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Coordinates

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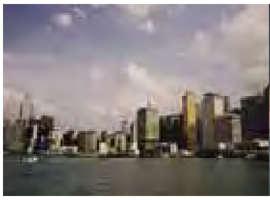
POSITIONING, NAVIGATION AND BEYOND

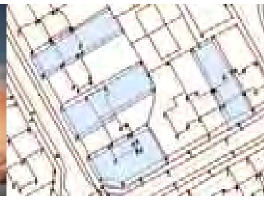
MyGEOID

Everest: the mounting dilemma

A cGIT publication

Articles





Columns

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MYCOORDINATES

Hurricane Katrina

According to some reports, the warnings were made well in advance.

Yet, not much was done. It happened in the world's most powerful country.

The aftermaths were stunning. Neighboring states were worried about how to manage refugees instead of expressing solidarity. There are reports of looting and hoarding. Even worse.

The issues were administrative, managerial and political.

Well thought out disaster management plans met the same disaster.

Technology comes into 'action'.

Internet is flooded with maps, GIS and 'pre' and 'post' satellite imagery.

Technology might deliver also.

But, if the crisis is human, then?

Bal Krishna, Editor
bal@mycoordinates.org

YOUR COORDINATES

No Coordinates/ Incorrect Coordinates

Kindly refer to the section "No Coordinates" appeared in July issue where the editor has sought sensible and funny questions both.

My submission is that funny questions may generate funnier responses. For your "Coordinates", I would suggest questions seeking technical or scientific information. No query should be for personal use and/or commercial gain. Then, a sound informative response would be helpful to others.

A person with "no coordinates" seeks "good coordinates".

However, the question "The difference between the Everest spheroid, a geodetic apple, and WGS 84, a geodetic orange" is a bold one. I would like to congratulate the person. Please do include the name in the future.

But, it is rather late. If asked earlier, a correct response would have alerted the policy makers before releasing the new Map Policy. Here, I am surprised by the response. With sincere apologies to Mr. N.K. Agrawal, I have to point out that his reply includes incorrect geodetic information, definitions, and explanations. I write this letter to stop any further damage, which such response might generate towards realization of a 21st century Indian Geodetic System and modernization of mapping and charting.

Muneendra Kumar Ph.D., munismk@yahoo.com

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Height of Mount Everest

On 5 May 1999 at 1030 Hours Nepal, for the first time, a survey team placed a GPS receiver on the Mt. Everest peak and was able to collect a good data set. Now read on!

Muneendra Kumar, Ph.D.

Around the year 1840, Colonel George Everest, Surveyor General of India, got completed the Great Trigonometric Surveys (GTS) project against all odds and his own recurring sickness. During this survey, a peak was spotted in the Himalayan range area shining well above in height over all other peaks. Later, it was confirmed that it was indeed the Earth's highest peak. In recognition of his special contribution to the GTS, this peak was named "Mount Everest" to honor him.

It became a challenge for mountaineers to climb the Earth's highest peak and for surveyors to determine its height. While the surveyors got their first success in 1852, the mountaineers succeeded in reaching the top of Mount Everest a century later in 1953.

Pioneering past surveys

In considering the details of the surveying methods and height determination, we must remember that each determined height belongs to its own time domain. Each time, it is as creditable an effort as any other preceding or following it.

The first authentic height of Mount Everest was determined in 1852 by the Survey of India (SOI) from the Nepal side. The height established was 29,002 Indian feet (See SIDEBAR "On the 'Right' Foot.").

SOI also made the second determination in 1954. This time the height derived was 29,028 Indian feet with uncertainty of ± 10 feet.

The Chinese State Bureau of Surveying and Mapping (SBSM) provided the third height in 1975, which was surveyed from the Tibet side. The reported height was 8848.13 meters with uncertainty of ± 0.35 meter.

Geodetic comments on old surveys

The various aspects of the old surveying methods and terms of reference now differ from the new 3-D modern surveys using the Global Positioning System (GPS). The most pertinent geodetic differences are explained as under:

a. Surveyed point - The vertical angles were observed from distant stations, two to three hundred miles away and 10 to 12 thousand feet lower than the Everest peak. Thus, one could never pinpoint the exact spot being observed.

b. Snowcap depth - As the amount of snow varies all the time, the point observed must have been different at the time of each of the above surveys.

c. Zero references - The Mean Sea Level (MSL) surfaces used by SOI in 1852 and 1954 could not be the same and as such they represented different vertical datums. Furthermore, two Indian MSLs would also differ from the Chinese vertical datum, which was defined by MSL along the Yellow Sea.

d. Basic unit of length - The unit used by SOI was the Indian Foot and it is different from the Chinese Foot (See SIDEBAR "On the Right Foot").

GPS surveys of 1998 and 1999

In 1998, the survey teams sponsored by the U.S. National Geographic Society (NGS) succeeded in collecting GPS data at a number of stations on the Nepal side including one at Mount Kala Pathar (or Black Stone) and the famous South Col campsite. NGS team could not collect data at the Everest peak, but was successful in collecting data at a rock outcrop (now known as Bishop Ledge), a few meters below the peak. During the same time, SBSM collected GPS data at five stations in Tibet. This joint survey ensured good network geometry.

On May 5, 1999, two GPS receivers were sent up from the South Col campsite with intentions to place one at the peak and the second at Bishop Ledge. As only one receiver could reach the peak area, top priority was given to occupy the peak only. The GPS data at the peak was collected for about 50 minutes between 10 and 11 am Nepalese Time. The peak was snow-covered (Note: Peter Athans, Everest conqueror, who was on the peak during GPS observations, confirmed this important aspect). An attempt to measure the cap thickness failed. At the same time, two additional GPS receivers were used to collect the data at the South Col and Mount Kala Pathar stations, which were also occupied in 1998. Chinese team(s) did not collect any GPS data in 1999 on the Tibet side.

It is important to note that the 1999 data set provides just the basic minimum survey connection between the Everest and two other stations. GPS data from the Tibet side, if collected, would have provided a check and improved the confidence level.

Computations

The computations were jointly performed with Dr. J.Y. Chen, Senior Geodetic Advisor of SBSM, China. I tried but SOI did not respond to participate.

First, a network of all the stations of the 1998 survey was set up and adjusted to ensure accurate determination of the ellipsoidal heights ‘h_{84}’ of all the participating stations, including Mt. Kala Pathar and South Col.

As the stations at Mount Kala Pathar and South Col were occupied in both the 1998 and 1999 GPS surveys, it was decided to use them as “anchor” stations. Thus, their absolute positions from the 1998 solution were to be used for computing the 1999 data sets.

After finalizing the network solution, the 1999 data sets were used to compute the ellipsoidal height ‘h_{84}’ of the Mount Everest.

Next, using the most accurate WGS 84 (EGM96) geoid model, the geoidal height ‘N_{84}’ was computed for the peak. Then, the “True” orthometric height ‘H_{84}’ was computed using the following equation:

$$H_{84} \approx h_{84} - N_{84}$$

Vertical datum

The new height is defined with the WGS 84 geoid as the zero reference or in the World Height System (WHS).

Accuracy estimation

Using the GPS survey technique, the absolute accuracy of the ellipsoid

Sidebar

On the “RIGHT” foot

Many units of “Foot” are in use, e.g., Indian, Chinese, British, Malaysian, U.S., and International. Effects on determination of the height of Mount Everest due to variations among these different units of “Foot” is geodetically too complex and thus not discussed in this article.

Note: There are at least two metric units currently in use. Hence, the new height is specified in the “International Meter”.

height ‘h_{84}’ is now in 5-10 cm range and thus no more a limitation. As the coverage and quality of gravity for the Mount Everest area is still poor, the absolute accuracy of the geoidal height ‘N_{84}’ was the critical factor. Thus, this restricted the final accuracy of the orthometric height ‘H_{84}’.

WGS 84 orthometric height

The WGS 84 orthometric height ‘H_{84}’ of the snow-covered peak of Mount Everest at 10:30 hours Nepalese Time on May 5, 1999 is 8850 International meter ± 2 meter (1 sigma).

Salient features of the 1999 height

a. The GPS data was collected at the peak itself.
b. Height is defined in a 3-dimensional global datum where the geoidal zero is fundamentally different from the local MSL defined zeros.
c. The survey was carried out with the most accurate satellite survey technique.

Is mount everest really higher in 1999?

In 1999, it was the first time that the height of the actual peak was determined in a new vertical datum. Thus, there is no such previous height to compare with. Also, any two surveyed heights of the snow-covered peak would always differ from each other. Furthermore, the ‘uncertainty’ due to the errors in the surveyed heights should be taken into consideration as a significant factor in any new comparison.

Thus, with presently available information, it is interpreted that Mount Everest is neither rising nor losing its height.

Tectonic uplift or subsidence belongs to geophysical interpretation(s) and thus that interpretation is not considered here.

What is next ?

The “waiting” now starts for
a. A new geoid model of improved absolute accuracy, which would help in improving the accuracy of the orthometric height
b. The measurement of the depth or thickness of the snowcap concurrently with the GPS data collection at Mount Everest, which will allow determining the height of the actual rocky peak.

Innovative recommendation

Let us start reckoning for comparison world’s high mountain peaks in high accuracy ellipsoidal heights, which we directly get from GPS surveys. We will then have more confidence in our “results”.

Conclusions

Heights, as determined in the past, were a great survey achievement, but now they are only historical.

GPS is a revolutionary surveying technique and with the availability of an accurate geoid model, the accuracy of height determination has reached an unprecedented level. Thus, it would be simpler to say:

"Now, we know how high is the highest mountain at 1030 Hours Nepal Time, 5 May 1999" in a global geodetic system and with a good absolute accuracy.

It is important to note that each new height determination may not necessarily mean that the Everest is going up or down. But, of course, there will always be a scope for accuracy improvement.

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Geodetic commentary

The old Indian Datum

Under the new Map Policy, it seems that India has decided to retain the old Indian Datum, which has been identified by "Everest", for DSMs. The following geodetic definition issues and "specifications" are worth commenting:

Vintage – 1880s.

Name – On a recent enquiry, four SOI experts provided four different names. However, it cannot be "Everest".

Spheroid – Inherited from British times, this nomenclature should have been corrected decades back to "ellipsoid".

Everest Ellipsoid – The semi-major axis "a" was defined originally by the Indian Yard. After the last calibration with the International Meter, the 1956 conversion factor has significantly changed the "scale" in meters.

Longitude Definition – The original zero definition was changed by applying a "correction" in 1905. Even with this correction, it is obvious that the Indian Datum has a significant defining bias with respect to the latest IERS realized zero longitude.

Multiple Datums – With the changing semi-major axis in meter, the Everest Ellipsoid has changed within India and also in other countries, which still use it to define their datums.

It is pertinent to note that there are many versions of the old Indian Datum, e.g., Indian 1916, 1954, 1960, and 1975. And, a few more versions exist due to arbitrary or unintentional modifications of the semi-major axis in many other countries, hidden within the classified records. In one case, nobody has any information who defined it, but one country is using it as its national datum; in another, the starting scale definition is unknown.

Accuracy – The accuracy is no match to the currently achievable level(s). A new adjust or transformation will not make any improvement.

Muneendra Kumar, Ph.D.

GISNet '11

The mission of this GISnet conference was to promote the applications of GIS, GPS, and RS in Vietnam

Tran Vinh Trung

Vice Minister (R) of education and training visits exhibition

The conference GISNet'11 was held in Hochiminh City, Vietnam by DITAGIS in two days August 8 and 9, 2005. It received the sponsorships of Ministry of Science and Technology, Ministry of Education and Training, Vietnam National University – HCMC, University of Technology, Center of IT Development, VIDAGIS company, VietCad company, and ThanhQuang company. The mission of this GISnet conference was to promote the applications, education, and services of GIS, GPS, and RS in Vietnam. It popularized the geographic information science and technology, the spatial science and technology to students, researchers and users in Vietnam.

This year, GISNet welcomed the presentation of Professor Doctor Nguyen Tan Phat, Vice Minister of Ministry of Education and Training, and President of Vietnam National University – Hochiminh City, of Doctor Bui Van Quyen, Head of Southern Office of Ministry of Science and Technology, of Associate Professor. Doctor Nguyen Minh Dan, Director General of Department of Science and Technology, of Associate Professor Doctor Phan Thi Tuoi, Rector of the University of Technology, of Professor Doctor of Science Truong Minh Ve, former Vice President of Vietnam National University – Hochiminh City, and other officers of Provincial Agencies, Director of Departments of Science and Technology, Departments of Post and Telecommunication, Departments of Science and Technology, Departments of Agriculture and Rural Development, Departments of Construction from many cities or provinces of Vietnam. Besides, there were 567 participants who were officers, researchers, scientists, graduate students, undergraduate students, technicians of GIS organizations and officials of governmental agencies in Vietnam. The conference also welcomed professors and researchers from Thailand and Canada.

The conference had keynote session in the morning and two technical sessions in the afternoon of the first day. The MEKOGIS meeting and workshop were held in the morning and afternoon of the second day.

In the keynote session, Doctor Bui Van Quyen had a speech about the rapid development of GIS. He said century 21 is a century of information and integration. Spatial information has been playing an important role. In order to help Vietnam to integrate to the world successfully, spatial information of the homeland should be controlled well. Therefore, geographic information science and technology, and space science and technology must be considered carefully. He recommended that GISNet should be an international GIS conference from 2006. In this session, the presentation of An overview of GIS development in Vietnam to 2005 of Professor Tran Vinh Phuoc was interested by many people. It was written on data from various departments and agencies in Vietnam. The short report of MEKOGIS also attracted participants' attention.

The sessions of Research with GIS and Research on GIS were opened with 30 papers which had been scored by a Board of Science of GISNet. Many interesting issues were presented there.

In the MEKOGIS meeting, many issues of MEKOGIS system were discussed. At the end of the meeting, researchers and officers agreed that the results of MEKOGIS should be deployed into the real world. Besides, internet should be used to learn flood events by everyone. Moreover, the government should promulgate a common regulation for agencies to use and share data of MEKOGIS system. In addition, the meeting concluded that MEKOGIS should be invested more and more to link other systems and to upgrade its capability.

The workshop about The development of Information Technology and Geographic Information System whose author was Professor Hoang Kiem was held in the afternoon of the second day. There were 36 participants in this workshop.

The magazine of Coordinates and International Journal of Geoinformatics were also circulated.

An Alternative Low Cost MEMS IMU/GPS Integration Scheme

The article investigates the use of artificial neural networks for developing an alternative integration scheme of low cost Microelectromechanical System (MEMS) Inertial Navigation System (INS) and Global Positioning System (GPS) for vehicular navigation applications. We are presenting here the first part of the article. The second part that focuses on The Conceptual Intelligent Navigator will be published in October issue of Coordinates

Dr. Kai-Wei Chiang and Dr. Naser El-Sheimy

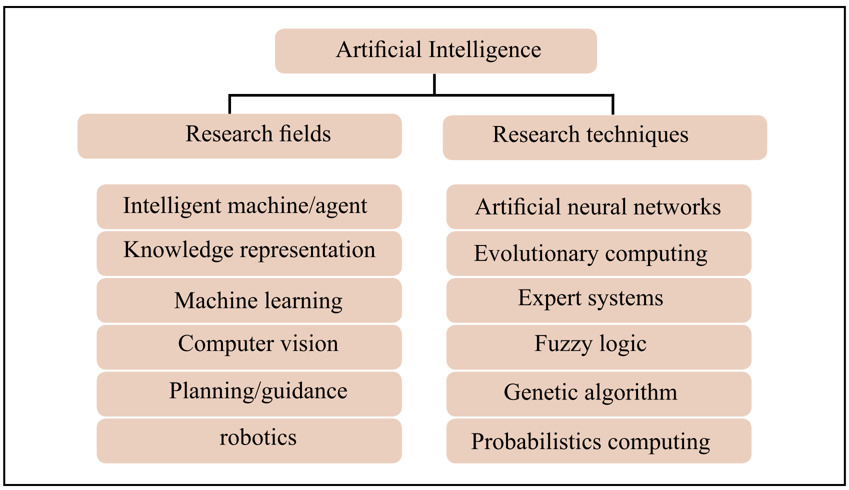
This article investigates the use of artificial neural networks for developing an alternative integration scheme of low cost Microelectromechanical System (MEMS) Inertial Navigation System (INS) and Global Positioning System (GPS) for vehicular navigation applications. The primary objective is to overcome the limitations of current INS/GPS integration scheme and improve the positioning accuracy during GPS signal blockages. The results presented in this article indicated that the proposed technique was able to provide 47% and 78% improvement in terms of positioning accuracy during GPS signal blockages.

Introduction

With the evolution of modern computer technology in hardware and software, the field of artificial intelligence has been receiving more attention in the development of new generation technology. Artificial intelligence (AI), also known as machine intelligence, is defined as the intelligence exhibited by anything manufactured (i.e. artificial) by humans or other sentient beings or systems (should such things ever exist on Earth or elsewhere) [Cawsey, 1999]. It is usually hypothetically applied to general-purpose computers. The term is also used to refer to the field of scientific investigation into the plausibility of and approaches to creating such systems.

Artificial intelligence has been verified as a successful and effective tool for providing solutions to certain engineering and science problems that can not be solved properly using conventional techniques [Cawsey, 1998]. The goal of applying artificial intelligent technologies is to provide intelligence and robustness in the complex and uncertain systems similar to those seen in natural biological species [Honavar and Uhr, 1994]. According to Russell and Norvig [2002], the techniques and the related research fields of artificial intelligence (AI) are given in Figure (1).

Figure 1: The techniques and the related research fields of artificial intelligence



It is well known that Kalman filter approach has been widely applied as the core algorithm for INS/GPS scheme for many navigation applications. Although it represents one of the best solutions for INS/GPS integration applications, it has limitations in terms of model dependency, prior knowledge dependency, sensor dependency, and linearization dependency for general INS/GPS integrated navigation applications [Chiang, 2004]. Consequently, in order to overcome or reduce the impact of these limitations, several research works have been conducted to investigate possible alternative algorithms for INS/GPS integration scheme [see for example, Chiang, 2004]. The incorporation of Artificial Intelligence Algorithms (AIAs) for developing alternative INS/GPS integration scheme is fueled by the need for intelligent systems and the limitations with the current INS/GPS integration scheme.

Among artificial intelligent methodologies shown in the Figure (1), ANNs have been extensively studied with the aim of achieving human-like performance, especially in the field of pattern recognition and robot control and navigation [Mandic and Chambers, 2001]. ANNs are composed of a number of nonlinear computation elements which operate in parallel and are arranged in a manner reminiscent of biological neural interconnections. In addition, ANNs are designed to mimic the human brain and duplicate its intelligence by utilizing adaptive models that can learn from the existing data and then generalize what it has learnt [Ham and Kostanic, 2001]. Therefore, this article attempts to evaluate an alternative INS/GPS integration schemes developed by the authors for general land vehicular navigation and positioning applications using low cost MEMS INS.

Problem statement

According to Chiang [2004], the limiting factors of Kalman filter based INS/GPS integration are given in brief as follow;

Model dependency

Generally speaking, the development a model to be used in the Kalman filter starts with the construction of a full scaled "true-error model", whose order is then reduced based on the prior knowledge and the insight gained into the physics of the problem, covariance analysis, and simulation [Salychev et al, 2000].

Typically, the dynamics model is based on an error model for three position errors, three velocity errors, and three attitude errors in an INS (the system error states). These errors are also augmented by some sensor error states such as accelerometer biases and gyroscope drifts, which are modeled as stochastic processes (i.e., 1st Gauss Markov process or random walk) [Rogers,2003]. In fact, there are several random errors associated with each inertial sensor. Therefore, it is usually difficult to set a certain stochastic model for each inertial sensor that works efficiently at all environments and reflects the long term behavior of the sensor errors. Hence a model-less navigation algorithm that can perform the self-following of the vehicle under all-conditions is required.

Prior knowledge dependency

As mentioned previously, some initial knowledge is required to start a Kalman filter, such as the state transition matrix ($F_{k,k-1}$), the measurements design matrix (H_k), the noise coefficient matrix (G_{k-1}), the system noise covariance matrix (Q) and the measurements noise covariance matrix (R). Among them, the Q and R matrices are the most important factors for the quality of the Kalman filter estimation for an INS/GPS integrated system. Theoretically, the optimal Q and R matrices can guarantee the optimality of the estimation; however, tuning the Q and R matrices can be time consuming and it requires experience and background in both systems. Consequently, the requirement of human intervention for Q/R tuning is very high. In other words, the tuning process can be regarded as a special form of learning as it is usually done by an expert and needs time to obtain the optimal solution. Consequently, a new navigation algorithm that can reduce the level of human intervention and is capable of learning by itself to adapt the latest dynamic model is preferred.

Sensor dependency

The need to re-design algorithms based on the Kalman filter (i.e., states) to operate adequately and efficiently on every new platform (application) or different systems (e.g. switch from navigation grade IMU to tactical grade IMUs) can be very costly. In addition, the Q and R matrices tuning is heavily system dependent [Vanicek and Omerbasic, 1999]. As a result, a new navigation algorithm that is adaptable and can reduce the level of sensor dependency is highly desirable.

Linearization dependency

INS/GPS integration for land vehicular navigation is composed of non-linear dynamic in nature. However, since the principle of Kalman filtering is to estimate a linear dynamical model using a recursive algorithm along with certain stochastic information, the linearization of INS or GPS dynamics model is required [Brown and Huang, 1992]. However, the linearization process is usually a 1st order approximation process that results in deviations between the assumed "true error model" and the real "true error model". As a result, a new navigation algorithm that is nonlinear in nature and can reduce the impact of linearization is preferred.

The impact of those limiting factors projects on the positional error during GPS outages. In other words, each of those factors contributes certain amount of positional error accumulation when the Kalman filter operates in prediction mode.

Objectives

The objectives of this article are to: (1) provide a brief review about the latest development of alternative INS/GPS integration scheme and (2) evaluate an alternative INS/GPS integration scheme developed by the authors for the use of a low cost MEMS INS/GPS integrated system.

Recent development of alternative INS/GPS Integration schemes

The primary objective of developing alternative INS/GPS integration scheme is to reduce the impact of remaining limiting factors and improve the positioning accuracy during GPS signal outages. The recent research activities involved with developing alternative schemes for general navigation applications fall into two categories:

Alternative filters

Xu [1996] suggested a new self-learning navigation filter associated with probability space and non-Newtonian dynamics. This new filter relied basically on the information contained in measurements on the vehicle: position fixes, velocities and their error statistics. Mohamed [1999] suggested Adaptive Kalman filter (AKF) based INS/GPS integration architecture. Fredrik et al., [2002] proposed a framework for positioning, navigation and tracking problems using particle filters (sequential Monte Carlo methods). It consisted of a class of motion models and a general non-linear measurement equation in position. Frykman [2003] suggested particle filters based aircraft integrated navigation with the utilization of INS and GPS. Shin and El-Sheimy [2004] suggested an UKF based INS/GPS integration scheme.

AIAs

Meng and Kak [1993] suggested a neural network-based navigation algorithm for a mobile robot. Townsend et al., [1994] proposed a Radial Basis Function (RBF) Networks approach for mobile robot positioning. Dumville and Tsakiri [1994] utilized a neural network to integrate DR and GPS for land vehicle navigation. Chansarkar [1999] utilized RBF networks for GPS positioning and navigation. Forrest et al., [2000] suggested an inertial navigation data fusion system employing an unsupervised neural network as the data integrator to estimate INS errors. Ojeda and Borenstein [2002] proposed a fuzzy logic rule-based position estimation algorithm for mobile robots as one of the prototypes of marsian rovers.

As for INS/GPS integration, Chiang and El-Sheimy[2002] and Chiang et al., [2003] first suggested an INS/GPS integration architecture utilizing Multi-Layer Feed-Forward Neural Networks (MFNNs) for fusing data from DGPS and either navigation grade IMUs or tactical grade IMUs. Chiang [2003] proposed an MFNN based INS/GPS architecture for integrating IMUs with Single Point Positioning (SPP). Chiang [2004] proposed an optimal GPS/MEMS integration architecture for land vehicle navigation utilizing neural network. Chiang and El-Sheimy [2004] proposed the idea of developing the conceptual intelligent navigator that used ANNs approach for next generation land vehicular navigation and positioning application. In addition, El-Sheimy and Abdel-Hamid [2004] suggested a model derived from Adaptive Neuro-Fuzzy Interference System (ANFIS) to bridge GPS outages in MEMS-INS/GPS land vehicle navigation.

The common characteristic of those research works is to reduce the impact of those limiting factors mentioned above. According to the results and conclusions given by Mohamed [1999], Frykman [2003], Ojeda and Borenstein [2002], Shin and El-Sheimy [2004], Chiang [2004] and El-Sheimy and Abdel-Hamid [2004], a comparison between different INS/GPS integration schemes is given in Table 1.

Table1: Comparison between different INS/GPS integration schemes

	Current	Alternative filters			AIAs		
	EKF	AKF	PF	UKF	ANN	ANFIS	FES
Model Dependency	√	o	√	o	x	x	√
Prior Knowledge Dependency:	√	x	√	√	x	x	√
Sensor Dependency:	√	√	√	√	x	x	x
Linearization Dependency:	√	√	x	x	x	x	x
Parameter tuning/training	h	s	h	h	s	s	h

√: Yes, x:No,, o: Improved; PF: Particle Filter, FES: Fuzzy / Expert system, h: human tuning, s: self learning

As indicated in Table 1, the AIAs are able to provide more advantages for implementing alternative INS/GPS integration schemes. Due to the limited scope of this article, only ANN based INS/GPS integration scheme developed by the authors will be discussed as an example to demonstrate the benefits of incorporating of incorporating AIAs as the core component for alternative INS/GPS integration schemes.

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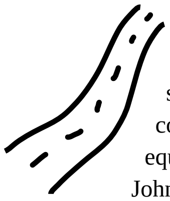
Business

Road Construction Project uses positioning technology



Trimble announced that it has been selected as the preferred supplier of machine control and survey equipment for Thiess John Holland, the lead contractor building Australia's largest road project¯EastLink in Melbourne. With total construction costs of AU$2.5 billion (US$1.9 billion), the scale of work required for timely completion of Melbourne's EastLink is beyond that ever tackled before on any single infrastructure project in Australia. EastLink's three-lane, freeway-standard road is expected to be built over three and a half years. Construction includes two million square meters of paved road, more than eighty bridges, seventeen interchanges and 1.6 kilometers three-lane twin tunnels. The project will deliver Melbourne's second fully-electronic tollway, comprising about 45 kilometers of freeway-standard road connecting the city's eastern and south-eastern suburbs. *www.connecteast.com.au*

ABB wins a $10 million space contract

Headquartered in Norwalk, Connecticut, U.S., ABB, the power and automation technology group, said recently that it has won a $10 million contract to supply the main component for a new satellite that will enable the Japanese government to study and measure greenhouse gases in support of the Kyoto protocol. The contract is with NEC Toshiba Space Systems, the primary equipment supplier to Japan's Greenhouse Gases Observing SATellite (GOSAT) program. GOSAT is being jointly developed by Japan Aerospace Exploration Agency (JAXA), the National Institute for Environmental Studies, and Japan's Ministry of Environment. The satellite will be launched by JAXA in 2008. *www.newswire.ca*

Space Imaging awarded $5.88 million contract

Space Imaging has been awarded a $5.88 million satellite imagery capacity contract from the National Geospatial-Intelligence Agency (NGA). This ClearView mid-year supplemental contract enables the NGA to acquire additional commercial imagery from Space Imaging's IKONOS satellite. *www.spaceimaging.com*

KVH receives $2.4 million in orders

KVH Industries has recently announced that it has received three new orders for its TACNAV vehicle navigation systems and T-FOG(TM) fiber optic gyro (FOG) upgrade. Together, the orders are valued at more than $2.4 million. The orders were placed by U.S. defense prime contractors and a foreign military, all of which are current KVH customers. KVH expects to recognize the majority of the contract revenue during the second half of 2005. *http://home.businesswire.com*

Intermap announces US$1.3 million mapping contract

Intermap Technologies Corp has recently announced that its wholly owned subsidiary, Intermap Technologies GmbH, has been awarded a new data acquisition contract in the amount of 1,033,418 Euros (U.S. $ 1.3 million). The contract is for delivery of Intermap's high-resolution digital elevation data and radar imagery. Delivery of the product is expected to occur during the third and fourth quarters of calendar 2005. *www.ccnmatthews.com*

Digital Aerial Solutions Purchases 2nd Leica ADS40

Leica Geosystems Geospatial Imaging has announced Digital Aerial Solutions (DAS) has obtained its second Leica ADS40 Airborne Digital Sensor, which will enable the company to double its collection capacity and facilitate faster turnaround in providing high quality digital data products to its customers.

Falcon II official listed geodetic measurement system

Falcon II now is listed as an officially certified geodetic measurement system and accredited for Lidar scanning in Russia. Currently only very few sensor systems have a valid certification for Russia but world-wide there is no other sensor system except the Falcon II which has been certified for enhanced accuracy. This is a direct result of the fiber based system concept that avoids any mechanics for laser beam deflection and though avoids mechanical errors in a very critical component. Also the outstanding pulse rate of 83 kHz, which is kept constant up to 1,600 m, has had a significant impact to achieve the extended accuracy, as this is also not achieved by any other sensor system. The certification has been performed in co-operation with PRIN, Moscow, the exclusive partner of TopoSys in Russia. *www.toposys.com*

GfK MACON AG is to become GfK MACON GmbH

By converting to the legal status of a limited liability company (GmbH), GfK MACON is completing its integration into the GfK AG network. GfK first acquired a share in the former MACON AG at the beginning of 2002. The company then increased its shareholding in GfK MACON to 100% at the beginning of 2005. The change of corporate form will take place this month. German company GfK MACON has been providing innovative geo-marketing solutions and consultancy services on all aspects of the topic of Area Planning since 1991. *www.gfk-macon.com*

RADARSAT International rebrands under MDA name

RADARSAT International and several other companies in the MacDonald Dettwiler and Associates Ltd. (MDA) family have been rebranded and are now conducting business under the common brand name “MDA”. RADARSAT International belongs to MDA’s Geospatial Services business area and is referred to as MDA Geospatial Services International. Acquired by MDA in 1999, RADARSAT International has over 16 years of experience in providing Earth observation data, products and services to the international geospatial marketplace. *www.mdacorporation.com*

Alliances

Contex Scanning Technology and Z Corporation Merger

Contex Scanning Technology and Z Corporation announced that they will merge to create a global leader in color scanning and 3D printing solutions for engineering markets, including computer-aided design (CAD), geographic information systems (GIS) and architecture, engineering and construction (AEC). The transaction is expected to close in the third quarter of 2005. Financial terms were not disclosed. The combined company will have annual revenue in excess of US$100 million (84 million euro), distribution in more than 80 countries, and more than 400 employees. “This merger is exciting because combining Z Corp’s 3D printers with our leading 2D scanning and data lifecycle management products delivers a complete solution for data collection, storage, processing, and output,” said Steen Borg, CEO of Contex Scanning Technology and CEO of the combined entity. *www.contex.com*

GeoTango appoints PCI as a worldwide SilverEye distributor

GeoTango, a supplier of 3D/2D mapping and visualization software based in Canada, has announced that it has entered into a distribution agreement with PCI Geomatics, a developer of image-centric geomatics software. Under the agreement PCI and its worldwide reseller network will resell SilverEye, GeoTango’s 3D building and measurement software. SilverEye is said to be the best way to rapidly generate 3D models of urban areas and facilities of interest. *www.geotango.com*

MapMart announces alliance with DigitalGlobe

MapMart, a division of IntraSearch Inc. has announced its recent alliance with DigitalGlobe Inc. as a direct reseller of QuickBird Satellite imagery products via its internet website www.MapMart.com. QuickBird products can be purchased directly through www.MapMart.com in standard panchromatic, multi-spectral or color (rgb) formats. The addition of QuickBird digital satellite imagery allows customers access to 2-foot multi-spectral imagery anyplace on earth. *www.mapmart.com*

Spot Image and ImageONE partnership

Spot Image and ImageONE have recently signed a commercial partnership agreement giving ImageONE exclusive rights to distribute FORMOSAT-2 data to the Japanese market. The agreement also grants three minutes per day priority reservation of the satellite’s resources on the orbit west of Japan. The FORMOSAT-2 Earth-observation satellite was launched by Taiwan’s National Space Organization (NSPO), in May 2004. It provides black-and-white images at two-metre resolution and colour images at eight-metre resolution. The NSPO has chosen Spot Image as exclusive global distributor of FORMOSAT-2 products and services outside Taiwan and China. *www.spot.com*

Products

Linear asset management software

Exor Corporation, providing Infrastructure Asset Management Solutions, has recently announced the latest release of its linear asset management software. The new release builds on Exor’s capabilities in the area of integrated asset management, and features significant enhancements for enterprise wide consolidation of asset registers and work practices through a spatial ‘Hub’. A major enhancement at the 3.2.1 release is the ability to model and include assets in databases that have no connection to a linear network – such as a recreational park – with the total flexibility Exor users have been used to. *www.exorcorp.com*

V-STARS/E4X Photogrammetry System

Geodetic Systems, Inc. (GSI), a provider of portable 3D coordinate measurement systems for industrial measurement, located in Melborne and Florida has announced the release of their new V-STARS/E4X Digital Photogrammetry system. This entry-level product can be used for a wide range of applications that do not require the highest level of accuracy or expandability as provided by GSI’s top-of-the-line V-STARS/S8 Single Camera and V-STARS/M8 Dual Camera systems. *www.primezone.com*

Citadel develops digital map of Hyderabad

Citadel, a GPS-GIS solutions company in India has developed a digital map of the city Hyderabad called InforMAPtion on a CD. The software will help the user locate and plan the routes to locations in the city. K Jayachandra, additional director general of police formally launched InforMAPtion recently. *www.business-standard.com*

SUMMIT EVOLUTION compatibility

DAT/EM Systems SUMMIT EVOLUTION Digital Stereoplotter is fully compatible with: • AutoCAD, Versions R14 through 2006, including AutoDesk Map3D and Land Desktop • MicroStation, Versions J, V8 and 2004 edition • ESRI ArcGIS, Version 9 *www.datem.com*

Bangkok to introduce GPS to its fleet of taxis

Bangkok has opened the first of 150 new electronic taxi stands that will allow pedestrians to summon a taxi by pressing a green button, signaling a dispatcher to send a taxi. The devices will display the estimated arrival time and license plate number of the approaching taxi. Taxis will be equipped with GPS as part of the service. The first arch-roofed electronic taxi stand was unveiled last week outside a superstore on the city's Phahonyotin Road, while the remaining stands are expected to be installed across the city by November. Besides helping Bangkok pedestrians easily hail taxis, the stands are meant to keep cab drivers from wasting fuel by driving around the city in search of fares. *www.chinapost.com.tw*

New GPS unit helps dodge traffic jams

Chicago-based Cobra Electronics in U.S. recently unveiled its new GPS navigation system, the first portable with real-time traffic information. The Nav One 4500 offers rerouting options based on the location of traffic congestion. Portable units appeal to people who want to be able to use a device in different cars, including in rental cars while on business trips or vacations. The data, refreshed every two minutes, is available for 48 major cities, including Chicago, New York, Los Angeles on down to smaller cities, including West Palm Beach, Fla., and Austin, Texas. Marsh said these cities include more than 70 percent of the U.S. population. *www.suntimes.com*

GPS to assist bikers at staying on track

One of the most frustrating things about any mountain biker is getting lost, confused or turned around. Outdated maps or guidebooks, poorly marked trails or junctions not marked at all can put the damper on just about any recreational ride. It's something that Mike Sladdin, an avid mountain biker, noticed about three years ago when he decided he wanted to start mapping the trails around his hometown of Aspen in U.S. Pursuing what he thought would be a useful tool for the mountain-bike community and a good business idea, Sladdin recently launched MountainTownTrails.com, a web site of downloadable GPS tracks and GPS-based maps concentrating on Colorado, Utah and the Rocky Mountains. Though the technology is not yet widespread, many say GPS mapping and tracking is the future for serious recreationists who don't want to worry about getting lost or taking a wrong turn. The main advantage of GPS biking is safety. *www.rockymountainnews.com*

Qinghai-Tibet Plateau moving northeast

The Qinghai-Tibet Plateau, dubbed "the roof of the world", is moving northward and eastward at seven to 30 millimeters a year, according to a Chinese researcher."The plateau is moving because it's being pushed by the Indian plate," said Dr. Tan Kai, a researcher with China Seismological Bureau who is collecting data for a GPS survey in the towering Kunlun Mountains in Golmud city of northwest China's Qinghai Province. Dr. Tan and his colleagues have found through the survey that Lhasa, on the southern end of the plateau, is moving 30 millimeters a year northeast at an angle of 38 degrees.

The seismological bureau has conducted more than 50 GPS surveys on the roof of the world since 1991. Of the country's 1,056 survey stations, 340 are in the plateau region, which is known as the "third polar of the earth". Dr. Tan said the GSP surveys can capture real-time, highly precise data to calculate velocity of the crustal movement. Results of the surveys will help scientists study the formation and evolution of the plateau and evaluate the region's risk of earthquake and other geological disasters. *http://news.xinhuanet.com*

GPS to study changes in hurricane intensity

Researchers are using a $3 million National Science Foundation grant in an effort to learn why sudden, dramatic changes occur in the intensity of hurricanes. The study will focus on how the interaction between a storm's outer rain bands and its inner eye can influence abrupt fluctuations in its strength.

Beginning on Aug. 15 through the rest of this year's Atlantic hurricane season, P-3 Orion aircraft from the National Oceanic and Atmospheric Administration and the U.S. Navy fly into hurricanes at sea armed with sophisticated Doppler radar and GPS technology.

The planes will record wind speed and direction, temperature, humidity, atmospheric pressure and other data to help scientists build a new computer model on hurricane intensity. The research team for the Hurricane Rainband and Intensity Change Experiment, or RAINEX, includes the University of Miami's Rosenstiel School of Marine and Atmospheric Science; the University of Washington; the National Center for Atmospheric Research; NOAA; and the U.S. Navy. *www.wftv.com*

Tracking fast-moving glaciers in Greenland

Two University of Maine scientists studying the effects of climate change in the Arctic have discovered that two glaciers in Greenland are moving at a not-so-glacial pace.

The scientists returned from a five-week expedition to the east coast of Greenland, where they studied the movement of five glaciers. They found that two of the glaciers are moving at a far faster rate than just a few years ago, raising questions about the effects of regional warming. To take measurements, the scientists drilled holes in the ice and placed GPS devices in them to precisely measure the forward motion of the glaciers by satellite.

One of the glaciers, called Kangerdlugssuaq, was moving at the rate of nearly nine miles a year, making it one of the world's fastest-moving glaciers, the researchers said. In the late 1990s, it was moving at about 3.5 miles a year. The glaciers' accelerated speeds in Greenland suggest that the climate is warming up, at least in that region reported the scientists. *www.seacoastonline.com*

GPS Industries at golf course in South Africa

GPS Industries, Inc. (GPSI) an innovator of Wi-Fi wireless and GPS-enabled multimedia communications and management solutions for golf facilities and residential communities, announces that two courses, one in South Africa, Pezula Championship Golf Course and White Hawk Country Club in Crown Point, In. have been installed with the Inforemer (TM) Wi-Fi GPS Golf Business Solution. Pezula Championship Golf Course has been selected as the first course in Africa to implement this GPS-based golf course management system. Both courses have installed the full Inforemer) management system, Wi-Fi network and equip their golf cart fleets with 10.4" color GPS units. *www.primezone.com*

Indian military equipped with Sarantel GPS antenna

Encore Software of Bangalore in India is incorporating U.K. based company Sarantel's GeoHelix GPS antenna in its new Saathi PDA for the Indian Army. The Sarantel GPS antenna ensures that every Indian soldier with a Saathi has optimum GPS reception across all environments and locations. The Saathi is a robust tactical GPS enabled PDA with integrated radio and a customised GIS application for displaying military maps and location of other devices. Weighing 875 grams, the Saathi can easily fit into a soldier's palm and also has a remotely operated self-destruction and activation feature for preventing misuse by unauthorised people. Encore Software integrated Sarantel's high performance miniature GPS antenna in the Saathi to ensure soldiers have stable GPS reception in unstable conditions i.e near people or other electronics in the radio. *www.businessweekly.co.uk*

GPS tracking data broadcast at German Grand Prix

A new TV feature for MotoGP broadcasts was introduced at the German Grand Prix, showing the location of a rider on the track - in real time. The system is based on GPS has been jointly developed by the teams, motorcycle manufacturers, leather suit manufacturers and Dorna Sports engineers. A transmitter-receiver, mounted either on the bike (GPS Data Bike) or inside the back protector of the rider's leather (GPS Data Rider), sends real time information to the TV International Program Feed unit, where it is converted into graphics and is inserted in the final television signal. This data is transmitted thanks to the On Board system installed on the bike. *www.crash.net*

Australia

Indigenous community in Australia maps cultural data

Traditional landowners in north west Queensland, Australia will soon be recording and mapping their own cultural heritage sites under a new arrangement with the State Government. The Mt Isa-based Mitakoodi-Juhnjlar aboriginal people will be the first to be taught the technical skills needed to gather their own data. They will be learning skills on using GPS programs and secondly being able to record those results onto software which will then go to official authorities for insertion into the official maps. *www.abc.net.au*

South East Asia

On-line street map available for Malaysian city

An on-line street map of the city Kota Kinabalu in Malaysia and surrounding areas is now available, to assist tourists and locals alike to locate places of interests or business premises as well as find out local events. The website, www.kkmap.com/streetmap, developed by a local GIS/IT solution provider, Menggaris IT Sdn Bhd, gives detailed information for every building and road with an easy interface for all to use. The map is based on data approved by the national Mapping and Survey Department. The website, the first in the State, provides the opportunity for advertisers to promote their products and services to a wider audience. *www.dailyexpress.com.my*

Vietnam's initiative on e-government

The government of Vietnam has approved a request by the Ministry of Post and Telematics (MPT), the General Statistics Office (GSO) and the municipal People's Committees of Hanoi, Ho Chi Minh City and Danang to borrow $93.7 million from the World Bank to launch the e-government project. Of the total, Hanoi will have the largest loan package of $35 million, which it will use to push the project in 12 districts. Three local state offices comprising the Departments of Information Technology, and Planning and Investment, and the People's Committee Office, will use the loan package to promote information technology and design the municipal e-government process and basic exchange portals. Hanoi authorities aim to offer at least three-to-five G2B (government-to-business) services including a GIS and online services to at least 15 per cent of its residents, as well as encouraging 35 per cent of small- and medium-sized enterprises (SMEs) to use ICT. *www.vneconomy.com.vn*

Europe

Education gets free access to digital mapping

Staff and students at several education institutions across U.K. are to be given free access to highly detailed Ordnance Survey digital mapping from this month. It is available through the online service, Digimap, provided by EDINA – a datacentre based at the University of Edinburgh and funded by the Joint Information Systems Committee (JISC). Digimap allows users to view, print and download maps of any location in Great Britain at a series of pre-defined scales. *www.publictechnology.net*

US

National biomass and carbon dataset

Scientists at the Woods Hole Research Center in U.S. are producing a high-resolution "National Biomass and Carbon Dataset" for the year 2000 (NBCD2000), the first ever inventory of its kind. Through a combination of NASA satellite datasets, topographic survey data, land use/land cover data, and extensive forest inventory data collected by the U.S. Forest Service, this "millennium" dataset will serve as an invaluable baseline for carbon stock assessment and flux modeling in the U.S. Funding for this project is provided by NASA's Terrestrial Ecology Program for a habitable Earth, seeking to conserve and sustain forests, soils, water, and energy by demonstrating their value to human health and economic prosperity. The Center sponsors initiatives in the Amazon, the Arctic, Africa, Russia, and North America. *www.eurekalert.org*

County flood maps modernization in US

Upgrades to county flood maps in U.S. have prompted lending institutions to require many of their customers to purchase flood insurance for the first time. Homeowners contend the added cost of such insurance is the only thing rising that threatens their well-being. The reason more people are being required to purchase flood insurance is flood maps, which indicate the areas of town that could see dangerously high water levels, were recently modified as part of the Federal Emergency Management Agency's (FEMA) flood map modernization program. The goal of the program is to create a more accurate digital product that will improve floodplain management across the country. *www.seacoastonline.com*

IIC Technologies announces TerraScan Training Course

IIC Technologies Pvt Ltd is pleased to announce TerraScan Training Course for TERRASOLID's comprehensive suite of LiDAR data processing and terrain modeling products. TERRA-suite of products are global industry leaders with their versatile functionalities. LiDAR is the latest method of capturing data for highly accurate and high-resolution topographic maps in a quick time. *www.iictechnologies.com or www.iicacademy.com.*

Hurricane Katrina and its aftermath

Hurricane Katrina severely pounded the Gulf Coast of U.S. with great force at daybreak on the 29th of August. Arriving with 145 mile an hour wind speed, the storm left more than a million people in three U.S. states without power and submerged highways. Hurricane Katrina, formed in the Bahamas in mid-August and struck South Florida on 25 August, killing nine people and leaving a million more without electricity. European Space Agency's multi-sensor Envisat satellite has gathered a unique view of Hurricane Katrina in the Gulf of Mexico. Envisat simultaneously acquired these images at 1550 UTC (1150 US Eastern Daylight Saving Time) on 28 August, with its Medium Resolution Imaging Spectrometer (MERIS) and Advanced Synthetic Aperture Radar (ASAR). While an optical image shows characteristic spiralling cloud patterns, a simultaneous radar observation pierces through the clouds to show how Katrina's 250-kilometre-an-hour winds scour the sea surface. *www.sciencedaily.com*

USGS committee drafts guidelines on satellite imagery

Recently a U.S. Geological Survey committee posted online new guidelines that note standard procedures for disseminating imagery, including images that are used in software products like Google's online maps and Google Earth. The guidelines, issued in response to security concerns, cover publicly available geospatial data on natural or man-made features of the earth. Data is provided to USGS via various sources, such as privately licensed satellite companies and the Defense and State departments. The guidelines target organizations where the imagery originates and aim to strike a balance between safeguarding information and sharing it with the public. While the guidelines outline how organizations can better evaluate whether content is "sensitive" or poses a security risk, they "do not grant any new authority." *www.govexec.com*

Russia launches Monitor-E to assess emergency situations

Russia launched a satellite designed to probe the surface of Earth. The Monitor-E satellite lifted off on a Rokot carrier rocket from the Plesetsk space center in northern Russia. The 750-kilogram satellite was put into a Sun-synchronous orbit 540 km above Earth one and a half hours later. The Monitor-E will be used to assess the aftermath of emergency situations, map surface areas, survey agriculture and forestry conditions. *http://news.xinhuanet.com*

Pakistan to launch remote sensing satellite system

Pakistan plans to launch a self-controlled Remote Sensing Satellite System (RSSS) at a cost of Rs19.3 billion to ensure strategic and unconditional supply of satellite remote sensing data for any part of the globe over the year. According to recent reports the project will be executed by the Pakistan Space and Upper Atmosphere Research Commission (Suparco) over a period of six years. *www.dawn.com*

Envisat monitoring China floods as part of Dragon Programme

China's rainy season has led to serious flooding in the northeast and south of the country. A joint Chinese-European team is gathering Envisat radar imagery of the developing situation to give the authorities a way to swiftly assess affected areas and plan their responses. This season's flooding is being monitored in near real-time by ESA's Envisat Advanced Synthetic Aperture Radar (ASAR) sensor, which can acquire imagery in both day and night and in all weathers. This activity is taking place as part of ESA's Dragon Programme of cooperation with the National Remote Sensing Centre of China (NRSCC) within the Ministry of Science and Technology of the PRC. *www.esa.int*

Satellite images used to manage floods in Andhra Pradesh

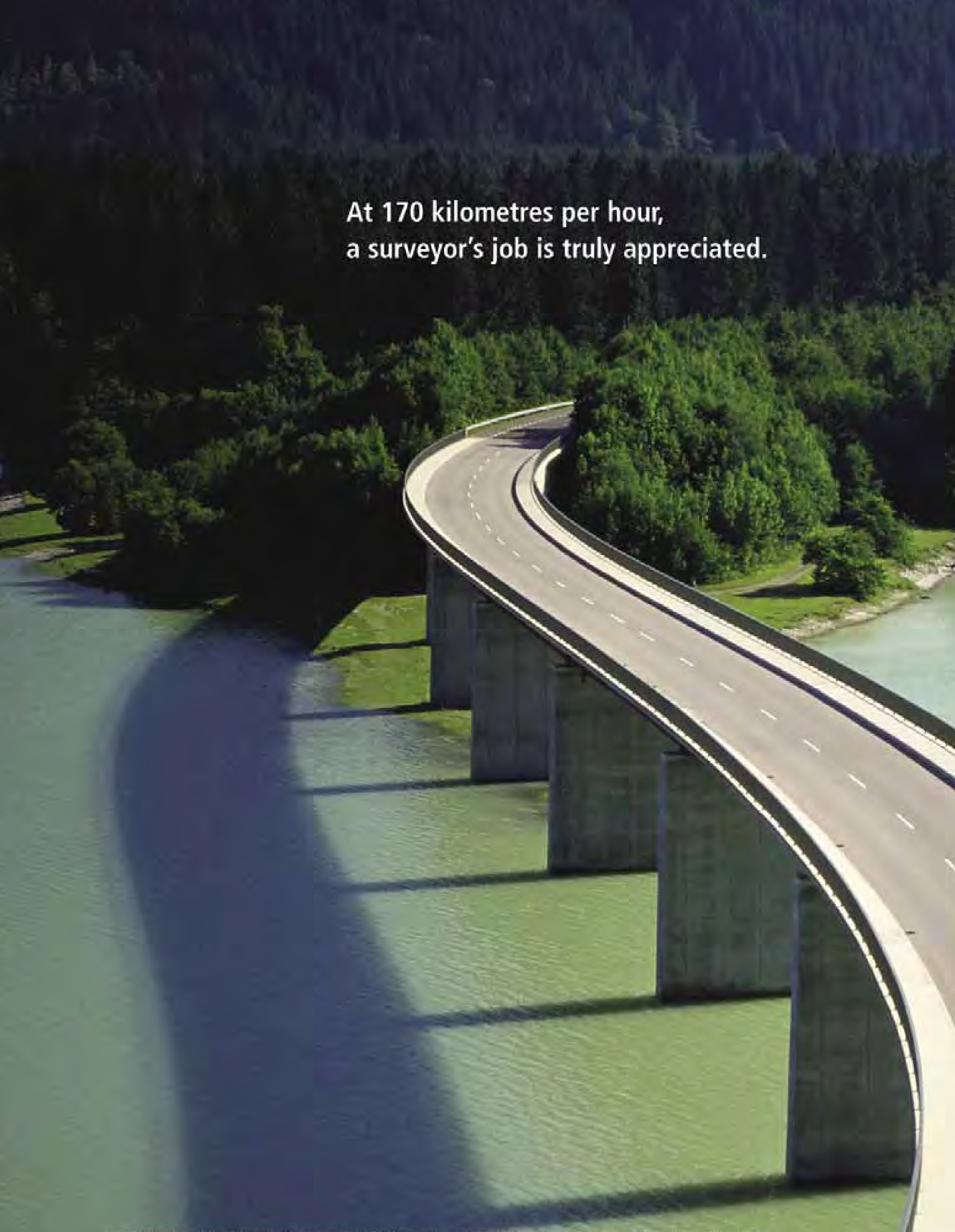
Satellite images have been used for the first time in the Indian state of Andhra Pradesh by the Krishna district administration to assess damage caused by floods. With the help of the National Remote Sensing Agency and using the database available at the Urban Development Authority, the officials were able to locate each and every house that was affected. GIS too came in handy for them in pinpointing the location of the houses. The administration undertook one of the longest flood relief operations in 10 years evacuating 21,628 families and organising 37 relief camps. *www.newindpress.com*

PSLV in India to launch foreign satellites

India's Polar Satellite Launch Vehicle (PSLV) will set off three foreign satellites, including one for Indonesia and the other for Singapore, in the coming two years. Three contracts have been signed for launch of foreign satellites using PSLV. Under an agreement between Antrix Corporation Limited and Indonesian agency, LAPAN, PSLV would be used to launch a microsatellite during 2005-06. There is also an agreement with Cosmos International, Germany for launching 350-kg Agile satellite for Italy during 2006-07, and with Nanyang Technological University, Singapore for launching a microsatellite during 2006-07. *www.expressindia.com*

Rubber Board of India to identify new areas for production

The Rubber Board in India is all set to promote rubber cultivation in nearly 4.5 lakh hectares of land in the non-traditional areas, prominently the North-Eastern Indian states. The Rubber Board has already identified the additional land by making use of the remote sensing data. Most of the areas fall in North Eastern states Tripura and Assam. *www.newindpress.com*


At 170 kilometres per hour,
a surveyor's job is truly appreciated.

Positional accuracy and integration of geographic data

Recent Positional Accuracy Improvement initiatives across Europe, North America and elsewhere suggest the need to constantly update and manage the geographic data to reflect ongoing changes in the real world. This article focuses on the consequences of changing reference frameworks for the use and integration of geodata

CARSTEN RÖNSDORF

In Great Britain most geodata that provides the reference and geographic context for more targeted user datasets created by individual organisations is issued by Ordnance Survey®. These user datasets may include Sites of Specific Scientific Interest or Basic Land and Property Units. Based on this reference data, users often integrate other datasets, such as statistical tables or their own geo-datasets, to support analysis and decision making. Others may collect geo-datasets by using Global Positioning System (GPS) equipment: the location of street furniture, for example. In all cases it is vital that data from different sources fits together spatially to enable the joint use and analysis.

There are two main drivers to change geodata. Firstly, there is the requirement to incorporate real-world change (RWC) such as new houses, roads or demolitions. By its nature, this results in additions or deletions to existing holdings. The second driver is when changes to technology make wholesale improvements to existing datasets a benefit or necessity.

Positional Accuracy Improvement

While changes in the real world usually have a low density and are taken into account by frequent updates of the reference data, other changes, such as the ones triggered by the Positional Accuracy Improvement (PAI), illustrate the necessity to manage dataset against reference changes in a far more organised way.

PAI and update issues are not specific to Great Britain. EuroSDR's international PAI workshops (www.dit.ie/eurosdr) have proved that the same issues are present in most countries with an advanced availability and use of GI. The experience in other European countries has shown that managing change to achieve interoperable data is a natural part of the evolution of geodata and its use within GIS. Before looking into the British scenario in a little more detail, the following examples illustrate the width of PAI-type issues:

USA: MAF/TIGER Accuracy Improvement

In the United States the most prominent PAI programme is undertaken by the US Census Bureau as part of the MAF/TIGER Accuracy Improvement Project (http://www.census.gov/geo/mod/maftiger.html). The programme aims at improving the accuracy of the TIGER (Topologically Integrated Geographic Encoding and Referencing System) database to 3.8 metres root mean square error (RMSE). In contrast to the current data, that has been reported to differ up to 150 metres from its (true) Differential-GPS position, this will benefit users of the data such as Local Government to allow them to insert census geography easily, use GPS on handheld computer and remove the need for paper maps, and to enable field staff to relocate a structure saving time and cost per case. The programme has an investment volume in excess of $200 million.

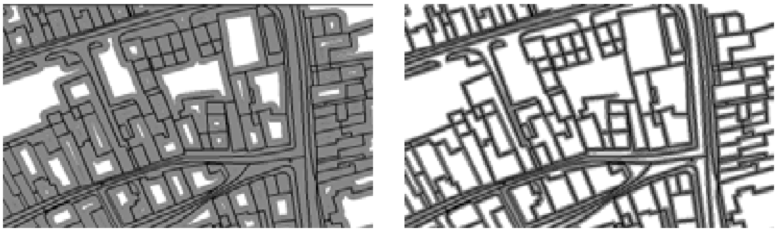
Germany: Integration of utility asset records

In a more localised scenario DEW, a German utility company based in Dortmund, was confronted with the problem of inheriting two different cadastral reference maps for the electricity and the gas/water assets after a merger. DEW successfully finished shifting more than one million GIS objects of the gas/water information layer to the reference of the new reference map using a sophisticated software tool. This example shows how water and gas pipeline data is created and displayed against cadastre (or alternatively topographic) data. While a lot of network assets are surveyed against real word objects such as house corners, most of the data that is used in the government sector—for example planning applications—was digitised against the reference map. As most Geographic Information Systems (GIS) store data in independent layers with geometry information as coordinate strings, no relationship information (or the original measurements as in the utility example) is retained after the dataset is created. If the reference data is positionally improved, the relationship between the reference data and the overlay user datasets is destroyed.

Ordnance Survey's PAI programme

It has been apparent since GPS was first used as a surveying tool that highly accurate GPS coordinates cannot always be seamlessly integrated into the map data of

Figure 1: Base map with 2.8m buffer zone (absolute accuracy before PAI) **Base map with 1.1m buffer zone (absolute accuracy after PAI)**



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the British National Geographic Database. This is due to a fundamental difference in Absolute Positional Accuracy between the GPS data and the existing data, which can trace its origins back to the late 19th century.

While differential GPS methods allow Absolute Positional Accuracies of a decimetre or better, features in large-scale Ordnance Survey map data have an Absolute Positional Accuracy of between 2.8 m Root Mean Square Error (RMSE) in rural areas and 0.4 m RMSE in urban areas. This indicates the accuracy of the absolute position of a coordinate in the context of the British National Grid coordinate system. In contrast to this, the Relative Positional Accuracy between features – two houses, for example – has always been significantly better.

Following earlier debates that go back to about the 1970s, Ordnance Survey started to plan a national programme to improve the Absolute Positional Accuracy of its rural large-scale map base at 1:2500 scale in the late 1990s. It applies to 152,000 km2 (or about two thirds of the area of Great Britain) and excludes the major urban areas, which were already resurveyed to a higher standard from 1947 onwards, as well as mountain and moorland regions, where a high Positional Accuracy is not necessary. The first block of improved data was released in November 2001 and the programme is scheduled to be completed by March 2006. As of July 2005 about 80% of the data has been issued. The aims are to future proof the large-scale topographic database for the addition of new building development and other change as well as providing a better relationship between Ordnance Survey's rural map data and users' own GPS-positioned data. The Absolute Positional Accuracy of the data after the improvement will be 1.1 m RMSE in rural areas and 0.4 m RMSE in selected rural towns. Following an analysis of the original and improved data it was found that the shifts can not be modelled in a mathematical way. The majority of shifts are less than 2.5 m in most areas, with only a very limited amount of extreme shifts of up to about 10 m.

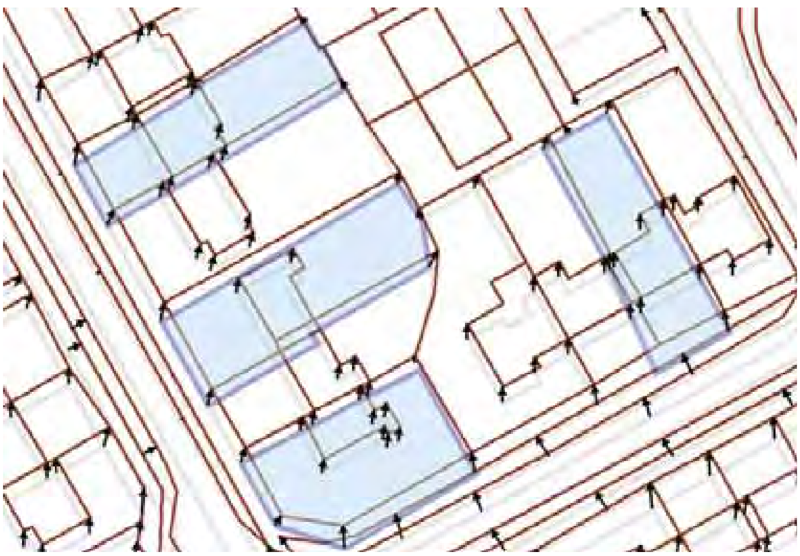
Prior to the start of the programme an extensive consultation process was conducted. Over the last four years Ordnance Survey has continued this communication with over 10 seminars, small workshops with select user groups, one-to-one dialogue and close liaison with system suppliers and solution providers. This work, in conjunction with engagement with representative bodies in government, has led to the development of a number of guidance documents and case studies, which are published on Ordnance Survey's dedicated PAI website www.ordnancesurvey.co.uk/PAI.

PAI for data users

Data users in Great Britain have learned that PAI may have a significant impact on their use of digital geographic data. In particular, automated searches, such as land charge searches for conveyancing, may produce different results if an initial search has been done on a pre-PAI reference dataset and a subsequent one, a few years later, utilises a post-PAI reference map. In the example of a contaminated land search there is the possibility for litigation if an authority knowingly uses datasets of different accuracy that either wrongly reduce the value of a property or miss vital information.

Once a user dataset is shifted to its post-PAI position, it can safely be used in conjunction with a post-PAI Ordnance Survey reference map, but not necessarily with other user datasets that haven't been shifted.

Figure 2: Base map before PAI (grey lines), after PAI (brown lines) and shift vectors (black arrows) superimposed with user data (blue polygons)



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The experience with PAI so far has shown that the creation of improved reference maps as well as the adjustment of user data requires an investment into data from both reference data providers as well as the users of this data

For searches that incorporate user data from different data providers, it is important to verify the PAI status of these external datasets before use. Therefore standardized metadata about the Positional Accuracy status of datasets or, maybe, even individual features is desirable.

Since the data is positionally improved and updated for RWC at the same time, all subsequent map updates will be based on the improved data. With about 5,000 km2 of PAI improved data to be released every month until March 2006, users are receiving more and more PAI data. The majority of Ordnance Survey's large-scale data users in rural areas are currently either working on strategies to use positionally improved reference data or actively using PAI data already.

An example: British Waterways

British Waterways is one of the organisations that has shifted all areas released to date. Martin Rivas, GIS specialist at British Waterways sums up his experience of implementing PAI in an area of 700km2: "The key to successful PAI implementation is to employ simple tools and a simple process as well as being able to rely on a robust system infrastructure. In addition to necessary data clean-up and quality assurance, it took on average two hours to shift 45 datasets in an area of about 20 km2.

British Waterways put an emphasis on the relationship between their various datasets and used topology rules (rules such as 'polygons of waterway features must always be polygons of the descriptive group inland water in Ordnance Survey's OS MasterMap® digital map product', http://www.ordnancesurvey.co.uk/oswebsite/products/osmastermap/) to validate them against each other." Martin Rivas also states that "Using topology rules means that we are certain to correctly maintain the exact internal relationships".

Falkirk Wheel (image attributed to British Waterways)

Data Management

Positional Accuracy Improvement happens on two levels: reference and user data are adjusted to generate datasets that can be used in conjunction with each other and are compliant with GPS measurements as well. Saying that, there is still a difference between the Absolute Positional Accuracy of a few centimetres that can be derived from GPS measurements and the improved accuracy of (1.1 m or 0.4 m RMSE) of the large-scale Ordnance Survey data. At this point in time and for the foreseeable future this accuracy is sufficient for the majority of uses and can be economically maintained by existing and proven technology.

The experience with PAI so far has shown that the creation of improved reference maps as well as the adjustment of user data requires an investment into data from both reference data providers as well as the users of this data. On the user side, it has become acknowledged that PAI is part of a wider data management strategy that is not sufficiently addressed by a number of data users; in fact, very few users manage RWC. As long as the data is kept in a well-guarded environment, like a small GIS team, this hasn't proved to be a big problem, but with the move to corporate information systems 1,000s of Intranet users and many potential Internet users will be accessing uncontrolled overlays of various datasets of different accuracy. This opens up an huge potential for misinterpretation and means that it will be important to manage the integrity of datasets against each other.

Conclusions

The management of both RWC and PAI illustrates a simple fact: geographic data used as a reference to provide spatial context needs to continuously reflect the changes in the real world but, on the other hand, needs to be stable enough to ensure that the reference is not lost over time. In OS MasterMap this is supported by the existence of Topographic Identifiers (TOIDs) and feature life-cycle rules to enable users to manage these changes in respect of their own data.

Positional Accuracy is an issue of Geometric Interoperability that is becoming more and more relevant in many countries and is largely triggered by the widespread use of GPS as a very accurate surveying and positioning technique. PAI is often seen as a painful exercise. In practice, supported by British Waterways' experience, the preparation and planning can be quite complex but the application is fairly easy and straightforward, even for a bigger organisation with thousands of users.

For data users PAI implementation is a necessary investment in maintaining their data holdings. If applied correctly, it will deliver improved data management capabilities and will allow better data integration to empower organisations to make better decisions.

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Galileo update

Galileo – the European Programme for Global Navigation Services for civil purposes is an initiative led by European Union. We provide regular updates to our readers on the Galileo programme.

EU and India seal their agreement

After intensive exchanges held since January 2004, negotiations on India's participation in Europe's satellite radio navigation programme finally reached approval. The agreement, initialled today in New Delhi at the occasion of the EU-India Summit in the presence of UK Prime Minister Tony Blair as EU Presidency, European Commission President José Manuel Barroso and Indian Prime Minister Manmohan Singh, will ensure the availability of highest quality Galileo services in India as well as cooperation to establish regional augmentation systems based on EGNOS and GALILEO. Welcoming the outcome of the negotiations, Vice-President of the European Commission Jacques Barrot said: "This is another important step for the development of GALILEO as an international programme, but also a major milestone in the EU/India partnership". The agreement was initialled by Mr Francisco Da Camara Gomes, Head of the EC Delegation in India, representing the European Union, and Mr G. Madhavan Nair, Secretary, Department of Space, representing India. Considering that India has well proven capabilities in space, satellite and navigation related activities, the agreement will provide a positive impulse for India and European industrial cooperation in many high tech areas.

India is the fourth country joining the GALILEO programme, after the signature of agreements with China, Israel and Ukraine. Discussions are also under way with Argentina, Brazil, Morocco, Mexico, Norway, Chile, South Korea, Malaysia, Canada and Australia. http://europa.eu.int/

Galileo satellite payload testing

Testing of the first Galileo satellites, which form part of what is called the Galileo System Test Bed (GSTB), is under way. One of the two satellites arrived at the ESA-ESTEC test facilities in late July, while the payload of the other spacecraft is now being tested in Italy.

The payload of the GTSB-V2/B satellite, being developed by Galileo Industries, is just completing a first series of tests at the Alenia Spazio facilities in Rome. In particular, the specially developed navigation payload has been subjected to a range of extreme temperatures in vacuum. This simulation of the space environment realistically validates the payload's performance in orbit. The campaign will continue with mechanical testing. The payload's functionality will have to be proven while exposed to strong vibration, high acoustic noise levels and shock, as encountered during launch. Whereas the mechanical investigations can be considered standard satellite testing, the first validation in the thermal vacuum environment had been awaited with special interest, as it has given early feedback on the in-orbit performance of the newly developed payload.

www.esa.int

The role cadastral data modelling in e-Land administration

This paper describes the importance of cadastral data modelling in data management as well as coordination among subsystems in an e-LA

KALANTARI M, RAJABIFARD A, WALLACE J AND WILLIAMSON I

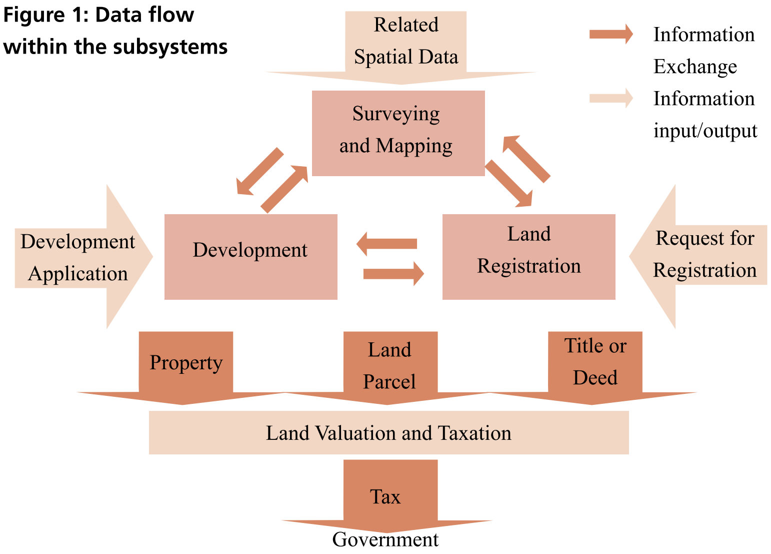
Land administration systems evolved from a focus on core functions of regulating land and property development, land use controls, land taxation and disputes (Dale & McLaughlin, 1999) to an integrated land management paradigm designed to support sustainable development (Enemark et al., 2005).

In the new land management paradigm, the core functions of land administration remain organized around three sets of agencies responsible for surveying and mapping, land registration, and land valuation (Dale & McLaughlin, 1999). These agencies are encouraged to take up new opportunities for better management of diverse internal approaches and overall delivery of LAS policy. Also the unique institutional, economic, legal and technical settings of each country or jurisdiction are recognized.

In Australia, the diversity of agencies leads land administration to diversification of services and functions to mange real property. For example the land registry places emphasis on the holding and the registration of private rights, restrictions and responsibilities on property parcels. At the same time the land development subsystem is concerned with use restrictions imposed through zoning mechanisms. Taxation and valuation focus on the economic function of the real property.

Although these processes seem to be independent, each is generally applied to the real estate parcels and moreover they, and other systems such as utility supply, can be all related together. For example, local governments supply property details to the extent of their local government areas; the water utilities prepare proposed plans of their area of interest. On ground identification is provided by surveyors through development plans which are added to the property data set. The land taxation office requires the change of property use as well as the property owner to calculate the revenue and tax for specific purposes. Ideally, these activities require exchange of information among the subsystems; in the digital world, they should not duplicate information but should use each others' data sets as a resource and as an input for their own database (Figure 1).

Figure 1: Data flow within the subsystems



Each subsystem has specific functions and services. These specific functions or services directly impact on their databases. For example a register of title or deeds normally contains a record of the attributes associated with each parcel: its owner, the interests held and description of land. In an open registry, functions and services include providing this information to the public. In valuation and taxation systems several techniques for estimating the value of the property may be used; each technique serves different purposes and makes different assumptions. For land use planning and land development control, the organization needs various datasets as well as various functionalities for analysis and decision making. The unique perspective of each agency causes it to implement specific functionalities to deliver its services and to develop different data structure.

To meet government needs for up-to-date, complete and comprehensive information, e-LA intends to treat the data and services of each of the agencies holistically, by improving data management and coordination. Cadastral data modelling is one idea offered to implement to this strategy.

Cadastral data modelling is particularly important in the domain of land management that relates to land administration and land markets. The modelling of a cadastral system has received special attention focused on the International Joint FIG Commission 7 and COST Action G9 Workshop on Standardization in the Cadastral Domain in 2004. The next two sections discuss importance of cadastral data modelling in data management and coordination among subsystems.

Cadastral data modelling and data management

The core of cadastral domain model developed in the European context includes (Oosterom et al., 2004) :

- The subject: group ownership with non-defined membership
- The rights: the recognition of types of non-formal and informal rights
- The object: units other than accurate and established units

Cadastral data refers to all data related to these three components in the subsystems. Studies show that data management of land administration systems is one of the major cost items. Figures of between 50 and 75 percent of related total costs are quoted. The data component includes items such as data modelling, database design, data capture, and data exchange (Roux, 2004), and data catalogue.

Cadastral data must be able to be updated and kept current (Meyer, 2004). Although recent advantages in data capture technology make this easy, these initiatives are made in 'isolation' and no common view is formulated for the handling of cadastre and other related data. Consequently, the data sets cannot be easily integrated and shared because of the lack of harmonization between them. Further, no effective measures or supporting digital tools exist for the direct data access and propagation of updates between them in order to keep data sets up-to-date and in harmony (Radwan et al., 2005). The process of boundary data capture is an example of the problem. To gain maximum benefit from existing data, the building process should not only extract data from the documents and build the boundary network, but it should also analyze the data and provide a measure as to the reliability and accuracy of the computed coordinates. This opens the way for coordinates to be used more widely as the primary way for surveyors to convey instructions on how to locate the physical boundaries of a property (Elfick et al., 2005). If efficient and cost effective methods for capturing cadastral data including spatial and non-spatial data are realized in the cadastral data modelling, effective data management in e-LA is possible.

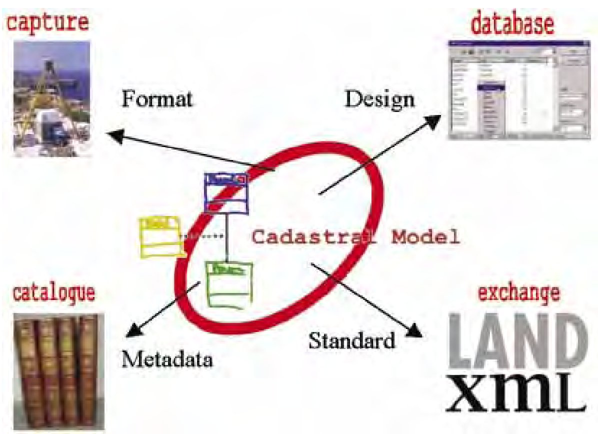


Figure 2: Role of cadastral data model in data management

The Cadastral database should join the attribute and spatial data and present them in an integrated portal, because attributes are as important as spatial information for decision support (Meyer, 2004). However the integrated portal does not necessarily allow attribute data and spatial data to be put together. They enable the user to access various distinct databases using a unique portal. Systems architecture design changed in response to the growing need to access data sets which were developed individually but simultaneously from various distinct databases within various divisions of large organization; these datasets increasingly have to be accessed at an integrated level (Vckouski, 1998). Introduction of new systems architecture facilitating access to cadastral databases whether spatial or non-spatial should be recognised in cadastral data modeling to achieve an e-LA.

Data must be standardized so that information can be shared across jurisdictional boundaries (Meyer, 2004). Therefore cadastral data needs to have its own exchange language to better communicate among various organisations. Because of the nature of cadastral data, especially in spatial context, a specific language is needed for cadastral objects and elements to permit exchange and migration of the data. Cadastral data modelling which understands specialised exchange language for cadastral data will facilitate exchange data among various subsystems.

Data will provide linkages to more detailed information that can be obtained from data producers (Meyer, 2004). The catalogue is a way to provide consistent descriptions about the cadastral data. The objective of the cadastral data catalogue is to develop a description of each object class, including a definition, a list of allowable attributes, and so on (Astke et al., 2004). An expanded cadastral data model including a data catalogue, facilitates data publication across a network.

Figure 2 illustrates the role of modelling data management. It formulates the proper way of capturing spatial and non-spatial cadastral data. Database design is based on data modelling. Data modelling is a conceptual level of modelling which underpins the design of logical and physical models of the database. The modelling component allows the data catalogue to fit metadata in the proper position whether it is separate or integrated with the other data. Also modelling introduces standards for the exchange and conversion of data among the various services for different organizations.

Cadastral data modelling and coordination among subsystems

An effective cadastral data model must describe what is fundamental to a business, not simply what appears as data. Entities should concentrate on areas of significance to the business.

The existing cadastral data models include the subject, the object and the rights associated with them. They follow a classic concept for the cadastral domain within land administration, based on historical arrangements made for land registration, surveying, building and maintaining the cadastre (Wallace & Williamson, 2004). However, to achieve e-LA, the model should also include the ICT based business processes among its subsystems.

Huge efforts to improve land administration are focused in utilization of ICT like the electronic submission and processing of development applications, e-coveyancing, the digital lodgment of survey plans, online access to survey plan information and digital processing of title transactions as a mean of updating the database. A comprehensive e-LA needs to incorporate the requirements of all these processes in all subsystems in the cadastral data model For example, the electronic conveyancing system should be developed in conjunction with the land taxation subsystem and land registry subsystem to ensure that all land transfer requirements are met in one simple process. The tax systems rely on properties not parcels and they have a property identifier that links the title, local government and tax systems. They are interested in property price and land use. The descriptions of vacant land, residential property, industrial property, rural property and commercial property are crucial for many taxation regimes. Only some of that information can be accused from land registry.

An expanded cadastral data model which realises both land taxation and land registry requirements can facilitate the processes within an electronic conveyancing system.

Local governments independently gather data layers, like dog exercise reserves and sites, walking trails, location of recreation clubs like horse riding clubs, as well as open spaces within the local government boundaries. This sort of information is associated with land parcel and property layers which are not found in the digital cadastral database of a country or state.

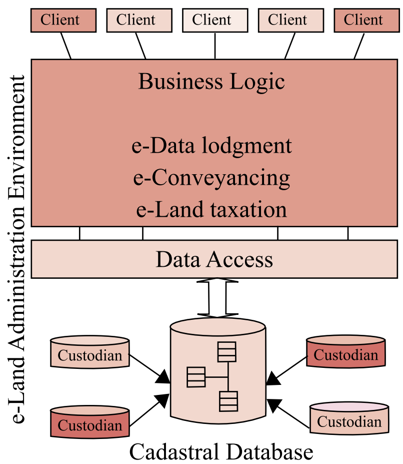


Figure 3: Role of cadastral data modeling in coordination among subsystems

An expanded cadastral data model which realises this kind of large scale and local land information can facilitate data flow among subsystems. It allows easy plug and play between local land information and cadastral database.

To achieve e-LA, cadastral data modelling is a basic step toward efficient service delivery (Figure 3), because data are defined in the context of business processes. It allows every single process in land administration subsystems to directly influence the core cadastre model. The modelling process should recognize the business processes to mirror them in the core cadastral model.

Conclusion

The paper reviewed the functions of land administration subsystems and revealed data flow and process among them. It described an e-LA concept and its goals, including holistic coordination among the subsystems and effective service delivery. It argued that the current cadastral data models are traditional and are based on the historical context of land administration and cadastres which need to be developed to fully realise e-LA. Cadastral data modelling was identified as playing a key role in e-LA especially for data management and coordination among subsystems.

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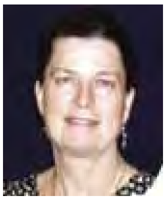

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Malaysia precise geoid (MyGEOID)

The Malaysian geoid project (MyGEOID) is unique where the whole country is covered by with dense airborne gravity with the aim to make the best possible national geoid model

Ahmad Fauzi Nordin, Samad Hj. Abu, Chang Leng Hua & Soeb Nordin

GPS infrastructures that have been established in Malaysia are mainly served as a ground control stations for cadastral and mapping purposes. Another element that has not been utilised is the height component due to its low accuracy. Conventional levelling is still the preferred method by the land surveyors to determine the stations orthometric height (H) with a proven accuracy. Therefore, Department of Survey and Mapping Malaysia (DSMM) has embarked the Airborne Gravity Survey, with one of the objectives is to compute the local precise geoid for Malaysia within centimeter level of accuracy. With the availability of the precise geoid, the "missing" element of GPS system is solved.

The Malaysian geoid project (MyGEOID) is unique where the whole country is covered by with dense airborne gravity, with the aim to make the best possible national geoid model. The basic underlying survey and computation work of the Malaysian geoid project was done by Geodynamics Dept. of the Danish National Survey and Cadastre (KMS; since Jan 1 part of the Danish National Space Center) in cooperation with JUPEM. With the new data the geoid models are expected to be much improved over earlier models (Kadir et al. 1998).

Objectives

The main objective of the Malaysian geoid model (MyGEOID) is to be able to compute orthometric heights H that refer to the national geodetic vertical datum (NGVD). Mathematically, there is a simple relation between the two reference systems (neglecting the deflection of the vertical and the curvature of the plumb line):

$$H = h^{GPS} - N \qquad (1)$$

where, h^{GPS} is the GPS height above the ellipsoid and N the geoid seperation. In the above equation it is important to realize that H refers to a local vertical datum, h^{GPS} refers to a geocentric system (ITRF/WGS84), to which the computed (gravimetric) geoid also usually refers.

In practice, the expression shows the possibility of using GPS leveling technique, knowing the geoidal height N, the orthometric height H can be calculated from ellipsoidal height h. Deriving orthometric height using this technique with certain level of accuracy, could replace conventional spirit leveling and therefore make the levelling procedures cheaper and faster.

The existence of datum bias (differences between geoid and local mean sea level) will not gives satisfactory results if based on the above formula. In order to overcome this problem, fitting the gravimetric geoid onto the local mean sea level (NGVD) will minimize the effect of datum biases.

Gravity data acquisition and processing

Gravity data

The Malaysian airborne gravity survey was done on a 5 km line spacing, covering mostly Sabah and Sarawak in 2002 and Peninsular Malaysia in 2003. The airborne gravity data system used was based on the Danish National Space Center (DNSC)/University of Bergen system, used extensively for Arctic gravity field mapping. The system is based on differential GPS for positioning, velocity and vertical accelerations, with gravity sensed by a modified marine Lacoste and Romberg gravimeter. The system has a general accuracy better than 2 mgal at 5 km resolution.

For the Malaysia airborne survey, the system was installed in a An-38 aircraft (Figure 1, below), and the aircraft turned out to be very suitable for the airborne survey, with accuracies estimated from cross-overs well below 2 mgal r.m.s.

The airborne gravity survey was flown at different elevations, as topographic conditions permitted, see Figure 2 and 3. The data were therefore required to be downward continued to the surface, before applying the Stokes formula gravity to geoid transformation. The downward continuation was done by least-squares collocation using the planar logarithmic covariance model (Forsberg, 1987), using all available gravity

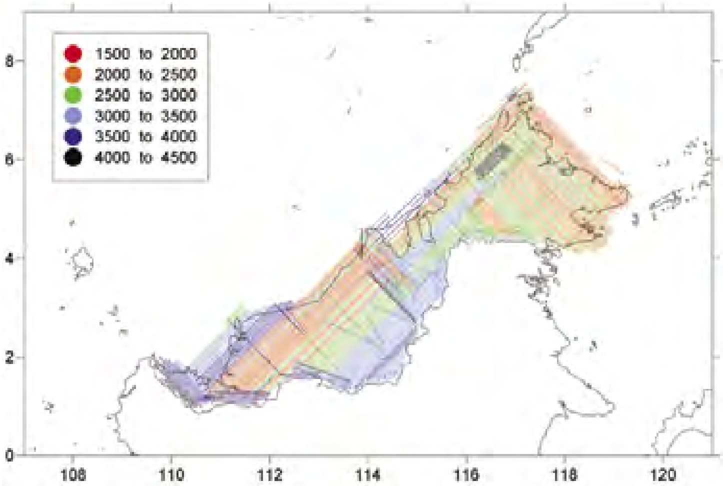


Figure 2: Flight lines in East Malaysia. Colour coding represents flight elevation

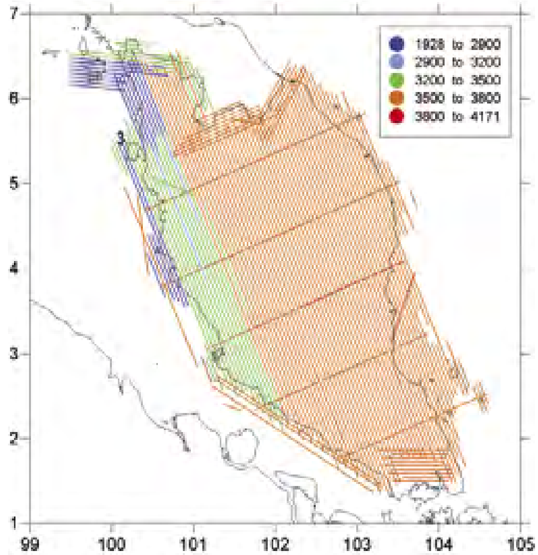


Figure 3: Flight lines in penninsular

data in the process (airborne, surface, marine and satellite altimetry gravity data). The Stokes' integration was implemented by spherical FFT methods (Forsberg and Sideris, 1993).

The existing surface gravity data coverage was only of significance in Peninsular Malaysia (Figure 4). Here the relatively dense surface gravity data coverage in the lowlands will strengthen the geoid compared to the situation in Sabah and Sarawak, where a minimum gravity data was available.

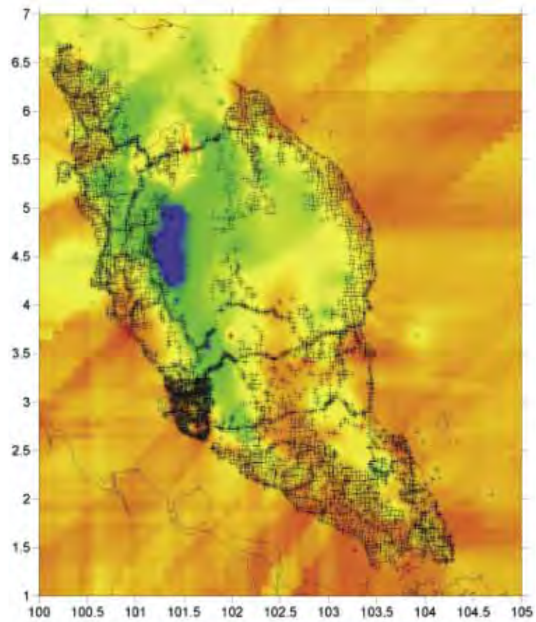


Figure 4: Surface gravity coverage in Penninsular Malaysia (colours indicate anomalies)

Gravimetric GEOID computation

The gravimetric geoid height N is in principle determined by Stokes' equation of physical geodesy, which gives the expression of the geoid height N as an integral of gravity anomalies around the earth (σ)

$$N = \frac{R}{4\pi\gamma}\iint_{\sigma} \Delta g \, S(\psi) \, d\sigma \qquad (2)$$

where Δg is the gravity anomaly, R earth radius, γ normal gravity, and S a complicated function of spherical distance ψ (Heiskanen and Moritz, 1967). In practice global models of the geopotential from analysis of satellite data and global mean gravity anomalies are used, e.g. for the current global model EGM96 (Lemoine et al., 1996)

$$N_{EGM96} = \frac{GM}{R\gamma}\sum_{n=2}^{N}\left(\frac{R}{r}\right)^{n}\sum_{m=0}^{n}(C_{nm}\cos m\lambda + S_{nm}\sin m\lambda)P_{nm}(\sin\varphi) \qquad (3)$$

For the Malaysian project new GRACE satellite data combination models were used (GGM01C). This model is a combination model to degree 180 based on 1° mean anomalies, essentially derived from the same terrestrial data as EGM96, but having superior new satellite information (GGM01S) at the lower harmonic degrees.

A third data source for the geoid determination is digital terrain models (DEM's), which provide details of the gravity field variations in mountainous areas (the mass of the mountains can change the geoid by several 10's of cm locally). The handling of digital terrain models is done by analytical prism integration assuming known rock density (Forsberg, 1984). The new satellite data SRTM was used together with JUPEM DEM's for this purpose.

With the data from spherical harmonic models, local or airborne gravity, and DEM's, the (gravimetric) geoid is constructed by remove-restore techniques as a sum

$$N = N_{EGM} + N_{gravity} + N_{DEM} \qquad (4)$$

Table 1: Gravimetric Geoid Technical Details

Data	WMG03A	EMG03C
Gravity Data	Terrestrial = 5634 points Airborne = 24 855 points	Terrestrial = 691 points Airborne = 37 109 points
Grid Ranges	0° – 8° N 98° – 107° E	0° –9° N 106° – 121° E
Contour Range	-16 meter – 10 meter	28 meter – 60 meter
Grid Interval	1' x 1'	2' x 2'
Altimetry Data	KMS02	KMS02
DEM Model	DTED/SRTM	DTED/SRTM
Terrain Resolution	DTED = 3" SRTM = 30"	DTED = 3" SRTM = 30"
Computation Technique	2-D FFT	2-D FFT
Global Geopotential Model	GGM01C	GGM01C
Reference Frame	ITRF2000 (GDM2000)	ITRF2000(GDM2000)

Figure 5: Final gravimetric geoid for East Malaysia (EMG03A) Contour interval 2 m.

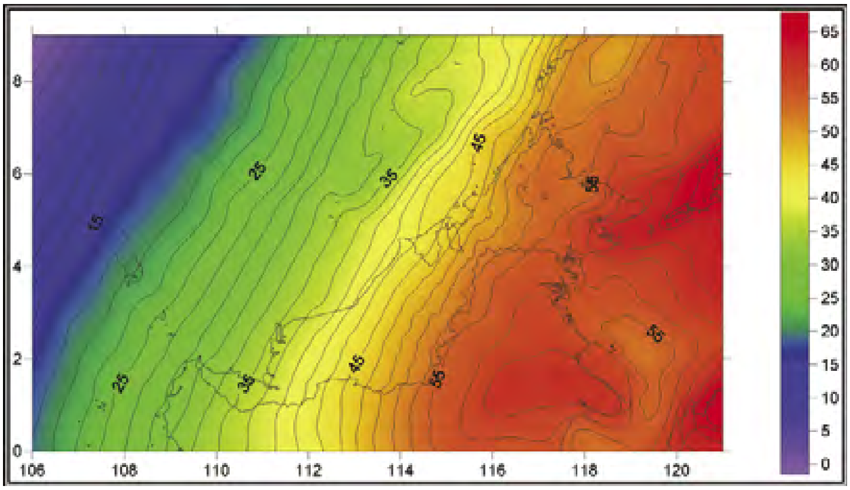
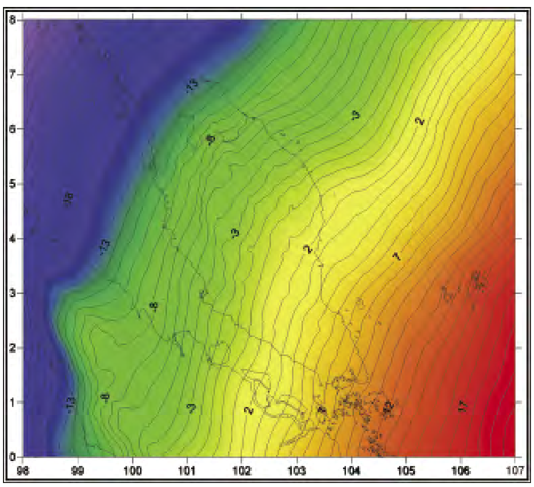


Figure 6: Final gravimetric geoid for Peninsular Malaysia (WMG03C)



Contour interval 1 m.

The summary of gravity data used in the gravimetric geoid computation are tabulated in Table 1 and the computed geoid models for Sabah and Sarawak (EMG03C) as in Figure 5 and Peninsular Geoid model (WMG03A) as in Figure 6.

Fitted GEOID modelling

The existence of datum bias (differences between geoid and local mean sea level) will not gives satisfactory results if based on direct reduction formula (1). In order to overcome this problem, fitting the gravimetric geoid onto the local mean sea level (NGVD) will minimize the effect of datum biases.

GEOID modelling by surface fitting

The most common method in geoid modeling techniques is by fitting a surface on a reference points. In this fitted geoid modelling, the strategy is to fit the gravimetric geoid for Peninsular Malaysia (WMG03A) to the geometric model or sometimes referred to as a "GPS-geoid" (Forsberg 1998).

$$N_{GPS} = h_{GPS} - H_{levelling} \quad (5)$$

However, in a local area, determined geoid model with surface fitting just works in the coverage area of the reference points properly. The model doesn't give reliable results for the extrapolation points. Researches shows that this method gives better results where the geoid have a regular trend and with well distributed and intensive reference points, and it is essential that both levelling and GPS height are as error-free as possible.

The fitting of the gravimetric geoid to GPS-geoid surface is in the grid form and involve modeling the differences:

$$\varepsilon = N_{GPS} - N_{Grav} \quad (6)$$

By adding the correction ε (corrector surface) to the original gravimetric geoid will fit the gravimetric models to the

NGVD. The common fitting models is the 4-parameter Helmert model

$$\varepsilon = N_{GPS\,(i)} - N_{Grav(i)} = \cos\varphi_i \cos\lambda_i a_1 + \cos\varphi_i \sin\lambda_i a_2 + \sin\varphi_i a_3 + R_i a_4 \qquad (7)$$

Where, $N_{GPS(i)}$ and $N_{Grav(i)}$ are the geoidal height at point (i) obtained from gravimetric and GPS-geoid models respectively. a_1 to a_4 are the four unknown parameters, φ_i and λ_i are the latitude and longitude and R is the the residuals geoid error as describe in Heiskanen and Moritz, 1967.

The geoid undulations of interpolation points were determined according to Least Squares Collocation (LSC) method. Collocation is the most general form of the adjustment process which includes least squares adjustment, filtering and prediction (interpolation, extrapolation) steps with in a combined algorithm. In the process the covariance function must be determined for the residuals geoid errors ε' as a function of distance s.

$$C(s) = \mathrm{cov}(\varepsilon', \varepsilon') \qquad (8)$$

In the Gravsoft software package the covariance model of a second order Markov model is used (Forsberg 1998).

$$C(s) = C_0(1 + \alpha s)\, \varepsilon^{-\alpha s} \qquad (9)$$

Where, a is the quantity need to be specified by the user and the C_0 automatically adapted by the data, and the prediction model is:

$$\varepsilon' i = C_{ix}\,[C_{xx} + C_{nn}]^{-1}\, x \qquad (10)$$

Where, x {ε1... εn) is the vector of geoid errors with apriori variance matrix n.

GPS data acquisition, processing and adjustment

Data acquisition

GPS observation on Benchmark project was carried out by DSMM in 2003 and 2004. GPS Observation period for the data sets are between 4 - 9 hours, with the observations divided into three separate network for Peninsular, Sabah and Sarawak. A total of 53 stations have been observed in Peninsular and 133 stations in Sabah and Sarawak. The station breakdowns are tabulated in Table 2, and stations distribution for Peninsular and Sabah and Sarawak as in Figure 7 and 8 respectively.

GPS data procesing and adjustment

Bernese GPS Post Processing Software Version 4.2 has been used to process the whole GPS campaign data for Peninsular and Sabah, and Trimble's Geomatic Office (TGO) Version 1.61 was used for GPS data from Sarawak. The standard processing strategy as employed by DSMM were used with the following parameters for Bernese 4.2:

- Independent Baseline
- IGS Final/Rapid Orbit
- Baseline Wise Solution
- QIF Strategy for Ambiguity Resolution
- 30/60 minutes – Troposphere Estimation

The output from the data processing is the stations coordinates with it respective covariances and the resolved baseline ambiguity is at the level between 60 – 90 %.

The GPS network adjustment was carry out using Geolab adjustment software from Microsearch Corparation for the three independent GPS networks of Peninsular, Sabah and Sarawak. The adjustment of the networks is based on the new Geocentric Datum for Malaysia 2000 (GDM2000) and the standard error modeling and scaling have been adopted. The statistics of the adjustment results are as in Table 3.

Table 2: Station Breakdown for Data Set 1

Station Type	Penninsular	Sabah & Sarawak
MASS Stations	9	8
GPS Station	5	32
SBM or Eccentic/ Benchmark	39	112
Total	**53**	**152**

Figure 7: Station's Distribution for Peninsular Malaysia

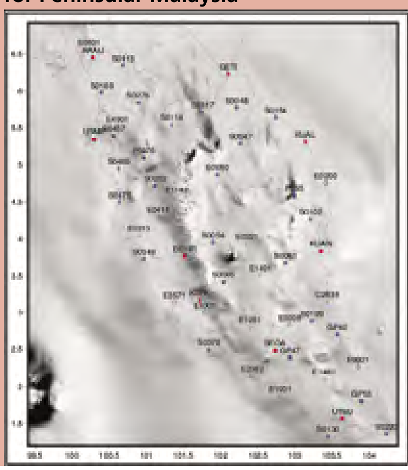


Figure 8: Station's Distribution for Sabah and Sarawak

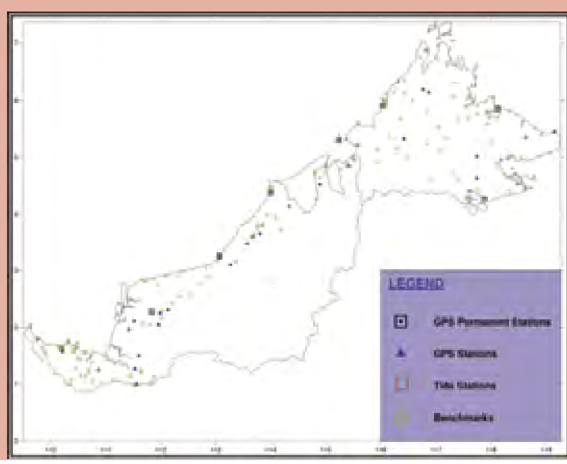


Table 3: Network Adjustment Statistics

No.	Parameter	Peninsular	Sabah	Sarawak
1.	No of Stations		57	95
2.	No of Parameters		156	249
3.	No of Observations		351	2038
4.	Degree of Freedom		195	789
5.	Chi-Square Test	Passed	Passed	Passed
6.	Flag Residuals (Pope's Tau)	No	No	No
7.	2D Error Ellipses (95%)	0.009–0.020 m	0.011–0.024 m	0.009–0.046 m
8.	1D Error Ellipses (95%)	0.010–0.027 m	0.017–0.050 m	0.015–0.121 m
9.	Relative 2D Error Ellipses (95%)	0.009–0.017 m	0.005–0.025 m	0.010–0.046 m
10.	Relative 1D Error Ellipses (95%)	0.009–0.028 m	0.014 – 0.054 m	0.019 – 0.121 m
11.	Baseline Precision	0.10–0.65 ppm	0.20-3.20 ppm	0.30–13.52 ppm

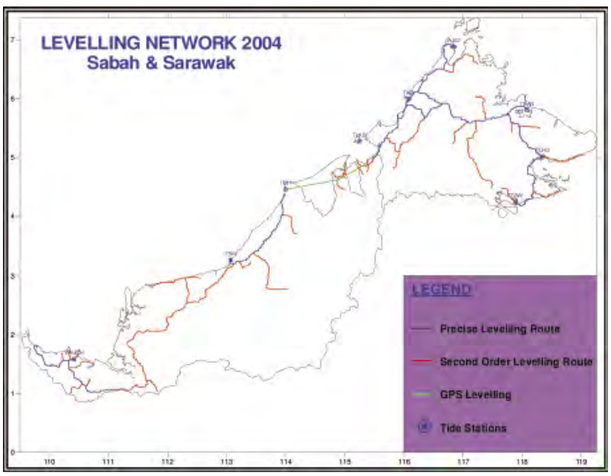
Levelling network

The vertical control in Peninsular Malaysia, Sabah and Sarawak was constructed separately. The new height datum for Peninsular Malaysia was determined in 1994 based on the mean sea level (MSL) value from the tide gauge in Port Klang after more than 10 years of observation (1984-1993). The height was transferred from Port Klang using precise levelling to a Height Monument in Kuala Lumpur by 3 different precise levelling routes.

In Sarawak, there are six vertical datums known as Pulau Lakei Datum, Original Datum, Bintulu Datum, Merapok Datum, Limbang Datum and Sabah Datum. Pulau Lakei Datum and Original Datum are based on MSL 1955 and MSL 1935 respectively. Meanwhile, Bintulu Datum and Merapok Datum are based on triangulation station network heights which are connected to Pulau Lakei Datum and Original Datum. Limbang Datum is referred to a year of tidal observation at Limbang Jetty and Sabah Datum refers to one month tidal observation at Sipitang in 1949. As for Sabah, beginning 1997, all levelling network that has been run by DSMM refers to MSL in Kota Kinabalu based on 10 years of tidal observation (1987-1997).

Figure 9: Precise Levelling Network (Peninsular)

Figure 10: Precise Levelling Network (Sabah and Sarawak)



The leveling network in Sabah and Sarawak has recently unified by adopting the MSL value from Kota Kinabalu Tide Stations.

Fitted GEOID modelling

Peninsular malaysia (WM Geoid04)

A total of 39 Benchmark observed with GPS have been used in the computation of Peninsular Malaysia fitted geoid model. The computation was done iteratively, and the results in every iteration, closely examined in every iteration.

Figure 11, shows the corrector surface range between 0.95 – 1.60 m, with two stations namely S0220 (minimum Diff.) and E1142 (maximum Diff.) shows the bull-eyes characteristic. Investigation on the suspected stations show that E1142 located on the highland (Cameron Highland) and S0220 is at the tip of Peninsular Malaysia (Sungai Rengit). Both SBM connected using precise leveling survey but not in the form of leveling loop (hanging line). The levelling lines are also not in the main adjustment of the Peninsular Malaysia Precise Levelling Network.

In the second iteration, S0220 and E1142 were excluded from the process, and the results show an improvement with the corrector surface is well distributed (Figure 12). The corrector surface range is between 1.14 – 1.44 meter with the formal standard error is 0.020 m in the least square collocation adjustment.

Sabah and Sarawak (EMGeoid05)

In Sabah and Sarawak, 60 out of 71 benchmarks with MSL values were used in the fitted geoid model computation. Six

Figure 11: Corrector Surface plotted from Iteration-1 results

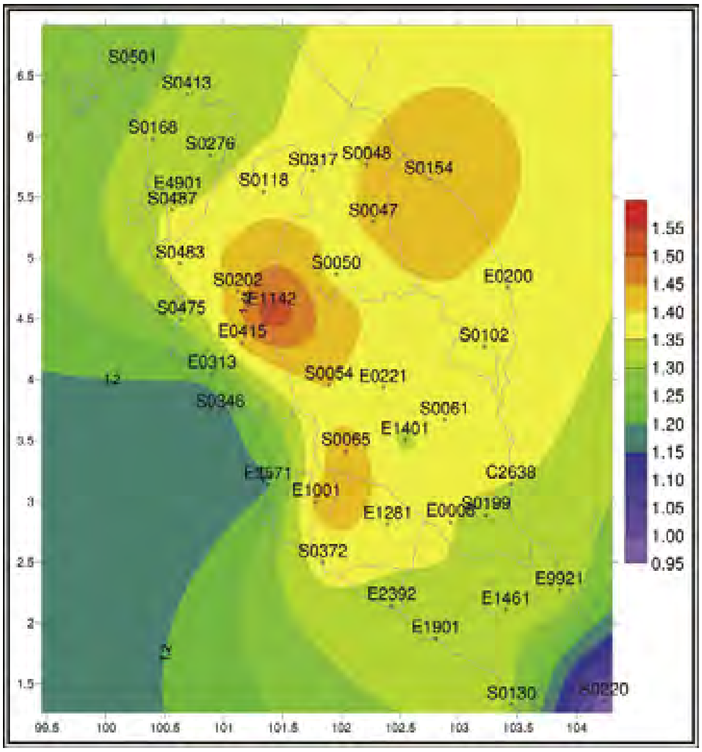
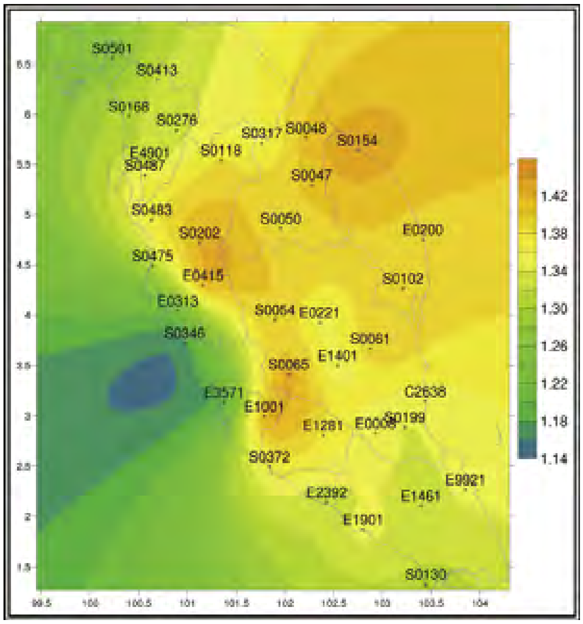


Figure 12: Corrector Surface plotted from Iteration-2 results



iterations have been carried out with eleven benchmarks excluded before the final fitted geoid model finalized.

Figure 13 shows the corrector surface that range between 0.55 – 1.75 meter from the first iteration. The plot clearly shows the "bull-eyes" that represent the existent of outliers in one of the input component. In the subsequent LSC adjustment, benchmarks which suspected as outliers removed. The final 6th iteration with 60s benchmarks yield the formal error of 0.029 meter with corrector surface range between 1.10 – 1.45 meter.

Quality assessment

In order to have more realistic assessment of the WMgeoid04 model, comparison using three independent data sets has been carried out.

Basic Formula:

$$H_{WMGeoid04} = h_{gps} - N_{WMGeoid04} \quad (11)$$

$$\delta H = H_{WMGeoid04} - H_{Levelling} \quad (12)$$

Where,

$H_{Wgeoid04}$: Orthometric Height Derived from GPS and Fitted Geoid Model

h_{gps} : Ellipsoidal Height

$N_{Wgeoid04}$: Geoid Height from Fitted Geoid Model

H_{NGVD} : Published Levelling Height

δH : Height Difference Table 4: Comparison Statistics

Evaluation of WMGeoid04 fitted geoid models using independent data sets show that the accuracy is 0.033 meter based on the following formula.

$$\sigma^2 = (\sigma^2 I + \sigma^2 II + \sigma^2 III)/n \quad (13)$$

This value is more realistic when compare to the formal error of 0.020 m from the LSC adjustment.
From a total of 115 benchmarks that have been evaluated (Data 1, II and III), only 13 benchmarks (11.3%) were found to be an outliers.

For EMGeoid05, only one set of independent data are available with achievable accuracy of 0.042 meter.

Figure 13: Corrector Surface plotted from Iteration-1 results

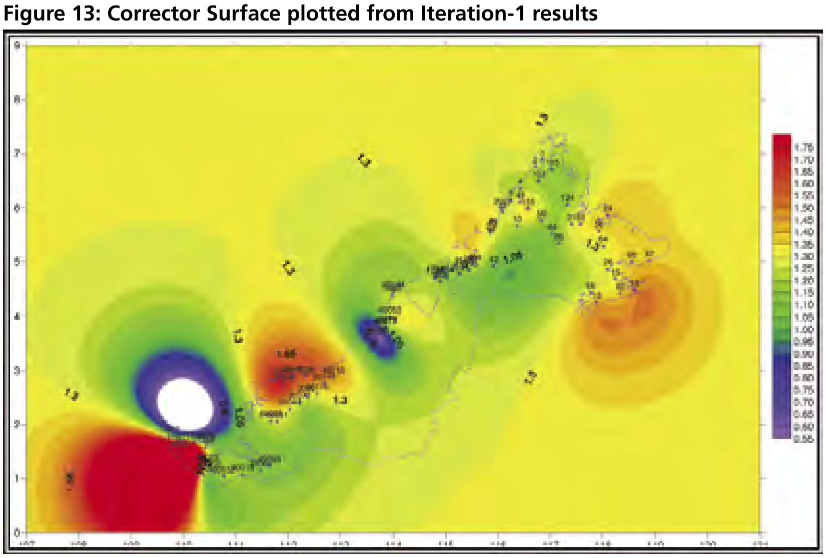


Table 4: Comparison Statistics for WMGeoid04

No.	Parameter	Data I	Data II	Data III
1.	No of Stations	35	44	36
2.	No of Rejected Stations	2	7	4
3.	% of Rejected Stations	5.7 %	15.9 %	11.1%
4.	RMS of Diff.	0.042 m	0.042 m	0.038 m

Figure 14: Corrector Surface plotted from iteration-6 results

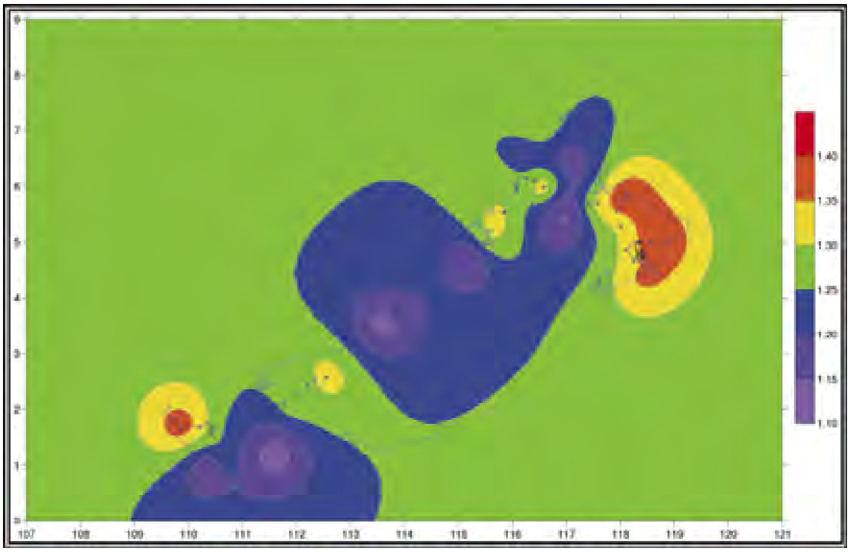


Table 5: Comparison Statistics for EMGeoid05

No.	Parameter	Data I
1.	No of Stations	25
2.	No of Rejected Stations	11
3.	% of Rejected Stations	44 %
4.	RMS of Diff.	0.042 m

Conclusions

The Malaysian gravimetric geoid is apparent accurate to few cm r.m.s, with larger errors closer to the international borders (Forsberg, 2005). The geoid is fitted to GPS-levelling information, and any errors in HLevelling and hGps, will directly affect the high quality of the gravimetric geoid; in other cases it will help control longer wavelength errors. The balance between fit of GPS, and errors in geoid and GPS, is delicate, and undoubtedly there will be many regions in the present geoid where GPS users can expect problems due to fitting of GPS-levelling data with errors.

Based on the statistical analyses, it can be concluded that the accuracy of fitted geoid models of WMGeoid04 and EMGeoid05 is 0.033 and 0.042 meter respectively, and can be used for height determination. To achieved certain level of accuracy in determination of orthometric height (H), accuracy of observed GPS network has to be better than 1 ppm (relatively) and the vertical errors (95% Conf. Region) have to be less than 3 cm.

Real Time Kinematic (RTK) survey and MyRTKnet service provided by DSMM with 3 cm level of accuracy can make use of the models for engineering survey, rapid height monitoring and establishing levelling route.

Recommendation

Fitted geoid model WMGeoid04 and EMGeoid05 is the product of GPS on Benchmark observation. In order to improve the results and to achieve 1 cm geoid, the recommendations listed below need further considerations:-

i. New GPS observation on Standard Benchmark (SBM) to densify current GPS Levelling Network, with the distribution between ≈ 10 km nations wide.

ii. The existing Precise Levelling Network based on spirit levelling carried out from 1985 to 1995. The levelling networks need to be carefully analyzed, and possibility of carry out a new adjustment including analysis of subsidence and land uplift.

iii. Resurvey by levelling and GPS of selected, suspected erroneous points with large geoid outliers.

iv. If long GPS observation is needed, GPS processing software must be capable of producing the solution with the statistic and to model the troposphere with the adequate parameters.

v. Make a new GPS-fitted version of the gravimetric geoid as new batches of GPS-levelling data become available, and as GPS users report problem regions for heights.

vi. GPS levelling technique need the antenna height measure correctly. The use of stable Bipod with fixed antenna height will minimize the error especially with the shorter baselines.

vii. Levelling route is always following the federal and states road, hence, the BMs are established along the roadside, which the clearance of 15° is difficult to get. To overcome this situation, the use of stable Bipod with more than 2 meter will certainly solve the problems and also minimize the disturbance of vehicle passing by.

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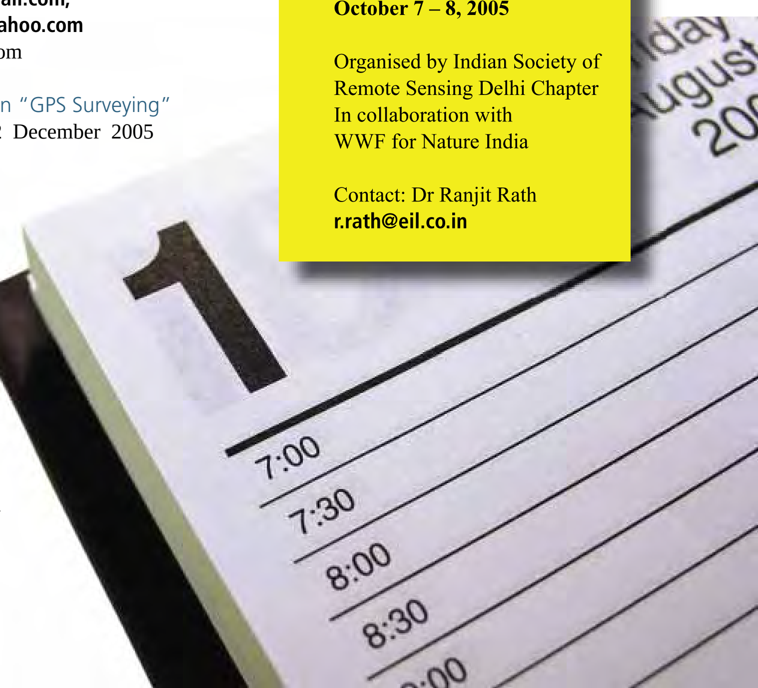

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