or iOS and take advantage of existing motion sensors found in common smartphones. It mitigates the high noise found in low cost MEMS. It also integrates the fact that the phone can be held in different ways (hand, pocket, belt, texting, etc...) while the user is moving. *www.gpsbusinessnews.com*

Malaysia mulls installing GPS in heavy vehicles

The Transport Ministry, Malaysia will consider installing GPS in heavy vehicles to monitor and detect offences committed by their drivers. Deputy Minister Datuk Ab Aziz Kaprawi said the plan was within the framework of the ministry. *http://www.nst.com.my/*

Russian imaging satellite in orbit after Soyuz launch

Russia recently launched a civil remote sensing satellite aboard a Soyuz rocket, lofting a spacecraft with a modernized high-resolution digital camera to collect imagery of Earth for Russian government. The images will be used by emergency personnel, environmental scientists, urban planners and other officials, putting Russia in a league with commercial observation satellites owned by companies in the United States and Europe. *www.spaceflightnow.com*

First images from space by Planet Labs

Planet Labs announced plans to launch the world's largest fleet of Earth imaging satellites to image the changing planet and

Unmanned Aerial Vehicle (UAV) Market (2013 - 2018)

According to industry estimates, UAS operations will increase manifold in a variety of key military and civil areas. About 50 U.S. companies, universities, and government organizations in the U.S. are developing over 150 different unmanned aircraft designs. From an operational, infrastructure and safety perspective, this presents a number of challenges due to the diversity of aircraft, control stations, levels of autonomy, and communications methods. UAV's width is of a wide spectrum of size, endurance, and performance characteristics, often different from manned aircraft. The global UAV market size can be expected to grow to $8,351.11 million by 2018. (HALE/MALE/SUAV) Market has the highest business potential throughout the study period. USA and Israel will be the maximum revenue generator, among the countries manufacturing UAV's. *www.reportlinker.com*

Kashmiri students in India develop UAV

Three engineering students from Kashmir have developed an UAV, which they claim is the first Unmanned Aerial Vehicle made in the Valley. Brother-duo Shahnawaz Shafi (18) and Shuaib Shafi (21) and their classmate Basit zargar (18), all pursuing mechanical engineering from Kashmir Government Polytechnic College here recently demonstrated the UAV. The trio said they are working on the project to further enhance its range from the present 20 metre and improve its functionality. *http://articles.economictimes.indiatimes.com/*

Boeing's maritime drone to add Royal Navy's intelligence

UK's Ministry of Defence has purchased an unarmed ScanEagle UAV as a part of a £30m contract to boost surveillance and reconnaissance capabilities of British warships. It is the first drone ever designed specifically for the purposes of maritime operations. The prototype was tested in 2002 and the aircraft has been used by several nations since. *http://eandt.theiet.org/*

Copters, UAVs to man skies in Indian metros

Seven metropolitan cities Delhi, Mumbai, Kolkata, Chennai, Hyderabad, Bangalore and Ahmedabad will soon have individual air surveillance systems where helicopters with gun-toting commandos, balloons fitted with cameras and sophisticated sensors and unmanned aerial vehicles (UAVs) will keep round-the-clock vigil over the cities.

The system, which was successfully used in the Capital during the 2010 Commonwealth Games, will now be replicated in all these cities under the 'Safe City Project' of the home ministry. It will be a permanent feature in all the seven metropolitan cities, unlike the one used in Delhi only during the Games period. Funds will be used to procure modern equipment like GPS/GIS for dial 100 system and patrol cars, CCTV systems, vehicle scanners, vehicle number plate identification system, cyber patrol and communication monitoring system and integrated GIS-based automated vehicle tracking and management system. *http://articles.timesofindia.indiatimes.com/*

provide open access to that information. They revealed the first images from their first two satellites. Its goal is to provide universal access to information about the changing planet. The company plans to achieve this by launching a fleet of Earth imaging satellites, called 'Doves', that when acting together can provide a new image of the planet at an unprecedented combination of resolution and frequency. *www.planet-labs.com*

China completes satellite ground station network

A network of remote sensing satellite ground stations that covers all of China's territory has been successfully constructed. The network comprises an operation and data processing center, and three ground stations in the cities of Beijing, Kashgar and Sanya. *http://zeenews.india.com/*

Vietnam, Belgium hold talks on 2nd remote sensing satellite

The Vietnam Academy of Science and Technology held discussions with Belgian partners about the second remote sensing satellite for Vietnam. The first one was successfully launched early last month. According to Vietnam Academy of Science and Technology, Belgian partners, including Spacebel, AMOS – Advanced Mechanical and Optical Systems and QinetiQ Space, will support Vietnam in the first phase of designing, manufacturing and launching the VNREDSat-1B satellite. *www.thanhniennews.com*

Hyderabad, India to soon have a digital public database of roads

In a first of its kind initiative in Hyderabad, volunteers from the student chapter of 'Engineers without Borders', which is a non-profit society involving engineers and other professionals in the field of constructive change, have been roped in for the project on creating a digital map of all of the roads in the city. Around 15 volunteers have been visiting the area to be covered with printed maps and satellite images. Roads and landmarks are noted and then the data is scanned, digitized and added to the database. *http://articles.timesofindia.indiatimes.com/*

NavCom introduces StarFire Rapid Recovery

NavCom Technology, Inc has announced the release of new software for its Sapphire-based receivers, including the SF-3050, SF-3040, and LAND-PAK. The multi-frequency GNSS (GPS+GLONASS) receivers are now capable of supporting NavCom's new StarFire Rapid Recovery feature, which allows users to quickly regain StarFire accuracy after short GNSS signal blockages caused by shading, bridges or other similar constraints. Other new features include support for proprietary GLONASS RTK correction messages from third party base stations and a new web server interface for the SF-3050.

NavCom's StarFire Network, a Global Satellite Based Augmentation System, provides five centimeter horizontal accuracy worldwide and the freedom and flexibility that a DGPS solution offers. It offers 99.999% uptime, a seven satellite constellation, and StarFire over IP (SFoIP) delivery for redundancy to ensure system availability and position accuracy. *www.NavComTech.com*

European Secured Navigation arrives with First Galileo PRS-only Positioning

QinetiQ and Septentrio have announced jointly that another major milestone in the Galileo European Navigation Satellite System's development and deployment programme has been achieved. On the 12th March 2013, staff at the European Space Agency at ESTEC, Noordwijk, The Netherlands, achieved the first ever navigation solution using only the encrypted Galileo Public Regulated Service (PRS) signals broadcast by the four Galileo In-Orbit Validation (IOV) satellites launched in 2011 and 2012. Septentrio and QinetiQ working in close partnership developed one of the two PRS test user receivers used in this historic first test. Positioning accuracy of ~10 m was achieved, excellent for a first test so early in the system's deployment. The TUR-P now continues to be used as part of the campaigns running during the GALILEO In Orbit Validation Phase. *www.septentrio.com*

Spirent launches Multi-Frequency GNSS Testing System

Spirent Communications has launch a new multi-frequency GNSS record and playback (RPS) test system, GSS6425. It provides customers with RF recordings for several constellations (GPS, GLONASS, Galileo, BeiDou, QZSS) and frequencies (L1, L2, L5), as well as wider bandwidth (30MHz). This self-contained and portable system allows users to record and playback data in the field without the need for an additional PC or external power. It is also capable of recording additional sources including inertial and dead reckoning sensor outputs and vehicle CAN bus data. *www.Spirent.com*

Hemisphere GNSS New Crescent Vector GNSS Compass Module

Hemisphere GNSS has launched its new Crescent Vector H200 GNSS compass module, a high-performance receiver for heading, positioning, heave, and attitude. It is designed for professional marine, navigation, and land applications in challenging and dynamic environments.

It processes L1 GPS and GLONASS signals to deliver precise heading, greater positioning reliability, and better performance in challenging environments. Through using two separate antennas, Hemisphere GNSS' patented Vector technology computes the heading and pitch or roll angle while stationary or in motion. It can compute heading accuracy to 0.02 degrees using a 5-meter antenna separation.

Lockheed Martin... GPS III tests are successful

A Lockheed Martin led industry team has completed successful functional integration tests of the spacecraft bus and network communications equipment on the first satellite of the next generation Global Positioning System, known as GPS III.

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The recent testing of GPS III space vehicle 1 (SV 1) bus—the portion of the space vehicle that carries mission payloads and hosts them in —assured that all bus subsystems are functioning normally and ready for final integration with the satellite's navigation payload. Systems tested included: guidance, navigation and control; command and data handling; on-board computer and flight software; environmental controls; and electrical power regulation. The SV 1 satellite's network communication equipment subsystem that interfaces with the ground control segment and distributes data throughout the space vehicle also passed all tests as expected. *www.satnews.com*

CSR launches SiRFstarV 5e GNSS engine

CSR have introduced their SiRFstarV 5e GNSS engine, a new solution optimized for indoor positioning on smartphones, cameras and health devices. It supports concurrent GPS, GLONASS, SBAS and QZSS signals to provide a fast TTFF and the first commercial implementation of this new engine comes from wireless solutions specialist Telit Communications in the form of their Jupiter SE868-V2 module. *www.CSR.com*

TerraStar GNSS Positioning for African Aerial Surveys

Johannesburg-based GeoDuster Technologies has commissioned TerraStar GNSS's TerraStar-D Precise Point Positioning (PPP) service for a series of aerial geophysical, exploration and environmental surveys being carried out in Africa by Terrascan Airborne of Germany aboard a specially-equipped light aircraft.

Using a combination of GPS and GLONASS satellite signals, the high-precision service is being deployed in conjunction with Septentrio dual-frequency AsteRx2eL GNSS receivers for geo-referencing high-density magnetic gradient radiometric measurements, often acquired in remote locations and difficult environments. *www.terrastar.net*

Trimble's new UAS targets big survey, geospatial projects

Trimble Navigation Ltd. has unveiled new Unmanned Aircraft System (UAS) - the UX5 aerial imaging rover with the Trimble Access aerial imaging application - for large, geospatial and survey projects.

The UX5 and the imaging app are being sold to the surveying, oil and gas, mining, environmental services, and agriculture sectors in markets where UAS commercial operations are allowed, including Australia, Canada, the United Kingdom and Africa. But not the U.S. market, as FAA regulations continue to restrict their use.

Nexteq Navigation offers platform for accelerating GNSS receiver development

Nexteq Navigation has launched accelGRx, a platform for accelerating professional-grade GNSS receiver development. The platform provides open and production-ready hardware and software building blocks for GNSS receivers. accelGRx is designed for organizations looking to research and develop new techniques and algorithms requiring deep in-receiver integreation or quickly produce a small, high-performance receiver.

accelGRx supports GPS L1 and Beidou B1, and the hardware is GLONASS and Galileo ready. It pairs a compact form factor and industry standard pin layout with a code and phase precision of 4 cm and 0.4 mm respectively for both GPS L1 and Beidou B1. It incorporates an array of software development tools, including the ability to record and play back digitized signals.

Leica Nova MS50 MultiStation

Leica Nova MS50 MultiStation is the world's first instrument that combines total station technology with 3D laser scanning, imaging and GNSS positioning in one easy-to-use solution. It puts powerful laser scanning capabilities in the hands of land surveyors, plant surveyors, construction managers, BIM professionals, public safety professionals and a broad range of other users who have never before worked with rich point clouds or 3D datasets. It provides users with a complete, streamlined workflow that allows users to capture, create, manage and use 3D object-based spatial data directly in the field as part of a survey workflow for better decision making. *www.leica-geosystems.com*

USAF to integrate Locata's non-GPS based positioning system

Locata Corporation has announced that the US Air Force 746th Test Squadron (746 TS) recently awarded New Mexico, USA based TMC Design Corporation a contract to install and integrate the Locata Non-GPS Based Positioning System (NGBPS) on White Sands Missile Range (WSMR). The Locata system will give the 746 TS an entirely new and enhanced capability, allowing them to evaluate the operations of mobile and airborne position, navigation, and timing (PNT) equipment in GPS-denied environments. The operational installation of the NGBPS system will consist of both fixed and mobile Command and Control (C2) nodes, and a network of LocataLite transceivers deployed on WSMR. *www.locatacorp.com*

GPS-challenged navigation and geo-registration solution for USAF

Northrop Grumman Corporation has been awarded a phase two inertial navigation system-related contract from the Air Force Research Laboratory to continue improving geo-registration accuracy for positioning and pointing applications, even in GPS-denied conditions.

Geo-registration of data is critical for accurate interaction between systems, such as locating targets and handing off coordinates to another aircraft. Having successfully demonstrated a prototype system in phase one, Northrop Grumman will flight-test the integrated system in phase two as well as incorporate additional improvements such as highly detailed 3-D map generation in the algorithm. *www.northropgrumman.com*

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Worksite conditions are seldom perfect and GNSS signal outages can cause costly delays, but NavCom will help get you up and running again with StarFire Rapid Recovery.

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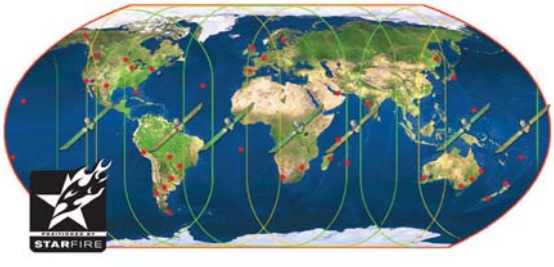

www.navcomtech.com

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iOne infrastructure Metric Mapping System

Visual Intelligence has unveiled its new geoimaging solution, iOne Infrastructure Metric Mapping System (iOne IMS), which is a major technological milestone for infrastructure metric mapping and surveying. It allows aerial imaging companies to capture more imagery and data at a fraction of the up-front investment and operating cost of competing products. When installed on aircraft, the iOne IMS collects ortho, stereo, forward and backward oblique, multispectral 4-band and point cloud product generation—all in a single pass. *www.visualintell.com*

Paragon Software Systems announces National Street Level Routing in China

Paragon Software Systems, Inc. has launched national street level mapping for routing vehicles in mainland China. The mapping allows users of the Paragon software to create optimized routes and schedules for their transport operations in China using accurate data. This follows Paragon's recent announcement about implementing Simplified Chinese language into its software. Its software is Unicode compliant, which makes it possible to translate it into any language and enables its use anywhere in the world. *www.paragonrouting.com*

Esri Joins Global In-Location Alliance

Esri has joined the worldwide In-Location Alliance. Esri joins a growing number of companies that have come together to drive innovation and market adoption of high-accuracy indoor positioning and related services. Esri will help to define standards for indoor mapping and logistics across many industries including health care, higher education, finance, government, and retail. *www.esri.com*

MARK YOUR CALENDAR

July 2013

International Geoscience and Remote Sensing Symposium (IGARSS 2013)
22-26 July
Melbourne, Australia
www.igarss2013.org

August 2013

International Summer Seminar on GNSS
19-24 August 2013
Tokyo , Japan.
http://www.gnss-pnt.org/summer_seminar/index.php

8th International Symposium on Digital Earth 2013 (ISDE 2013)
26-29 August
Kuching, Sarawak, Malaysia
http://isde2013.utm.my/

September 2013

Multi-GNSS environment for sustainable development
9 - 13 September 2013
Hoi An, Vietnam
http://navis.hust.edu.vn

Geo-Empower Middle East Summit
16-18 September
Dubai, UAE
www.flemminggulf.com/All-Categories

ION GNSS 2013
16 – 20 September
Nashville, Tennessee, USA
www.ion.org

GDI APAC 2013: Geospatial Defence & Intelligence 2013
17-18 September
Singapore
www.geospatialdefenceasia.com

FOSS4G 2013
17 – 21 September
Nottingham, UK
http://2013.foss4g.org/geohack/

FIG: LADM 2013
24 – 25 September
Kuala Lumpur, Malaysia
www.isoladm.org

International Symposium & Exhibition on Geoinformation (ISG 2013)
24 - 25 September
Kuala Lumpur, Malaysia
www.voronoi.com/isg2013

October 2013

Intergeo 2013
8 – 10 October
Essen, Germany
http://www.intergeo.de/en/index.html

34th Asian Conference on Remote Sensing
20 – 24 October 2013
Bali, Indonesia
www.acrs2013.com/

ISGNSS 2013
22-25 October
Istanbul, Turkey
http://mycoordinates.org/isgnss-2013/

UN GGIM AP
28 – 30 October
Tehran, Iran

November 2013

GSDI World Conference (GSDI14) and the AfricaGIS 2013 Conference
4 - 8 November
Addis Abbaba, Ethiopia
www.gsdi.org/gsdiconf/gsdi14/

ICG-8: Eighth Meeting of the International Committee on GNSS
10 – 14 November
Dubai, United Arab Emirates
www.oosa.unvienna.org/oosa/en/SAP/gnss/icg.html

SPAR Europe/European Lidar Mapping Forum
11-13 November
Amsterdam, The Netherlands
www.sparpointgroup.com/Europe/

ISPRS: Serving Society with Geoinformatics
11 – 17 November
Antalya, Turkey
www.isprs2013-ssg.org

December 2013

ION Precise Time and Time Interval Meeting (PTTI)
2 – 5 December
Bellevue, WA, United States
www.ion.org

Fourth ESA Colloquium on Galileo
4 – 6 December
Prague, Czech Republic
www.congrexprojects.com/13c15/

6th European Workshop on GNSS Signals and Signals Processing
5- 6 December
Munich, Germany
http://ifen.bauv.unibw.de/gnss-signals-workshop/

March 2014

Munich Satellite Navigation Summit 2014
25 – 27 March
Munich, Germany
www.munich-satellite-navigation-summit.org

April 2014

ENC-GNSS 2014
14 – 17 April
Rotterdam, The Netherlands
www.enc-gnss2014.com

June 2014

XXV FIG Congress
16 – 21 June
Kuala Lumpur, Malaysia
www.fig.net

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