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# Use of Non linear optimization and fuzzy regulators for Operative Control of River Basin Runoff

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**Abstract**

The contribution outlines the possibilities of use of artificial intelligence methods at construction of controlling algorithms for operative control of river basin runoff. Using the example of Vranov, Znojmo, Dalesice, Mohelno and Brno reservoirs system on the Dyje River the article shows the achieved effects of controlling algorithms based on combination of non-linear programming and fuzzy regulators during the flood situation in August 2002.

***Keywords*****:** *methods of artificial intelligence, neurone network, fuzzy-regulators, non-linear programming, controlling algorithms.*

## 0.1 Method

This contribution outlines the possibilities of use of artificial intelligence methods at construction of controlling algorithms for operative control of river basin runoff during floods. The basic question when using this method as a part of operative control of river basin runoff is the determination of controlling quantities course in relation with changing state of controlled system and other contingent input quantities (failures). This is true especially with dynamic systems, which work with significant delay. In the river basin with reservoirs the task is solved to find relation of controlling discharges,or positions of individual reservoirs valves with temporal and spatial variation of precipitation above the river basin, river network discharge and filling individual reservoirs. This article shows four possibilities how to use methods of artificial intelligence.

The first possibility substitutes real continuous space of solution inputs by discrete space and in discrete points of this space determines the values of controlling quantities with optimisation. For each of discrete point of solution input space the values of controlling quantities are calculated in advance. Such created examples of corresponding quantities are written into input-output matrix which describes the final behaviour of controlled system.

This matrix can then be used as a training matrix for neurone network (or any other learning hybrid system, etc.), which approximates the relation between discrete points of solution input space and corresponding calculated controlling discharges and for concrete actual inputs very quickly determines the corresponding value of controlling quantities.

The second possibility does not solve the discrete points of solution input space (corresponding controlling quantities) in advance, but in each temporal step, when changing controlling quantities, calculates the values of controlling discharges with the help of optimisation algorithm using actual state of the system and valuation of future inflows (precipitation prediction). This method uses simulation model with optimised parameters selection, where parameters are unknown controlling discharges. A part of this algorithm is a neurone-regulator, or fuzzy regulator which in relation with the value of controlling discharge (which is unknown) in each calculation temporal step directly quantifies the values of valve positions and thus enables the calculation of corresponding controlled discharges. The course of action setting and controlled quantities is then changed almost continuously.

The third possibility is a combination of the methods described above. A neurone network (or hybrid network) is set from optimisation calculations (done in advance and trained afterwards) of controlling quantities in discrete points of solution input space with optimisation algorithms. A part of these algorithms are for instance fuzzy regulators, which in single temporal steps of the solution determine the setting of valves and afterwards enable quantifying the course of controlled outflows. With actual state of input quantities the trained neurone network then quickly determines the values of controlling discharges (or directly the valves positions). They are then quickly proceeded e.g. with fuzzy regulator.

The last described possibility uses other methods, e.g. respects expert opinions and uses them for setting the neighbourhood function of fuzzy regulator or determines limit (critical) values of discharge in selected profiles and calibrates corresponding neurone-fuzzy regulator with the use of specialised tuning.

### 0.1.1 Application

Part of this contribution presents the results of controlling algorithm application based on combination of non-linear programming and fuzzy-regulation method mentioned in the second possibility. Developed programme was successfully used for the simulation of operative control of water discharge through Vranov, Znojmo, Dalesice, Mohelno and Brno reservoirs system on the Dyje River during the flood in August 2002.

**Conclusion**

Controlling algorithm is functional and gives very good results. It could be used for reservoirs which enable continuous remote valve control or which are equipped with programmed controlling microcomputer (fuzzy – regulator), which after determination of controlling quantity with central controlling computer enables the valves positions set up directly in controlling reservoir.

The certain vibration of reservoir outflow on an increasing branch of outflow can be removed with better setting up of a fuzzy - regulator. This was proved with additional experiments. The influence of prediction length on lowering culmination water outflow from the reservoir is quite considerable. The positive effect had the prolongation of prediction from 48 h to 78 h., then the influence of prediction length started to decrease - it was significant though.

The chosen time interval between decision time points 6 h (repeated calculation of controlling quantities) we consider too long. It depends on the possibilities of issuing repeatedly specified values of predicted inflow into the reservoir. The decrease of the interval leads to better smoothing of controlled outflow from the reservoir. When using real (measured) predictions of water inflow into the system it is necessary to shorten this interval.

Algorithm required that the calculated controlling quantity course or set up of valves position in predicted period is constant. Numerical experiments showed that separation of these quantities to two and more (the number of unknown quantities increases proportionally and solution takes longer time) leads to smoothing of controlled outflows and to another decrease of culmination discharges. If the time interval between decision time points $\Delta\tau$ is shortened which is limited by the possibilities issuing operative predictions of water inflow into the reservoir, the similar effect is reached. Practice shows that hydrologic predictions of the discharges are often so inaccurate (accuracy of rain prediction) that used simplification we consider satisfactory.

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