Bayesian Reasoning for Tropical Cyclone Intensity Forecasting and Risk Analysis

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Improved methods for tropical cyclone (TC) intensity forecasting and risk analysis are the end products of this project leading to the wider use in the mitigation of the devastating impacts of tropical cyclones. Single-disciplined approaches in TC intensity forecasting by meteorologists and in risk analysis by social scientists so far have not seen satisfactory results. This is because of the intrinsically high degree of complexity in both the modelling and the problem domain parts of the project.

The current techniques of TC intensity forecasting are limited to linear regression methods, which may not provide the maximum accuracy for the available information. Bayesian inductive inference using the Minimum Message Length (MML) principle (Wallace & Freeman 1987) is used to investigate the likelihood that various different models (linear and non-linear) can be applied to TC intensity data. The features of these models may well suggest new insights into the formation of TC, facilitating better explanation of the most probable underlying functions of TC intensity, with the aim of providing improved forecasting capacity. In the past, Rissanen's Minimum Description Length (MDL) (Rissanen 1987), a related form of Bayesian inference technique, has been successfully applied to time-series analysis in a different problem domain.

An MML regression algorithm has been implemented to build forecasting models using data for the Atlantic basin. The promising results have warranted further development and testing expansions to different TC basins with varying degrees of data quality. The next step will be to consider whether the forecasts can be improved by incorporating a wider range of meteorological data into the analysis.

Tropical cyclone risk analysis encompasses variables ranging from the cyclone threat through to vulnerability in the form of social factors and building standards. Much of the interactions amongst these variables have either not been investigated or only been done in a highly subjective manner. A naive approach to setting up a Bayesian causal network for risk factors would be to try to capture all the interactions and consequences for which available data would be inadequate to provide reliable estimates of all of the free parameters. Using MML principles, a restricted class of variable interaction models will be developed to reduce the number of free parameters to a feasible level. In principle, this is very similar to the use of factor models in explaining multivariate covariance structures amongst real valued variables. Here, a hierarchy of increasingly complex model covariance structures is defined. MML principles have already been successfully applied to this factor problem (Wallace & Freeman 1992). Although the mathematical details will be significantly different, the theoretical approach used there should be applicable to Bayesian networks involving discrete variables and non-linear interactions. The techniques to be developed should have applications in other problem domains.

Much work will initially be theoretical and programming to build general framework for Bayesian networks involving real and discrete variables and exploring restricted classes of models for inter-variable dependence, e.g. logistic regression and log-odds ratio function. Once sufficient data has been collected from the surveys conducted by the Tropical Cyclone Coastal Impacts Program (TCCIP), interaction parameters in model Bayesian networks or risk predictions can be estimated. Risk prediction models based on regression techniques will also be developed to compare the results of the two approaches.

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