MONGOLIAN EXPERIENCES WITH THE PRACTICAL APPLICATION OF HIGH RESOLUTION SATELLITE IMAGERY CONSIDERING COST-BENEFIT ASPECTS

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Abstract:MONMAP has gathered vast experience with the practical application of different types of latest generation high resolution satellite imagery (HRI) in different fields. While the manifold possible applications of these images are quite well-known nowadays, and numerous scientific studies have been carried out, for a commercial user such as MONMAP the cost-benefit ratio is a crucial issue in connection with the identification of the most suitable type of imagery, and also with the selection of the most efficient processing and data extraction / generation method.

With the objective to gain indications for the provision of optimized services, practical applications of HRI in Mongolia in the following areas have been reviewed regarding specific appropriateness and benefits: civil aviation (obstacles, DTM, virtual reality aircraft approach planning), and mining (inspection, exploration base mapping, pit and dump volumes). For each one of the mentioned applications, the suitability of HRI in general, of different image types and processing approaches, and most of all the smart combination of HRI with other state-of-the-art data collection methods have been studied, aiming to provide high quality data at relatively low cost. Some summarized conclusions:

- Stereo HRI is ideal for mapping of the built up areas in the vicinity of airports, to satisfy the high accuracy requirements for DTMs and for final approach planning; beyond a certain distance from the airport, other methods of data collection might be more cost efficient, such as GPS surveys.
- Multispectral HRI is an efficient means to support the inspection of medium and large scale mining activities, even allowing the retrieval of information which might be very difficult to collect in the field. Knowledge-based, visual image interpretation outmatches all automated and semi-automated methods. However, due to the costs of the imagery, these methods can only be applied in a cost efficient way to large scale operations, and to accumulations of medium scale operations.
- Stereo HRI is suitable for base mapping required by large scale mining operations; for the calculation of pit, dump and stockpile volumes, photos taken by drones are more suitable, and laser scanning is the technique of choice for plant mapping.

1. INTRODUCTION

Mongolia is a fast growing economy with significant annual growth rates; gross national income per capita quadrupled between 2000 and 2008. The industry is the most important economic factor and contributes with over 39 % to the gross domestic product. Mongolia's wealth lies in its extensive mineral deposits, which account for a large portion of investment and government revenues.

At the same time, Mongolia is a vast country whose territory covers more than 1,560,000 km², and a population of less than 3 million people makes it the country with the lowest population density in the world (ca. 1.76 habitants / km²).

Such big countries with a rather low population density share a common problem: the cost of transportation infrastructure per capita is extremely high, and access to remote sites is very time consuming and costly.

Rapid economic growth requires careful planning and monitoring. High resolution satellite imagery provides excellent means for the elaboration of required base data. However, also satellite imagery becomes expensive when mapping of huge areas is required.On the other hand, for certain applications even higher resolutions are required.

Careful analysis and smart approaches combining different technologies are required for efficient mapping and monitoring under such circumstances.

TASKS, METHODS ANDRESULTS

Task 1

The International Civil Aviation Organization requires all member states to generate and submit electronic terrain and obstacle data (eTOD) for different areas in the vicinity of airports used for civil aviation. For this case study, data for the Terminal Manoeuvring Area (TMA) for 19 Mongolian airports needed to be collected. The TMA comprises an area of 45 km around the aerodrome reference point (coverage approximately 6362 km²); general data accuracy requirement is 5 m horizontal and 3 m vertical at 90% confidence level; obstacle collection requirements, mainly defined by a minimum obstacle height above the surface and a minimum obstacle height relative to the runwayare complex and mainly depend on the distance and location with respect to the runways.

2. METHODS AND RESULTS

Stereo HRI is suitable for both the extraction of obstacle data (except for some few very slim obstacles such as antennas) and the generation of terrains. However, the cost of acquiring the raw data for the entire coverage of the 19 TMA would be immense sum up to several million USD. The cost of aerial photos would probably be even higher; cheaper medium resolution imagery would not be an alternative considering the obstacle data requirements. Thus, a smart approach needed to be elaborated to reduce costs while complying with the requirements.

The eTOD data were generated based on a combination of the following techniques and base data:

- GPS surveys were carried out to collect ground control points, slim obstacles which cannot be identified in HRI, all obstacles in relatively large, sparsely populated areas, and additional peak elevations.
- Obstacles located in close vicinity of the airports, and furthermore in urban areas, where collected from stereo HRI using digital photogrammetric techniques.
- The stereo HRI was also used to generate terrain data (digital surface models, DSM).
- For the remaining areas, SRTM-1 SIR-C data were used to generate terrains. These data have been proven to be quite accurate for most of the Mongolian territory; they were refined with the GPS-measured peak data and merged with the terrains derived from the HRI.

Quality control measures showed that the resulting datasets were compliant with the requirements, and were generated at a fraction of the cost of either using HRI for the entire areas, or performing GPS surveys for all featured required to be captured.

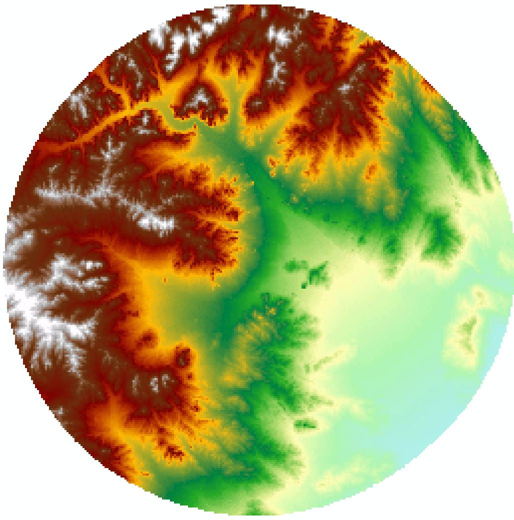

Figure 1: Seamless DSM for the Arvaikheer airport TMA, generated based on stereo HRI, SRTM-1 SIR-C data and GPS measured peaks.

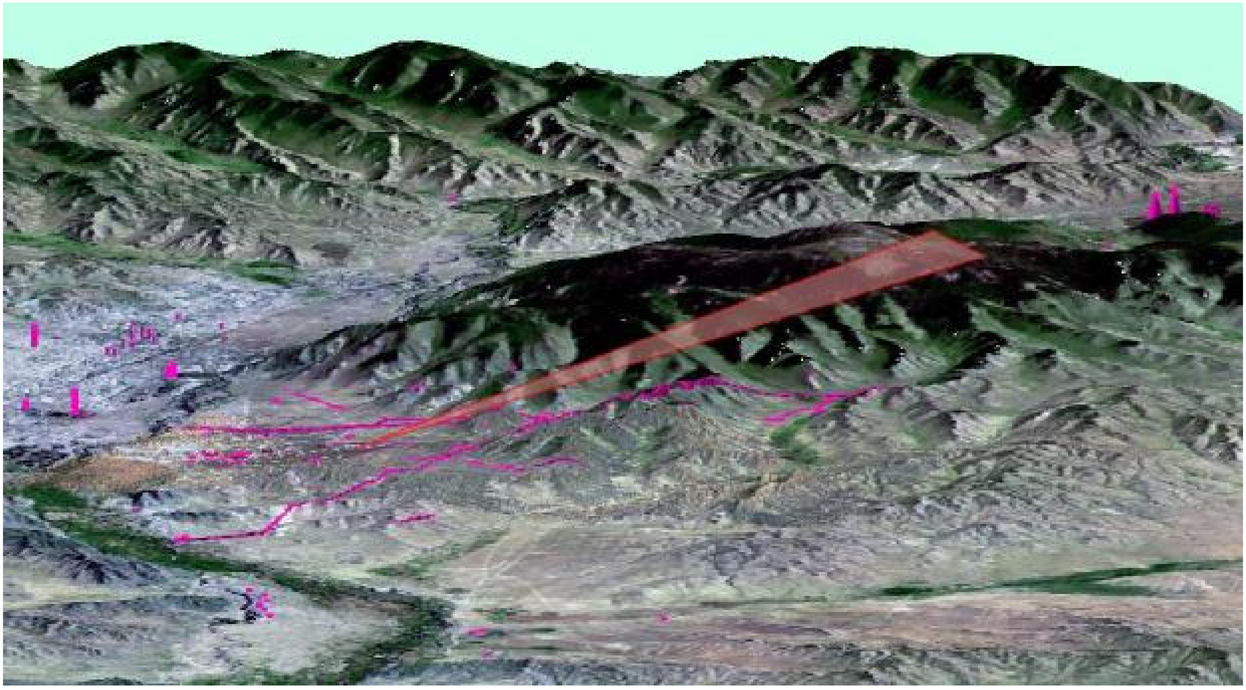

Figure 2: Terrain and 3D obstacle features used for approach planning; Chinggis Khan airport, Ulaanbaatar.

Task 2

The Mongolian General Agency for Specialized Inspection (GASI) is in charge of supervising the compliance of mining operations with the legislation and the approved annual mining plans. In Mongolia, mining operations are scattered all over the country, and field visits tend to be costly in terms of time and resources. GASI awarded a feasibility study to figure out several of their inspection tasks could be carried out using satellite imagery, and for which cases this method would be economically viable.

Methods and results

Different types of medium and high resolution imagery was acquired for two study areas with different characteristics regarding natural setting and mining activities: one steppe region with medium and large scale mining operations, and one mountainous region with scattered small scale gold mines. A classification scheme consisting in 22 land uses and impacts relevant to mining inspections was elaborated, including features such as open pits, dredges, dumps, recultivation measures and overspills. During a ground truthing campaign, samples for all those feature classes were surveyed. Subsequently, for each type of imagery it was analysed if the features could be identified through visual or semi-automated classification methods.

Visual, knowledge based interpretation of pan-sharpened HRI provided best results; practically all of the feature and land use classes could be identified in both study areas. Panchromatic and multispectral HRI were also useful, but with limitations. Medium resolution imagery, and also semi-automated classification method, did not provide satisfactory results.

Figure 3: Identification of land uses and impacts relevant to mining inspections using HRI.

The feasibility study proved that pan-sharpened HRI would represent and efficient means to support mining inspections. However, acquisition costs are relatively high, suitable images can generally only be acquired through tasking, and a minimum area for each image needs to be tasked. Considering the fact that only 18 of the currently 1210 licensed mining operations have a size of 80 or more km², image tasking can only be applied in an economic way to big accumulations of medium and large scale mining operations, such as in one of the study areas. In this area, the total of 46,5 km² of valid mining licenses could be covered by one square image of 100 km², resulting in an effective image cost of less than 50 USD / km² of active mining. Average size of a mining license in thisarea is 3,1 km², thus the cost of image acquisition would be on average 150 USD / license, not too much for a mining company.

However, for small scale mining operations and more isolated medium scale mining operations, HRI cannot replace field visits. To improve efficiency of these visits, a different approach was proposed, based on tablet PCs running a specialized GIS software connected to a small GPS receiver (mouse), allowing to navigate to specific features while displaying the company's operation plan maps and current position.

Task 3

Medium and large scale mining operations demand highly accurate base data and maps mainly for the following purposes: planning of mining infrastructure (generally at 1:5000 or 1:2000 scale), calculation of volumes of extraction areas, waste / overburden dumps and stockpiles (up to decimetre resolution), and plans of fixed mining machinery (e.g. conveyor systems at highest possible resolution).

Methods and results

Until recently, all these data have been collected through time consuming traditional surveying methods. Nowadays, more accurate and efficient methods are available. Economic generation of the above mentioned datasets can be achieved by a smart combination of different data collection methods.

HRI imagery is highly suitable for the generation of base maps up to 1:2000. 8 band multispectral imagery furthermore allows extraction of information about soils, vegetation and moisture.

Figure 4: Pan-sharpened 8 bands stereo HRI as basis for topographic and thematic mapping.

For volume calculations, higher resolution is required. Furthermore, volumes need to be calculated for a specific point in time, what cannot be guaranteed by image tasking. Apart from the relatively costly airborne LIDAR technology, two flexible modern techniques can be applied: laser scanning from the ground and application of drones (unmanned aerial vehicle, UAV) with cameras.

A comparison of both techniques showed that in most cases drones can provide suitable base data (surface models) for volume calculations faster than laser scanners, because to cover the entire area of interest, scanning is required from different positions due to view obstructions and the geometric characteristics of dumps and open pits, whereas drones can generally cover areas of a few km² within very few hours, achieving sufficient resolutions and accuracies of approximately 10 cm.

Figure 5: Orthomosaics generated from drone photos; scales 1:5000 (left) and 1:500 (right).

Laser scanners definitively have their strengths when extremely high resolution (1 cam and more) and views from the side are required.

Figure 6: Highest resolution laser scan of a mining plant.

3. CONCLUSIONS & RECOMMENDATIONS

Nowadays, besides further improved GPS technology, different means for acquiring base data for mapping are available, such as HRI in mono and stereo mode, and in panchromatic and up to 8 band multispectral mode, furthermore aerial photos taken by drones, LIDAR and ground-borne laser scanning systems. Integration of these data using standard GIS software is no problem anymore. Increasing demands for detailed and accurate spatial data on one hand, and the necessity to generate these data in the most cost-efficient way, often require smart approaches combining these new technologies in the best way.