A METHODOLOGY FOR DETERMINING STRUCTURAL PARAMETERS FOR EXISTING JAPANESE WOODEN HOUSES USING IMAGE PROCESSING AND GIS

画像処理と GIS を用いた日本の木造住宅のための構造パラメーター抽出手法

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ABSTRACT

Main family houses in Japan are wood frame structures. Seismic design codes for such structures had been improved in Japan; however, older houses do not meet recent high seismic demand capacity. On the other hand, retrofitting works for wooden houses – especially those were constructed before 1980 had been performed slowly. Kobe earthquake (1995) which struck around 8000 wooden houses and killed about 6300 people; among them about 5000 people because of structure collapse; was a proof that the retrofitting needs to be enhanced. A possible solution can be motivating residents in wooden houses to involve retrofitting efforts, by convincing them about the potential earthquake risk. To convince residents, experts need to provide information to residents in order to raise their awareness, and to motivate them to action, so that residents can exert direct personal control over the risk they may face. In all cases, residents need a diverse set of cognitive, social, emotional and other skills in order to understand the information that they receive about earthquake, interpret its relevance for their lives and communities, and articulate their view to others, in order to mitigate the risk. However, as diligent as they might be, individuals are helpless without comprehensible information about earthquake risk for them.

Simulation of seismic behavior of a wooden house where residents live and its neighborhoods using computer graphic technologies is a helpful method to provide comprehensible information about earthquake risk. To simulate the seismic behavior, individual houses need to be analyzed. However, lack of structural parameters for existing wooden houses has not allowed building the structural model of them.

Therefore, the basic objectives of this study are to determine structural parameters of existing wooden houses using the limited available sources, and to build their structural models using the determined parameters, in order to perform seismic analyze of them. Geometrical information of houses that is available in Geographical Information System (GIS) database is a candidate of available sources. Therefore, the address of house was considered as an input to identify house in GIS database. On the other hand, to have side view of the house, photo(s) of house, which can be taken easily using an ordinary digital camera like cellular-phone built-in camera was used as another input. Estimating approximate age of house was explained using top-view photo of house; however, it was assumed to have the age as another input from residents. A Graphical User Interface (GUI) was developed to receive inputs.

Then, to build the structural model of an existing wooden house, house dimension, wall location and area, column height, position and stiffness, mass (weight) of each story, beam length and position, and joint's local coordinates, stiffness and strength of the house were estimated using cited inputs.

Height of house was extracted from GIS data, and number of stories and height of each story was estimated. Then, vertex coordinates from GIS were used to form a 2D polygon cross section of the house. By extruding the cross section through the height of house, a 3D computer model of house was built. To estimate the position of columns inside the walls, architecture design of Japanese wooden was studied and showed that column arrangement is supposed to change due window and door position on the wall.

To estimate the window and door arrangement, photo(s) of house was used. Two methods were examined. In first method, the photo of house was analyzed to directly recognize objects in the house's image by edge detection and object recognition. It is showed that this method had high accuracy to detect different objects like roof of a specific house; however, it was not a robust method, i.e. it required high quality images using specific cameras and was sensitive to shooting situations like ambient brightness and camera's position, and therefore, it could not be generalized to apply in different situations.

In second method, a methodology was proposed through pattern match of 3D computer models vs. the existing house. First, the possible arrangements for window and door were adjusted by referring the architecture design of Japanese wooden structures, and added to the 3D computer models. By adding window and door, column positions were updated and various 3D computer models were built. 3D computer models were considered as objects in a 3D computer model class, and their parameters like column position were considered as object's features. Then, the real house was compared with all objects of the class and the best matched object was considered as the 3D computer model of the real house, and therefore the real house was considered to have same features as the object.

A factor was defined for validating the matching process and was showed that the matching could work as a robust method compared to direct object recognition, i.e. for about 84% of selected houses and in different shooting situations it could give acceptable match. As the result, house dimension, column height and arrangement, beam length and position, joint position, and wall arrangement and dimension of an existing house were determined. To compute mass (weight) of each story for the structural model, live load was ignored and dead load was calculated as summation of floor, ceiling or roof mass, plus wall mass. Mass of floor, ceiling, wall or roof was computed using the floor and wall area of the house.

To construct structural model using determined parameters, since the breakage of the wooden frame members is rarely seen in past earthquakes; members of wooden frame are considered to be rigid for the analysis purposes. The structure is modeled as an assembly of rigid elements connected by joint elements. Therefore, the stiffness and strength was concentrated on joints, and it was assumed that all joints have identical stiffness and strength value. Date of construction and wall arrangement were used and the strength value was estimated. Mass of each story and age of construction were used to estimate stiffness value.

Finally, a sample house was selected and analyzed using DEM, and the result was simulated in Virtual Reality. However, because the photo is assumed to be taken outside of the house, parameters those exist inside the house are not determined. Moreover, as the amount of houses and their variation in a city is huge, statistic approaches are commonly employed. Therefore, results of estimation obtained are in average and might not be sufficient for any individual house.