Multimedia and SD Based Interactive Learning Environments: Increasing Perception of Causal and Structure/Behavior Relationships

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Introduction

System Dynamics Based Interactive Learning Environments (SDBILE) have proved to mitigate some of the most basic limits to learning by providing rapid, unambiguous, concrete and systemic feedback on actions taken, and a low-risk setting in which mental models can be explored and tested. They can reflect back assumptions, and provide insight into the nature of the complex interactions that determine the behavior arising from the user decisions, allowing to highlight effects that may be obscured in real life due to high systems complexity such as feedback, non linearities, delays and uncertainty.

It is commonly accepted that the learning potential of SDBILE´s is particularly advantageous due to its support to the perception of causal effects among the several components of the system under study, and the understanding of the feedback relationship existing between system's structure and behavior. However, tools addressing efficiently these relationships are still scarce among most SDBILE´s. The use of multimedia for creating richer and more realistic learning environments, by allowing to "examine the problem" before making decisions, has been acknowledged as a powerful feature. To be effective, multimedia should be incorporated within learning environments taking into account the importance of utilizing technology for a purpose, rather then being dazzled by it (Lane, 1995).

In this paper, generic multimedia tools are presented, which aim at enhancing the perception of causal relationships and structure/behavior feedback. The main objectives underlying such tools, development procedures, and simple examples of their application in a SDBILE addressing watershed management (Jordão et al., 1997) are briefly described below. Detailed information can be found in the virtual proceedings.

"Causal Travelers"

Understanding causal relationships among variables within a system and its consequent behavior has for long been one of the key issues in system dynamics. Richardson (1994) has, extensively analyzed causal loop diagramming, and its major problems. As the complexity of the system under study increases, so does the number of causal loops, and the more difficult it becomes to represent causal relationships among variables in a synthetic, understandable way. This problem turns even more relevant if we consider the limited space available "on the screen" to display information within SDBILE´s. The use of multimedia to direct the users attention to relevant causal relationships, without getting lost in complex diagrams, is the main objective underlying the development and implementation of *Causal Travelers*.

Causal Travelers are essentially animation's that allow us to "travel" within the loops or causal links of the system, in order to trace them. In their simplest form, *Causal Travelers* have key frames representing the system variables, linked in a video or animation with "cross dissolve" transitions. Polarity of the causal relationship is displayed within the *Causal Traveler,* so that the user can better perceive how a change in one of the variables is transmitted throughout the causal chain or feedback loop. Additional messages that may be transmitted within a *Causal Traveler* include "other factors remaining unchanged" so that possible effects from other variables that may affect the chain are also included. Enhanced *Causal Travelers* may include sound for the description of the causal relationship, as well as hyperlinks that allow the user to trace alternative loops.

An example of a *Causal Traveler* developed for the SDBILE under construction is presented in figure 1. The full animation can be seen in the virtual proceedings.

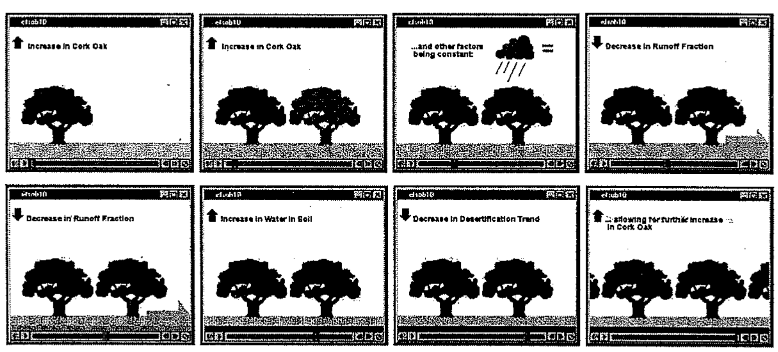

Figure 1 – ***Causal Traveler*** representing the causal effects of cork oak plantation in the water balance of an arid region.

"Dynamic Structure/Behavior" Windows

In order to allow better understanding of intimate relationships between systems structure and respective behaviour, Davidsen (1995a,1995b) has developed and incorporated in a business management simulator a combined tool featuring the simultaneous display of descriptions of behavior with the structural diagrams, whether causal loop, stock and flow, or hybrid diagrams. More recently, Vicente (1996) has developed tools such as the mass-balance display that are also of generic applicability for that purpose.

If the rate of change of variables within the learning environment is small, the use of such tools can bring up little additional information. Changes may be too small to be perceived in graphs, leading the user of the learning environment to direct his attention to those variables that have higher rates of change, which may not necessarily be the key ones driving the simulation.

Trying to overcome these problems, *Dynamic Structure/Behavior Windows* were developed. These rely on similar architectures to those described, but can be more efficient in representing infinitesimal changes among variables. The principle underlying these windows is to show only the direction of change that variables undergo every time step instead of their historic evolution for the duration of the simulation period. In their simplest form, *Dynamic Structure/Behavior Windows* are combinations of pictures representing the direction of change (positive, constant, and negative) and structural or causal diagrams.

The development of these windows calls for the incorporation of additional variables within the model, so that information concerning the evolution of the variables to be displayed can be obtained. The use of pipeline delays of one time step exemplifies this technique. Then, by considering the actual and previous value of the variable in question, the picture portraying the systems evolution (arrow up, equal sign, arrow down) is displayed within the diagram.

In more refined *Dynamic Structure/Behavior Windows*, the size of those pictures can vary, to reflect both the direction and magnitude of change. Additional features may include the display of the overall loop polarity, in order to facilitate the display of the dynamics of loop dominance during simulation.

A simple example of a *Dynamic Structure/Behavior Window,* incorporated in the SDBILE under development, is presented in figure 2.

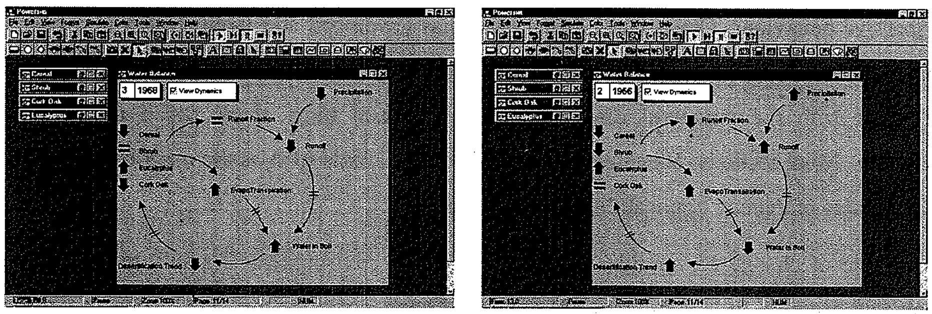

Figure 2 – ***Dynamic Structure/Behaviour Window*** for a sector representing effects between land cover structure and soil water balance. Symbols are updated continuously during simulation according to the evolution of the variables.

"Structure Look Up" Windows

Over emphasis of the technological elements of a simulation game can bias the importance associated with other elements of the package (Lane, 1995). But multimedia technology such as user friendly animation software designed to present additional information, directed to the issues at stake, can also, and should, be used to present information concerning the structural assumptions underlying the observed behaviors. Context sensitive animation's can be produced to reveal significant details, of relevance to the current simulation, namely by providing a "look up" at the systems structure.

This main objective can be accomplished through the use of *Structure Look-Up Windows*, in which animation's, text, and pictures are presented coherently from a systems perspective. An example of such window can be found in the virtual proceedings.

Acknowledgments

The authors wish to thank João Pedro Silva and Jorge Nelson Neves for their support in the development of videos and animation's. The development and presentation of this work was made possible through funding partially provided by Ph.D. Scholarship PRAXIS XXI/BD/5469/95 to the first author.