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Rapid multi-scale assessment of seismic vulnerability: an integrated approach based on multi-source imaging

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A rapidly growing spatial concentration of people, infrastructure and financial values in earthquake prone areas within the last decades lead to a drastically increasing seismic risk. Especially in developing countries rapid urban growth is often accompanied by unplanned settlements with a high degree of vulnerability, which dynamically changes over a short time-scale (a few years). The combination of a large spatial extent and spatial fragmentation together with the short time-scale, on which the modifications to vulnerability scenario occur, represents a major challenge for local governments. They are often unable to continuously update the exposed building stock in order to adjust disaster risk reduction efforts accordingly. Therefore an efficient vulnerability model should be able to cope with the increasing spatio-temporal variability of the dynamics of urban areas in order to successfully contribute to the main seismic risk model. Traditional approaches to the assessment of structural vulnerability, such as a building-by-building analysis by structural engineers, may provide with high quality vulnerability information, but can not adequately cope with the rapidly changing spatio-temporal conditions in present Megacities. In this context it is increasingly being recognised that geospatial technologies play a major role in predisaster vulnerability assessment and postdisaster impact assessment. Remote sensing and omnidirectional imaging show high potential for rapid earthquake vulnerability assessment on various spatial and temporal scales, covering large geographical areas at comparatively low costs.

We propose an integrated approach to multi-scale seismic vulnerability assessment which can be easily applied to different urban environments and efficiently be scaled based on the desired spatial and temporal level of detail. The proposed approach is focused on a novel multi-source evaluation of structural vulnerability based on satellite remote sensing and ground-based omnidirectional imaging.

On urban footprint and district level an analysis of urban structures on the basis of medium spatial but high temporal and spectral resolution satellite images is performed. Using image segmentation, multi-temporal change detection and machine learning based image classification the urban environment can be delineated into areas of homogeneous urban structure types. The outputs are used to identify representative sample areas for a more detailed analysis of the building stock with ground-based omnidirectional imaging and high spatial resolution satellite images. Furthermore these analysis can provide a first estimate of value and distribution of crucial vulnerability indicators, such as pre-dominant building-type, building-age or urban growth rate and distribution.

On building footprint level a ground-based, rapid survey of representative samples for each urban structure type is then performed using a omnidirectional imaging system driven around with a car. The images are georeferenced using GPS. Automatic processing of the acquired images provides an estimate of the most likely vulnerability class, following EMS-98 scale, for each building successfully located. The dominant vulnerability class can then be associated to the corresponding homogeneous cluster for extrapolating the high resolution vulnerability information to district level and therefore provide a detailed vulnerability classification for a complete city. Due to the high temporal resolution and large coverage of the satellite images, future surveys can be guided to newly changed parts of a city so that the results can be updated on an almost monthly base.
The integrated combination of satellite-based remote sensing and ground-based omnidirectional imaging allows for a rich visual description of the urban environment on different spatial scales, which can be easily updated on regular basis and in a standardized way due to the high temporal resolution of the input data and the speed of the ground-based survey. The proposed approach can be easily applied to different urban sprawls, and the underlying multi-scale structure eases the task of integrating information coming from different sources and at different levels of detail.

Preliminary results from our study site Bishkek, Kyrgyzstan, will be shown. The medium scale analysis of satellite images proved successful and a ground-based survey with omnidirectional camera in the delineated sample areas has already been carried out. Also preliminary results from the automatic analysis of the captured omnidirectional images will be discussed.