SYSTEM DYNAMICS MODELING USING MULTIMEDIA

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ABSTRACT

System dynamics models are tools that allow one to explore the quantitative behavior of systems through time. However, real systems are usually multidimensional with both quantitative and qualitative variables. Recent developments in digital video and sound processing suggest the enhancement of system dynamic models with streams of images and sounds related to the systems those models try to represent. A framework to integrate systems dynamics modelling and multimedia technologies is proposed herein. A multimedia systems dynamics water pollution model is included for illustrative purposes.

INTRODUCTION

The main goal of a mathematical modeller is to support decision making with his/her mathematical models. Typically, these models attempt to describe a natural or artificial system and relate decision variables with impact variables. A set of values for decision variables defines a strategy; the set of impact variables composes the objective function.

Applying a mathematical model with such a structure, any decision maker can test strategies and, eventually, select the best strategy to be implemented. Unfortunately, they rarely do so because they mistrust models.

Models tend to not include the abstract and subjective system components, are often based on mathematical formulations that are not understood by decision makers, and their user interfaces are usually poor. In short, models tend to be removed from the systems they try to describe.

Multimedia technologies relying upon the digital processing of images, video and sound provide platforms for the development of models more realistic and easier to use. The interface of these technologies and system dynamic models is addresses herein with the goal of achieving that tight linkage between visual, auditory, textual and numerical representations that creates the feeling of immersion common to many computer games and virtual reality systems as discussed in Laurel (1992).

MULTIMEDIA TECHNOLOGIES

Multimedia technologies may be analyzed in two dimensions: multimodal interaction, consisting of computer interaction modes using the mouse, natural language, voice or gestures; and multimedia information, including several data types, presented concurrently and in a correlated manner Guimarães (1993).

The second dimension is the most relevant for the purpose of this work. The goal is to develop system dynamics models presented and used as multimedia documents. These documents have two major features: the integration of video and sound in addition to a system dynamics model; and a non-linear structure.

Video constitutes the most faithful means of recording the world of change Morrison and Morrison (1982). Video may be used to show backgrounds, point scenes or transitions. It may be natural or synthetically generated. Also, synthetic video may be superimposed on video images of natural sights. Video manipulation includes zooming, transitions (wipes, dissolves, fades) and highlighting Fox (1991).

The role of sound includes the reinforcement or replacement of visuals, conveying patterns and signaling exceptional conditions as discussed in Brown and Hershberger (1992). Stereo sound may also be used to provide the notion of space and sound icons to create movement or illustrate point scenes as shown in Gaver and Smith (1990).

The large streams of data resulting from adding video and audio can only be handled through compression and decompression mechanisms. Standards for data compression and hardware processing such as JPEG and MPEG are discussed in Fox (1991).

The non-linear structure comes from the typical representation of a multimedia document as a graph where each node contains information (text, images, video or sound). The nodes are connected by links, which help the user to move from one node to another. This is the classical structure associated to hypertext presented in Nielsen (1990) among others. Standards addressing the structuring of hypertext documents such as HyTime are also presented in Fox (1991).

SYSTEM DYNAMICS AND MULTIMEDIA

To achieve meaningful and enriching multimedia dynamic models one has to establish a relationship between the information limited numerical representation and the information rich multimedia model. While the numerical representation deals with level, rate and auxiliary variables, the multimedia model deals with image and sound objects.

To establish the relationship between variables and objects one has to analyze the system at the verbal description and causal diagram levels. It is readily shown that it is impossible to establish a direct correspondence between some variables and relationships between variables, and real objects. Mathematical modelling tradition is to penetrate behind the external appearances of phenomena and identify their underlying mechanisms. Instead of representing objects and their interactions, models tend to depict reality as a set of processes. The use of analogical representations, such as visual images of objects, is rarely adopted in mathematical modelling.

Even if one would adopt such analogical view, it is obviously difficult to obtain real images and sounds on the different system states through time. Finally, the coordination between the numerical and multimedia representations (windows) is a significant implementation problem as system dynamics models may produce substantially diverse results from slightly different initial conditions.

These problems are addressed herein from both methodological and implementation standpoints. To overcome the first problem, it is proposed to follow some of the lessons of movie making. Verbal descriptions of problems are movie scripts with actors (objects) that have roles. These roles include a definition of their behaviors and interactions (relationships). The more abstract relationships may be only expressed by voice or natural language. The parallel system dynamics model stems from the script skeleton: the causal diagram. At this stage, one has to establish the mapping between the image objects and the correspondent level, rate and auxiliary variables. The definition of sound objects should be directed towards the signaling of patterns and exceptional conditions that may arise in the system dynamic model run.

The multimedia model objects change through time. In principle, only the more significant changes should be displayed in the multimedia window using images or video, and sound. If for some of the meaningful events, real footage can not be obtained one has to resort to animation. Images of transitions may be achieved with popular morphing programs.

The coordination between the system dynamics and multimedia models is only possible, at this stage, by pre-defining the scenarios to be explored with the system dynamics model. For each scenario, every significant system change activates the pre-recorded video and/or audio clips.

Implementation of a multimedia system dynamics model was done in this case in a Apple Macintosh Quadra workstation using Aldus Supercard®. Video processing was achieved with Adobe Premiere® and sound editing with SoundEdit®. Similar tools are also available for DOS and Unix environments.

Future developments include extensive user testing to determine appropriate mixes of numerical, visual and sound information and the creation of an open multimedia platform. To accomplish this goal, one has to be able to run both the system dynamics and the multimedia model without a priori coordination. A possible method to solve this problem, involves extended cellular automata formulations and a sound generating scheme based on images.

APPLICATION

A simplified model was created to simulate the evolution of the Sado's Estuary area. Four major variables were considered in the model: population, industry, agriculture, and pollution (figure 1). Relations between these variables were established in order to translate the development of this particular area since 1960.

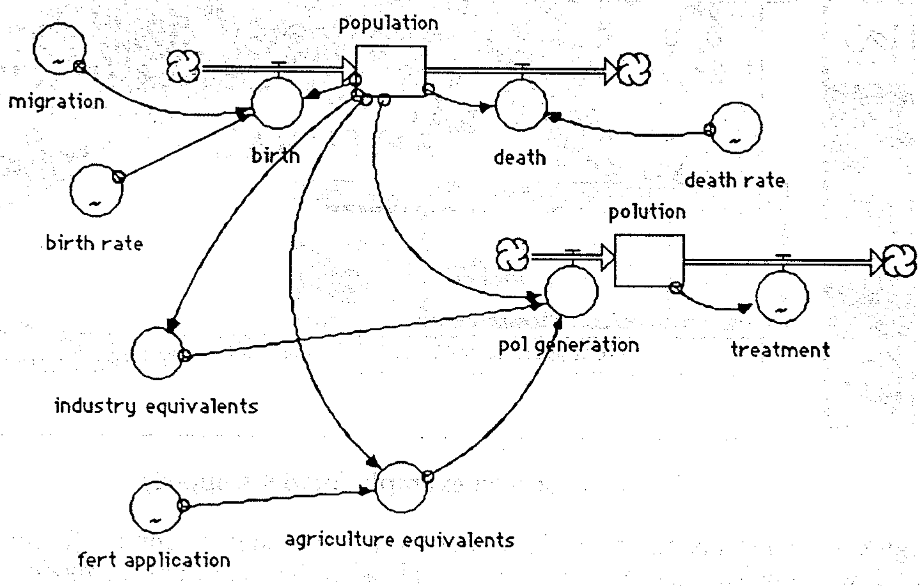

Figure 1. Model diagram

Each step of the model represents one year in real time. The number of steps to include in one run of the model are entered through the menu "Simulation". In this menu the simulation is set On or Off.

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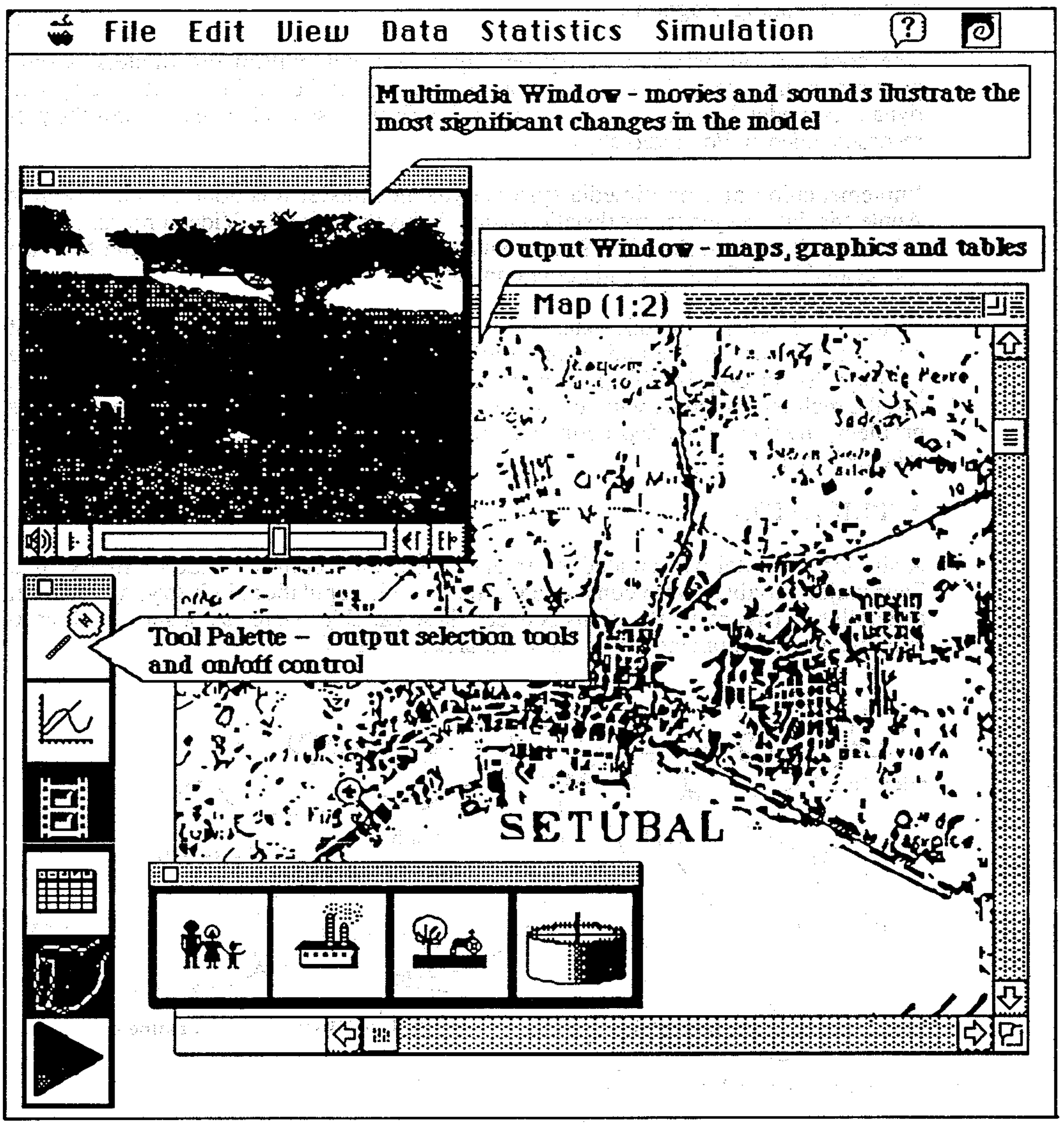

Figure 2. Screen example (model stopped)

Figure 2. represents one possible output while the model is running (in this case the windows shown are those which were visible after the last run of the model.
The Tool Palette, on the left side of the screen includes icons representing a zoom option (to be used in the map window) and an icon to stop or continue the running of the model (in this case the stop icon is visible). Other icons represent the output information to be presented which can also be selected through the menu "View".

After each run of the model the several optional outputs, if selected, are updated and shown on screen: Video clips, charts, tables and maps.

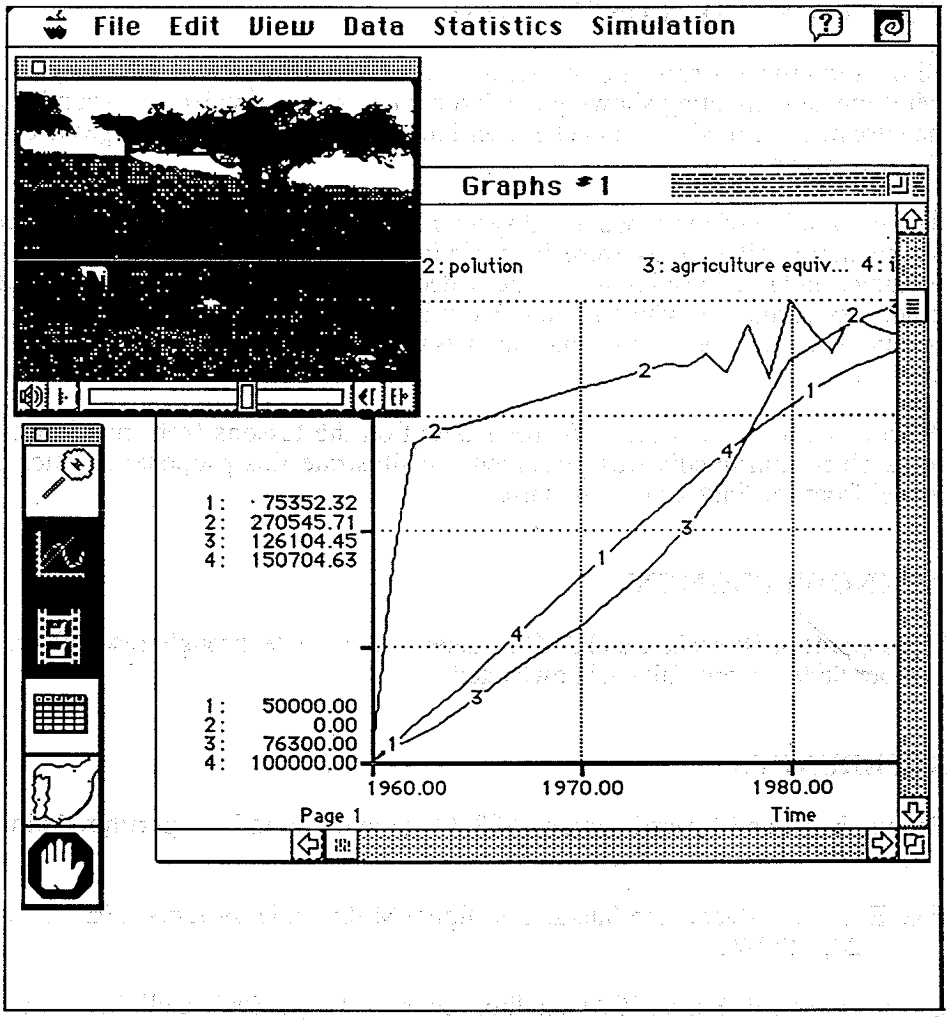

Figure 3. Screen example (model running)

In Figure 3 an example with two output windows is presented. One for multimedia information (like video clips) and one for the charts of the several variables modeled. Notice the tool palette on the left side of the screen. Both the map and charts icon are hilited, showing that these two windows are selected and presented on screen.

While the model is running it is possible to change the level of the variables modeled. For this it is necessary to stop the model run, through the Simulation menu or by using the tool palette. Whenever the model is stopped , another palette appears on screen. This palette contains four icons representing the input variables of the model: population, industry, agriculture and pollution. These input variables can also be selected through the menu "Data". Clicking each of these icons or menu items allows the user to input new values for the variables, its characteristics (e.g., several types of industries and water treatments) and location. Selecting the proper icon the user can insert water treatment facilities, and verify the corresponding multimedia effect.

After all the changes are finished the model can run again, using all the updated data.

SUMMARY AND CONCLUSIONS

Simulation models should be easier to use and closer to reality than they usually are. Multimedia computing allowing the digital processing of video and sound enables the development of models with better user interfaces and including images and sounds of the real systems.

The integration of multimedia and system dynamics modelling was discussed herein. Three major difficulties were identified: the mapping between system dynamics variables and relationships and image, video and sound objects; the inexistence of such objects covering the whole system evolution; and, finally, the coordination between system dynamics and multimedia windows in a multimedia system dynamics modelling environment.

A proposal to solve these difficulties based on the lessons from movie making and research in multimedia was presented. To illustrate this proposal a water pollution model from the Sado estuary was used.

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RESUME

ANTONIO da Nóbrega de Sousa da CAMARA
Born May 13, 1954 in Lisbon, PORTUGAL

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Licenciado in Civil Engineering (IST), 1977
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ACADEMIC CAREER

Assistant Professor, (New University of Lisbon), 1982-87
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MAIN RESEARCH PROJECTS

Principal investigator and co-principal investigator of seven research projects sponsored by JNICT and one project sponsored by the U.S. NSF in the areas of simulation, decision support systems and geographic information systems.
Principal investigator in the project "Water Quality Management of the Tagus Estuary", sponsored by the Ministry of the Environment.
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PUBLICATIONS

30 refereed papers published in journals such as Water Resources Research, Journal of Environmental Engineering and Journal of Water Resources Planning and Management, ASCE, Journal Water Pollution Control Federation, Water Research, Ecological Modelling, Annals of Regional Science, Journal of Environmental Management, Journal of Forecasting and Simulation.

SOFTWARE

Main author of the program "The Picture Simulator", used in universities and research institutes in the U.S., U.K., Germany, Holland, Belgium, Italy, France, India and Mexico.

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Invited lecturer at MIT, Cornell, Johns Hopkins, Rensselaer, Georgia Tech, Virginia Tech, Imperial College, Birbeck College, Free University of Amsterdam and at several workshops and conferences organized by the European Community, European Science Foundation and NATO.