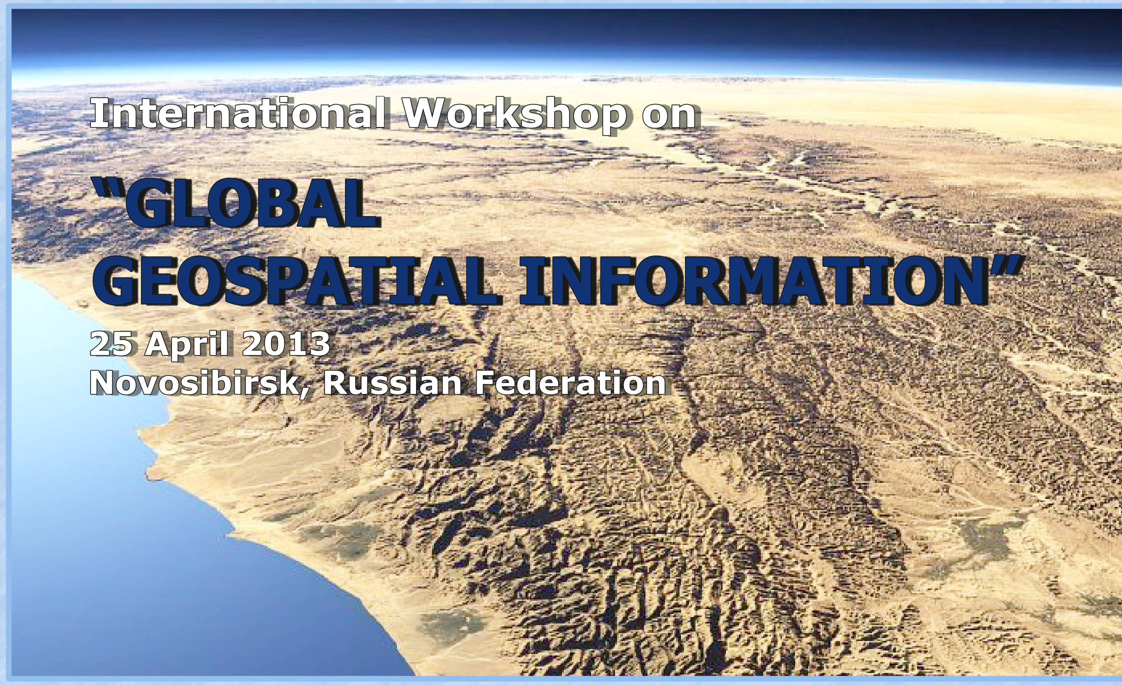
INTERNATIONAL SOCIETY
FOR PHOTOGRAMMETRY
AND REMOTE SENSING (ISPRS)

SIBERIAN STATE ACADEMY
OF GEODESY (SSGA)



International Workshop on

"GLOBAL GEOSPATIAL INFORMATION"

25 April 2013
Novosibirsk, Russian Federation

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"SIBERIAN STATE ACADEMY OF GEODESY"
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The workshop confirmed growing interest in the issues of mapping which have gained importance for the national and global management of resources and for sustainable development with increasing emphasis on environmental issues. The current status of topographic mapping and data base updating in the world were discussed.

The proceedings are meant for professionals, surveying and mapping agencies, services, other institutions, and the private sector, including both the status of technological and legal issues pertaining to geospatial data.

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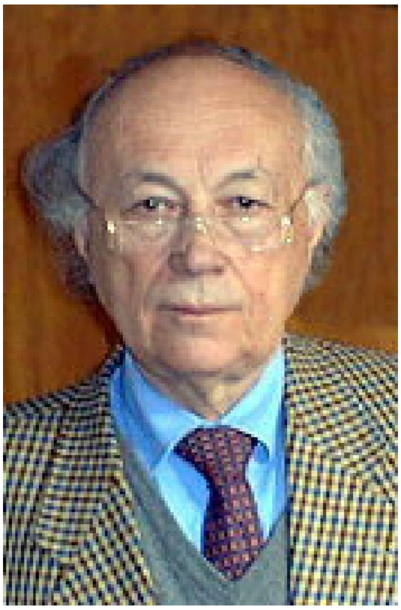
INTRODUCTION TO THE WORKSHOP OF ISPRS WG IV-2: "GLOBAL GEOSPATIAL INFORMATION'



We meet at the 80th Anniversary of the Siberian State Academy of Geodesy and the Interexpo Geo Siberia 2013 for the first meeting of our Working Group. The Working Group was initiated by the Activities of the United Nations Secretariat in New York since the 1960´s. It has put he topic of "Status of Mapping of the World" onto the agenda of the UN Cartographic Conferences for Asia and the Pacific and for the Americas since the 1970´s and it has passed resolutions to continue efforts to determine the status.

Since that time ISPRS has actively cooperated with the UN Secretariat on that topic, when Arthur Brandenberger of Laval University, Quebec has compiled a joint UN publication.

When the UN Secretariat has transformed its globalized efforts influenced by the rapid IT development into UNGGIM, created in 2009, it became clear that ISPRS with its long term concerns for mapping would relaunch a joint initiative with UNGGIM on the topic. There are of course other NGO´s joined together in JB-GIS with an interest in the topic, which ISPRS wants to carry forward, but not to monopolize. Therefore it welcomes contributions by JB-GIS members and by members of the industrial community, such as the global activities of "Geospatial".
Basic Mapping has always been the concern of governmental activities. The United Nations have a direct link to the governments of the globe, even though it can pass only recommendations and not directives and laws to them, which are the task of governments.

Like the NGO´s also the United Nations depend upon cooperation between its members. In this sense it makes sense to join efforts.
ISPRS has identified the necessity to make the issue of the status of mapping and map updating a sustainable one. Therefore it has established a working Group to make this a task to be sustained in future years by the networks established by NGO´s.

In this sense we hope that this first working group meeting can lay a foundation for cooperation on the topic of geospatial information.

Em. Prof. Gottfried Konecny
Co-Chair of the Working Group

THE INTERNATIONAL SOCIETY FOR PHOTOGRAMMETRY AND REMOTE SENSING (ISPRS) STUDY ON THE STATUS OF MAPPING IN THE WORLD

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ISPRS WG IV/2

KEY WORDS: Mapping Status, Topographic Mapping, Map Updating

Abstract:
Within the UN Secretariat and the ISPRS Community there has been a long-time interest to document the current status of basic mapping and its updating in the world. The early attempts for the UN Cartographic Conferences in the 1960´s, 1970´s and 1980´have not been followed up due to lack of resources. After the creation of UNGGIM by UN ECOSOC in 2009 a new attempt to continue this has been launched under the initiative of ISPRS. A joint questionnaire was designed between ISPRS and UNGGIM, and the GGIM Secretariat has mailed it to the UN member States. 91 answers have been received. These are analysed in the paper, subject to verification. An ISPRS Working Group has been created to assure sustainability of the effort.

I. Introduction

1. In 1968, 1974, 1980 and 1987 the UN Secretariat has completed studies on the status of world topographic mapping. Topographic maps at that time constituted the basis for reliable geospatial information, as they do up until today.

   Topographic maps were and are principally compiled by activities of the governmental national mapping agencies (NMA's). Representatives of these agencies of the UN member countries have regularly exchanged views on the status of mapping at the UN Regional Cartographic Conferences for Asia and the Pacific and for the Americas.

   The issues of mapping have gained importance for the national and global management of resources and for sustainable development with increasing emphasis on environmental issues.

   The last summary on the status of mapping has been published by the United Nations in their publication "World Cartography" in volume XX, published in 1990 (ST/TCD/14). It reflected the status of topographic mapping surveys up until the year 1986. As of 1980 the scope of mapping also began to include cadastral mapping, as a basis for land management issues.

   The results of the published study for topographic mapping coverage of the land area of the world resulted in the following summary:

scale/range	1:25 000	1:50 000	1:100 000	1:200 000
Africa	2,9 %	41,4 %	21,7 %	89,1 %
Asia	15,2 %	84 %	56,4 %	100 %
Australia and	18,3 %	24,3 %	54,4 %	100 %
Oceania	86,9 %	96,2 %	87,5 %	90,9 %
Europe	100 %	100 %	100 %	100 %
Former USSR	54,1 %	77,7 %	37,3 %	99,2 %
North America	7 %	33 %	57,9 %	84,4 %
South America				
World	33,5 %	65,6 %	55,7 %	95,1 %

The survey also revealed that not only the coverage of maps was an important factor, but also the update rates of the topographic map. These were in summary:

scale/range	1:25 000	1:50 000	1:100 000	1:200 000
Africa	1,7 %	2,2 %	3,6 %	1,4 %
Asia	4,0 %	2,7 %	0 %	1,9 %
Australia and	0 %	0,8 %	0 %	0,3 %
Oceania	6,6 %	5,7 %	7,0 %	7,5 %
Europe	0 %	0 %	0 %	0 %
Former USSR	4,0 %	2,7 %	0 %	6,5 %
North America	0 %	0,1 %	0 %	0,3 %
South America				
World	5,0 %	2,3 %	0,7 %	3,7 %

Since the last publication of the data on the status of mapping there have been highly effective technology improvements in IT in sensor technology and in the availability of satellite platforms.

Foreseeing these UN Cartographic Conferences have passed a number of resolutions to update the effort on the status of mapping within existing resources.

2. The Ninth UNRCC for the Americas in New York 2009 in its resolution 3/IX has tasked the UN to prepare a study on the status of mapping in the world by study to be directed to the national geospatial information authorities in the world.

   In this context the International Society for Photogrammetry and Remote Sensing ISPRS has offered technical support to the GGIM Secretariat.

3. In preparation for this survey by the UNGGIM Secretariat a questionnaire was jointly designed, which was sent out to the geospatial information authorities on April 27, 2012.

II. Design of the Questionnaire

4. The questionnaire was designed to give answers, not only on the progress in area coverage of mapping during the last 26 years, and the status of up-to-dateness of the maps, but also on the status of introducing new technology and expanded tests in the different countries, characterizing the existing national infrastructure for mapping.

   Altogether 27 questions were formulated as multiple choice questions:

   A) **National Topographic Mapping Coverage**: 7 questions

   1) the scales of mapping in use in 8 categories (1:1000, 1:5000, 1:25 000, 1:50 000, 1:100 000, 1:250 000, 1:500 000, 1:1 000 000 or similar) and coverage of the data in km^2 or in % of the national area

   2) the age of map data

   3) restrictions imposed on the availability of maps

   4) maps for sale or for free

   5) procedure of map updates by map sheet or by features

   6) methodology for updating (field surveys, photogrammetry, satellite imagery, third party data, crowd sourcing)

   7) inhouse or outsourcing operations

   B) **National Imagery Acquisition** (7 questions):

   8) is there a national aerial photography program flown at regular intervals; are domestic services used; is the imagery analog or digital

   9) is there a national satellite imagery acquisition program providing images at regular intervals; are these domestic sources

   10) use of radar or lidar sensors

   11) is Lidar used for DEM's and at which resolution

   12) are orthophotos produced and at which scale

   13) is there a national DEM

14) is there the intention or use of 3D information for urban and rural landscape models

C) **National surveying and Cadastral Coverage** (8 questions)

15) are there licensed surveyors

16) is there a national cadastral map coverage and is the NMA responsible for cadastral mapping

17) what is the use of cadastral maps (titles, tax)

18) are cadastral maps based on geodetic control

19) are property boundaries monumented in the field

20) updating methodology of property maps

21) number of employees or private surveyors engaged in cadastral operations

D) **Organisation** (6 questions)

22) is topographic mapping nationally funded

23) annual budget

24) number of staff (total and technical) in NMA

25) legal or regulatory mandate of NMA

26) products in % supplied as
- hard copy maps
- digital data
- online downloads
- web services

27) archival practices

5. The questionnaire is intended to provide an overview of the current status of mapping the world with characteristic questions relating to the use of new technology for mapping and the cadastre including institutional arrangements on a national level.

III. Status of the Responses

6. After the mailing of the questionnaire on April 27, 2012 altogether 91 responses have been received to date. This is a favourable response. A follow-up process is continuing from the GGIM Secretariat with the help of regional committees.

   ISPRS has also addressed their national member organisations to solicit further official responses by personal contacts.

7. ISPRS has initiated the analysis of the responses. A MS-Access database has been developed by Mr. Uwe Breitkopf of the Institute for Photogrammetry and Geoinformation of Leibniz University, Hannover to systematically analyse the replies to the 27 questions in a simplified manner. The database is now usable for the analysis of the responses and is easily expandable and is available to GGIM.

8. The database principally needs to include information on all 193 UN member countries and on all non-UN member regions, bringing the total of areas to be included to over 200.

9. Some information on these over 200 regions can be obtained from international map vendors. The Institute of Photogrammetry and Geoinformation of Leibniz University Hannover has used the web published database of Eastview Geospatial to arrive at an estimate of the map coverages and the update status of the entire globe.

10. The results obtained so far need verification by additional correspondence.

11. To make the effort sustainable, ISPRS has established an international Working Group (WG IV-2 "Status of Geospatial Data Bases") within its Commission IV (Geospatial Data Bases) for the 2012 – 2016 Congress Period.

12. The first meeting of the Working Group will take place during Interexpo GEO-Siberia in Novosibirsk, Russian Federation, from April 24 to 26, 2013, organized by the Siberian State Academy of Geodesy.

13. With respect to the UNGGIM effort the results of the 2012 survey a publication is intended by July 2013.

14. The verified results are also to be presented to the GGIM Meeting of Experts on Global Geospatial Information Management in Cambridge, July 24 – 26, 2013.

IV. Replies

15. 91 replies were received from 90 U.N. member countries plus 1 from Northern Ireland.

16. European replies (36) were nearly complete, except for Russia, Belarus and Montenegro (3). Small countries, such as San Marino, Liechtenstein or Monaco, which do not have own mapping administrations, were not included in the survey.

17. From the Americas the survey also returned good results (15), except for Argentina, Paraguay, Bolivia, Venezuela, Guyana, Suriname, Cuba, the Dominican Republic, the Caribbean Islands and the Bahamas.

18. Africa is partly covered (20). Missing are Angola, both Congos, Gabun, Nigeria, both Sudans, Libya, Kenya, Djibouti, Tanzania, Somalia, Eritrea, Malawi, Mozambique, Zimbabwe, Swaziland, Lesotho, Benin, Liberia, Sierra Leone, Gambia, Western Sahara, Mali, Chad, Equatorial Africa

19. In the Pacific (3) most of the Island States are missing, as well as Antarctica.

20. The biggest gap of responses is from Asia (15) : The Arab States, Central Asia, Afghanistan, Pakistan, India, Bangladesh, Myanmar, Thailand, Indonesia, Timor Leste, North Korea.

21. The replies cover only about 50% of the land areas of the globe.

22. Also not covered are bathymetry and hydrography of the ocean areas, which cover about 2/3 of the globe.

V. Results of the Analysis to date

23. For the 91 countries and regions, which have replied, the analysis of the results by the Questions asked is as follows:

A) National Topographic Mapping Coverage

Question 1) Extent of existing Geodata or Map Coverage at various scale ranges

Most NMA's have only listed their coverages for the scales, for which they are responsible. No mention was made in some responses of the large scale coverage of urban areas under responsibility of the municipalities. This still needs to be locally verified.

Some NMA's have provided graphical indexes of their map coverage, and some have even indicated the last update of the maps, but the supplied data were inconclusive with respect to the data coverage in km^2 or in % of the national area.

Some NMA's have listed links to their web-sites. Most of these are in their national languages. Again it is very difficult to extract the desired information.

Nevertheless, a map was derived to show the available largest scale coverages of the counties, which have replied. See Fig.1 to Fig.4 for the scale ranges 1:25 000, 1:50 000, 1:100 000 and 1:250 000 with the percentage of coverage for each country, if available.

Since some countries did not submit the information with sufficient clarity or did not respond at all, another approach had to be taken for those areas. The Eastview Geospatial database for ordering international maps has been analyzed to derive an estimate of the map coverage at different scale ranges for the land areas of the globe. A distinction has been made in 3 categories: Fig.5 shows the coverages of maps at the largest available scale for maps produced by the country itself.

It is no secret that countries, which have or had global security concerns, did their own mapping of the globe. These were done by the US Defence Agencies and the Defence Agencies of the former Soviet Union. Their maps are now for sale by Eastview. Fig.6 shows the coverages at the largest available scale produced by the USA and Fig. 7 produced by the Russian Agencies.

Question 2) Current Age of Existing Geodata

Fig. 8 shows the average age of the largest map coverage for a country having given a report. Moreover, the Eastview database contains the dates of issues of the listed geodata and maps listed for a country or region not having submitted a report. This permits to assess the actuality of the available global map content at the largest available scale shown in Fig. 9.

Question 3) Restrictions on Map Data Distribution

In most countries the maps are freely accessible without restrictions (68 countries). Only 22 countries (out of the 90) have restrictions on maps for the public. (See Fig. 10)

Question 4) Sale of Maps

In most countries map data are for sale in analog and digital form. 39 countries have web distribution facilities and 51 have not. (See Fig. 11). Generally only small scale overview maps are available through the web.
In 77 countries maps in various forms are offered for sale. Only in 5 countries they are offered at no cost. (See Fig. 12)

Question 5) Updating Strategy

72 countries out of 90 update their maps. 15 countries do not have updating programs. 46 countries carry out updating by map sheets and 29 by features.

Question 6) Updating Methodology

The methodology of updating in 35 countries is by photogrammetry supported by field surveys in large and medium scales and from satellite images supported by field surveys and aerial imagery at small scales. 23 countries list a combination of photogrammetry and field surveys. 2 countries list field surveys only, 7 aerial images only and 3 satellite images only. 9 countries utilize crowd sourcing combined with other methods.

Question 7) Inhouse Capabilities of NMA´s

50 NMA's have inhouse mapping operations, 13 practice outsourcing and 27 have both. (See Fig.13)

B) National Imagery Acquisition

Question 8) National Aerial Imagery Program

55 countries have a national aerial photography program, 33 do not. 50 countries use digital imagery only, 10 use traditional analog imagery only and 23 utilize both types.
7 countries have no own facilities. (See Fig.14)

Question 9) Satellite Imagery Uses by NMA

74 NMA´s use satellite imagery for mapping. 17 countries do not.

Question 10) Use of Radar or Lidar

Radar imagery is used in cloud prevalent countries, and Lidar in most developed countries. Developing countries have not introduced this technology. Altogether 46 countries use radar or lidar sensors, 44 do not. (See Fig.15)

Question 11) Lidar DEM

Lidar is used for DEMS mainly in the developed world. 46 countries use it for DEM Generation.

Question 12) Orthophoto Program

Orthophoto technology is generally used in 82 countries to bridge the time gap for map updates. Only 8 countries do not use it. (See Fig.16)

Question 13) Interest in 3D technology by NMA

45 country NMA´s are interested in 3D modelling information for viewing urban landscapes, 45 are not. (See Fig.17)

Question 14) National DEM

National DEM's are established in 64 countries, in 26 countries not.

C) National surveying and cadastral coverage

Question 15) Licensed Surveyors

75 countries have licensed surveyors for property surveys, 15 have not. (See Fig.18)

Question 16) Responsibility for Cadastral Mapping and Cadastral Map Coverage

A national cadastral map coverage is available in 17 countries, but not in 29 countries.

Only 41 NMA´s have the responsibility for the real estate cadastre. 49 have not. (See Fig.19)

Question 17) Use of Cadastral Maps

The use of cadastral maps is generally for securing titles (45), for taxation (39), for land registration (50), for conveyancing (36) and for other reasons (17).

Question 18) Cadastral Maps and Geodetic Control

In 77 countries cadastral maps are based on geodetic control, in 13 not.

Question 19) Monumentation of Property Boundaries

In the majority of countries (65) property boundaries are monumented in the field, in 24 countries they are not. (See Fig.20)

Question 20) Updating of Cadastral Maps

Updating of property maps in 68 countries is done by transaction procedures, in 22 countries this is not linked to transactions.

Question 21) Number of Cadastral Employees

The number of employees or private surveyors engaged in cadastral operations is usually much larger than the personnel engaged in topographic surveys.

D) Organisation

Question 22) National Funding for Mapping

Topographic mapping is nationally funded in 80 countries, in 10 not.

Question 23) Mapping Budget

Some countries list their budget and this is proof that mapping is a very substantial highly regarded operation.

Question 24) NMA staff

The number of staff engaged in mapping in the developed countries exceeds the number of staff in the developing countries.

Question 25) Legal Status of Mapping

In most countries (77) NMA's have legal or regulatory status, in 11 countries they have not.

Question 26) Form of Map Products Supplied

Even in developing countries the supply of digital map data exceeds that of analog products. Online and web delivery of map data is generally only available in developed countries. 56 countries list hard copy maps as possible output, 55 digital media, 31 downloads and 29 the web.

Question 27) Archival of Geodata

All countries care about archiving their map data in analog or digital form. 37 list servers, 53 do not. They use more conservative media. (See Fig.21)

VI. Discussion

24. Another access database has been created by ISPRS to compare the results of the current 2012 GGIM study data with the data of 1986 published in World Cartography XX, 1990.

To compare the country data between 1986 and 2012 it is necessary to relate the areas of the countries of the world to the current status, as some countries have merged (e.g. Yemen) and some have split (Sudan – South Sudan, Serbia –

Kosovo). This is no problem, if the data for mapping coverage are available for each scale at a km^2 basis.

25. The UNRCC Resolution 3/IX of E/Conf 99/3 New York 2009 recommended that the study should take into consideration official national mapping agencies, other institutions, and the private sector, including both the status of technological and legal issues pertaining to geospatial data.

26. In this regard ISPRS has established contacts to the following private sector institutions, in the hope that they will communicate for the purpose of the study their acquired imagery and mapping coverages:
    - Google Earth and Google Maps (imagery and maps)
    - Microsoft Bingmaps (imagery and maps)
    - TomTom (road features)
    - Navteq (road features)

27. ISPRS has also established contacts to the commercial map providers
    - Eastview Geospatial, Minneapolis, Mn., USA
    - ILH Stuttgart, Germany

    These companies provide internationally available maps for sale including map indexes which can help to verify the information obtained in the surveys and permit to supplement missing data.

28. The questionnaire survey conducted by the GGIM Secretariat has not only provided the requested data, but the questionnaires have also identified discussion partners, with whom it will be possible to clarify the desired information, so far missing and to verify mutual misunderstandings in answering and evaluating the responses. This task is to be undertaken next before a next version is to be presented to the UNGGIM Expert Meeting in Cambridge, England in July 2013.

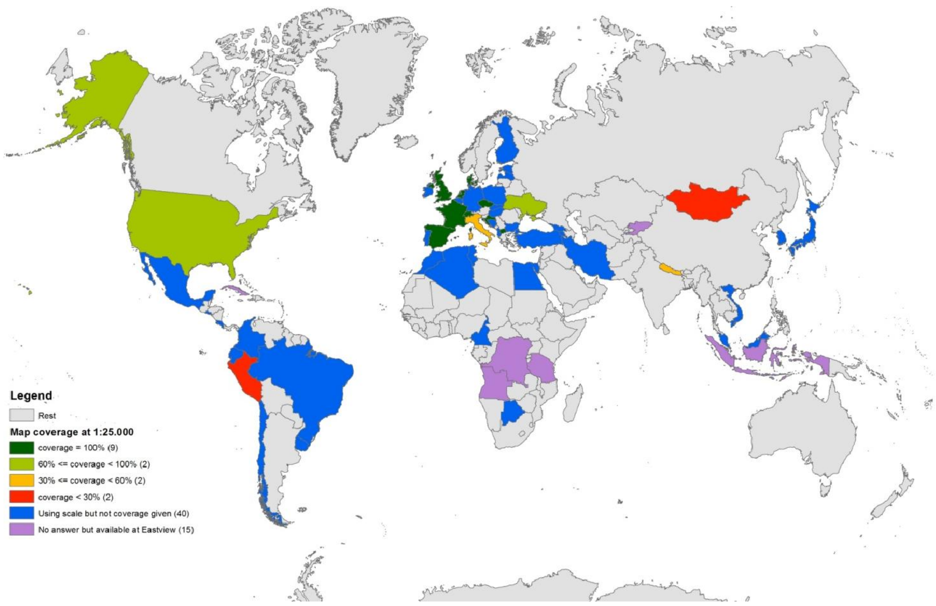

Fig. 1 Coverage 1:25 000 maps with percentages

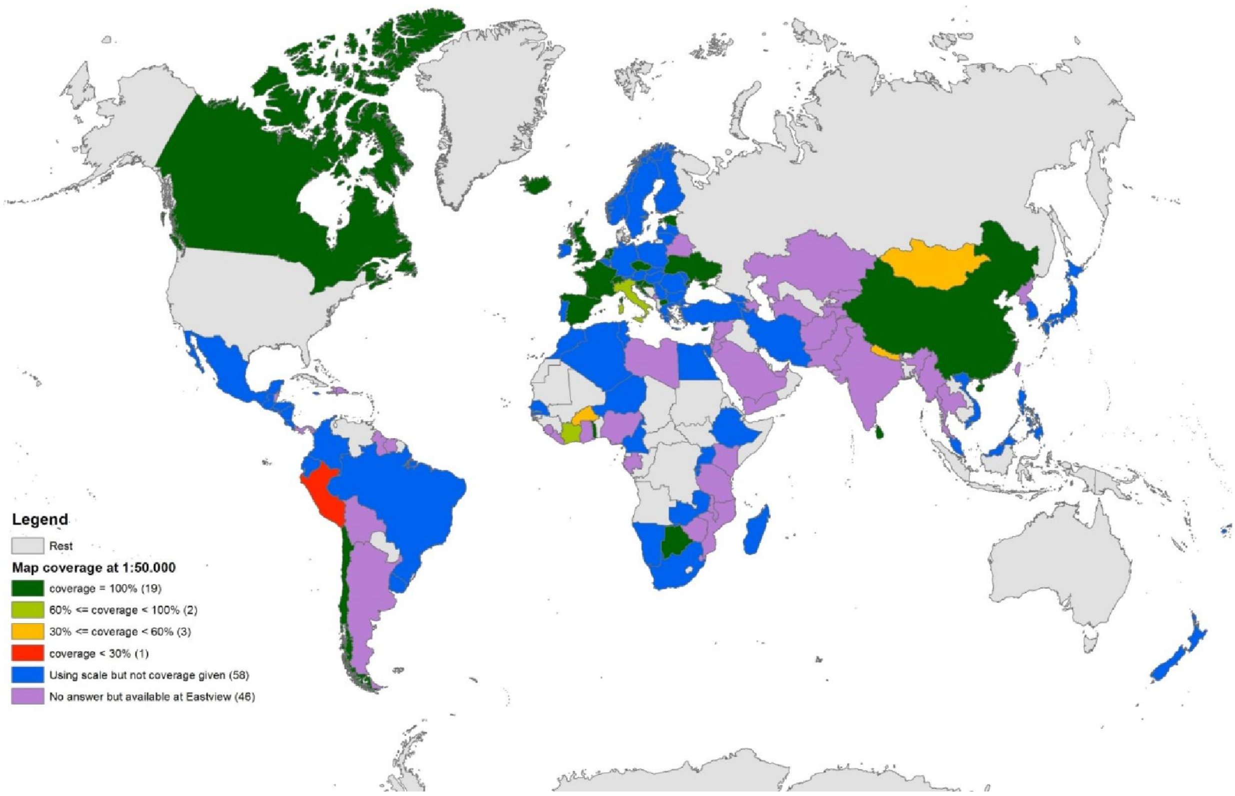

Fig. 2 Coverage 1:50 000 maps with percentages

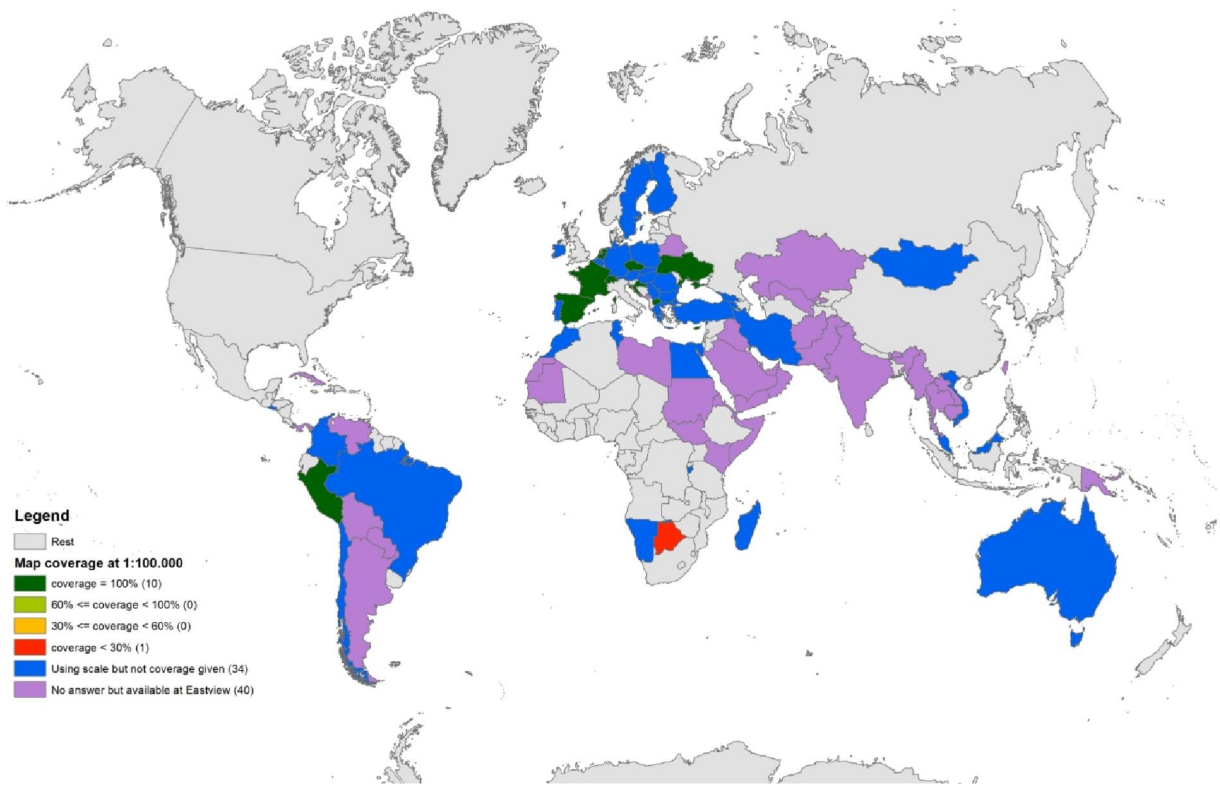

Fig. 3 Coverage 1:100 000 with percentages

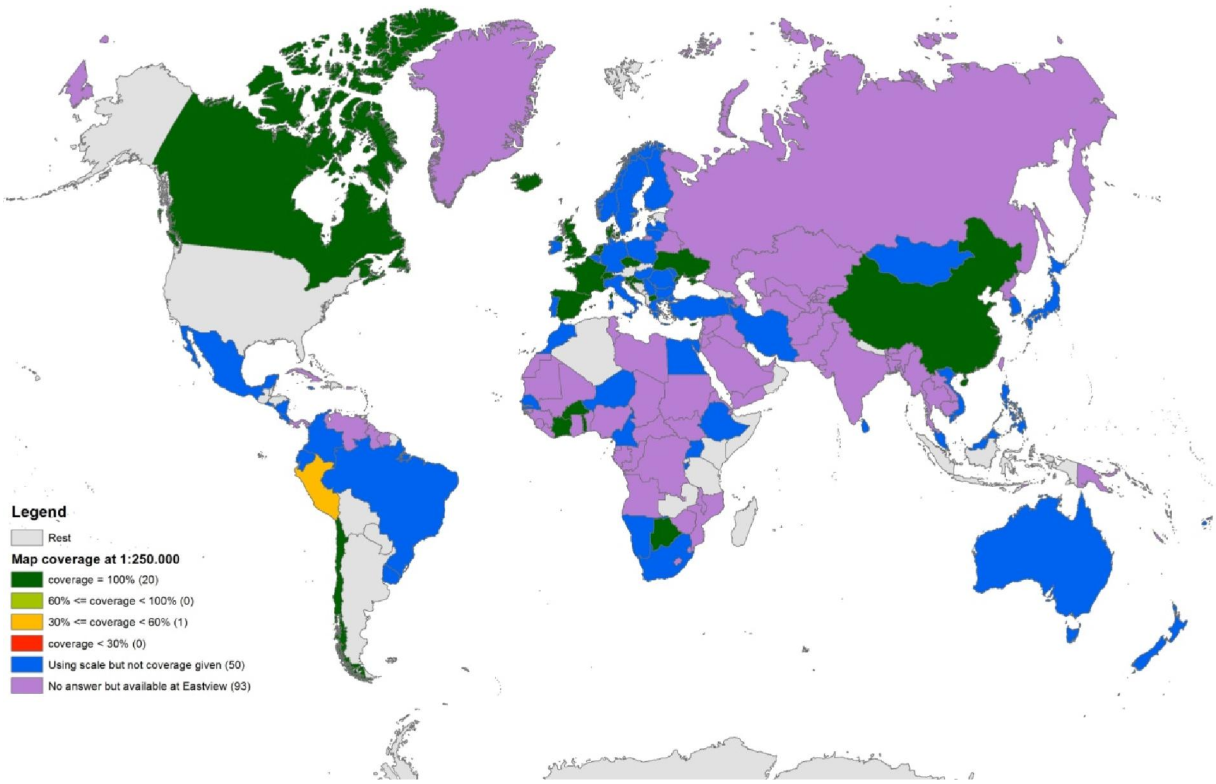

Fig. 4 Coverage 1: 250 000 with percentages

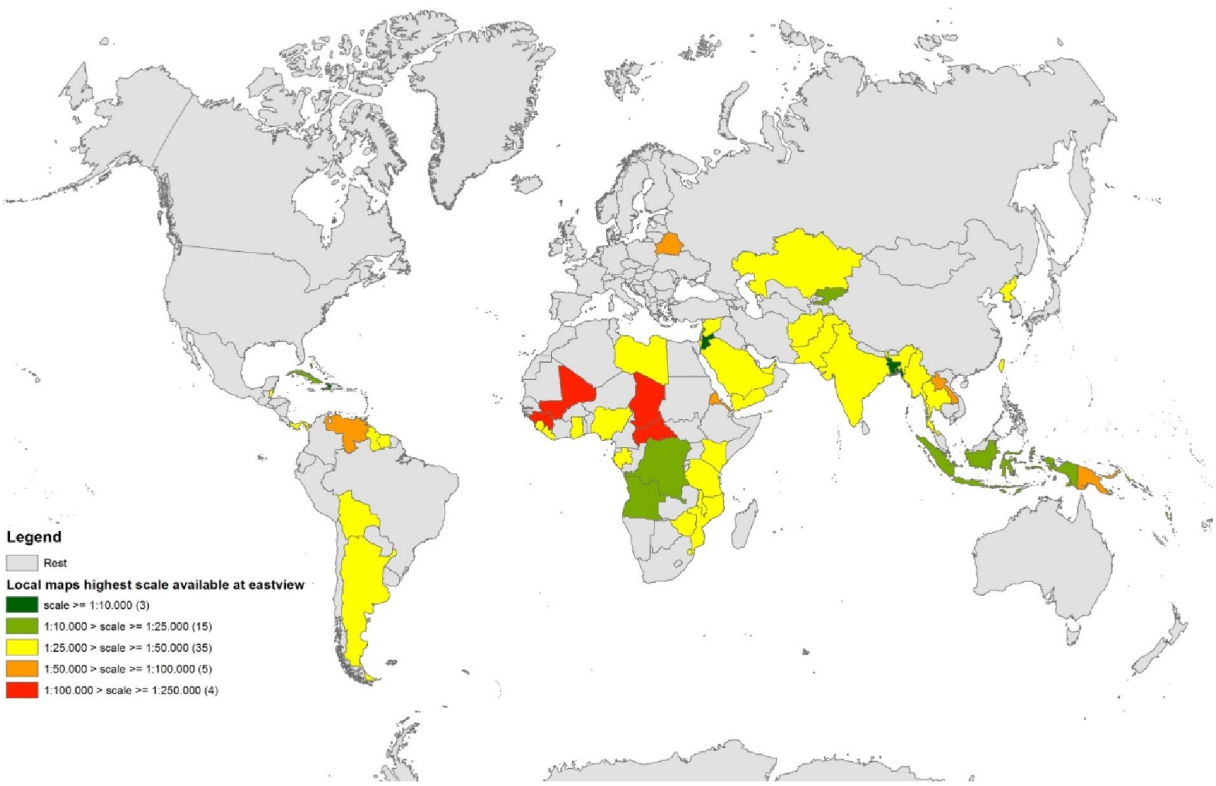

Fig. 5 Availability of Locally Produced Maps from Eastview Geospatial at scales 1:10 000 to 1:250 000

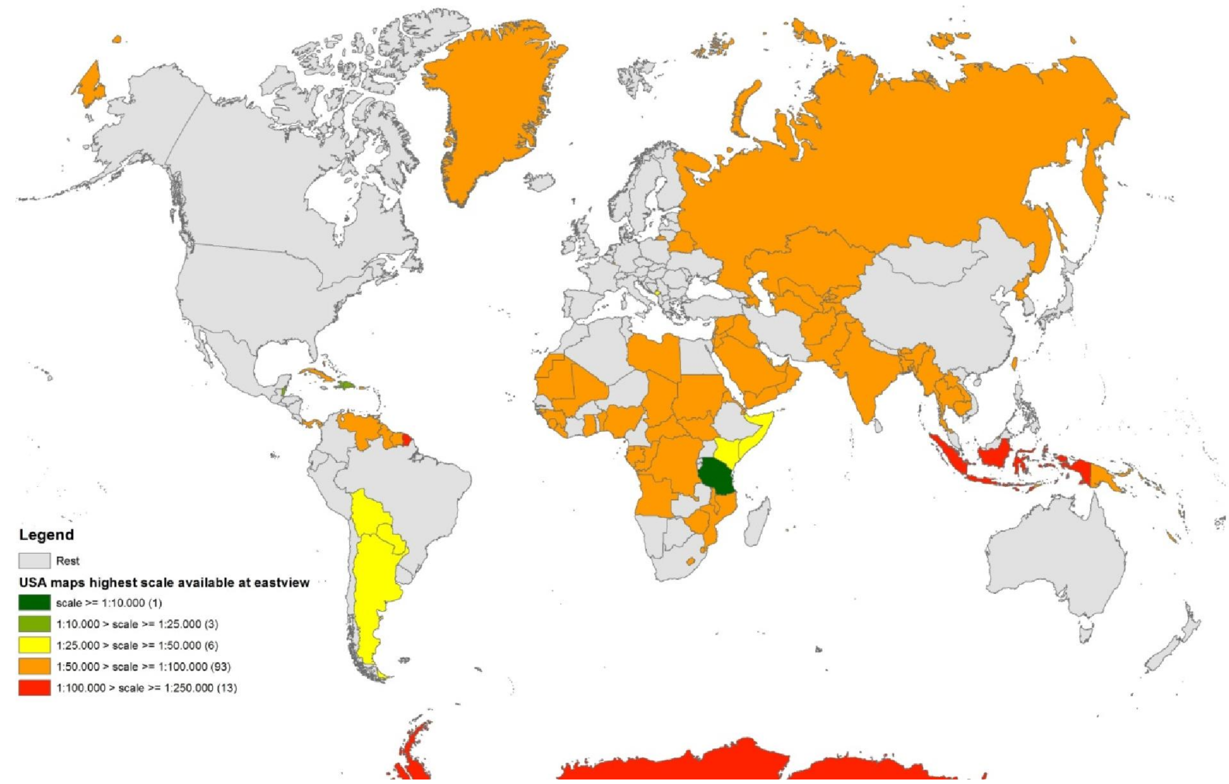

Fig. 6 Availability of US Produced Maps from Eastview at scales 1:10 000 to 1:250 000

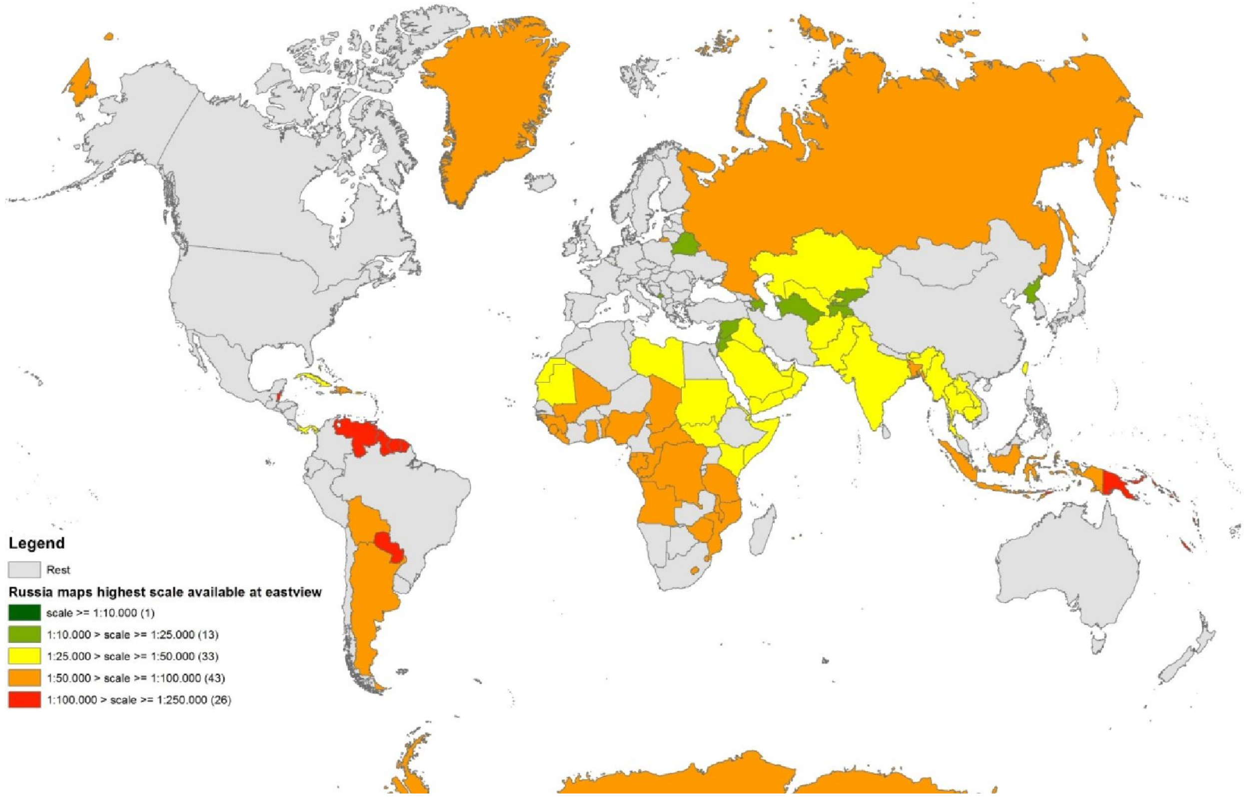

Fig. 7 Availability of Russian Maps at Eastview at 1:10 000 to 1:250 000

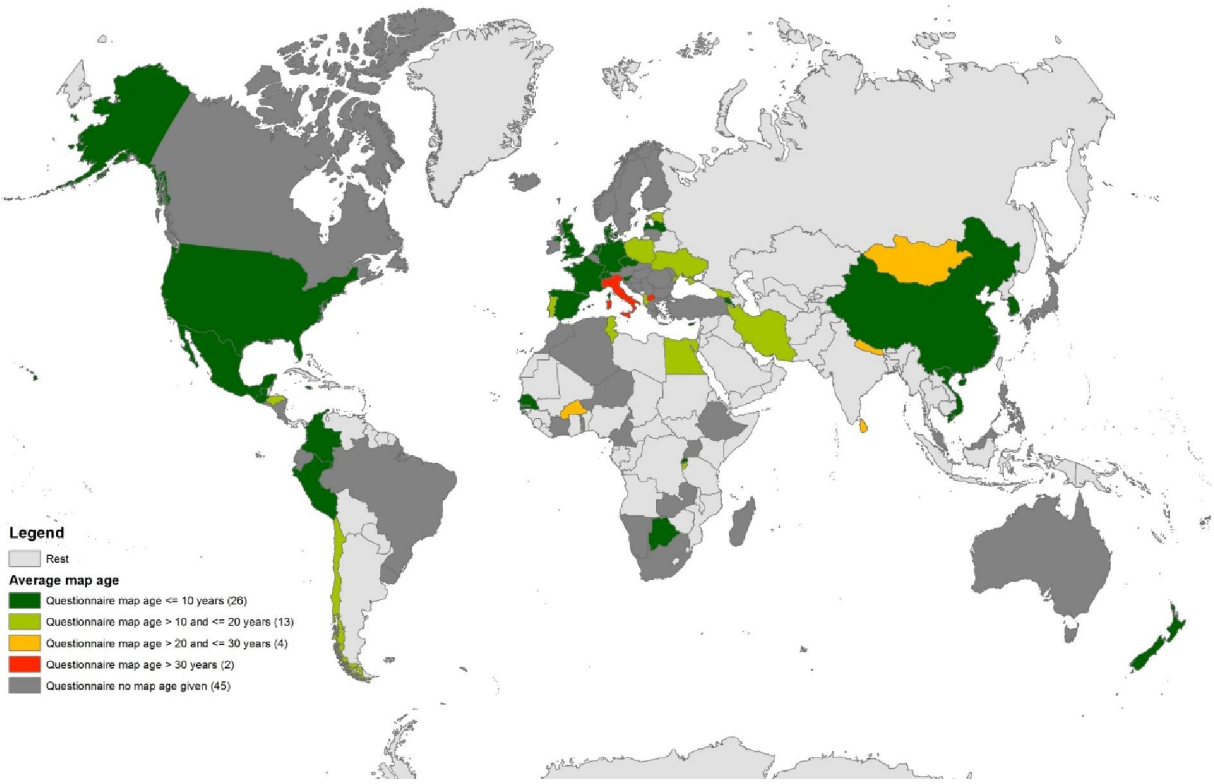

Fig. 8 Map Age from Questionnaires for largest scale cover

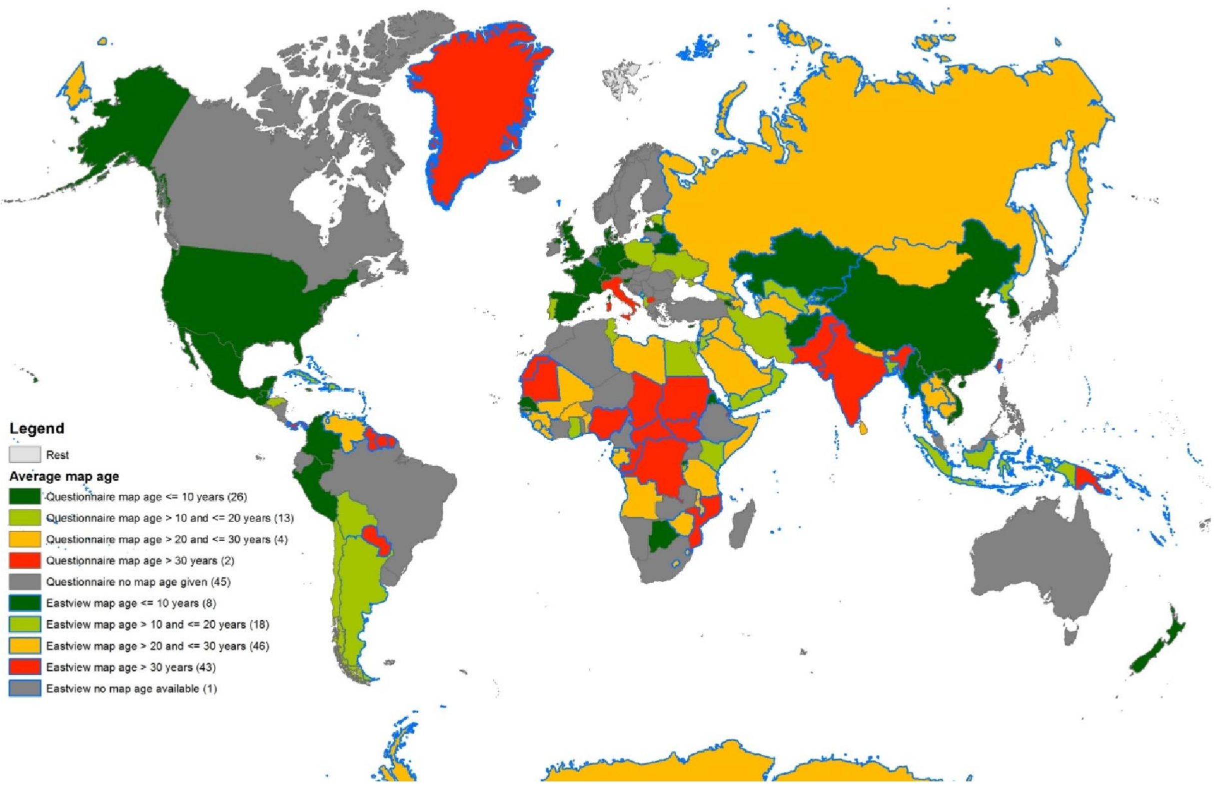

Fig. 9 Age of largest scale cover maps from Questionnaire and Eastview data combined

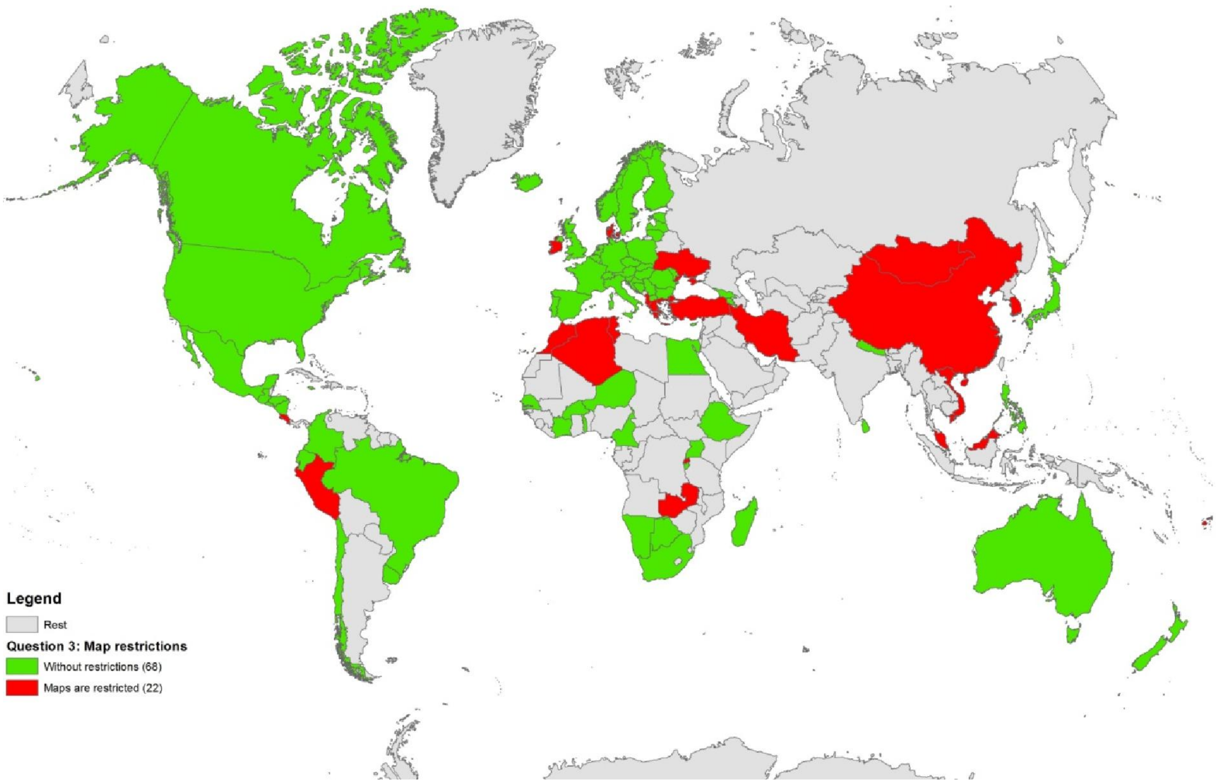

Fig. 10 Map Restrictions

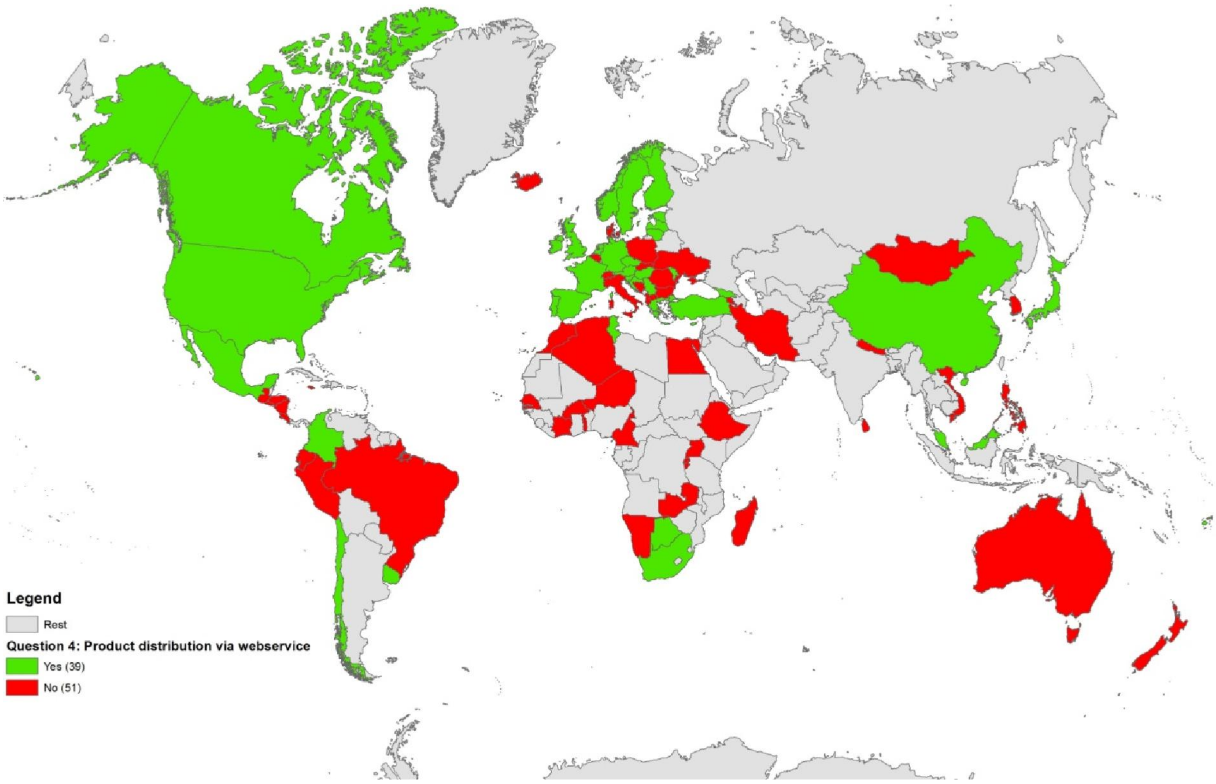

Fig. 11 Map distribution by web

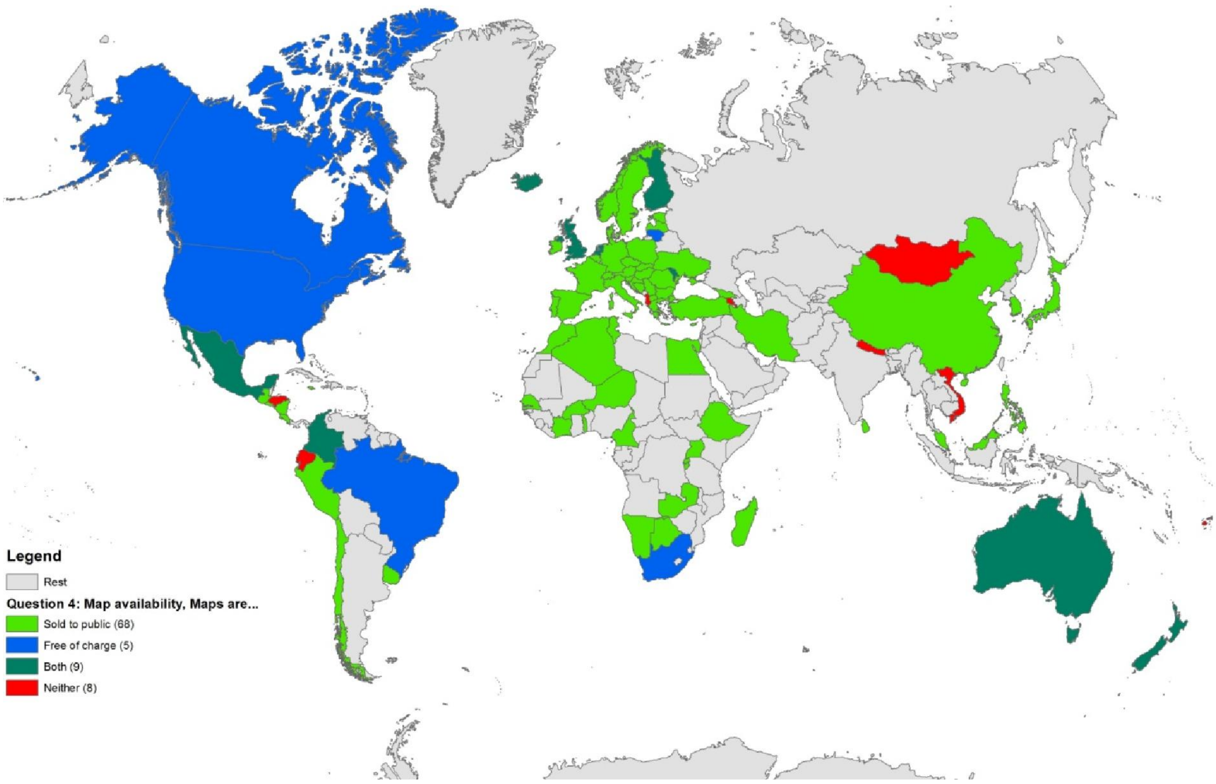

Fig. 12 Map Availability for sale or free of charge

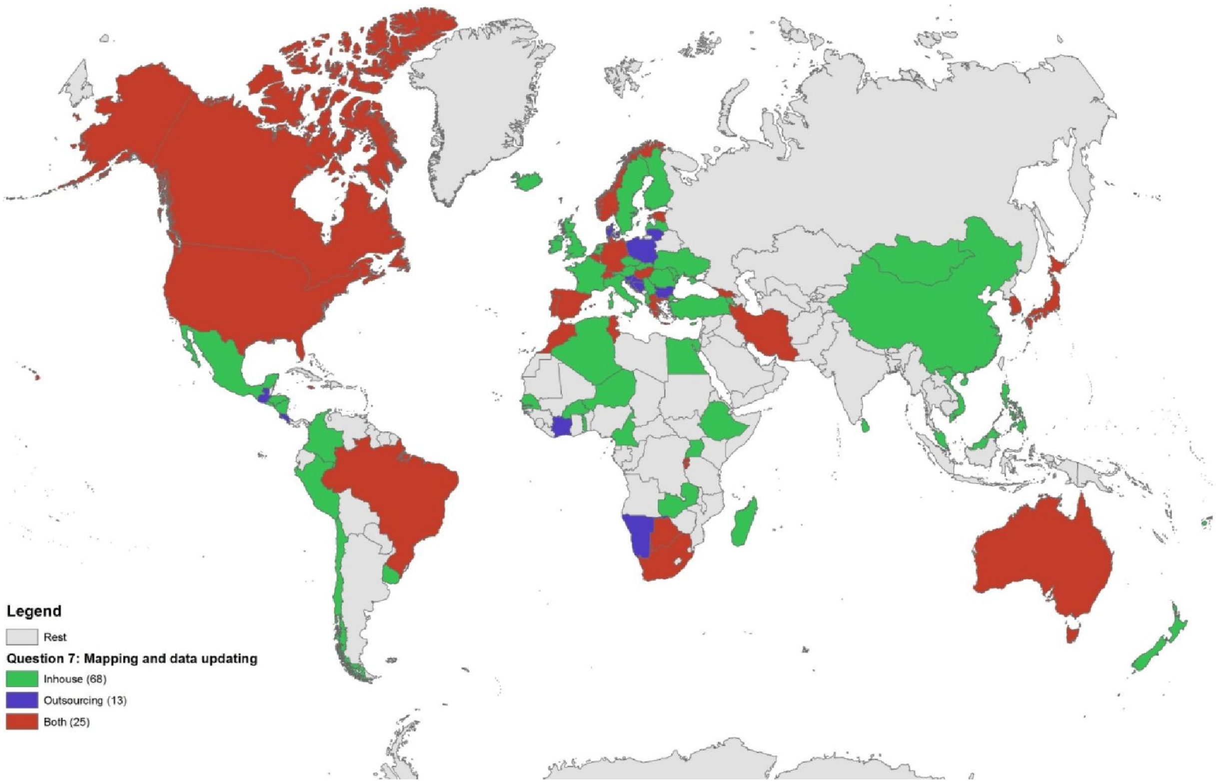

Fig. 13 NMA In-house Operation or Outsourcing

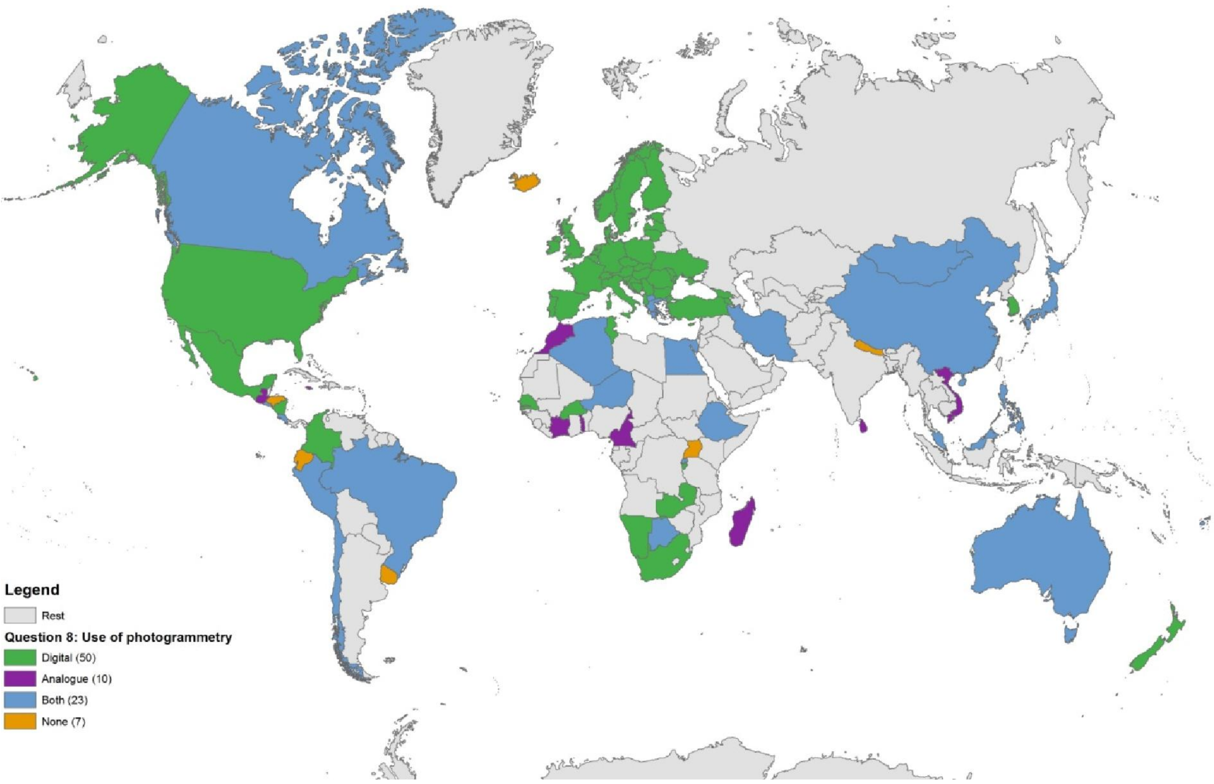

Fig.14 Digital or Analog Photogrammetry Use

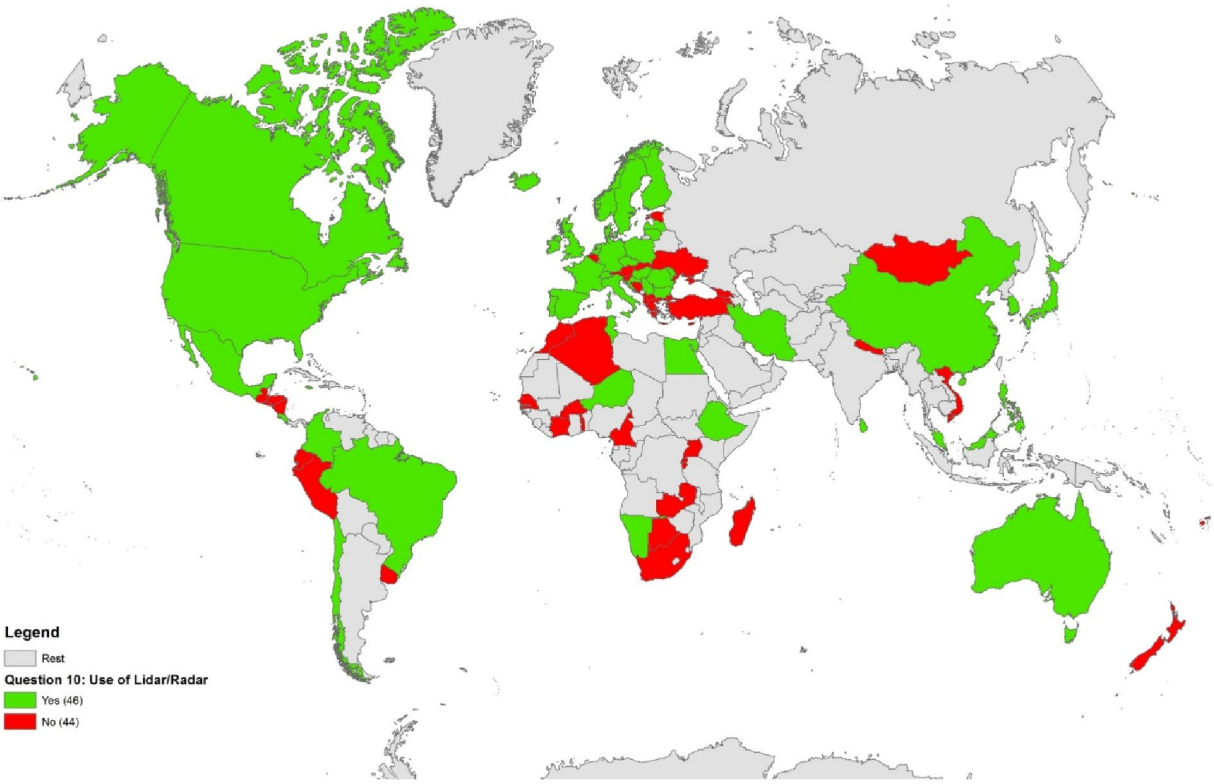

Fig. 15 Radar and Lidar Uses

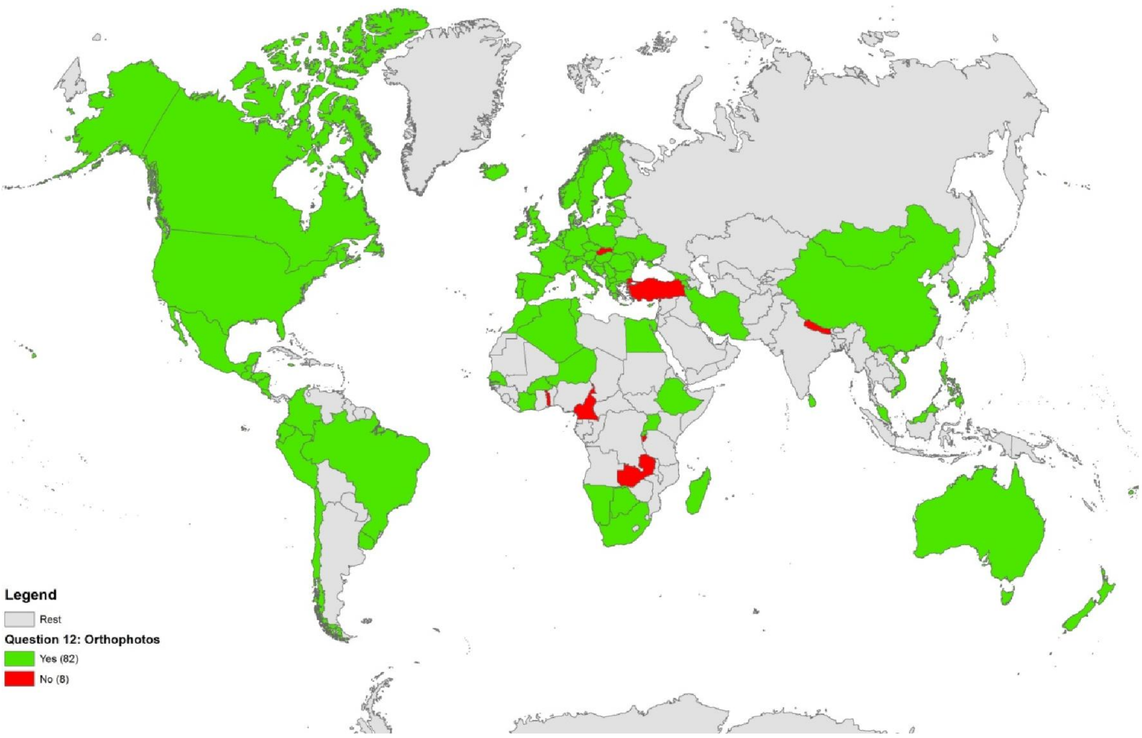

Fig. 16 Orthophoto Programs

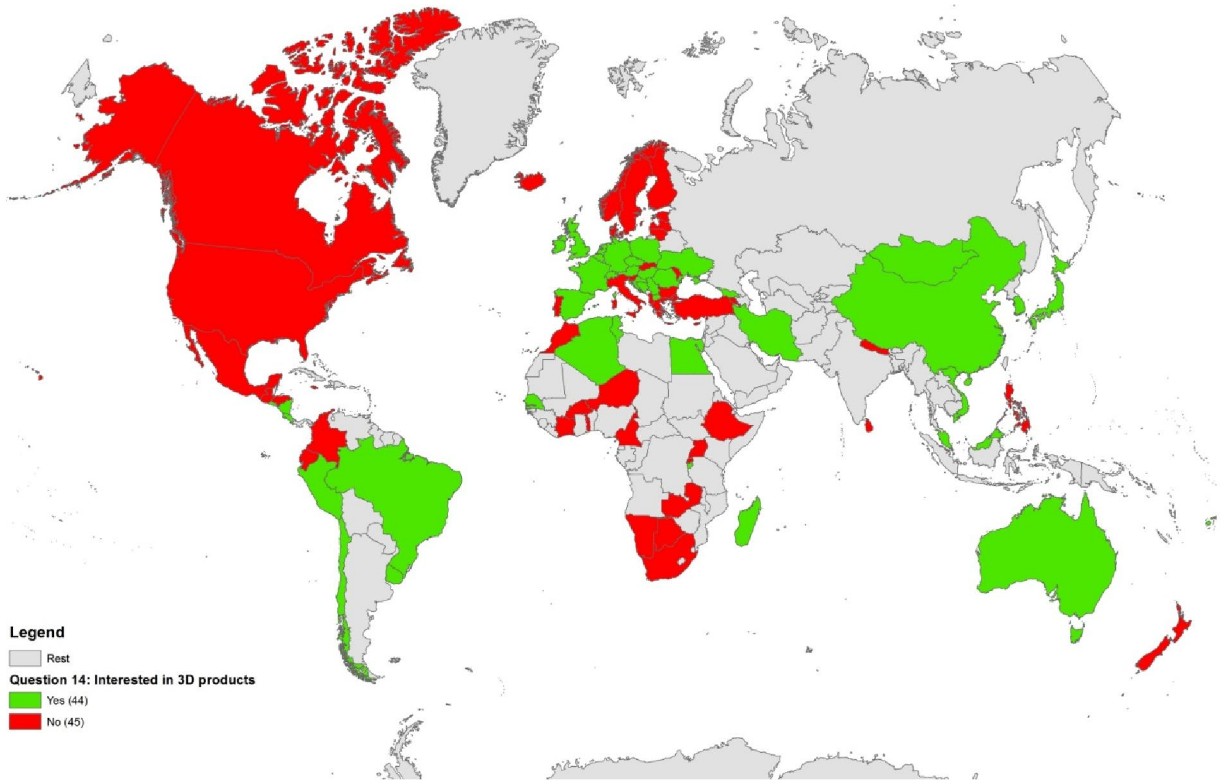

Fig. 17 NMA Interest in 3D

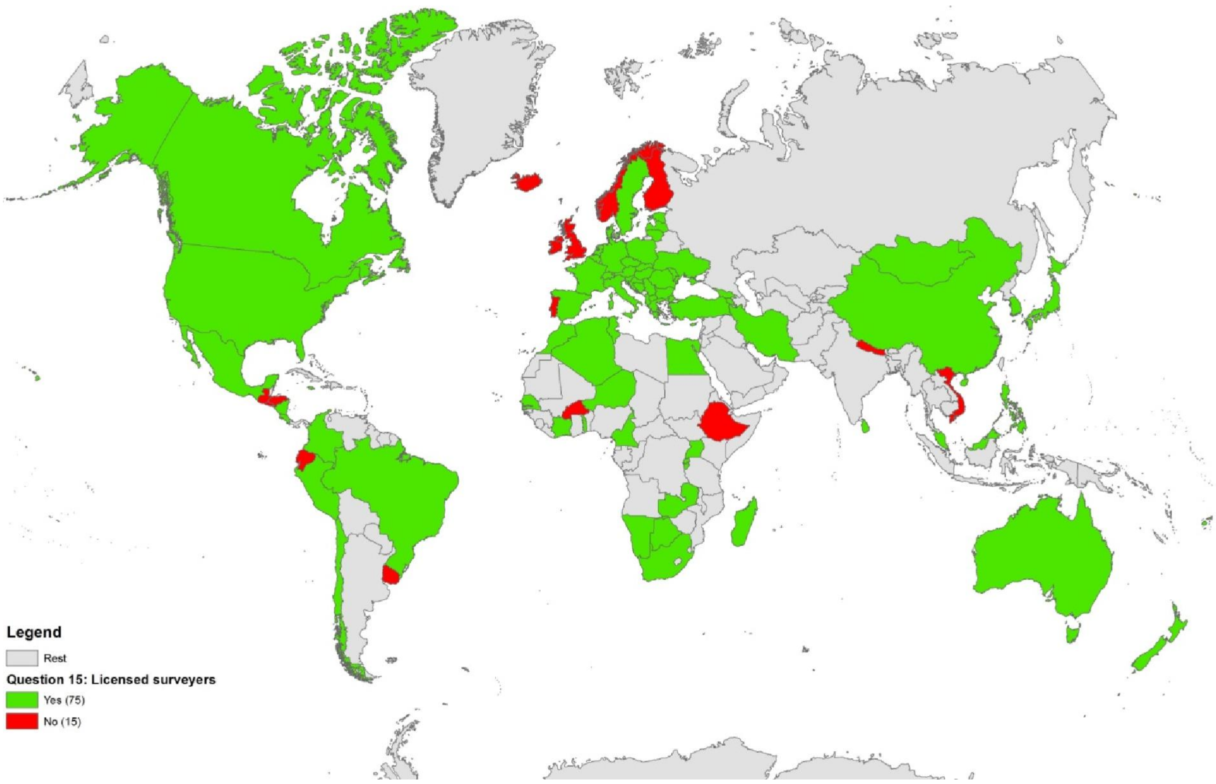

Fig. 18 Licensed Surveyors

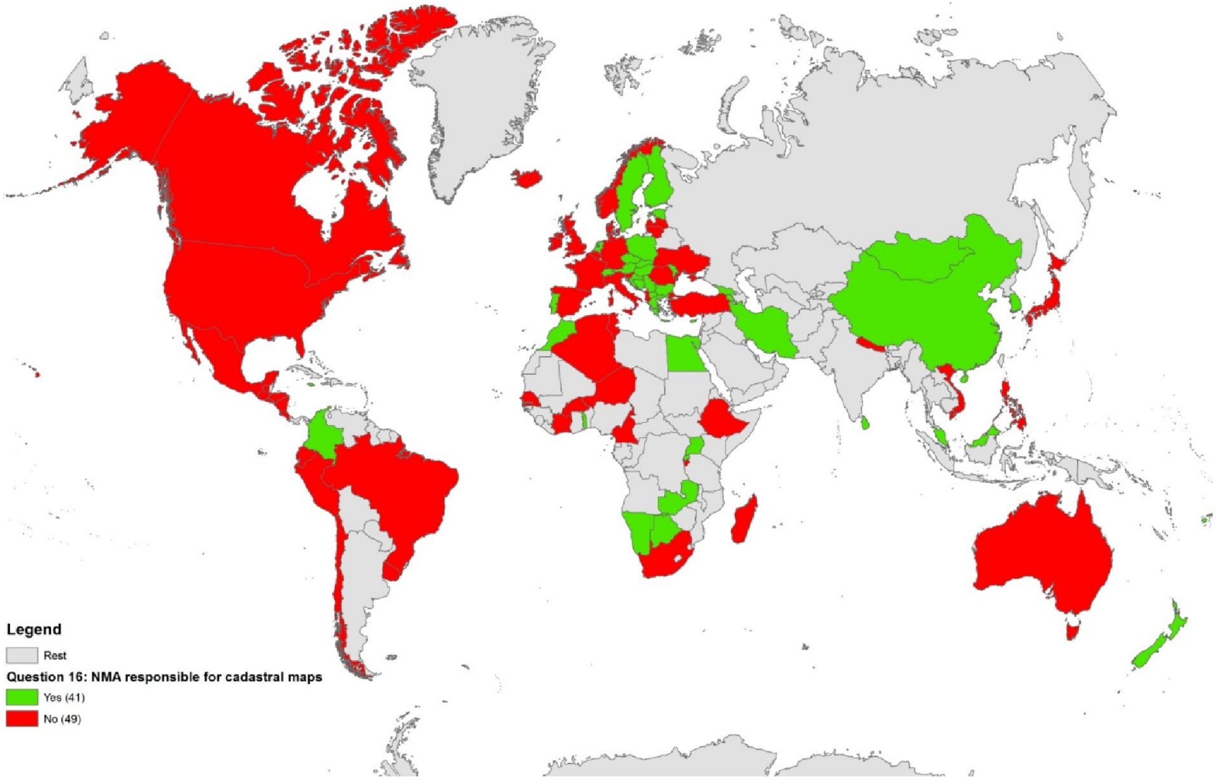

Fig. 19 NMA responsibility for cadastre

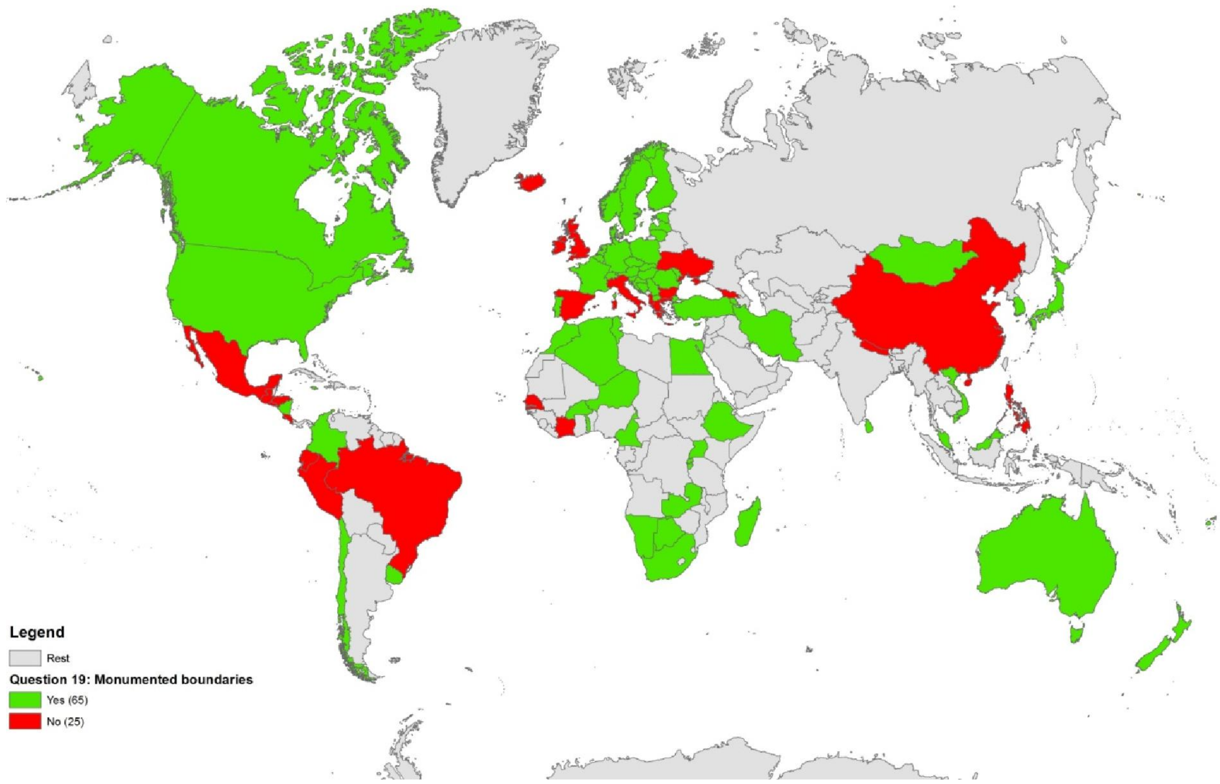

Fig. 20 Monumentation of Property Boundaries

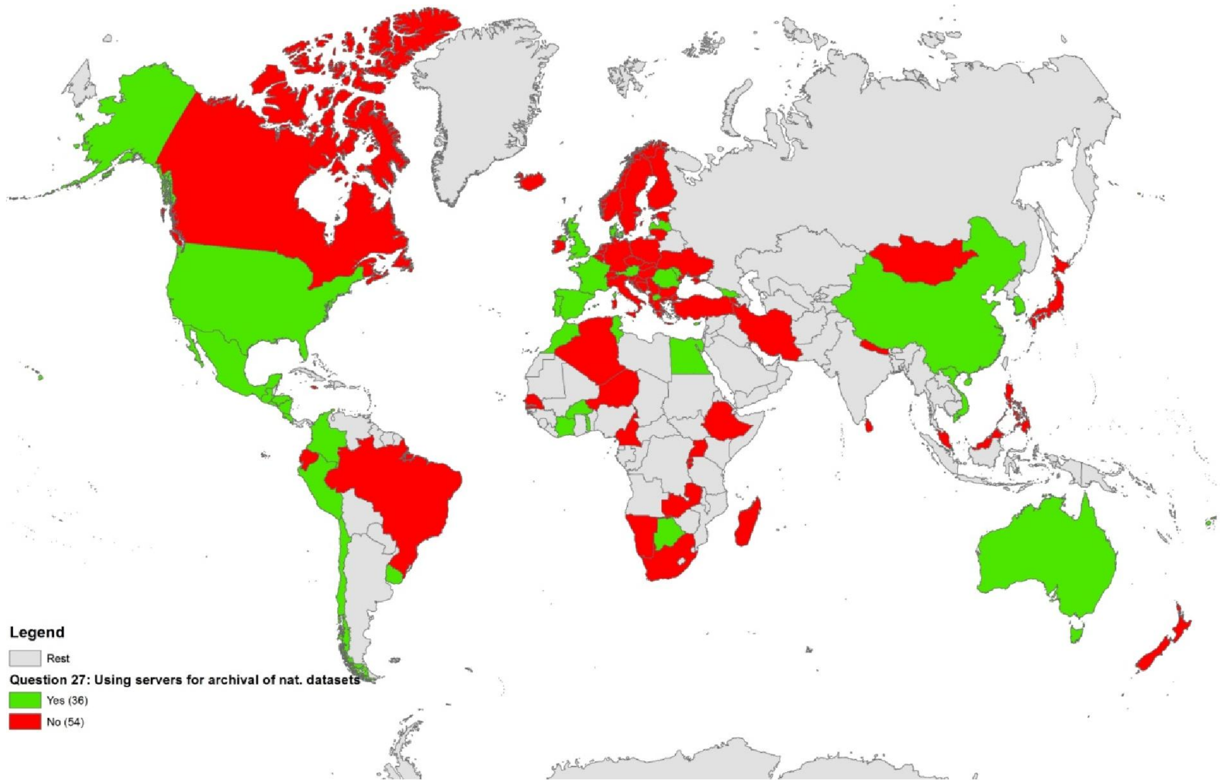

Fig. 21 Use of Servers for Map Archival

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NEXT GENERATION SMART CITIES - THE ROLE OF GEOMATICS

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ABSTRACT:
More than half of the global population lives in urban areas. This will increase to 70% by 2050. Urban growth is most rapid in the developing world, where cities gain an average of five million residents every month. As cities grow in size and population, harmony among the spatial, social and environmental aspects of a city and between their inhabitants becomes of paramount importance. This harmony depends on several cornerstones: sustainability, wealth and justice.
Since a number of years the issue of "Smart" Cities is being used both as buzzword and technical term to indicate the urgent need of change in the development and management of cities. In this context the "Spatial intelligence" of cities plays an important role. It refers to informational and cognitive processes, such as information collection and processing, real-time alert, forecasting, learning, collective intelligence, distributed problem solving, which characterize "intelligent" or "smart" cities.
Here Geomatics technologies and know-how become crucial elements in developing such concepts and maintaining them over long periods of time. Geomatics is understood as the unity of Geodesy, Surveying, Photogrammetry/Remote Sensing, Spatial Information Systems, Visualization/Cartography.
This paper, after a brief definition of the smart city concept, will describe to what extent Geomatics technologies can contribute to the realization and advancements of smart cities. As example and test-bed we will use the currently active SEC-FCL project (**S**ingapore-**E**TH **C**entre for Global Environmental Sustainability - **F**uture **C**ities **L**aboratory). This project has nine research streams (modules): Urban Sociology, Low Exergy, Landscape & Ecology, Digital Fabrication, Transforming and Mining Urban Stocks, Territorial Organization, Mobility and Transportation Infrastructure, Urban Design Strategies, and Simulation Platform. The Simulation Platform is the place where Geomatics and other data for all the other modules are being generated, analyzed and simulated. A new installation, the Value Asia Lab, serves as interface for interactive visualizations and simulations.
Among the many Geomatics technologies our paper will focus on 3D city modeling. With projects in Punggol and Little India, both districts of Singapore, we will show how high-resolution stereo satellite images are used in city modeling.
The major part will deal with the derivation of a very high resolution model of the NUS (National University of Singapore) campus from 5 cm footprint aerial UAV images, Mobile Mapping System laser-scan point clouds and terrestrial images. This is a very complex problem to be solved. We show work in progress.

1. INTRODUCTION

For the first time in human history, more than half of the global population lives in urban areas. This will increase to 70% by 2050. Shanghai's population has almost doubled in a decade, from less than 13 million residents in 2000 to an estimated 23 million today, and by 2050 it is expected to exceed 50 million. Cities cover just 2% of the Earth's surface yet consume about 75% of the world's resources. So it becomes obvious that cities are the key element when coping with climate change and reduction of use of resources. Since city growth can hardly be avoided, one must be able to cope with its consequences. Here it is essential that harmony exists or is generated among the spatial, social, economical and environmental aspects of a city and between their inhabitants. This harmony hinges on 3 key pillars: Earth environment, economic development and social equity. These pillars are balanced through sustainability. In this context the concept of a SMART city has emerged. Usually "smartness" is expressed by its 6-axes model: smart economy, mobility, environment, people, living, governance. Only if all these elements are in balance a city can fulfill its request for sustainability and quality of life. In other words, a city can be called 'smart' if investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure will fuel sustainable economic development, a high quality of life, with a wise management of natural resources, through participatory governance.

A smart city possesses spatial intelligence**.** This summarizes all components in terms of brain-, hard- and software which are required to manage a city efficiently with the goal to sustain high quality of life over a long period of time (resilience). As such it refers to informational and cognitive processes, such as information collection and processing, real-time alert, forecasting, learning, collective intelligence and distributed problem solving. In this environment the Geo-Spatial Information Sciences play a key role, providing for the underlying theoretical framework and practical procedures for data acquisition, processing, analysis and representation.

Traditional methods of planning and managing cities do not work anymore in this new environment. New approaches are necessary. While interactive design and planning will still be of need and value, computerized techniques must find more interest. It is generally agreed that context is a key element in the design of future new and the transformation of existing cities. Context must include societal, governmental, economic and technological components. This context must be transformed to and modelled in the digital (computer) domain. The so created models must be supported and activated by data. The complexity of the political, social and economic decision-making processes requires precise, reliable, actual and largely complete data. Most of this data is spatially related. This clearly emphasizes the relevance of the Spatial Information Sciences, especially also Geomatics, for any future-oriented design and planning process.

Li et al., 2013 are presenting an overview dealing with "*Geomatics in Smart Cities – Concept, Key Techniques and Applications".* They outline the current shift from Digital Cities to Smart Cities. They see Digital Cities, The Internet of Things and Cloud Computing as important supporting technologies for Smart Cities and discuss how these technologies can be implemented and then will contribute to a better management of cities. As new technologies for Smart Cities they describe briefly the location cloud, remote sensing cloud, integration of video and GIS, integration of space-borne, air-borne and terrestrial sensors and GIS, indoor and underground navigation, ubiquitous sensing via smart phones and spatio-temporal data mining. Finally they show four concrete “smart” applications in Wuhan and Sichuan: Smart municipal supervision, smart transportation, smart environment monitoring, smart tourism.

Wang, 2013 describes the role of GIS in a Smart City context. He clearly emphasizes the advantages that modern GIS technology brings to the Smart City and underlines this with examples from transportation and mobility, risk management, urban planning, noise mapping and solar energy. Under the term “Interdisciplinary Urban GIScience” he addresses issues from volunteered geographic information collection, cloud computing and SDI and geo-visualization and human-computer interaction. With the help of GIS cities have already succeeded in transforming their managements to a more efficient level. Yet, much remains to be done to make full use of the potential of modern GIS.

Actual, accurate and complete data is very crucial for designing, modeling and planning in Smart Cities. Geomatics always has played a significant role when it comes to reality-based data acquisition and processing. The present times are characterized by the availability of a great amount of different sensors for a variety of data collection activities.

Laser-scanners, both from the aerial and terrestrial platforms play a very important role in today’s fast data collection scenery. Huang, 2013 gives an account of the state-of-the art in airborne laser point cloud processing for the purpose of generating 3D city models, in particular buildings. The overall process of modeling from point clouds is split up in detection, feature extraction and 3D model generation. A particular point of discussion is the quality control of the results of otherwise automated procedures. Standard methods for quality evaluation are still missing. While raw data acquisition with aerial and terrestrial platforms is very fast today, there are still many bottlenecks in data processing, considering the pipeline from unstructured point clouds to structured surface models.

Another approach for reality-based modeling is via the use of images. Mueller-Arisona et al., 2013 investigate a new method of combining reality-based 3D models, generated from images, with procedural (generic) modeling in a single workflow, in order to derive high quality/higher resolution hybrid building models. They show how the approach increases the level-of-detail and texture quality compared to using photogrammetry alone, and how their methodology is applicable in practice in terms of a concrete case study based on satellite imagery and terrestrial façade photographs. As project example serve the new-town building towers in Singapore’s Punggol area. In this project context two leading software packages are used: Cyber City-Modeler for reality-based modeling and City Engine for procedural modeling.
This paper will, starting from a brief description of goal and set-up of the SEC-Future

Cities Laboratory, describe the ever increasing role that Geomatics plays in this context. This role is not only related to raw data acquisition, but also to data administration in data bases, processing, analysis, and representation. We also emphasize the importance of Geomatics for the SEC-FCL project in Singapore.

In a second part we show with a few examples some of the products that Geomatics can deliver. We derive 3D city models from high-resolution stereo satellite images. We also report about our project of collecting very high resolution (5 cm footprint) aerial images by flying with a UAV over the campus of NUS (National University of Singapore). We then combine the aerial data with laser-scanned terrestrial point clouds, produced by a Mobile Mapping System, in order to produce a complete city model, showing also the façades in 3D.

2. SEC-FUTURE CITIES LABORATORY

In Schmitt, 2012 the "Digital Chain" is promoted, which is a concept of data acquisition, data handling and decision making on an architectural scale, involving design, construction and facility management of buildings. This "digital chain" is reflected in the concept and work of the **SEC-Future Cities Laboratory**. The Singapore-ETH Centre for Global Environmental Sustainability (SEC) was established by ETH Zurich and Singapore's National Research Foundation (NRF) in 2010. It is an institution that frames a number of research programmes, the first of which is the Future Cities Laboratory (FCL).The SEC strengthens the capacity of Singapore and Switzerland to research, understand and actively respond to the challenges of global environmental sustainability. It is motivated by an aspiration to realise the highest potentials for present and future societies. SEC serves as an intellectual hub for research, scholarship, entrepreneurship, postgraduate and postdoctoral training. It actively collaborates with local universities and research institutes and engages researchers with industry to facilitate technology transfer for the benefit of the public. The FCL is a highly trans-disciplinary research centre focused on urban sustainability in a global frame. It is home to a community of over 100 PhD, postdoctoral and Professorial researchers working on diverse themes related to future cities and environmental sustainability. For details see http://futurecities.ethz.ch. Within this project a city is seen as an urban metabolism, and the concept of stocks and flows is used to describe and analyse its status and dynamics. This is done on three different levels of scale: S (small)-scale: the individual building, M (medium)-scale: the urban part and L (large)-scale: the territory. Ten different research modules investigate into stocks and flows of energy, materials, capital, people, water, space and information. The information part is treated on the Simulation Platform. Its goal is to support design and decision-making processes with new techniques and approaches to data acquisition and processing, information visualisation and simulation. The Simulation Platform currently encompasses more than 20 researchers. Figure 1 shows the research modules of the SEC-FCL project in Singapore. The Simulation Platform models information in terms of stocks and flows and assembles and produces data needed by the other modules for storage, processing, analysis, visualization, animation.

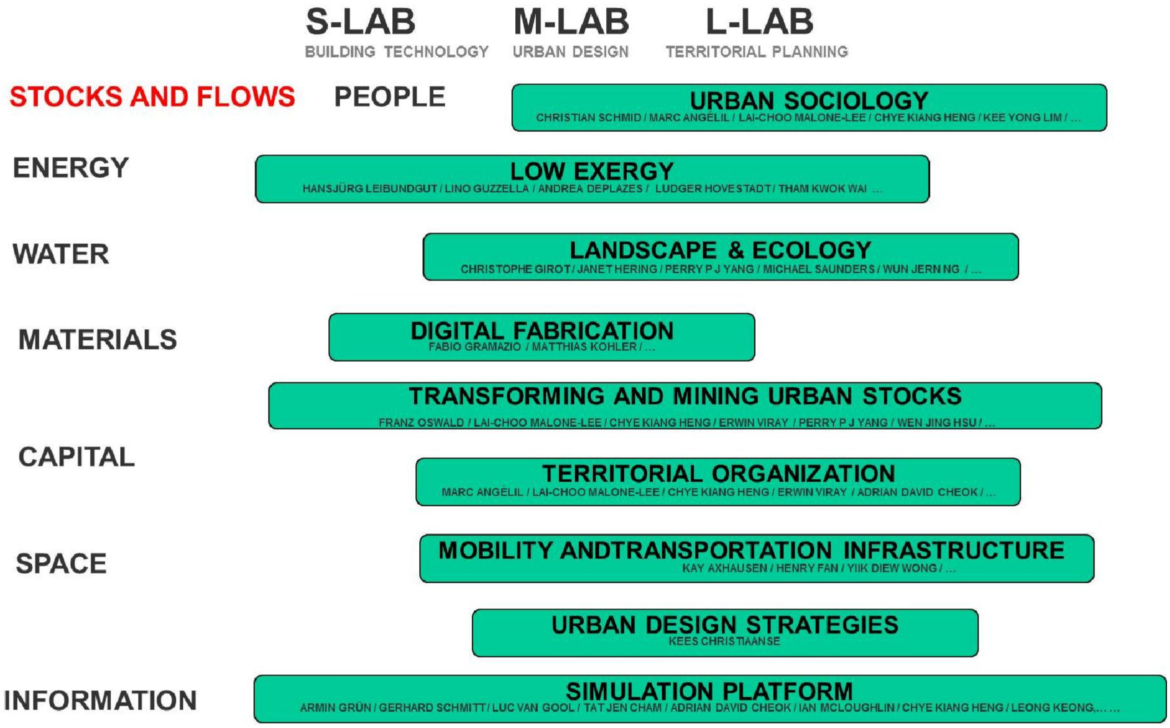


Figure 1. Research modules of the SEC-FCL project in Singapore. Geomatics procedures are implemented on the Simulation Platform, but also support the other modules (cc: SEC-FCL).

3. ROLE OF GEOMATICS

The "digital chain" may also serve as a synonym for the role that Geomatics plays in the context of Smart Cities. If we understand Geomatics as the science of acquiring, modeling, analysing and representing spatially-referenced data, then it integrates as key disciplines Geodesy, Geodetic Mensuration, Photogrammetry and Remote Sensing, Cartography and Geoinformatics. Much of the work of the SEC-FCL Simulation Platform is concerned with Geomatics issues. Some of the Geomatics-related R&D topics of the Simulation Platform are:

- Automatic or semi-automated generation of Digital Surface Models (DSM) from satellite, aerial and terrestrial images and/or LiDAR data
- Further development of the semi-automated techniques (like CyberCity Modeler) onto a higher level of automation
- Integrated automated and semi-automated processing of laser-scan point clouds and images, both from aerial and terrestrial platforms
- Streamlining the processing pipeline for UAV image data projects
- Exploring the various applications of UAV-based thermal imaging
- Set-up of GIS with 3D/4D capabilities
- Change detection and updating of databases
- Combination of real and synthetic (e.g. planned) objects (reality-based and

generic modeling) - see CC-Modeler and City Engine
- Handling of dynamic and semantic aspects of city modeling and simulation.

This leads to 4D city models
- LBS system investigations (PDAs, mobiles)
- Establishment of a powerful visualization and interaction platform ("Value Lab Asia")

Figure 2 shows the research work packages of the Simulation Platform. From the topics it becomes clear that Geomatics plays a key role there.
Besides its own R&D program the Simulation Platform has a distinct service function with respect to all other SEC-FCL modules and scientists. A major component of this service function is the maintenance of a GIS and the training of other researchers in GIS-related topics.

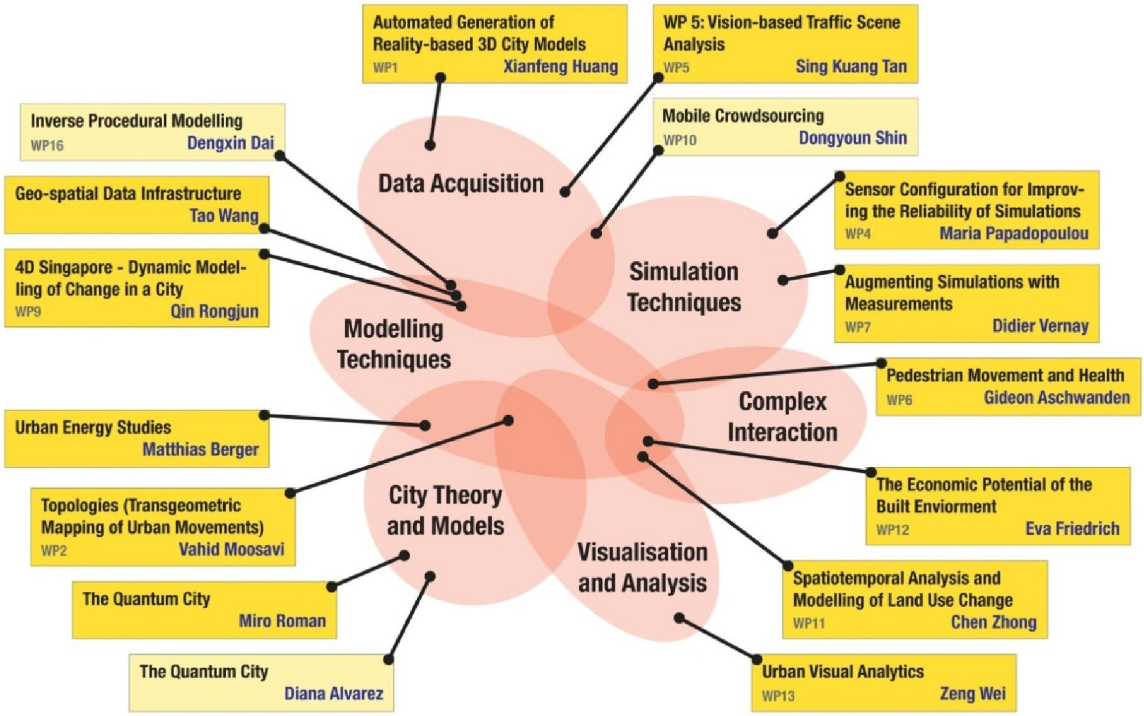


Figure 2. Work packages of the SEC-FCL Simulation Platform (cc: SEC-FCL)

Currently, the GIS database includes data from Singapore (and partly from Indonesia, Thailand, China and Malaysia) like:
+ 3D city models of Rochor, Punggol and NUS campus
+ DTM, DSM at different resolutions
+ Master plans in vector format
+ Land use map, drainage patterns
+ Buildings: coordinates, building type, number of floors above and below ground, number of flats and rooms, roof type and shape, type of ownership, value (insured value/ market value), status of protection as heritage, life cycle of the lot/buildings, age
+ Thermal building data

+ Historical plans/cadaster
+ Census data 2010 with location
+ School catchment areas
+ Navteq road network
+ Georeferenced post codes
+ Climate/weather data, temperature of ground at various depths, annual temperatures of rivers and ocean

Besides above, the database also includes 40 layers of POIs, Singapore address points, Singapore detailed control plans and Google images.

Among all the Geomatics technologies we can address in this paper only a few more in detail. 3D city modeling is of course of crucial importance. 3D city models may serve many purposes, as for instance environmental monitoring, planning (buildings, roads, location), mobile communication, LBS, energy (solar), natural hazards, tourism, real estate, architecture, landscape engineering, monument preservation, smart homes, insurances (risk transports, etc.), 3D car navigation, homeland security, police, fire-squad, traffic and crowd control.

4. 3D CITY MODELS FROM SATELLITE IMAGES

It is a particularity of Singapore that aerial images are not available, they are still highly classified. Therefore we have produced 3D city models for some areas of interest from high-resolution satellite images. The sub-pixel georeferencing accuracy of both projects is described in Wang and Gruen, 2012.

We have generated 3D models for the traditional shophouse-dominated district Rochor ("Little India") from IKONOS stereo-images and for the newly built-up area Punggol from WorldView-2 stereo-images. Figure 3 shows the geometry model of Rochor, overlaid by cadastral map data. This model is used in a large multi-module research study called Rochor+. The Rochor+ district displays probably the largest diversity with respect to its urban morphology and its social composition in the whole of Singapore. This abundance of variation makes the district a specimen of study to some of the modules. Therefore 15 researchers from 5 different modules have chosen the district as research area. It is expected that this urban system can make a crucial lesson for Singapore's future developments.
Figure 4 shows a view onto a part of the Punggol model, which carries texture from satellite images on the terrain and on the roofs. The Punggol area is of totally different type. It is a newly built district which will finally house about 350 000 people, roughly the size of Zurich, Switzerland. It is a special case of urban planning, where mainly flats for lower income people were planned and are built. Also the functional mixture is unique with over 97% of the built area residential in a high-rise typology, currently without hotel or theater. The area is designed for living and offers recreational facilities, but no commercial or industrial functions. The occupants

therefore have to commute to work, which puts a heavy additional load on the transportation system.

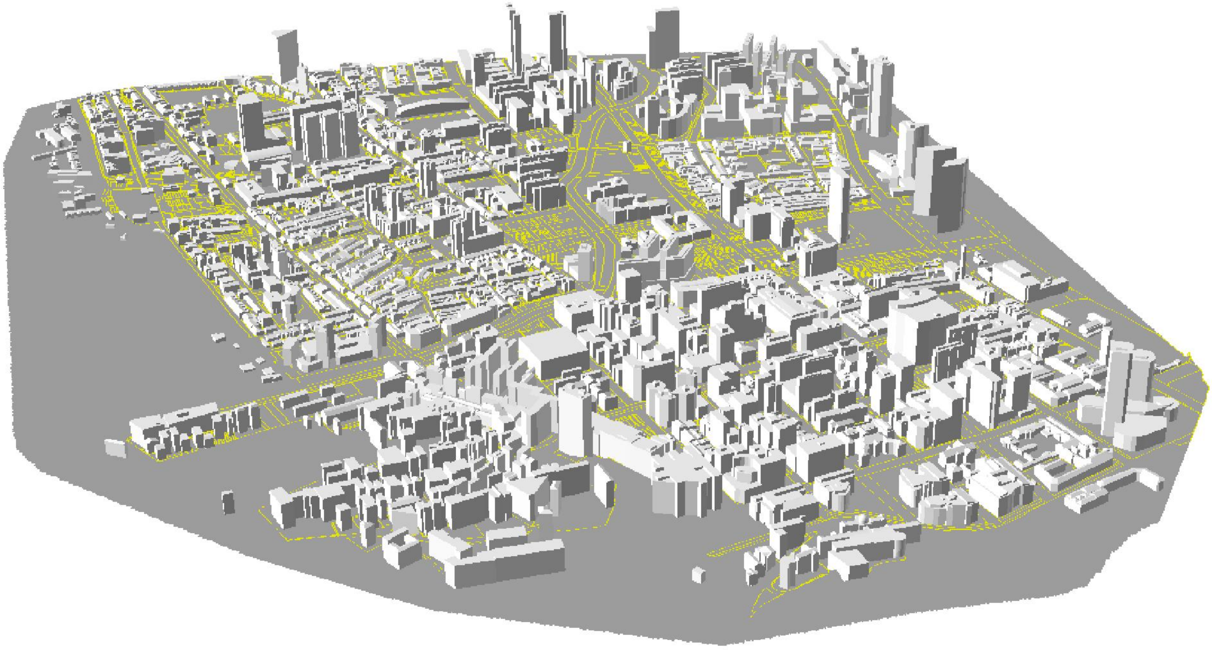


Figure 3. 3D model of Rochor ("Little India"), derived from an IKONOS stereo-model using CyberCity Modeler, with an overlaid cadastral plan.

Figure 4. Partially textured 3D city model of Punggol, Singapore. The model was derived from a WorldView-2 stereo-model by using CyberCity Modeler.

5. VERY HIGH-RESOLUTION 3D MODEL OF THE NUS CAMPUS

A major effort was devoted towards setting up a pilot project with the goal to collect very high resolution data of various types (images and point clouds) over the NUS (National University of Singapore) campus area. With this data methods of 3D data processing for city model generation should be exercised and further developed and refined.

The input of our work is: (1) raw point clouds from a Mobile Mapping System (MMS); (2) UAV images; (3) few Ground Control Points (GCPs), (4) optional: Terrestrial images for geometric modeling of façades and texture mapping.

The UAV part of the project is described much in detail in Qin et al., 2012, while the integrated processing of aerial and terrestrial image data and laser-scan point clouds from a Mobile Mapping mission is addressed in Huang et al., 2013. From this last publication we take the main workflow of this project as (see also Figure 5).

(a) Aerial triangulation of UAV images
(b) Integration of UAV-derived control point data to geo-reference and adjust the MLS point cloud data
(c) Modeling of the roof landscape from UAV images
(d) Measurement of the DTM from UAV images
(e) 3D modeling of façades from MLS data and (if needed) from terrestrial images
(f) Modeling of DTM from MLS data
(g) Fusing façade and roof models and the DTMs to generate a complete geometry model
(h) Optional: Texture mapping from aerial and terrestrial images

The complete procedure is shown in Figure 5. From the input image data, control points and raw point cloud data we can derive a complete 3D site model, achieved by integration of these input data sources. One of our byproduct is a precisely georeferenced point cloud from raw data without much field work.

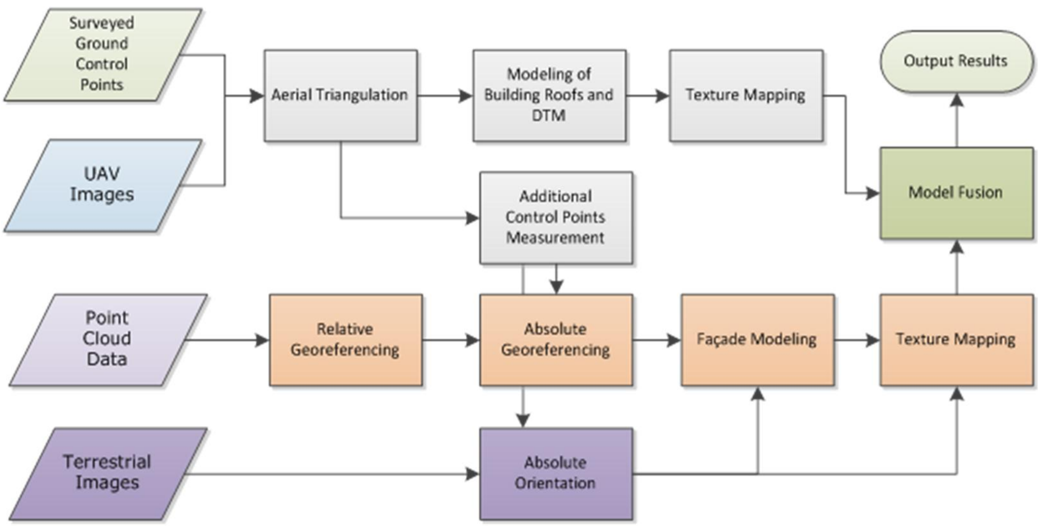


Figure 5. Flowchart of integrated data processing

5.1 UAV data over NUS campus

The modeling area covers approximately 2.2 km^2. This may not be a large area in mapping, but considering the restricted flying height of 150 meters and a camera constant of 16 mm with off-the-shelf cameras, we obtained 857 images in total with a pixel size of 5 cm. There was another restriction concerning the flight: the UAV was not allowed to fly across the major public roads and should stay strictly within the campus boundaries, which splits the whole areas into 3 parts. This required the flight path to follow the border of the campus closely.

The AscTec Falcon 8 was used for the mission. It is a two-beam octocopter with 4 rotors on each side, powered by battery. It has a build-in GPS/IMU, barometer, electronic compass and stabilizing system for both the camera and the platform. It has up to 300 meters remote controlling distance with a maximal operation slot of 20 minutes. Since the octocopter needs some power to keep operating, one of the biggest disadvantages is the short operation time. Due to signal disturbance and unexpected circumstances like strong wind, loss of connection, etc. we only took maximal 25 images per flight for safety reasons, sometimes even less, especially when the flight was taken near the boundary of the mapping area. Figure 6 shows such a small sub-block.

Figure 6. A 4x4 sub-block of the NUS UAV campus block

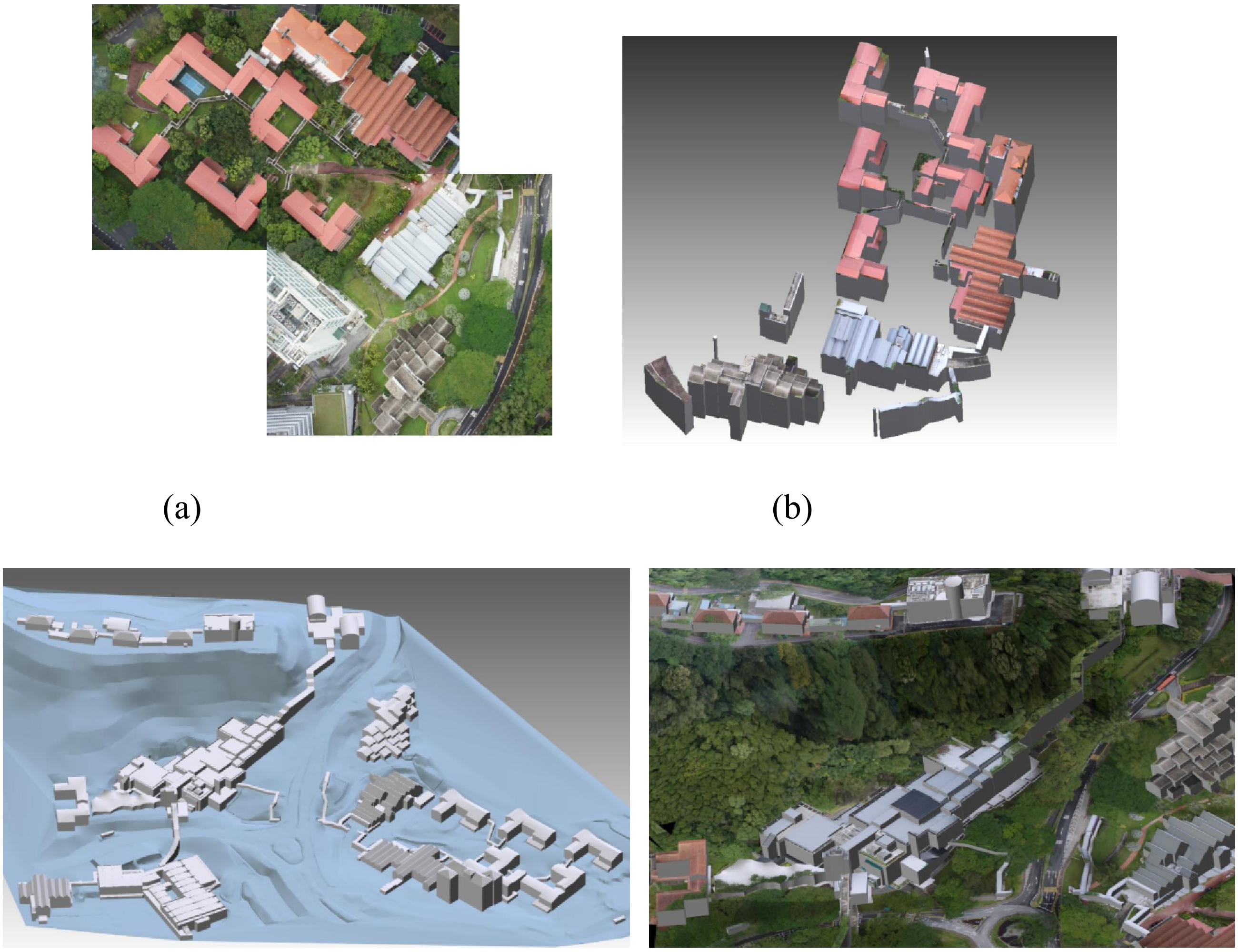
The first step in data processing is georeferencing/triangulation. Due to the limit of flying only small sub-blocks at a time, the complete block of 857 images actually consisted finally of 47 small sub-block units. This unconventional block structure and other particularities caused many problems with commercial software and it took us some time to finally find two software packages which delivered reasonable results (APERO and pix4D).

We measured in total 39 GCPs by GPS. 11 of those points served as check points in order to have some external accuracy check, while the rest (28 points) were used as GCPs in triangulation. With the fully automated triangulation software APERO (Pierrot Deseilligny and Clery, 2011) we received quite acceptable results with free-network bundle adjustment, with an average re-projection error of 0.5 pixels. When using GCPs as described above our check point analysis resulted in RMSEs of 7 cm in planimetry and 6 cm in height. Compared to the pixel size of 5 cm these values are not very good but acceptable.

We used Cyber-City Modeler (Gruen and Wang, 1998) to model buildings on the NUS campus. It is a semi-automatic procedure. While the key roof points are measured manually in stereo mode, the software fits the topology automatically. Giving semi-ordered point clouds measured in a Digital Workstation following a set of criteria, it will automatically generate roof faces and wall faces, where only a small amount of post-editing is needed. It greatly reduces the operation time for constructing building models and can generate thousands of buildings with a fairly small work force. It is also invariant of model resolution, and is able to generate finer details on building roofs such as air-condition boxes, water tanks, etc. We used ERDAS StereoAnalyst as Digital Workstation and implemented a converter between StereoAnalyst and Cyber-City Modeler.

Since Singapore is a tropical country with a large amount of tree canopy around the city, we face difficulties in DTM measurement, especially with images taken at such low altitude of 150 m. Green plants lead to many occlusions. Therefore, for areas where there are trees the DTM resolution cannot be guaranteed. In this scenario, to build an accurate terrain model even under the plant canopy, extra information is needed. We obtained this information by acquiring LiDAR point clouds from a Mobile Mapping System (RIEGL VMX 250), driving around campus. The LiDAR points are used to assist in building a precise terrain model under the trees along the roads and also to derive 3D façade models. For this latter purpose we also have acquired terrestrial images in photogrammetric mode. This is work in progress. Results will be shown elsewhere.

Intermediate results of the building models are shown in Figures 7 b,c,d. This sequence of images shows the development of models from buildings alone, over a combined DTM/building model to a hybrid model including texture from UAV images.



(a) (b)

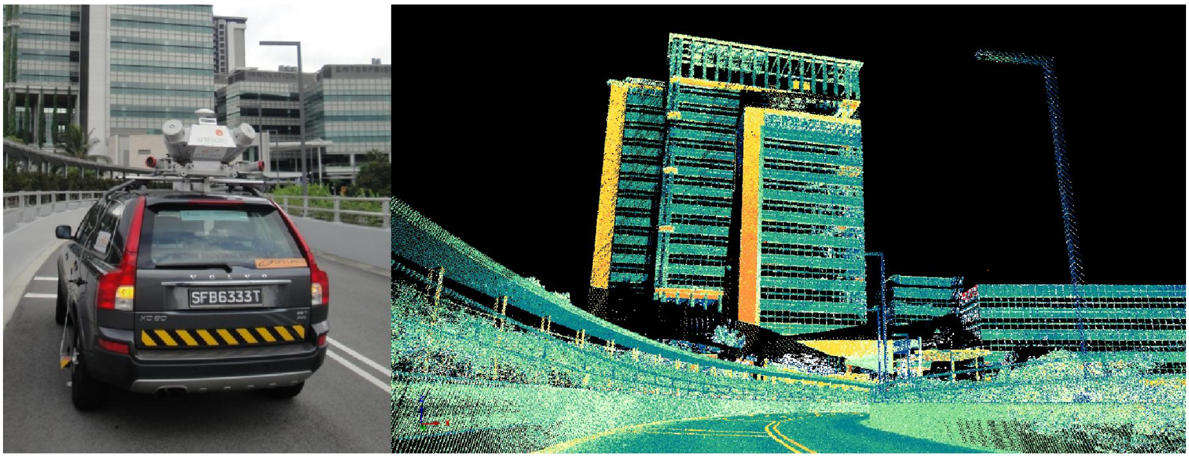
(c) (d)

Figure 7. 3D models of parts of the NUS campus, derived from UAV images. (a) 2 UAV images, (b) geometry model of buildings, (c) buildings and DTM, (d) textured model.

5.2 Acquisition and georeferencing of Mobile Mapping point cloud data

The Mobile Mapping System used is RIEGL WMX-250, which consists of two RIEGL VQ-250 laser scanners, an IMU/GNSS unit, a distance measurement indicator, and two calibrated optical cameras. The system can collect time stamped images and dense point clouds with a measurement rate up to 600K Hz and 200 scan lines per second. Figure 8a shows the system installed on a car. Figure 8b shows a sample of point cloud data of the CREATE area, located at NUS campus “University Town”, rendered according to the intensity values.

This project delivered a 16.1 km long trajectory of point clouds and video images. This resulted in 34.4 GB raw point cloud data of road sides, which have been collected within 3 hours, with 5.25 GB sequences of overlapping street images. Due to the mostly bad quality of these images they have not been used.



(a) (b)

Figure 8. (a) Mobile Mapping System and (b) point cloud example data at CREATE building at NUS campus “University Town”

Figure 9 shows the MMS trajectory. The small image blocks represent the intensity values of the Laserscanner.

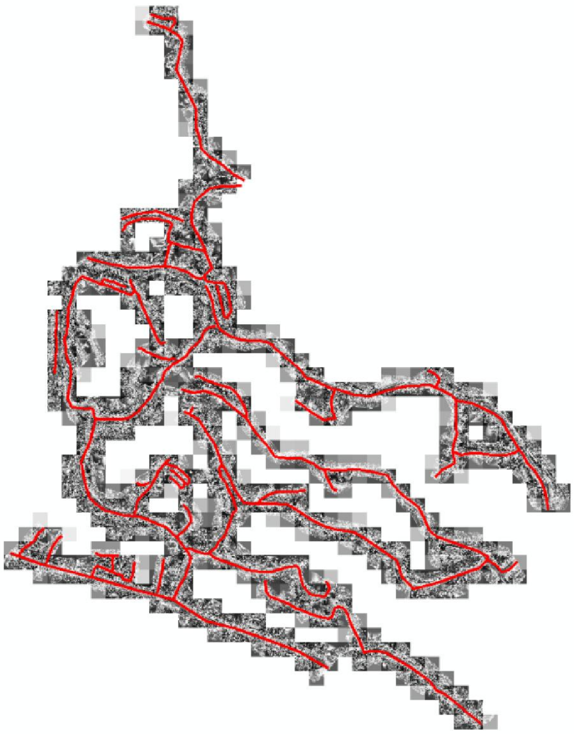


Figure 9. Trajectory of recorded MMS data at NUS campus.

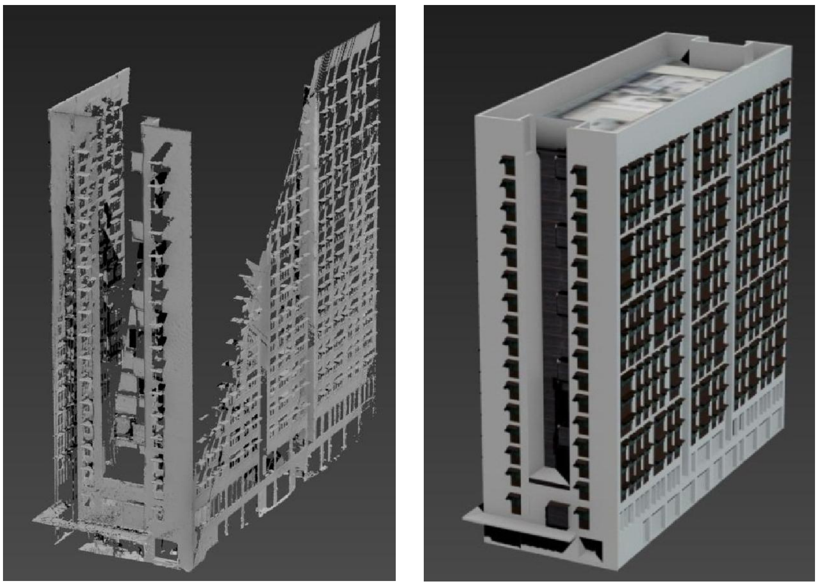
The point clouds have been georeferenced with control points derived from the adjusted UAV image block. Due to many GPS signal losses a great number of control points (169) had to be introduced.
The software used for trajectory adjustments is RiProcess, designed by the RIEGL company for managing, processing analyzing and visualizing data acquired with airborne and terrestrial mobile laser scanning systems. A two-step procedure is applied to adjust the data using well defined control points in the point clouds. The

locations of these control points were chosen regarding criteria like spatial distribution, but also at crossroads, where there were overlapping areas from different passages. In these overlapping areas the fitting is done in two steps, first relative, then absolute to the control points.

A georeferencing accuracy check has been conducted on newly measured check points, rather than on the control points themselves. We manually measured 16 check points from both the UAV stereo images and the point cloud data, evenly distributed over the whole area along the roads. For details of the procedure see Huang et al., 2013.

An accuracy analysis of the georeferencing resulted for the 16 check points the following RMSE values of 11 cm for planimetry and 20 cm for height. These are values which could be expected given the cumulative error budget of UAV images and Laserscan point clouds.

The 3D modeling with point clouds is work in progress. We just present here one building, which was derived from a highly incomplete point cloud, while the texture was taken from terrestrial images. Under the given project conditions high incompleteness of the point cloud is rather the rule. Figure 10a shows the point cloud of the building, while Figure 10b shows the texture mapped building, completed with the 3D roof model derived from UAV images.



a) b)

Figure 10. Result of MMS point cloud data processing. (a) point cloud from MMS, incomplete (roof is missing totally), (b) textured model, including roof structure from UAV images, texture from terrestrial images.

While the 3D façade is derived from the MLS point cloud, the roof geometry and texture comes from the UAV images. Since the MMS point cloud has been registered to the coordinate system of the UAV data, the photogrammetric roof model should fit closely to the façade model.

The manual modeling procedure using 3ds Max works as follows:

(a) Wrap the building point cloud into a mesh model and import it into 3ds Max
(b) Import the photogrammetry roof model into 3ds Max. Both datasets do not match perfectly. The deviation is adjusted manually.
(c) Edit the façade plane to generate the façade features such as windows, balconies and awnings, according to the geometric features in the point cloud mesh model.
(d) For the façade area without point cloud coverage, the façade features can be deduced from the features generated already. Terrestrial or oblique images of the façade can also provide further information for this deduction.
(e) Texture the façade with terrestrial images, which should have been calibrated for good fit (especially the lens distortion should have been removed).

Conclusions

In the first part of this paper we have shown what Geomatics can contribute to the newly evolving smart cities. As an example we have described the functions and products of Geomatics in the context of the SEC-FCL (Singapore-ETH Centre for Global Environmental Sustainability – Future Cities Laboratory) project. A particularly important function is 3D/4D city modeling. We have shown how high-resolution stereo satellite images can be used to derive such models. This followed a fairly standard procedure. Georeferencing with subpixel accuracy was achieved by bias-corrected Rational Polynomial Functions (RPF). The buildings were modeled using CyberCity Modeler and a derivative therefrom. Texture mapping in Punggol was done with an in-house developed software.

In a pilot project the campus of the NUS (National University of Singapore) has been recorded by a Falcon-8 octocopter. This aerial image data has been amended by point cloud data from a Mobile Mapping System and terrestrial images. This results in procedures of fusion on the levels of data processing and of value-added data. At this very high level of resolution (5 cm image footprint) we are facing some serious modeling problems, both from images and point clouds, which cannot be solved by automated routines. Therefore manual and semi-automated modeling still play a key role. This is work in progress. The richness of the data allows many more investigations and products.

Geomatics contributes significantly to the spatial intelligence of modern smart cities. Where does the future take us? It is easy to predict. Those cities that do not change, that do not forge ahead with the use of innovative urban planning, technological and governance models, and intelligent use of resources, those that do not follow the concept of smart cities, will be left behind, with all the negative consequences for their population. They will lose financially, miss the best human talents and suffer economically and environmentally. Yet, in forward-looking and future-oriented cities Geomatics will continue to play an important role in this scenery.

In conclusion, geospatial techniques and Geomatics technologies, in combination with other engineering subjects and social and natural sciences, play an indispensable role in the development of future smart cities. This opens new venues and opportunities for Geomatics, both in terms of R&D and practical applications. It is up to the scientific, development and professional communities to make good use of these opportunities.

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References

Gruen, A., Wang, X., 1998. CC-Modeler: a topology generator for 3-D city models. ISPRS Journal of Photogrammetry and Remote Sensing, 286-295

Huang, X., Gruen, A., Qin, R., Du, T., Fang, W., 2013. Integration of mobile laserscanning data with UAV imagery for very high resolution 3D city modeling. Presented Paper International Symposium on Mobile Mapping Technology, Tainan, Taiwan, May 1-3 (http://conf.ncku.edu.tw/mmt2013/)

Li, D., Shan, J., Shao, Z., Zou, X., Yao, Y., 2013. Geomatics for Smart Cities - concept, key techniques and applications. Geo-Spatial Information Sciences, Taylor&Francis, Vol.16, No.1, March, 13-24

Mueller-Arisona, St., Zhong, Ch., Huang, X., Qin, R., 2013. Increasing detail of 3D models through combined photogrammetric and procedural modeling. Geo-Spatial Information Sciences, Taylor&Francis, Vol.16, No.1, March, 45-53

Pierrot Deseilligny, M. and Clery, I., 2011: APERO, open source bundle adjustment software for automatic calibration and orientation of set of images. Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XXXVIII-5/W16, 269-276

Qin, R., Gruen, A., Huang, X., 2012. UAV Project – building a reality-based 3D model of the NUS (National University of Singapore) campus. Proceedings of the ACRS2012, Pattaya, November 26-30, (http://acrs2012.gistda.or.th/download/)

Schmitt, G., 2012. A planning environment for the design of future cities. In: Mueller-Arisona, S., Aschwanden, G., Halatsch, J., Wonka, P. (Eds.). Digital Urban Modeling and Simulation. Communications in Computer and Information Science, no. 242, Springer-Verlag Berlin-Heidelberg

Wang, T., 2003. Interdisciplinary Urban GIS for Smart Cities: advancements and opportunities. Geo-Spatial Information Sciences, Taylor & Francis, Vol.16, No.1, March, 25-34

Wang, T., Gruen, A., 2012. Georeferencing accuracy analysis of WorldView-02 and IKONOS images of Singapore based on RPFs. Proceedings of the ACRS2012, Pattaya, November 26-30, (http://acrs2012.gistda.or.th/download/)

HIC MAPPING WITH HIGH RESOLUTION OPTICAL SPACE IMAGES

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KEY WORDS: Optical space images, high resolution, scene orientation, accuracy, information content

ABSTRACT:
Topographic mapping traditionally was based on aerial images. With high and very high resolution optical space images now a competition to aerial images exists. The optical space images today are available without restrictions. Dominating criteria for mapping are the accuracy and the information content – what elements can be identified in the images. The accuracy is determined by the scene orientation and the relative accuracy within the stereo model. The direct sensor orientation reaches standard deviations up to 2m. If this is not satisfying or sensors with lower direct sensor orientation accuracy shall be used, ground control points or other methods for the scene orientation have to be used. The location accuracy of the SRTM height model or TerraSAR-X scenes for several applications is satisfying and SRTM can be used instead of control points. The relative accuracy within the stereo model is not the limiting factor for the possible map scale, this is the information contents or object identification. The information content is dominated by the ground sampling distance (GSD), but it may be influenced also by the image quality. The image quality can be analyzed by edge analysis.

INTRODUCTION

Very high resolution space images with up to 0.5m ground sampling distance (GSD) today are competing with digital aerial images for mapping purposes. The access to high resolution space images is simple and not restricted as it is in several countries the case for aerial images. The direct sensor orientation of optical satellites has reached standard deviations of the ground coordinates in the range of 2m, enabling mapping also without ground control points. With the radar satellites TerraSAR-X and TanDEM-X even a direct sensor orientation in the range of 0.1m is possible (Eineder et al. 2013). Such accuracy requires the information of the Earth tide and the continental drift. This allows accurate ground control information determined from radar images for the orientation of optical images. Nevertheless also classical ground control points may be used to improve the sensor orientation.

The image quality of the very high resolution space imagery is usually very good and can be compared with original digital aerial images, so the generation of topographic maps is not a problem. By the rule of thumb a GSD of 0.1mm in the image is required for topographic mapping, corresponding to a map scale of 1:5000 based on images with 0.5m GSD. As side condition the GSD above 5m is not useful for topographic mapping because it does not allow the identification of some objects important even for small map scales. Of course today maps are generated via Geo Information Systems (GIS), but even if the information is directly connected with ground coordinates, the information details define a presentation scale corresponding to the former map scale.

VERY HIGH RESOLUTION OPTICAL SPACE SYSTEMS

The definition "very high resolution" varies depending upon the application. Here it is used for optical images with 1m GSD and better for the panchromatic channel. Only space systems from which images are available without restrictions are mentioned. The high number of military reconnaissance systems is not included here.

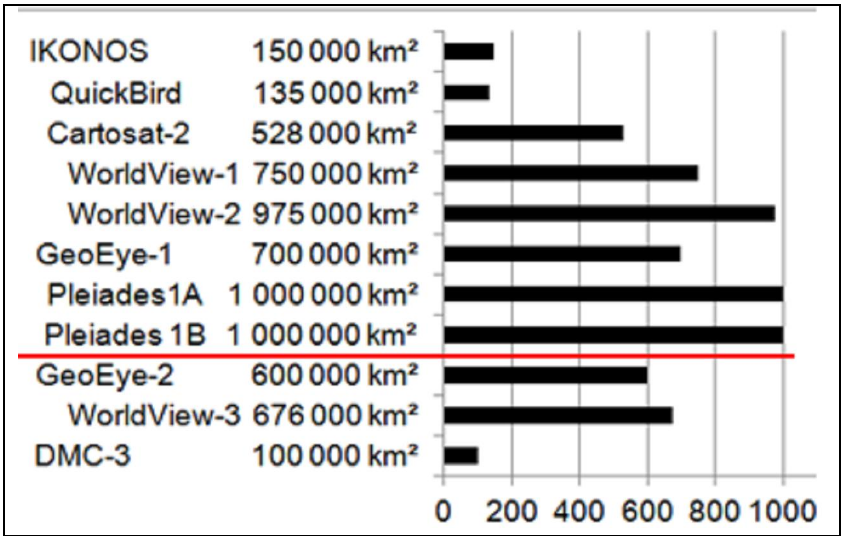


Figure 1: Theoretical daily imaging capacity

The possibility to get actual images is strongly depending upon the imaging capacity (figure 1). Against the time before 2007 the today imaging capacity of the listed sensors is more as 20 times higher, enabling a quite improved access to actual data.
In table 1 only active satellite systems from which images are available without problems are included. Military reconnaissance satellites are not shown. Resurs-DK 1 is not listed because of restrictions with image resolution and the since 2010 reduced resolution to 1.3m GSD. OrbView-3 was only active from 2003 up to 2007.

Most systems have a very high resolution panchromatic channel and lower resolution multispectral channels. Usually there is a linear relation of 4.0 between the panchromatic and the multispectral resolution, requiring a pan-sharpening for very high resolution colour images. EROS-B, the Cartosat-2 series and KOMPSAT-3 are equipped with staggered arrays, that means with 2 CCDs shifted half a pixel against each other. So the physical pixel size is two times larger as the nominal size. For example Cartosat-2 has physically 1.64m GSD, but by the staggered arrays images with 0.82m GSD are generated. This is really improving the image quality, but not with the factor 2.0. Usually the effective pixel size of staggered systems is larger by approximately 20% (0.98m effective GSD instead of nominally 0.82m GSD) (see figure 6).

Table 1. Actual very high resolution optical satellites

Sensor , launch	**Altitude**	**GSD pan**	**Swath nadir**	**Pan/ms** channels
IKONOS 2 1999	681 km	0.82m	11.3km	Pan, 4ms
QuickBird 2001	450 km	0.61m	16.5km	Pan, 4ms
EROS B 2006	508 km	0.7m	7 km	Pan
KOMPSAT-2 2006	685 km	1m	15km	Pan, 4ms
WorldView-1 2007	494 km	0.45m	17.6km	Pan
WorldView-2 2009	770 km	0.46m	16.4km	Pan, 8ms
GeoEye 1 2008	681 km	0.41m	15.2 km	Pan, 4ms
Cartosat-2, 2A, 2B, 2007-2010	631 km	0.82 m	9.6km	Pan
KOMPSAT-3, 2012	685 km	0.7 m	16.8 km	Pan, 4ms
Pleiades 1A, 1B 2011/2012	694 km	0.7 m	20km	Pan, 4ms

Pleiades 1A and 1B have 0.7m GSD, but the images are distributed with enlarged size with 0.5m GSD. Of course by this enlargement the image quality is not improved.

In 2013 GeoEye-2 with 0.34m GSD and in 2014 WorldView-3 with 0.31m GSD and Cartosat-3 with 0.33m GSD for the panchromatic channel shall be launched. Up to now it is not clear if GeoEye-2 and WorldView-3 images will be available with this resolution or if they will be reduced to 0.5m GSD because of legal restrictions in the USA. In addition a series of other very high resolution satellites is announced.

SCENE ORIENTATION

For data acquisition the relation between image and ground position is required. This relation is expressed via the scene orientation. From the two dimensions in the image it is not possible to determine three coordinate components in object space, so two images taken from different positions or the object height must be available. For perspective images the image orientation is expressed by the three coordinate components of the projection centre and three rotations. In general we have the same situation for CCD-line scanner images, but here the orientation is changing from CCD-line to CCD-line, so additional information about the relation of the projection centres and the changes of the rotations is required. For satellites the orbit location is not a problem, today this is known via GNSS-position with sub-meter accuracy, the limitation of the orientation information is caused by the attitudes. The modern optical satellites are taking the images in pre-planned orientations, mostly in North-South direction or in any other chosen direction. That means the satellite rotation is changing from line to line (figure 2).

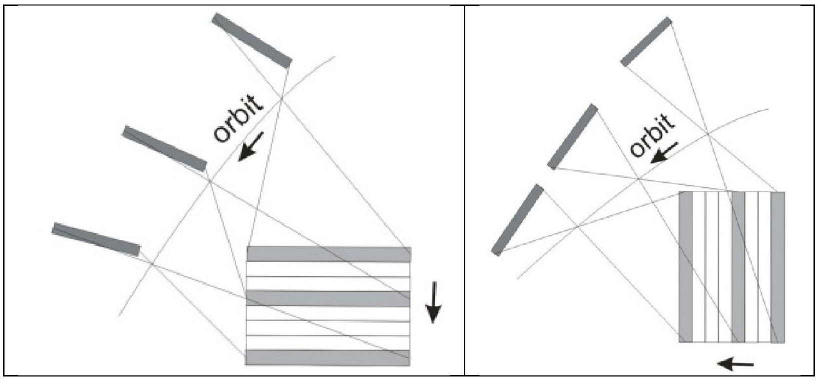


Figure 2: CCD-line orientation during imaging

The control and orientation of the individual CCD-line attitude is available based on inertial measurement units (IMU) with satisfying accuracy. Based on the header information delivered together with satellite images, the scene orientation can be reconstructed and improved by ground control points.

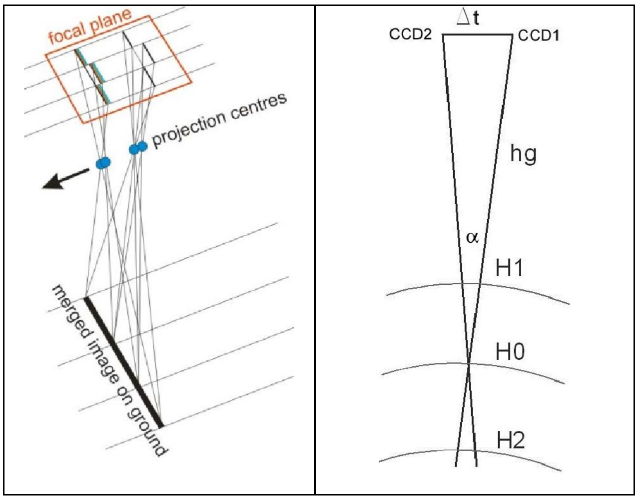


Figure 3: left: combination of CCD-lines to a homogenous line in object space
right: mismatch of the sub-CCD-lines depending upon object height

Most very high resolution satellite images are based on a combination of CCD-lines (figure 3 left). The CCD-lines are usually connected to homogenous images, respecting the difference in time and also rotations of the individual CCD-lines. By theory such a combination of the individual CCD-lines is only possible for a fixed height of the terrain (figure 3 right), but in reality the misfit between neighboured CCD-lines in an area with strong height variation is quite below one pixel. In most cases today the images are projected to a plane with constant height (e.g.

IKONOS/GeoEye Geo, OR Standard or SPOT level 1B), simplifying the scene orientation. At the beginning of the IKONOS imaging the former company Space Imaging did not like to publish the scene orientation, but based on the view direction of the image centre, the general orbit direction and the imaging time the imaging geometry could be reconstructed just based on one ground control point up to sub-pixel level (Jacobsen 2002).

Today most satellite images are delivered with Rational Polynomial Coefficients (RPC) expressing the image position by the relation of third order polynomials of X, Y, Z. They have the accuracy on the level of the direct sensor orientation. Several test with different types of satellite imagery showed the same accuracy based on geometric reconstruction as with bias corrected RPCs (RPCs improved based on ground control points).

If no or not satisfying orientation information is available, by geometric reconstruction the image geometry can be determined by adjustment if a satisfying number of ground control points is available with satisfying three-dimensional distribution. Another possibility is the use of approximations as 3D-affine transformation (figure 4, formula 1).

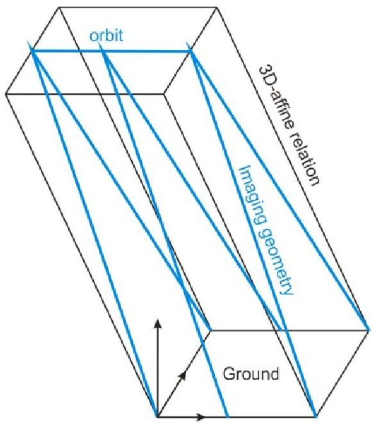


Figure 4: 3D-affine transformation in relation to real imaging geometry

$$xij = a1 + a2 \cdot X + a3 \cdot Y + a4 \cdot Z$$

$$yij = a5 + a6 \cdot X + a7 \cdot Y + a8 \cdot Z$$

(Formula 1)

$$xij = a1 + a2 \cdot X + a3 \cdot Y + a4 \cdot Z + a9 * X * Z + a10 * Y * Z + a13 * X * X$$

$$yij = a5 + a6 \cdot X + a7 \cdot Y + a8 \cdot Z + a11 * X * Z + a12 * Y * Z + a14 * X * Y$$

Formula 2: extended 3D-affine transformation for original images.

The 3D-affine transformation is only an approximate replacement of the correct geometric relation - it does not respect the perspective geometry in the CCD-line and no possible scan not in the flight direction (figure 2), in addition it requires more and three-dimensional well distributed ground control points. With a higher number of ground control points in rolling areas similar accuracy as with geometric reconstruction or bias corrected RPC-solution can be reached. With larger height differences in the object space the 3D affine transformation causes increased discrepancies. With an extended 3D-affine transformation (Jacobsen 2008, formula 2) the perspective condition in the CCD-line and a scanning not in the flight direction are respected. With a satisfying number of three-dimensional well distributed ground control points the same accuracy as with geometric reconstruction or bias corrected RPC-solution can be reached, but this is possible with a smaller number of ground control points by geometric reconstruction or bias corrected RPC solution.

Also the Direct Linear Transformation (DLT) sometimes is used for the orientation of optical satellite images. In general the DLT should not be used – it is based on the geometric model of perspective images what is not the case for today space images and it uses 11 unknowns which are strongly correlated in the case of the narrow angle optical space images. The extreme correlation of the unknowns can cause large deviations in areas with lower number of ground control points or especially in areas outside the range of the control points which cannot be controlled by the discrepancies at the used control points.

	SX, SY [m]	SZ [m]	GSD	Spx [ground pixel]
SPOT -3	8.4	4.1	10 m	0.4
MOMS	3.5	4.5	4.5 m	0.4 / 0.13
Cartosat-1	1.5	2.5	2.5 m	0.7
IKONOS	1.0	1.7	1 m	0.2
ASTER	10.8	14.6	15 m	0.5
GeoEye-1	0.3	0.5	0.5 m	0.7
WorldView-2	0.5	0.3	0.5 m	0.2

Table 2: Root mean square differences at independent check points

Sensor orientation by geometric reconstruction or bias corrected RPC-solution is independent upon the type of images (original images or images projected to a plane with constant height). With both methods and both image products the same accuracy has been reached. In general standard deviations of the coordinate components of 1.0 GSD or better were reached as the examples in table 2 show. The limiting factor is the identification of the control points in the images – with better control point identification the accuracy is better. This explains why the results in the height are similar to the results for the horizontal coordinate components

An orientation accuracy of one GSD is totally satisfying for mapping purposes.

MAPPING

The generation of topographic maps is dominated by the image resolution – with better resolution the details can be identified and classified better and the geometry is improved. In figure 5 the identification of details in the GeoEye-1 image is quite better as in the IKONOS image. The scanned analogue aerial photo (figure 5 left hand side) is disturbed as usual by the photo grain and is not better as the IKONOS image with lower nominal resolution. The effective resolution of this aerial photo, determined by edge analysis with point spread function, with 0.74m is clearly below the nominal resolution of 0.63m (see image 6).

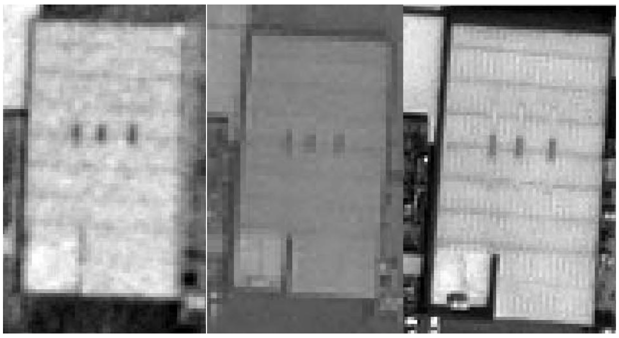


Photo 63cm GSD IKONOS GeoEye-1

Figure 5: From left: building in aerial photo 63cm GSD, IKONOS (1m DSD) and GeoEye-1 (0.5m GSD)

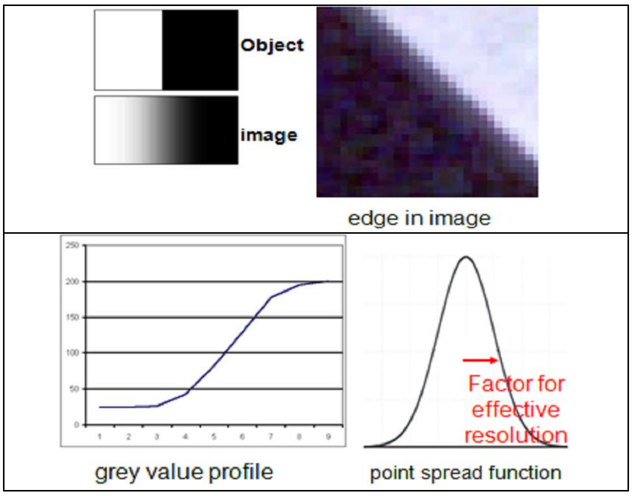


Figure 6: Determination of effective image resolution by edge analysis

An object with a sudden change of the brightness is imaged with a continuous change in the image (figure 6, upper part). The grey value profile, averaged over several pixels, shows the continuous grey value change in the image. A differentiation of this profile leads to the point spread function (figure 6, lower part). Half the width of the point spread function corresponds to the factor for the effective resolution; this multiplied with the nominal resolution is identical to the effective resolution, including the information for the identification of the objects.

Mapping can be based on a stereo pair or by mono-plotting based on ortho images. A stereoscopic view has some advantages for the correct object recognition, so few errors of object identification can be avoided as the misidentification of an excavation as building in an image with 2m GSD, but the final influence to the map contents is usually limited.

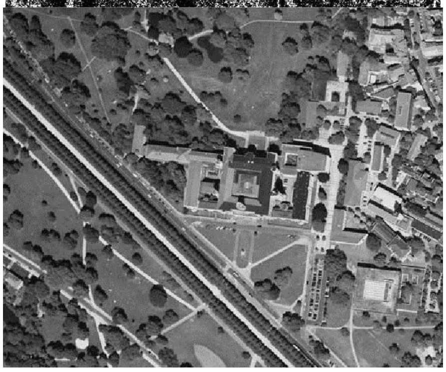
Figure 7:
Comparison of object identification in panchromatic and colour image

The colour of pan-sharpened images simplifies and speeds up the object identification (figure 7) (Dowman et al. 2012). As demonstrated by figure 7 in an unplanned area with not regular arrangement of buildings the identification of the buildings is quite simpler in colour images. Nevertheless nearly no loss of objects occurred by mapping based on panchromatic images, but the mapping supported by image colour is more economic because of the faster mapping.

With German TerraSAR-X, TanDEM-X and the Italian CosmoSkymed radar satellites with up to 1m GSD are available for civilian application. Synthetic Aperture Radar (SAR) images also can be used for mapping purposes (Lohmann et al 2004). Radar has the advantage of penetrating clouds, so images can be taken at any time and because of the active imaging also during night. This is important for tropical regions with nearly permanent cloud coverage and for time critical disaster monitoring. In some tropical regions SAR images are the only possibility for mapping, but as the comparison of a TerraSAR-X image with an optical image in the same area (figure 8) demonstrates, is the mapping with SAR-images not as easy. For humans optical images are corresponding to the standard view of objects, so the interpretation is simple. The imaging principle of radar is different and requires some training and understanding of radar imaging for the correct interpretation. An intensive test of information extraction from optical and SAR images (Lohman et al.

2004) showed that even trained staff especial in urban areas could not extract the same amount of information from SAR as from optical images. In urban area the radar layover makes the mapping of objects complicate. In rural areas the image information is roughly the same. As a very rough rule of thumb can be stated, that with two times the resolution of SAR-images, similar information as in optical images can be extracted as for example 1m GSD from SAR corresponds to 2m GSD from optical images (figure 9).

Figure 8: TerraSAR-X radar spot light image with 1m GSD



Same area in optical image with 1m GSD

Figure 9: above: optical image, followed by mapping with optical image, below: SAR image followed by mapping with SAR image (Lohmann et al 2004)

As figure 10 shows, depending upon the map scale different contents is required for topographic mapping. Starting with the presentation scale 1:25 000 map generalization starts – not all objects are shown, the information is grouped, partially replaced by symbols and not so important parts are eliminated. So in the map scale 1:25 000 all buildings and streets are included but not with the details included in the scale 1:5000. The map with scale 1:50 000 in the southern part instead of a sequence of 7 buildings includes just the symbol of 4 buildings and in the scale 1:100 000 the smaller roads are eliminated. Corresponding to this, for the generation of maps different details have to be extracted from the images that means a lower image resolution may be satisfying for topographic mapping.

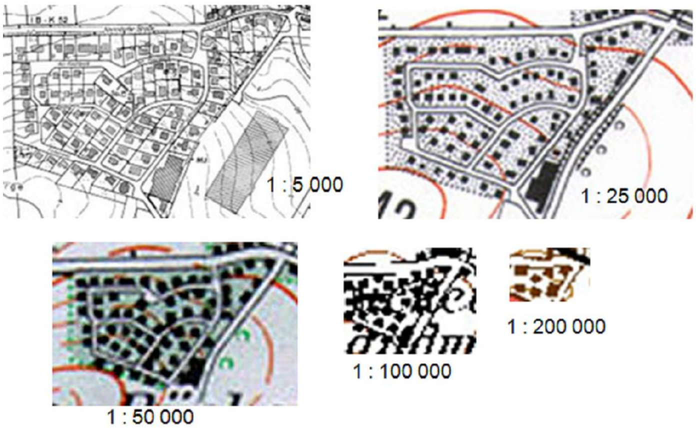


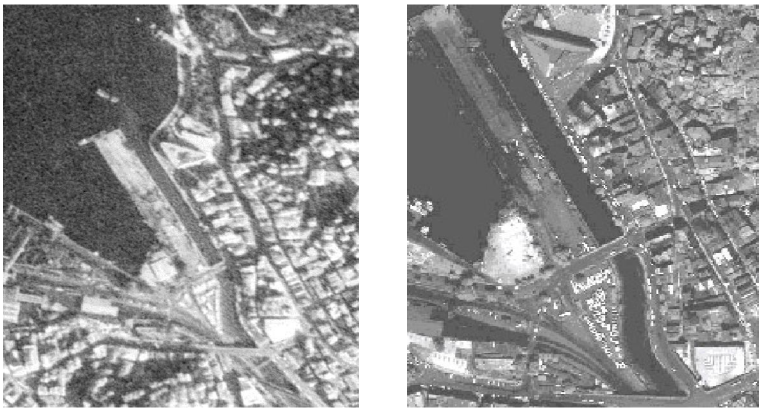
Figure 10: Information contents of topographic maps with different scale

Topographic mapping for civilian application started with SPOT-1, having 10m GSD for the panchromatic channel, in 1986. But a resolution of 10m was not really satisfying for any map scale because it did not allow the identification of all map details important for any scale, as for example railways and streets. For example a major road in Nigeria could not be identified in SPOT images because of overhanging trees from both sides. This became better with the former military satellite images as CORONA and KFA1000, but with the disadvantage that no actual images could be ordered. With IRS-1C in 1995 the resolution was improved to 5.8m GSD, but the effective resolution of the staggered CCDs was limited to effective approximately 7m GSD. The real breakthrough for topographic mapping came with IKONOS in 1999. The 1m GSD-images of IKONOS and later from the other very high resolution satellites have been intensively used for topographic mapping, especially in areas where the access to aerial photos was restricted. Nevertheless also today country wide mapping mostly is less expensive with aerial images even if they may have the same resolution as the space images.

The comparison of some space images in figure 11 demonstrates the differences. The scanned KFA-1000 photo with nominally 1.6m GSD has the typical influence of the image grain causing a reduced effective resolution of approximately 2m. The contrast in original digital images is quite better and more details can be identified with higher resolution.

The GeoEye-1 image in figure 12 in a fast view cannot be separated from an original digital aerial image. The samples of scanned aerial photos with 0.7m GSD in figure

12 are not as good. So today it is not important if the image has been taken from space with 700km distance or from air with 5km distance if the ground resolution is the same.



KFA-1000, 1.6m GSD IKONOS, 1m GSD

QuickBird, 0.6m GSD WorldView-1, 0.5m GSD

Figure 11: comparison of optical space images (not full resolution)

Figure 12: above GeoEye-1 image with 0.5m GSD, below samples from aerial photos with 0.7m GSD

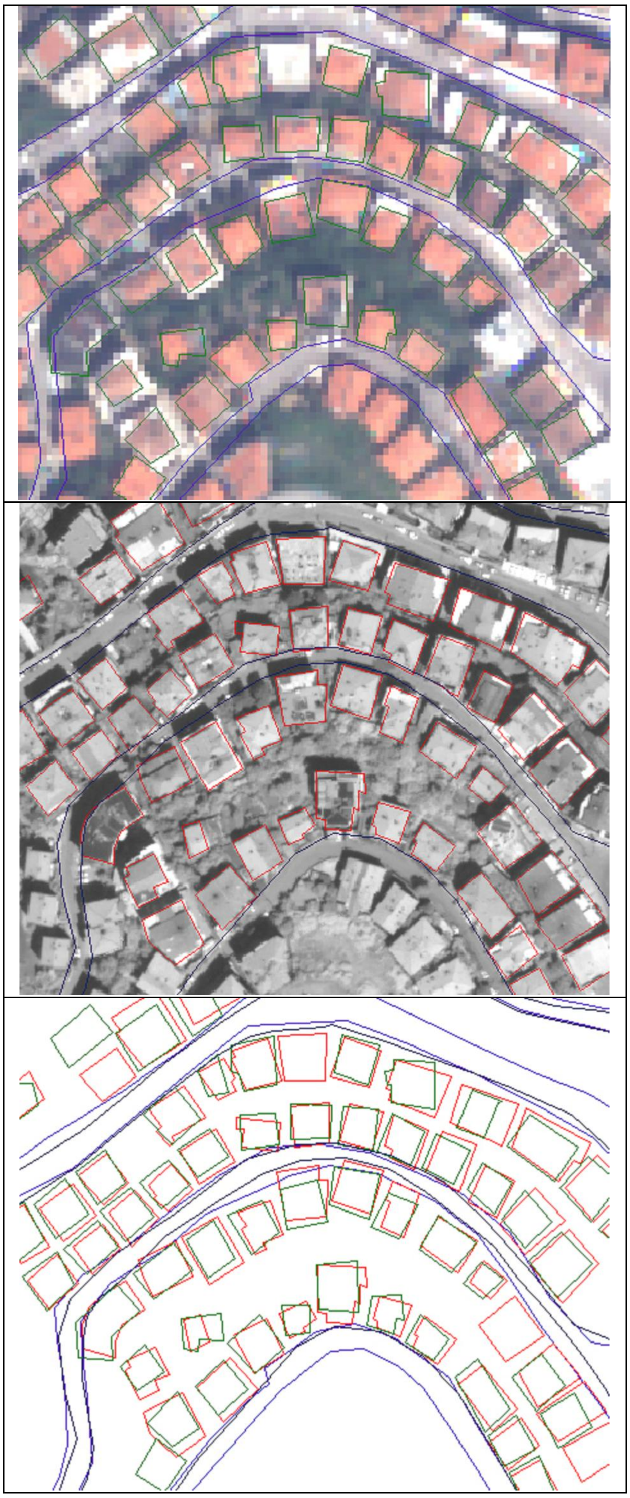


Figure 13: above: mapping with QuickBird colour image (2.4m GSD), Centre: mapping with QuickBird panchromatic image (0.6m GSD), below: overlay of generated vectors

The mapping test demonstrated in figure 13 shows that buildings can be mapped in images with 2.4m GSD – any building has been identified. But the details required for a larger map scale as 1:5000, including all building extensions can only be identified in the image with 0.6m GSD.

	required GSD
urban buildings	2m
foot path	1 - 2m
minor road network	5m
rail road	5m
fine hydrology	5m
major road network	10m
building blocks	10m

Table 3: required GSD for topographic mapping

As result of several mapping tests the required GSD for the identification of the different objects as listed in table 3 has been found. Of course as mentioned above there are differences in the object details depending upon the used GSD.

Based on several maps of different scale, generated with different space images, as rule of thumb we have the relation of approximately 0.05mm up to 0.1mm GSG in the map scale required for satisfying topographic maps. In addition we have the side condition that the GSD should not be smaller as 5m to guarantee the mapping required in any case independent upon the map scale. Figure 14 shows this relation in a graphical manner. It includes also the information that thematic maps sometimes have not the same requirement, so dependent upon the topic also larger scale thematic maps can be generated.

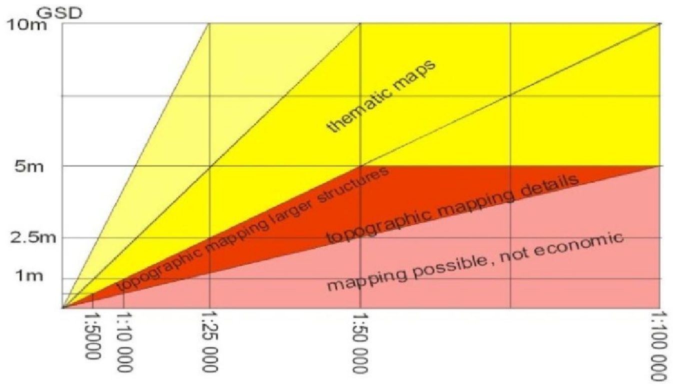


Figure 14: Required ground sampling distance for mapping

The above mentioned relation of image GSD and map scale is based on the identification of the objects; the accuracy has not been respected up to now. For topographic maps usually a standard deviation of 0.2mm up to 0.3mm is required. For the map scale 1:10 000 this corresponds to 2m up to 3m. For example with IKONOS-images having 1m GSD, which is required for such a map scale, under operational conditions well defined objects can be mapped with standard deviation of 1 GSG or 1m. That means the horizontal mapping accuracy can be reached without problems with images required for the identification of objects or reverse the limiting factor for the map scale is the image resolution and not the accuracy.

MAP UPDATE

Existing topographic maps must not be generated again, in most cases if not too much has been changed, a map update is more economic. Of course for map update the same relation of image GSD to map scale exists. Map update sometimes is very time consuming for identifying the changes. Very often some objects are not recognized. The update of buildings may be supported by a digital surface model.

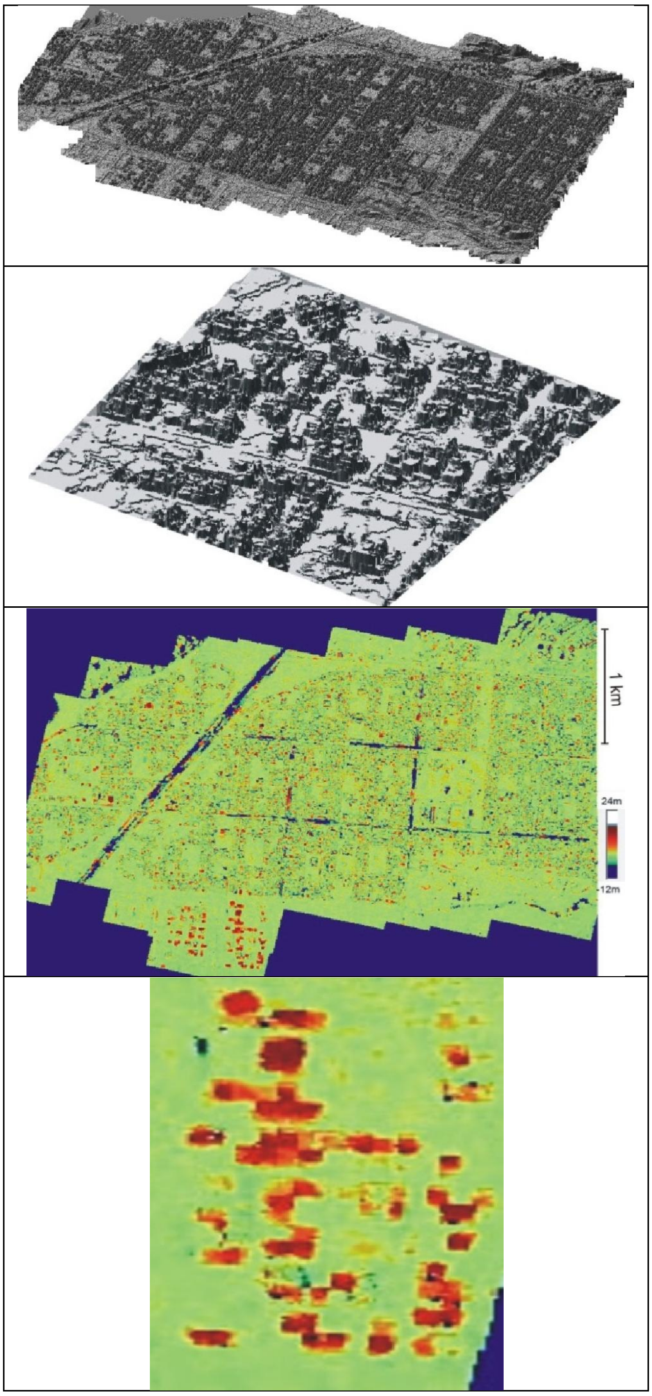


Figure 15: above: 3D-shaded view to IKONOS DSM (imaged in May 2008), centre above: sub-area GeoEye-1 (imaged in September 2009), centre below: difference of both height models, below: detail of a new settlement

For the update of a 3D-building model a digital surface model (DSM) based on an IKONOS stereo pair from May 2008 and a DSM based on a GeoEye-1 stereo pair from September 2009 has been generated (Alobeid et al. 2011). The differences of both DSM (figure 15) show the changes. All changed buildings have been identified including buildings where just one level has been added. Especially such changes just by one level are very difficult to be identified by manual inspection. In the whole suburb changes occurred and not just in new settlement areas.

CONCLUSION

Topographic maps today can be generated based on satellite imagery in the same manner as with aerial images. The resolution may be the same and the image quality shows no remarkable difference between optical space images and digital aerial images. Under special conditions maps are generated with SAR images, but this requires special training for the operators and causes especially in build up areas some problems, so it is usually limited to tropical areas and disaster mapping.

If the rule of thumb of approximately 0.1mm GSD in the map scale is respected, the map contents based on optical space images can be compared with contents based on aerial images. Today the availability of actual space images has strongly been improved caused by the higher number of optical satellites and the strongly extended imaging capacity. For limited areas it is simpler to organize mapping based on space images as to start a photo flight.

REFERENCES

Alobeid, A., Jacobsen, K., Heipke, C., Alrajhi, M., 2011: Building Monitoring with Differential DSMs, ISPRS Hannover Workshop 2011, IntArchPhRS Vol XXXVIII-4/W19

Büyüksalih, G., Baz, I., Alkan, M., Jacobsen, K., 2012: DEM Generation with WorldView-2 Images, ISPRS Symposium Melbourne 2012, IntArchPhRS Vol XXXVIII-B1

Dowman, I., Jacobsen, K., Konecny, G., Sandau, R., 2012: High Resolution Optical Satellite Imagery, Whittles Publishing, ISBN 978-184995-046-6

Eineder, M., Bamler, R., Cong, X., Gernhardt, S., Fritz, T., Zhu, X., Balss, U., Breit, H., Adam, N., Floricioiu, D., Globale Kartierung und lokale Deformationsmessungen mit den Satelliten TerraSAR-X und TanDEM-X, Zeitschrift für Vermessungswesen 1/2013, pp75-94

Jacobsen, K., 2002: Mapping with IKONOS images, EARSeL, Prague 2002"Geoinformation for European-wide Integration" Millpress ISBN 90-77017-71-2, pp 149-156

Jacobsen, K., 2008: Satellite image orientation, International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XXXVII, Part B1 (WG I/5) pp 703-709

Jacobsen, K., 2011: Characteristics of very High Resolution Optical Satellites for Topographic Mapping, ISPRS Hannover Workshop 2011, IntArchPhRS Vol XXXVIII 4/W19

Lohmann, P., Jacobsen, K., Pakzad, K., Koch, A., 2004: Comparative Information Extraction from SAR and Optical Imagery, Istanbul 2004, Vol XXXV, B3. pp 535-540

CHARACTERISTICS OF WORLDWIDE AND NEARLY WORLDWIDE HEIGHT MODELS

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ABSTRACT:

Worldwide and nearly worldwide covering height models are partially available free of charge in the internet, partially the data are available without restrictions, but have to be purchased. These height models are based on optical or radar space imagery. Depending upon the type of input data and the used sensor orientation the spacing and accuracy, as well as the characteristics, of the height models are different. An overview about the absolute and relative accuracy, the consistency, error distribution and other characteristics as influence of terrain inclination and aspects is given. Not in any case the information content corresponds to the point spacing and partially the accuracy varies remarkably. Partially by post processing the height models can or have to be improved.

INTRODUCTION

Digital height models (DHM) are required for several remote sensing and GIS application. The generation of DHM is time consuming and expensive, so available nearly worldwide covering height models should be taken into account if they are able to solve the requirements of handled projects. For most freely available height models some accuracy information is available, but the quality of a DEM cannot be described just with one figure for the accuracy. In addition different accuracy descriptions are in use and the accuracy may depend upon some parameters as terrain inclination, aspects and number of images used for the point determination. It is also necessary to separate between relative and absolute accuracy – the whole DEM may be shifted in X, Y and Z. In addition the definition of the height model as Digital Elevation Model (DEM) with the height of the bare ground or as Digital Surface Model (DSM) with the height of the visible objects as vegetation and buildings is important. Based on automatic matching of optical images DSMs are generated. Height models based on Synthetic Aperture Radar (SAR) covering large areas are usually determined by interferometry (InSAR) based on InSAR-configurations. By radargrammetry usually only smaller areas are handled. For height models based on SAR the height in the vegetation areas depends upon the wavelength – the long wavelength L- and P-band can penetrate the vegetation while with C- and X-band deliver heights close to the top of the vegetation.

SPECIFICATION OF ACCURACY

Traditionally the geometric quality of a DEM is determined with a more precise height model. For a correct definition of the accuracy it has to be checked if there are systematic differences between the investigated DHM and the reference DHM (figure 1). The shifts and scale differences should be determined by adjustment to guarantee an optimal fit. Shifts are often based on datum problems, but it may be caused also by limitations of the orientation accuracy.

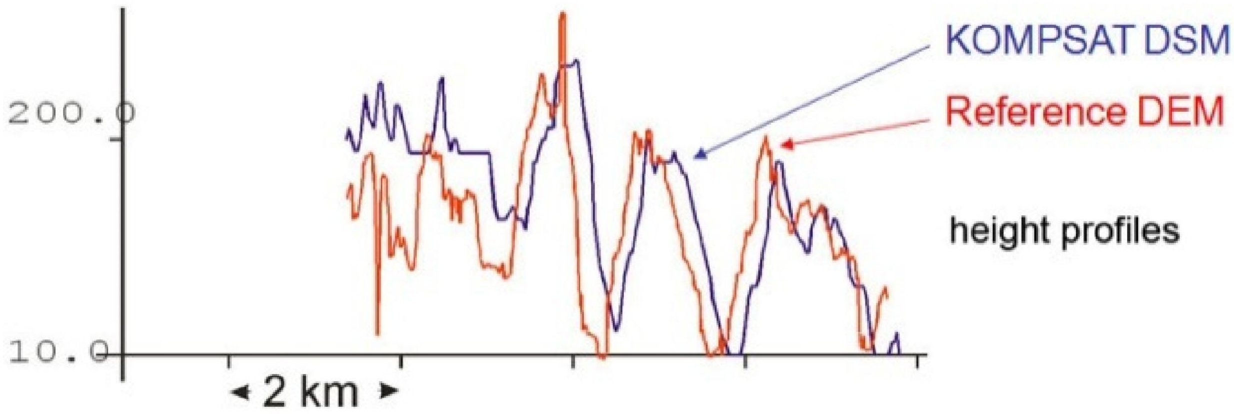


Figure 1: Shift of height models caused by datum problems in a mountainous area – shift in X=80m, in Y=187m, leading to RMSZ reduction from originally 50m to 15.8m

The accuracy figures or uncertainty parameters are "parameter, associated with the result of a measurement, that characterizes the dispersion of the value that could reasonably be attributed to the measure and" (JCGM 100:2008). JCGM 100:2008 (Evaluation of measurement data – Guide to the expression of uncertainty in measurement) of the Joint Committee for Guides in Meterology, where ISO is a member, is related to measurements. Of course computed object coordinates are no direct measurements, but the accuracy figures can be used for this if similar conditions for the determination exist. If this is not the case, we have to express the accuracy depending upon the different conditions e.g. terrain inclination or number of images per object point.

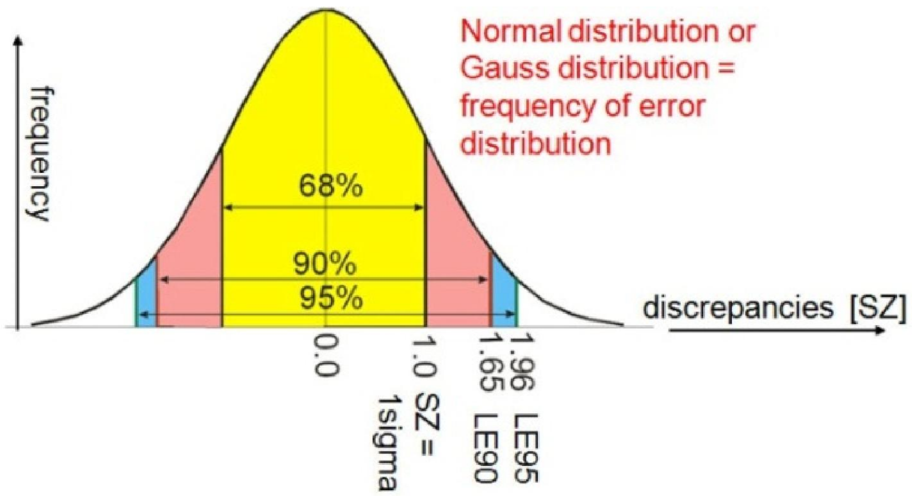


Figure 2: Relation SZ to LE90 / LE95

Table 1: accuracy figures

figures	definition
RMSZ	Square mean of discrepancies
SZ	Square mean of (discrepancies – bias)
MAD	Linear mean of absolute values of discrepancies
NMAD	MAD related to 68% probability (MAD*1.48)
LE50	Median value of discrepancies
LE90	Threshold including 90% of discrepancies
LE95	Threshold including 95% of discrepancies

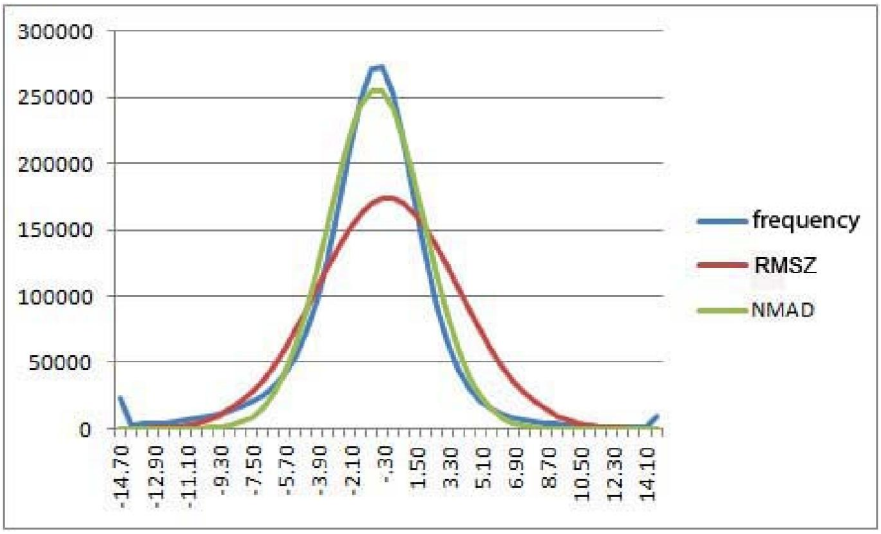


Figure 3: Frequency distribution of discrepancies of Cartosat-1 DSM against reference DEM in open areas and normal distribution based on RMSZ and NMAD

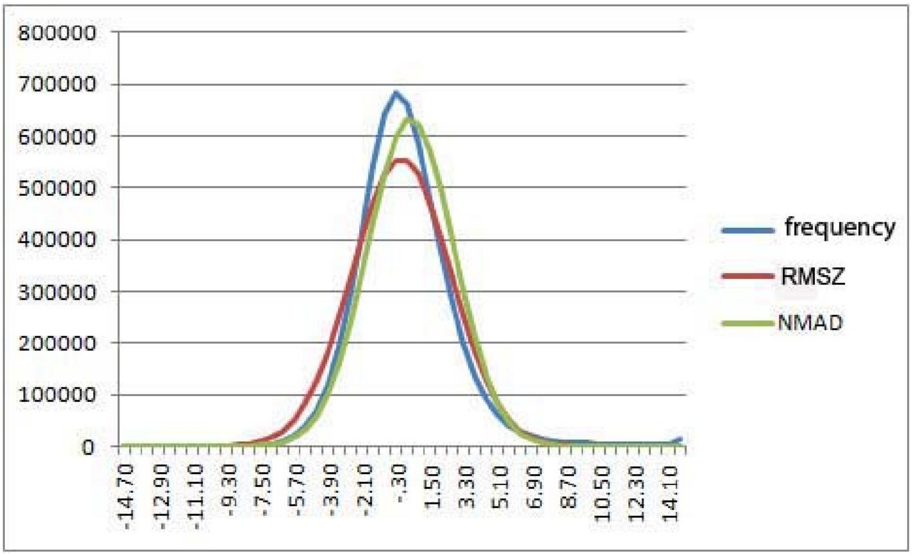


Figure 4: Frequency distribution Cartosat-1 DSM against reference DEM in open areas after filtering points not belonging to bare earth and normal distribution based on RMSZ and NMAD

The justification and meaning of the accuracy figures has to be checked in relation to the frequency discrepancies of the height discrepancies of the evaluated DHM against the reference DHM. In figures 3 and 4 the frequency distributions (blue lines) are compared with the normal distributions for the same number of discrepancies and based on the root mean square discrepancies and the NMAD as standard deviations of the normal distribution. Under the condition of normal distributed discrepancies NMAD should be identical to SZ. If no bias is available RMSZ is identical to SZ. In figures 3 and 4 the function related to RMSZ is centered to the discrepancy 0.0, while the function related to NMAD is centered to the bias. In figure 3 the normal distribution related to NMAD is not far away from the frequency distribution, while the normal distribution related to RMSZ does not fit very well. This is caused by the higher number of larger discrepancies – the frequency distribution of the extreme positive and negative class contain all respected larger discrepancies, so it goes up significantly. The larger discrepancies influence the RMSZ via the square mean quite more as the normalized linear absolute mean. The "open areas" in the test field contain also elements not belonging to the bare earth, namely single trees and buildings. If such elements are filtered out, the normal distribution especially based on the RMSZ fits quite better (Passini et al. 2002). The shown relation is a typical result for all investigated height models.

Table 2: accuracy figures of Cartosat-1 DSM/DEM against reference DEM – test area Warsaw

Accuracy figures	Not filtered	filtered	Not filtered / filtered
RMSZ	3.77m	2.56m	1.47
SZ	3.72m	2.51m	1.48
MAD	1.75m	1.53m	1.14
NMAD	2.59m	2.27m	1.14
LE50	1.73m	1.51m	1.15
LE90	5.43m	4.09m	1.33
LE95	7.65m	5.21m	1.47
SZ (slope)	3.74m + 3.45m*tan(slope)	2.48m + 8.3*tan(slope)	
Not used (>40m)	0,02%	0%	

Table 2 shows the different accuracy figures. In the case of the not filtered DSM, which includes single trees and buildings, there is a relation of 1.46 between SZ and NMAD while this is reduced to the relation of 1.10 for the filtered data. For exactly normal distributed values SZ and NMAD should have the same value. Only for the filtered data we have a satisfying similarity between the Cartosat-1 DHM and the reference DEM. The dependency upon the terrain inclination can be neglected because of the dominating flat area. By filtering elements not belonging to the bare ground RMSZ, the standard deviation SZ and LE95 are strongly improved by factors 1.47 up to 1.48. Also LE90 is changed by the factor 1.33 while the change of MAD and NMAD is limited to 1.14. That means NMAD is not so sensitive for larger discrepancies.

The relation for this example is typical for all analyzed height models – it is not so simple to express the uncertainty of the determination just by one figure. NMAD expresses the uncertainty for the majority of the height discrepancies better as SZ, but a higher number of larger discrepancies have to be expected as expressed by the normal distribution. In addition for undulated terrain the dependency upon the terrain inclination has to be respected. If elements not belonging to the bare ground are included in the data set, we have no homogenous relation for expressing the uncertainty. Under operational conditions usually the details of the accuracy are neglected and we are working with accuracy figures not describing the uncertainty precisely.

The often used linear errors LE90 and LE95 are thresholds in the frequency distribution. These thresholds are strongly depending upon the larger discrepancies which are usually caused by not homogenous data sets. By this reason LE90 and LE95 are not recommended.

ANALYZED DATA SETS

The world-wide old GTOPO30 of the USGS and US NGA has been replaced by the GMTED2010:
(http://eros.usgs.gov/#/Find_Data/Products_and_Data_Available/GMTED2010), which is available also with 7.5 arc-seconds (arcsec) point spacing, corresponding to 231m at the equator (Danielson & Gesch 2011). The former GTOPO30 with just 30 arcsec point spacing was very inhomogeneous, this has been improved for large areas by the use of SRTM-height models.
By interferometric synthetic aperture radar (InSAR) based on the Shuttle Radar Topography Mission (SRTM) in 2000 a height model has been generated for the area from 56° Southern up to 60.25° Northern latitude:
(http://www.cgiar-csi.org/data/elevation/item/45-srtm-90m-digital-elevation-database-v41) – NASA/USGS.

The SRTM height model is available with 3 arcsec point spacing, corresponding to 93m at the equator. The original information with 1 arcsec spacing up to now is available only for the USA and for other areas only under special national agreements. The first version, available since 2003, included some gaps in mountainous and dessert regions which now are improved by gap-filling (Reuter et al 2007).

Parallel to the US C-band on the SRTM there was also the German/Italian X-band. Also based on this, height models are available, but they have larger gaps between the data stripes (figure 6). On the other hand the data are free available with 1 arcsec spacing (http://www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10212/332_read-817/).

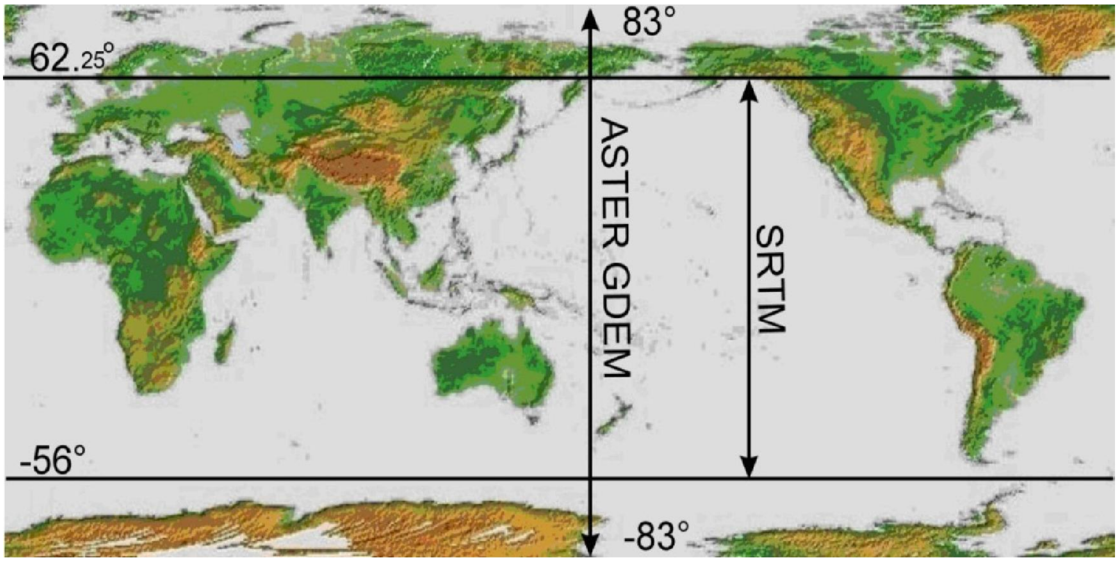


Figure 5: Worldwide coverage by SRTM DSM and ASTER GDEM

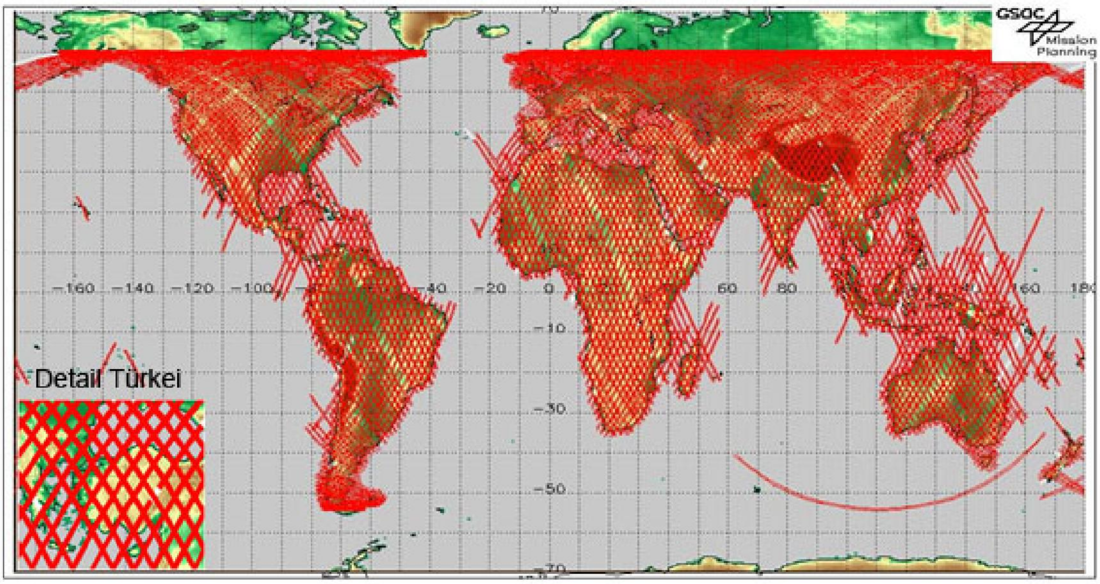


Figure 6: Gaps between the strips covered by STRM X-band

Based on the Japanese optical stereo sensor ASTER on the US platform Terra with 15m ground sampling distance (GSD) and a base to height relation of 1:2.1, several stereo models have been generated since 2000. All stereo models have been used for the generation of height models by automatic image matching (Tetsushi 2011). The ASTER GDEM is covering the range of the latitude from +83° up to -83° with a point spacing of 1 arcsec, corresponding to 31m at the equator. In the first version the three-dimensional shifts of the individual height models have not been respected correctly, leading to a loss of resolution of the height models (not so detailed contour lines as corresponding to the spacing). By this reason an improved version, the ASTER GDEM2 has been generated and is available free of charge since 2011. ASTER GDEM(2) is a product of the Japanese METI and the US NASA (http://www.gdem.aster.ersdac.or.jp/login.jsp).

In addition to the above mentioned free of charge available data also other height models can be bought. SPOT 5 carries in addition to the large HRG instruments the HRS (High Resolution Stereo) a stereo sensor with 5m x 10m GSD and a base to height relation of 1:1.2, used for the generation of height models as SPOT DEM or Reference 3D for large parts of the world with 30m spacing (http://www.astrium-geo.com/en/198-elevation30) (Jacobsen 2004).

By the Indian optical stereo satellite Cartosat-1 (named also IRS P5) nearly the whole world has been covered. Cartosat-1 has 2.5m GSD, it has a view direction of 5° ahead and 26° behind, corresponding to a height to base relation of 1.6 if the curvature of the orbit is respected. So based on Cartosat-1 height models nearly at any location may be generated. For example the German company GAF in cooperation with the German Aerospace Center DLR offers the generation of Cartosat-1 height models.
The Chinese ZY-3 has two inclined views with 3.2m GSD and a nadir view with 2.1m GSD, so it can be used similar as Cartosat-1 for the DSM generation, but since the launch in 2012 not a corresponding coverage of the world has been reached.

Just now the radar satellites TerraSAR-X and TanDEM-X of the DLR are flying close together for the generation of worldwide height models by InSAR which shall be available 2014 as TanDEM-X Global Elevation Model with 12m spacing, 2m relative and 10m absolute LE90.

ANALYSIS OF HEIGHT MODELS

4.1 GMTED2010

GMTED2010, covering the whole world, is available with 30, 15 and 7.5 arc-seconds point spacing. It is available with different versions – DCS, MAX, MIN, MED, MEA and STD. STD is the quality layer including the estimated local standard deviation, while all other are height models. The DSC-file contains the best information about the DSM, the justification of the other files is hardly to understand. The following accuracy information is only based on the DSC-file.

In the Jordan test area GMTED2010 shows against the reference height model a RMSZ of 4.35m with a bias of -1.42m corresponding SZ of 4.11m and a NMAD of 3.43m. The bias is shown as correction – that means the GMTED2010 height model is above the reference DTM. As function of the terrain inclination we have: SZ=3.36m+0.27m*tan(slope). For the SRTM height model similar values are computed but this is not a surprise because both are based on the same data set. It should not be forgotten, that SRTM has 3 arcsec and GMTED2010 only 7.5 arcsec point spacing, so the terrain can be described more precise by SRTM. The Jordan test area has no forest and it is not very rough, so the height values are more accurate as in other areas. The frequency distribution (figure 7) shows again a quite better fit to the normal distribution based on NMAD as on SZ.

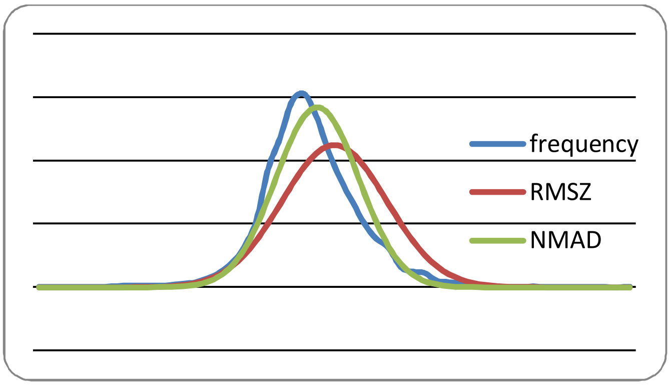


Figure 7: Frequency distribution GMTED2000, test area Jordan

In the mountainous and very rough Zonguldak test area with an average slope of 0.3 and an average change of the slope from one grid point to the next of 0.15 the conditions are not as optimal. GMTED2010 has an RMSE of 8.75m, a bias of -5.11m and SZ=7.10m or SZ=7.71m+2.89m*tan(slope). Again this is very close to SZ=7.08m for SRTM C-band. A reverse investigation including the influence of DTM interpolation leads to SZ=15.34m for GMTED2010 or SZ=14.2m+10.0m*tan(slope), while it is for SRTM C-band: SZ=10.39m or SZ=7.80m+18.56m*tan(slope), showing the advantage of smaller DHM-spacing for a precise description of the surface in mountainous area.

4.2 ASTER GDEM, GDEM2 and SRTM

ASTER GDEM is based on automatic matching of the ASTER stereo models while SRTM is based on InSAR, so some differences in the characteristics have to be expected. InSAR has some problems in mountainous areas with foreshortening (figure 8). In the foreshortening parts the backscattered signal from different ground elements is overlaid and cannot be separated, so the height determination fails in such parts.

For ASTER GDEM all available stereo pairs have been used. This is varying strongly depending upon the location (figure 9), caused by cloud coverage and imaging priority. But also within one scene the number of images/object points is strongly varying as shown by the example in figure 10. Figure 12 gives an overview about the variation of the number of images/object point in 12 test areas. In one test area the average just 2.5 images/point and in another 50.1 images/point have been used.

In nine test areas with different character the geometric quality of the height models from SRTM, ASTER GDEM and ASTER GDEM2 have been analyzed. The test area

Zonguldak is a rough mountainous area, partially covered by forest, while Jordan has nearly no vegetation and is smoothly mountainous. Mausanne includes forest areas and some rolling up to mountainous parts. Inzell is dominated by steep mountainous area, partially covered by forest, while Gars includes smooth mountainous parts. Pennsylvania has rolling parts and large forest areas, while Philadelphia includes downtown areas of the city. Arizona has nearly no vegetation and includes some mountainous parts. Warsaw is covered by forest areas and is dominantly flat, it has the disadvantage of a limited number of images/object point used for the matching. The Warsaw test area of GDEM1 in the average has only 9.84 and GDEM2 14.5 images/object points. This is quite less as in the other test areas, explaining why in the flat area the standard deviation of the GDEM1 and GDEM2-data are higher as in other test areas. Here for GDEM1 the standard deviation of the height can be expressed as SZ = 17.00m – 0.85∗ number of images or 15.1m for 2 images up to 3.4m for 16 images and for GDEM2: SZ=19.05m – 0.72∗number of images or 17.61m for 2 images up to 3.21m for 22 images. In other test areas the dependency of the accuracy upon the number of images is not so clear.

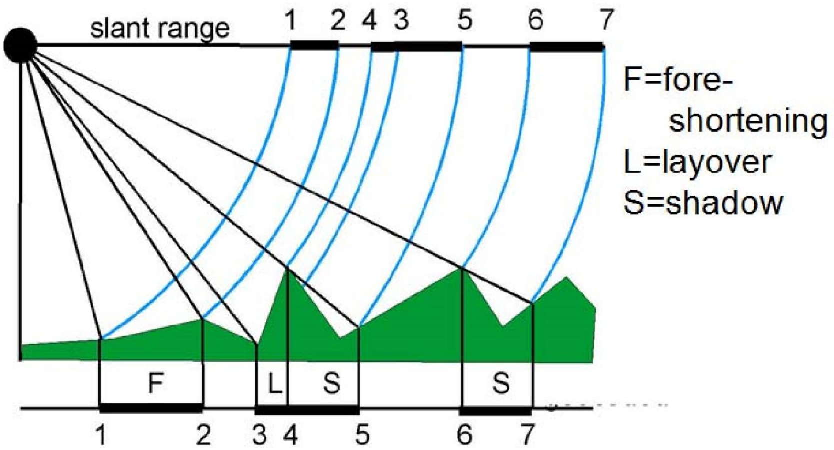


Figure 8: Slant range geometry of SAR

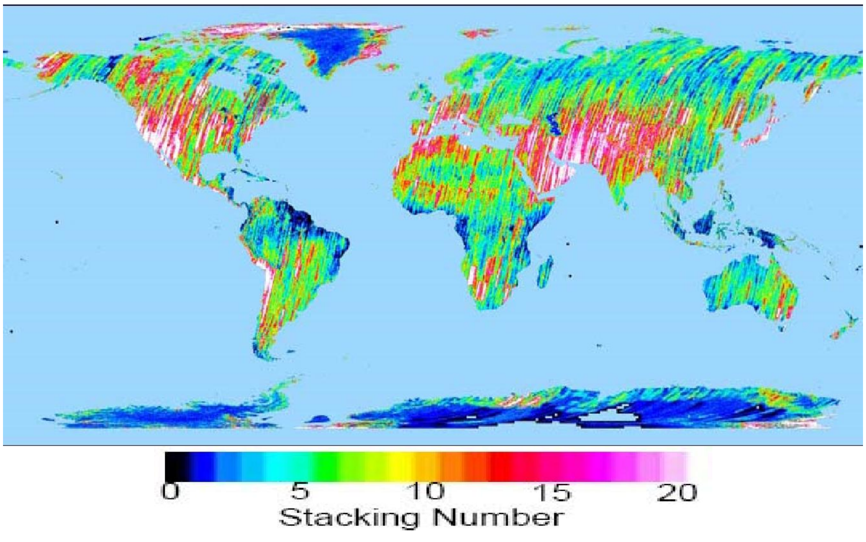


Figure 9: Number of images/object point used for ASTER GDEM

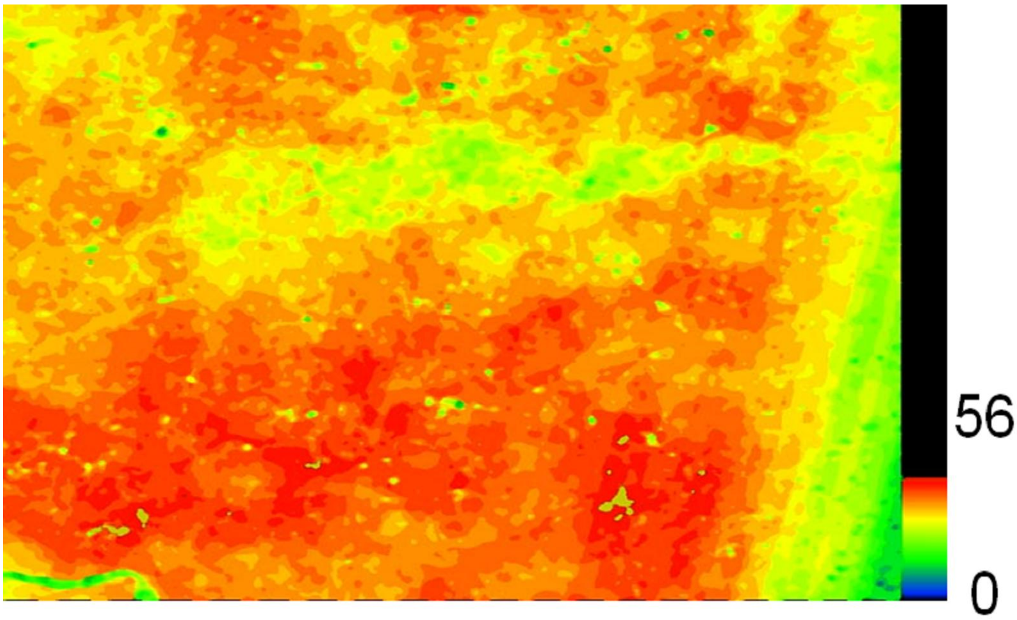


Figure 10: Color coded number of images used for ASTER GDEM in test area Pennsylvania

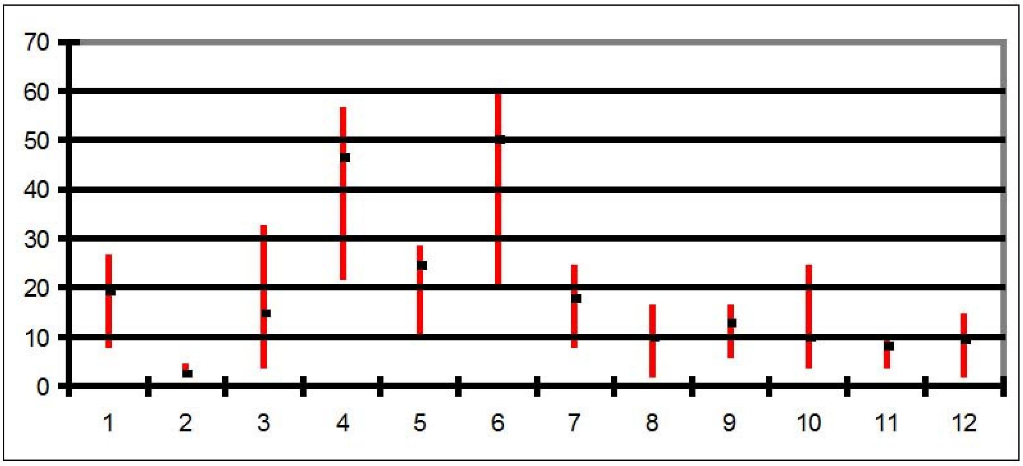


Figure 11: Variation of number of images/object point in 12 ASTER GDEM test areas – in average 24.8 images/object point

It is the question, what is the height accuracy. Figures 12 up to 15 present different results of the point heights, in addition we have the influence of the DHM interpolation being quite different depending upon the point spacing and the terrain roughness. Finally it depends upon the use of the height models and the individual frame conditions. The root mean square differences of the original data against reference data (fig. 12) are influenced by shifts in all 3 coordinate components. The standard deviations in fig. 13 do not differentiate between open areas and forest as well as the dependency upon the terrain inclination. In figure 14 the standard deviations for the open areas and flat parts are shown. Figure 15 compares the root mean square values of all test areas and shows the strong dependency upon the frame conditions. Depending upon the use of the height models, information about different geometric quality figures have to be used.

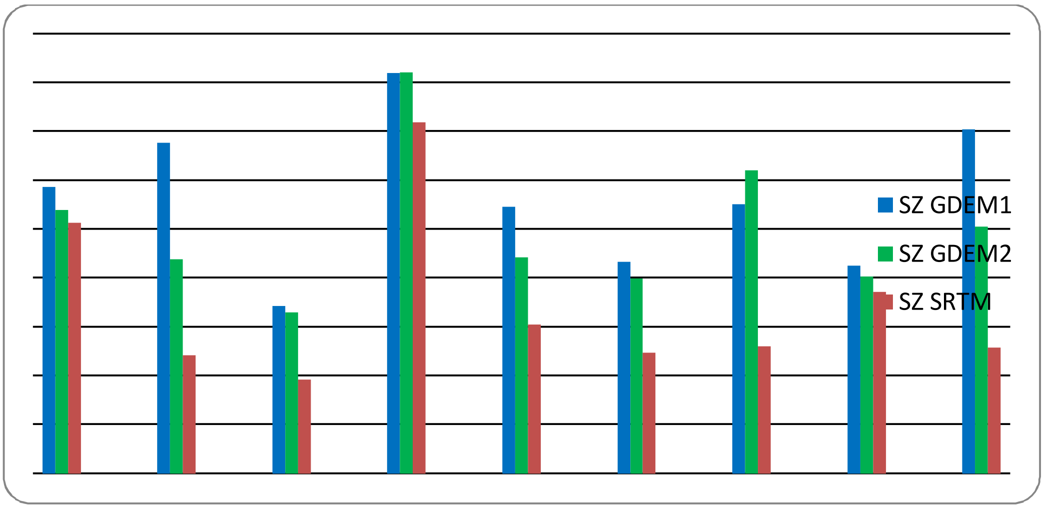


Figure 12: Root mean square differences of original data against reference data [m] (absolute standard deviation), RMSZ over all test areas: GDEM1: 11.66m, GDEM2: 10.38m, SRTM: 7.60m

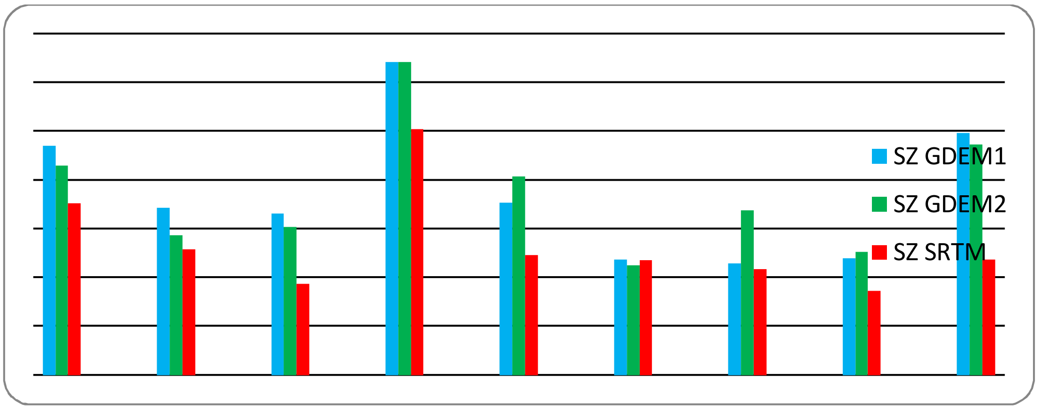


Figure 13: Standard deviation of height after shift correction (relative standard deviation), SZ over all test areas: GDEM1: 7.88m, GDEM2: 7.85m, SRTM: 5.69m

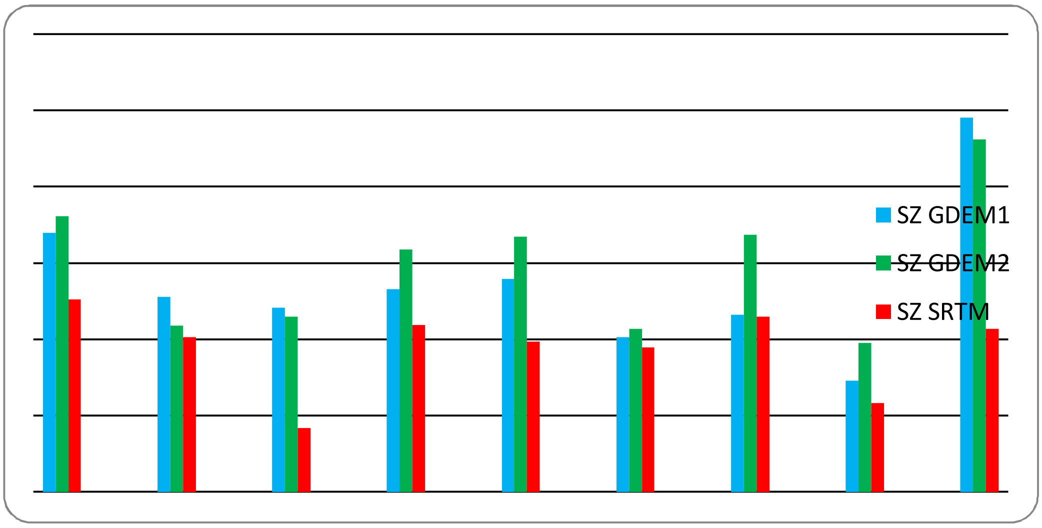


Figure 14: Standard deviation of height after shift correction for flat and open areas, SZ over all test areas: GDEM1: 5.76m, GDEM2: 6.17m, SRTM: 3.93m

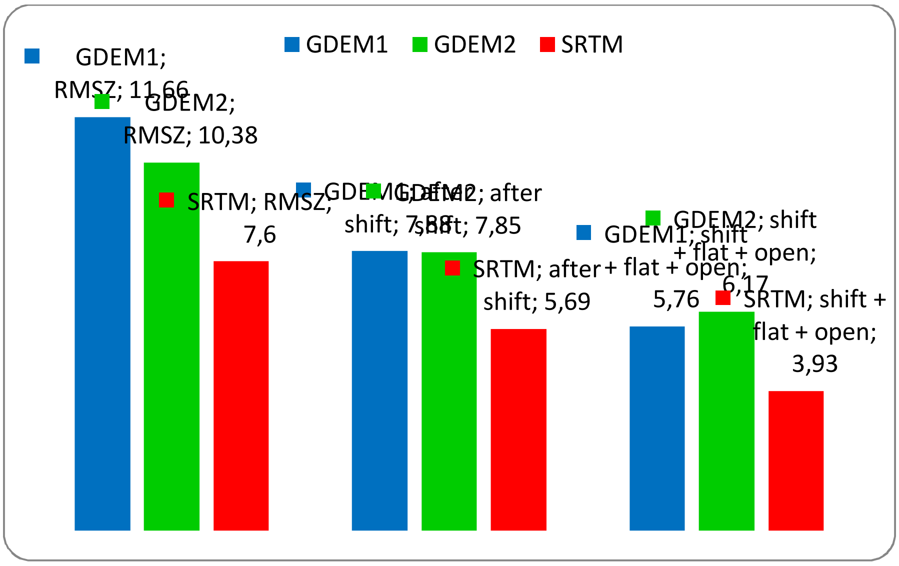


Figure 15: RMSZ / SZ average of all used test areas

In general NMAD in flat and open areas is approximately 10% below SZ and in mountainous and forest areas up to 50% smaller.

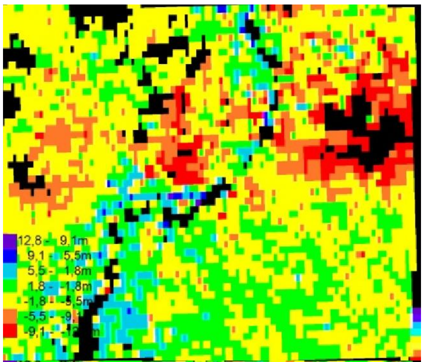


Figure 16: Differences of original SRTM DSM without gap filling against reference DEM – Philadelphia city

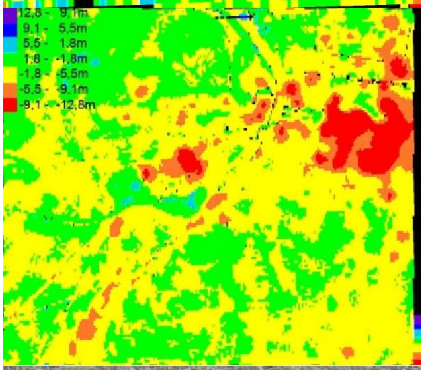


Figure 17: Differences of ASTER GDEM2 against reference DEM – Philadelphia city

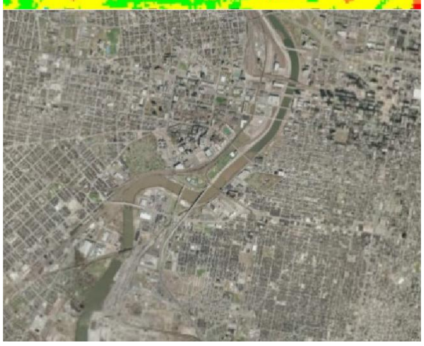
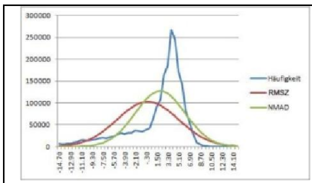


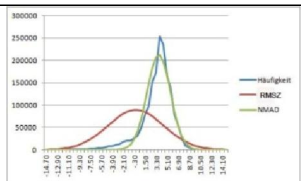
Figure 18: Google Earth of the same area – Philadelphia city

The examples of the differences between SRTM DSM respectively ASTER GDEM2 and the reference DEM in figures 16 and 17 highlight some of the problems of these height models. Both are DSM with the height of the visible surface. The down town area on right hand side and in the center are shown in red color (above 9.1m height differences) caused by the buildings located above the bare ground. The original SRTM DSM has some gaps (shown in black) caused by radar layover and on the river. Such gaps are not present at ASTER GDEM2. The standard deviation of SRTM is 4.1m while it is 6.7m for ASTER GDEM2. This does not mean, that SRTM is better it only has gaps in the areas with larger discrepancies.

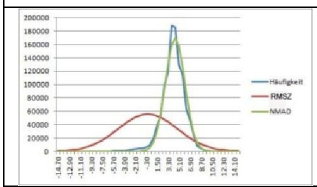
The frequency distributions of the SRTM height models (figure 19) against a reference DEM show also some typical effects. In this case SRTM has a bias listed in table 3. In the SRTM DSM small forest areas included causing an asymmetric distribution (upper left). If the analysis is reduced to the open areas, there are still some single trees and buildings included, nevertheless the normal distribution based on the NMAD is not a bad description of the frequency distribution. This becomes better if the DSM is filtered to a DEM (lower left). In this case the normal distribution based on the NMAD and shifted by the bias fits satisfying to the frequency distribution of the discrepancies. The normal distribution based on SZ and not shifted by the bias does not describe the frequency in a satisfying manner.



SRTM DSM



Open area



Open area filtered

Figure 19: Frequency distribution of SRTM height models against reference DEN test area (close to) Warsaw

Table 3: accuracy figures for SRTM DHM Warsaw [m]

	RMSZ	bias	SZ	NMAD
SRTM DSM	5.07	2.05	4.63	4.11
Open area	4.56	3.75	2.59	1.91
Open + filtered	4.83	4.47	1.84	1.59

The large values for the accuracy figures in table 3 are caused by small forest parts. For the open area there is still a larger discrepancy between SZ and NMAD, which becomes smaller in the case of filtered height data. In general the relative height accuracy of the SRTM-data in the Warsaw test area are very good.

4.3 SRTM X-band

As mentioned, in addition to the height model based on the SRTM C-band, which is available free of charge in the internet, based on the German/Italian SRTM X-band also height models have been generated and are available via the WEB (http://www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10080/150_read-817/) now also free of charge. The SRTM X-band DSM by theory should be more precise as the SRTM C-band DSM, but the C-band DSM in most cases is not only based on one height model, it uses the average height based on all available models. By this reason the investigated X-band height models have nearly the same accuracy as the C-band height models (Jacobsen 2005). Nevertheless the SRTM X-band height model is available with 1 arcsec point spacing which is an important advantage against the 3 arcsec of the SRTM C-band DSM.

4.4 REFERENCE 3D

Large parts of the world are covered by Reference 3D, based on SPOT 5 HRS stereo models (figure 20). They are not free of charge, but have the advantage of a point spacing of 30m, partially distributed with 20m spacing. Within the ISPRS a scientific assessment of height models based on SPOT 5 HRS has been made (Baudoin et al. 2004), some details are presented in Jacobsen 2004. The orientation accuracy of the SPOT 5 HRS stereo models not supported by GCP is in the range of RMSZ=5m to 9m. The root mean square height differences after bias correction for open areas is in the range of SZ=5m to 6m; that means it is close to the results of the SRTM DSM. But the better point spacing has some advantages for the resolution. On the other hand SPOT 5 as well as the HRS sensor has a spectral range from 0.48µm up to 0.70µm wavelength that means only the very first part of infrared is included, causing problems for image matching in forest areas where the dominating reflection is in the infrared range. A HRS DSM in a forest area in Turkey demonstrated that in such areas a gap filling by SRTM 1 arcsec data is made (Buyuksalih, Jacobsen 2008); reverse several SRTM gaps have been filled with HRS DSMs.

The frequency distribution of the height discrepancies in the test area Black Sea (figure 21) has the typical shape. In the open areas the distribution of the height discrepancies is expressed very well by the normal distribution based on NMAD. In this case Reference 3D has a very good accuracy in the open areas of SZ=3.1m and NMAD=2.5m, even LE90 reaches 4.5m. With 0.59m the bias of this height model is limited. As it is also shown in figure 21, Reference 3D is filtered for large discrepancies, so the normal distribution of Reference 3D data usually does not show a higher number of larger discrepancies as it is the case for other height models.

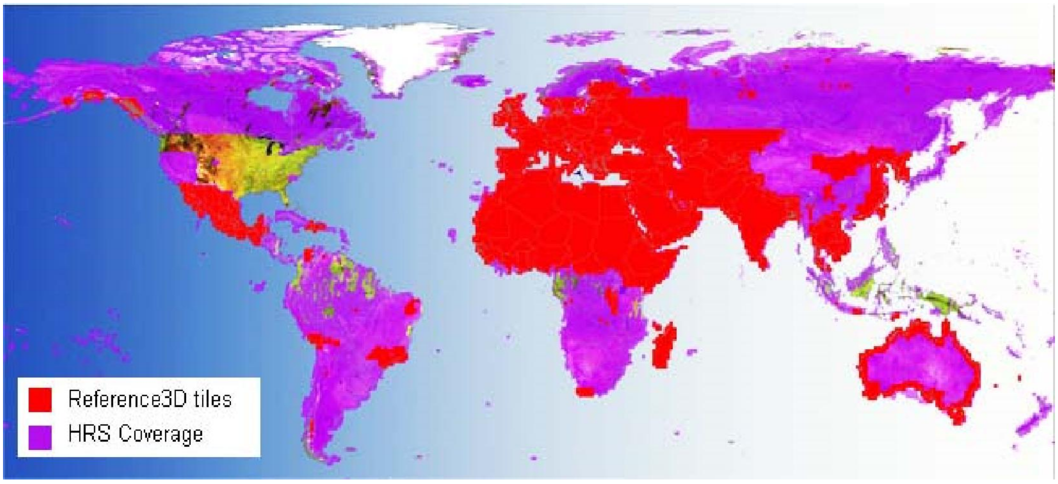


Figure 20: Coverage by Reference 3D and SPOT-5 HRS images

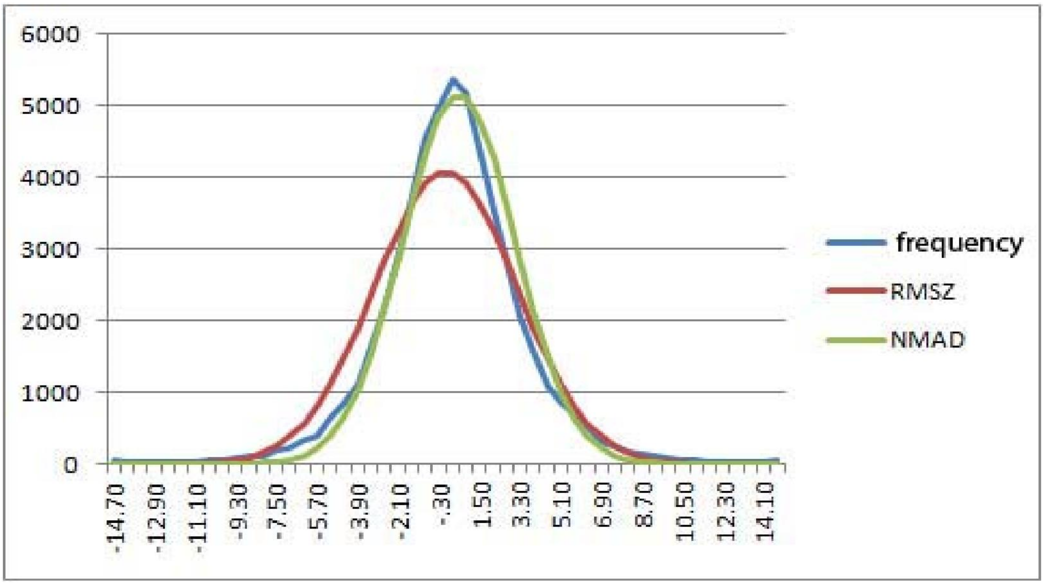


Figure 21: Frequency distribution of Reference 3D in open areas, test field Black Sea

4.5 CARTOSAT-1

As shown by figure 22, nearly the whole world is covered by Cartosat-1 stereo pairs. In some areas (red in figure 22) several Cartosat-1 stereo pairs are available for the same area.

Cartosat-1 has 2.5m GSD, corresponding to this, the system accuracy as usual is one GSD in the height, corresponding to SZ=2.5m or NMAD 2.2m. The system accuracy is available for open and flat areas and a scene orientation based on ground control points. For usual terrain the standard deviation is in the range of 4m. The accuracy of the direct sensor orientation of Cartosat-1 even after calibration is not better as 100m. If no ground control points are available, Cartosat-1 height models can be geo-coded by means of the SRTM-height model. The absolute accuracy of the SRTM height model is in the range of 3m (figure 23), satisfying very often as reference for other height models.

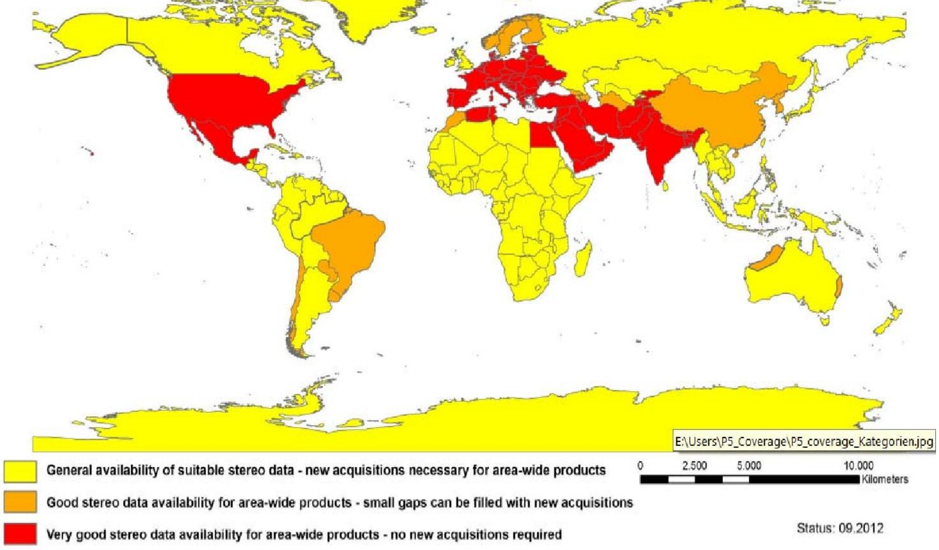


Figure 22: Coverage by Cartosat-1 stereo scenes

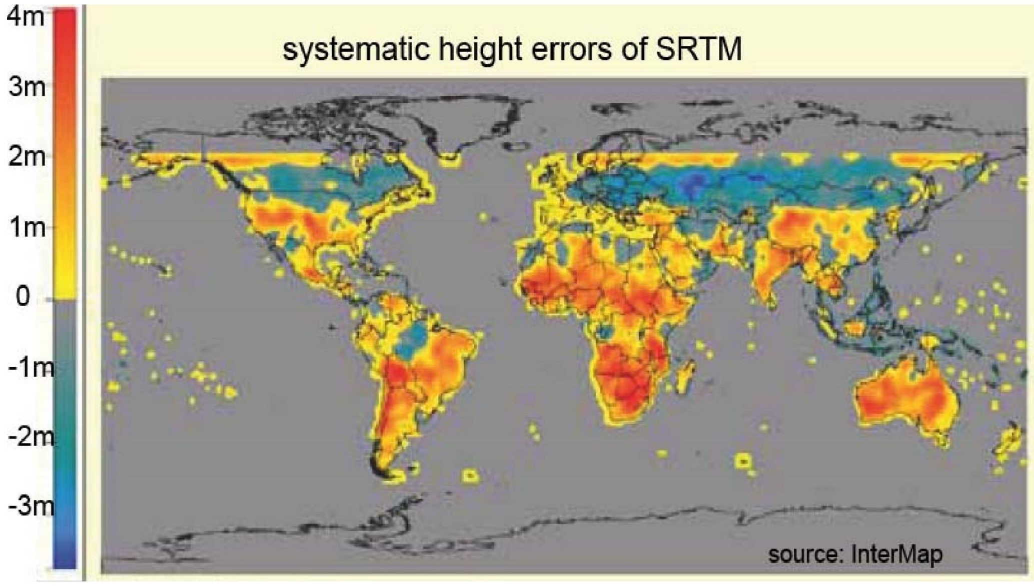


Figure 23: Systematic height differences of SRTM DHM determined by height profile points of ICESat-data source: Intermap

4.6 NextMap World 30

The private company Intermap generated with a combination of the SRTM DSM with 3 arcsec spacing, ASTER GDEM-2 with 1 arcsec spacing and GTOPO30 for the polar regions with 30arcsec a worldwide height model with 1 arcsec spacing. The systematic positional errors have been improved by ICESat height profile points having accuracy in the range of 0.1m up to 0.2m. The morphologic details of ASTER GDEM2 have been combined with the accuracy of the SRTM DSM improved by ICESat data. The height models have been determined for blunders and gaps have been filled with other data. Meta data include information about the used input data. Intermap specifies the NextMap World 30 DSM in the average with 5m standard deviation. Water areas have been flattened and the height of the oceans is 0m.

4.7 TanDEM-X Global DEM

The German radar satellite TerraSAR-X has been launched 2007, since 2010 the identical TanDEM-X is available. Both satellites are flying since 2011 in a so called Helix configuration with a base component across the orbit of approximately 200m up to 400m (figure 24). This is an optimal configuration for height determination by Interferometric Synthetic Aperture Radar (InSAR).

The first coverage of the whole world by TanDEM-X has been completed, now a second coverage is flown together with a repeated coverage in difficult areas as mountains and densely built up areas. With the repeated coverage the bottle neck of radar by layover shall be reduced.

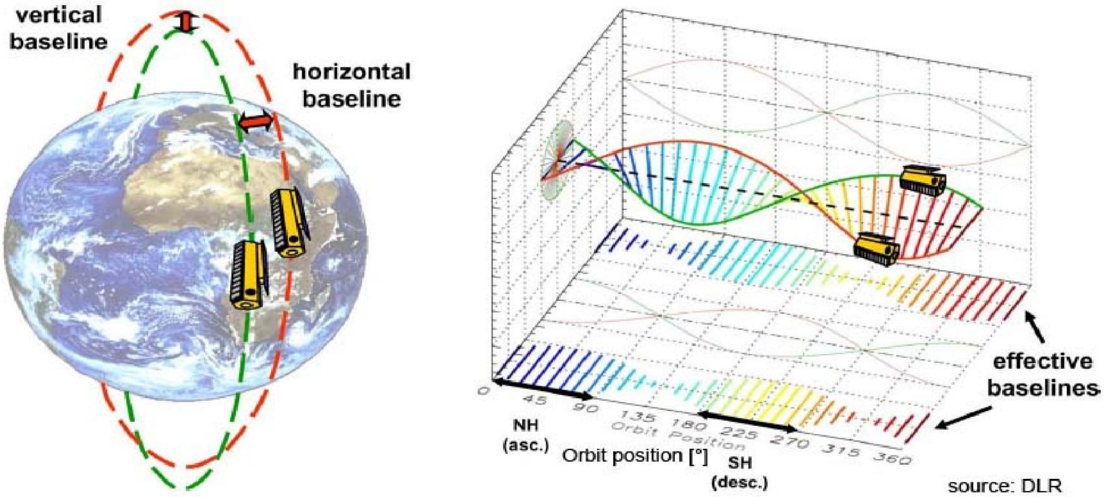


Figure 24: Helix orbit configuration of TanDEM-X

The TanDEM-X Global DEM is specified with an absolute height accuracy LE90 < 10m and a relative accuracy within the tiles of 1° x 1° of LE90 < 2m, corresponding to RMSZ < 6m and SZ < 1.2m for terrain with inclination below 20%. For terrain with an inclination above 20% LE90 is specified with 2.4m. The grid spacing will be 0.4 arcsec, corresponding to 12m at the equator. On special request FDEM and HDEM are offered with 0.2 arcsec spacing (6m at the equator).

As usual with the X-band radar a DSM will be generated – the X-band radar only penetrates the vegetation slightly depending upon the incidence angle (figure 25).

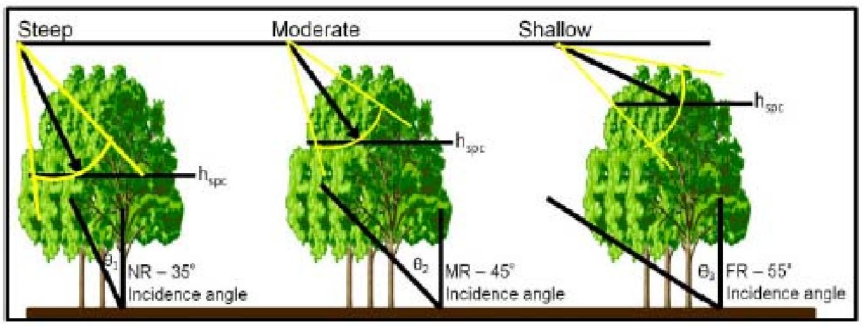


Figure 25: Penetration of X-band radar into canopy (Tighe et al. 2012)

RESOLUTION OF HEIGHT MODELS

The accuracy of a height model is the dominating criteria, but it is not the only one. For several applications the resolution of the DHM is important. Resolution is close to the relative accuracy – the accuracy of one point in relation to the neighbored. The relative accuracy in most cases is better as the absolute accuracy because it is not dependent upon a bias caused by the orientation. The term relative accuracy has to be specified in detail – is it relative within one scene or is it relative just in relation to neighbored points (figure 25). Figure 26 shows, that directly neighbored points of ASTER GDEM2 in the test area Jordan have a standard deviation in height of 2.87m, while with 10 points distance (approximately 290m) the relative standard deviation with 4.48m is not so far away from SZ=4.88m for the whole scene.

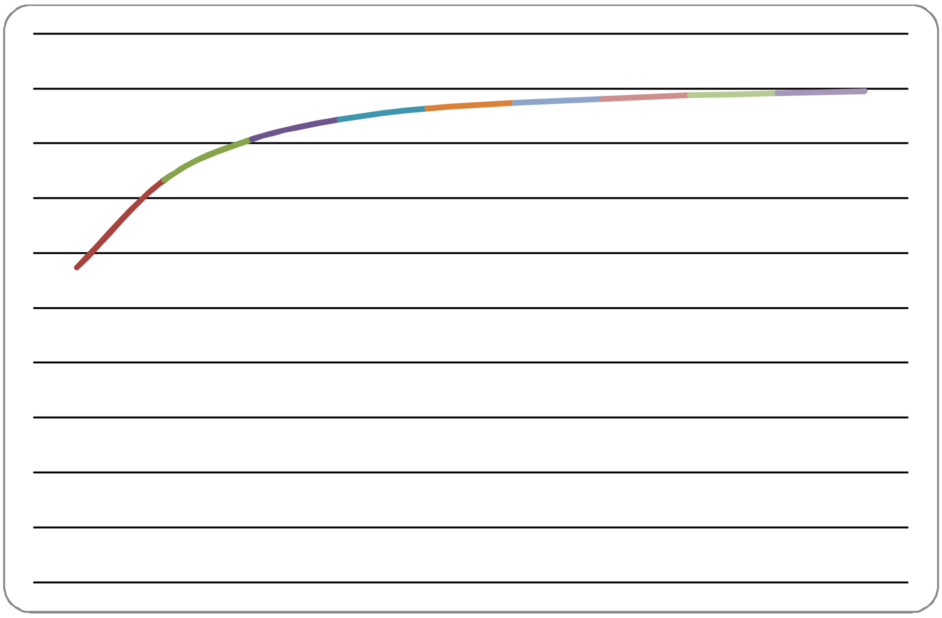


Figure 26: Relative standard deviation of Aster GDEM2 in test area Jordan
Horizontal: point distance [0.1 arcsec] Vertical: relative standard deviation [m]

Visually the relative accuracy can be seen with the details of contour lines. Figure 27 demonstrates the resolution of the different height models with a part of the test area Zonguldak. The reference model has 10m point spacing, showing any details; the contour lines of the SRTM X-band data with effective 27m spacing are not far away from this. The ASTER GDEM2 corresponds to this, while the first version of ASTER GDEM does not show the details, it corresponds with the details of the contour lines to SRTM C-band with approximately 80m point spacing. Of course with the GMTED2010, having 201m point spacing, the contour lines are quite more generalized, but it cannot be compared with the old GTOPO30 having 800m spacing and a lower accuracy. The obvious improvement of the ASTER GDEM-resolution is also stated in Tetsushi et al. 2011.

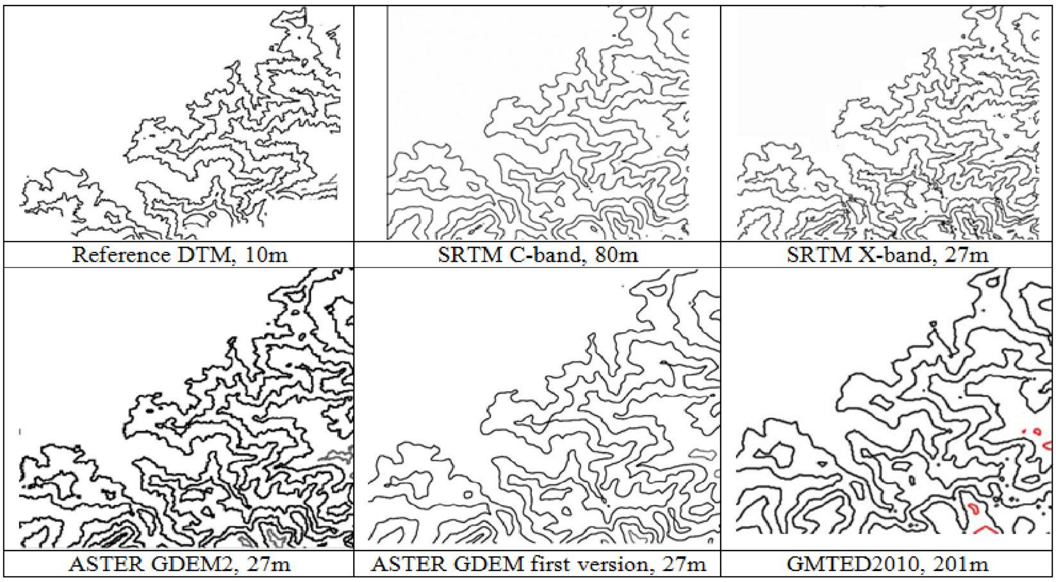


Figure 27: Contour lines based on different height models

CONCLUSION

The shown investigation demonstrates that it is not possible to explain the accuracy of the nearly worldwide covering height models just with one figure. The accuracy depends beside the specification of the accuracy upon the characteristics of the test areas, especially the terrain inclination and roughness as well as the coverage by forest, because most of the height models are digital surface models with the height of the visible surface and not the bare ground. In the used test areas the worldwide GMTED2010 is dominated by SRTM heights, leading to similar accuracy of the included height points. ASTER GDEM2 has been improved against the first version of ASTER GDEM especially with the relative accuracy, clearly improving the resolution. Also the absolute location in all three coordinate components is better, but the relative standard deviation of height within the scenes is on the same level. The gap filling of the SRTM height models did not play an important role for all used test areas, so no clear difference between the first SRTM-version and the actual one has been identified. In general the SRTM height models are more accurate as the height models based on ASTER, but the GDEM2 now has a clearly better resolution, fitting to the spacing of 1 arcsec as SRTM C-band DHM available only with 3 arcsec point spacing. The SRTM X-band DHM, available only for parts, has advantages against GDEM2 – it has the same resolution but a higher accuracy. SPOT reference 3D is on a similar accuracy level as SRTM but is not so much affected by large errors. In dense forest areas for reference 3D no money should be spend for SPOT reference 3D because there it is dominated by SRTM heights used for gap filling. NextMap World 30 combines advantages of SRTM and ASTER GDEM2 together with an improved orientation, but it is not free of charge. In 2014 with the TanDEM-X Global DEM we will have a clear improvement against the existing large area covering DHM based on space information with the resolution and the accuracy. Nevertheless individual height models based on very high resolution space images with 0.5m GSD are with the system accuracy of 1.0 GSD for the height still better, but the generation is more expensive.

The planned use of the height models is important for the selection of the accuracy figures shown above – it is possible to respect / determine the shifts in X, Y and Z and shall a DSM be used or are only the open areas important. In addition the terrain inclination plays an important role. For the description of the terrain itself the accuracy loss by interpolation, dominated by the point spacing and the terrain roughness, has to be respected.

REFERENCES

Baudoin, A., Schroeder, M., Valorge, C., Bernard, M., Rudowski, V., 2004: A scientific assessment of the High Resolution Stereoscopic instrument on board of SPOT 5 by ISPRS investigators, ISPRS Congress, Istanbul 2004, Int. Archive of the ISPRS, Vol XXXV, B1, Com1, pp 372-378, http://www.isprs.org/publications/archives.aspx

Büyüksalih, G., Jacobsen, K., 2008: DSM generation with high resolution space imagery over mountainous forest area, International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XXXVII, Part B1 (WG I/5) pp 865 - 871

Danielson, J., Gesch, D., 2011: Global Multi-resolution Terrain Elevation Data 2010 (GMTED2010), http://pubs.usgs.gov/of/2011/1073/pdf/of2011-1073.pdf

Jacobsen, K., 2004: DEM Generation by SPOT HRS, ISPRS Congress, Istanbul 2004, Int. Archive of the ISPRS, Vol XXXV, B1, Com1, pp 439-444, http://www.isprs.org/publications/archives.aspx

Jacobsen, K. 2005: DEMs based on space images versus SRTM height models, ASPRS annual convention Baltimore, 2005

Jacobsen, K., 2010: Comparison of ASTER GDEMs with SRTM Height Models, EARSeL symposium 2010, Paris, pp 521-526, http://www.earsel.org/?target=publications/proceedings/symposium-2010

JCGM 100:2008: Evaluation of measurement data – Guide to the expression of uncertainty in measurement, http://www.bipm.org/utils/common/documents/jcgm/JCGM_100_2008_E.pdf

Passini, R., Betzner, D., Jacobsen, K., 2002: Filtering of Digital Elevation Models, ASPRS annual convention, Washington 2002

Reuter, H.I., Nelson, A., Jarvis A., 2007: An evaluation of void filling interpolation methods for SRTM data, International Journal of Geographic Information Science, 21:9, 983-1008 + http://srtm.jrc.ec.europa.eu/literature/Reuteretal2007.pdf
Tetshshi, T., et al., 2011: ASTER Global Digital Elevation Model Version 2 – Summary of Validation Results,

http://www.ersdac.or.jp/GDEM/ver2Validation/Summary_GDEM2_validation_report_final.pdf

Tighe, M.L.,King, D., Balzter, H., Bannari, A., McNairn, H., 2012: Airborne X-HH Incidence Angle Impact on Canopy Height Retreival: Implications for Spaceborne X HHA TanDEM-X Global Canopy Height Model, IntArchPhRS, Vol XXXIX part B1, 2012

MAPPING SERVICES IN THE CZECH REPUBLIC

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KEY WORDS: Czech Republic, map, database, GIS, orthophoto

ABSTRACT

The paper describes the State Map Set of the Czech Republic. Scales, map contents and availability for users are presented. Map publishing on Geoportals, access to present and historical maps, remote sensing data and map updating are hot topics in the last few years. The Czech Republic as a country of the European Union not only follows the Union rules and recommendations, however, it also develops relations between end users and data providers at a world level with free Open Access to Cadastre. A new system of basic registers – Register of Inhabitants, Register of Persons, Register of Land Identification, Addresses and Real Estates, and Register of Rules and Rights connecting, unifying and harmonizing personal, spatial and other data are in the full functionality in the Czech Republic.

INTRODUCTION

Mapping history is very long in the world. The second half of the 20th century marked an important change with world computerisation. However, it was already the first half of the 20th century, which brought a new data source for mapping – aerial imagery and the second half of the century satellite imagery. The previous classic methods of mapping were enlargened by new methods using computer tools – digital vectorisation and image processing.

The history of the Czech Republic mapping system is strongly influenced by the history of the country. The Republic was a part of the Austria-Hungarian monarchy. The mapping of the monarchy was performed both in a large scale as cadastre maps and medium scale of military mapping. Both map types were used even in newly created Czechoslovakia after 1918. A new political situation after the 1948 also led to a new policy of mapping services in the country.

Czechoslovakia split mapping services into two different lines – a civilian and military ones in 1969. The civilian line is available for all users from 1:5 000 to 1:500 000 scales. They are used also as a topographic base for thematic layers. The Topographic Service of the Czechoslovak Army processed the mapping after the World War II up to 1969. Since 1969 two different mappings were performed; civilian and military. The civilian maps were open for selected organisations and did not comprise coordinates; the military were marked as secret for all except for the Army. The lines differ by their content, areas of map sheets and map sheet layout graphic outlook. The civilian map series was open to public after 1990.

STATE MAP SET OF THE CZECH REPUBLIC

The State Map Set of the Czech Republic is map sheets covering the whole country. Their processing respects unit rules, is performed by a state organisation and in the name of public needs. The Set comprises of basic state topographical maps and thematic state maps.
The State Map Set covers a large range of map layers starting by cadastre maps as the large-scale base maps. The cadastre of real estate is a collection of data on real estate in the Czech Republic including its register, description and its geometric and spatial determination. It includes a registry of ownership and other material rights and additional rights to real estate provided by law.

The base of cadastre maps can be found in the Stable Cadastre made in 1826-1843 (the Bohemian part) and 1824-1836 (Moravia and Silesia). The Stable Cadastre comprised of three parts – a part called "evaluating" classifying the land to determine land price, a written part with data about individual real estates and maps – Imperial Imprints. The Imprints used a 1:2880 scale, cities were mapped in more detailed scales – either 1:1440 or even 1 : 720. Two thirds of the present cadastre maps are in the digital vector format and the rest in the raster format (scanned). A certain number of cadastre maps – were newly mapped after 1918 - is at 1: 1000 or 1: 2000 scales.

The following large-scale map layer is the State Map at 1:5000. The layout of the map sheets is defined by division of each 1:50 000 map sheet to one hundred of 1:5 000 map sheets. The topography of these maps is a result of a generalisation of cadastre maps and heights are derived from 1:10 000 maps. The Republic is covered by 16 301 map sheets of this scale.

Base maps of the Czech Republic being a set of medium-scale maps of topographic character, are at scales of 1:10 000, 1:25 000, 1:50 000, 1:100 000 and 1:200 000. The maps contain planimetry, altimetry and lettering. They are processed in a uniform layout of map sheets specifically designed for the purpose of their compilation considering optimal coverage of the territory by map sheets. Individual map sheets are trapeze-shaped and oriented approximately in geographic directions. The 1:10 000 map scale has become a base for a row of the base map scales where 1 : 25 000 maps are a result of the 1:10 000 map data generalization, the 1:50 000 map layer is derived from the 1:25 000 layer by generalization and so forth.

The maps use Bessel's ellipsoid and the Czech coordinate system - S-JTSK (Křovák) data.

The map of the Czech Republic at the scale of 1:500 000 is a general geographic map of a small scale showing the entire territory of the Czech Republic on a single map sheet.

All map layers are processed using digital technology.

The maps are maintained by the Czech Office for Surveying, Mapping and Cadastre.

MILITARY MAPS OF THE CZECH REPUBLIC

The country was mapped as a part of the Austria-Hungarian Monarchy by three Military Mappings. The Third Military Mapping was performed between 1874 and 1880 at 1:25 000, in military important areas even 1 : 12 500 . The generalized maps of the Third Military Mapping to 1 : 75 000 were used with Czech lettering even in Czechoslovakia between two World Wars up to 1956. However, the two independent military mapping campaigns covering the whole territory of the country were performed after the WW II: mapping at 1:25 000 scale between 1952 and 1957; and mapping at 1:10 000 scale between 1957 and 1971.

A new system of military maps was developed after 1969 after the division of civilian and military mapping Map series at 1:25 000, 1:50 000, 1:100 000, 1:200 000, 1:500 000 and 1:1 000 000 scales have been processed. They used Krassovski's ellipsoid and Gauss-Krieger's coordinate system. The map layers were produced and maintained by the Topographic Service of the Czechoslovak Army.

THEMATIC MAPS

Thematic maps are produced by state organizations like the Czech Geological Survey, Czech Hydrometeorological Institute, Regional Authorities, etc. All maps using various scales (usually from 1: 25 000 to 1: 2 500 000) are based on the civilian maps.

The Czech Geological Survey has a database of 13 map layers at 1:5 000, 33 map layers at 1:25 000 and 1:50 000,

FROM ANALOG TO DIGITAL MAPS

The period of 90's of the 20th century was a period of paper map conversion to digital maps. The digitisation was performed in two steps. The first one was scanning of map and raster maps were offered as geocoded maps sheets. The second step was their progressive vectorization. The process concerned both of topographic – civilian and military, and thematic maps. The map vectorization was in fact a process of transformation from analogue maps to maps in geographic information systems.

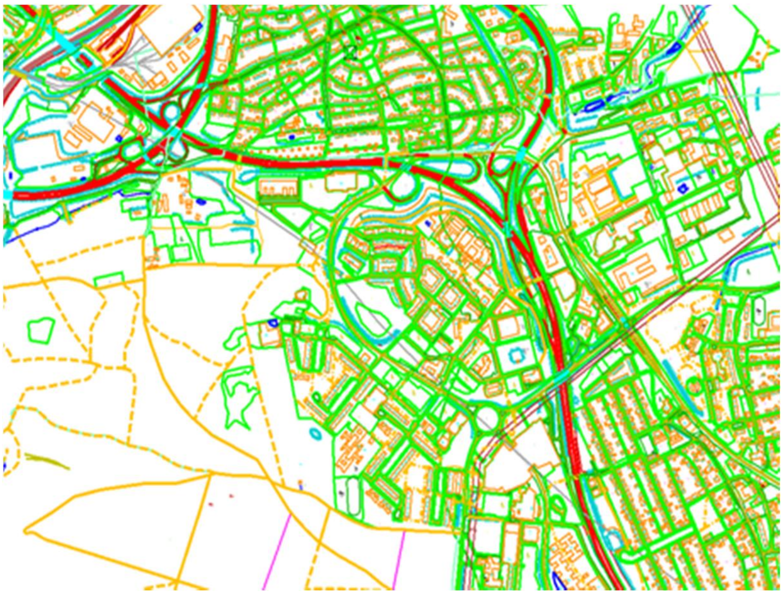
The Cadastre maps are in the raster format for the whole country. There are two vector format data available. The first one - Digital Cadastral Maps (DKM) are cadastral maps in S-JTSK datum created by the renewal of the cadastre documentation by new mapping on the basis of land adaptation results, by change of the file of geodetic information (with exception of digitized Cadastre Maps) or by transfer of its numeric representation to digital form.

The second one - Digitized Cadastre Maps are cadastre maps in S-JTSK datum created by the renewal of the cadastre documentation by revision – transfer of analogue map to digital form (KMD) or (KM-D), i.e. digital form of a cadastral map is created according to former rules, especially in Gusterberg or St. Stephen datum.

The Basic Maps of the Czech Republic at 1: 10 000 were a base for ZABAGED, Digital Geographical Model of the Czech Republic having the data types equivalent to the 1 :10 000 scale. The data object categories form eight groups:

1. Communes, economic and culture objects
2. Transport network
3. Underground utilities
4. Water bodies
5. Land units including protected areas
6. Vegetation and land cover
7. Terrain relief
8. Geodetic points

ZABAGED comprises 122 basic types of geographical objects and more than 350 attributes. Fig. 1 shows a spatial and table form of electricity network.



Kategorie objektů:	3. ROZVODNÉ SÍTĚ A PRODUKTOVODY
Typ objektu: (s pořadovým číslem)	3.03 ELEKTRICKÉ VEDENÍ
Kód typu objektu:	AT030
Definice objektu: Uspořádání vodičů, izolačních materiálů a konstrukcí pro přenos elektrické energie mezi dvěma body elektrické sítě.	
Geometrické určení objektu:	linie
Geometrická přesnost:	B
Zdroj dat geometrických:	původní zdroj: ZM 10 letecké měřické snímky, ortofoto, šetření v terénu, dokumentace ČEPS, a.s.
Zdroj dat popisných:	dokumentace ČEPS, a.s.

Atributy:

Název atributu	Datový typ	Předmět atributu	Hodnota atributu	Význam hodnoty atributu (identifikátor)
NAZEV	VARCHAR2(30)	označení vedení		-
NAPETI	VARCHAR2(5)	nejvyšší napětí v kV		-

Fig. 1 Vector and attribute parts of ZABAGED

The ZABAGED data are updated from aerial orthophotos regularly in the 3-year cycle. The data are generalised for Base Maps of the Czech Republic at 1:25 000 scale.

ZABAGED is a fundamental vector and attribute data source for all other smaller scales. There are two databases created from ZABAGED as it is shown on Fig. 2.

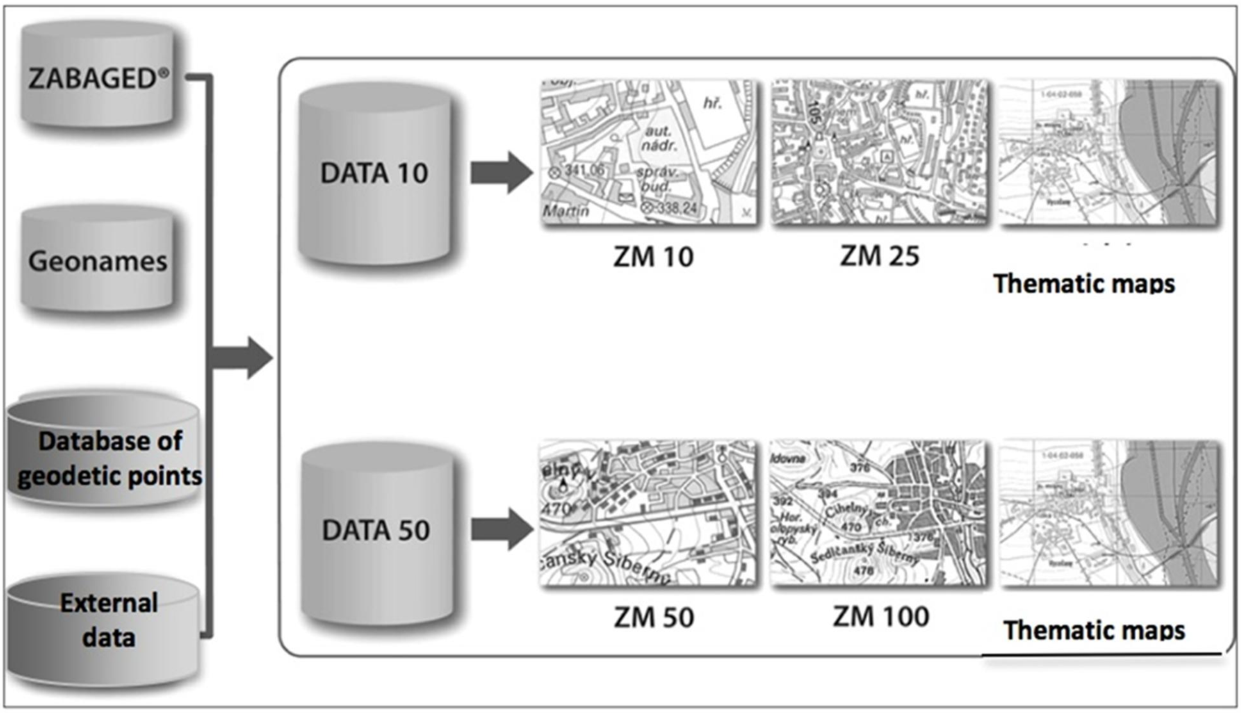


Fig. 2 Data structure for producing Base Maps at 1:25 000, 1:50 000, 1:100 000 scale from ZABAGED, Geonames database, Database of Geodetic Points and External Data

The Base Map of the Czech Republic at 1:25 000 (ZM 25) is the basic state map series of medium scale. It is a general geographic map, i.e., map of a topographic nature. Maps of this scale cover the whole republic by 773 map sheets. Their dimensions and indexing are derived from the map layout of 1:50 000 Base map by a division into four sections. The ZM 25 maps contain planimetry (settlements and individual objects, communication networks, hydrology, administrative and cadastral boundaries, boundaries of protected areas, vegetation and soil surface), altimetry (contour lines and terrain steps) and lettering. Map lettering includes toponymy of objects, standardized geographic nomenclature, contour values, height values, border information and external information - for the territory of the Czech Republic only.

The Base Map of the Czech Republic at 1:50 000 (ZM 50) is the basic state map series of medium scale and a synoptic geographic map. The entire territory of the Czech Republic is covered by 211 map sheets. Their dimensions and indexing is derived from the map layout of 1:100 000 Base map of the Czech Republic by splitting into four sections.

The ZM 50 contains planimetry, altimetry and lettering – the same as at ZM 25, however, both for territory of the Czech Republic, and neighbouring states on appropriate sheets. The ZM 50 layer is the most used base map for thematic maps.

The Base Map of the Czech Republic at 1:200 000 (ZM 200) is the basic state map series of medium scale. It displays the entire territory of the Czech Republic in a continuous map layout in 18 map sheets. Their dimensions and indexing represent a basic map layout used for all basic map layers of the Czech Republic. The ZM 200 contains planimetry (settlements and individual objects, communication networks, hydrography, boundaries of regions and districts, boundaries of protected areas, land cover and soil surface), altimetry (contour lines and terrain edges) and lettering (only at the territory of the Czech Republic).

The Map of the Czech Republic at 1: 500 000 (MČR 500), the base state map, is a synoptic general geographic map covering the Czech Republic on a single map sheet.

The MČR 500 contains planimetry (settlements, transportation highways, speedways and 1st class roads, hydrology, state and regional boundaries, vegetation and land surface - forests), spot heights, geographic coordinate grid, description and the map legend.

Since 1999 when the Czech Republic became a member of NATO, military maps in digital format, which are produced by the Geographic Service of the Czech Republic Army, serve for military purposes only; 1:200 000 scale was replaced by 1:250 000 scale. The maps use WGS-84 system. Digital Mo

Map of Land at 1:25 000 and 100 000 from 2007 are open to public.

Altimetry data of the Czech Republic territory, maintained by the Land Survey Office, are recently stored in ZABAGED and provide height information on terrain relief.

The ZABAGED altimetry uses 3 types of contour objects with 1, 2 or 5 m basic intervals: The contours are three-dimensional vectors. The other altimetry data type is a digital terrain model in 10 x 10 m regular grid. The data were a result of vectorisation of contours of 1:10 000 Base map of the Czech Republic (ZM 10). These contours mostly from 1957 – 1965 period photogrammetric processing were updated in 2005 – 2009 period by photogrammetric processing. The final product is 10 x 10 m grid of 3D points.

New altimetry has been measured since 2010 by aerial laser scanning. Two digital models of relief are produced: they are called the Digital Terrain Model of the 4th Generation (DMR 4G) and the Digital Terrain Model of the 5th Generation (DMR 5G). DMR 4G is an altimetry system using the regular 5x5 m grid. The layer covers two thirds of the country and it is planned to be complete in 2013. The DMR 5G is created by TIN. The TIN model is planned to be finished in 2015; 30 % per cent of the Czech Republic territory has already been processed. The last altimetry data is Digital Surface Model of the Czech Republic of the 1st Generation (DMP 1G) whose processing should be finished by 2015.

MAP AVAILABILITY IN THE 3RD MILLENIUM

The period after 2000 can be called as an access to the map data from distant computers via the Internet. A new element, geoportals , offer their data including map data. The map portal service is twofold; open access using WMS tool to raster map data and usually paid access to vector map data. The portal services are redundant as the same data/maps are placed in several servers. The portals are organized by individual data providers and by regional and state organisation grouping data from different data/map providers.

The civilian topography map data provided by the Czech Office for Survey, Mapping and Cadastre (ČÚZK) are on its Geoportal (see the introductory page of the ČÚZK Geoportal on Fig. 3).

The geoportal opens an access to all base maps and cadastral maps also using information tables of individual products. The Czech Office for Survey, Mapping and Cadastre created the Information System of Cadastre of Real Estate. The basic information about cadastral maps of the system is shown on Fig. 4. The same table type information is available for all base map layers with updated information on the present state of data.

These data are presented on the CUZK Geoportal in two types of services for access to the cadastre data.

One access is called Open access to (Previewing) the Cadastre and it is a free service for any user. The data are informative only. A user is allowed to:

1) find real estate and its parcel number, commune, area, parcel type, map sheet, land use, type of land use, owners, protection, soil type and other data,
2) find information about neighbouring parcels,
3) find information about other real estates of the parcel's owner,
4) use various map background – cadastre map, cadastre map and aerial orthophoto mosaic, map of the land cadastre, map of the land cadastre and aerial orthophoto mosaic

Figs. 5 and 6 are examples of the attribute and spatial data a user is allowed to find on the CUZK Geoportal.

The second access is called Remote Access to the Cadastre and it is a paid service for registered persons only. The data are referenced data. ¨

Military maps are produced from two map databases – DMÚ 25 and DMÚ 100. These databases – Digital Model of Land at 1:25 000 and 1:100 000 are on IZGARD geoportal maintained by the Military Geographic and Hydrometeorological Office. DMÚ 25 comprises 190 objects of 20 categories, DMÚ 100 comprises 102 objects in 15 categories. Maps of other scales are available only for military purposes defined by the NATO rules. Fig. 7 shows the military portal IZGARD. 1:25 000 maps are updated from aerial orthophotos and the other map scales are produced by generalisation of this scale

Final map sheets for printing are processed from the digital objects of the databases.

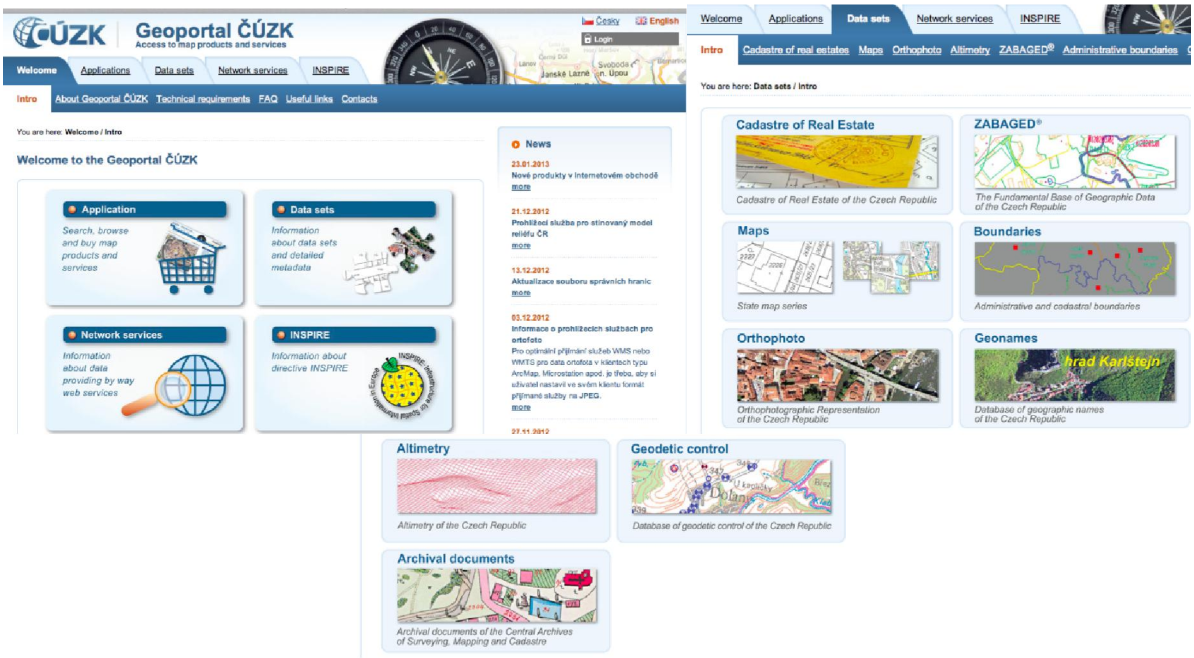


Fig. 3. Geoportal of the Czech Office for Survey, Mapping and Cadastre

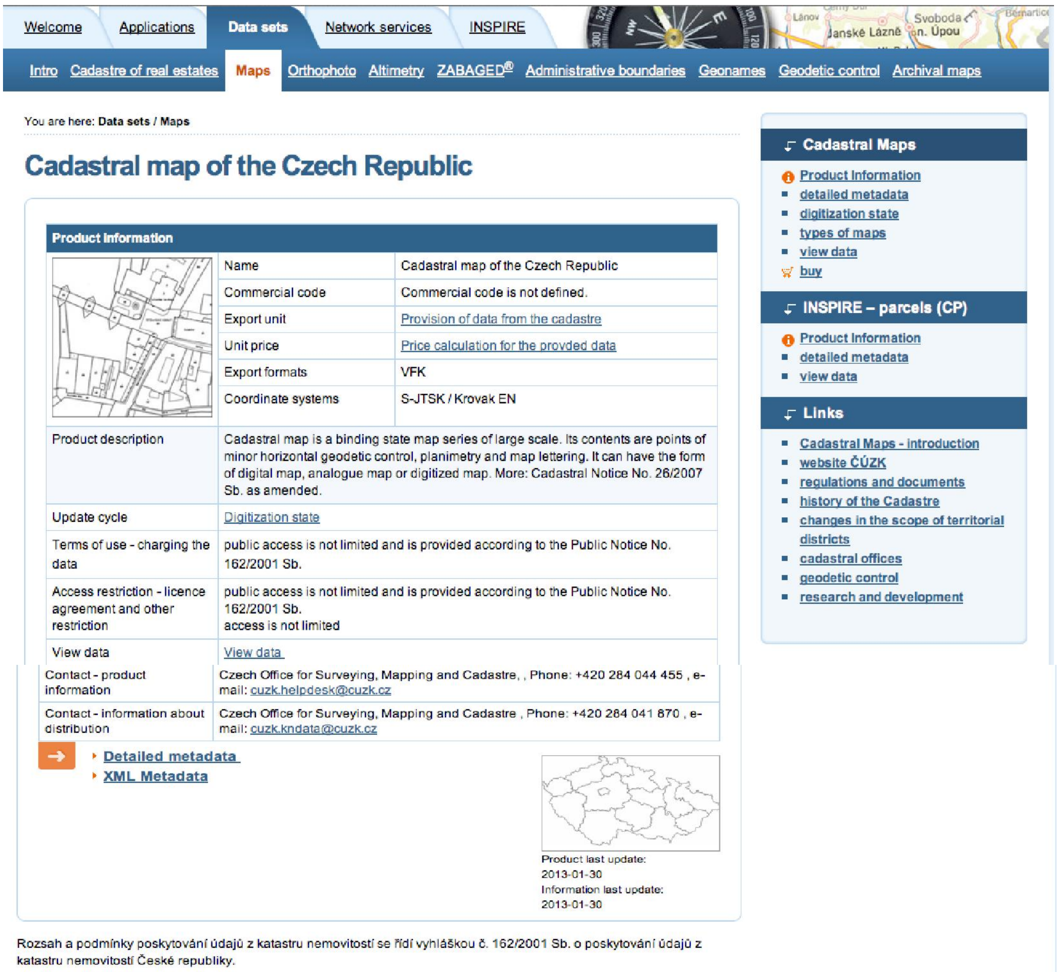


Fig.4. A part of product information on vector data of Cadastral maps on the CUZK Geoportal

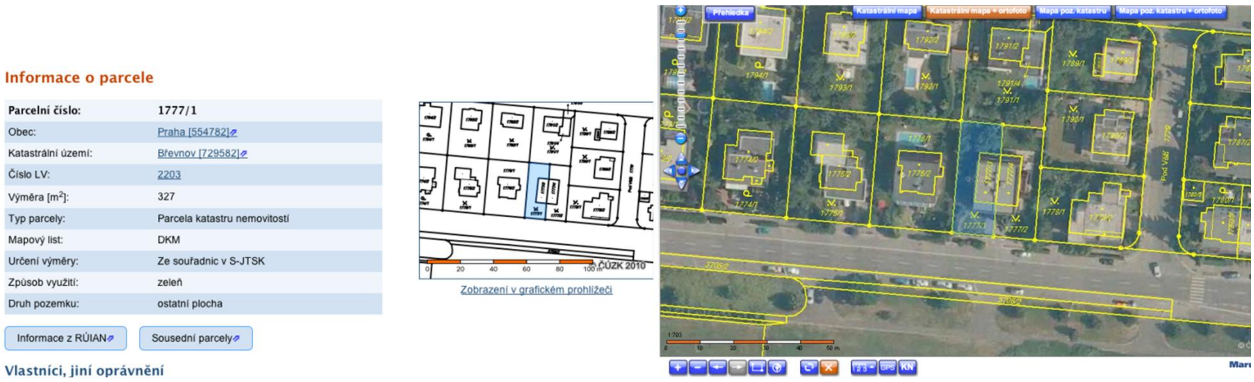


Fig 5. Information about a parcel and Cadastre vector data imaged with aerial orthophoto mosaic

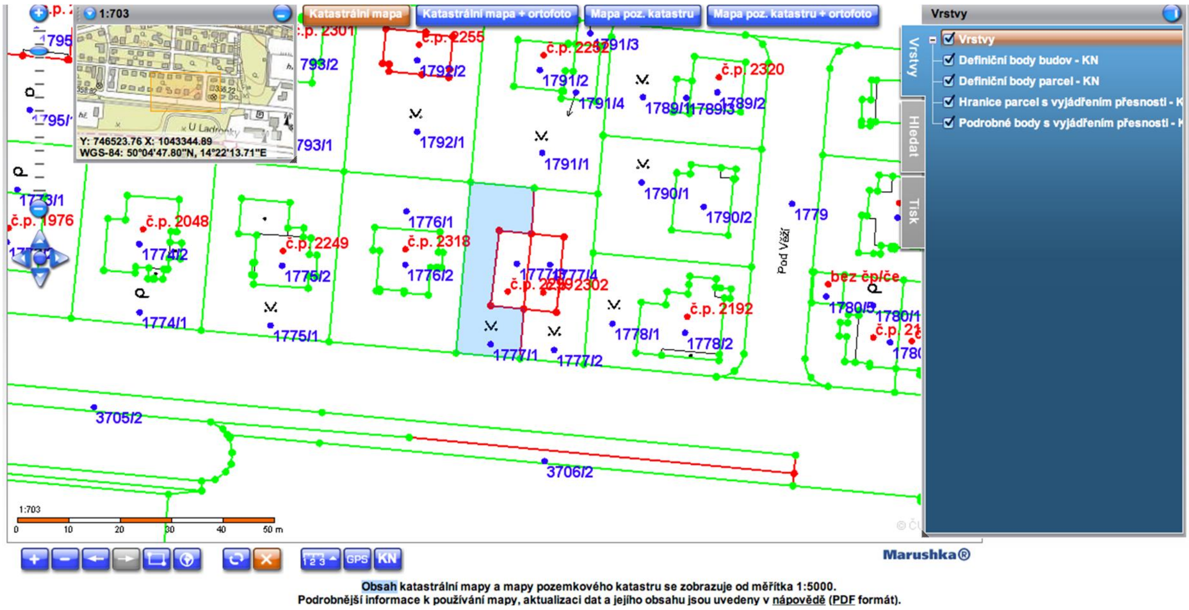


Fig.6. Cadastre map of the Information System of Cadastre of Real Estates

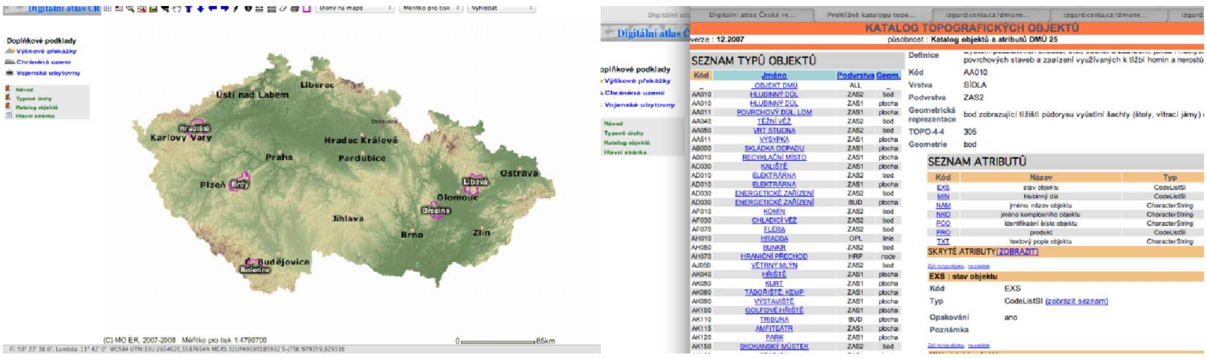


Fig7. First page of IZGARD geoportal, part of a list of object and one object attribute table

FROM INFORMATON SYSTEMS ON GEOPORTALS TO REGISTERS

The Information System of Cadastre of Real Estate has been interconnected in 2012 with four registers - Register of Land Identification, Addresses and Real Estate, which is another spatial information system and three non-spatial information systems Register of Persons, Register of Inhabitants, and Register of Rights and Duties. The registers were defined by Law 111/2009 and are managed by the Ministry of Internal Affairs.

The Register of Land Identification Addresses and Real Estate (RUIAN) is a free open access system on website of the Czech Office for Survey, Cadastre and Mapping. It does not comprise of any personal data. The data sources are:

- Information System of Cadastre of Real Estates
- Territorial Identification Address Register
- And other registers – Czech Post, Czech Statistical Office, etc.
- Spatial data from 1:10 000 topographic map database.

RUIAN unifies postal addresses (address points), parcel numbers and building objects as it shown in Fig. 8.

CONCLUSION

The Czech Republic offers a large range of maps of medium scale both in civilian and military mapping. All are available in raster and vector formats. The large-scale maps – cadastre maps are all in the raster format and a part of the country in the vector format (the vectorisation has not been finished yet). Updating of their vector and attribute part is performed in several hours after data validation. Complete updating for medium scale maps are three years. Map sheets are printed only if ordered from digital databases.

The present role of maps in the society has changed. They are stored, maintained and produced in and from the digital format. They permit the creation of an environment for models of parts of the Earth combined with many other data, originally not even planned to be linked up with. The link brings a new step of data quality and data update. Being stored in a unique record for all users is an enormous data storage savings, simplification of data handling thanks to their uniqueness, simplification of data updating, etc. The advantages are for all sides - data providers, end-users and inhabitants. Non-spatial data update is still easier and less time consuming; that is why it can be nearly in real time, unlike most maps.

Very important part of all above mentioned data are metadata, which were not mentioned in the paper. They form another important and indispensable part of all spatial data in the maps. They respect the rules of the European system INSPIRE and are available on geoportals.

Fig. 8. Example of advantages of RUIAN – two address points in two streets refer to one building object

REFERENCES

CUZK Geoportal. http://geoportal.cuzk.cz, cit. 14 February 2013

Czech Office for Survey, Mapping and Cadastre (COSMC, ČÚZK). www.cuzk.cz, cit. 14 February 2013

Information System to the Cadastre of Real Estates (Remote Access to the Cadastre). https://katastr.cuzk.cz/uvod/, cit. 14 February 2013

IZGARD Geoportal. www.izgard.cenia.cz, cit. 14 February 2013

Open Access (Preview) to the Cadastre. http://nahlizenidokn.cuzk.cz, cit. 14 February 2013

Register of Land Identification, Addresses and Real Estates (RUIAN). http://vdp.cuzk.cz, cit. 14 February 2013

THE STATUS OF CONSTRUCTION AND UPDATING OF NATIONAL GEOSPATIAL DATABASES IN CHINA

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ISPRS WG IV/2

KEY WORDS: geo-spatial database, construction, update

Abstract:
After years of efforts, the construction and updating of the geo-spatial databases in China have made great advances. Currently the national level databases have covered the whole territory and under dynamic updating. While the provincial and municipal level databases are expanding the coverage and increasing the update frequency. This paper briefly introduces the status of the national and provincial level databases.

1. Introduction

The administration of geographic information in China operates under the principle of unified leadership and decentralized organization, including national level, provincial level, municipal level and county level. The National Administration of Surveying, Mapping and Geo-information of China (NASG) is the leading organization in the central government in charge of geographic information in the whole country.

The responsibilities of NASG include: (1) Formulate laws, regulations, development plans, policies and technical standards in surveying, mapping and geo-information; (2) Organize and manage topography, boundary and cadaster surveying and mapping; (3) Establish and maintain national geodetic reference systems; (4) Provide public and emergency geo-information services; (5) Coordinate national geomatics industry development; (6) Regulate surveying, mapping and geo-information market; (7) Manage national basic surveying and mapping results; (8) Supervise map publication; (9) Promote technological innovations and international exchanges in geospatial information fields.

Under the unified administration of NASG, the national level, provincial level and municipal level geo-spatial databases are constructed and maintained with funding from the national, provincial and municipal governments separatly. Generally the scales of national level database include 1:1 million, 1:250,000, 1:50,000. The scales of provincial database include 1:10,000 and 1:5,000. The scale of municipal level database includes 1:2,000, 1:1,000 and 1:500.

National Geomatics Center of China (NGCC) is the government agency for national level databases construction, maintenance and distribution. There is one similar agency in each province and municipal, responsible for the databases within the area.

2. Status of national geo-spatial databases

During 1990-2005, the first version of national level geo-spatial databases was established by digitizing the paper topographic maps. This first version databases include:

(1) 1:1 million scale database. There are totally 77 map sheets. The contents include topographic features, place names and digital elevation model (DEM). The construction was finished in 1993 and the first update was finished in 2002.

(2) 1:250,000 scale database. There are 816 map sheets. The contents include topographic features, place names and DEM. The construction was finished in 1998 and the first update was finished in 2002.

(3) 1:50,000 scale database. There are 24218 map sheets. The contents include topographic features, place names, digital raster graph (DRG), digital ortho model (DOM) and DEM. The construction was finished in 2006.

These databases effectively alleviated the urgent need from social-economic development. However, due to the constraints of technical conditions and limited experiences at that time, the completeness, accuracy and uptodateness of these databases are not good enough.

Since 2006, several important programs have been implemented by NASG to upgrade the national level geo-spatial database. The programs include image data acquirement, 1:50,000 database updating, second time 1:250,000 database updating, surveying and mapping in western unmanned area.

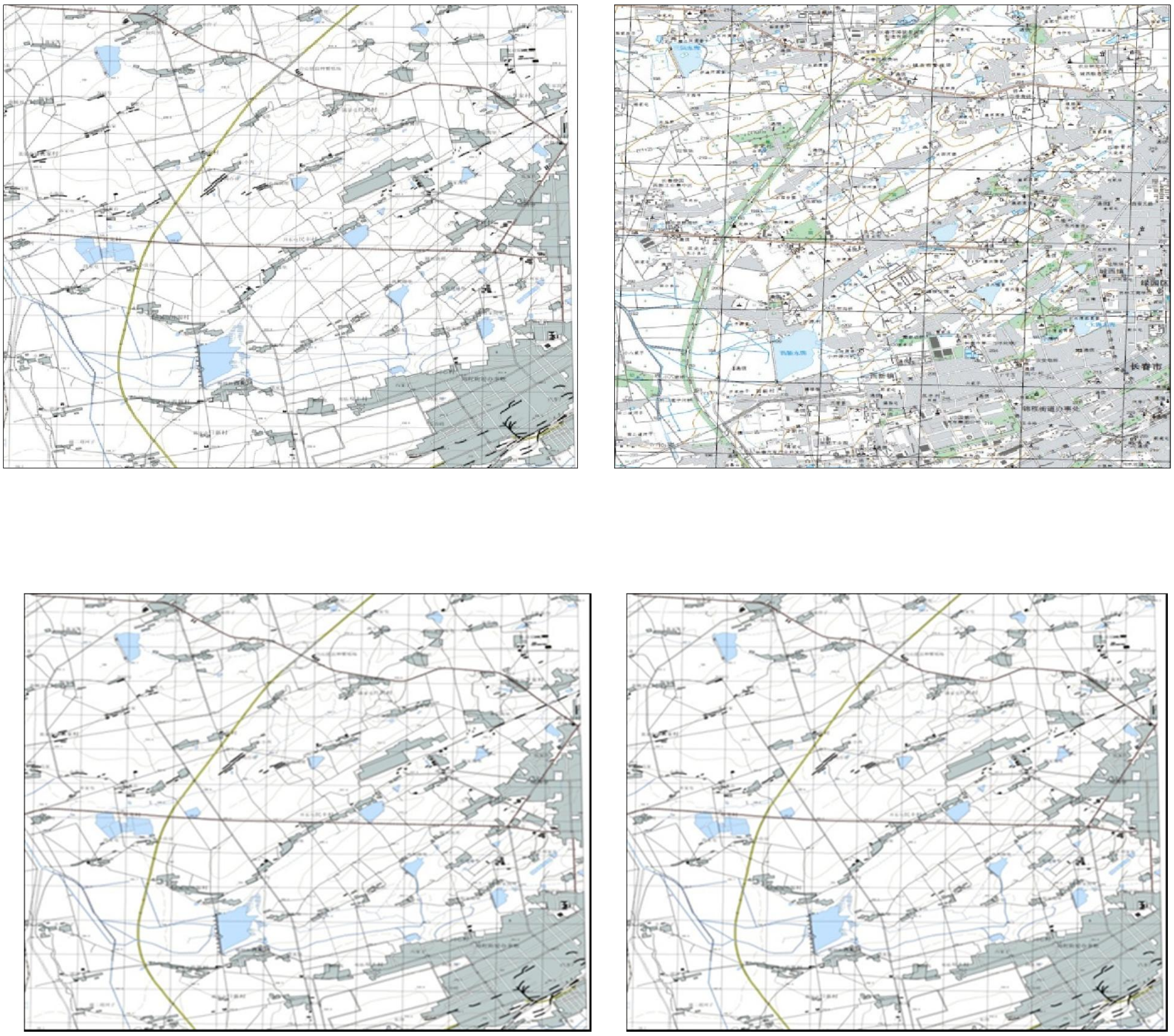
2.1 National image acquirement program

A great volume of satellite images and aerophotos have been collected. Recently more and more images come from Chinese surveying satellites such as ZY-3, etc. According to statistics, there are already about 1158 TB images in the National image database, among them 965 TB aerophotos and 194 TB satellite images. There are several versions of low resolution (≤ 2.5 meter) satellite image covering the whole land area. Approximately 9 million square kilometers land area has been covered by high resolution images (> 1 meter). These aerospace remote sensing image data have greatly supported the construction and updating of the geo-spatial database, as well as various applications.

2.2 1:50,000 database updating

During 2006-2011, NASG had finished the updating of 19150 sheets of 1:50,000 data, covering 80% of land territory. The updated contents include topography features, 1 meter and 2.5 meter DOM, and DEM.

The updated topographic features include water system, residential area, traffic, boundary, contour, land cover, control points, etc. The catalog of features increased from 101 to 437 (as shown in Fig.1). The uptodateness of all features is 2006-2010(as shown in Fig.2). The images are all acquired after 2005 while 80% are after 2007 (as shown in Fig.3).



(a) before updating (b) after updating

Fig. 1 Feature catalog increased

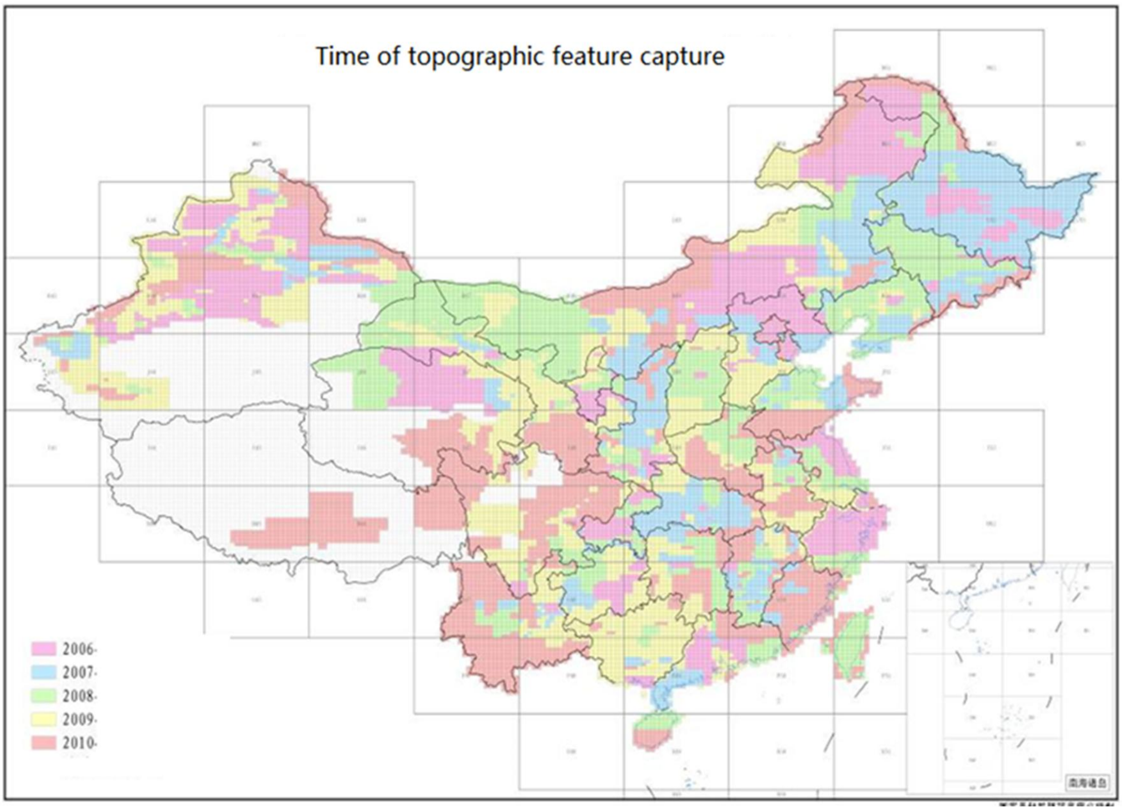


Fig. 2 Uptodateness of topographic features

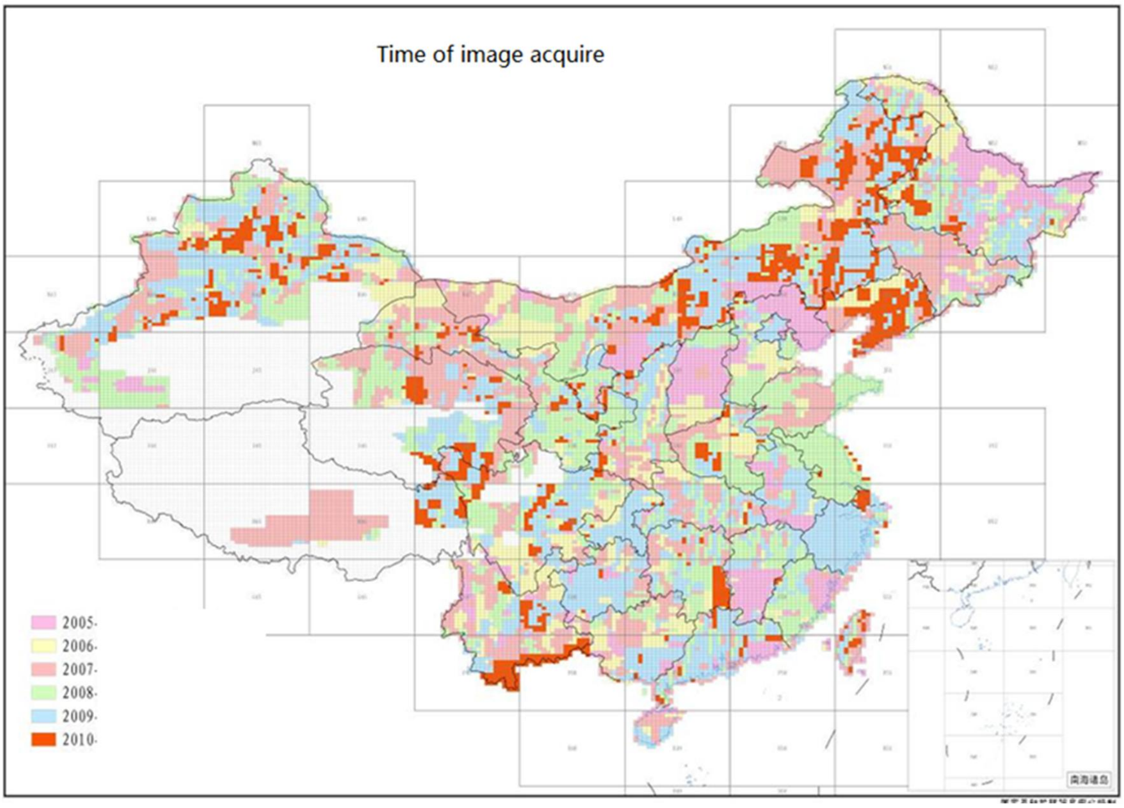


Fig. 3 Uptodateness of DOM

2.3 The second time updating of 1:250,000 database

The second time updating of 1:250,000 database was finished in 2008. Most place names had been field verification. All high level roads (highway, national road, provincial road) had been updated with GPS data. See Fig.4, Tab.1, Fig.5 and Fig.6.

Fig. 4 Field verification and GPS data collection

Table 1- Statistic of updated key features

features	Updated map sheets	Percentage of updated map sheets	Average updated proportion
water	527	64.6%	9.7%
boundary	594	72.8%	27.9%
Road	699	85.7%	20.9%
Railway	398	48.8%	9.5%
Village area	667	81.7%	34.4%
Residential area	496	60.8%	75.3%
contours	232	28.4%	0.1%

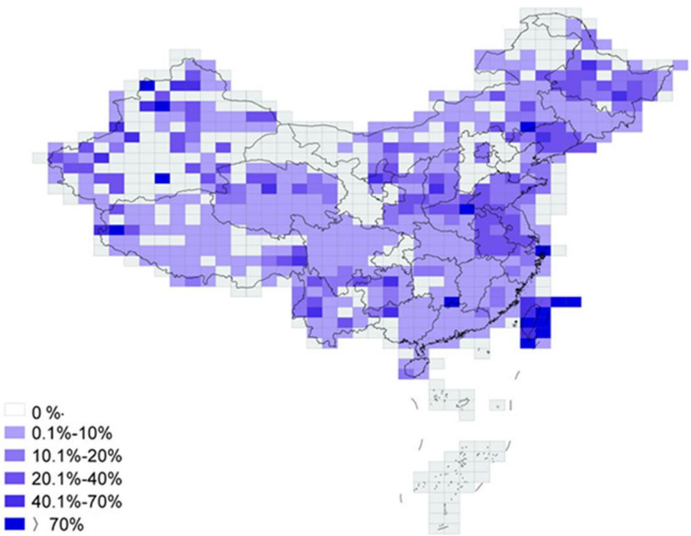


Fig. 5 Updated water features

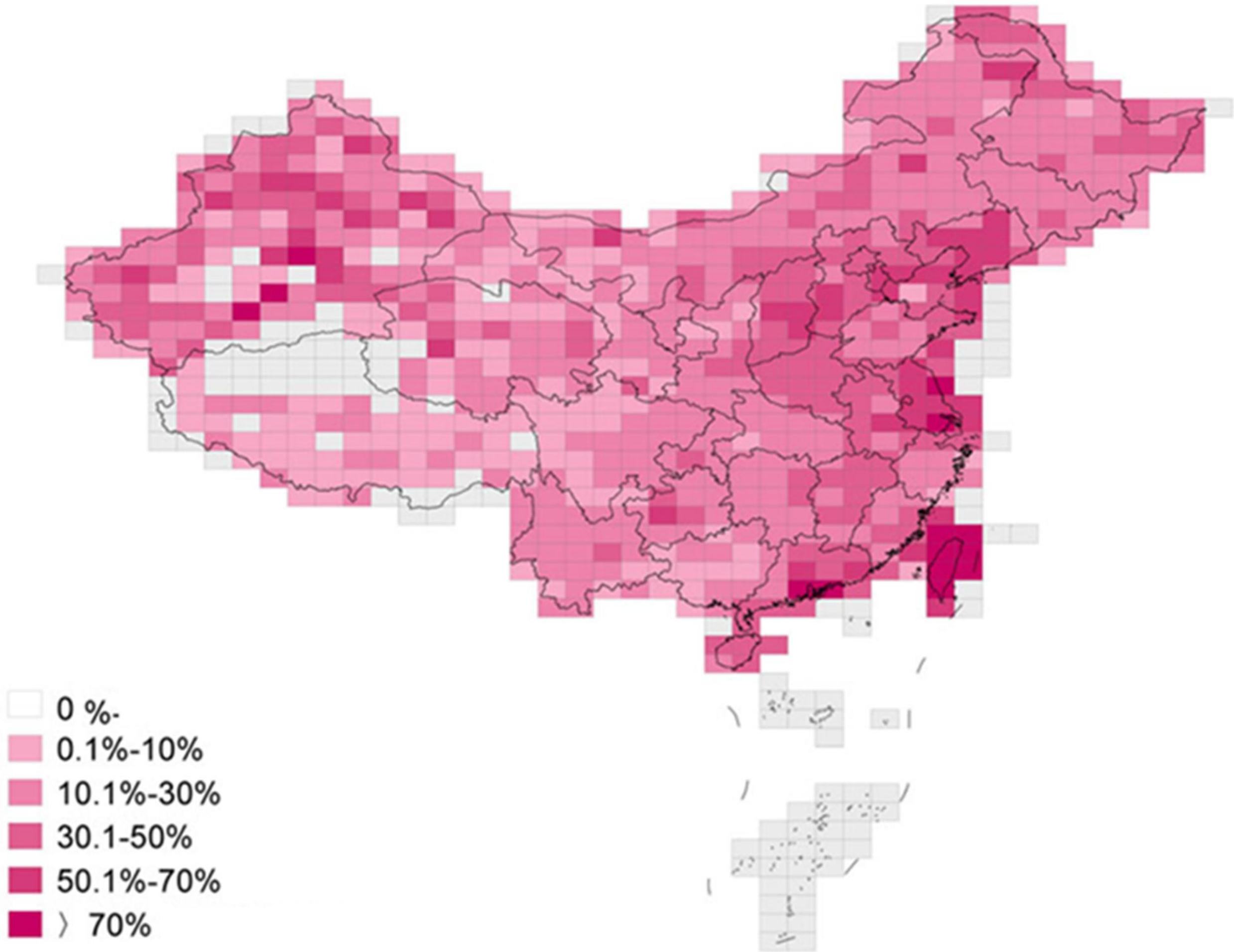


Fig. 6 Updated roads

2.4 Surveying and mapping in Western unmanned area

Before 2006 there are no 1:50,000 maps or date in the desert or mountainous western area of China. During 2006-2011 NASG carried out the program to survey the 2 million square kilometers unmanned area. Some special techniques have been used to fit the special natural and geographical environment of the area, such as digital mapping with three-dimensional large-scale satellite image, scarce control point adjustment, InSAR, etc. Total 5032 map sheets have been finished and the database has been established accordingly.

3. Status of provincial geo-spatial database

By 2010, the 1:10,000 scale database has covered more than 45% territory of China (As shown in Fig.7). Among 31 provinces in China, 20 have established the 1:10,000 database covering the whole province; 5 have database covering more than half of the province. More than 10 provinces have finished the first round updating. Some provinces in eastern part of China update their database every 2 or 3 years while update key features twice a year.

Fig. 7 Coverage of 1:10,000 scale database

4. Status of municipal geo-spatial database

NASG launch the "digital city" program in 2006. By now more than 310 cities start to build the municipal geo-spatial database and more than 150 of them have finished. The large scale geo-spatial database has covered more than 0.2 million square kilometer urban areas.

5. Conclusion and further tasks

After years of efforts, the construction and updating of the geo-spatial databases in China have made great advances. Currently the national level databases have covered the whole territory and the provincial and municipal level databases are expanding the coverage. All of the databases are under continuous updating.

In order to keep the up-to-dateness of the databases, NASG started to dynamically update national database since 2012. The main aims include updating and publishing National 1:50,000 database covering the whole country once a year and using the result to update smaller scaled databases at 1:250,000, 1:1,000,000. While in provincial and municipal level, the surveying and mapping agencies are also work hard to increase the frequency of the updating.

PHOTOGRAMMETRIC RESEARCH PROJECTS AT MICHIGAN TECH INTEGRATED GEOSPATIAL TECHNOLOGY PROGRAM

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ISPRS WG IV/2

KEY WORDS: Photogrammetry, Sensor Modeling, Open-source portals, HCI

EXTENDED ABSTRACT:

Michigan Technological University (Michigan Tech) is a research university located in the Upper Peninsula of Michigan. Michigan Tech is a leader in both undergraduate and graduate science, technological, and engineering education and research. Michigan Tech began as the Michigan Mining School in Houghton in 1885 to train mining engineers to better operate the local copper mines. The university is now organized into two Colleges (Engineering and Science & Arts), and three Schools (Forest Resources & Environmental Science, Business, and Technology). Michigan Tech offers over 120 degree options, including 37 masters and 25 doctoral options. Our university includes 437 faculty, over 6000 undergraduates, and approximately 1000 graduate students.

Michigan Tech is an emerging research institution with approximately $65 million in annual research expenditures in 2011-2012. Over the last five years, Michigan Tech has had the fastest growing research program in the State of Michigan. The National Science Foundation's most recent national research rankings list Michigan Tech 163rd among all research institutions (662) and 118th among public national institutions, 66th among institutions without medical schools. In addition, Michigan Tech has the highest number of licenses and invention disclosures (per $10 million in research) of any Michigan institution. The university is listed as a high research activity, STEM-dominant institution under the current Carnegie classification, and produces 50-60 science and engineering PhDs per year.

Faculty from several areas on campus collaborate on remote sensing and GIS-related research. In the School of Forest Resources and Environmental Science, remote sensing and geographic information science are used to gain a better understanding of how the underlying spatial patterns of vegetation, animals, and natural features are related across landscapes, ultimately leading to more-informed decisions regarding the sustainable use of resources. Our faculty investigates these areas using technologies such as remotely sensed imagery, geographic information systems

(GIS), and the Global Positioning System (GPS), presenting their results on paper and digital maps. Faculty from the School of Technology and Geological and Mining Engineering and Science also collaborates on related research.

Likewise, faculty from across campus collaborate on water-relate research. Our faculty study many areas of water resources, including forest and wetland ecohydrology, vegetation-atmosphere exchange of water, the effect of climate change on hydrological processes, hydrological modeling, water-resource conservation and sustainability, wetland restoration, classification, mapping, aquatic-terrestrial links, and conservation and management of wetland and upland ecosystems. Faculty from biology and civil/environmental engineering are also active in freshwater research. Our success in water-related research recently led the State of Michigan to commit resources to construct at $25 million Great Lakes Research Center(GLRC) on the campus of Michigan Tech. Center already started its operations and many geospatial faculty members, researchers and students are involved in GLRC projects.

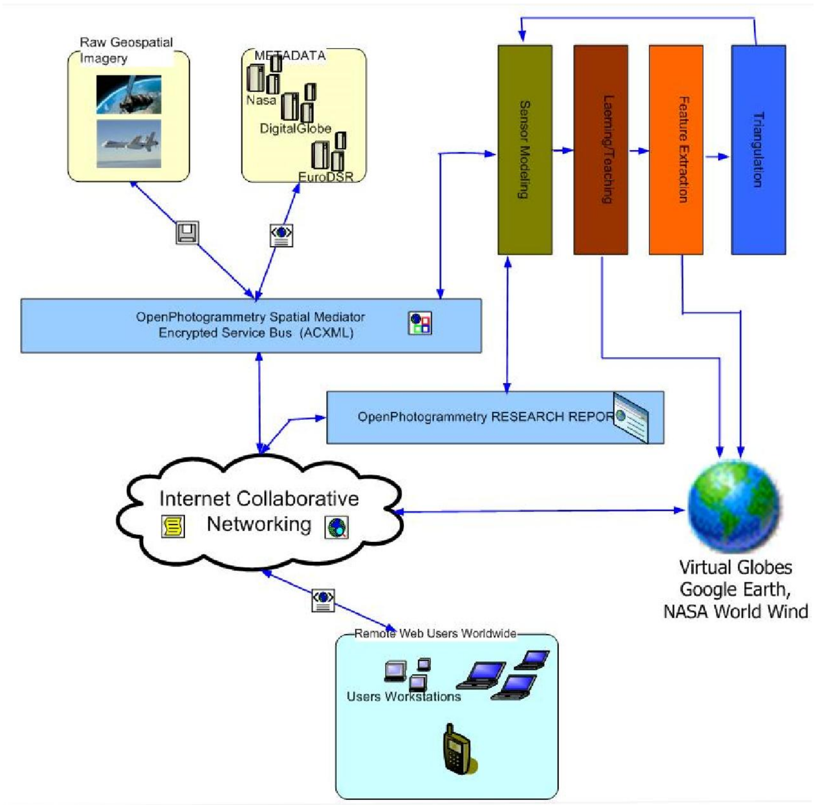
Integrated Geospatial Technology graduate program was established in 2010 and currently is heavily involved in the training of the geospatial workforce in the United States and many other countries.

(http://www.mtu.edu/gradschool/programs/degrees/geospatial/) Research performed by Integrated Geospatial Technology graduate students is an important program element bringing a bridge between training and education. Current presentation outlines some preliminary results from two graduate student research projects associated with photogrammetric science and engineering.

The first project is OpenPhotogrammetry and it is associated with the development of the open-source geospatial web-portal challenging photogrammetric processing of remotely sensed imagery. OpenPhotogrammetry geoportal operates objects representing different types of solutions for various geospatial imaging sensors. OpenPhotogrammetry, when fully developed, is foreseen as a useful instrument for the research of sensors deployed in global mapping in the framework of Service-Oriented Programming Architecture (SOPA) as depicted in Figure-1a. Figure-1b is a sample of the current state of Openphotogrammetry geoportal web-implementation.

A second project outlined in current presentation is associated with the development of the collaborative environments based on novel human-computer interaction technologies such as encephalogram of the brain (EEG) and eye-tracking (ET). The establishment of optimal human-computer symbiosis when the computer system is designated to perform operations where computer algorithms are more efficient and humane analyst can perform operations where the human brain is more efficient than a computer is a promising research direction. Figure-2a outlines an operational workflow of such a collaborative geospatial information processing environment.

Figure-2b shows such a collaborative environment experimental use for teaching Photogrammetry.



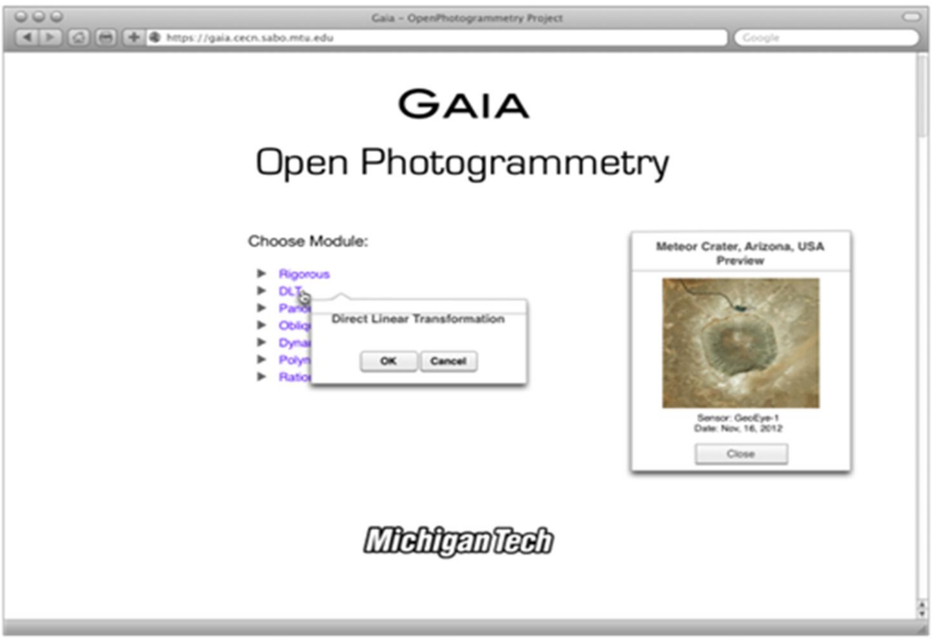


Figure-1 a) Structure of the OpenPhtogrammetry as a SOPA b) Sensor model selection screen of the current version OpenPhotogrammetry geoportal.

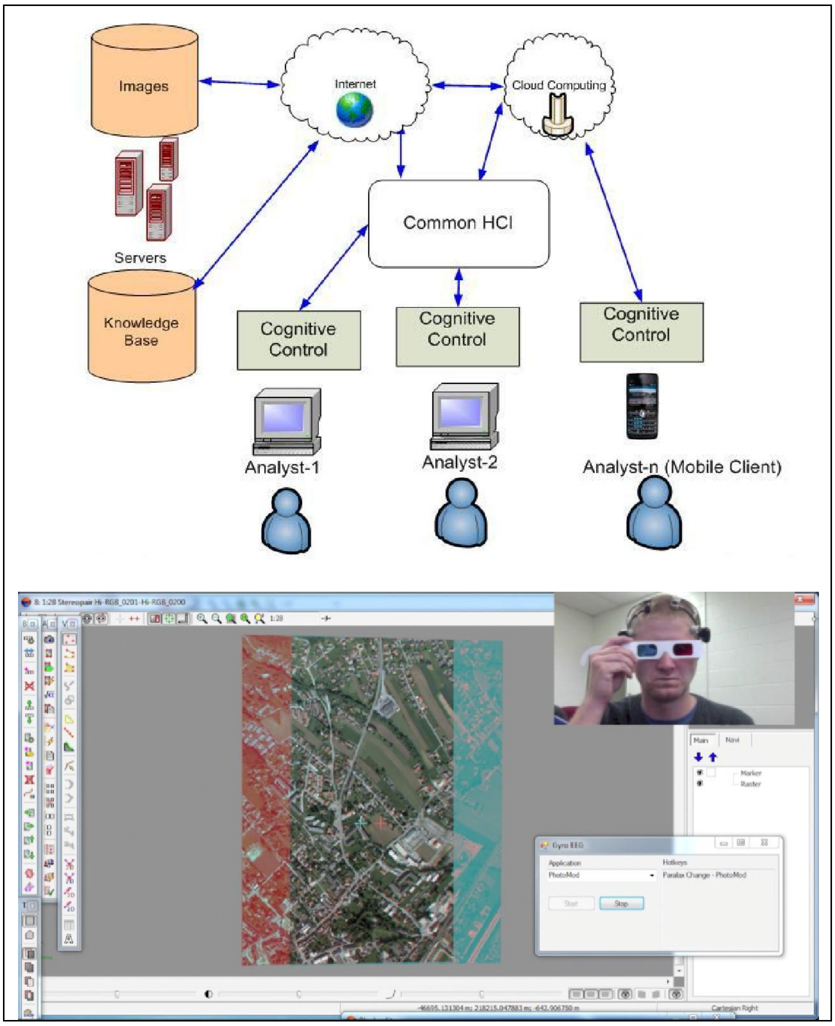


Figure 2 a) Collaborative geospatial environment system architecture b) Experiment of cognitive control of softcopy photogrammetric workstation in application for Photogrammetry teaching.

Both projects can be termed as a "knowledge fusion" because are associated with integration of geospatial disciplines (photogrametry, geodesy, cartography, GIS) and non-geospatial disciplines such as computer sciences, data mining, human-computer interactions and cognitive sciences. Such a research projects are very important elements of training modern geospatial workforce for the global mapping and other modern world challenges. Presentation outlines the current state of research projects in more details.

BIOGRAPHICAL NOTES

Dr. Eugene Levin, CP, Program Chair of Surveying Engineering and Assistant Professor at School of Technology at Michigan Tech University. Dr. Levin also directing Integrated Geospatial Technology graduate program. He received M.S. degree in astrogeodesy from Siberian State Academy of Geodesy in 1982 and Ph.D in photogrammetry from Moscow State Land Organization University in 1989. He is UP Michigan regional director for of American Society of Photogrammetry and Remote Sensing (ASPRS). Dr. Eugene Levin is an ASPRS Certified Photogrammetrist. Dr. Levin intensively involved in the Michigan Tech Geospatial Initiative development, and is a geospatial technology expert in the fields of photogrammetry, aerial and satellite imagery, remote sensing, GIS, 3-D terrain modeling visualization automated feature extraction, and digital cartography. He has 25+ years of experience in US, Israeli and Russian academy and geospatial industry. He held research and managing positions with several Russian, Israeli and US research, academic institutions and high-tech companies, including: Research Institute of Applied Geodesy, Omsk Agricultural Academy, Rosnitc "Zemlya", Ness Technologies, Physical Optics Corporation, Digital Map Products, American GNC, and Future Concepts. He has served as a Principal Investigator and Project Manager in multiple award-winning government programs.

Kevin Takala is a graduate student at Integrated Geospatial Technology graduate program. He obtained a B.Sc. in Surveying Engineering from Michigan Tech University in 2011. His research is concentrated in 3D Visualization and use of EEG systems for geospatial application control.

Ioakeim Tellidis is a graduate student at Integrated Geospatial Technology graduate program. He obtained a B.Sc. degree in Structural Engineering from the Technical University of West Macedonia (Greece) in 1996. His interests and past projects related to photogrammetric processing of the UAV imagery bring him to work on his graduate degree with Michigan Tech.

3D SPATIAL INFORMATION INFRASTRUCTURE FOR THE PORT OF ROTTERDAM

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ISPRS WG IV/2

KEY WORDS: Infrastructure, Internet/Web, Database, Visualisation

ABSTRACT: The maintenance of the complex infrastructure and facilities of Port of Rotterdam is based on large amounts of heterogeneous information. Almost all activities of the Port require spatial information about features above- and under- ground. Current information systems are department and data oriented and cannot reflect the new process- & project-oriented needed for information exchange. Moreover most of the systems are able to process only two-dimensional data, while increasing number of 3D design models is becoming available. This complexity of activities and diversity of information challenges the Port authority to look for more advanced 3D solutions. This paper presents research in progress related to developing a 3D SII in support of information and process management within the Port of Rotterdam. The discussions and the research findings within this project are very relevant to the development of corporative information infrastructure for any large institution of a company.

INTRODUCTION

The Port of Rotterdam (www.portofrotterdam.com) is one of largest in the world. Spread on the area of 105 sq. km over a distance of 45 km, the Port has 350 million consumers Since 2013 a new extension of the harbour into the see (called Maasvlakte 2) is becoming operational. The harbour area accommodates a large number of companies such as oil refineries, petrochemical industry and general cargo trans-shipment handlings. The fast cargo train to Germany the Betuweroute (www.betuweroute.nl) as well as the densely populated area around the harbour (the City of Rotterdam) also contribute to the dynamic of the region.

The continuous development and maintenance of the infrastructure, facilities, logistics and other assets of the Port of Rotterdam requires the management of a broad spectrum of heterogeneous information. A large number of public and private stakeholders (e.g. companies, environmental authorities, municipalities, institutions and citizens) are constantly involved in the exchange of critical information. Much of this information concerns infrastructural features that are embedded in a constantly changing environment. These features are spatially distributed above ground (topography, cadastral parcels), underground (cables and pipes, geological and geotechnical data) and in the water (depth of the river bed). Our investigations of processes and data as well discussions with the experts within the Port identified the following requirements:

3D data management: The need for 3D data management is motivated by two developments. On one hand many management processes need more accurate information about the third dimension, on the other hand an increasing number of newly design constructions are delivered as 3D Building Information Models (BIM). For example, the underground infrastructure (cable and pipe networks) is becoming very dense and therefore very good estimates for available free underground space are needed prior issuing permissions for new networks. Newly designed quays are typical examples of constructions delivered as 3D BIM. As substantial part of the data sets in the management processes consist of traditional 2D drawings (having limited records about z component as an attribute), incorporating such 3D models becomes a very challenging task.

An integrated 3D model: In the last years the information management paradigm in the Port of Rotterdam has changed from data-oriented to process-oriented. The process-oriented approach poses higher requirements to the information management: one feature needs to be defined only once in the systems to avoid inconsistent and conflicting information. Currently the information is managed by a large number of applications with their own information model. This leads to large data diversity in three domains: geometric, semantic, topology and resolution/accuracy. Geometric diversity revers to the representation of the data sets, e.g. vector, pixel, voxel, etc. Semantic diversity addresses the definitions of features and the matching or integrations between the data sets. Data based on existing semantically rich data models are often converted to semantically poor models and data formats, which leads to information loss. As the data are managed in different systems the topologically correct data sets (when available) need to be converted in non-topologically data structures, which reflect the consistency of data. Resolution & accuracy of different data sets has a critical impact during integration of data for the purpose of one project or process.

These aspects have been addresses by a nationally funded project 3DSDI for the Port of Rotterdam. This paper elaborates on our ideas for an appropriate 3D Spatial Information Infrastructure (SII). The paper is organised as follows: the next section 2 briefly presents 3D developments in the region, which can be used as basis for the intended 3D SII. Section 3 presents the scope of the intended 3D SII. Section 4 briefly discusses some initial results. Section 5 elaborates on the short coming developments.

3D DEVELOPMENTS IN THE COUNTRY AND THE REGION

The requirements of 3D SII for the Port of Rotterdam are also motivated by the 3D developments in Netherlands and the Municipality of Rotterdam. 3D spatial information was highly stimulated by the so called 3D pilot in the Netherlands. Large companies and small businesses are interested in, have access to or possess 3D spatial information (structured and non-structured) in various scales and resolutions and the need for integrated modelling (above, below and on the surface) is growing (Emgard et al 2008, Stoter et al 2010, Van den Brink 2012a, 2012b, Zlatanova et al 2010).

The 3D pilot was initiated by the Dutch Kadaster, Geonovum (the National Spatial Data Infrastructure executive committee in the Netherlands which develops and manages the geo-standards), the Netherlands Geodetic Commission (NCG) and the Dutch Ministry of Infrastructure and Environment. The pilot has passed two phases. The first phase (January 2010 until June 2011) established a uniform approach for acquiring, maintaining and disseminating 3D geo-information in collaboration between 65 stakeholders. A major result of the pilot was a national 3D standard realised as a CityGML Application Domain Extension (Groger et al 2012). The standard is compliant with and based on the existing 2D national Information Model for Geo-information (called IMGeo), which is the actual large scale topographic map of Netherlands. Further technical details about the ADE are reported in Van den Brink et al (2012a; 2012b). The second phase concentrated on more result-oriented issues and prepared several best practice documents. About 100 organisations participated in the second phase (completed in the autumn of 2012). The best practice documents describe tools and techniques that have been developed for supporting the implementation of the 3D standard. Specific attention was paid on the alignment between CityGML and IFC (see www.3dpilot.nl).

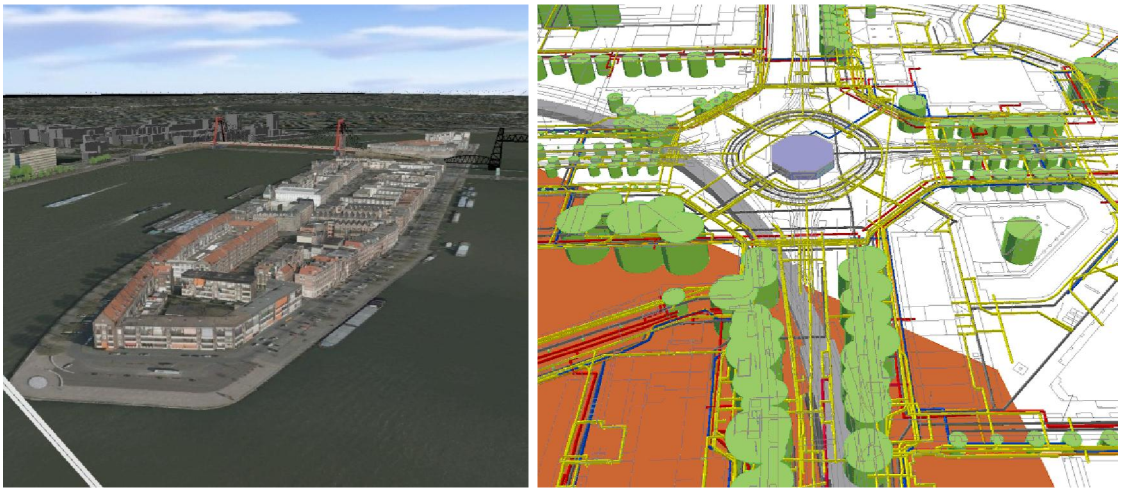

Fig 1: City of Rotterdam: 3D city model (left) and b) 3D underground infrastructure (right)

Another important factor in the discussions for 3D SII is the availability of 3D data in the municipality of Rotterdam. The municipality of Rotterdam is one of the closest partners and frequent contractor of the Port. Most of the data sets needed for the functioning of the Port are obtained from the Municipal offices. A large number of the new quays are also designed by specialised offices of the Municipality of Rotterdam. Since 2007 the city of Rotterdam has a complete height data set and shortly after that starts working on 3D data reconstruction. The municipality was actively involved in the 3D pilot and made available various data sets to the participants in the pilot. The city authority has created and made freely downloadable an object-oriented LOD2, CityGML model for all buildings (http://www.rotterdam.nl/links_rotterdam_3d) (see also Fig.1, left). Additionally, the municipality is responsible for the maintenance of the underground networks in the entire region. It registers all underground networks with their 3D coordinates (Fig. 1, right).

All these developments have established a solid foundation for the development of 3D SII the Port Rotterdam.

3D SII FOR PORT ROTTERDAM

The development of a 3D SII is expected to have a high positive impact for the Port for the internal and external information flow in Port of Rotterdam, as well as for the stakeholders of the entire region. The improved models and system architectures shell increase the productivity and provide additional means to check the up-to-dateness, correctness and consistency of data. An appropriate system architecture that makes relevant information available on the internet will stimulate stakeholders to check and alert for inconsistencies and needed updates (i.e. 'citizens as sensors', Goodchild, 2007). A 3D generic model for the Port of Rotterdam is expected to prevent loss of critical data during the construction process (for renovation or new quays at Maasvlakte 2) and to give better overview on the occupancy of industrial territories, infrastructure above and below the surface, keeping records about the geotechnical and geological conditions on land and sea shore. 3D measurements of sand excavations along the shore could be combined with the construction works within areas already in use. The 3D models of the industrial areas can be later used for safety, security and surveillance or visibility analysis (e.g. for security cameras) replacing existing 2D maps.

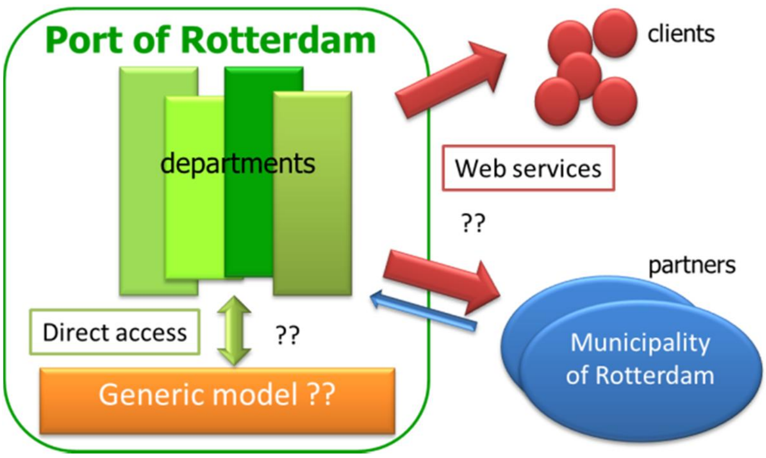

Fig 2: Information exchange for the Port of Rotterdam

Based on initial studies on process and data exchange, communication with clients and companies, and the needed data for management and maintenance of assets, we have identified three different information exchange paradigms between: 1) different departments, 2) Port of Rotterdam and its partners and 3) Port of Rotterdam and its clients (Fig 2.). A generic 3D model (or set of models) has to be envisaged to allow integration of different data sets in one environment and for the different departments, clients and partners. This model should be seen as a major part of the SII and aims at the alignment, harmonization and integration of existing spatial data models as well as the development of additional umbrella meta-models and missing domain models. Related to the model, two aspects require special attention:

- The set of features (assets), which have to be included in the model considering their semantics, geometry, topology, appearance, granularity or levels of detail (LOD). Moving to 3D, it should be also evaluated how to link the concepts of BIM (e.g. IFC) and GIS (e.g. CityGML). The generic model will give the conceptual view on the information to be managed by the Port. Some sections of it will be implemented as data structure, but many sections will be used only as a reference model to obtain data from clients and partners.
- The data structure, which would be most appropriate to maintain the features, which are maintained by the Port of Rotterdam. At present, many data sets are still maintained by individual departments, although large parts of the information are managed centrally in database management system (DBMS). A central management is clearly a choice that will ensure consistency and re-use of information, but will require a data model that can serve the needs of all departments.

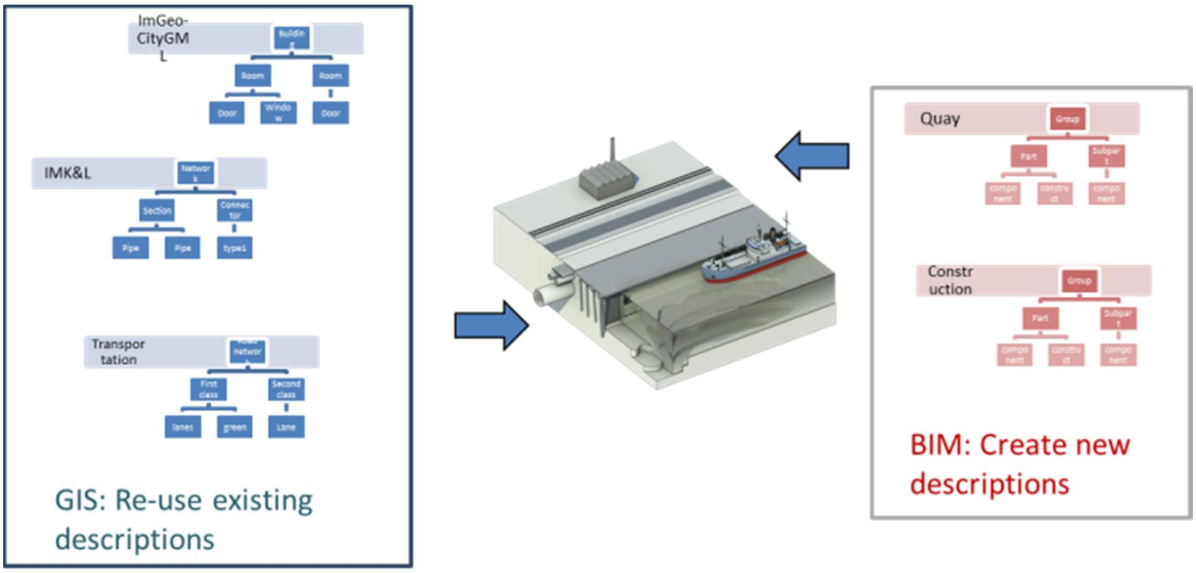

Fig 3: 3D generic model integrating GIS and BIM data: a conceptual view.

The generic 3D model should incorporate data from GIS (existing) and BIM (design) domain (Fig 3). While developing the GIS branch of the model, the following principles will be taken into consideration:

- Features will be defined only once, but all the properties needed for the work of the Port will be maintained. This implies that all the features will be intelligent objects, having strict definitions and consistently structured properties and relationships.

- Features, which can be identified in existing standards (GIS and BIM) will be re-used. A special attention will be given to the Dutch Information Doman Models. Among those models the topographic large-scale model (IMGeo) and the Information model for Cables and Pipes (IMKL) are most interesting. Relevant features from other models will be re-used as well.
- New features will be defined only when similar notations cannot be identified in existing models.
- International standards, discussions and tendencies related to 3D information management will be close followed and taken into consideration. Special attention will be given to developments within OGC and Web3D.

The most important assets within the Port of Rotterdam are the quays. At present, there is no a definition of quays in BIM. Quays are complex constructions and no one has developed a formal description any of the BIM standards. Within this research a new model will be developed for the one of the BIM standards (i.e. IFC).

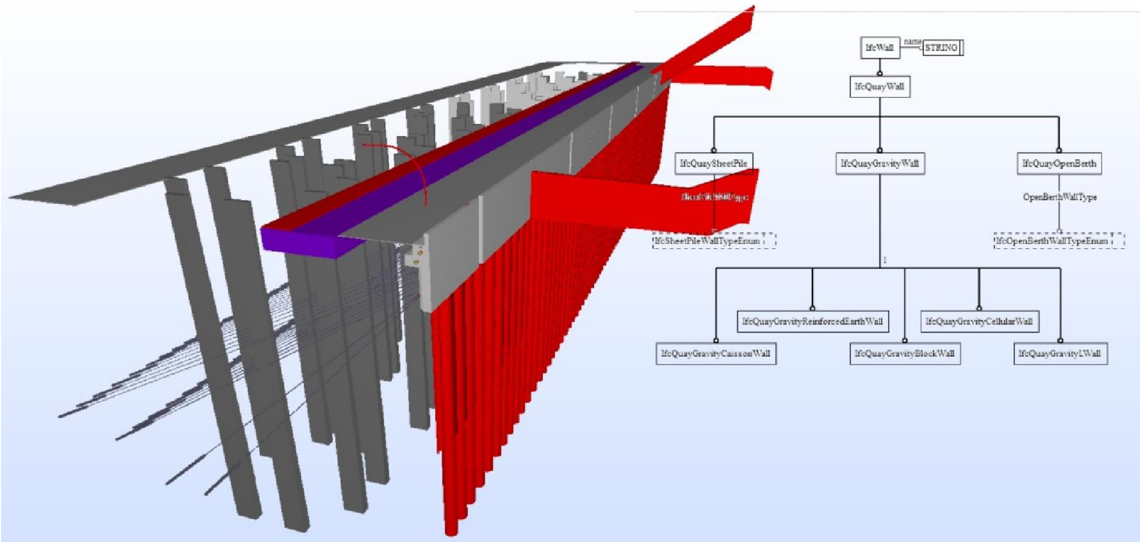

Fig 4: 3D model of quays and top classes of the IFC domain model.

A critical question to be answered is the link between the design and existing spatial objects. As well-know from the literature, BIM and GIS concepts for representing features differ significantly (Döllner, and Hagedorn 2008). A critical analysis has to be therefore performed to evaluate the applicability of the two concepts and estimate the consequences on the generic model. Several options will be investigated: 1) keep BIM representation as core and map to GIS representation whenever necessary, 2) keep GIS representation and convert the new BIM designs upon receive and 3) keep both representation and establish links between semantically similar objects and their elements (Beetz et al 2009; Hess and de Vries, 2006; Hijazi et al 2010). The third approach is being currently investigated since no conversions will be required.

To replace the cumbersome and verbose exchange of file-based information between stakeholders, we intend to develop a Service Oriented Architecture that will allow just-in-time extraction and integration of distributed data sources through web services or direct access. Depending on the type of the users (departments of the Port, Clients or Partners) different levels of access to the generic model has to be provided. In general, the departments have to be able to have full access (read&edit&) to the information from the generic model via the software packages in use. The external stakeholders will be given only read access or a very limited update access. What kind of services will be implemented is still under investigation.

The intention is to reuse existing technologies such as the OGC family of geospatial information access standards through e.g. Web Feature Services (WFS) (Lapierre and Cote 2008), (spatial) queries of partial BIM as provided by BIM Server (Beetz et al 2010) or other BIM related technologies (Coates and Arayici, 2012). On a technological level, mature, open and established technologies like SOAP, Google Protocol Buffers and RESTful services would guarantee their usability in production environments. Which approach will be followed depends on the types of uses and the tasks they need to perform. Related to this is the question of the standards, to be used for exchange of information: GML, CityGML, BIM (IFC) or the Dutch Information Domain Models.

To make efficient use of the structured, interconnected information provided by the model described earlier, data integration and visualization clients are currently in process of development. These allow the selection of relevant spatial data according to the generic model and provide visual means for multi-criteria and multi-dimensional analyses in 2D or 3D to support decision processes. Flexibility and ease of use is provided by their web-based nature, using upcoming vendor-independent, open standards like HTML5 and WebGL.

IMPLEMENTATIONS AND TESTS

The developed model and systems architecture will be tested with two scenarios: high-performance quays and underground pipes. Both scenarios have been identified as having critical importance for the Port of Rotterdam.

A quay wall can represent different aspects of information management: an assembly of structural engineering components, a series of logistical units consisting of bollard slots, a piece of real estate or as the target zone of a navigation channel that has been externally contracted for constant excavation to guarantee a certain ship draft for a client. When frequent re-occurring changes, such as renting out a berth to a new client, have to be organised. Presently this is done in an ad hoc process where relevant information is gathered, processed and communicated in an unstructured way involving different internal and external stakeholders. Often objects appear with different definitions by the domain applications. This use case is intended for testing the integrated model (especially BIM and GIS integration) and the performance of 3D spatial analysis.

The second use case is to be used for testing the 3D visualisation aspects of 3DSII. Underground cables and other infrastructural features are obtained from external parties such as the Municipality of Rotterdam in the form of 2D networks (although the data are 3D). The planning, execution and documentation of new infrastructural projects however is depending on additional, three dimensional aspects and needs to be streamlined in order to prevent unwanted side-effects such as cable damage during construction and unnecessary earthworks due to ill coordinated, parallel projects or lack of underground space.

The first developments concentrate on two aspects related to the use of the model: 3D analysis (clip and cross section) and 3D visualisation (using Web GL). One of the largest advantages of a well-structured 3D model is the ability to integrated data in one 3D environment and to perform 3D analysis. Therefore as a first step even before developing the model, we considered important to demonstrate some aspects of 3D analysis and visualisation. A test area was identified and all possible data sets (currently in possession or of importance for Port Rotterdam) were collected and made available for testing the developments.

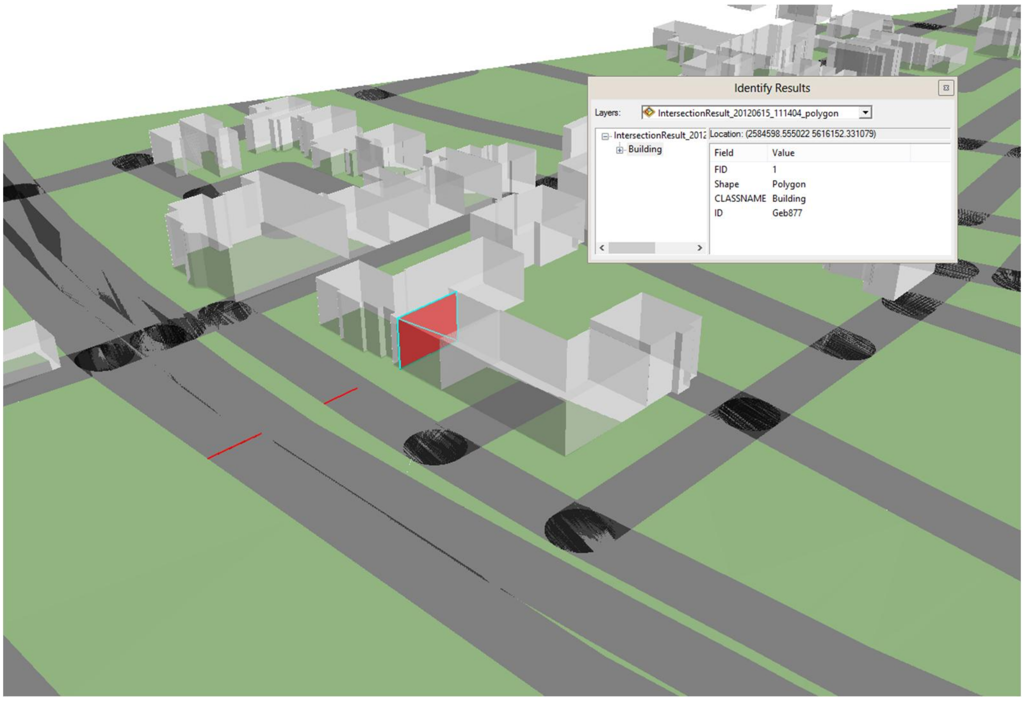

Fig 5: A profile: all the resulting features are valid objects and inherih the attributes of they belong to (courtesy W. Goedhart)

Our study on the process management revealed that two 3D operations clip and cross section are needed in several stages of the project management of a new development (e.g. quay). Firstly, 3D clip operation is needed within the cost-benefit analysis. The area for development has to be delineated and analysed against all existing assets, which will be affected. This operation is currently performed in 2D, which often leads to miscomputations and inaccuracies. The clips and the cross section must be performed in 3D. The new resulting objects have to be valid and preserve the attributes of the original object. Figure 5 demonstrates the 3D cross section with a vertical plane. Two streets and one building are intersected in with the vertical plane and are highlighted in the figure. The cross section operator can be performed in all directions (and not only vertical). This operation could be a solution to providing 2D geometries to existing systems, which cannot easily be extended to 3D. Presently the developed algorithms can be applied to CityGML models, but the intention is to be adapted for the model that would be developed for the Port of Rotterdam. Presently, the operations are developed considering GIS data types (i.e., point, curve, surface and polyhedron). This means that the more elaborated geometric primitives available in BIM models are not considered. The objects of the quay model are therefore converted to triangular meshes. However not all the objects could have been consistently modified and have been omitted from the test data set.

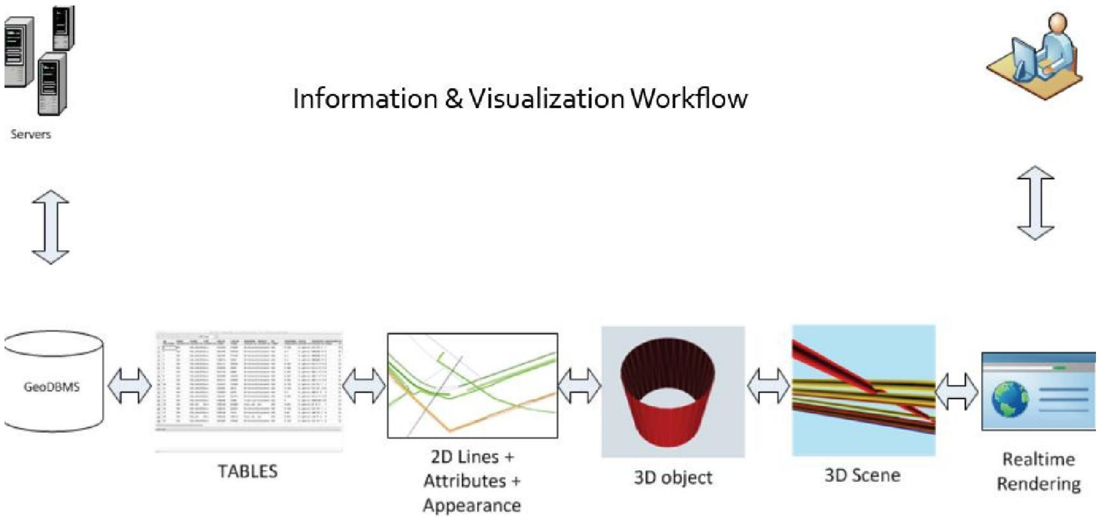

Fig 6: 3D visualisation work flow for pipelines (Guerrero 2012)

The second prototype concerns 3D visualisation. The goal was to investigate and select an appropriate approach for integrated visualisation of above and underground data in one environment. The focus was on pipes and cables. Utility networks are tricky objects for visualisation because they are usually maintained as simple lines and required significant modifications to be adapted for 3D rendering.

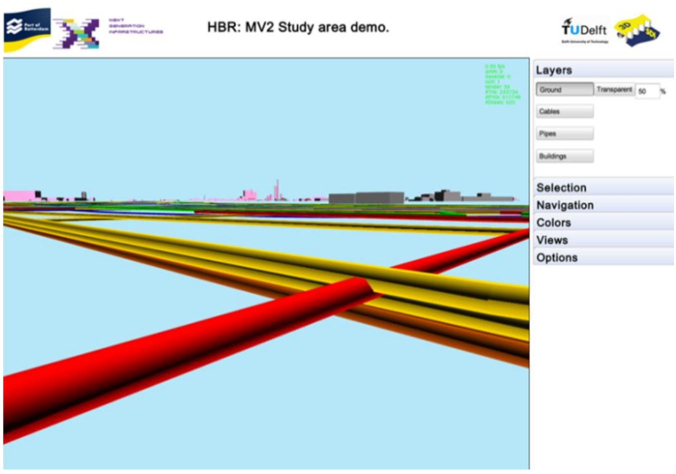

Fig 6: Visualisation of pipes, buildings, surface model (transparent) in WebGL client using X3D/X3DOM (Guerrero, 2012)

Furthermore, the performance of some new technologies such as WebGL (X3D/X3DOM and SceneJS) and Layar was tested. The developed prototype is able to: extract pipes and cables from a data base with their attributes, convert the lines to an appropriate 3D representation, visualise the 3D pipes (using WebGL or Layar) together with above ground information, allow for simple interaction such as query of attributes, switching layers, etc. (Fig 6).

It has been successfully demonstrated that the needed transformations and adaptations can be executed in the required time to make the work with the model comfortable. Figure 4 illustrates the integrated visualisation of buildings (CityGML LOD2), 3D utility networks and surface data (topographic map of 1:10000) (Fig 6). More details on the way 3D pipes have to visualised, e.g. the number of faces, which has to be used to represent one cylinder, the max number of objects that should be visualised in one scene, etc. can be found in Guerrero 2012.

DISCUSSION AND FUTURE DEVELOPMENTS

In this paper we presented the challenges in spatial information management and the intended developments toward corporate 3DSII for the Port of Rotterdam. Our research concentrates on technical aspects of 3D SII, i.e. 3D conceptual model, 3D visualisation and 3D operations to be performed on the model. Several prototypes have been developed, but they are still running independently from each other and from the model. Further developments will address the integration of these components. Although incomplete the prototypes have demonstrated that 3D GIS data (buildings, cables and pipes, and surface model) can be integrated with the quays provided as BIM model. The current approach was to convert the geometries of the BIM model to a GIS data types. However it was not possible to transform all the BIM objects. Large amounts of objects were lost. Current commercial packages still cannot convert BIM models to GIS representations without loss of data. Therefore the current model keeps the geometry as in the original BIM objects.

The most challenging aspect in this research is the conceptual model. As mentioned previously, the model should serve as a virtual container where all kind of (spatial) features can be appropriately accommodated for integrated visualisation and analysis. The model might not be physically implemented in any system, but parts of it can be of use in the different departments or sections of the Port. This also implies that many of the current systems will not need to be modified. The internal models will remain untouched and appropriate mappings (semantic and geometric) will be provided. A formal framework for performing the mappings has to be developed as well.

REFERENCES

Beetz,J., L. van Berlo, L., R. de Laat, and P. van den Helm, (2010) Bimserver.org - an Open Source IFC model server, Proc. of. 27th International Conference on Applications of IT in the AEC Industry CIB-W78, Cairo, November 2010, 1-8)

Beetz, J., J.P. van Leeuwen and B. de Vries, (2009) IfcOWL: A case of transforming EXPRESS schemas into ontologies, Artificial Intelligence for Engineering Design, Analysis and Manufacturing. 23, 1, 89-101

Coates, P. and Y. Arayici (2012) Optimisation of the BIM authoring tool in Architectural practice: a case study approach, Int. J. on 3D Information Modelling, 1, 2, 30-45

Döner,F., R. Thompson, J. Stoter, Ch. Lemmen, H. Ploeger, P. van Oosterom and S. Zlatanova (2010) 4D cadastres: First analysis of legal, organizational, and technical impact - with a case study on utility networks, Land Use Policy, 27, 1068-108

Döllner,J. and B. Hagedorn (2008) Integrating GIS, CAD and BIM data by service-based virtual 3D city models, Urban and Regional Data Management; UDMS Annual 2007, 157-170 (2008)

Emgård. KL and S. Zlatanova (2008) Design of an integrated 3D information model, Urban and regional data management: UDMS annual 2007, Taylorand Francis Group, London, 143-156

Goodchild, M.F, (2007) Citizens as sensors: the world of volunteered geography, GeoJournal 69, 4, 211-221

Gröger, T. Kolbe and A. Czerwinski, OpenGIS CityGML Implementation Specification. (2012) http://www.opengeospatial.org/standards/citygml (last accessed 25-03-2013)

Guerrero JI, 2012, Three-dimensional reconstruction of underground utilities for real-time visualization, Master thesis TU Delft, 2012, 103 p. avalible at www.gdmc.nl (alast accessed 26.03.2013)

Hess, C. and M. de Vries,(2006) From models to data: A prototype Query Translator for the cadastral domain, Computers, Environment and Urban Systems, 30, 529-542 (2006)

Hijazi, I., M. Ehler and S. Zlatanova (2010) BIM for geo-analysis (BIM4GEOA): set up of 3D information system with open source software and open specifications (OS), International Archives of the Photogrametry, Remote sensing and Spatial Information Sciences, Vol. XXXVIII-4/W15, November 4-5, 2010, Berlin, Germany, 45-49

Isikdag, U. and S. Zlatanova (2009) Towards defining a framework for automatic generation of buildings in CityGML using BIM, 3D geo-information sciences, LNG&C, Springer Verlag, 79-96

Lapierre, A. and P. Cote (2008) Using Open Web Services for urban data management: a testbed resulting from an OGC initiative offering standard CAD/GIS/BIM services, Urban and Regional Data Management; UDMS Annual 2007, Taylor and Francis, London, 381-393 (2008)

Penninga, F. and P.J.M. van Oosterom (2008) A simplicial complex-based DBMS approach to 3D topographic data modelling, in: International Journal of Geographical Information Science, 22, 7, 751-779

Scarponcini, P., S. Camateros, O. Custers, S. Zlatanova and P. van Oosterom, (2008) Introduction to SII, Creating Spatial Information Infrastructures: Towards the Spatial Semantic Web, CRCpress Taylor and Francis group, Boca Raton, xiii-xxiii

Stoter,J.E., J. Beetz, H. Ledoux, M.l Reuvers, R. Klooster, P. Janssen, F. Penniga, S. Zlatanova and L.van Den Brink, 2012, Implementation of a national 3D standard: case of The Netherlands, to be published in: 3D geographical information, Lecture Notes in Geoinformaton and Cartography

Stoter, JE, G. Vosselman, J. Goos, S. Zlatanova, E. , Verbree, R. Klooster, M. Reuvers, 2011, Towards a national 3D spatial data infrastructure: case of the Netherlands. Geoinformation: Organ de Deutschen Gesellschaft für Photogrammetrie und Fernerkundung e.V., 2011(6), 405-420.

Stoter, J., M. Reuvers, G. Vosselman, J. Goos, L. van Berlo, S. Zlatanova, E. Verbree and R. Kloosterg, (2010) Towards a 3D geo-information standard in the Netherlands, International Archives of the Photogrammetry, Remote sensing and Spatial Information Sciences, XXXVIII-4/W15, November 4-5, 2010, Berlin, Germany, 63-67 (2010)

Tegtmeier, W., S. Zlatanova, P. van Oosterom and H. R.G.K. Hack (2009), Information management in civil engineering infrastructural development: with focus on geological and geotechnical information. In: Kolbe, Zhang&Zlatanova (Eds.), Proceedings of the ISPRS workshop, vol. XXXVIII-3-4/C3 Commission III/4, IV/8 and IV/5: Academic track of GeoWeb 2009 conference: Cityscapes International archives of photogrammetry, remote sensing and spatial inform ation sciences (pp. 1-6). Berlin, Germany: ISPRS

Van den Brink, L., J.E. Stoter and S. Zlatanova, 2012a. Establishing a national standard compliant to CityGML, accepted for International Journal of Geographical Information Science IJGIS

Van den Brink, L., J.E. Stoter and S. Zlatanova, 2012b. Modeling an application domain extension of CityGML in UML, ISPRS Archivers, 3D GeoInfo Symposium, Quebec, Canada, 16-17 May. 2012.

Zlatanova, S., L. Itard, M. S. Kibria and M. van Dorst, 2010, A user requirements study of digital 3D models for urban renewal, In: Open House International, Volume 35, 3, pp. 37-46

UPDATING AND REFINEMENT OF NATIONAL 1:500000 DEM

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ISPRS WG IV/2

KEY WORDS: DEM, update, refinement

ABSTRACT

TIN based interpolation is one of the most popular and efficient methods for generating DEM since it makes it is possible to convey more comprehensive information including height, geomorphic feature, and hydrologic feature and so on during the process of interpolation. However, some defaults exist in this method, especially in flat area. It may reduce the precision of DEM and make DEM products cannot meet the requirements of practical applications. In this paper, a new method is presented for updating the DEM based on the updated 1:50,000 DLG database. The automatic extraction algorithm of geomorphic features is introduced. The practical work flow is designed and a software system is developed. The method has been applied to the update of the national 1:50,000 DEM database.

INTRODUCTION

1:50,000 Digital elevation model (DEM) is the digital model representation of a terrain's surface. DEM consists of the elevation matrix of some ground point sampled at regular intervals, storing the elevations of ground points and the morphological characteristics of the undulation of earth's surface; it is widely applied in many aspects of national economic construction and social development, such as land-use planning, environmental management and protection, disaster prevention and relief, and national defense construction.

The methods for the generation of DEM include mathematical interpolation of the contour lines, digital photogrammetry, and LiDAR. In the contour-line-based mathematical interpolation method, DEM is generated using mathematical interpolation algorithm based on the information of the contour lines, elevation points, and water system, as well as various terrain features.

Mathematical interpolation algorithms are typically divided into the vector-based interpolation algorithms and raster-based interpolation algorithm. In vector-based interpolation algorithm, the interpolation of triangulated irregular network (TIN) is more common, because it can make full use of many information sources, such as elevations, topographical features, and hydrological information, by employing some mathematical interpolation methods, such as linear interpolation, polynomial surface interpolation, or directly adjacent interpolation. Furthermore, the results of interpolation have less redundancy, but higher terrain fitting accuracy than the other two methods.

Nevertheless, the TIN-based interpolation method cannot adapt to some flat or sharp undulating regions, and the results of interpolation depend on the richness of the topographical features. Thus, these deficiencies exist in the 2001 version of the 1:50,000 DEM database.

With the completion of the national 1:50,000 database update, more accurate and real-time topographic data will be obtained, and this will make it is possible to update the 1:50,000 DEM dataset better and faster. For these reasons, we discussed the aspects of the update of digital elevation model based on the updated version of 1:50,000 topographic data, presented a novel and automatic algorithm for the extraction of topographical features and the raster-based DEM interpolation, and developed a practical software system for a quick update and refinement of 1:50,000 DEM.

TECHNICAL ROUTES

The overall technical routes for the update and refinement of 1:50000 DEM is shown as follows. First, the reasonable update areas are found out by analyzing the changes of geomorphic features; second, the topographic features, including the contour lines, elevation points and water system, are picked out from the updated version of the 1:50000 topographic database; third, an updated version of the DEM data is generated by employing one of appropriate mathematical interpolation methods, according to the designed grid size.

For the refinement of DEM Interpolation, a fully automated software system with a novel and effective algorithm for the collection of a terrain feature points is developed.

For the generation of the high-precision and realistic DEM data, a mathematical interpolation algorithm that adapts to various topographic types is developed. In most areas, linear interpolation can be used on triangulated irregular network to build the regular-grid DEM data; however, regular raster interpolation should be directly used to build the regular-grid DEM data in some special areas, such as plains and coastal areas.

The process of the update of 1:50,000 DEM is shown in Fig. 1.

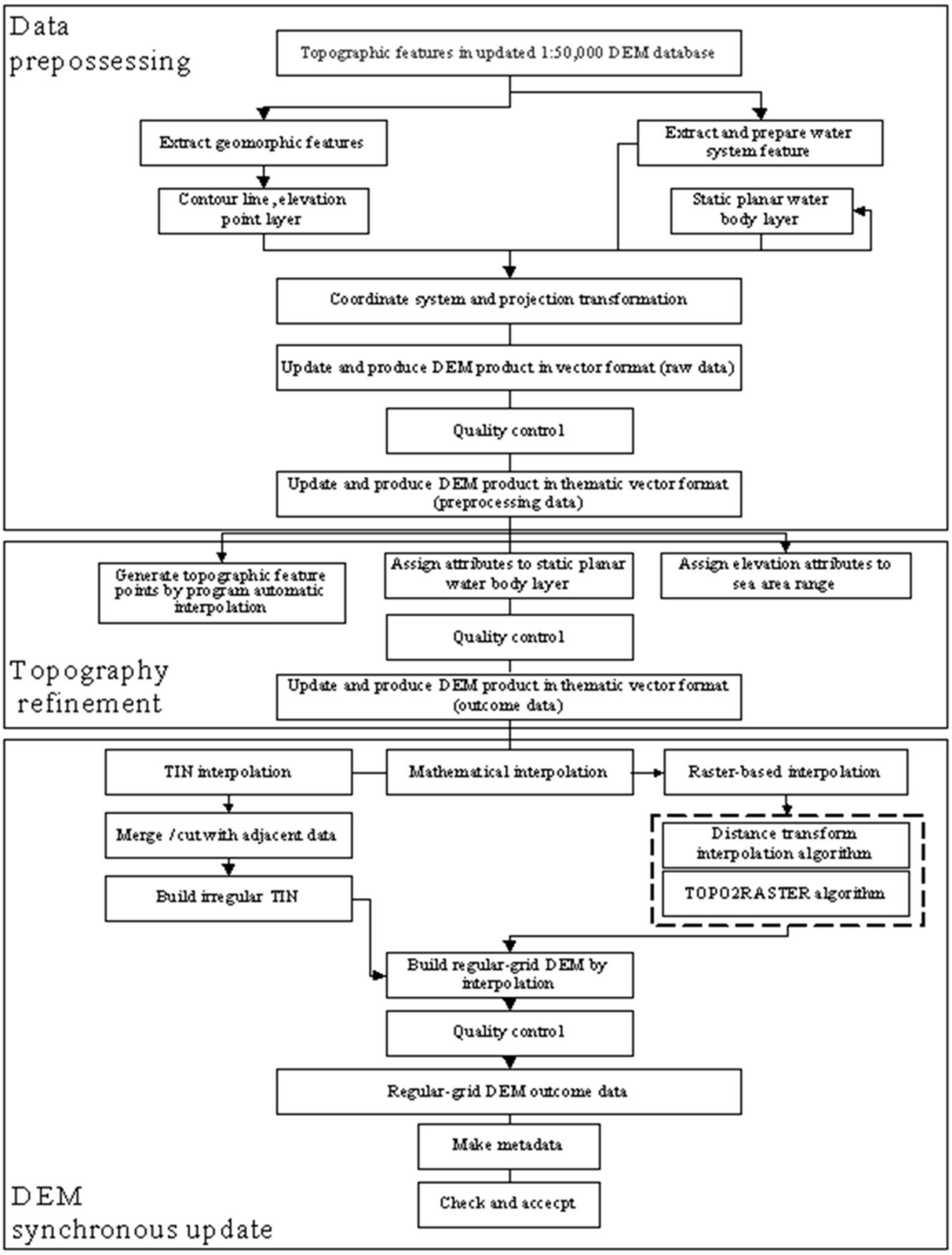

Fig. 1 The work flow of DEM production

KEY TECHNOLOGIE

Change Detection of Geomorphic Features

Compared to the changes of ground features, the overall changes of geomorphic features are small, and the changes are often some small topographic changes of local areas. The types, variance, and distribution area of geomorphic changes can be approximately determined from geomorphic change detection. Furthermore, the update and refinement of 1:50,000 DEM can be achieved by designing more adaptive technical routes and interpolation algorithms if the targeted regions with higher priorities of update and refinement can be identified out.

The contour lines and elevation points in the current updated version of the 1:50,000 topographic database are interpolated and compared with these of the earlier versions of 1:50,000 DEM data interpolation. Using the interpolated result, a mathematical statistical model is then built to define the topographic change rate that reflects the degree of landscape changes.

The rate of geomorphic change is the ratio of the area of the regions on the map, where elevation changes are more than a certain threshold, to the total area of the map.

The work flow of change detection of geomorphic features in 1:50,000 DEM is shown in Fig.2.

On the basis of a detailed statistical analysis of the maps, we found that the rate of geomorphic change of 21% maps is more than 5% when the change threshold is set as 1 meter.

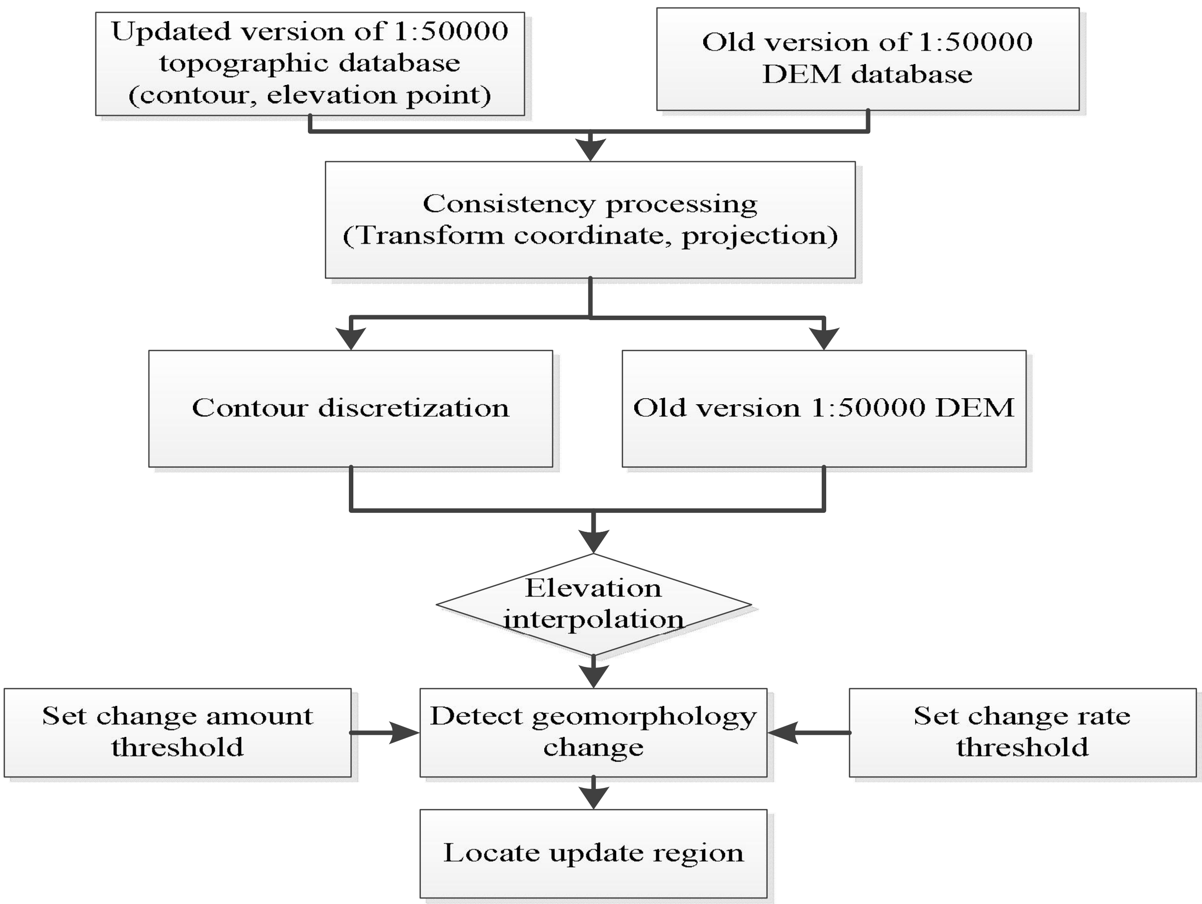

Fig. 2 The work flow of change detection

Automatic Extraction of Topographic Features

In the process of the interpolation of DEM data based on contour lines, topographical features, such as the ridge lines, valley lines, and terrain transform lines with elevation information, are one of the most important interpolated data sources.

Rational use of various types of terrain features can greatly improve the final terrain simulation of the DEM data, but can also optimize the relative height accuracy of the DEM data.

During the production of the older version of DEM data, some the topographical features have been collected by automatic extraction or manual interaction. However, the spatial distribution and geometric features of these topographical features are not reasonable enough, the elevations of these topographical features are not consecutive enough, and there is lots of redundant elevation information among these topographical features.

There are many methods for the extraction of terrain feature information, such as the contour skeleton extraction methods based on the degree of the contour curvature, Delaunay triangulation network and Voronoi diagram; the extraction methods of combining raster and vector; and the flat triangular elimination method. On the basis of a comprehensive comparison and analysis of these algorithms, a topographical features extraction algorithm based on iterative triangulation optimization is proposed, as shown in Fig. 3.

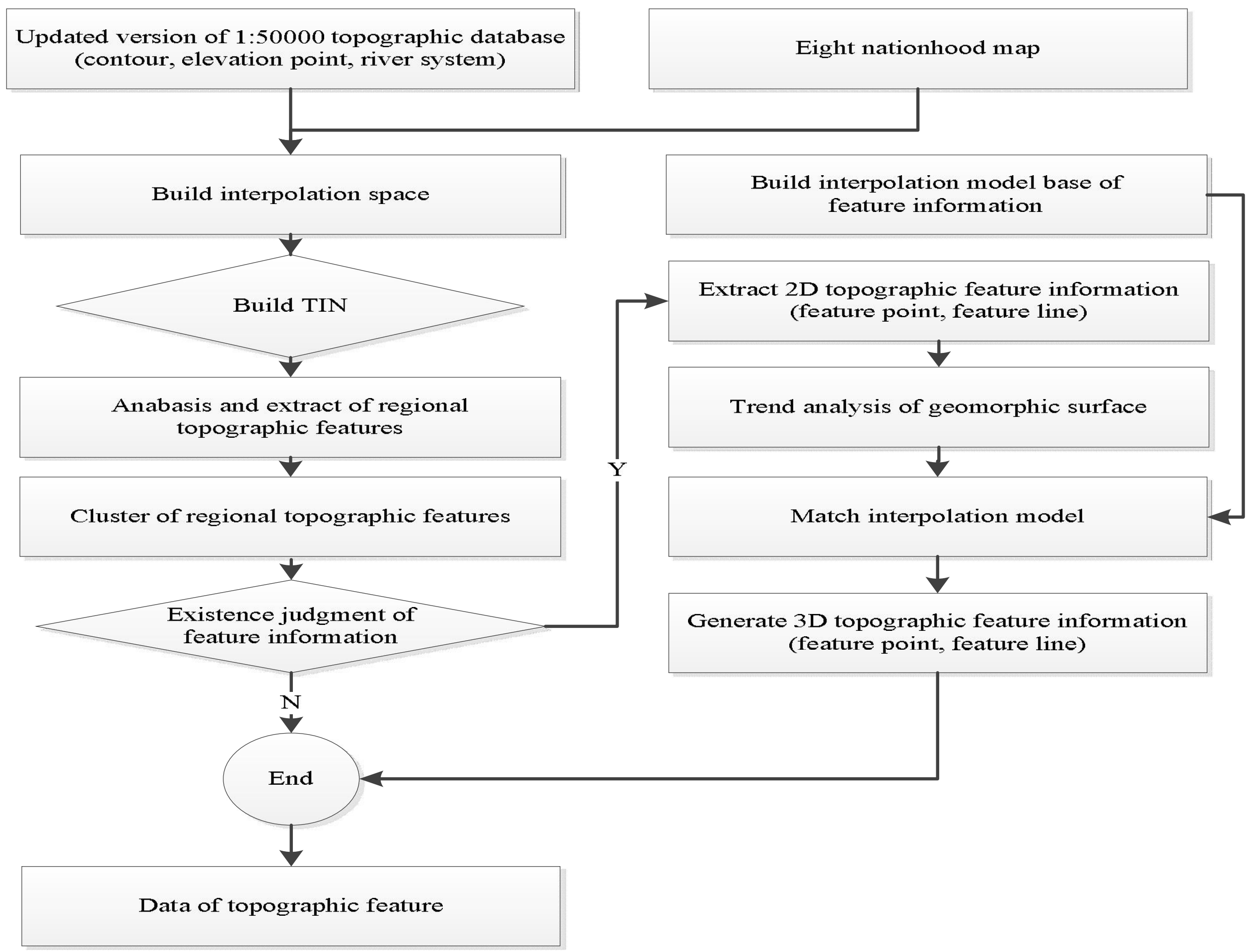

Fig. 3 The technological flow of feature point interpolation

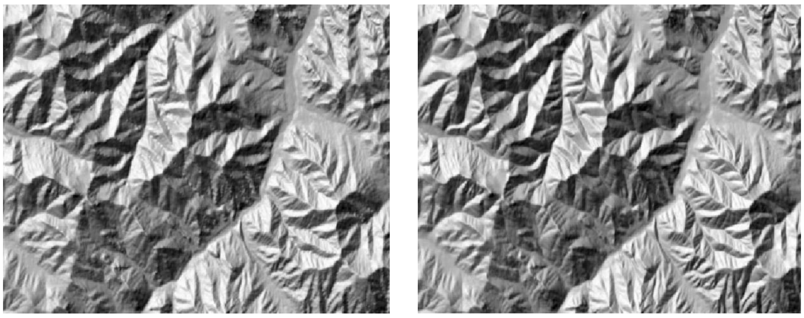
Fig.4 Comparison of the old version of DEM and the current version of DEM

Raster-based DEM Interpolation Algorithm
According to the problem that TIN interpolation algorithm is unable to express the real terrain of flat or sharp undulating regions, a DEM grid interpolation algorithm that can direct interpolate to generate DEM data is designed.

Raster-based Distance Transform Interpolation Algorithm
This algorithm works as follows. First, the elevation information, such as contour lines and elevation points, is rasterized. Second, the contour lines with the mean elevation of two adjacent contour lines is inserted between the two adjacent contour lines by employing the cartographic algebra middle distance transform algorithm and considering weight coefficients of these elevation points. Third, the second step is repeated to complete the interpolation until every grid cell on the map sheet is filled with the elevation information. The interpolated map sheet is the final DEM we expected. The work flow of raster-based distance transform interpolation algorithm is shown in Fig. 5.

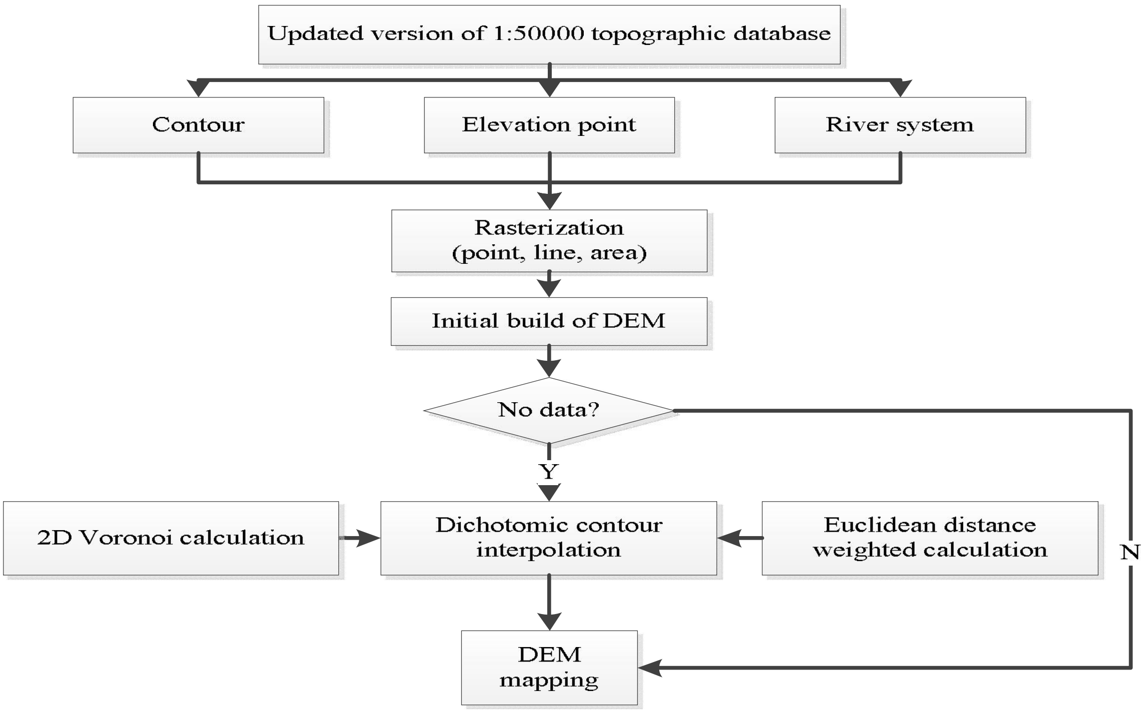

Fig. 5 The work flow of raster-based distance transform interpolation algorithm

Raster-based Topographical Features Interpolation Algorithm

This algorithm considers not only direct elevation information, such as contours, elevation points, but also hydrological information, such as the distribution of lakes and the trend of rivers, for the analysis and prediction of the elevation to be used for raster-based interpolation. The detailed steps are shown as follows. First, the original elevation information, such as contour lines and elevation points, is rasterized. Second, the trends of rivers are determined according to the trend and distribution of rivers, before the estimated elevations of points sampled along the rivers are calculated by considering the relationship between the trends of rivers and its surrounding contour lines. These estimated elevation information is rasterized and filled into the original grid. Third, Thin-plate spline operator is iteratively used to refill the new grid until the whole raster map is covered with the elevation information. Finally, the elevations of lakes are calculated by considering the surrounding elevation information of the lakes, and are reassigned to get the final raster map sheet.

After the application of the proposed raster-based DEM interpolation algorithm, the deficiencies of the traditional TIN interpolation algorithms are avoided, and the overall DEM quality of flat or sharp undulating regions are also improved. Figures 6 and 7 show the comparisons of the three interpolation methods mentioned above.

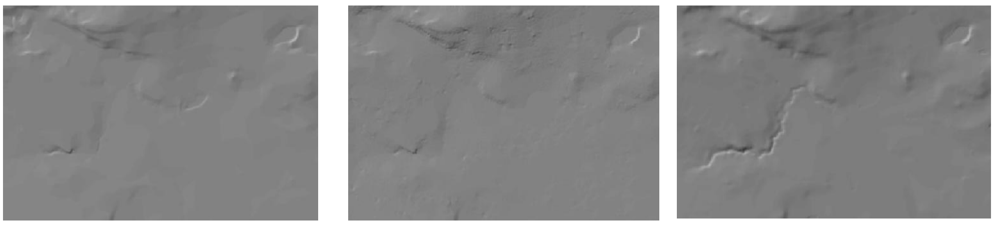

Fig. 6 Comparisons of three interpolation methods
(the DEMs, in sequences, is generated by the TIN interpolation method, the distance transform Interpolation method, and the topographical features interpolation method)

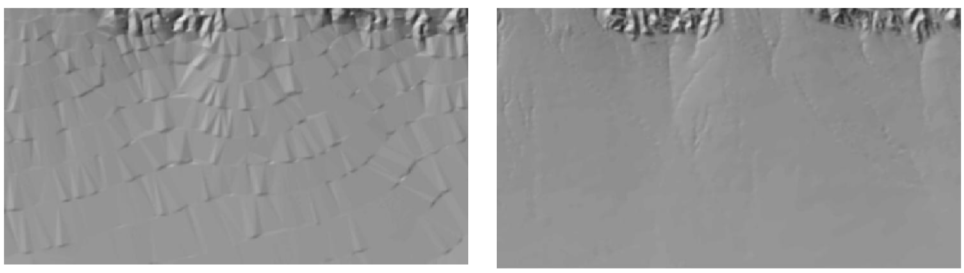

Fig. 7 Comparisons between the older version of DEM (generated by the TIN interpolation method) and that of the current version (generated by the raster-based topographical features interpolation method)

DEVELOPMENT OF THE SOFTWARE

Given that the update and refinement of nearly twenty thousand of the 1:50,000 DEM, including data production and project acceptance, must be completed within only a few months, we established a principle of "centralized storage, distributed production, unified management of tasks", and developed a fully automatic 1:50000 DEM updating software system, which allows a high degree of integration across the customization of production programs, data preprocessing, automatic extraction of topographical features, DEM interpolation, quality inspection, metadata entry, batch processing and other functions. The design of the software system is shown in Fig. 8.

The system consists of three modules, including the management module, the DEM production module, and the data access module. The management module is designated to manage the whole DEM production, including the dispensation of production tasks, and the linkage display of production progresses; the DEM production module is designated to control each sub-process of DEM production; and the data access module is designated for data compression, data sources download, outcome data upload and backup and other functions.

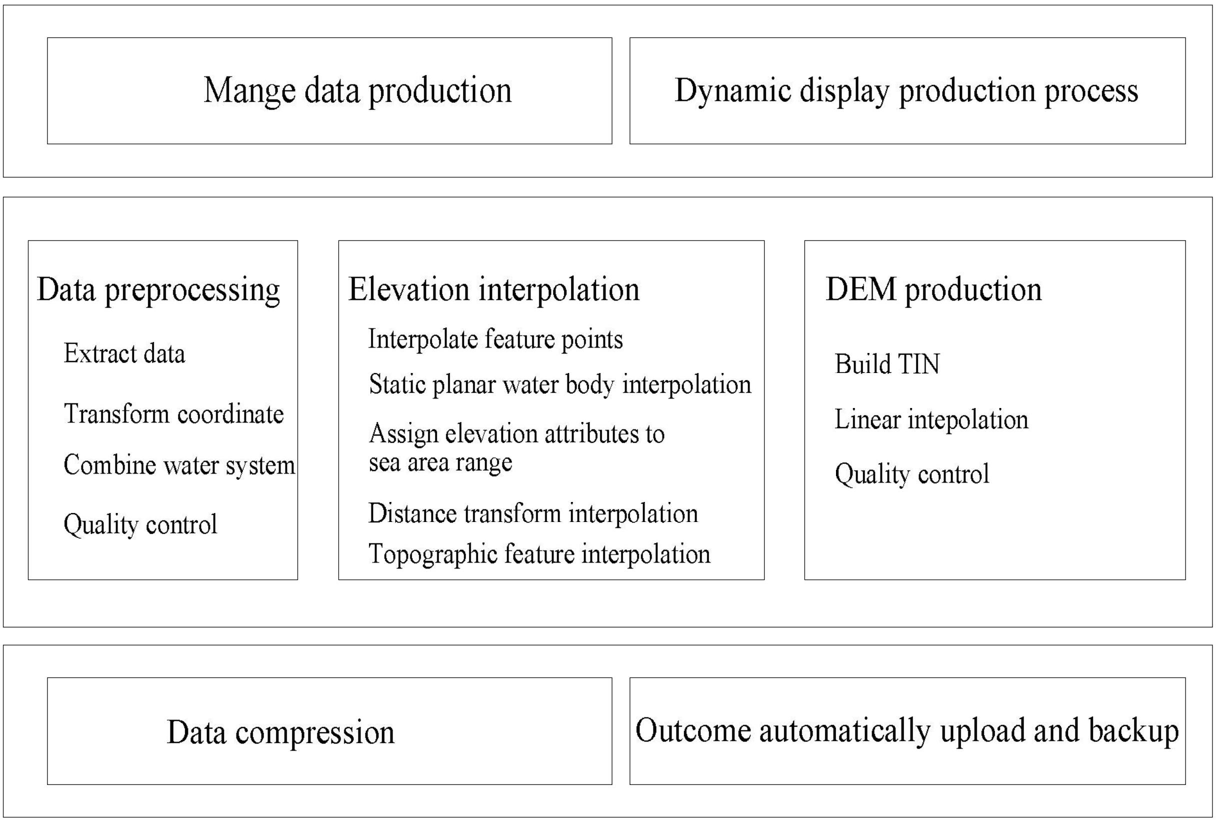

Fig. 8 The design of the software system for the update and refinement of the national 1:50,000 DEM

CONCLUSION

According to the national urgent need of updating 1:50,000 database, a technical route for updating 1:50000 DEM based on an updated version of the 1:50000 topographic data is proposed; moreover, many algorithms are proposed, such as the algorithm for the extraction of topographic features based on iteratively optimized triangulation networks, the raster-based distance transform interpolation algorithm, and the raster-based topographical features interpolation algorithm; finally, a practical software system is developed for the national quick update and refinement of the 1:50,000 digital elevation model.

REFERENCES

[1] CHEN Jun, WANG Donghua, SHANG Yaoling, LIAO Anping, ZHAO Renliang, LIU Jianjun, ZHU Wu, LI Limeng. Master Design and Technical Development for National 1∶50000 Topographic Database Updating Engineering in China, Acta Geodaetica et Cartographica Sinica, 39(1):7-10,2010

[2] CHEN Jun, WANG Donghua, SHANG Yaoling, JI Jianpei. Quality Control Methods and Implementation of National 1:50,000 Digital Elevation Model Database, Science of Surveying and Mapping, 29(7): 88-91, 2004

[3] LIU Jianjun, CHEN Jun, WANG Donghua, QIAO Chaofei, SHANG Yaoling. The Study of Description and Application of Contour Adjacency Relationship, Acta Geodaetica Et Cartographic Sinica, 2004, 33(2): 174-178

[4] LIU Jianjun, WANG Donghua, SHANG Yaoling. The Software Automatic Checking Methods for the Quality of Contour Digitizing, Developments In Surveying and Mapping, 26(4)：36-38, 2001

SPATIAL DATA MANAGEMENT BASED ON STANDARDS AND OPEN SOURCE SOFTWARE PRODUCTS

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ISPRS WG IV/2

KEYWORDS: spatial data infrastructure, object model of spatial data, geoportal, Editor for Geospatial Data Catalogue (information management system), Standard ISO 19110, WMS and WFS standards.

Abstract: In order to create a geospatial data infrastructure (GDI), it is necessary to solve complex organizational, legal and technological issues. Currently, there is a number of multi-purpose commercial GIS, the most common of which are ArcGIS (www.arcgis.com), MapInfo (www.mapinfo.ru), GIS Panorama, etc. These GIS can store, manage, publish maps and map layers of indefinite scale and complexity. They have powerful functionality; through their use one can solve almost any application tasks. However, the high cost of the GIS and the high level of qualifications required in the projects push many users to consider other options.

We offer the efficient technology for GDI management by building an integrated domain object model in the form of appropriate classifiers and by developing spatial data storage and geo-portal on their basis.

GDI in Russia has been created over almost ten years. [1] There are numerous external and internal reasons due to which the goal of building a global geospatial data infrastructure has not been reached on a nationwide scale up to the present moment. There are some infrastructures covering a particular industry or area, but They are usually autonomous and isolated.

According to the conclusions of the UN Committee of Experts on Global Geospatial Information Management [2]:

1. The growing number of sensors in everyday devices which collect and provide geospatial information will increase and alter the dynamics of data collection. This will also increase the role of geospatial data, both active and passive, creation and collection by citizens.

2. Free and open access to data will become a standard and geospatial information will increasingly be seen as an essential public good.

3. Monopolies held by National Mapping Agencies in some areas of specialized geospatial data will be eroded completely.

4. Progress will be made on bridging the gap between official and crowdsourced data, moving towards true collaboration.

Thus, there is a need to create some tools for geospatial data preparation which would possess sufficient functionality, but it would have affordable price and reasonable quality for the general public.

Currently, there is a number of multi-purpose commercial GIS, the most common of which are ArcGIS (www.arcgis.com), MapInfo (www.mapinfo.ru), GIS Panorama, INGEO, etc. These GIS can store, process, publish maps and map layers of arbitrary extents and complexity. They have powerful functionality; by using them one can solve almost any application tasks. However, the high cost of the GIS and the high level of qualifications required by the projects make many users to explore other options.

In this article, we propose a Web-GIS solution that is an original product of Technology 2000 LLC. Considering the features of the new approach from the viewpoint of service recipient (organizations, agencies or individuals), the following competitive advantages of Web-GIS solutions can be named:

- It provides an easy and flexible tool that allows you to create a collection of object models in different subject areas (e.g. energy companies), to cost-effectively and efficiently build an integrated spatial data infrastructure;

- Deliberate restriction of the functionality and drastic simplification of the working methods in the system results in a significant increase in the number of potential active users;

- Reducing costs of acquisition and ownership of the system through the use of open source software products results in significant economic benefits for system users;

- As it complies with common standards set for exchange of geographic information in networks, the situation of sticking to once selected provider of software solutions and their specific encoding formats/storage of geographic information is avoided;

- By providing their own geospatial data to general public for a fee, get the opportunity of a right of joint use with other users to access other geospatial data resources;

- Along with applications (analytical, calculated, report wizards, etc.), it is not limited in scope of application and can be used in local government bodies, ministries, economic entities and by individuals.

GDI information model

At the designing stage of the GDI information model, it is important to determine the composition of the databases, the sources of their formation, the use of information resources contained in these databases. Besides, it is important to sustain compliance with certain design criteria.

The first of them is to select the data presentation model. Standard data models are basically two-dimensional. They are based on well-known principle of essence - relationship and allow building relational tables of any complexity. However, experience shows that the concept of essence is not rich enough in its capabilities and does not provide a logical transition from one and the same essence in the different states.

In order to create GDI information model, one needs use more complex data models, including not only two, but three data element representation: object, property, and attribute. The use of this model for data processing resolves difficulties in concepts of logical transition from one category to another, thus enables to reflect and set multiple links between different concepts (objects, properties, and attributes) and ultimately, provides the depth and quality of the analytical work, reducing the effort applied in information systems.

The analysis shows that the GDI information model can be completely described by international standard ISO 19110 (Geographic information - Methodology for feature cataloguing [3]). According to ISO 19110, any spatial data catalogue is described with the help of the following pieces of information: the type of the object with its properties, the association between types and restrictions that can be imposed on all the information. In this case, the correspondence between the conceptual information model and ISO 19110 can be set as follows: object - feature (object type), listed value - property, the attribute – listed value (domain).

Technology for GDI creation

The distinctive features of the proposed technology are:

- No need to program for creating spatial data layers. Through use of Editor for Geospatial Data Catalogues (information management system) create an object-oriented model of a particular domain, and then automatically generate an integrated software & information environment that is configured to this object-oriented model.

- Based on the open source software products.

The architecture of Web-GIS technology is presented in Figure 3. The main components of this architecture are:

• Editor for Geospatial Data Catalogues (information management system) (original design of Technology 2000 LLC) to create an object-oriented models of particular service domains and integrating them into a single model;

• Storage of spatial objects for collecting, storing and processing geospatial data, based on DBMS (Oracle 11g Spatial, PosatgreSQL / PostGIS, etc.) which incorporates components for processing spatial data;

• Joint geoportal implemented with the help of Liferay geoportal constructor;

• Geoserver implementing WMS and WFS services according to OGC standards [5];

• Web-server like Tomcat, to link the Web-services with DBMS.

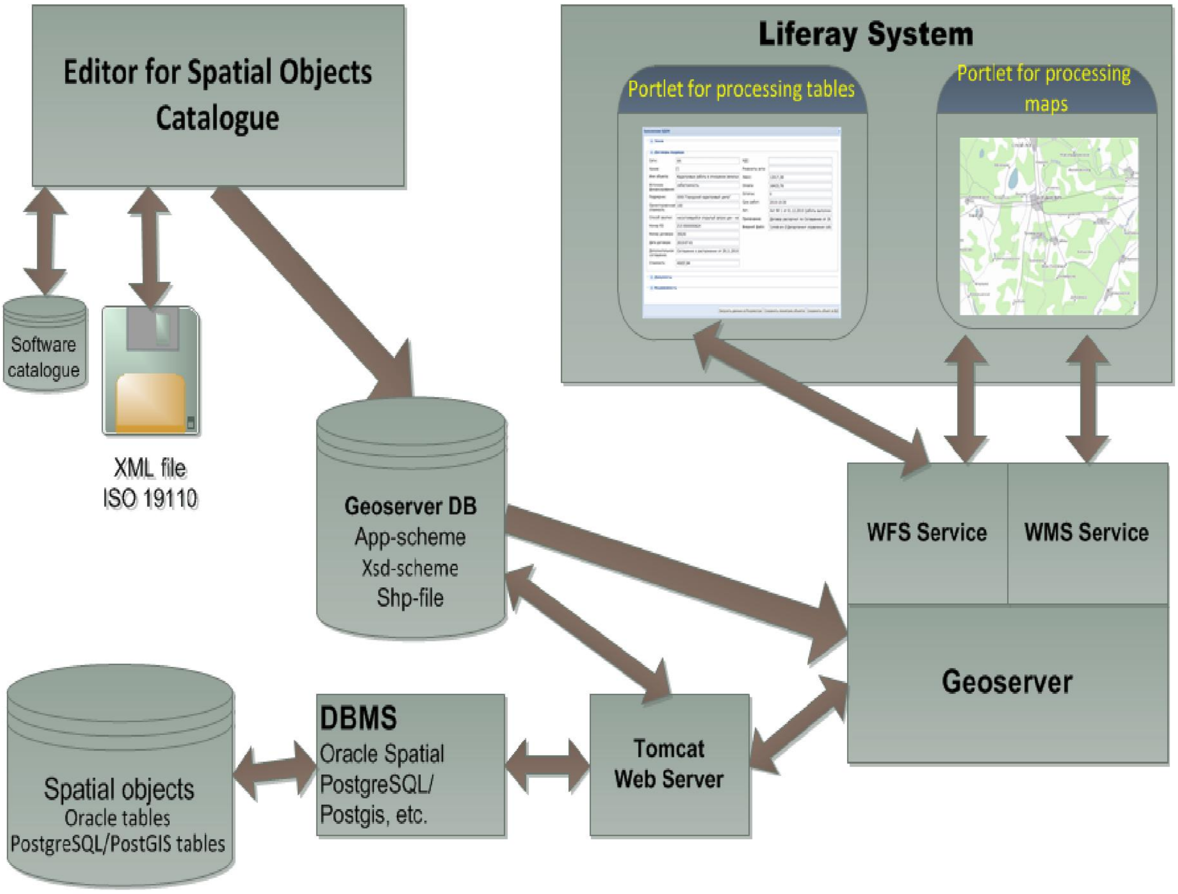

Figure 1 Web-GIS technology for creating GDI.

GDI creation for a particular service using this technology consists of the following steps (Figure 1):

1. With the help of Editor for Geospatial Data Catalogues (information management system), create a feature catalogue of the data domain.

2. Editor for Geospatial Data Catalogues (information management system) generates APP-scheme.

3. APP-scheme is connected to Geoserver.

4. Editor for Geospatial Data Catalogues (information management system) generates structure description of service spatial data. The structure is loaded into the storage of spatial data.

5. Geoserver is connected to the storage of spatial data containing different sources of spatial objects (shp-files, DBMS Oracle, PostgreSQL / PostGIS, etc.). The source can be either empty or contain some pre-loaded with information.

6. Liferay registers project and users. Access privileges are set i.e. the proper administration is ensured.

7. In Liferay, the portlets are connected: for processing objects in tabular form and in the form of maps, as well as a portlet for spatial object storage. In the portlet processing objects as tables, Geoserver interacts with objects via APP-scheme based on the WFS service. The map portlet visualizes maps with the help of Geoserver based on WMS service. In order to work with object attributes, one can use the same forms as ones in the table processing portlet based on WFS - service.

8. User starts filling his partition of spatial data storage using portlets common for all services.

High speed and quality of the GDI can be achieved thanks to simple interface (context-dependent graphical editor of spatial objects), and by providing the full functionality needed for processing spatial data. Spatial objects are applied by the users to the cartographic basis, using a specialized editor.

Editor for Geospatial Data Catalogues (information management system) is based on the international standards ISO 19110. This standard defines how to classify the types of objects, their attributes, relationships between objects (hierarchical and associative), their operations and restrictions imposed.

Editor for Geospatial Data Catalogues (information management system) plays an integral role for the Web-GIS technology (Figure2), as it is used to prepare an app-scheme, which is later on used in other services for generating database schemes for a specific DBMS or spatial data files. It can also play an integral role in the interaction between various GIS (Figure 4). For example, it can be used to transfer a catalogue from KB Panorama GIS into MapInfo. The process is as follows. First, the KB

Panorama GIS catalogue file in rsc-format is imported into the internal database framework by using Software Catalogue Editor, and then exported into a Mif/Mid (MapInfo) file. The process is fully automatic, without any manual data correction.

Software Catalogue Editor supports the distributed data processing technology:

- Local level of offline databases;
- A central master data database directly related to the catalogue section of Spatial Object Storage.

Local level consists of a set of offline databases, each of which contains one or more catalogues of spatial objects being stored in the local database, i.e. DBMS Access. These databases may operate in geographically remote locations. Catalogues can be shared in data bases with the help of XML-format file, whose scheme is based on ISO 19110 standard. The local version of Software Catalogue Editor has absolutely the same functionality and interface as a version based on a central database.

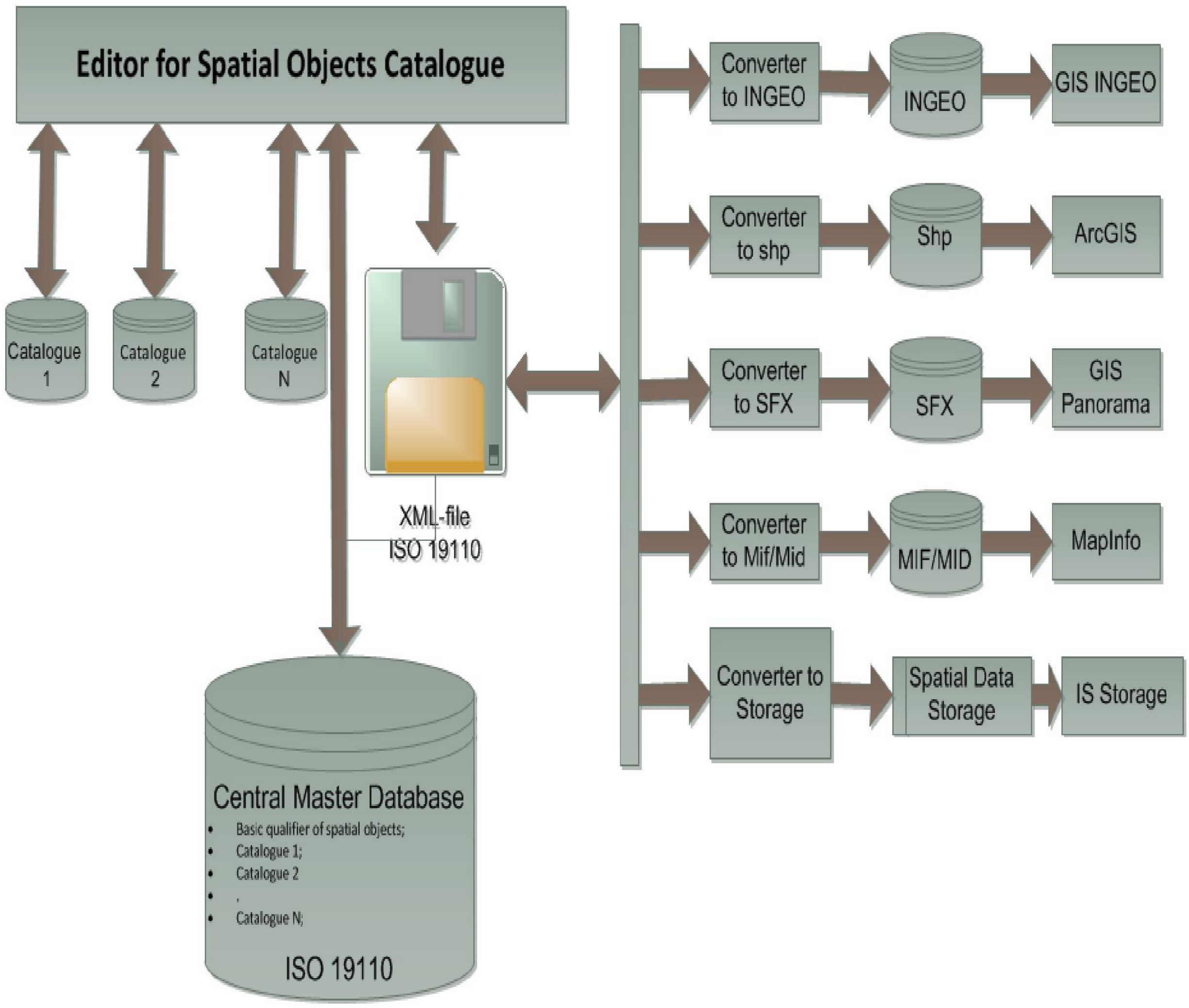

Figure 2. Scheme showing automated preparation of catalogues and qualifiers

The central database contains all the catalogues required for operation of information systems in a GDI node. The central database can be set on the basis of any standard back-end DBMS, such as Oracle 11g, PostgreSQL / PostGIS databases, etc. For most types of spatial data sets, one should develop standard qualifiers of objects. Where appropriate, it is preferable to use the established symbols and object types (topography). One object for different tasks may relate to different types. The required standardized or generic qualifiers include a master plan, urban management, duty plan of the land plot (as part of a master plan), etc.

Editor for Spatial Object Catalogues is a tool that enables us to distribute the process for catalogue and qualifiers development, while making it well-coordinated as well. both by distribution and well-coordination.

Storage of GDI spatial objects is based on the ideology described in [1]. This ideology is implemented by using software, issued in the form of the relevant portlet. The functions and interface of this software are described in [4], as well. We suggest using open source (freely available) DBMS PostgreSQL / Postgis as the main DBMS for the Storage, as it is the most appropriate in terms of cost. The established commercial DBMS (Oracle 11g Spatial, MS SQL Server 2008) can also be applied. The key content to be formed in the storage of GDI spatial data is the basic spatial data, such as:

- boundaries of municipal entities, settlements, internal administrative divisions;
- master plan as part of the topographic plan layers:
  - ❑ capital structures;
  - ❑ roads, streets, driveways (areal and linear);
  - ❑ graph of road network;
  - ❑ railways, rail transport;
  - ❑ sidewalks, landscaping (lawns, flower beds, fountains);
  - ❑ surface objects of water resources;
  - ❑ woodland objects, green areas, parks,
  - etc.

Joint GDI geoportal is operated through such open source software systems, as Geoserver, Liferay, Tomcat.

Geoserver 2.1.2 manipulates geospatial data, providing the user with WFS (for access to spatial objects) and WMS (for working with maps). Access mechanism is independent of the data storage format, since it is based on the universal description of data in the form of app-scheme.

Liferay is an environment for the construction of geoportals based on portlets. It serves as to create and maintain portal projects. Eclipse system is an environment for portlet development.

Tomcat 6.0 is a Web server. Tomcat can provide access both to spatial data stored in databases (DBMS Oracle Spatial, PostgeSQL / PostGIS, MS SQL Server, etc.), and to the shp-files stored directly on Geoserver.

Geoportal GDI provides the opportunity for not only official services to take part in the formation of spatial data but for enterprises and individuals as well, that fully complies with the future trends of geospatial data for the next five to ten years, described in [5]. By the way, as the process is based on the general (standard) qualifiers and catalogues, it will be a well-coordinated and semantically uniform.

Geoportal is not intended to replace or absorb information management systems operated by the services. It implements a set of services working with spatial data required for departments, enterprises and individuals.

Conclusions

We have examined the object Web GIS technology and shown that it can be effectively used to create various GDI. The main features of this technology are:

- The integration of all the services on the basis of the feature (object) catalogue of a domain created with the help of specialized software Editor for Geopatial Objects Catalogue which is in compliance with the international standard ISO-19110;

- The integrated spatial data storage, the structure of which is generated automatically based on the domain in the environment of Editor for Geospatial Object Catalogue;

- Work with geospatial data through GDI geoportal, which is based on a domain catalogue, supported by the storage and provides a range of services for processing geospatial data required by organizations, companies and individuals;

- Use for the implementation of open source software.

References

1. *Concept and the development of geospatial data infrastructure in the Russian Federation* / / Spatial data. - 2006. - № 3. – p. 6-9, 11.
2. *UN Committee of Experts on Global Geospatial Information Management. Future trends in geospatial information management: the five to ten year vision*. (eds.) - Eng. - Mode of access: http://gis-lab.info/docs/futuretrendsgeospatialinformationmanagement_12april.pdf
3. ISO 19110:2005 *Geographic information. Methodology for feature cataloguing* (eds.) - Eng. - Mode of access: http://www.iso.org/iso/catalogue_detail.htm?csnumber=44459
4. Anisimova, O.L., Zraenko Yu.D., Komosko V.V., Pestov I.D., S.V.

Serebryakov. *Storage of spatial objects in the GDI UFD regional node.* Part 1. Storage model. / / Spatial data. - 2010 – No. 1 - p.14-22
Part 2. Storage model. / / Spatial data -2010 – No. 1 - p.32-40
5. *Overview: WFS, WMS, WCS* (eds.) - Eng. - Mode of access: http://www.geowebguru.com/articles/95-overview-wms-wfs-wcs

CREATION OF MULTISCALE COVERAGES OF RUSSIAN TERRITORY BY ORTHORECTIFIED SATELLITE IMAGES

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ISPRS WG IV/2

ABSTRACT:

In the end of 2012 SCANEX finished complete coverage of the whole territory of Russia (about 17 million square km) with 0,5 m resolution imagery data from GeoEye and WorldView-2 satellites. The images were collected within the frames of the project for Rosreestr and were supplied in global (WGS84) and local coordinate systems. All of the data were also orthorectified.

Of cause there are a number of images with snow, but SCANEX will replace them during next two years.

The next questions is: Will Rosreestr provide access to this data for commercial maps producers, etc? This is very important if to take into account current condition of global maps.

At SCANEX's side, we developed service Express.Kosmosnimki (express.kosmosnimki.ru), which provides authorized remote access to orthorectified satellite images with the ability to load them into the end-user environment, which can be a website, the geoportal or desktop applications (ArcGIS, MapInfo, Credo-Dialogue, Autodesk, etc.). In other words, the data is physically stored on SCANEX servers, but you can work with them remotely via the Internet.

Service is designed to simplify and speed up access to the data, if the user needs the finished product or satellite images to create their own products.

Each user of the service has access to his "personal map" (a set of ordered data) on a special website. Custom user key is used for access authorization and accounting of statistics.

Currently, the service provides the following data:
1. GeoEye-1 (2009-2012) - about 50% of the Russian Federation
2. Mosaics of SPOT 5 - more than 1.5 million sq. km
3. IKONOS (2010-2012) - about 2 million sq. km. In the near future the volume of IKONOS data will be extended to 50 million sqr. km collected worldwide.

The cost of data on Express.Kosmosnimki is 0.23 to 1.25 US dollars per 1 square kilometer a year (10% of the commercial price). It is quite cheap and well used by commercial map providers today.

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