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APPLICATION OF HIGH-RESOLUTION SATELLITE IMAGE FOR SEISMIC RISK ASSESSMENT

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SUMMARY

The high-resolution satellite images are now available for civilian use in many countries. Using such images to collect urban information for seismic risk assessment can reduce much of the very costly and laborious urban survey and provide better temporal resolution than traditional methods. Based on a study in India city Dehra Dun, some aspects on urban feature recognition and a brief introduction on the incorporation of data within GIS/RS package are discussed in this paper.

INTRODUCTION

Municipal seismic risk assessment is an onerous work with huge data requirement. Except for cities with well-developed urban information management, a lot of data on demography and inventory have to be prepared before any analysis can be carried out. Furthermore, with the quick pace of urban development seen in many places around the world, it is often not good any more to depend on the survey results obtained years ago.

On the other hand, since the advent of high resolution remote sensing, more and more attentions are now paid to the application of high-resolution images for urban study. Since then application of high resolution images in urban studies grows from more straightforward physical form mapping to provide indicators of urban social and economic functioning [1].

The application of high-resolution images in seismic risk assessment now seems inevitable considering the temporal accuracy and data-updating requirement of a meaningful seismic risk assessment. Also, the advantages of using high-resolution images for seismic risk assessment are obvious: 1) it is cost-effective and with sound accuracy if applied properly, 2) it is more practical in a huge and often complex urban environment where the painstaking survey can hardly be possible without enormous human labor input, cooperation from different public institutions and good training of people involved, and 3) it can provide data that can inspire new insights than the traditional methods for seismic risk assessment.

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In our study we carried our urban survey for seismic risk assessment using IKONOS image with an effective resolution of 1 meter for the India city Dehra Dun. Launched in 1999, IKONOS is the first commercial satellite with the highest publicly available resolution[2]. The various applications of high-resolution imagery that IKONOS provides are said only to be limited by the imagination.

A small part of the image is shown as Fig 1, which represents an area of around 300m in width and 270m in length. Part of a railway station and its vicinity can be clearly identified. Most of the important features related to type of building and their spatial distribution can be well recognized. This image would be very helpful in order to obtain urban information for seismic risk assessment.

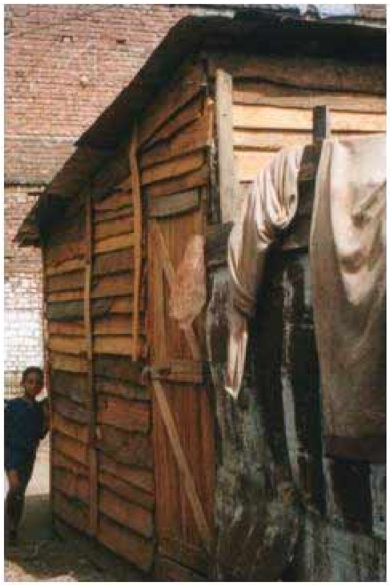
Dehra Dun is middle-sized city with population of around half a million. It is located in India state of Uttaranchal and is about 300km northeast to Capital Delhi. Since there is seldom any urban information management available and the conditions on traffic and settlements are rather deteriorated in many parts of the city, it must be a laborious work to investigate the whole city, not to mention the limit of a project and the staff available. Therefore, it is necessary to develop certain procedures to extract necessary information from the high-resolution satellite image for seismic risk assessment.

Fig. 1 a small part of the IKONOS image of Dehra Dun

BUILDING CLASSIFICATION

The building features are probably the easiest to be observed from the image due to their difference in material, structure, size and layout (Fig.2).

As we observed, there are mainly four types of buildings in Dehra Dun: reinforced concrete buildings (later referred as RC buildings), properly built brick buildings with plaster or cement (later referred as brick buildings), brick wall huts without plaster and with light roof like felt or plastic clothe (later referred as brick hut) and wooden cabins (later referred as cabin).



(a) Wood cabin **(b) Brick building**

Fig. 2 Different types of buildings

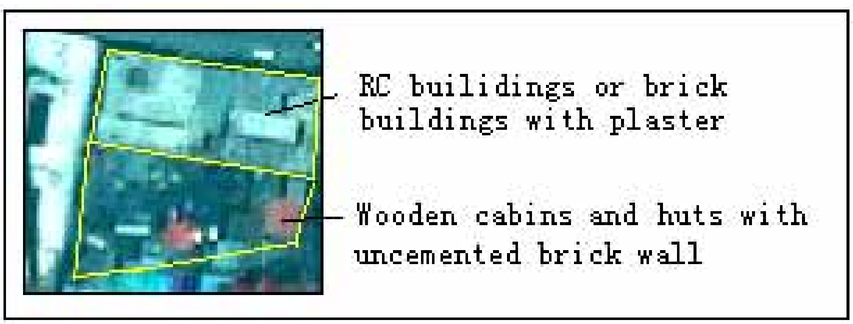


Fig. 3 Different appearances of buildings on IKONOS image

The RC buildings and the brick buildings all use the heavy material as roof. Generally, they have two or three stories. They all appear lighter and bigger in image (Fig. 3). But in term of seismic resistance, the RC buildings are much better for its stronger columns, though there is no frame built. As for brick buildings, though it is capable of standing higher levels of earthquake shaking, it may cause much heavier human disaster than any other types of buildings for the heavy material used. Compared with RC buildings the brick buildings owed by people with moderate income are less splendid and often without out yard associated with.

On the other hand, the cabins and huts all use the low reflectance materials such as the wood, felt or plastic clothe as roof. Because these materials easily get rotten, as a result, they appear much darker in image (Fig. 3). These buildings only have one story and owed by people with low income. For this reason, they also appear smaller and less impressive. These two types of buildings act much differently under earthquake condition. The cabins are much flexible under earthquake loads. It allows much large amount of deformation before it collapses. Even if it collapses, there is a better chance that people live inside could still survive. But for those live in the brick huts, they may not be so lucky. The brick wall still too heavy even the roof is much lighter. In their appearance in the satellite image, the cabin is a little bit of darker and they often built along the riverside. But further investigation is needed to have a clear idea of the two.

Based on these evidences and with certain field investigation for validation, we can classify the building blocks into four classes using the IKONOS image. An attribute table associated with this classification is also made (Table 1). This table can be used to evaluate the seismic resistance of buildings and human and economic loss later.

Table 1. The building classes

Class	Material	Roof	Structure	Seismic resistance
RC buildings	Brick &RC	Heavy	Structure with seismic design	Good
Brick buildings	Brick & plaster	Heavy	Structure	Normal
Brick huts	Brick	Light	Non-structure	Poor
Cabins	Wood	Light	Non-structure	Good

ECONOMIC AND HUMAN LIVING CONDITIONS

Economic and human living conditions are also necessary for seismic risk assessment to give an assessment of property and human loss. There is more than one clue to estimate the economic status using the high-resolution satellite image. But all these should be used in combination of certain ground-truth data from the survey. Otherwise, it is simply not possible to make any quantification reference.

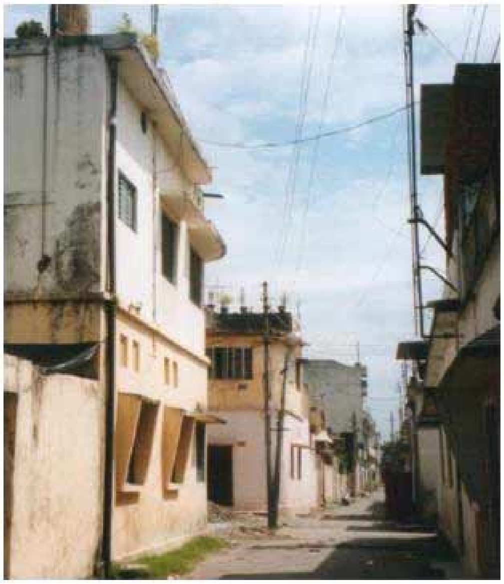
Simply, from the first class large and beautiful RC buildings to the fourth class cabins with hardly any furniture inside, presumably, people owe them should have less income. Economic indicators can be assigned to each building class using some of the statistic information from survey.

Although it is not a clear-cut situation, there is also a social division in different parts of the city. In some districts, there are more good buildings like RC or brick buildings, while in other parts cabins and huts cluster together. This makes it possible to classify different districts according to their composition of building classes. This classification of buildings also associates with possible property loss during earthquake at district level. Because we know that there are less valuables in cabins or huts compared with the brick buildings while the RC buildings often have the most valuables inside. What is more, for the dwellings of the same area from the image, the RC buildings will have less people live inside compared with the often over-occupied cabins and huts. It is not uncommon to find that may poor family with three or four children live in a small cabin or hut.

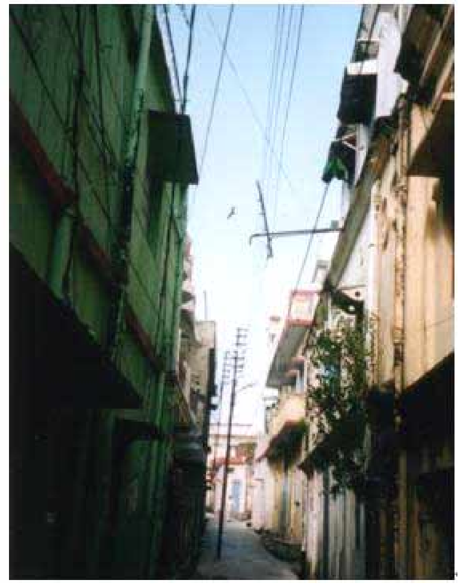
The economic feature can also be inferred from the geographic location of buildings. Many of the cabins, as we have noticed, are located along the riverside, where there is no property claims so the poor family can build their residences free of land charge. It is also hardly to find any huts in the city center and commercial parts of the city. This is also a clue for the determination of economic factors and human living conditions.

COMMUNICATION FEATURES AND OTHER IMPORTANT FACILITIES

Based on investigation, we can classify the road system in the city into three classes: main road, street and narrow street. The main road has two or three lanes. The street has only one lane, which is about two and a half meters in width (Fig.4). The narrow street is only around one and a half meters wide (Fig. 4). Under most situations we can easily recognize different class of roads from the satellite image. But, because the urban development in Dehra Dun is not under strict public regulation sometimes, there are also some roads that have width in-between of the above-mentioned classes. Extra cares should be given to these roads.



(a) Street



(b) Narrow street

Fig. 4 Street of different class

With the classification of both roads systems and its neighboring buildings, we can estimate the possible blockades in the roads if the buildings on both sides collapse under certain earthquake scenario. It is believed there is little chance that the main roads would be blocked if the one or two stories buildings collapse. But the collapse of three stories buildings on both sides would damage the traffic condition much, while the one lance street may likely to be blocked. For the narrow streets, even the collapse of huts and brick can cut the traffic completely.

The water towers, gas stations due to their unique shape and association can be identified from. This information will be very useful for the assessment of secondary hazard like damage to some equipment by water or fire.

SOCIAL FUNCTIONS OF BUILDING

The social functions of building will affect the assessment of human activity when an earthquake occurs and the condition for relief effort. There are four main social functions of the buildings: commercial use, residence, school and public use.

Most of the commercial use buildings are small shops and more than half of them are for dual use, that is, they are both shops and residence. A rule-of-thumb is to mark the building along the main commercial streets as dual use buildings, except those larger buildings used as big stores or the small hut, which are not likely to be used as shop. For other area, a percentage for each type of use can be assign based on the investigation of some typical street. For those buildings off the street or buildings along the narrow street, almost all of them are used as residence, because these locations are not very suitable for commercial activities.

Most of the school buildings are all RC buildings or brick buildings and some of them have playground associated, which can serve as site for emergent evacuation.

There are also some Hindu Temple and Muslim Mosque in the city. These buildings are generally built well. Their social function can be classified as public (Fig.5). For these public buildings, the number of people inside can vary many times. They are almost empty in some period of the year, but they are very crowded during some special date, where people have celebrations or other ceremonies. The seismic risk assessment must take this factor into account.

Fig. 5 Part of a Mosque in Dehra Dun

DATA INCORPORATION AND ANALYSIS WITH ILWIS GIS/RS PACKAGE

The first step to establish an urban information system is mapping with ILWIS. ILWIS is a GIS/RS package developed by the International Institute of Earth Observation and Geoinformation Science (ITC), the Netherlands, which supports mapping based on the satellite image [3].

The building blocks and streets in the study area are marked out according to their corresponding building or streets class. This is used as a base map, upon which other maps such as population density and economic values can be made using the information from both survey and the base map. Earthquake hazard map are prepared beforehand as raster maps.

Thus we have a complete urban information dataset in form of either maps or tables for seismic risk assessment including element at risk (population, social activities and economic values) and empirical vulnerability study.

With this dataset, we can make seismic risk assessment for certain earthquake scenarios using different methods available.

CONCLUSION

It can be found that there are certain advantages to use high-resolution satellite images for seismic risk assessment in urban area. It can be much efficient with much less work for urban survey. The high-resolution image provides a plenty of information on urban setting and, combined with ground truth information and knowledge on local circumstance, it can be used to establish an urban information system for seismic risk assessment. Since the satellite has relatively high temporal resolution, it serves well for the upgrading need of seismic risk assessment without laborious urban survey.

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REFERENCES

1. Jean-Paul Donnay, Mike Barnsley, and Paul Longley, Application of Remote Sensing in Urban Studies, Kluwer Academic Publishers, The Netherlands, 2001.
2. Lillesand T. & Kiefer R., Remote Sensing and Image Interpretation, John Wiley & Sons, Inc, USA, 1999.
3. ITC, Ilwis 3.1 User Manual, ITC, the Netherlands, 2002.