Seismic hazards and damage assessments based on remote sensing and GIS technologies

Dissertation abstract

SEISMIC HAZARDS AND DAMAGE ASSESSMENTS BASED ON REMOTE SENSING AND GIS TECHNOLOGIES

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Indeed spatial tectonic (i.e. earthquakes) and non-tectonic (i.e. land subsidence) hazard assessments play a key role in identifying and mitigating the potential consequences in the hazardous cities. InSAR is a space-based method which allows us to monitor a wide field of ground (i.e. from tens of km to more than 100 km) at low costs with a regular revisit interval. At the present time, various phenomena in different fields can be studied by SAR imagery (e.g. surface flow studies, tectonic movements, monitoring of wetlands and water resources). In most circumstances, GIS, expert systems and statistical methods are also used along with the remote sensing technologies (i.e. InSAR). This thesis was more sophisticated interdisciplinary work, (**Fig. 1a**) among space geodesy, seismology and earthquake engineering focused on seismically active country Iran (**Fig. 1b**). In order to depict application of GIS and remote sensing in earth sciences, we firstly focused on seismic networks in Iran. This works showed feasibility of remote sensing and GIS technologies in earthquake-related studies. At the first step, effect of topography on seismic amplification owing to shape of terrain has been studied and characterization of seismic stations in 4 independent Iranian networks are presents based on ASTER digital elevation data and Topographic Position Index (TPI). At the second step, surface deformation along the North Tabriz Fault (NTF) deduced from Synthetic Aperture Radar Interferometry (InSAR) technique is estimated. The estimated slip rate would be important for initial hazard estimation of Tabriz city which is located in the near of the NTF, also using empirical relations and inverse modeling, the approximate locking depth of the NTF was estimated. Beside this, we have fairly focused on excessive water extraction and underground water declining trend between 2003 and 2010 and we have found out that the study area had a potential of land subsidence owing to its arid and semi-arid climate and necessity of the agricultural activities for ground water extraction. Thus, three regions of rapid subsidence with a maximum rate of 20 mm/year were detected. In order to delineate areas affected by subsidence, a sophisticated image segmentation method is proposed and the Tabriz basin is classified into 4 sub-basins with respect to amount of flow accumulation analysis. Having adequate and reasonable classes of the wells needs a watershed transform analysis. The analyzed piezometer measurements support emergence of the land subsidence phenomenon in Tabriz basin and consequently the accelerated ground water extraction after 2008.

We also described the development of a comprehensive earthquake catalog for NW Iran by unifying all of the records (historical pre-1900 earthquakes + instrumental events) and determined some of the seismicity information such as range of magnitudes, number of events, length of the potential faults and their distance from the built areas. The statistical results of instrumental earthquake catalogs in the study area with a radius of 150 km indicated that the seismogenic depth was approximately 20 km and fewer daytime than nighttime earthquakes were recorded. Based on the obtained seismicity, we have developed a GIS-based earthquake scenario for a magnitude of 7 on the NTF and information are reported in two main tasks (1-seismic microzonation; 2- building and human damages). An accurate seismic microzonation map of the study area has created through a series of influential parameters in site amplification (i.e., geology, alluvial thickness, ground water level and sedimentology) which enhances the ability and resilience of experts and urban planners against natural disasters.

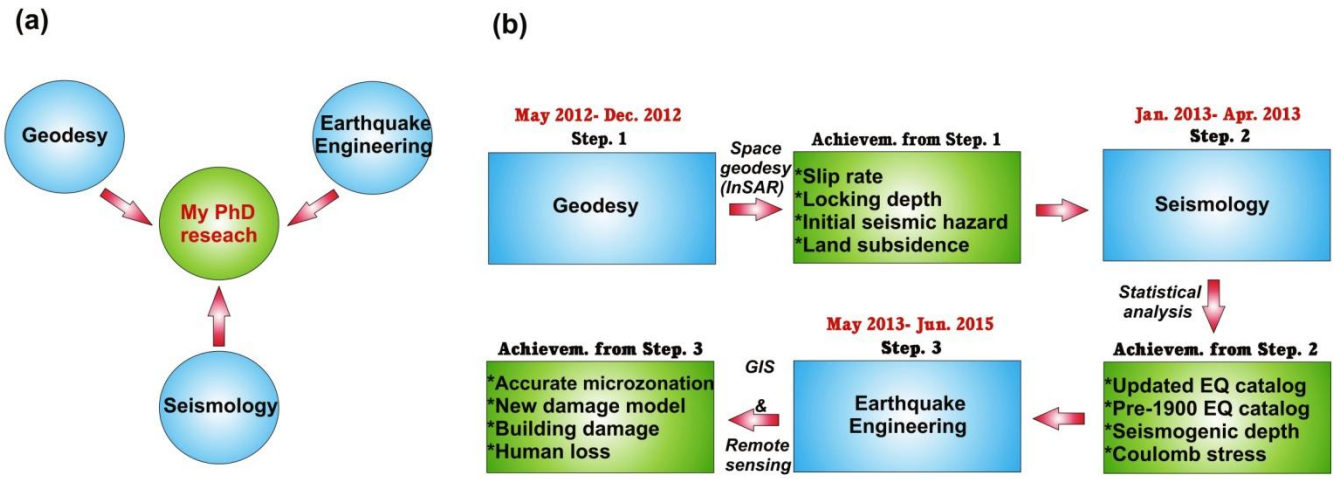

Fig. 1. (a) Summary of my PhD research; **(b)** Flow chart of the implemented schedule and the achievements at each of three steps.

The applied model outputs the damaged area, a 3D scene of demolished buildings, rate of daytime and nighttime casualties and the number of required resources. These results allow decision-makers to plan safer shelters or settlement areas for survivors. Overall, the area of district two in the city of Tabriz is approximately 42.92 km^2 and includes parks, streets, alleys and vacant lands, while the pure residential area is 6.8 km2, of which 3.1 km2 is totally destroyed as a result of the simulated earthquake. In detail, the total base area at all damage states (D1, D2, D3 and D4) for steel-1, RC, steel-2, brick-steel and brick-stone are 1.829, 1.003, 0.101, 2.711 and 0.002 km2, respectively. The results demonstrate that 69.5% of existing buildings are completely destroyed, and the rate of fatalities is approximately 33% after a nighttime scenario. Finally, the same procedure was applied to an actual earthquake (first event on the 11th of August, 2012 of the Ahar twin earthquakes) to validate the presented model based on two aspects: (1) building damages and (2) seismic intensity. Overall the results suggest that the seismic hazard potential in district two of Tabriz city is almost high according to the seismic and vulnerability steps. For example brick-steel masonry buildings are most vulnerable (78%

total damaged builds are masonry) in district two, most likely due to the disintegration of the mortar and bricks. Some old unreinforced masonry buildings in district two may even collapse as a consequence of a moderate near field earthquake. As a concluding remark must be noted that currently attentions should be focused on poor building construction, especially low quality materials, which do not comply with building standard codes for earthquake-resistant design, and the lack of proper supervision during the construction operations of private buildings.

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学位論文審査報告書（甲）

１．学位論文題目（外国語の場合は和訳を付けること。）

Seismic hazardsand damage assessments based on remote sensing and GIS technologies （リモートセンシングと GIS 技術による地震危険度および被害評価）

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３．審査結果の要旨（600～650 字）

本学位申請論文に関し、第１回審査委員会を開催し審査方法を決定するとともに、論文の内容について検討した。さらに、平成２７年７月２９日に行なわれた口頭発表後に第２回審査委員会を開き、協議の結果、以下のように判定した。

本論文は、リモートセンシングと GIS 技術を駆使して地震危険度および被害の評価の精緻化について研究したものである。まず、衛星データと標高データを対象地域の強震記録とともに解析することにより、対象地域の地震危険度を詳細に評価している。さらに、対象地域の地質、地形、建物属性、社会インフラ属性などの様々なデータを、GIS 技術を駆使して解析し、地震被害マイクロゾーネーションマップを作成している。この評価手法を、2012 年 8 月に対象地域の近くで発生した Ahar 地震に適用し、地震被害評価の精度の検証を行なったところ、非常に良い結果を得ている。これらの成果はインパクトファクターの高い国際学術雑誌に３編の査読付き論文として発表しており、既に高い評価を得ている。

以上の研究成果は、測地学、地震学、地震工学のそれぞれの分野の知見をリモートセンシング技術と GIS 技術を駆使して融合し、精度の高い地震危険度評価および地震被害評価を行う手法を提案しており、工学的価値が極めて高いと認められる。よって、本委員会は本論文が博士（工学）に値すると判断した。

４．審査結果　(1) 判　　定（いずれかに○印）　（合　格）　・　不合格

(2) 授与学位　　博　士（　工　学　）