FORMULATION OF SYSTEM DYNAMICS MODELS

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ABSTRACT

System dynamics models are usually formulated from verbal descriptions of problems. To define such models, one maps the verbal descriptions into a set of equations. This mapping process remains much of an art despite the use of causal diagrams, to extract from the verbal descriptions the variables (nouns or noun combinations) and the direction, degree of dependence and polarity of the relationships to be included in the simulation model. This paper presents an attempt to formalize the translation of verbal descriptions into causal diagrams. The proposed methodology is based on the decomposition of the text into a sequence of inferences. All the nouns and adjective-noun combinations in each inference are then identified and inserted into an adjacency matrix to facilitate the selection of the relevant variables and polarized relationships by the modeler. Implementation of this method on a computer is discussed. A preliminary solution is presented. The description of a simple environmental impact problem is mapped into a causal diagram using the proposed approach for illustrative purposes.

INTRODUCTION

Verbal descriptions of problems are the basis for system dynamics models. From those descriptions, diagrams including variables and directed relationships between variables can be derived. System dynamics equations are then defined from these diagrams. Both the diagrams and the equations are part of the modeling effort, which often is done by someone who is not the expert that wrote the description.

The process of synthesizing the problem protocol into a diagram becomes, in these instances, a source of potential conflict. Diagrams may not fully capture the information richness of verbal descriptions; and these may be not conveniently structured, they may be redundant or insufficient.

These conflicts arise from the subjectivity still associated with diagram drawing. This paper presents an attempt to insert some objectivity in the process. A simple application is included for illustrative purposes.

PROPOSED METHODOLOGY

Hayes et al. (1977) and Hayes (1981) proposed that a problem solver should extract the information from a verbal description of the problem by grammatical and semantic analysis and then construct a representation of the problem that is adequate for its solution. Hayes (1981) agreed that a graph representing variables as nodes and 0-1 relationships as directed arcs is, in general, such a representation. However, little is said by these authors on how to perform the text analysis and define the diagram.

Text analysis has been the subject of considerable work in the cognitive sciences with related although somewhat different goals. This work has foccused on story summarization and understanding, yielding interesting ideas on how to decompose a text in "units" and then connect those units in a summary or a graph (Anderson, 1976; Black and Bower, 1980; Kay and Black, 1986; Kintsch and Van Dijk, 1984; Schank, 1975), or in a sequence of inferences (Thomas, 1986), while maintaining the structure and content of the original text.

These ideas underly the proposed methodology to derive a causal diagram from a verbal description, which includes the following steps:

- Break down the description into a series of inferences by looking for inference indicator words (i.e., because, thus, then) or modal words (i.e., must, can, can not) (Thomas, 1986). This procedure may help the decomposition of large texts into a discrete number of units.

- Scan for variables in each inference, by looking to nouns, adjective/nouns and other combinations involving nouns (Richardson and Pugh, 1981).

- Develop an adjacency matrix (Cristofides, 1975) with the entities previously identified. These matrices are denoted by A= [aij] and:

- aij=1 if the value of xj depends on the value of xi and the polarity of the relationship is positive.

- aij= 0 if xi is not related to xj.

- aij= -1 if xj depends on xi and the relationship is negative.

This pairwise analysis allows one to infer from the text all the directed relationships and their polarity. The process will make clear which are the inconsistencies in the verbal description.

- Translate the adjacency matrix into a causal diagram. This diagram will then be used in the writing of the model.

APPLICATION

The application of the proposed methodology can be illustrated by a description of the environmental impacts of the Torrao dam, which will be built in Amarante, Northern Portugal. Environmental impact assessment is a task where, often, reports by experts have to be synthesized by modelers.

The Torrao dam problem can be stated as follows:

"In Amarante, social stresses are being generated over the construction over the construction of the Torrao dam.

The water volume required for this dam will increase the local humidity and destroy many river ecosystems, **thus** reducing leisure activities, which will also be affected by the expected reductions in fish species diversity. Important reductions in regional income are anticipated **due to** the considerable patrimony to be flooded.

Water level oscillations will also produce accumulations of litter in the town margins, endangering public health **as a consequence**. Nevertheless, the dam will have beneficial impacts, mainly in terms of electrical production, which will increase the regions's income.

The assessment of the dam impact in terms of income, local humidity, leisure and public health, expressing a regional welfare status, is perceived as a required step before any decision on the Torrao dam construction".

To develop a causal diagram for this model, the text was browsed searching simultaneously for nouns, indicating variables, and also for inference indicator words. In the verbal description, the underlined words are the identified variables and the inference indicator words are represented in bold.

The adjacency matrix that was built to identify the relations between variables is shown in Table 1. The causal diagram that was derived from this matrix is presented in Fig. 1.

As with other applications of the proposed method, the diagram will be the primary tool for both the expert and the modeler to discuss the validity of the text synthesis into a graph. The use of systematic procedures for identifying variables and polarized relationships enhance the possibility of reaching a more consensual diagram and thus a better system dynamics model.

SUMMARY AND CONCLUSIONS

The derivation of causal diagrams from verbal descriptions is an essential step in system dynamics modelling. This paper attempted to show how one can reduce the process subjectivity.

The selection of variables, by identifying nouns, and the definition of relationships, by using an adjacency matrix, are the main concepts underlying the proposed methodology. A simple environmental impact assessment model was formulated to illustrate the approach.

Table 1

Adjacency Matrix for the Amarante Dam Model

	Dam	W Vol	L. Hum.	R. Ecos.	Leisure	F.S. Div.	Income	Patr. Fl.	Oscil.	Litter	Pub. H.	Prod.	Welfare
Dam		1				− 1						1	
Water Volume			1	− 1				1					
Local Humidity													1
River Ecosistems					1								
Leisure													1
Fish Species Div.					− 1								
Income													1
Patrim. Flooded							− 1						
Oscilation										1			
Litter											− 1		
Public Health													1
Production							1						
Welfare													

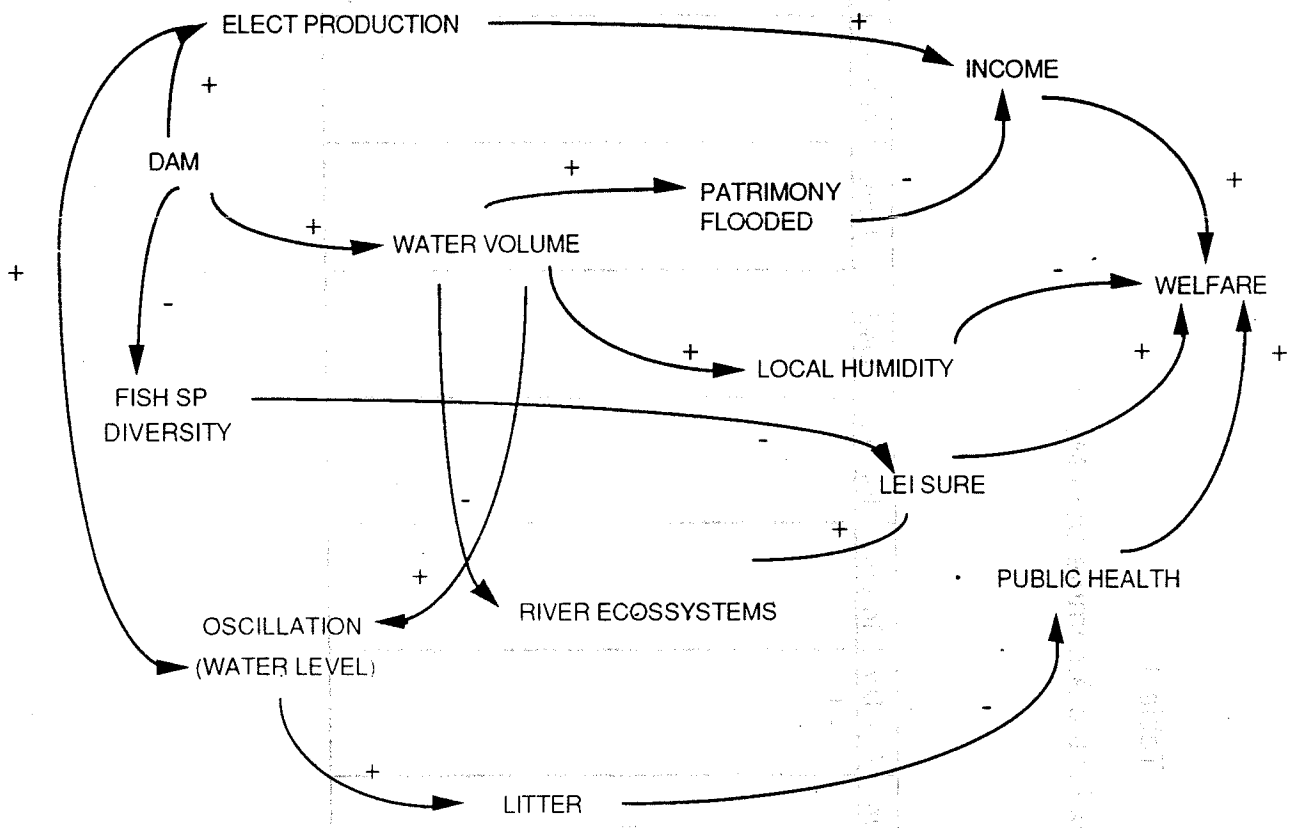

Fig. 1. Causal Diagram of the Amarante Model

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