A General Purpose Simulator for Dynamic Modeling of Wastewater Treatment Plants

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ABSTRACT

This paper describes the development and application of simulation-based technologies for the analysis and control of wastewater treatment plants. Emphasis is on the development of a **General Purpose Simulator** for wastewater treatment plant modeling. The GPS described in this paper makes use of an advanced graphics-based modeling environment, allowing the user to control and interact with the simulation of the plant as the simulation progresses.

The wastewater treatment plant simulator consists of two independent modules: a) a *Screen-Oriented Modeling Interface* (**SOMI**) used to specify (graphically) the characteristics of the wastewater treatment plant, i.e., process models, connectivity, initial conditions, kinetic parameters, etc.; and b) an *Interactive Simulation Interface* (**ISI**) allowing the user to interact with the simulation (i.e., modify control variables and model parameters) as the simulation proceeds.

Developed on a SUN 3/160 workstation, the simulator is being ported to a number of other hardware platforms, including the Macintosh II and IBM-PS2 (80386) personal computers.

INTRODUCTION

Environmental engineers have always been interested in understanding the dynamics of wastewater treatment plants, whether it be the operation of a primary clarifier, the performance of a digester, or the dynamic response of a biochemical treatment process such as the activated sludge process. For many years, engineers and researchers have been developing comprehensive mechanistic models to describe the time-varying nature of such systems. With the advent of powerful multi-user/multi-tasking microcomputers and workstations, the full benefits of these models can now be realized through the use of a *General Purpose Simulator* (**GPS**), such as the one described in this paper.

A *simulator* differs from a *simulation model* in that a simulator allows the user to maintain full control of the simulation as the simulation progresses. In principle, a simulator is nothing more than an interactive simulation. In practice, however, the elements of a simulator can be quite complex and are a function of the objectives of the modeler, e.g., real-time control, operator training, design and analysis, etc. (Patry and Chapman 1989) The purpose of this paper is to describe the basic elements of a GPS for the analysis, simulation, and control of dynamical systems. While the GPS described herein can be applied to any dynamic system, the basic features of the simulator will be illustrated using dynamic models of wastewater treatment plants (Patry 1989).

BASIC ELEMENTS OF THE GENERAL PURPOSE SIMULATOR (GPS)

Because of the complexity of wastewater treatment plants, the general purpose simulator (**GPS**) should offer a high level of flexibility with minimal user training. With the advent powerful graphics-based microcomputers, the use of object-oriented modeling concepts can effectively be used to achieve these goals.

Under this approach, the user does not require any knowledge of programming. Instead, an icon-based modelling approach is used for the specification of the problem, i.e., components of the wastewater treatment plants, including properties and initial conditions of the processes (objects). The graphical (icon) description of the plant is then automatically translated into a high level language, compiled, linked and executed without any direct intervention from the user. Finally, execution of the model is initiated and linked to an on-line display and control system allowing the user to view the state of the system as the simulation progresses and providing him full control over all elements of the simulation, including model parameters, control variables, etc. The main building blocks of the GPS are shown in Figure 1.

SCREEN-ORIENTED MODELLING INTERFACE (SOMI)

System specification (Figure 1) is achieved through the use of a *Screen-Oriented Modelling Interface* (**SOMI**) designed to provide an icon-based approach to system specification. While the SOMI is problem-specific, the basic components are generally applicable to most dynamical systems. For the purpose of illustration, a SOMI for the specification of an activated sludge wastewater treatment plant is shown in Figure 2. The important components of the SOMI, include: a) the drawing board; b) the library of processes; and c) functional support.

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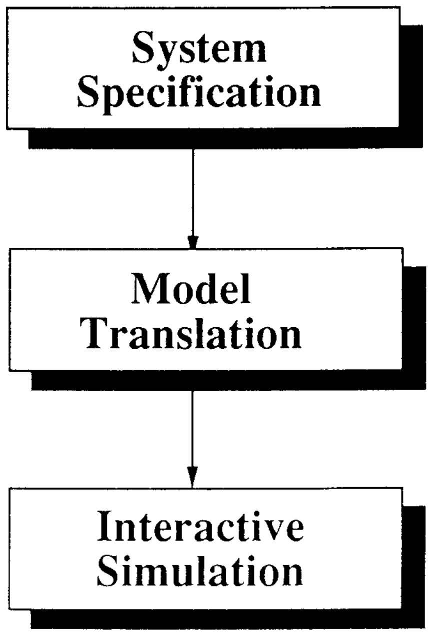

Figure 1. Basic Elements of the General Purpose Simulator

Drawing Board.

The drawing board is used for the specification of the elements of the system. For example, in the current application, a user specifies the sequence of wastewater treatment processes (liquid and sludge lines), along with their connectivity. Process parameters and initial conditions are specified by clicking on the process and entering the appropriate variables using the menu-driven window system.

Library of Processes.

A comprehensive library of treatment processes, written in ACSL (*Advanced Continuous Simulation Language*, Mitchell and Gauthier 1986), a Fortran-based simulation language, is available to the user. The library of processes includes:

- ✓ primary clarifier models (3);
- ✓ activated sludge models (10);
- ✓ secondary clarifier/thickener models (3);
- ✓ anaerobic digester models (3); etc.

Functional Support.

Finally, the SOMI provides a number of support functions to assist the user in the specification of the liquid and sludge line treatment sequences, including object manipulation, object (process) editing, printer support, etc.

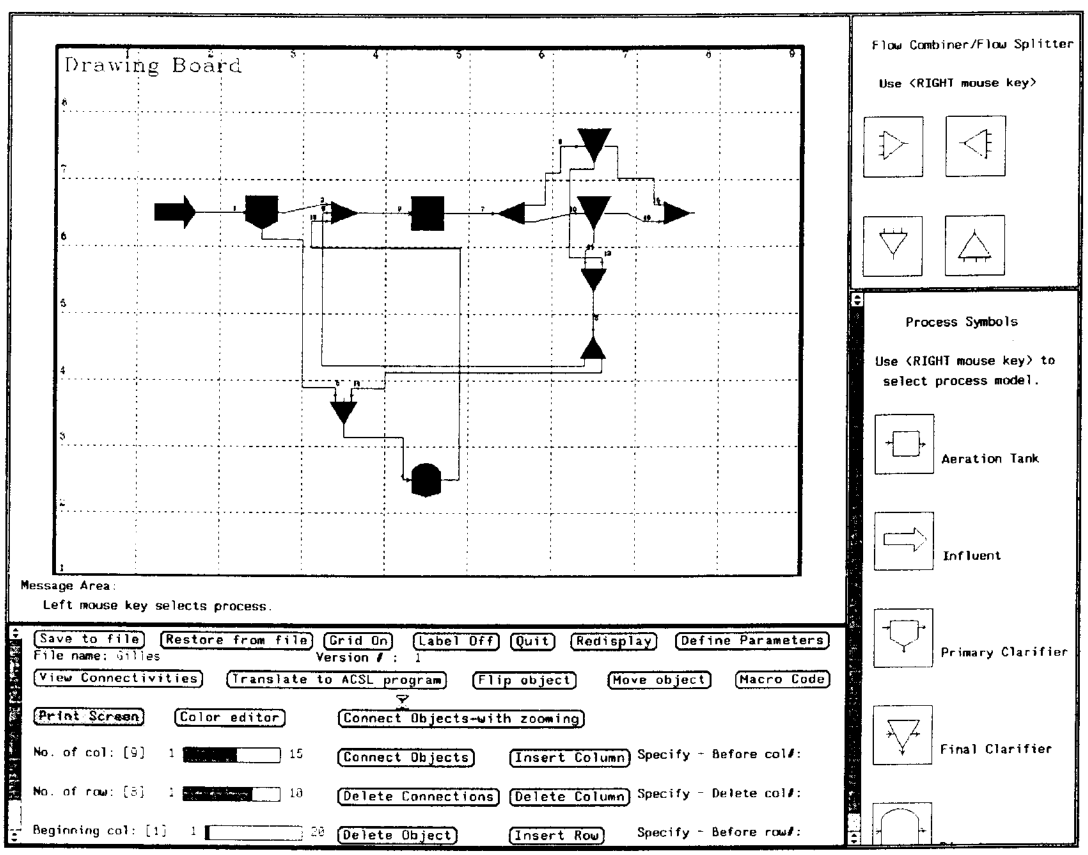

Figure 2. Elements of the Screen-Oriented Modeling Interface (SOMI).

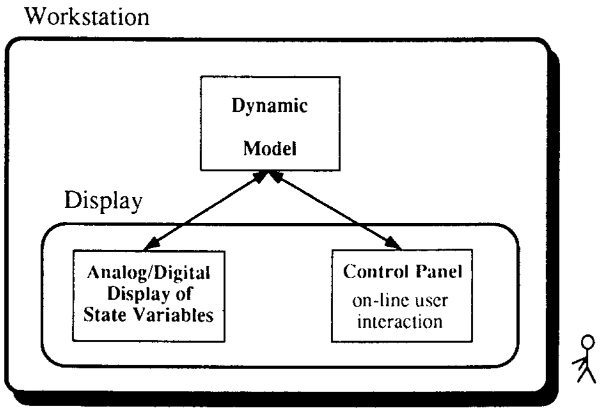

Figure 3. Integration of the dynamic model to the simulator.

INTERACTIVE SIMULATION INTERFACE

The general purpose simulator (GPS) provides the user with immediate feedback on the state of the system as the simulation progresses. This is achieved by integrating the dynamic model to the *Interactive Simulation Interface* **(ISI)** shown in Figures 3 and 4. However, in addition to providing on-line information on the state of the system through X-Y plots, digital dials, and analog charts, the GPS allows the user to interact directly with any of the model parameters, allowing him to change any of the control variables, or parameters, as the simulation progresses. The dynamic performance of a typical activated sludge process (Figure 2) is shown in Figure 4. For example, between days 3 and 5 (Figure 4), a hydraulic load is simulated by manually altering the flow to the plant. The response of the state variables (soluble substrate, nitrate and ammonia concentrations) to this change in flow condition is shown in Figure 4. Similarly, failure of the aeration system was simulated by turning off the air flow to the aeration tank between days 7 & 8. The resulting performance in state variables is obvious.

CONCLUSIONS

The potential benefits of simulators in the analysis, design and operation of water resources, in general, and wastewater treatment plants, in particular, are obvious. Such tools can provide a better understanding of the mechanistic basis of the models, in that they allow the user to appreciate the response of the system to changes in control variables. In addition, simulators can be used effectively for the calibration of complex models. Finally, simulators such as the one described in this paper can provide the bridge between theory and practice, allowing for efficient operator training.

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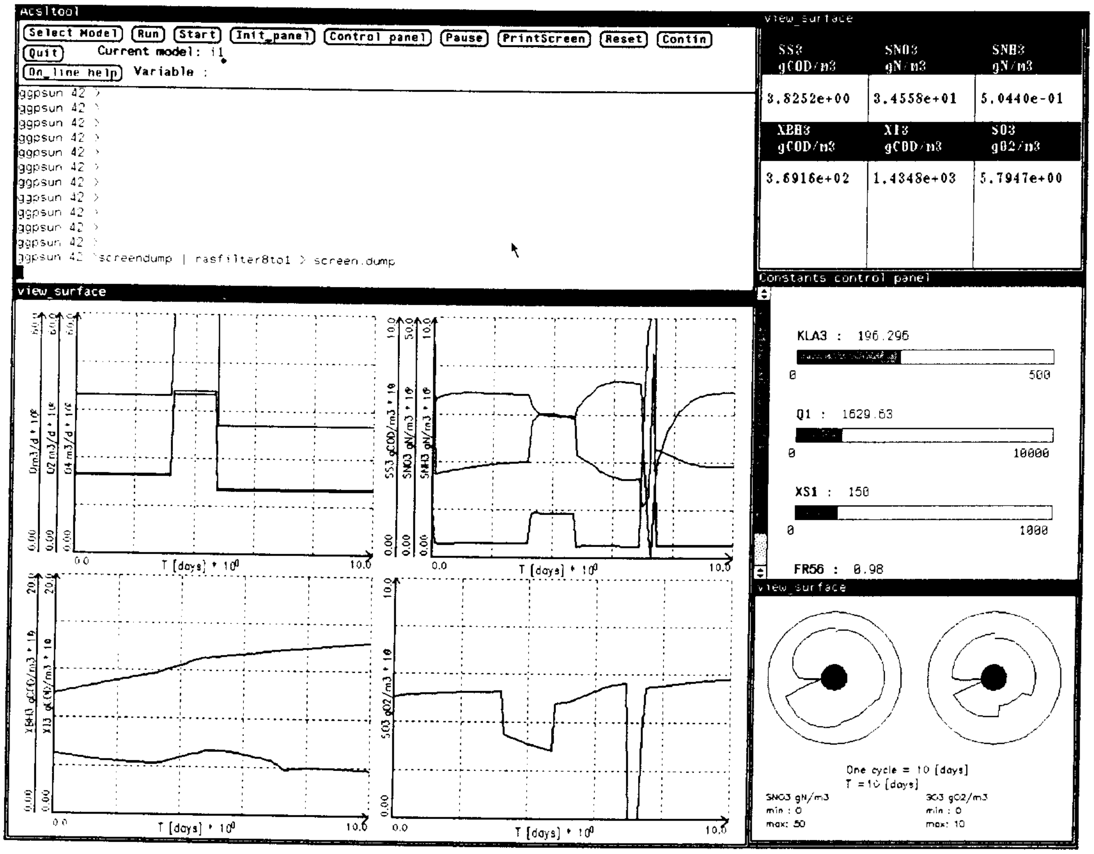

Figure 4. Interactive Simulation Interface (ISI).