Automatic Calibration and Uncertainty Modelling of Rainfall-Runoff Models

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Floreon+ System

- FLOods REcognition On the Net
- Modular web-based system for environmental risks modelling and simulation in the Moravian-Silesian region, Czech Republic

- Flood risk
- Transportation risk
- Water and air pollution risk

- Results should simplify the process of disaster management and increase its operability and effectiveness
Rainfall-Runoff Models

• Describe how rainfall transforms to runoff in a specified area
• Can be used to simulate and predict stream flow and overland flow
• Several methods used – Unit hydrograph, SCS-CN, Green-Ampt...

source: https://www.meted.ucar.edu/hydro/basic/RiverForecast/
Math1D Model

- In-house RR model
- Semi-distributed
- Combines several methods
  - SCS-CN for soil infiltration (CN Curve)
  - Unit hydrograph for distribution of effective runoff (Unit hydrograph)
  - Kinematic wave approximation for river flow delay (Manning Coefficient)
- Implemented in C++
- Parallelized by OpenMP
RR Model Calibration

• Finding a configuration of schematization parameters that leads to the lowest error in the output
• To calculate the error, real measured data are needed for model calibration
• Simulation needs to contain measurement part
• Standard simulation:
  5 days of measurement
  2 days of prediction
Calibration Process

1. Start
2. Initial settings of model parameters
3. Model solving
4. Model error check
   - If model error check is positive, go to Model parameters update
   - If model error check is negative, go to Multiple models solving

Optimization step:
- Model parameters update
- Multiple models solving

5. Stop
Different coefficients can be used for RR calibration

- Error in magnitude and position of peak point
- Error in cumulated volume of discharge for the whole simulation
- Special hydrologic indicators (Nash-Sutcliffe efficiency)
Calibration Methods

- Multidimensional optimization problem for each calibrated schematization parameter
- Local optimization methods
  - Line search
  - Interior point method
- Global optimization methods
  - Pattern search
  - Global search
  - Multi-start interior point
  - Genetic algorithms
Parallelization

- Calibration process parallelized by OpenMP
- Basin schematization contains several gauges and is divided into many channels and sub-basins
- Hierarchy of the basin can be taken into account but limits parallelization options
Experimental Results

Volume calibration

Scalability

Nash-Sutcliffe
Uncertainty Modelling

• Some input data of RR models can be inaccurate rainfall and temperature prediction hydrological parameters of modelled catchment even rainfall and discharge measurements

• The goal is to model these uncertainties and estimate possible flooding scenarios in the near future along with their probability
Statistical Evaluation of ALADIN Forecast

- ALADIN is a numerical model for short term forecast (2-3 days) of climate situation in Europe
- Statistical evaluation of 5 year data (2007-2012) to evaluate probability distributions of rainfall prediction errors
  \[ \text{error} = S_{\text{measured}} - S_{\text{predicted}} \]
- 36 measurement gages in all catchments in Moravian-Silesian region
- 48 hour predictions with 6 hour timestep
Evaluation Results

- ALADIN underestimates the forecast average error 0.5 mm/h, median 0.1 mm/h/h
- Kurtosis is very high (71.3), not a normal distribution
- Error significantly depends on the measured precipitation intensity
- Error does not depend on station location, nor on forecast time offset
Kernel Density Estimation

- Kernel density estimation non-parametric method used for modelling of probability distribution of errors
- Precipitation intensity divided into several categories based on official CHMI categorisation
Uncertainty Modelling with Monte Carlo Method

- Modelled probability distributions used for generating parameters for Monte Carlo simulations of RR models
- Percentiles extracted from MC results to create confidence intervals
Parallelization

- Monte Carlo simulations parallelized by OpenMP/MPI
Conclusion and Future Work

- Calibration increases precision of RR predictions but can take a while – inconvenient for critical situations
- Uncertainty modelling provides additional information useful for decision support
- Parallelization shortens the execution time – precise results are provided quickly even in critical situations
- Future work
  
  Hybrid parallel implementation of calibration
  More granular categorisation of rainfall intensities
  Automatic re-evaluation of kernel density estimates
Thank you for your attention