SYSTEM FORMALITATION AND MODELS BUILDING

(An approach to Zeigler's view through a University/Unemployed model)

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In this work, we examine advantages of formalization, and specially Zeigler's system formalization, relating it to the most fundamental concepts used when building models with System Dynamics (SD). This is exemplified through the University/Unemployed model. We finish talking about the relations between model, theory and system concepts[1].

I. THE SENSE OF FORMALIZATION IN SYSTEM DYNAMICS METHODOLOGY

If we formalize any speech, we assign it some logical or mathematical structure in the hope that the exact and completely explicit relations and properties of this structure represent adequately the conceptual relations and properties that intuitively articulate that speech.

When we formalize a theory, we discover fundamental morfisms between its different versions and between it and other similar theories. We eliminate the superficial characteristics, the unnecessary suppositions, and select its essential structure. The formalization of a theory facilitates the work of analysing objectively which are the minimal necessary assumptions to formulate it. To formalize a family of scientific concepts is a way to explicitate their epistemologically relevant meanings. The conceptual clarity is a necessary requirement to use successfully a piece of knowledge. Therefore, the formalization is not an extrinsic task for the sustantive scientific activity whose products are going to be formalized. The formalization of scientific theories, with the help of logic or with the set theory procedures, has

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decisively contributed to the scientific development in very diverse areas such as the probability theory, the quantum mechanics, the learning theory, the special theory of relativity or the economy.

What is the sense of formalizing the basic concepts involved in a methodology as distint from formalizing theories?

In a methodology, like SD models building methodology, the most important things aren't the deductive and inferential relations among determinate propositions, as when we formalize theories. Here, the really important one is the semantics preciseness and correction of the concepts that constitute the fundamental basis of application of that methodology. The formalization of these concepts must offer their meaning in an explicite and rigorous way. Exactly this is what we do when we define something. While the formalization of theories looks for the deductive structures, the formalization of methodologies mainly goes towards the formal definition of certain concepts.

An usual way to make formally clear a concept is to assign it a conjuntist predicate. For that reason, the set theory language, and not the inferential language of logic, becomes completely adequate for the formalization of methodologies. Also, the formalization of SD methodology must be directed towards the exact definition in conjuntist terms of its more basic concepts. For example, the concepts of system, model, specifications of a system, system structure and behaviour, simulation, etc.

In a general approach, BUNGE (1979) has proposed a suggesting formal frame able to clarify many of these concepts, specially the concept of system. But his statements are developed in only one level. The various specifications or models we can build from a real system and the complex relations among the real system, their models and the special operation of simulation, need of a more detailed analysis. ZEIGLER suggests a multi-level hierarchy of system specifications, attempting to formalize these concepts.

II. ZEIGLER'S FORMALIZATION AND SYSTEM DYNAMICS

ZEIGLER (1976, 1984a and 1984b) considers a model as a possible specification of a system and, from that, he reviews the hierarchy of levels in which a system can be specified. The two hierarchies that he establishes (first in 1976 and later in 1984) are different in some aspect, but, in general lines, he begins them with the lowest levels, like those of "black box", and goes up to rise multicomponent systems.

The most interesting thing, for our purposes, is that if we examine them from top to bottom, each upper level represents a structure whose behaviour is represented at the one immediatly lower. Reversely, if we examine them from bottom to top, we can see them as a description of system modelling process: you have a reference mode, a behaviour-mode, that must be explained by a structure.

The first levels in the 1984 hierarchy -Observational Frame (level 0), Input/Output Relation Observation (level 1) and Input/Output Function Observation (level 2)- represent observation data. The behaviour of a system is described in them, without any explanation about the reason of its behaviour. These, specially the level 2, will represent what we normally understand by reference mode or data to contrast a model. Those facts that we have and from which we try to build a model. For example, in the model we have in this paper, about the influence that the number on unemployed of a specific graduation has on the number of student registred in this same speciality, the reference mode could be the more or less exact statistics that you have about the number of unemployed people of some carrier, like, for example, Pedagogy. From those and from others, like those about the number of matriculated students, a model,that explains the implications of those data between them, can be constructed. At the time of building a model, or this concrete model about which we are talking, we try to make it adequate to explain the reference mode that we had. Also, these data are going to allow us to test the model.

In ZEIGLER's 1984 hierarchy, we saw the reference mode associated with the three first levels, specially with the most complete of them, level 2 named Input/Output Function Observation, because the other two, levels 0 and 1, will represent degenerated reference modes.

Once the model is built to explain the reference mode, we have ascended a step in the hierarchy and explained this behaviour through certain structure. Now, in this following level, we can find the structure of a system. Here, a set of internal states appears. In ZEIGLER's terms, this set is named Q. Already, we are building properly a model of a system and not only a model for its observational data. Q is useful to explain how the system memory, the past behaviour, affects its future outputs. In SD, these internal states are properly specified by the " level variables". This facilitates the simulation and permits us to explain, for example, the "delays", like that of the our model EDU-2 (see DYNAMO equations) between the number of unemployed of a specific graduation and its influence in the number of students registered in the same speciality.

The set of states Q is a concept of models building that needn't have any real correlate. The only important thing is that in this concept we introduce all the information that allows us to account for the system behaviour and simulate it. At this level of ZEIGLER's hierarchy, we are not limited to observe the system, but to explain it and to predict future behaviours. Now, we have two of the most important tasks in the models building proccedings: 1) to account for a concrete behaviour-mode, building a model that can produce and explain it, and 2) to predict future behaviours of which we have not observations (In the end, this lead to qualitative analysis of the model).

In this paper we show a model about the dynamic relations between the registration in a specific graduation and the unemployed people in this same graduation. It is a specification of a system in which a certain structure is supposed. In a first version, EDU-1, the clip that controls the number of students registered, was not included. In EDU-1, PE and VPR can grow in a great proportion (figures 1,2 and 3). Both versions are built on plausible but hypothetical data for its later application to concrete situations. So, after building EDU-1, we try to ensure that PE and VPR remain among certain stable values and to control their explosive behaviours. The number of students registered is drastically reduced to a maximun of 1000, i.e. if they exceed this number, only 1000 could be registered. In this simple way, we succeed in stabilizing the number of unemployed at the same time as the number of students (figures 4, 5 and 6). At this point, we could apply EDU-2 to real data and try to control concrete educational systems.

In the qualitative analysis of EDU-2, it must be noted that it depends to a great extent on its "table". Very small variations here can produce important oscillations in the result of the simulation. Also, in a sensitivity analysis, we can see that EDU-2 is very sensitive to small relative variations in the values of the exogenous variables. When these two variables have very unlike respective values, those remarkable qualitative oscillations are obtained.

III. UNIVERSITY/UNEMPLOYED MODEL (DYNAMO EQUATIONS AND SOME VIEWS)

We show all the DYNAMO equations for EDU-2. Without the CLIP, we obtain EDU-1. Figures 1, 2 and 3 correspond to EDU-1 most important views; and figures 4, 5 and 6 correspond to EDU-2.

L PE.K=PE.J+(DT)(FPE.JK-FPG.JK-FPF.JK) PE is the number of registered students in a specific graduation X

N PE=PEI

C PEI=12948 PEI is the initial number for PE

L PG.K=PG.J+(DT)(FPG.JK-FPD.JK) PG is the number of graduated students in X

N PG=PGI

C PGI=4000 PGI is the initial number for PG

R FPG.KL=(PE.K-(PE.K*TDN))/TDC FPG is the PG rate

C TDC=11 TDC is the average duration of graduation X

R FPF.KL=PE.K*TDN FPF is the rate of failures from PE

C TDN=0.32 TDN is the ratio of normal failure in X

R FPD.KL=PG.K/TVM FPD is the rate of mortality

C TVM=40 TVM is the average laboural life

R FPE.KL=CLIP(TCA,B.K,C.K,D) FPE is the PE rate

C TCA=1000 TCA is the control constant for PG

C D=1001

A B.K=EPE.K*TPM*TRP.K

A C.K=EPE.K*TPM*TRP.K

E EPE EPE is the exogenous for the total student population

C TPM=0.4 TPM is the intrinsic motivation ratio towards X

A RPA.K=DELAY3(VPA.K,TR) RPA is the delay in the social recognition of VPA

C TR=8 TR is the normal ratio of registration in X

A TRP.K=TABHL(TRPT,RPA.K/TPP,0.5,1.5,0.5)

C TPP=100 TPP is the recognized unemployed ratio

T TRPT=1.2/1/0.3

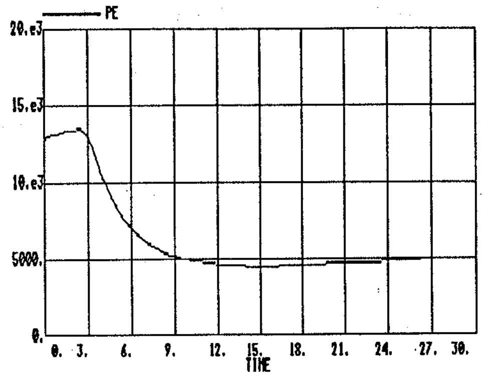
A VPA.K=VPR.K*TPA VPA is the number of unemployed in X that are working in something different to their specific graduation

C TPA=0.8 TPA is the ratio of VPA

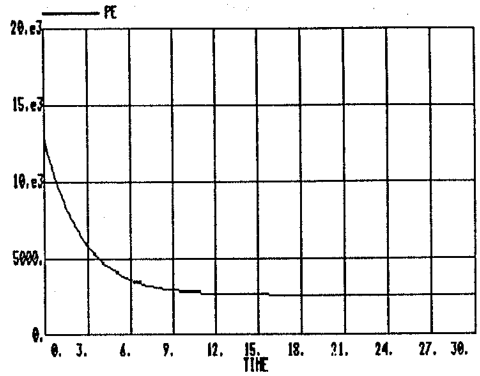
A VPR.K=PG.K-EDG.K VPR is the total unemployed in X

E EDG EDG is the exogenous social demand of graduates in X

A PPA.K=(VPR.K*100)/PG.K PPA is the ratio of unemployed in X



(Figure 1)



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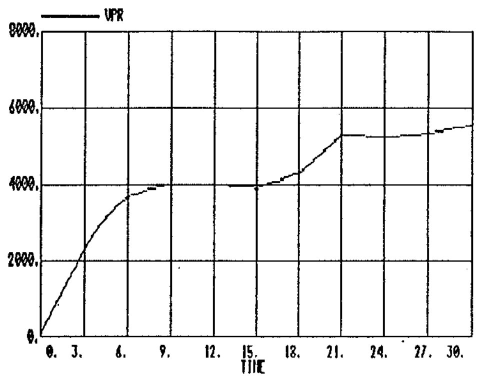

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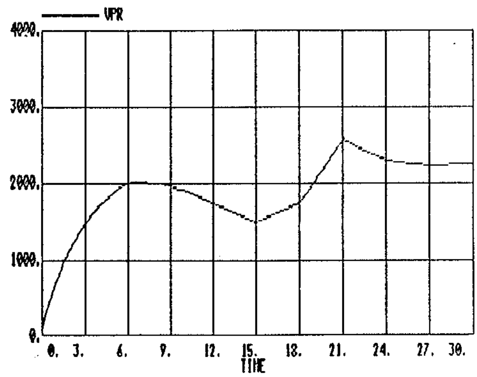

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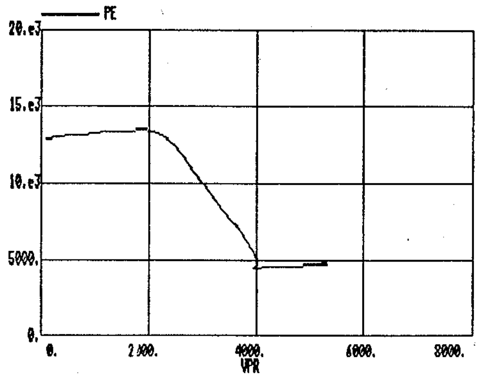

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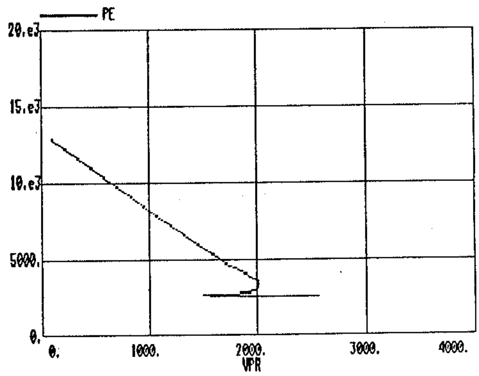

(Figure 6)

IV. RELATIONS BETWEEN THE CONCEPTS OF MODEL, THEORY AND SYSTEM

Zeigler's concept of model seems to clarify well the intuitive concept of system used in SD. But, this is not the only possible use of this concept. In logic and philosophy of science we also talk about models in a very precise and developed sense, linked to what is known as model-theory. In model-theory, a possible realization or interpretation in which all the valid statements of a theory T are satisfied is called a model of T -TARSKI (1953)-. We could reformulate this definition in more familiar terms saying that if a system works or behaves in the way a theory indicates, if in it we obtain all that the theory says, then this system is a model of this theory and the theory is true about that model. We must obtain all that the theory says, but it isn't necessary to obtain only this. The model can have a much more complex structure than necessary for the verification of the theory. So, it can be also a model for other theories. This will often happen in models such as those of SD. In philosophy of science there is a strong tendancy -see, for example, SUPPES (1960) or MOSTERIN (1984)- to maintain that the concept of model used in model-theory is the fundamental and basic concept required for an exact formalization of any branch of the empirical science, and that the other concepts of model are derived from it. In any case, we think that it will be very advantageous to achieve an adequate conceptual relation between the two above mentioned uses of the concept of model (there are other uses of "model", for example, as synonymous of "paradigm", but they are unprecise and metaphorical). At least, this would be a specific important problem for formalization in this field. And ZEIGLER doesn't say anything about that. At this point, we suggest two intuitive definitions -based on some ideas of MOSTERIN (1984):

1- System A is useful as a <u>technologically adequate model</u> (TAM),in the sense of "model" used in SD, for system B if and only if 1) A is equal or more known than B, and 2) a description exists of B which can be isomorfic with A.

2- System A is useful as an <u>epistemologically adequate model</u> (EAM), in the sense of "model" used in SD, for system B if and only if 1) A is equal or more known than B, 2) a scientific theory T exists, or could exist, from which A is a model in the model-theory sense of "model", and 3) B is also a model of T in this last sense (So, system B will be adequately represented by system A and T in some of its characteristics. It is important to point out that this relation of representation isn't necessarily an isomorphism. Normally, it will only be a homomorphism).

These definitions would be effective to make interesting remarks such as the following: (1)- We would epistemologically reject models that, although they serve as TAMs (always in the "model" sense used in SD) aren't models of any possible scientific theory (in the model-theory sense). (2)- If system A is useful as an EAM for system B, a possible description of B must exist, which can be isomorphic with A. Therefore, A will be useful too as a TAM for B. That is, every EAM is also a TAM, but not every TAM will be, only for that, a EAM. (3)- TAMs will be "valid" models in ZEIGLER's sense -ZEIGLER (1984:80-90). The description we do of B capable of maintainig the isomorphism with A (which the definition 1 demands) is obtained from the experimental restrictions under which B offers its characteristic behaviour-mode. (4)- To have conceptual systems (differential equation systems, computer programs, etc.) or real systems (simulators, prototypes, etc.) which are useful as TAMs for others systems, and with which we can control them, design them, etc., must not obstruct nor be incompatible with the building of conceptual or real systems that also are useful as EAMs for those systems. We can control the reality without knowing it completely, and we can know it without being able to control it (this makes an important difference between Science and Technology). But, any capacity of control must, in some way, entail the possibility of increasing our knowledge of that piece of reality we control. In short, the way to work in a methodology often linked to pragmatic and instrumental concerns, such as the SD, can't allow us to forget the realistic claims of our more selective knowledge.

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