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On the integration of ontological models of risk in artificial intelligence and machine learning applications to advance multi-hazard risk assessment

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Many areas of the world are prone to several natural hazards, with their occurrences possibly compounded, cascaded, or otherwise connected, either causally or across space and time, and effective risk reduction is only possible if all ensuing relevant threats are considered and analyzed. The examination of multiple hazards for the assessment of risk poses a range of additional challenges partly due to the differing characteristics of underlying processes, partly due to the broader range of consequences and the related risk-driving factors (e.g, exposure and vulnerability).

Considering the increasing availability of data about some components of risk, in the past decade several frameworks and approaches including artifical intelligence and in particular machine learning algorithms have been proposed to support multi-hazard/multi-risk assessment studies.

However, several challenges can be acknowledged that hinder the application of machine learning: the complex interplay among the risk components in multi-hazard contexts, for instance, along with the paucity of available quantitative information on impact (i.e., damage, loss) might impair the development of training datasets of adequate size and quality. Furthermore, information on multi-hazard risk is relying on heteogeneous data, often qualitative. Lastly, but not least, additional uncertainty is associated to the complexity and current lack of consensus in the conceptual definition of high-impact multi-hazard events by the different involved scientific as well as praxis-oriented communities.

In this context, the use of ontologies and semantic data representations may prove useful to tackle the above-mentioned challenges. An ontology is a structured representation of shared knowledge about a specific domain, encoded in the form of axioms, natural language labels, synonyms, definitions and other types of annotation properties. Risk-oriented ontologies can be used for instance to provide a common operational basis to the basic underlying conceptual definition, to be agreed upon and shared across communities with different scientific background.

Furthermore, ontologies can be used to access and exploit background knowledge in order to build better predictive models, expand or enrich feature engineering in machine learning or to constrain the search for a solution to an optimization problem (e.g., setting hard constraints based on logical inferences). Formal ontological representations can also provide a consistent support to the development of so-called explainable models, therefore controlling the unnecessary spread of "black box" models in sensitive operational environment such as, e.g., impact forecasting and early warning.