MAPPING FROM SPACE

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ABSTRACT:

The paper outlines the historical development of tools for high resolution imaging and mapping of the Earth's surface from space.

FOREWORD

On April 27, 2004 Armin Grün celebrated his 60th birthday, a mid-time event in his distinguished career. Armin has served the international photogrammetric community in many ways. Starting his academic activities at the Technical University of Munich under Prof. Gotthard, and his stay at Ohio State University his work in analytical photogrammetry soon influenced the scientific contributions to the International Congress of Photogrammetry and Remote Sensing (Helsinki 1976, Hamburg 1980, Rio 1984). When he became professor at ETH in Zürich prior to the Kyoto Congress in 1988 he assumed the responsibility for ISPRS Commission V (Close Range Photogrammetry and Machine Vision) setting new standards for this commission. At the Washington Congress 1992 he became second vice president of ISPRS until the Vienna 1996 congress and chairman of the ISPRS Financial Commission until the Amsterdam 2000 Congress. During these activities, and as corresponding member of the German Geodetic Commission Armin became a close personal friend of mine, and his 60th birthday is a good opportunity to wish him well on his continuing professional career.

Armin's principal interest has been in developing digital photogrammetric breakthroughs ranging from machine vision to other terrestrial applications, as is natural for a photogrammetrist representing Switzerland as one of the best mapped countries in the world. Armin has nevertheless covered mapping applications in other parts of the world, for example the beautiful Mt. Everest map, which he compiled for the National Geographic Society (USA) using space images of the German Metric Camera to supplement the Swissair aerial survey flight.

In this sense my paper on "Mapping from Space" is a small contribution to Armin's broad interests in photogrammetry.

1. MAPPING FROM SPACE 1957 TO 1970

Access to space platforms for imaging and mapping started with the launch of the first Russian Sputnik in 1957, after the Russian space program headed by Koroljov surprised the world. This prompted the USA to strengthen its space program headed by Wernher von Braun.

While the first aims using space platforms were directed toward military reconnaissance applications under classified operations, President John F. Kennedy's plea to land a man on the moon in the 1960's prompted the American-Russian race to the moon, which was eventually won by the USA by landing man on the moon and returning him back to earth in 1969 in the Apollo program.

To reach this success a number of permissions had to be carried out. One of these was the Lunar Orbiter program. Its aim was to send five satellites orbiting the moon, and sensing its surface to determine suitable landing sites.

To return into lunar orbit after the landing the lunar landing module had to land on a surface with an inclination of less than 2 degrees. This necessitated a mapping program of about 20 possible land sites in flat areas of the moon.

At a time, when digital sensing and transmission of digital imagery was not yet possible with sufficient resolution due to technological limitations, the Lunar Orbiters used optical cameras with Bimat film, which was developed on board of the spacecraft, and read out and transmitted in strips down to Earth. Restitution of these images at the NASA Manned Spacecraft Center in Houston, Texas required a "reinvention" of photogrammetric principles (Konecny and Refoy, 1968; Konecny, 1968). Eventually the task was accomplished with the creation of "geocoded" digital elevation models for the landing tasks as early as 1967.

Even though the Lunar Orbiter images required extensive calibrations, the use of analytical aerial triangulation block adjustments, and the application of image matching techniques, the Lunar Orbiter Missions 2 and 3 were sufficient to complete the task. For that reason Lunar Orbiter 5 was utilized to map the entire surface of the moon, creating a high resolution lunar coverage of a quality better than was available for the Earth.

2. REMOTE SENSING FROM 1972 ONWARD

After the lunar landing had been accomplished in 1969 there was public criticism in the USA on account of the high costs expended. Wernher von Braun counteracted this criticism with the words "no single dollar was spent on the moon", stating indirectly that the spinoff created by the lunar race had in effect given the USA a lead in technology for applications on Earth.

The Landsat program launched by ERTS-1 (later named Landsat 1) in 1972 prompted a huge new international interest in imaging and mapping the Earth's surface, henceforth to be known as "remote sensing".

Even the socialist countries under the leadership of the USSR internationalized their efforts in this direction in the socalled "Interkosmos" program utilizing camera technology (MKF6, Kate 140).

The 1970's, 1980's and 1990's marked the times of ever increasing spatial resolutions obtainable from space. Gradually military classification restrictions were relaxed. These were discussed at many United Nations Regional Cartographic Conferences, during which the Latin American countries and the USSR still insisted in 1978 that the releasable ground resolution limit should be 50 m.

Landsat TM in 1982 with 30 m resolution broke this limit for international use. At the same time the USA operated their military CORONA program, started in 1968 yielding 3 m resolution panoramic photographs from space. 30 years after the CORONA program was launched these images are now publicly available as a historic record by the USGS.

In Germany an initiative was taken to launch a photogrammetric camera (RMK by Zeiss) in the European Spacelab as part of the US Space Shuttle program as "Metric Camera". In this 10 day mission carried out in 1983 10 % of the land surface of the Earth was imaged in stereo with 16 m resolution. Tests with this imagery showed that a planimetric accuracy of ± 20 m could be reached. Armin has used such images for the Mt. Everest map.

There was considerable interest in these images by the French IGN and CNES, which were preparing for their SPOT program launched in 1986 with 10 m panchromatic and 20 m multispectral resolution.

The USA launched in 1984 in Space Shuttle a "Large Format Camera" with even better resolution and accuracy. The Space Shuttle camera uses were terminated by the Challenger disaster in 1986.

The German government decided to concentrate on the design and construction of the modular optical multispectral scanner MOMS, which flew for the first time on Space Shuttle as MOMS-2 with 5 m panchromatic, 15 m stereo, and 15 m multispectral resolution in 1993. In a reflight of this scanner on the Russian MIR platform from 1996 to 1999 at a slightly higher altitude with 6 m panchromatic, 18 m stereo, and 18 m multispectral resolution about 45 M km^2 of the Earth's land surface were imaged. The accuracy tests showed ± 6 m for planimetry and ± 8 m for elevation.

In 1986, at the ISPRS Commission II Symposium in Leipzig organized by the GDR Commission President Klaus Szangolies, the USSR began to show their high resolution photographic images taken with the KFA 1000 with 7 m resolution, supported by the TK 350 images for stereo. These images became internationally available in 1987. High resolution images of the KVR 1000 camera with 2 m resolution became available in 1996.

It is remarkable that in 1996 India, a developing country, launched its remote sensing satellites IRS C/D with 6 m resolution.

3. HIGH RESOLUTION SATELLITES

Ikonos 2, launched in 1999, marked the first international success in high resolution imaging. This was followed in 2000 by the launch of the Israeli EROS A1 satellite with 1,8 m resolution, and in 2001 by the 0,6 m resolution satellite Quickbird. These satellites provide the capability of stereo imaging along the orbital path.

Tests carried out with Ikonos imagery in Hannover (Jacobsen, 2004) demonstrate that the base-height ratio of stereo imaging is too small. A height accuracy of only 4 m was obtained. If, however, a digital elevation model with accuracies between 2 and 4 m is available, orthoimage restitution can be carried out to 1 m pixel accuracy. This also requires the use of 4 ground control points in the corners of the image to be independent of the rational polynomial coefficients delivered with the images for use without ground control at lesser accuracy.

These tests make the use of the new Spot 5 HRS camera launched in 2003 quite interesting, since it provides a more favourable base-height ratio. Even though the staggered array sensor only has a ground resolution of 2,5 m, height accuracies of ± 3 m have been achieved (Jacobsen, 2004).

The use of such sensor systems is only at the beginning. The Japanese satellite Alos with 2,5 m ground resolution to be launched 2005, the Indian Cartosat with 2 m ground resolution to be launched in 2004, and the CBERS satellite with 2 m ground resolution in 2005 should provide similar capabilities.

4. RADAR INTERFEROMETRIC SYSTEMS

All weather mapping of cloud covered areas has been the aim of airborne radar systems since the 1960's (e.g. the Brazilian RADAM project yielding a radar coverage of the 8 M km^2 large country).

The US satellite Seasat provided a radar capability from space in 1978 for a three months duration. The European Space Agency's ERS ½ provided a more continuous radar coverage from 1991 onward, followed by the Russian Almaz 1991, and the Japanese JERS in 1994. The highest resolution radar satellite is the Canadian Radarsat since 1995 with an optional 6 m radar pixel.

Radar satellites (in particular ERS1 and 2 in a tandem mission) provided the possibility of radar interferometry. For this the satellite orbits and the base between overlapping images must be accurately known.

To make radar interferograms at ideal conditions NASA, NIMA, and the DLR initiated the Shuttle Radar Topographic Mission SRTM in 2002 using a 60 m expanded beam carrying the second antenna during the Space Shuttle flight of 10 days.

The c-band radar of NASA/NIMA covered the entire land surface of the earth, while the lightly more accurate x-band radar of DLR had an interleaved coverage.

Tests have shown that for flat, non-vegetated areas elevations derived from the interferograms are ± 5 m or better. As compared to the globally available DTED2 data with ± 18 m this is a significant advantage.

Only in steep mountain terrain radar interferometry has problems due to radar foreshortening and radar shadows. The global DEM strategy must therefore be to use SRTM data in flat areas supplemented by optical data (Spot 5 HRS, Alos etc.) in mountainous areas.

5. SMALL SATELLITES

Satellite programs are expensive ventures. They were supported in general by governments (USSR, USA, ESA, Japan, India, etc.) or by consortia supported by governments (Space Imaging, Earthwatch, Ofek). Target oriented satellite missions can nowadays, however, be undertaken at smaller costs with dedicated small satellites (Röser et al., 2001). The University of

Surrey, UK has claimed that in this way 95 % of the performance of a large satellite can be reached with 5 % of the cost.

In this way smaller nations such as Korea (1993), Portugal (1993), Thailand (1998), Chile (1998), Malaysia (1999) have been able to launch their own small satellites using the commercial launch facilities made available by Russia or India. Some of these small satellites launched offered experimental image acquisitions (Uosat 12, 10 m pan, 1999) (Tubsat DLR, 6 m, 1999) (Bird DLR, 50 m thermal, 2003). Many more such missions planned demonstrate that operations from space are in the process of internationalization.

6. THE FUTURE ROAD

A review of the current situation on mapping from space shows:

- The facilities and the technology for mapping from space are operational;
- The need for up-to-date mapping information of the globe is still not fulfilled;
- The imagery archives of existing satellite data are not yet exploited for these purposes;
- It is a credit to the space technology nations Russia and USA, and those who have ventured in joint developments to have internationalized the possibilities for mapping from space.

Mapping from space is thus at the beginning of operational use.

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