8th International Conference on Seismology & Earthquake Engineering
11-13 Nov. 2019, Tehran, Iran

CLUSTERING MICROTREMOR DATA WITH FUZZY GUSTAFSON KESSEL ALGORITHM

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Keywords: Seismic microzonation, Hazard, GK algorithm, Microtremor, site effects

The analysis of local seismic Hazard through the identification of zones with seismically homogeneous behavior is named seismic microzonation. It identifies and characterizes stable zones prone to local amplification of seismic motion and zones prone to seismic hazards. Seismic microzonation represents a highly useful tool for seismic prevention and risk assessment in land management, for the design of buildings or structures and for emergency planning. It provides a knowledge base of local seismic hazards in different zones and permits the establishment of hazard hierarchies that may be used to plan seismic risk mitigation measures at various scales. A ground motion prediction is an important key to assess and mitigate the earthquake hazard. There are some factors by which level of strong ground motion is controlled. For this purpose, methods for characterizing site effects is required. It is also required for the study of soil behaviors during strong ground shaking. As it has been noticed from many past earthquakes, the major damage to property and manmade structures is mostly found in the region of soft sediments.

First of all, it is better to have extensive acquaintance with the area zone. Central Asia is a region with high probability of large earthquakes, mainly due to the Asia-India continental collision where the northward-moving Indian plate collides the Eurasian plate (see e.g., Molnar and Tapponnier, 1975). The Central Iranian zone extends between Alborz and Kopehdagh from the north and Zagros and Makran in the west to south and east of Iran. The Central Iranian crust has been a decoupled part of Africa before becoming part of Eurasia after the opening of the Neotethys in Triassic times. This microplate, which formed in pre-Paleozoic times, has no sign of any Variscan orogeny (Delaloye et al., 1981). The Tabas and Yazd blocks are separated by a 600-km-long and relatively narrow belt (the Kashmar-Kerman tectonic zone). The Lut block, which is composed of Paleozoic to Mesozoic rocks has different lithology from those of Central Iran (Crawford, 1972; Stöcklin, 1974). High seismic activity in this packed and fixed area were carried out for quantifying the level of seismic hazard. Yazd province and its surrounding area between central Iran Block and the edge of Central desert is the study area. Generally, this region is calm seismically. Concerning statistics studies of occurred earthquakes and analytic studies based on concentration and activity of faults in this area, five separated Zones including very high risk, high risk, low risk, and very low risk Zones are identified. East and southern Part of the region have higher seismic potential (Adib et al., 2003). It is worth to study microzonation and find soil response of each cities separately due to active tectonics of Yazd province. In this study, we use the microtremor data were collected from the City of Meybod, north of Yazd Province (central Iran) on a flat and clayey plain located at longitude 54°2′10″E and latitude 32°14′4″N.

In relation to different contexts and objectives, seismic microzonation studies may be carried out at various levels of growing complexity and commitment, in three levels (Bramerini et al., 2015):

- **level 1** is a preparatory level for actual seismic microzonation studies; it consists of a collection of existing data that are processed to divide the investigated area into qualitatively homogeneous Micro zones in relation to the above-described phenomena.
- **level 2** introduces a quantitative element associated with the homogeneous zones by using additional and focused

investigations (where necessary), in addition to defining the seismic microzonation Map.
• **level 3** produces a detailed seismic microzonation map covering particular issues or areas

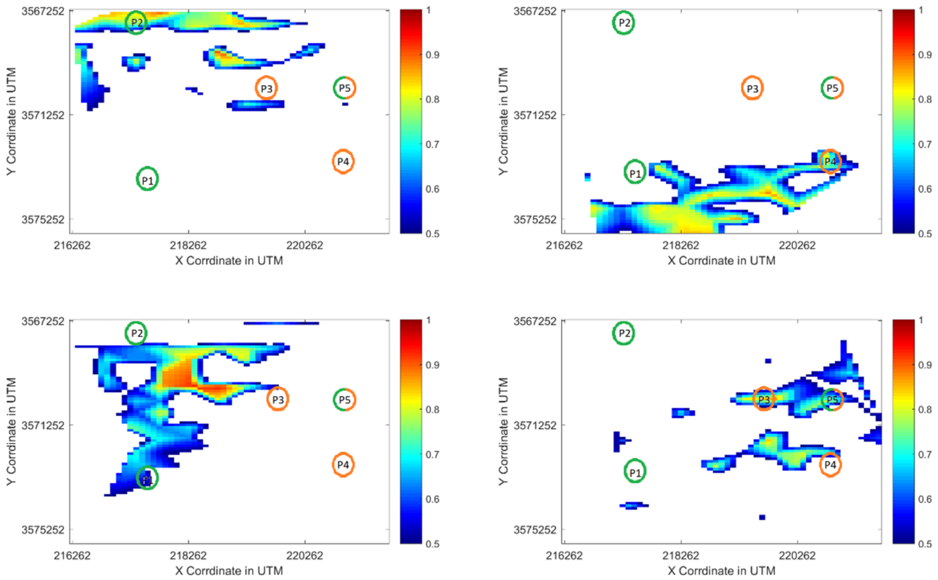

Figure 1. The results of fuzzy G-K clustering for Meybod microtremor data. Fuzzy membership values of four clusters are shown in four subplots. Only the membership values between 0.5 – 1 (higher probability for that class) is presented. P1, P2, P3, P4 and P5 fairly deep boreholes are shown by circles. Orange=Clay dominant, Green=Silt dominant, Orange-Green=Mix Clay and Silt.

Using the geotechnical studies and information from five boreholes, in the north and northeast, eastern part of the area and finally the middle part of the area (drilled to a depth of 70–95 m) in order to determine the dominant soil type of the region. These geological data will be finally compared with the theoretical results. In processing, data set divided into a few subsets by using GK algorithm (discussed by Gustafson and Kessel, 1978), including coordinates, dominant domain and frequency. The exact task of clustering is to define the best grouping in a set of data, where the term 'best' is achieved by mathematical validation techniques. The processed data for 160 stations by applying fuzzy logic in data analysis. This algorithm employs an adaptive distance norm to detect hyper ellipsoidal clusters of different orientations in the dataset in four columns (X,Y, Peak Frequency and Peak Amplitude) is the input features (attributes) for the clustering routine. The aim of choosing these attributes is to find spatial correlations as a hard constraint (X and Y of the stations), dependencies of zones to the recorded peak frequency and finally the dependency to amplification factors. The clustering results primarily show a nice correlation between observed lithology in boreholes.

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