Multicriteria Decision Support for Flood Management Based on Digital Maps

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Summary. In this paper we will describe a decision support system capable of simulation and adaptive control of flood prevention measures in a system of water reservoirs. The system is based on a collection of 8-th layer digital maps which provide information about the physical coordinates, water flow and wealth distribution at flood risk. The management optimization criteria are grouped in three vectors: those related to individual gains/losses at each reservoir, those related to the risks and losses in the recipient valley, and those related to the costs of flood management measures.

The problem to be solved can be defined as dynamic multicriteria coordination, with the environmental, financial and human-life-protection-related criteria in each vector of agents' criteria mentioned above. We assume that in the region, which can be coordinated by the same decision-maker(s), there exist n water reservoirs. The reservoirs are divided into N subsystems , each of them having a separate direction, economical goals, individual instructions on how to act in case of flood emergency, and a specified region, which should be protected in the first order of importance. The latter information can be regarded as components of the *i-th* subsystem preference structure, for $i=1,\ldots,N$. Motivated by the situation in the Upper Vistula Basin, which served as a playground for an implementation and experiments, we consider the case where all reservoirs are located on the feeders, while the flood wave on the recipient between and beneath the mouths of the feeders is controlled by the coordinated release of water from reservoirs belonging to different subsystems. Such situation may occur when larger cities and industrialised areas are situated in the recipient river valley.

To select a compromise management strategy we apply an easy-to-define temporal preference information in form of time-dependent reference points. This information will be aggregated in such a way, so that two polyhedral multifunctions in the criteria space, J_1 and J_2, represent the desired and avoidable values of criteria for each moment of time of the flood management period, respectively. Using this approach we will design an hierarchical decision support architecture that assists the flood coordinating unit as well as allows to select optimal reservoir control strategies in the situation of flood emergency. The usually adopted control actions include spontaneous releases of water from the reservoir based on the precipitation forecasts. As side effects, the water level may sink below the minimum necessary to keep the ecosystems in reservoir lakes intact, while the fluvial ecosystems below the reservoir can be destroyed. We show that these effects may be minimised by a suitable coordination. The solution of the coordination problem will require the prior knowledge of each single reservoir's management preference models. We design the principles of management coordination by constructing a common preference structure to be applied by the supervisory control centre. We assume that the water reservoirs and river beds are modelled by the system of controlled ordinary differential equations:

$$x' = f(x,u,t,\eta),\ x\in I\!R^n,\ t\in[t_0,T],\ u\in I\!R^k,\ \eta\in I\!R^n, \tag{1}$$

which result from a discretization of Saint-Venant equations [1]. Their coefficients are calculated based on digital maps, while the water flow data are updated from precipitation forecasts derived from meteorological radar and satellite data. The described model makes possible efficient computation and proved useful in real-time simulations, when the dimension of the system (1) was between 37 and 140.

There are diverse environmental, social, economical benefits of implementing the coordinated flood management. The most important ex-post indicator is the estimated number of human lives that can be saved if the flood wave is kept within safe limits, determined by a GIS, or if it grows in a predictable manner. The environment can be kept intact by preventing unjustified and unnecessary water releases. The economic criteria, i.e. the value of losses that could be avoided is another widely used objective.

Keywords: multicriteria decision support, multicriteria optimal control, dynamical preference structures, reference sets, water reservoir systems, GIS

References

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