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Coupling urban information and disaster simulations for integrated earthquake-tsunami simulation in urban areas

FUJITA, Kohei[1*], Tsuyoshi Ichimura[2], HORI, Muneo[2], M. L. L. Wijerathne[1], Seizo Tanaka[2]

[1]Department of Civil Engineering, University of Tokyo, [2]Earthquake Research Institute, University of Tokyo

The 2011 Tohoku Earthquake caused strong ground motion and tsunami in the same area, and the expected Tokai, Tonankai, and Nankai Earthquakes are possible to be an earthquake and tsunami disaster. To make effective mitigation strategies, we need to grasp the overall consequences of urban disasters under earthquake and tsunami hazard scenarios. Currently, physics based disaster simulations with city models that reflect the properties of a city are used for simulating damage of urban areas under an earthquake or tsunami hazard. In this study, we integrate such disaster simulations to perform a seamless simulation of a series of earthquake and tsunami hazard scenarios.

Such an integrated simulation has many components such as datasets of city configuration stored in the Geographic Information System (GIS) and each of the component simulations, leading to a complex structure of the simulation system. Note that we need to convert data between the I/O interfaces of each component since each interface has different formats, such as vector/raster, ASCII/binary, and big/little endian formats. Thus, the key to perform an integrated simulation is a smart way to couple information of urban areas with each of the component disaster simulations.

In this study, we couple information of urban areas and disaster simulations using a common city model. A common city model is a common dataset that stores information of an urban area. Here, we use GIS data as source of urban information, although other spatial/temporal information of urban areas obtained from Computer Aided Design (CAD) data, sensors placed in urban environment, or other resources can be used as a source. Urban information and disaster simulations are coupled by converting relevant parts of the common city model to inputs of each of the component simulations, and writing the results of component simulations back to the common city model. All data conversion is performed in full automation for application to large datasets. By using this method, we can utilize multiple GIS datasets and integrate multiple component simulations by only adding data conversion modules between the additional dataset/simulation and the common city model; we do not have to think about direct interactions between each component simulation and GIS dataset.

As an application of the developed method, we perform a simulation targeted on a coastal area of Sendai. We first construct a common city model from GIS data and perform seismic response analysis of structures. Here, we use two dimensional vector GIS data to model the external shape of buildings and Digital Elevation Map to model the ground elevation. For seismic response analysis, we model beams and columns as non-linear line elements and analyze response of structures using the one component model. The structures are excited using the observed waveform in the 2011 Tohoku Earthquake. We assume a condition for a structure to collapse and modify the city configuration accordingly. At last, we perform high resolution tsunami simulation on the original and modified city models. We use a fluid analysis code using three-dimensional analysis methods, in particular, Smoothed Particle Hydrodynamics, to compute local flows around buildings. Since such a high resolution simulation becomes large in scale, the code is parallelized using standard distributed memory parallelization methods. Results show that the flow of tsunami changes according to the modifications in the building configurations; a seamless simulation of earthquake and tsunami disasters can be performed targeted on an existing city. We plan to enhance the tsunami simulation code for analyzing destruction of buildings and flow of structural debris due to tsunami loading.

Keywords: integrated natural disaster simulation, coupling urban information and analysis, seismic response analysis, high resolution tsunami simulation