New Technical Enabling Tools for Data Acquisition and Maintenance of Topographic Data of Urban and High Mountain Areas to Support SDGs

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This chapter discusses the need of geospatial data and the new technical tools for data acquisition and maintenance of (topographic) data to support SDGs. The chapter provides an example of data acquisition for urban and high mountain areas.

16.1 Introduction

The definition of Sustainable Development Goals depends on the availability of data. Most data required for this are geospatial. The data are dependent on resolution and their object definition at a specific resolution.

Traditionally geospatial information was displayed in the form of maps at different scales. In order to be able to display the information for a certain object location and object size an appropriate scale is required. For data concerning the environment small scales of 1:250000 or 1:500000 may be sufficient, for urban data large scales ranging from 1:1000 to 1:10000 are more appropriate.

The larger the scale, the more effort in data acquisition with respect to time and cost is required. This is the reason why historically the global coverages in map scales have increased from 1:1 million in 1950 to 1:50000 in 2000.

These changes have been made possible due to improvements in technology. While in 1900 only terrestrial surveys by many surveyors were possible, by 1950 the accepted data acquisition technology was aerial photogrammetry

based on aerial photographs. The developments from analogue photogrammetry to analytical photogrammetry and then to digital photogrammetry between 1950 and 2000 have made significant improvements in mapping technology.

16.2 Global Progress in Mapping From 1900 to 2000

In 1900 terrestrial surveys were only permitted to generate maps in Europe, parts of India and parts of the United States of America (see [Figure 16.1](#)).

FIGURE 16.1

Global Topographic Mapping Coverage in 1900 [\[9\]](#)

Between World War I and World War II the mapping by photogrammetry was promoted by the International Society for Photogrammetry, founded in Vienna in 1910 [\[8\]](#). Progress came about by the design and production of stereoplotters in Germany, France, Italy, Switzerland and the USA and Britain. Russia and the soviet block had a rather independent development from the West developing its own instruments. This instrumentation was used greatly during the war-faring nations in World War II to produce maps for the areas affected by the military war operations in Western and Eastern Europe as well as in great portions of Asia and the Pacific.

After the war ended in 1945 the International Society for Photogrammetry met in 1948 in the Hague, Netherlands. Its President was the first post war Prime Minister of the Netherlands, William Schermerhorn. He convinced the Dutch government of the mapping needs of the third world countries. In order to cope with the problem the Dutch government made a donation

to the United Nations by establishing an International Training Centre for Photogrammetry (the ITC) in Delft in 1950. This school in addition to the instrument industry became responsible for spreading the photogrammetric mapping technology to most countries of the globe with a total of 1900 students from 170 countries. When Schermerhorn retired as director of the ITC the institution was relocated at Enschede in the 1960s and still contributes to the further development of mapping technology.

In Russia a similar effort to make photogrammetry known in the Soviet controlled areas took place by the educational institutions MIIGAiK in Moscow and by NIIGAiK in Novosibirsk.

The United Nations Secretariat in New York began to show an interest in the spread of photogrammetric mapping technology in the third world countries as early as 1955 when it organized the first United Nations Cartographic Conference for Asia and the Pacific and in 1976 for the Americas. These UNCC Conferences were the root for the establishment of the United Nations Global Geospatial Information Management (UNGIM) Secretariat in New York since 2011, now holding annual conferences.

Both UNCC as well as UNGIM showed an interest in the global progress of mapping. The results of the progress of mapping document the global coverage for 4 scale ranges: range IV: 1:250000, range III: 1:100 000, range II: 1:50000 and range I: 1:25000 with the following figures for the global data coverage [7, 6] (see Table 16.1.).

TABLE 16.1
Global Topographic Mapping Coverage: Progress
Between 1968 and 2012

Year	Range IV (1:250000)	Range III (1:100000)	Range II (1:50000)	Range I (1:25000)
1968	80.0%	38.2%	24.3%	7.7%
1974	80.0%	40.5%	35.0%	11.6%
1980	80.0%	42.2%	42.0%	13.3%
1986	87.4%	46.4%	49.3%	17.9%
2012	98.4%	67.5%	81.4%	33.5%

The second issue is the current state of these maps. The update rates have been determined for the years 1968 and 2012 as shown in Table 16.2:

TABLE 16.2
Global Update Rates of Topographic Maps in 1968 and in 2012

Year	Range IV (1:250000)	Range III (1:100000)	Range II (1:50000)	Range I (1:25000)
1968	27.7 years	37 years	55 years	31.2 years
2012	37 years	31.2 years	26.3 years	22.4 years

The regional update rates are shown in [Table 16.3](#) for the year 2012:

TABLE 16.3
Regional Update Rates for 2012

Region	Range IV (1:250000)	Range III (1:100000)	Range II (1:50000)	Range I (1:25000)
Africa	43.7 years	36.3 years	35.1 years	24.2 years
Asia	38.0 years	35.3 years	27.2 years	22.8 years
Australia and Oceania	30.4 years	29.0 years	16.5 years	22.4 years
Europe	21.8 years	21.1 years	17.1 years	13.8 years
N America	44.0 years	29.2 years	26.3 years	35.4 years
S America	31.5 years	30.1 years	34.7 years	9.8 years

Global base data for SDGs are therefore not available in updated form at the listed scale ranges in the form of geospatial base data. At the age of high resolution space imaging there are, however multiple coverages of global geospatial image data, which can be geocoded and spatially referenced. These images often permit to update areas of the existing global dataset and extract the missing information at these scale ranges at a cost.

16.3 Large Scale Mapping of Urban Areas

No global information is available for the urban scales 1:1000 to 1:10000. If mapping at these scales exists, it generally originates from local administrations at unclear and often unacceptable specifications for a transfer to global datasets.

But the problems for large scale data coverage and map age are similar to what exists for medium scale datasets originating from national mapping agencies shown in Tables 1 to 3.

It is possible to obtain these data from countries, which have included the generation and the maintenance of large scale datasets as a task for the national map agencies, as is the case for the Kingdom of Saudi Arabia, in which the main concentration of development is in rapidly changing urban areas.

The relevant large scale mapping efforts made by the Ministry of Municipal and Rural Affairs (MOMRA) concentrate on the mapping of urban areas for the country of 2.15 million km^2 with a population of 33 million, of which the urban population is 83%.

The dense urban area of the country covers 24450 km^2 and the suburban area including the dense urban area covers 318278 km^2 [1].

The topographic map data coverage of MOMRA is as shown in [Table 16.4](#):

TABLE 16.4
Topographic Map Data Coverage of Urban and Semiurban Areas in Saudi Arabia

Scale	(1:1000)	(1:2500)	(1:10000)	(1:20000)
Coverage in km^2	24450	39838	338278	1743032
Type of area	urban core	semi urban	rural	open country

In addition the topographic database contains orthoimagery coverage and DTM grid data for the mapped areas (Table 16.5):

TABLE 16.5
Orthoimagery and DTM Coverage of Urban and Semiurban Areas

Ortho Imagery Coverage in km^2		DTM Coverage in km^2	
	GSD		Grid Size
10 cm	39838	1m	39838
20 cm	17000	2m	17000
40 cm	1781500	5m	1781500

These vector maps are administered in an ArcGIS geodatabase. Updating using new aerial imagery by photogrammetric line mapping is currently being done. However, due to budget restrictions, it is not possible to schedule re-flights faster than every 5 to 7 years. From these flights digital orthophotos are generated from that imagery within one year. The digital orthophotos may be overlaid for the mapped areas from 5 to 7 years ago. These overlaps will be able to assess the need for new map updating contracts within a 2 year period. Depending on priorities an update of the mapped areas is possible in 5 to 10 years. For advanced countries, typical of what exists in Europe, the base data situation is listed for Great Britain and for Germany:

16.4 Large Scale Mapping in Europe

Great Britain with a territory of 219931 km^2 and a population of 60 million is covered by the Ordnance Survey Master Map at scales 1:1250 in urban areas and 1:2500 in rural areas. The Ordnance Survey with a staff of 1190 and an operating annual budget of 83 million British Pounds keeps the topographic data system based on an object structure, up to date with help from outsourcing contracts within 6 months by terrestrial surveys with total stations based on GNSS CORS networks.

Germany with a territory of 357386 km^2 and a population of 82 mil-

lion is covered by cadastral geometric records equivalent to a scale 1:1000 (ALKIS) including property boundaries and buildings. The topographic data for objects other than buildings are resurveyed for the topographic database (ATKIS) equivalent to a scale 1:5000. The cadastral records including the parcel boundaries are maintained by 226 survey authorities with a total staff of about 10 000 professionals in the 16 States of the Federal Republic on a transaction basis. These updates in ALKIS for parcel boundaries and buildings are available in the system within 1 to 2 months. The updates in ATKIS for other topographic data are available every 1 to 2 years using photogrammetry or GNSS based terrestrial surveys.

Both Britain and Germany possess a costly professional infrastructure, which does not exist in most countries around the globe, with the exception of some countries (in Europe, East Asia, Canada and Australia), and which cannot be built up in less than a generation.

For countries not having such a traditional professional infrastructure involving the legal, educational and cultural prerequisites the challenge must be in using digital automation technology to overcome the handicaps of traditional approaches.

16.5 Future Alternatives by New Technology

The alternatives for improving the situation are shown in [Table 16.6](#):

TABLE 16.6
The Alternatives for Improvement by New Technology

Source	Frequency	Acquisition	Detail	Feature Accuracy	Problem Areas
high resolution satellite imagery	1 year	easy	moderate	0.5 to 1m	limited to 1:5000
mobile mapping	as per request	easy	high	0.2 to 0.5m	hidden areas
object oriented 3D oblique imaging via models	1 year	easy	high	0.2 to 0.5m	automation technology for object generation

These improvements by application of new technology need some further remarks:

16.5.1 High Resolution Satellite Imagery

The biggest provider of high resolution satellite imagery is Digital Globe.

Since 1999 Ikonos provides imagery with a GSD 0.8m. In 2007 the resolution was improved on World View 1 to 0.5m GSD. In 2008 a GSD of 0.41m became available on GeoEye 1 and since 2017 World View 4 images with GSD 0.3m are available on World View 4.

Similar imagery is also available from ESA for Pleiades and Sentinel as well as for Komsat from South Korea.

After the images have been ordered, delivered and rectified on form of an ortho-image, multiple stereo coverages permit to derive DSMs and true ortho-images, which can serve to identify changes of topography, especially of buildings in urban areas. Investigations gave shown, that stereo images of satellites with 0.5m GSD can derive changes for monitoring data bases for buildings at the scale 1:5000. [2].

16.5.2 Mobile Mapping

The competitors for updating roads are Google, Here and Tomtom. Each update traffic routes by mobile vans. Some companies, such as Cyclomedia, use mobile vans with optical cameras to update building facades at high accuracy. Yet others, such as Tesla and the car manufacturing industry prefer high accuracy surveys by service companies in preparation for automatic driving.

The application of mobile mapping for map updating has nevertheless the handicap to overcome hidden areas by obstructed views.

16.5.3 3D Oblique Imaging via 3D City Models With Automated Object Creation of Buildings

A new more automated possibility exists by creating urban city models from overlapping oblique imagery. This imagery source may be combined with other airborne or satellite imagery, including UAV imaging and existing vector data and lidar surveys. The dataset is subjected to a sequence of algorithms using point cloud processing, image processing, computer vision tools, adjustments and deep learning for sparsity driven DTM extraction for optimized partial automation to generate DSMs and DTMs for later change detection, to extract LOD2 building models according to CityGML standards.

The semiautomatic deep learning based object extraction helps to generate building roof prints and to extract building facades for automated texture mapping.

The software system developed by the Turkish- Saudi Arabian company Geotech (headed by Kamil Eren) has been introduced internationally by the

name ‘CitiGenius’. It was used in a pilot project for Istanbul, in projects of Saudi Arabia, in the City of Hannover in Germany and in U.S. Cities. The point cloud extraction succeeded to extract DSMs and DTMs, true ortho-images and 3D building models according to City GML standards including object generation for buildings and their administrative use. An object-oriented database consisting of some 5900 buildings was obtained within one week. This database could be linked with relational data for property registration, which were generated and updated on a transactional basis.

CitiGenius follows the tradition of CityGML used for the urban city model of the city of Berlin. It covers within the city area of Berlin of 890 km^2 together with 590 000 buildings.

Urban change detection by CitiGenius promises to become an efficient tool for the acquisition and the maintenance of urban data, even though a number of steps are still required to customize it for use in a particular city or country, with a view to create an updatable urban information system.

16.6 The Use of New Stereo Satellite High Resolution Satellites by China for the Mapping of High Mountain Areas

A special application of the use of simultaneous stereo satellite high resolution images has been made possible by the launch of the Chinese satellite Ziyuan-3 in 2012, which permits near simultaneous stereo imaging with 2.1m GSD images. The imagery is particularly useful to map the neighbouring countries of China with high mountain areas at the scale 1:50 000. The simultaneous stereo views are imaged at the same illumination conditions. Combined with the utilization of accurate Beidou GNSS data it is said to be possible to survey mountain peaks within the accuracy of the Beidou positioning capability, estimated at 10 to 15m. As a result, an international cooperative project has been initiated to map the 14 highest mountain peaks of the world with an elevation of over 8000m.

Again this project involving partners in China, Germany, Austria and the USA can compare the stereo satellite capability with earlier attempts to produce 1:50 000 maps of the Nanga Parbat [5] and Mount Everest [10, 3, 4] with the stereo capability of new high resolution stereo satellites, such as Ziyuan-3.

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