BAYESIAN THEORY OF PROBABILISTIC FORECASTING VIA DETERMINISTIC MODEL

Principal Investigator: *Roman Krzysztofowicz*
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PROJECT SUMMARY

Rational decision making requires that the total uncertainty about a variate of interest (a predictand) be quantified in terms of a probability distribution, conditional on all available information and knowledge. Suppose the state-of-knowledge is embodied in a deterministic model, which is imperfect and outputs only an estimate of the predictand.

Theoretic foundations and mathematical models were developed for two approaches to producing a probabilistic forecast via any deterministic model. The *Bayesian Processor of Forecast* (BPF) quantifies the total uncertainty in terms of a posterior distribution, conditional on model output. The *Bayesian Forecasting System* (BFS) decomposes the total uncertainty into input uncertainty and model uncertainty, which are characterized independently and then integrated into a predictive distribution. In each approach, the distribution of predictand (posterior or predictive) results from a revision of a prior distribution; thus it is well calibrated, and has a non-negative ex ante economic value.

Since its first publication in 1983, the BPF has been applied to (i) two types of predictands: binary and continuous; (ii) two types of forecasts: deterministic and probabilistic; (iii) three paradigms: single predictand–single forecast, single predictand–sequential forecasts, time series of predictands–time series of forecasts; and (iv) several areas: sensor fusion, hydrology (e.g., streamflow, seasonal runoff, and flood forecasting), meteorology (e.g., precipitation and temperature forecasting).

Since its first publication in 1993, the theory of the BFS has guided the development of prototype systems for probabilistic forecasting of river processes (time series of stages, discharges, or volumes) via a deterministic hydrologic model of any complexity. For short-term forecasting in small-to-medium headwater basins, the theory was implemented as an analytic-numerical BFS. Two systems have been developed to date for forecasting a discrete-time, continuous-state stochastic process $\{H_n : n = 1, ..., N\}$ with lead time of N time steps. Each system takes a *probabilistic quantitative precipitation forecast* (PQPF) as input and employs a deterministic hydrologic model to calculate the response of a river basin to precipitation. The first BFS outputs a *probabilistic river stage forecast* (PRSF) in the form of a sequence of predictive n-step transition density functions. The second BFS outputs a *probabilistic stage transition forecast* (PSTF) in the form of a sequence of families of predictive one-step transition density functions whose product gives the predictive joint density function of the river stages $H_1, ..., H_N$. As such, the PSTF provides a complete, analytic characterization of predictive uncertainty about the process $\{H_n : n = 1, ..., N\}$; from it various forecast products can be derived, including a *probabilistic flood forecast* (PFF).

Current research concentrates on the *Ensemble Bayesian Forecasting System* (EBFS), which will implement the Bayesian theory of probabilistic forecasting entirely and exactly using Monte Carlo simulation. The EBFS will be applicable to basins of any size and complexity.