Testing and Application of Geospatial Techniques in Seismic Engineering †

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Abstract: Identification and classification of the different structures and infrastructures that make up a city (conventional buildings, power stations, nuclear power stations, routes of communication, etc.) are of great importance at the time of characterize their vulnerability and carry out estimates of seismic risk. Different types have different physical damage to some seismic movement, hence the importance of correctly assign a class of vulnerability. For this reason, it is necessary to know, updated form, the distribution and composition of structures and infrastructure of a city. Behaviour that presented these elements to a seismic phenomenon is linked, among others, building material and its geometric shape. Today, cadastral information updated about the infrastructure of a city does not have the data necessary and useful to carry out a calculation of seismic risk. For decades, the way of being able to have such information, has been through the development of campaigns of field for the elaboration of databases. This practice entails long time of work and the need for qualified personnel for the identification of the constructive typologies of the different structures. Nowadays, there are different geospatial techniques that allow data acquisition on a massive scale in a short time. In particular, by means of laser measurements, it is possible to have clouds of millions of points with geometric and radiometric information in a matter of seconds. This article presents a line of research whose main objective is to innovate in the vulnerability mapping and seismic risk estimation methods using geospatial techniques: static and dynamic laser. The end is contributing to knowledge and more accurate risk results, on which will be supported after the emergency plans that facilitate post event actions.

Keywords: geospatial technologies; seismic engineering; seismic vulnerability; building information modelling; developing; automation

1. Introduction

After de occurrence of an earthquake, the different elements that compose a city could suffer different levels of damage and losses. These represents the seismic risk of a location, which is defined throw a probability function [1].

The seismic risk is the convolution of two terms: (1) the seismic hazard, associated with the geological and tectonic of the site of study, and (2) the vulnerability of the buildings, associated with the constructive typologies and the seismic resistant capacities of the buildings. The seismic hazard translates into movement expected by future earthquakes with a certain exceedance probability. Seismic risk assessments determine the consequences of these movements.

Different parameters can define the seismic risk of a location. For instance, the probability of reaching or exceeding: (1) different physical damage on buildings (slight, moderate, severe, complete), (2) economic losses, and (3) casualties.

Based on the "Natural Disasters and Vulnerability Analysis" report [2], there are three fundamental components in the seismic risk estimation:

- The possibility of experiencing a natural or anthropogenic threat (hazard) in a region.
- The elements exposed to the hazard.
- The vulnerability of the exposed elements.

Seismic vulnerability is the structure inherent predisposition to suffer damage to the occurrence of an earthquake. It is directly associated with their geometrical and structural characteristics. This vulnerability depends on different factors such as building material, height of the building, earthquake-resistance construction design and its urban position, among others.

One of the components of the seismic risk assessments is a database that contains the elements settle in the area of interest. Nowadays, it is relatively easy to have data of citizens; nevertheless, the main difficulty appears defining the constructive and geometrical characteristics of the structures.

To build this database, it is use cadastral data. Albeit, it is highly recommended to complement the database from information collected with geospatial technologies such as LiDAR, photogrammetry, remote sensing, geographic information systems, etc. The use of these techniques is gaining great prominence in the area of natural and anthropogenic phenomena. Due to its availability almost in real time, with high precision and both for local and global scale, even in areas of difficult access [3].

The doctoral thesis of Hermosilla [4] is a reference of implementation of geospatial techniques in the studies of seismic risk. The author presents a methodology for automatic detection of buildings from aerial images of high resolution and LiDAR data.

In addition, it should be noted the doctoral thesis of Wieland [5]. It proposes a methodology for estimating the height of buildings based on the analysis of Omni-directional images.

A seismic risk assessment provides helpful for the emergency agencies. Allows knowing (with an exceedance and occurrence probability) which areas or locations would suffer more injuries after the occurrence of an earthquake. By utilising the information acquired through Geographic Information Systems (GIS), it is possible to improve emergency labours by speeding up the response of institutions [6].

Various published works serve as a reference in the application of geospatial technical for effective estimating damages caused after the occurrence of an earthquake. Which include, among others, Eguchi et al., 2012 [7] and Dell'Acqua et al., 2011 [8]. The studies above focuses on the use of aerial remote sensing techniques such as Synthetic Aperture Radar (SAR), satellites images of high and medium resolution and aerial LiDAR.

Over the past few years, specialist and researchers use terrestrial techniques for data capture, such as static and dynamic ground scanners to obtain point clouds. With this data source, it is possible to create three-dimensional models of buildings, known as Building Information Models (BIMs). Through this line of research, it is important to mention the following publications (among others): Chen et al., 2018 [9] and Pătrăucean et al., 2015 [10].

2. Hypothesis

The proposed thesis is defined in an active line of research. There are several authors (Pittore, M.; Chini, M.; Pierdicca, N; Anniballe, R; Bosché, F.; Chen, K.; Weisheng, L.; Tang, P., etc.) trying to implement new techniques and processes to improve results and achieve greater cost benefit. In spite of this, it has not yet been possible to define an efficient methodology that provides the expected results automatically and improves cost-benefit. For this reason, it is a contribution to the current state of the art to apply cutting-edge geospatial techniques to estimate damage in conventional structures, such as Mobile Mapping System (MMS). With this technique, it is possible to access the damaged area by the occurrence of an earthquake and scan the real situation on a larger scale. The principle benefits of using MMS is the increment of the resolution in the obtained results, without excessively increasing the cost.

3. Methodology and Objectives

A phased-methodology structures the proposed research. As shown in Figure 1, six phases define the methodology. Each phase pursues different objectives.
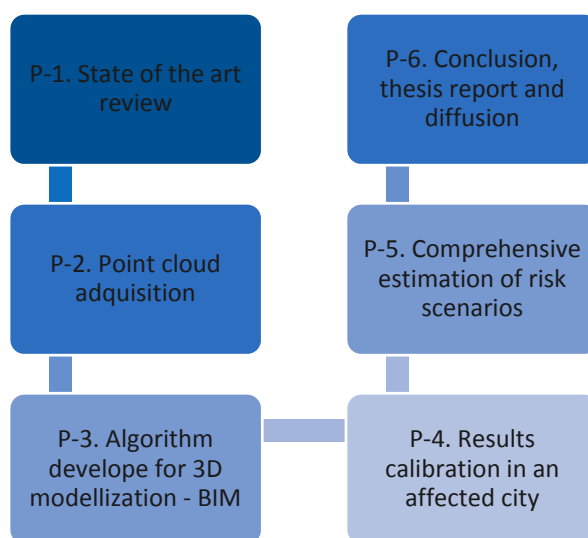

Figure 1. Thesis methodology workflow.

The first phase consists of a review of the state of the art. This review must be exhaustive and alive throughout the development of the thesis. Different publications of other works, supporting this research, compose a current database. In order to know more details about related authors, Section 1 can be revised.

In order to complete phase two, various point clouds have been considered. Specifically, three different point clouds from different acquisition techniques: (1) technical office acquired with terrestrial static laser scanner, (2) university college obtained with terrestrial static laser scanner, and (3) demolished building obtained with terrestrial dynamic laser scanner.

A dynamic survey was carried out in Alcalá de Henares. It was surveyed with a Mobile Mapping System, Leica Pegasus BackPack equipment, provided by Leica. This equipment consists of panoramic cameras (providing images), LiDAR system (providing point cloud) and positioning system (INS/GNSS).

Another survey was carried out; in this case it was a static topographic surveys. These surveys are framed within Bachelor and Master's thesis.

With the collected data, the following tasks are currently accomplishing in order to complete phase three:

- Treatment of the collected point clouds for subsequent exploitation.
- Algorithm development for automatic 3D modelling.

Phase three is still in progress. At the present time, the algorithm distinguishes some structural and architectural elements of buildings: walls, ceilings, floors and pillars. Moreover, the algorithm is under a quality control to improve the precision on the estimation of the mentioned elements.

Phase fours consists on a calibration of the results obtained in phases two and three. For this purpose, we will use data collected in a city where recent damage, due to a seismic event has, been recorded. Once the above phases have been completed, a methodology for estimating damage will be established.

4. Usefulness of the Research

In one hand, in the University environment, it is foreseeable that the proposed research will have a relevant impact due to the following aspects:

- It will constitute a new methodological development that will strengthen the line of research in seismic engineering of GIIS (UPM.
- The results will be published and presented in congresses, increasing the dissemination of the group in a scientific environment.
- Research will be strengthened using geospatial technologies. These technologies are directly related to the University degrees.

In the other hand, Geolyder S.L. is an engineering consultancy focused on the estimation of seismic risk assessments. It mainly develops projects in Spain and Latin America. Numerous projects are currently being developed within the framework of Emerging and Sustainable Cities Programs and Climate Change, Natural Risk and Urban Growth Programs of the "Banco Interamericano de Desarrollo" (BID). These projects cover all phases of a seismic risk assessment: seismic hazard, vulnerability and seismic risk. The proposed thesis will increase the projection of the company with a greater attraction of external resources foreseeable in the future.

Finally, it is worth mentioning the great social impact that this research can have. It will improve the present methodology for seismic risk assessments in areas affected by an earthquake. This will revert in the actions considered by emergency institutions.

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