Stochastic Management of the Open Large Water Reservoir with Storage Function with Using a Genetic Algorithm

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Abstract. Described models are used random forecasting period of flow line with different length. The length is shorter than 1 year. Forecasting period of flow line is transformed to line of managing discharges with same length as forecast. Adaptive managing is used only first value of line of discharges. Stochastic management is worked with dispersion of controlling discharge value. Main advantage stochastic management is fun of possibilities. In article is described construction and evaluation of adaptive stochastic model base on genetic algorithm (classic optimization method). Model was used for stochastic management of open large water reservoir with storage function. Genetic algorithm is used as optimization algorithm. Forecasted inflow is given to model and controlling discharge value is computed by model for chosen probability of controlling discharge value. Model was tested and validated on made up large open water reservoir. Results of stochastic model were evaluated for given probability and were compared to results of same model for 100% forecast (forecasted values are real values). The management of the large open water reservoir with storage function was done logically and with increased sum number of forecast from 300 to 500 the results given by model were better, but another increased from 500 to 750 and 1000 did not get expected improvement. Influence on course of management was tested for different length forecasted inflow and their sum number. Classical optimization model is needed too much time for calculation, therefore stochastic model base on genetic algorithm was used parallel calculation on cluster.

1. Introduction

For management of the open large water reservoir with storage function is used mostly deterministic model nowadays. Alleged advantages of deterministic model are using only one output value. If model is given only one output value it is significant simplification of problematic, which It is leaded to losing accuracy of management or to wrong evaluated situation (forecast and reality are totally different). On the other hand, stochastic model is working with fan of possibilities outputs, whose have given probabilistic distribution, therefore stochastic model should be better approximation of given problematic. Advantage of stochastic management is possibility of choice management for given probability of scenario.

Stochastic management with adaption way can use Monte Carlo method (MC method). Applicability of MC method in branch of water reservoir management has time hindrance (high claim to machine time), because 300 repeating of calculation is needed [1]. Adaption management using MC method and classic methods of optimization is good choice for stochastic management. High time consummation is given by optimization, which is repeated in every time step. In every time step is provided correction of management. For optimization process was chosen classic method (genetic algorithm), [2]. Time of calculation for this type of solution could be unbearable for common PC, therefore all calculations were provided by cluster. Program Matlab 2013 was used for assembly and work with model.

2. Model

Principe of adaptability is used by model and its core is genetic algorithm (GE), [3]. Differential evolution was chosen as method of optimization. Line of outflow is given by model; which length is corresponding with length of forecasted inflow. Solution is given by GE and it is the best solution for given forested inflow, but forecasted inflow is burdened by uncertainty. Influence of uncertainty could lead to different solution than with using 100% forecast (real values). This difference is leaded to faster emptying reservoir than it should be (volume is disappearing by jumps, not continuously). For this reason, model is looking for speed of emptying reservoir and if it was too fast in two previous steps outflow is decreased by ratio of real value of emptying and assumed value of emptying.

Model is contained balance equation and algorithm for crises management. If volume of water is descended under certain water level and forecast is longer than one month, the crises management is active. During crises is checked volume of water and outflows for whole period of forecast. If reservoir has insufficient volume or outflows are significantly different, crises management optimized outflow to new values which decrease variance of outflows or try to delay emptying of reservoir.

Earlier mention step is provided for all steps calculation. Number of repeating is given by sum of forecast. These values were tested 1000, 750, 500, 300, 250, 100 (number of repeating). Optimization is done for each step of forecast and all repeating. When all repeating is finished for one step (month), empiric probabilistic exceedance curve is constructed by model and corresponding outflow is chosen with given probability (user choice). Selected outflow is averaged with previous values of outflow for same probability.

3. Application

Model was applied to artificial open water reservoir with storage function, which lied on river Svitava (measured profile Bílovice nad Svitavou). The reservoir was designed to disorders were created during learning (testing) period. Adaptive management was applied for each time step (month). Mean monthly outflow was set to 4.25 m^3/s (water supply) and volume storage to 19.76 m^3/s.

Model was tested firstly with 100% forecasted inflow for different length of forecast (deterministic model). Those results were taken as the best course of management.

Inflows were created by Zone stochastic autoregressive recurrently forecasting model. Forecasting model was used 6 zone and 4 months backwards. Forecasted line of inflow was length 1 – 12 months. Number of forecast was tested. Given probability values were tested (99, 95, 90, .. a5 .., 10, 5, 0.001). Likewise, number of preview values outflow used for averaging was tested.

4. Evaluation

The main criterion of successfulness was sum second square of error between results of stochastic model using forecasted values of inflows and results of classic deterministic model using 100% forecast of inflows for corresponding length of forecast. In Figure 1 are showed different probability courses, on horizontal axis are months and on vertical axis are outflows (water supply) from open water reservoir. Outputs of stochastic model were compared to classic deterministic model. Results of stochastic and deterministic model (100% forecast) are showed in Figure 2 on horizontal axis are months and on vertical axis are outflows (water supply) from open water reservoir.

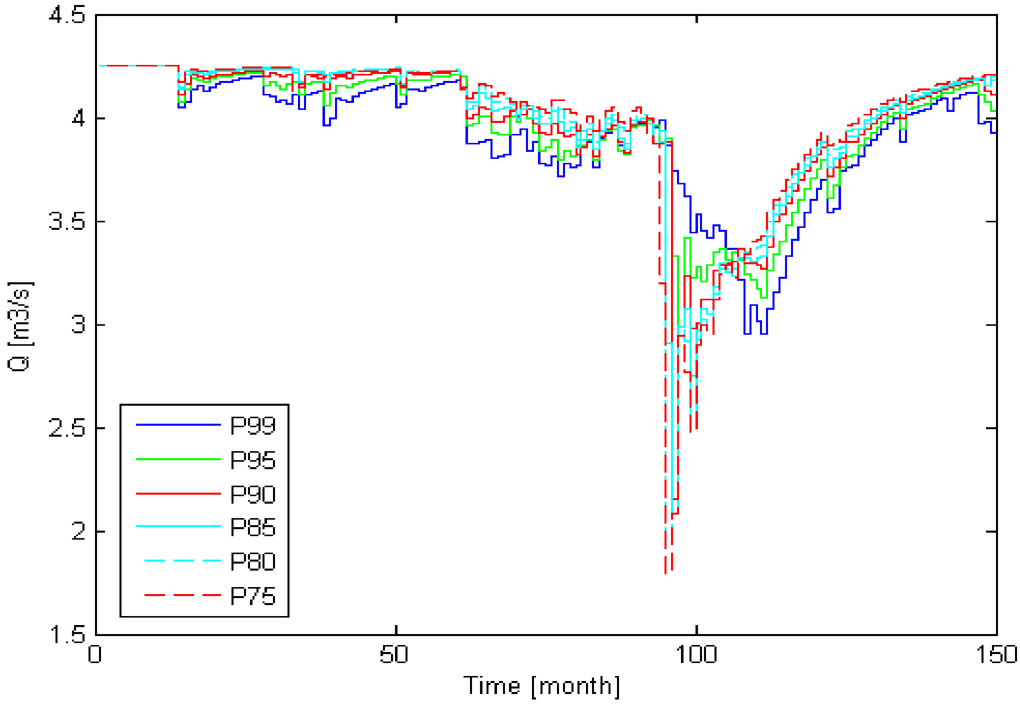

Figure 1. Stochastic model (chosen probability)

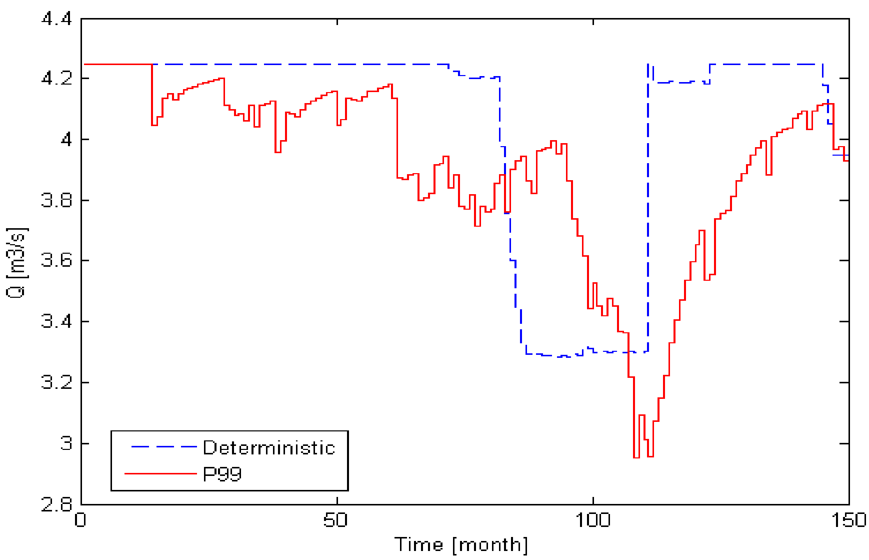

Figure 2. Results comparison

Even though fuzzy model done some artificially disorder, the main process was better than results of stochastic classic model. Disorders were longer and shallower. The best results were given with length of forecast 4-6 months forward. On the other hand, stochastic classic model did not do artificially disorder, but main disorder was deep.

Each probability of outflow had different process of management and different depth and duration of disorder was created. The smallest error was reached for 99% probability and using 4 backwards outputs for averaging in general. If model were used different number of previous outflows for averaging, the smallest error was reached for different probability of outflow (5 and more previous outflows 99%, 3 previous outflows 95%, 2 previous outflows 85%, 1 previous outflow 75%), but error was higher than for scenario with 4 preview outflows. Number of forecast had impact for course of management. Results of stochastic model were creditable from number of forecast 500. If model were used smaller number, more artificially disorders were created. In Figure 3, is shown course of stochastic management with 4 previous outflows (3b) and 2 previous outflows (3a) for different probability of outflow.

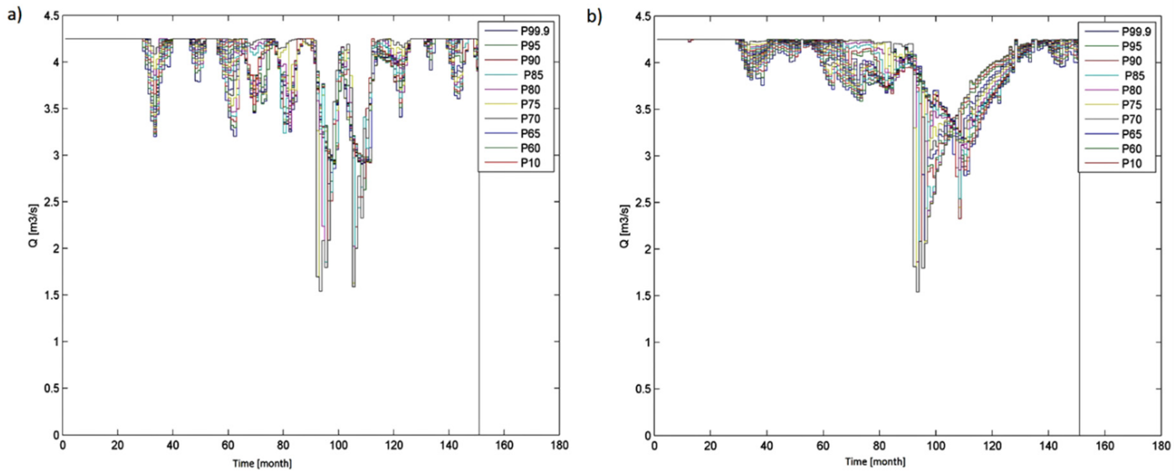

Figure 3. Stochastic model results for different number of used outflow backwards for averaging a) 2 outflows backwards are used for management, b) 4 outflows backwards are used for management

5. Conclusion

From above text is clear that, results of stochastic model are dependent on number and length of forecasted inflows and given probability of outflow from open water reservoir. Number of previous outflows used for averaging had huge impact on course management. If four previous outputs were used it was reached the best results. Length of forecast influenced course also. The longest length did not bring the best results, because entropy of forecasted line of inflow is increased. The best length of forecast is in interval from 7 to 8 month, it is depended on given probability of outflow. If model were used high number of forecasted inflow, the better results were obtained. If 500 line of forecasted inflow were used, results were almost same as 750 or 1000 line of forecasted inflow. The difference in courses of management was lower than 2 %. The main disadvantage of model base on GE is speed of calculation for analysis longer period of management, but it is not big obstacle in real process, because management is provided by moth step. The calculation (length 150 month, length of forecast 8, number of forecast 500, number of probability 1) took model 26 hours on common PC, but calculation (length 150 month, length of forecast 10, number of forecast 500, number of probability 1) took over 400 hours. Sane calculation in cluster took 3 and 10 hours. Model provided management logically. We can obtain good results with shortening time if model is used clusters. If model is not used clusters for stochastic management of longer period of management, the time consumption will be unbearable for longer length of forecasted inflow than 8.

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