Roadmap for Re-establishment of Geospatial Relationship of the Control Points and Features in Nepal due to Gorkha Earthquake 2015

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KEYWORDS

Geospatial Relationship, Control Points, Topographical Features, Earthquake, Change Detection

ABSTRACT

Occurrence of earthquake in Nepal is obvious as it lies in earthquake prone zone. Amount of destruction caused by an earthquake will depend upon the magnitude of the earthquake and the strength of the infrastructures. On 25th April 2015, Nepalese people experienced a huge earthquake of magnitude 7.6 in Richter scale. The earthquake destroyed and damaged a noticeable amount of human lives and infrastructures due to which spatial relationship between points of the affected area were disturbed. The disturbance of the relationship was assessed by some of the case studies in the area. Therefore, it is necessary to re-establish the spatial relationship in the existing database for making use in reconstruction phase of the earthquake and for designing and implementation of development projects in future. The suitable methods for performing this activity are adopting modern technologies such as Global Positioning System (GPS), Remote Sensing method, and modern field survey method using Total Station Theodolite. Therefore, a roadmap needs to be designed to retain spatial relationship with respect to the adjusted coordinate of control points and update the database of the country.

1. Introduction

Since, Nepal lies in earthquake prone zone and ranked 11th in the list of earthquake prone countries of the world, consequently, from time to time, it is witnessing earthquakes of magnitude ranging from less than 4 to more than 8 Richter scale. Earthquake caused in Nepal is due to pushing the Tibetan plate of Eurasian plate upward by the Indian plate due to which every year, the mass of land moved northward by approximately 4 cm. Based on this truth, Nepalese people experienced a huge earthquake of local magnitude 7.6 in Richter scale on 25th April 2015, Saturday at 11.56 AM, whose hypocenter was about 15 km deep below the surface of the earth and its epicenter was in Barpak village of Gorkha district. The earthquake was recognized as the Gorkha earthquake 2015. The earthquake destroyed large number of infrastructures including national heritage monuments, settlements *et cetera* and there was a loss of large number of lives including human, animals and birds. Obviously, the tremor displaced the location of control points which disturbed the spatial relationship between the points with respect to its original positions. Therefore, a roadmap is designed for the re-establishment of spatial relationship of the points and features not only within the area affected by the earthquake but also that of entire Nepal. The reason is that the location of origin of the spatial data of entire Nepal which is at Nagarkot, was disturbed by the earthquake.

The roadmap navigates for assessment of damages and analyzes the changes in the location and determines a technique to re-establish the spatial relationship between the points and features. Changes in the location of the control points can be assessed by Global Positioning System (GPS) method and that of the features can be assessed and updated by new remote sensing technology using Drone and traditional field survey method using Total Station Theodolite. The results will guide in the right direction for reconstruction phase of the earthquake and for designing and implementation of development projects in future.

2. Damage caused by the Earthquake

The magnitude 7.6 in Richter scale of Gorkha Earthquake 2015 was strong enough for destruction of weak infrastructures of the affected areas. Accordingly, a large number of infrastructures like houses, buildings, monuments, temples, palaces, schools, official buildings, *et cetera* and other infrastructures including roads, irrigation canals, hydro power stations, electricity poles, *et cetera* were damaged and destroyed. Destruction of these infrastructures took life and injured large numbers of human and livestock. According to the theory of Omori, every bigger earthquake will be followed by the smaller tremors termed as aftershocks. So, after the major earthquake on 25th April 2015, a series of aftershocks were experienced among which two bigger aftershocks: the first one on 26th April and second on 12th May 2015 measuring 6.9 and 6.8 Richter scale respectively were experienced and further destroyed the structures and took lives of more human and livestock. In total, 8,835 people were killed and more than 22,000 were injured and 133 cultural heritages structures and 5,91,648 houses were completely destroyed as well as 608 heritages structures and 2,76,395 houses were partially damaged. In the context of livestock, around 56,000 of animals and 5,00,000 birds were killed due to the earthquake.

Photo 1: Clockwise from top left Destroyed building, Monument (Dharahara), School (Durbar High School) and Basantapur Durbar Square

3. Damage caused by other natural phenomena

After occurrence of the Earthquake, additional damages were made due to other natural phenomenon such as landslides, debris flow, avalanches, *et cetera*. Due to shaking of ground by the earthquake, the land especially in the mountainous region and Himalayan region became very unstable and loosen its grip, therefore, at number of places, there were landslides, debris flowing down the slopes containing soil and rocks and avalanches depend upon the nature of the ground. These natural phenomenons damaged and destroyed large number of settlement areas. The consequence of disasters was loss of lives including human and animals. For example, in Langtang valley, a huge avalanche came which swept away the total settlement of the area and around 350 people were missing. Similarly, immediately after the major earthquake on 25th April 2015, there was a huge avalanche at Sagarmatha base camp. The avalanche swept away mountain climbers who were on the way to atop the Sagarmatha. Later, it was declared that 10 Nepalese porters including some guides and 5 foreign mountain climbers were dead and 61 were injured by the avalanche.

Photo 2: Clockwise from top left Rock fall at Bhotang Village of Kavre, Landslide at Arniko highway and Avalanche at Sagarmatha base camp

4. Change Detection in Topography

Changes in topographical features at the areas affected by the earthquake have to be analyzed in two steps namely control networks used for the preparation of maps and the features that were shown in the existing topographical maps.

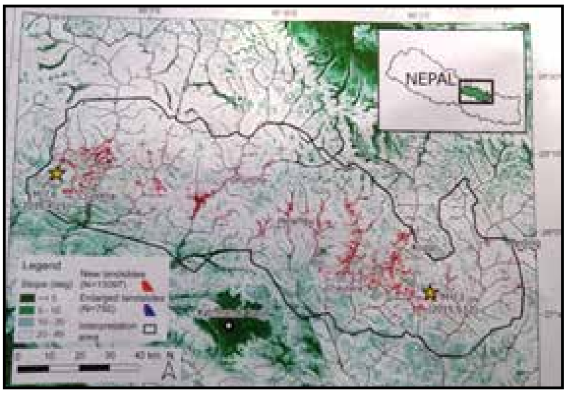
In case of detecting the changes in the control networks, it can be carried out either by determination of coordinate of the points by astronomical survey or by the system of ITRF 2008. The former method is a traditional method which is almost not in use now-a-days due to availability of artificial satellite based system such as Global Positioning System, GPS or Global Navigation Satellite System, GNSS.

Immediately after the occurrence of the earthquake, Survey Department took initiations to detect changes at the control points surrounding Kathmandu and its peripherals. According to the press release 2015 of Survey Department about the shift in the ground due to the earthquake, five control points located at Nagarkot of Bhaktapur/Kavre district, Phulchowki Danda and Bungamati Lakhe Danda of Lalitpur district, Swayambhu of Kathmandu district and Kumari Danda of Nuwakot district were chosen to take the measurements. GPS measurements were taken continuously for 24 hours in those points. Data processing of the measurements and the computation of new coordinate of these points were based on the data collected continuously for 24 hours at the points of 13 international cities namely Hong Kong, Lhasa, Banglore, Hyderabad, Kajakasthan, Oman, Mongolia, *et cetera*. Data processing of the coordinates before and after the earthquake was based on the system of Realization of Service in International Terrestrial Reference Frame (ITRF) 2008. As per the results, it showed that Kathmandu and its peripherals moved about 1.8 metres south-west and the earth surface were raised about 0.8 metre.

Since it was confirmed that there is changes in the coordinate of points at those five points, it is obvious that there could be changes in the coordinate of the points located at earthquake affected areas and consequently it is necessary to detect the amount of changes in the coordinate of these points as well.

Secondly, due to destruction and damages in the settlements, infrastructures at heritage sites, other infrastructures and the area of landslides caused by the main earthquake and aftershocks, it is obvious that the existing maps will not match the ground situation. Therefore, it is necessary to detect the amount of changes in the areas. One of the effective methods to detect the changes is by using remote sensing techniques. In case of small area, unmanned aerial vehicle (UAV) also called Drone is a very useful tool for analyzing the amount of changes. The method was used in Sankhu area of Kathmandu by ICIMOD immediately after the occurrence of the earthquake of 2015. Since the affected area was too big, it is recommend comparing the recent satellite image of the area with the archive image before the earthquake for finding out the amount of changes in the topographical features.

Recently, the Kaken Japan Research team for hazard mapping of earthquake-induced landslides initiated the three-year (2016-18) research project on the development of landslide hazard mapping technology. The project area covered 7.8 x 10^3 square kilometers of hills extending from Barpak, Gorkha to Chautara, Sindhupalchowk excluding the snow and glacier covered areas. The objective of the study was to analyse the landslides occurred due to the Gorkha Earthquake 2015 and the aftershocks and to contribute in reconstruction of severely damaged areas. The study was carried out by the members of J-Rapid Research Project of Japan Science and Technology Agency and the Japan Landslide Society for Satellite Data Utilization Project initiated by Ministry of Land, Infrastructure, Transport and Tourism (MLITT) of Japan. The study team prepared a landslide inventory as a first step for landslide assessment and mitigation of future landslide disaster in the affected areas.



Map 1: Landslides location of the Study Area

The findings of the study was presented by the team in a mini-workshop entitled "**the 2016 Japan-Nepal Mini-workshop on the 2015 Gorkha Earthquake-induced landslides"** which was jointly organized by the Kaken Japan Research team for hazard mapping of earthquake-induced landslides and Nepal Landslide Society at Kathmandu on 26th November 2016. The findings were focused on issues from a geological-geomorphological point of view. The team detected 13,087 newly formed landslides and 750 enlarged old landslides within the study area due to the main shock on 25th April and aftershocks. The study also showed that the areas could be susceptible future landslides by rain and earthquakes. The finding was based on the visual interpretation of optical satellite images provided by archive of Digital Globe Co. Ltd, Google Earth, Japan Aerospace Exploration Agency (JAXA) and National Aeronautics and Space Administration (NASA).

5. Re-establish Geospatial Relationship

From the discussion in the above paragraphs, it is clear that control points have been moved and there are lots of changes in topographical features. Therefore it is necessary to re-establish the geospatial relationship between the features in the database and if necessary to update the existing maps. The process for re-establishment of geospatial relationship could be performed in the following phases:

1) Re-establish the first order control network

It is necessary to re-establish the existing first order network because it is already detected that the origin of the network situated at Nagarkot was displaced due the earthquake. Therefore, coordinate of rest of the first order points of the network will definitely affected. Re-establishment of the first order network can be done by making GPS measurements at all the 68 first order points of the network and compute the fresh coordinates of the points based on data processing using system of Realization of Service in ITRF 2008. Based on the new data, analyze the situation and prepare a report. This will guide how to proceed further for the lower order control orders.

2) Re-establish the lower order control network

As the lower order control networks are based on the first order control network, the coordinate of the points in those networks will also be affected in the values. In order to overcome this issue, GPS measurements at all the second and third order points to be done and then re-computation and adjustment of the coordinates of the measured points has to be performed.

3) Change detection in topographic features and update the database

After re-establishment of the control network, topographical database need to be updated. In first instance, change detection of topographic features is to be identified and marked by comparing existing maps with the recent satellite image data with appropriate resolution. Then, correct the database of topographical base maps considering newly computed coordinates of the control points.

In case of database of the area outside the earthquake affected area, first of all, assess the effect caused by the change in the coordinate of the control points. If the effect is not visible due to the resolution of the database, the database can remain as it is but if the effect is noticeable then the database has to re-model with respect to the new coordinate of the control points.

4) Monitor the progress of reconstruction and update the database and maps

The country is in the phase of reconstruction of the damaged and destructed settlements and infrastructures. Some of the settlements were constructed at new sites and design and pattern of the features were also different from those in the past. Therefore, it is necessary to update the existing database and the topographical base maps.

As per the plan of National Reconstruction Authority, the reconstruction phase will be completed by five years period. But observing the progress so far made, it seems, it will take more time than it is expected. Therefore, it is recommended to update the database by the method of continuous process.

In order to do this, teams should be deputed to monitor the reconstruction at heritage sites and newly constructed settlement areas. As soon as the reconstruction of the site or area is completed, the database can be updated by collection of data applying appropriate technology which could be either ground survey method using Total Station Theodolite or remote sensing method by flying Drones. One of the examples of completion of reconstruction site was houses of the Giranchaur integrated settlement for quake survivors, built by the **Dhurmus Suntali Foundation**, in Melamchi of Sindhupalchok district as shown in the photo 3. The newly built settlement was inaugurated, on Friday, October 28, 2016 by the Honourable President Bidya Devi Bhandari and handed over to the locals.

Photo 3: Houses of the Giranchaur integrated settlement for quake survivors, built by the Dhurmus Suntali Foundation, in Melamchi of Sindhupalchok district

Based on the amount of changes in topographical features in a map, a decision is to be taken to either wait for the further changes before printing the map or to print immediately after the data is updated. In general, if there are changes of about forty percent of the features of a map, the revised data need to be printed immediately; otherwise, the map could be outdated and could not be used effectively.

6. Conclusion

Gorkha Earthquake 2015 not only damaged physical infrastructures and human and livestock but also affected the spatial relationship between the control points and topographical features. A few case studies for detection of changes are also referred in which GPS and Remote Sensing technology was adopted. In order to re-establish spatial relationship of the control points and the topographical features, modern technology using GPS and field survey method using Total Station Theodolite or Drone is recommended. The newly adjusted control points and updated spatial data are necessary for the reconstruction phase of National Reconstruction Authority and for designing and implementation of development projects in future. Therefore, the concerned authority should design a short term and long term plan for the re-establishment of spatial relationship of the control points and the features.

References

Poster of the J-Rapid Research Project of Japan Science and TechnologyAgencyand the Japan Landslide Society for Satellite Data Utilization Project, 2016.

Press Release Document of Survey Department about the shift of Land, 2015.

Sharma R.K., (2016), *A Glimpse of Earthquake in Nepal and Earthquake/Tsunami in Japan* published in Milan Magazine, Japanese Alumni Association of Nepal (JAAN), Kathmandu

Sharma R.K., *A Perspective View of the Earthquake 2015*, (unpublished and the script is in *Devnagari*)

Sharma R.K., (2016), *Data Acquisition for Search, Rescue and Relief Operation in Affected Areas Caused by Natural Disaster,* published in Nepalese Journal on Geoinformatics, Number 15, Survey Department, Kathmandu, pp. 27-29

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