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Preface

Dear Participants,

Confronted with the ever-increasing complexity of technical processes and the growing demands on their efficiency, security and flexibility, the scientific world needs to establish new methods of engineering design and new methods of systems operation. The factors likely to affect the design of the smart systems of the future will doubtless include the following:

- As computational costs decrease, it will be possible to apply more complex algorithms, even in real time. These algorithms will take into account system nonlinearities or provide online optimisation of the system's performance.
- New fields of application will be addressed. Interest is now being expressed, beyond that in "classical" technical systems and processes, in environmental systems or medical and bioengineering applications.
- The boundaries between software and hardware design are being eroded. New design methods will include co-design of software and hardware and even of sensor and actuator components.
- Automation will not only replace human operators but will assist, support and supervise humans so that their work is safe and even more effective.
- Networked systems or swarms will be crucial, requiring improvement of the communication within them and study of how their behaviour can be made globally consistent.
- The issues of security and safety, not only during the operation of systems but also in the course of their design, will continue to increase in importance.

The title "Computer Science meets Automation", borne by the 52nd International Scientific Colloquium (IWK) at the Technische Universität Ilmenau, Germany, expresses the desire of scientists and engineers to rise to these challenges, cooperating closely on innovative methods in the two disciplines of computer science and automation.

The IWK has a long tradition going back as far as 1953. In the years before 1989, a major function of the colloquium was to bring together scientists from both sides of the Iron Curtain. Naturally, bonds were also deepened between the countries from the East. Today, the objective of the colloquium is still to bring researchers together. They come from the eastern and western member states of the European Union, and, indeed, from all over the world. All who wish to share their ideas on the points where "Computer Science meets Automation" are addressed by this colloquium at the Technische Universität Ilmenau.

All the University's Faculties have joined forces to ensure that nothing is left out. Control engineering, information science, cybernetics, communication technology and systems engineering – for all of these and their applications (ranging from biological systems to heavy engineering), the issues are being covered.

Together with all the organizers I should like to thank you for your contributions to the conference, ensuring, as they do, a most interesting colloquium programme of an interdisciplinary nature.
I am looking forward to an inspiring colloquium. It promises to be a fine platform for you to present your research, to address new concepts and to meet colleagues in Ilmenau.

Professor Peter Scharff
Rector, TU Ilmenau

Professor Christoph Ament
Head of Organisation

Table of Contents

CONTENTS

Page

6 Environmental Systems: Management and Optimisation

10 Mobile Communications

11 Education in Computer Science and Automation

52nd Internationales Wissenschaftliches Kolloquium
Technische Universität Ilmenau
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T. Pfützenreuter / T. Rauschenbach

Surface Water Modelling with the Simulation Library ILM-River

ABSTRACT

The MATLAB / Simulink toolbox ILM-River is a library for simulation and controller design of surface water systems consisting of rivers, channels, reservoirs and hydropower plants. Started with simulation objects for run-of-river reservoirs and river sections, in the last time the library was enhanced with models for complex surface water systems, chemical pollution propagation and an interface to the finite element groundwater simulator FEFLOW.

INTRODUCTION

Designing controllers for reservoirs or channels typically requires an analytical model of the system. Beside the mathematical calculation of the controller law and the associated parameters, simulations methods are often used to test and optimize control strategies. This requires a model of the controlled process.

The toolbox ILM-River contains models for the most important elements of surface water systems and is used in different projects. It consists of two modules called River-MOD and River-CON.

River-MOD implements simulation models needed for modelling channels, reservoirs or river sections with their special characteristics. The control-oriented hydrodynamic models developed for River-MOD are well suitable for the design and the verification of control strategies. With the aid of a graphic editor, it is straightforward to build the entire model for one or more reservoirs or river sections.

The newest additions to the library are a set of simulation models for complex surface water systems, an interface to the groundwater simulator FEFLOW allowing the combined simulation of surface and ground water resources and the possibility to simulate chemical pollution in water bodies. These enhancements will be presented beside the already existing elements in detail.

The module River-CON implements different control concepts for reservoirs. Beside traditional control according to operating rules, several advanced concepts are integrated:

- a fuzzy control strategy for smoothing of discharge,
- a concept for the coordinated control of multiple river sections (cascades) to improve the flood control.

These methods allow to test and compare different strategies for controlling the output of reservoirs and river sections.

As examples, this paper presents the simulation model for a run-of-river reservoir and the propagation of benzene entering a river. Both pollution types, the continuous and the on-time pollution, are shown with their simulation results.

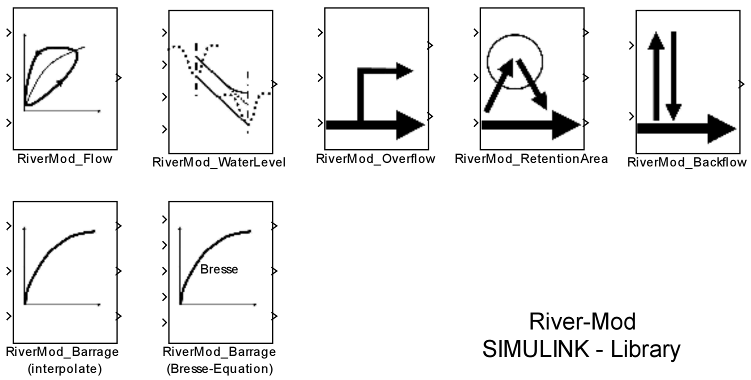

Fig. 1 The run-of-river simulation library

MODEL LIBRARY RIVER-MOD FOR SURFACE WATER MODELLING

Run-of-river Reservoir Modelling

The simulation models for the run-of-river part of River-MOD rely on an analytical description of the hydrodynamic behaviour of reservoirs. For control, it is sufficient to know the behaviour at gauges for water level and flows. Typically, simulation models describing instationary hydrodynamic behaviour of rivers and channels base on the Saint-Venant-equations [Abbott 1998]. However, such models are not suitable for an on-line optimization, because solving the differential equations system requires a lot of computational time. Furthermore, it is difficult to simulate overflow regions and backflow behaviour with these models. That's why new control-oriented hydrodynamic simulation models were developed, which meet all demands with respect to accuracy and simulation speed. More information on the particular blocks shown in fig. 1 is given in [Pfuetzenreuter 2005].

Complex Surface Water System Modelling

Modelling a complex surface water system often results in a detailed simulation model with hundreds of parameters and a long simulation duration. The new development for River-MOD reduces the modelling effort by using simplified simulation blocks. Using these blocks results in a fast, reliable simulation model, that is sufficient for control and optimization tasks [Rauschenbach 2005].

The library contains the most important elements of a typical surface water system:

- Catchment areas: advanced models based on methods introduced by Lorent and Gevers [Lorent 1976],
- River and channels: elements like river and channel sections, weirs, sluices, control gates with their dynamic behaviour,
- Water supply systems: ground and surface water works, customer demand estimation
- Groundwater: groundwater storage models, interface to finite element simulator FEFLOW.

Using these elements, major parts of surface water systems can be modelled (fig. 2). Typically, the data driven parameterization is done using optimization techniques. All elements of this library are able to simulate the chemical pollutant transport and elimination processes described in the next section.

Chemical Exposure Modelling

Chemical pollutants reaching water bodies often represent risks for people and environment. That's why it is necessary to model transport, sedimentation and

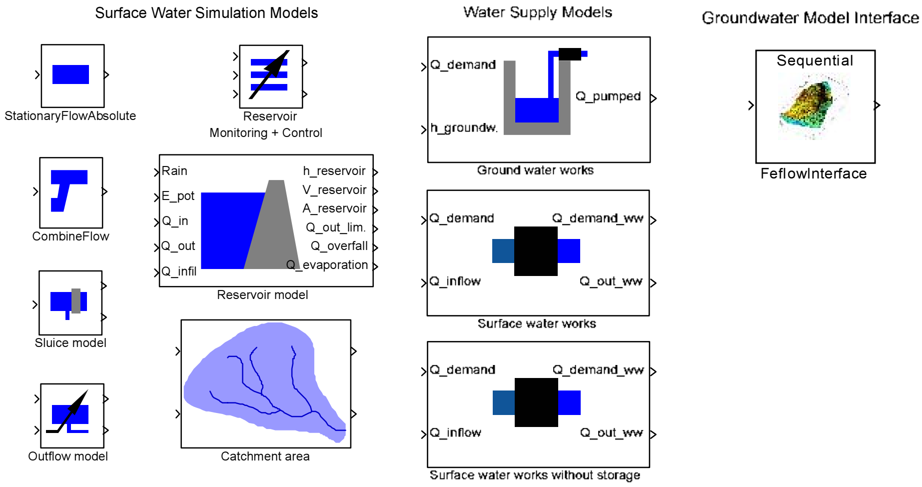

Fig. 2 New blocks of the River-MOD simulation library (only important blocks are displayed)

elimination of such substances.

The simulation blocks of the River-MOD library are able to simulate these processes and implement one-dimensional methods for simulation of two different scenarios:

- continuous pollution as consequence of natural and human life, industrial or agricultural production,
- one-time pollution, typically due to accidents or terrorist attacks.

The continuous pollution is modelled according to the methods developed by the GREAT-ER project as described in [Schowanek 2001]. The method assumes an instantaneous mixture of river and pollutant flows and a constant concentration along the cross section of the river. This leads to simple but efficient computation methods for the concentration down the river. The one-time pollution simulation was newly developed at Fraunhofer Center and takes into account the transport processes diffusion, dispersion and advection [Trapp 1997]. Both methods are designed with regard to a high computation speed. This allows a seamless integration of quality modelling aspects into existing simulation models.

Coupling Surface and Ground Water Simulation

A current project at the Fraunhofer Center for Applied Systems Technology deals with the water allocation of the city of Beijing, China [Rauschenbach 2005]. One project emphasis is on the combined simulation of surface and ground water in the wider area around the city. The groundwater simulation is performed with the finite element simulator FEFLOW while the surface water, lumped parameter model runs on MATLAB / SIMULINK using the simplified simulation blocks. Coupling both models requires to analyze the physical interconnection and to develop an appropriate software concept.

The physical coupling concentrates on the most important interchange processes:

- groundwater withdrawal at wells,
- groundwater infiltration from rivers, lakes, reservoirs, irrigation,
- artificial recharge of groundwater at seepage fields.

The surface water simulation model computes all flow rates (withdrawal, infiltration, recharge) from its internal states. These time-dependent rates are transmitted to FEFLOW und used for simulation of a predefined period. As output, FEFLOW sends the hydraulic heads at all locations the surface water simulator is interested in. During simulation, the surface water model is responsible for starting and controlling the groundwater simulator as well as for the coordination of data transfer.

MODEL LIBRARY RIVER-CON FOR RESERVOIR CONTROL

Especially run-of-river reservoirs are often built to use the environment-friendly hydropower for generation of electric energy. In most cases, this fact leads to the construction of reservoir cascades in rivers. The reservoirs in a cascade influence one another by hydraulic link-up. As a result, the natural flow behaviour is strongly affected by the control strategies of the reservoirs. This leads to an increasing demand of advanced control strategies for reservoir cascades.

Reservoir cascades have further tasks in addition to energy generation, e.g. to prevent overflows and to guarantee ship navigation. To avoid dangers for people and real values, the energy production has to subordinate to these tasks. Rules were created to support the operators in implementing the predefined strategies. Two modules of the model library River-CON realize a control according to such operating rules, a PID-controller with multiple parameter sets and a similar Fuzzy-concept. However, these concepts cannot optimally solve the mentioned multi-criterial tasks necessary for a coordinated operation of reservoir cascades. Instead, a newly developed concept called MEFURO is well suitable for such problems. Furthermore, a module for smoothing of discharge was integrated into River-CON. For more information to the particular control strategies see [Pfuetzenreuter 2005].

SIMULATION MODEL APPLICATIONS

Simulation Model for a Run-of-river Reservoir

Using the ILM-River toolbox different simulation models for river reservoirs were developed. As an example, this paper presents the model for the Danube reservoir Ybbs (fig. 3). Primary aim is to model the dynamic behaviour of the flow section between the two hydropower plants Wallsee and Ybbs. The model must describe the real inflow and discharge behaviour as well as the water level trajectories at the gauges [Rauschenbach 2001].

The total length of the reservoir Ybbs is approx. 34 km, the width ranges from 150 m to 1.000 m. The bottom slope in the reservoir is $3{,}4 \cdot 10^{-4}$. Downstream the gauge Au (in the middle of backwater storage) water bypasses the hydropower station Wallsee at flow rates higher than 6000 m³/s. Hence, the downstream gauge of station Wallsee does not register the total flow to the reservoir Ybbs. For this reason, it is necessary to consider the effect of bypassing in the model. The activation of the retention rooms shown in fig. 3 occurs by opening floodgates and using pumping stations at a flow rate of 4700 m³/s. Starting at a flow of 5400 m³/s, the water enters the retention rooms directly. Fig. 4 shows the rough simulation model of the reservoir Ybbs.

With this model, good simulation results are achievable in all flow ranges. As an example, fig. 5 shows the simulated discharge of the hydropower station Ybbs during

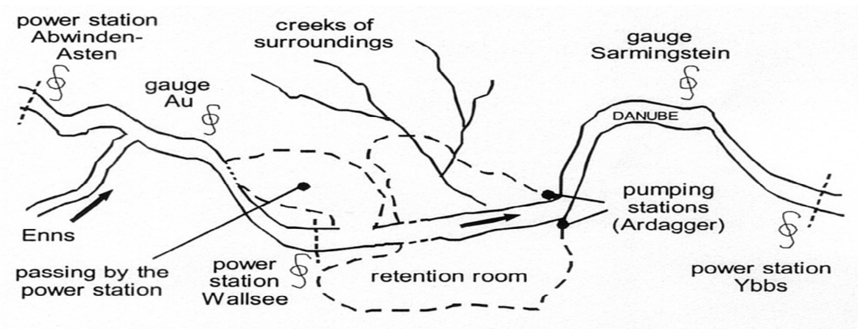

Fig. 3 River section between hydropower stations Abwinden and Ybbs

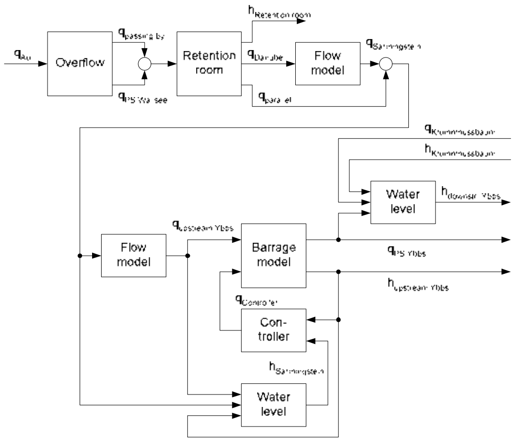

Fig. 4 Simulation model for reservoir Ybbs

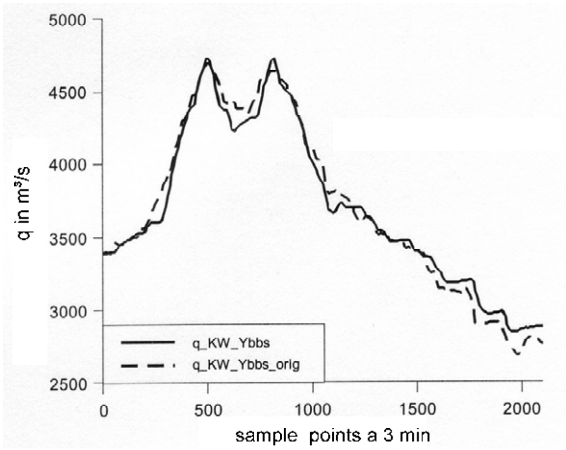

Fig. 5 Simulation results for flood in July 1993

the flood of July 1993 compared to the original data. Using a PID controller, the simulated behaviour is similar to the recorded time series. As the controller uses different water levels at the reservoir to control the outflow, the water levels are also reproduced very well.

Chemical Exposure Model

Using the simulation blocks of the complex surface water system library, many different tests were performed. For example, the simulation results of a river's continuous pollution with benzene are shown in fig. 6. At the location of the entry, the concentration of benzene is given by the ratio of the flow rates of river and pollutant. Downstream the concentration reduces by elimination processes like sedimentation, degradation and volatilization. If the whole river section is polluted, the concentration becomes stationary because of the continuous pollution with benzene.

Another scenario assumes that a one-time pollution with benzene has occurred. Using the newly developed propagation method described earlier, the results shown in fig. 7 were obtained. The propagation wave changes its appearance while it spreads through the river section. Therefore, the concentration of benzene is lower but prolonged due to the simulated diffusion and dispersion processes [Thibodeaux 1996].

CONCLUSION

This paper presented the latest additions to the MATLAB / Simulink toolbox ILM-River. The library consists of two modules for simulation and control of surface water systems and allows an integrated management of surface and ground water resources using the

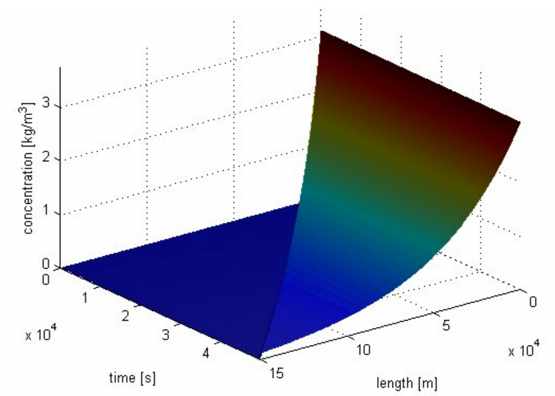

Fig. 6 Continuous pollution simulation in a river section, length 15 km

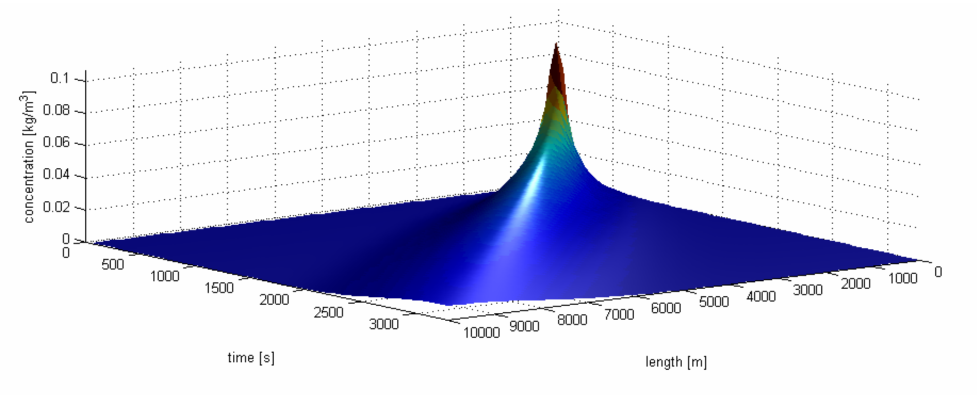

Fig. 7 Simulation of on-time pollution along a river section, length 10 km

interface to the finite element groundwater simulator FEFLOW. The chemical exposure modelling assists in estimating risks if pollutants enter a surface water system. The example of modelling a run-of-river reservoir in the Austrian Danube shows the practical usability of the simulation blocks.

The further development of the library is an ongoing work. Especially the pollution simulation methods have to be tested intensively. In addition, the models for the water supply network like pumping stations and waterworks as well as models for wastewater treatment are actively under investigation.

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