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Vector-Valued Seismic Demand Analysis within Earthquake Risk Assessment

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Traditionally, the assessment of damage within earthquake loss estimation studies has been based on single scalar parameters, such as macroseismic intensity or peak ground acceleration. However, it seems reasonable to suppose that a more comprehensive characterisation of the ground motion would lead to a better understanding of the seismic response of buildings. Moreover, it is believed that it is possible to reduce the overall epistemic uncertainty in the estimation of damage by accounting for multiple ground motion parameters, each of them giving different information regarding the same underlying motion. Therefore, a vector-valued analysis framework is required in order to accomplish the purpose of carrying out a multi-descriptive ground-motion characterisation.

Concurrently, Nonlinear Time-History Analysis (NTHA) has become a powerful and accurate tool for seismic assessment of structures enabling the response of a structure to be described through the use of different parameters (interstorey drift ratio, maximum displacement at each floor, final structure profile, etc). Just as the use of a single numerical value is an insufficient representation of a ground motion, a single measure of structural response cannot fully describe the state of a structure following an earthquake event.

As a consequence of the above, this study investigates how to improve estimates of damage prediction through the use of relationships that efficiently relate vectors of Intensity Measures (IMs) to vectors of Engineering Demand Parameters (EDPs). These vector-valued measures have been incorporated into the widely adopted probabilistic approach proposed by the Pacific Earthquake Engineering Research (PEER) Center. Such a methodology is required to compute the probability that a given ground motion will cause a given level of demand in the structure as a function of a scalar or vector of intensity measures.

From the point of view of regional risk assessment, it is necessary to divide the building stock into representative groups, as the main interest is a portfolio of existing buildings and not the assessment of single structures. The dataset of structural performances used herein is obtained by conducting a large number of NTHA using models of five case-study reinforced concrete frames with varying height and number of storeys that are representative of the existing frames commonly encountered in Europe and the Mediterranean.

In this study, vectors of intensity measures collectively encapsulating information regarding the amplitude, energy content and duration of ground motions are used to infer vectors of EDPs, including measures of maximum response, energy measures and combined measures such as the Park and Ang damage index. Multiple-multivariate regression models have been developed in order to estimate the efficiency of each combination of vector-valued IM and EDP measures to be employed in the probabilistic structural performance-assessment framework.

The optimal vector IM is chosen herein by reducing the standard deviation of the prediction errors. For each different building model of a given period subjected to a given ground motion, this study focuses on finding the vector of IMs that maximises the efficiency for the prediction of a vector of EDPs.