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A Framework for the Simulation of Human Response to Global Change

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The research project GLOWA-Danube (www.glowa-danube.de) investigates Global Change effects on the water cycle of the Upper Danube river basin (Germany, ˜80.0000 km2). GLOWA-Danube is an interdisciplinary project that attempts to develop integrated strategies and tools for water and land use management. Within GLOWA-Danube 16 natural and social science simulation models are integrated in the coupled simulation system DANUBIA. A primary scope of DANUBIA is to evaluate consequences of IPCC derived climate scenarios for the coming 50 to 100 years.

Within GLOWA-Danube the socioeconomic models (Household, Farming, Economy, Demography, Tourism and Watersupply) are mainly responsible for calculating water demand, water extraction and water prices. Beyond this, the 'farming model' simulates activities of farmers which result in land use changes, and the 'economy model' predicts household income and industrial development. The socioeconomic models form the so-called 'Actors component', which is linked to the other main DANUBIA-components Atmosphere, Landsurface, Rivernetwork and Groundwater.

Socioeconomic (or better: human) response to Global Change - be it of climatic, technical or political origin - can in most cases be described as a reaction to changing conditions and is quite often based on a decision process. In contrary to physical processes, human reactions can usually not be described in a deterministic way: They are more often the result of complex considerations, which include individual possibilities and preferences along with typical, type dependent 'thinking'. In order to simulate this type of behaviour in DANUBIA, the ’Actors concept’ was developed and implemented by the generic DeepActor framework as an extension of DANUBIA.

An actor is the smallest entity capable of making a decision. An actor in the case of DANUBIA is for example a farmer or a water supply company. It has to be noted that, since DANUBIA is a raster based system with a spatial discretisation of 1 by 1 km grid cells, an actor in the most cases does not explicitly represent a real person or organisation but rather an abstract, effective ’mean’ of real actors located in each grid cell. An actor is located on one or more of these cells that in turn define the environment of this actor. Within each time step of a simulation run, each actor observes its environment and selects plans to execute as a reaction to its observations. Plan execution results in the execution of associated actions that model explicit state modifications of the simulation area. Different actors may have different course-of-actions as well as varying preferences, represented by their individual plans and their type-specific decision procedure.

The DeepActor framework applies object-oriented techniques to provide the basic building blocks of this concept in form of abstract base classes and predefined relationships among them. A concrete model may implement different actor, plan or action types by extending the respective abstract base class. Therefore the framework serves as a common architectural basis for the modelling and implementation of socio-economic models in GLOWA-Danube. To demonstrate the application of the DeepActor- (or MultiActor-)approach, the development of the models ’DeepWaterSupply’ and ’DeepHousehold’ is described.

DeepWaterSupply is a model of the water supply sector comprising water extraction, treatment and distribution. It acts as a link between the natural ’supply side’, simulated by a groundwater and a surface water model, and the socio-economic ’demand side’ simulated by a household, tourism, farming and an economy model of water consumption in the respective sectors. The main aim of DeepWaterSupply in the context of Global Change is to react reasonably to all possible changes on the supply and on the demand side. Based on the framework the DeepWaterSupply model implements the actor type water supply company (WSC). A WSC compares the demands to the state of the resources on the supply side. Depending on the result a WSC chooses from different plans ranging from ’business as usual’ to ’crisis management’. The strictly object-oriented DeepActor framework allows a model implementation and extension (new types, plans, ...) at a minimum effort. For the water supply sector, the Multiactor-Approach has the advantage that it facilitates a flexible and realistic response to system changes. Scenarios can be easily defined by adjusting actor types and preferences and critical states can be identified without having to model the infrastructure of individual WSC explicitly.

The DeepHousehold model was designed to estimate the water use of households under changing surrounding conditions. The households get their water from the DeepWaterSupply model. They use it for showering, toilet flush, laundry etc. The wastewater is passed through virtual clarification plants to the model Rivernetwork. Water use in households is mostly unconscious and follows long learned habits. But in special situations (e.g. heat waves, price alteration, or new investments) an active decision for options is necessary. A household actor decides upon different plans depending on its preferences and the surrounding conditions. Among other things the air temperature, the modernity of the plan and the social desirability are used for a utility calculation. The DeepHousehold model uses the DeepActor framework to implement different household lifestyles. The strictly object oriented approach and the sophisticated framework make it possible to implement these lifestyles with their different preferences sequentially and calibrate them one after another. The model is useful for scenarios like water innovation diffusion or long lasting heat wave periods with temporary water scarcity.

This contribution presents the overall concept of the DeepActor approach as implemented in DANUBIA and demonstrates its application using the practical example of the models DeepWaterSupply and DeepHousehold. The main focus however is on the description of the DeepActor framework which realizes a general concept for including socioeconomic components in integrated hydrological decision support models.