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Assessment of a fuzzy based flood forecasting system optimized by simulated annealing

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Flood forecasting is an important tool to mitigate harmful effects of floods. Among the many different approaches for forecasting, Fuzzy Logic (FL) is one that has been increasingly applied over the last decade. This method is principally based on the linguistic description of Rule Systems (RS). A RS is a specific combination of membership functions of input and output variables. Setting up the RS can be implemented either automatically or manually, the choice of which can strongly influence the resulting rule systems. It is therefore the objective of this study to assess the influence that the parameters of an automated rule generation based on Simulated Annealing (SA) have on the resulting RS.

The study area is the upper Main River area, located in the northern part of Bavaria, Germany. The data of Mainleus gauge with area of 1165 km^2 was investigated in the whole period of 1984 and 2004. The highest observed discharge of 357 m^3/s was recorded in 1995. The input arguments of the FL model were daily precipitation, forecasted precipitation, antecedent precipitation index, temperature and melting rate. The FL model of this study has one output variable, daily discharge and was independently set up for three different forecast lead times, namely one-, two- and three-days ahead. In total, each RS comprised 55 rules and all input and output variables were represented by five sets of trapezoidal and triangular fuzzy numbers.

Simulated Annealing, which is a converging optimum solution algorithm, was applied for optimizing the RSs in this study. In order to assess the influence of its parameters (number of iterations, temperature decrease rate, initial value for generating random numbers, initial temperature and two other parameters), they were individually varied while keeping the others fixed. With each of the resulting parameter sets, a full-automatic SA was applied to gain optimized fuzzy rule systems for flood forecasting.

Evaluation of the performance of the resulting fuzzy rule forecasting systems (with the intention to draw conclusions on the best SA parameters) was carried out in two steps:

a) Evaluation of objective functions such as Nash-Sutcliffe and RMSE for all RSs.

b) Manual evaluation of the preselected results from the first step. The evaluation was based on visual inspection (scatter plots, time-series and Degree Of Fulfilment (DOF) graphs) as well as logical interpretation of the rule systems.

Comparing the results showed that there were SA parameter sets which lead to forecast systems of equally high quality (with respect to objective criteria such as Nash-Sutcliffe), however the underlying rule systems significantly varied from each other. Therefore, manual inspection played a key role in finding the overall best results.

In the presentation, the procedure of preparing different sets of SA parameters, the evaluation process of different results and the performance of the optimal RS will be explained and presented by an example.