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A Bayesian Network approach for flash flood risk assessment

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Abstract:
Climate change is contributing to the increase of natural disasters such as extreme weather events. Sometimes, these events lead to sudden flash floods causing devastating effects on life and property. Most recently, many regions of the French Mediterranean perimeter have endured such catastrophic flood events; Var (October 2015), Ardèche (November 2014), Nîmes (October 2014), Hérault, Gard and Languedoc (September 2014), and Pyrenees mountains (Jun 2013). Altogether, it resulted in dozens of victims and property damages amounting to millions of euros. With this heavy loss in mind, development of hydrological forecasting and warning systems is becoming an essential element in regional and national strategies. Flash flood forecasting but also monitoring is a difficult task because small ungauged catchments ($\sim$10 km2) are often the most destructive ones as for the extreme flash flood event of September 2002 in the Cévennes region (France) (Ruin et al., 2008). The problem of measurement/prediction uncertainty is particularly crucial when attempting to develop operational flash-flood forecasting methods. Taking into account the uncertainty related to the model structure itself, to the model parametrization or to the model forcing (spatio–temporal rainfall, initial conditions) is crucial in hydrological modelling. Quantifying these uncertainties is of primary importance for risk assessment and decision making. Although significant improvements have been made in computational power and distributed hydrologic modelling, the issue dealing with integration of uncertainties into flood forecasting remains up-to-date and challenging. In order to develop a framework which could handle these uncertainties and explain their propagation through the model, we propose to explore the potential of graphical models (GMs) and, more precisely, Bayesian Networks (BNs). These networks are Directed Acyclic Graphs (DAGs) in which knowledge of a certain phenomenon is represented by influencing variables. Each node of the graph corresponds to a variable and arcs represent the probabilistic dependencies between these variables. Both the quantification of the strength of these probabilistic dependencies and the computation of inferences are based on Bayes' theorem. In order to use BNs for the assessment of the flooding risks, the modelling work is divided into two parts. First, identifying all the factors controlling the flood generation. The qualitative explanation of this issue is then reached by establishing the cause and effect relationships between these factors. These underlying relationships are represented in what we call Conditional Probabilities Tables (CPTs). The next step is to estimate these CPTs using information coming from network of sensors, databases and expertise. By using this basic cognitive structure, we will be able to estimate the magnitude of flood risk in a small geographical area with a homogeneous hydrological system. The second part of our work will be dedicated to the estimation of this risk on the scale of a basin. To do so, we will create a spatio-temporal model able to take in consideration both spatial and temporal variability of all factors involved in the flood generation.

Key words:
Flash flood forecasting - Uncertainty modelling – flood risk management –Bayesian Networks.