A Prospect of Digital Airborne Photogrammetry Approach for Cadastral Mapping in Nepal

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Abstract

Although the history of land recording system is very old in Nepal, systemic cadastral survey was commenced only after the promulgation of Land Measurement Acts in 1963 and the implementation of land reform programme in 1964. Cadastral survey of all 75 districts of Nepal was completed in 1995/96 using traditional graphical method with plane tables and telescopic/plane alidades. Derived information from the existing maps now are outdated and do not fulfill the needs of the general public. 27 out of the 83 district survey offices under Survey Department, Government of Nepal are presently involved in cadastral mapping of the village block areas which previously have been left out in the first phase of surveys (1964-1996). These offices as well are engaged in the preparation of new mapping series of the districts using the same traditional graphical survey method. The speed of this survey is relatively slow and the general public also is not very satisfied with this resurveying method. People now are soliciting for updated and reliable land information based on new cadastral maps due to greater demand for land market and higher land values. Now the time has come to adopt an appropriate innovative approach for resurveying in the country in order to meet the growing public demands on reliable land information system as well as to provide prompt services. Although various technologies in cadastral mapping are currently available, digital airborne photogrammetry using aerial photographs probably could be an appropriate technology for resurveying in Nepal, especially in the hilly districts for developing accurate and reliable land information system.

1. Introduction

Although the art of surveying and preparation of maps has been practiced from the ancient times, the methods for demarcating land boundaries have been evolved after the man has develop to sense the land property. The earliest surveys were carried out mainly for the purpose of recording the boundaries of land plots. The spatial component of land including accurate delineations of land boundaries was found to be important for administrators and rulers. This eventually has lead to evolve the cadastral survey. Cadastral survey along with its map is basically the parcel based land information showing the demarcation of every parcel boundaries. In addition, it includes land tenure, land use, land value and all other attributes of land which are needed for land administration. Many tools and techniques have been applied in the past in the field of cadastral survey from chain surveying to plane table surveying (with plain alidade/telescope alidade). For the last few decades various techniques have been evolved in the cadastral surveys such as digital cadastre using Total Stations and Global Positional Systems (GPS) instruments, digital aerial photography, and cadastral mapping using high resolution satellite images.

After the introduction of photogrammetry in the mapping processes, approaches in cadastral surveys as well have been changed dramatically. Photogrammetry was first invented in 1851 by Laussedat, and has continued to develop over the last 160 years. Over time, the development of photogrammetry has passed through the phases of plane table photogrammetry, analog photogrammetry, analytical photogrammetry, and has now entered the phase of digital photogrammetry (Konecny, 1994). After the development of aeroplanes in the early twentieth century, aerial photogrammetry technique has been applied in the field of mapping as well as in cadastral surveying. The first aerial photographs were taken over Italian territories in April 24, 1909 by William Wright. Likewise the first aerial camera was built by Oscar Messter in Germany in 1915 (Agor, 2011).

Cadastral survey of all 75 districts of Nepal was completed in 1995/96 using traditional graphical method with plane tables and telescopic/plane alidades. Derived information from the existing maps now are obsolete and do not fulfill the needs of the general public. An innovative survey technique must be adopted for the preparation of new series of cadastral maps for the country in order to create up-to-date land information database. The traditional graphical surveying methods are now very expensive and

would take a long time. Analytical aerial photogrammetry technologies for cadastral mapping have been applied in many nations of the world (e.g. Zimbabwe, India, and Cyprus) for the last few decades. Digital photogrammetry technology, one of the latest technologies in the field of digital mapping, will provide accurate cadastral maps with relatively in short period of time and could be reasonably inexpensive. Prospective of digital aerial photogrammetry technique for the preparation of new series of cadastral maps in Nepal is briefly illustrated in this paper.

2. History of Cadastral Survey in Nepal

Although Systemic Cadastral Survey was commenced only after the promulgation of land reform programme in 1964, the history of land recording system is very old in Nepal. The land recording system has been organized for land taxation during the Lichhabi Era (about 1,300 years ago). In those days, land taxation was the prime source of revenue to run the state activities and cadastral survey was basically, in the form of description of land (such as Shresta & Lekhot). Likewise, during the period of Malla Era (14th to 18th Century), significant improvements including the classification of lands, specification for land measurements, provision measurement units (as hale, pate, kute, kodale etc.), development of special profession for land survey and measurement (Dangol), land adjudication and boundary description of land etc. were made. During the period of Rana Rules, the essence of the cadastral maps was realized as an indispensable component for land administration and the chain survey method then was introduced to prepare cadastral maps in 1923 (1980 B.S). Cadastral Survey, showing parcel boundary in the form of map, has been initiated and land records simply comprised of inventory of land parcels, land classification and landowners. This type of cadastral survey has been carried out in some major districts of Nepal but it was sporadic.

Several evolutions in the field of cadastral surveys, basically in techniques and tools for surveying, have been taken place since then. Major evolution however occurred after the establishment of Survey Department in the year of 1957 (2014 B.S). The Land Measurement Acts was introduced in 1963. With the implementation of this act, the cadastral maps became the legal documents defining the boundaries of all land properties and have provided the basic data for land administration including for land taxation. In addition, these maps became an integral part of the land registration process. Systematic cadastral surveys then were carried out on the priority basis of all the districts of Nepal in 1964. Major tools used in surveying basically were plane tables, plain alidades and chains. Later, plain alidades and chains were substituted by telescopic alidades and measuring tapes. The initial survey however was focused mainly for fulfilling the land reform programmes of 1964 and collecting land revenues, and fewer preferences have been given to the usual cadastral objectives. Moreover, National Geodetic Network Systems (NGNS) have not been established for cadastral mapping until 1969. Out of 75 districts of Nepal, cadastral maps of 38 districts were prepared without the national geodetic control points forming the island map sheets of cultivated land. After the establishment of Geodetic Survey Branch under Survey Department in 1969, cadastral surveying of remaining 37 districts was conducted on the basis of NGNS. Cadastral survey office was as well established in each district after the completion of the cadastral surveying of the district. Major responsibility of the district survey office is to maintain and update the cadastral maps and associated documents derived during the process of property transactions and parcel subdivisions.

Cadastral survey of all 75 districts of Nepal was completed in 1995/96 using traditional graphical method with plane tables and telescopic/plane alidades. However, nearly 20,000 hectares of conglomerated village block areas (so called Gaun Blocks) along with government lands were not mapped out due to the time constraint while conducting surveying works in the districts. After the accomplishment of the first phase (Eksoro Napi) of the cadastral mapping, the government has then decided to conduct surveys in the remaining village block areas scattered in many districts of the country, and Survey Department has so far completed surveying of more than fifty percent of these block areas (SD, 2011). These surveys are being conducted at the scale of 1:500 using graphical methods with plane tables, telescopic alidades and measuring tapes. Furthermore, resurveying of 38 districts that were not based on the national control network systems has been carrying out since 1996 with the preference given to the urban and suburban areas having high land values and transactions. Where control points are not enough, GPS technology is being introduced for the establishment of new control points in the village block areas as well as in the resurveying areas.

In 2006, a significant evolution in cadastral survey has taken place in Nepal after the Survey Department has introduced digital cadastral mapping in one of the municipalities of Kabhre district as a pilot project, using latest technology. The main objective of this mapping was to prepare digital cadastral database of the area to mitigate the land disputes, to secure land ownership rights and to develop parcel based land information system. A separate office called Banepa Survey Office was established in 2006 to carry out digital mapping of Banepa Municipality which has been accomplished in the year of 2010. Moreover, land ownership certificates of ward 7 of this municipality have been distributed, while ward 6 is implemented. Equipments such as Total Stations, computers, GIS softwares (Arc GIS and Survey Analyst) along with the other extension softwares (for example Parcel Editor) were used for the mapping. In the middle of 2010, this office has commenced to perform surveying of another municipality of Kabhre district (Dhulikhel Municipality) using the same technology (SD, 2011).

3. Need of New Cadastral Database in Nepal

Although the cadastral mapping of the entire country was completed in 1996 using graphical survey with plane table technique, derived information from the existing maps now are outdated and do not fulfill the needs of the general public. Moreover, existing cadastral maps are not accurate enough for the present planning and development of the country. Twenty-seven out of 83 district survey offices under Survey Department are presently involved in cadastral mapping of the village block areas which previously have been left out without mapping in the first phase of surveys (1964-1996). These offices are as well engaged in the preparation of new mapping series of the districts where cadastral surveys were not based on the NGNS. The scale of the new mapping series is generally at 1:500 and traditional graphical survey method with plane tables and telescopic alidades is being used. The speed of this survey however is relatively slow and the general public also is not very satisfied with this resurveying method. It is because of the fact that people are asking for updated and reliable land information based on new cadastral maps due to greater demand for land market and higher land values, especially in the urban and suburban areas. In addition, people are more aware of their ownership rights, areas and dimensions of land plots and values. Other reasons for the need of digital cadastral mapping in Nepal are land fragmentation resulting in small parcel size, problem of maintaining paper maps for the long period of time, scale factor in demarcation of plot boundary in the field, significant increase in property transactions etc. Considering all these facts Survey Department, Government of Nepal now has to adopt an appropriate innovative approach for cadastral mapping in the country in order to meet the growing public demands on reliable land information system and to provide speedy services. As cadastral data is an essential component upon which all the development activities as well as land administration is based on, an alternative solution must be solicited for providing accurate and reliable land information for effective planning and sustainable development of country.

4. Current Technologies for Digital Cadastral Mapping

A graphical ground surveying method using plane table and telescopic alidade for the purpose of cadastral mapping is no longer an appropriate solution for developing accurate and reliable land information system. A digital survey technique must be adopted for the preparation of cadastral maps in order to create up-to-date continuous digital cadastral database. These databases as well must support the thematic overlays and topographical data in seamless form and must replace the manual techniques associated with the creation and maintenance of the cadastral plans at various scales.

One of the widely used technologies currently in cadastral survey is a digital mapping using Total Station instruments, computers and softwares (for example in Bangladesh, India etc.). Survey Department has already performed digital cadastral mapping in one municipality of Kabhre district of Nepal, using this latest technology. Digital data of the study areas are acquired in the field using Total Station instruments. Ground Control Points (GCPs) are provided in the field using Total Station instruments. The data captured by Total Stations are directly transferred to a PC/Laptop computer. The raw data captured from field are managed as a separated layer. The acquired data are then processed in the computer using appropriate softwares such as Arc GIS/Arc Arc Map and Survey Analyst. Maps and associated attribute data are created as per required and digital cadastral database are then created after processing.

Another extensively used technology in cadastral survey these days is the use of optical remote sensing images such as high resolution satellite images IKONOS and Quick Bird. Photogrammetric techniques along with field verifications are used to produce digital cadastral maps. First of all, satellite images are geometrically corrected. Then vector data layers of land parcels and other detail like roads, building etc. are initially prepared from the geometrically corrected satellite images. Sufficient amount of control points are established in the field using GPS instruments. These details then are verified in the field as per required. Many countries in the world have adopted this technology for cadastral mapping (e.g. Turkey, Bhutan and Bulgaria). In most of the studies where satellite images were used for cadastral mapping have however indicated that they have faced problems in delineating land parcel boundaries correctly. This actually does not fulfill the objectives of the cadastral mapping where high accuracy of parcel boundary is required.

One of the other techniques for preparing digital cadastral maps is the use of analogue aerial photographs with application of digital photogrammetry method (Wijayawardana, 2002). Since 1940s, attempts have been made to use aerial photography for cadastral surveys. Digital photogrammetry emerged as the most efficient technology for mapping large areas for cadastral surveys. Many nations in the world have applied this technique for updating the existing cadastral maps (e.g. Bhutan, Srilanka, India and Cyprus). In this technique, first of all suitable scales of aerial photos of the project area are acquired. The acquired photos are scanned with a high resolution scanner and are then georeferenced using the control points. Orthophotos and mosaics from the georeferenced photos are also produced using the appropriate photogrammetric softwares. Then parcel boundary information is extracted by on screen digitizing using appropriate GIS softwares. Field verifications along with orthophotos, palmtop/laptop computers and GPS are conducted to correct unclear parcel

boundaries as well as to solve boundary disputes between land owners in the fields. Although this surveying method may be cheaper and provide better land parcel boundaries compared to the photogrammetric technique with the use of high resolution satellite images, it may not be appropriate for the hilly areas due to relief displacement and shadowing effects. This surveying technique however may be suitable for the plain areas with latest aerial photographs.

5. Digital Airborne Photogrammetry Technique in Nepal

5.1 Justification of New Approach

Cadastral mapping of the entire country was completed in Nepal in 1996 AD using graphical survey with plane table technique. Information derived from the existing maps now are outdated and do not fulfill the needs of the general public. An appropriate innovative approach for resurveying is needed in order to meet the growing public demands on reliable land information. Apart from that, the new approach should increase the speed of mapping and reduce costs & time, particularly where a large area have to be resurveyed. One of the widely used technologies in updating existing cadastral maps is the use of digital aerial photographs with the application of digital photogrammetry. In this technology, digital photographs captured directly from the digital camera are stored and processed on a workstation setup; and many photogrammetric tasks are highly automated (e.g. automatic Digital Elevation Model (DEM) extraction and digital orthophoto generation). The output products are in digital form, such as digital maps, DEMs, and digital orthophotos saved on computer storage media. Therefore, they can be easily stored, managed, and applied as per required.

In comparison to analogue photographs, digital photography has several advantages which include stereo matching, edge response, noise estimation and classification. In addition, there are no requirements of films, photo labs, scanning, noise from film grains and cost of duplication (Perko, 2005). An important novel feature of the digital systems, in comparison to analog systems, is their high radiometric potential, which was empirically proven by Honkavaara and Markelin et al. (2008). This could significantly improve the automation potential processes during the production of orthophotos.

Although the legal boundaries of parcels cannot be determined from the photographs without extensive verifications/adjudications on the ground, this technique can be as accurate as and significantly faster than ground surveys. A study of digital photogrammetry technique conducted by Agrawal and Kumar (2008) in Nizamabad district of Hyderabad, India show that for rural and urban areas, accuracy of the linear measurements up to 0.25 metres with a confidence level of 90% for distances within 1,000 metres was achieved. This accuracy level is good enough for resurveying of hilly districts of Nepal where most of the existing cadastral maps were prepared at the scale of 1:2,500 with accuracy level less than 0.50 metres for linear measurements. This technology probably is an appropriate technology for resurveying in Nepal, especially in the hilly districts such as Achham and Arghakanchi, in order to develop accurate and reliable land information system for effective planning and sustainable development of country as well as to meet public's satisfaction.

5.2 General Processes in Digital Aerial Photography Technique

5.2.1 Acquisition of Digital Aerial Photographs

At first, new digital aerial photographs are acquired for the project area at a suitable scale. A proper flight planning is performed based on the parameters which include flying height, ground resolution, the focal length and the pixel size of the sensors etc. These-days commercial softwares are available for the flight planning processes.

Frame based cameras such as UltraCams from Vexcel Imaging Austria and DMC (Digital Mapping Camera) from Intergraph, designed especially for precision photogrammetric applications are generally used for the acquiring digital aerial photography. Direct georeferencing is increasingly applied in connection to the photogrammetric film/frame cameras. For the geocoding of orthophotos and their tone-matched mosaics new in-flight determinations of the coordinates of the exposure stations and the sensor orientation have been made possible by in-flight differential GPS and by Inertial Measuring Units (IMU)/ Inertial Navigation System (INS). The prerequisite for the use of this technique is an airborne system calibration of camera. Appropriate numbers of GPS Stations and Tracking Stations are commonly linked to the in-flight GPS. Additional GCPs are established in the field using GPS instruments where necessary. As in the analogue photography, side overlaps and forward overlaps for stereo coverage are needed and they follow the same principles. For True orthophoto generation, especially in urban areas, higher overlaps like 80%-90 % are required (Newmann, 2003).

One of the studies carried out in Andra Pradesh Province of India has recommended that aerial photos at 1:10,000 scale are appropriate for the rural areas and 1:4,000 for the urban areas in order to maintain the accuracy of the outcome maps (Agrawal and Kumar, 2000).

Once the digital raw data are acquired from the flight, they require post processing to create the final output images which will be used for subsequent digital mapping.

5.2.2 Generation of DEM and Orthophotos

One of the major processes in digital photogrammetry using aerial photography for cadastral mapping is to create DEM. The principle method of generating DEMs from digital

photographs is now automatic stereo matching using the GCP data and additional control data derived from aerial triangulation. Existing digital database, where necessary, may be supplemented while creating DEMs. If airborne GPS and IMU/INS data (which can be referred to as exterior orientation) is available for each photo, GCPs may not be required while processing for DEM creation. Various softwares have been developed over many years and packages such as L P Suite sold by Leica Geosystems, and Match-T are now widely used. These softwares can process hundreds of images or photographs with very few GCPs, while at the same time eliminating the misalignment problem associated with creating photo mosaics. Editing software as well comes with the package and this has significant use, especially at large scales. Major factors affecting the accuracy of DEM during the processes are accuracy of the source data/derived elevation, terrain characteristics, sampling method and interpolation method (Dowman, 2002).

Orthophotos are valuable means in digital mapping process in order to obtain accurate planimetric features with an efficient and speedy manner. In the digital photogrammetry, orthophotos are generally created from the digital photos through orthorectification processes using DEMs and triangulation results. Scale variation and relief displacement in the original photography are removed in the orthophotos. The orthophotos has the geometric characteristics of a map and the image qualities of a photograph. The objects on an orthophoto are in their true orthographic positions. Hence, it is possible to measure true distances, angles and areas directly from them. For the hilly regions, where the elevation differences are very high, true orthophotos may be appropriate. True orthophotos can be generally obtained from three line digital scanners using algorithms that use information from all three looks. Matching algorithms using only two images may be able to produce true orthophotos if breaklines can be utilized (Dowman, 2002).

5.2.3 Digitization of the Known Parcels

For the digital cadastral mapping, parcel boundaries of the details can be extracted by using a computer and appropriate GIS softwares. Orthophotos, with their continuous tone imagery of the ground, provide large number of details which are identified and extracted. Then vector data layers of land parcels and other details like roads, building etc. are initially prepared from the orthophotos. Other ground features as well can be collected and subsequently attributed to reflect the spatial and non-spatial characteristics associated with a feature. However, the major problem is to collect information of the terrains which are covered by obstacles such as trees, high buildings, etc. Unclear details are subsequently verified in the field.

5.2.4 Verification/Adjudication in the Field

In cadastral mapping undertaken by photogrammetry technique, there is a need for follow-up ground surveys to verify the actual location of legal boundaries that may not be visible on the photography or may have been wrongly identified. To overcome this, survey team with GPS and related orthophotos if needed Total Stations instruments, should go to the field to check the parcel boundaries. For efficiency and accuracy in surveying, it is worth to use large scale orthophotos for field adjudication process as well as for land registration. Land owners could trust more on images and models rather than on maps as they could visually interpret their parcel boundary. This will also expedite in identification of ownerships on the ground in the presence of owners.

5.2.5 Final Production of Digital Cadastral Database

After the completion of field verification/adjudication processes, final digital cadastral database along with the attribute data are prepared. These databases can be readily updated as per the changes in land parcel information. Updated, accurate and reliable land information will then be utilized for effective planning and sustainable development of the country.

6. Conclusions

Cadastral mapping of the entire country was completed in 1996 AD using graphical survey with plane table technique. Derived information from the existing cadastral maps now are outdated and do not fulfill the needs of the general public. Furthermore, it is not accurate enough for the present planning and development of the country effectively. Now the time has come to adopt an appropriate innovative approach for resurveying in the country in order to meet the growing public demands on reliable land information system and to provide prompt services. A digital survey technique must be adopted for the preparation of cadastral maps to create up-to-date continuous digital database. Although various technologies in cadastral mapping are currently available, digital aerial photogrammetry probably could be a suitable technology for resurveying in Nepal, especially in the hilly districts for developing accurate and reliable land information system. It should be borne in mind that for performing cadastral mapping through digital aerial photogrammetry technique, sophisticated infrastructural set up such as workstation and appropriate photogrammetry softwares is mandatory. Apart from that skilled manpower is needed in the implementing institution.

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