Application of machine learning and cluster identification for insight in the spatio-temporal changes of seismogenic processes triggered by water reservoirs

The reservoir triggered seismicity (RTS) is one of the first anthropogenic seismicity cases, known since 1930's cases in Algeria and the USA and having the potential to generate disastrous events. The most famous examples are Koyna, India in 1967 (magnitude 6.3 and about 200 casualties) and tragic 2008 Wenchuan China events (magnitude 7.9 and 88 000 casualties). The latter one is still under scientific debate about the possible reservoir related origin. Despite the early recognition of the triggering role of water level changes in reservoirs, the process is still not fully understood. Moreover, recent discoveries have showed that the fluids may play a significant role in accelerating the occurrence of shallow tectonic events in southern California. Therefore, it is important to identify the enhanced permeability or possible fluid migration paths in regions of water reservoir triggered seismicity. This is the first main aim of this project. The second main aim of the project is to determine how the seasonality patterns in hydrological extreme phenomena (rainfalls, floods, and droughts) influence the seismic activity in the vicinity of reservoirs. We plan to use various numerical and statistical methods. One of these is machine learning (ML) techniques. ML is a discipline that studies how to build digital systems automatically improving the analysis through experience. The seismology and ML complete and benefit from each other. New problems in seismology and datasets supply a testbed for various ML and force to compel the development of the new ML algorithms. The ML techniques in event detection and relocation are allowing to increase the available data for the detailed seismicity analysis. Data processed by deep learning detection and location together with relocation techniques allows increasing the number of useful data, even if the poor quality of the data or an insufficient number of stations limited the initial amount of data included in the catalog. We plan to identify and locate enhanced permeability paths using precise location and relocation techniques of seismic events. The identification of repeating or similar type of events, located in the same area allows showing the zones of the increased permeability. These areas are considered as main channels of the pore-pressure or fluid migration into the fault zones responsible for earthquake occurrence.

The origins of RTS might be seasonal, related to increased precipitation and water level in the lake and groundwater. We intend to investigate whether and how the seasonality patterns in hydrological extreme phenomena (rainfalls, floods, and droughts) influence the seismic activity in the vicinity of reservoirs. To achieve the abovementioned goals the reservoir water level fluctuations and the groundwater head will be studied. The reservoir water levels are available at the IS-EPOS platform for at least four different locations in Italy, Poland, and Vietnam. To improve the investigation of the seasonality patterns, we should check how water level changes in the reservoir influence the stability of the fault. Basing on the calculations, we can check which hydrological extreme phenomena are the most influential. All the seasonality patterns will be tested with statistical tools. The main part of this analysis consists in checking if the observed time patterns are significant as tested against the randomly reshuffled series. Monthly average water level and seismic activity can be tested to discern the statistical significance of associations between these parameters, which then would allow finding cause and effect relationship and the physics behind it. Similar statistical tests may be used to investigate extreme hydrological phenomena occurrence patterns. Seasonal trends and uncertainties of the datasets will be addressed in this project. We count that while carrying out the theoretical modeling calculations and case study we will discover all hidden sources of the uncertainty. Moreover, once we analyze the level of uncertainty of the investigated system we are going to apply the statistical techniques to diminish the uncertainty to an acceptable level. This part of the project results may be also utilized in any other statistical analysis in other research. It is worth to mention that the project research will use both new data acquired in the field and datasets stored in IS-EPOS platform (tcs.ah-epos.eu) as a result of earlier infrastructural projects: IS-EPOS (within the framework of Innovative Economy) and the biggest infrastructural project in Solid Earth sciences in EU: EPOS IP (within the framework of EU Horizon 2020).

The role of permeability paths and pore-pressure variation in RTS, which will be the results of this project, may contribute to increasing the knowledge about any shallow seismicity processes. The results of this project along with the recent results about the role of fluid in injection induced seismicity may become a vital input to the general knowledge about the role of fluids migration in the process of triggering earthquakes.