Notes on conceptual distance in simulation using the *POLIS* model as a basis for discussion

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0. Abstract

The paper deals with an extension of the POLIS modeling process that concerns war-vessel type dynamics. The study provides an opportunity for considerations on conceptual distance in SD models. We address the question with by stating that a complex system cannot be simulated by an invariant model and that its changes require adjustments in the conceptual distance which can also imply the treatment of discrete events. The models of Kuhnian theory suggested by the literature allow us a comparison for concluding that the POLIS approach could be of more interest in the simulation practice of complex systems.

1. Introduction

The POLIS modeling process was born from the idea of a unitary explanation of the different patterns recognized for the ancient Mediterranean city-states. The system approach to activities at sea and the historiographic interest in simulating the past are effectively combined in the model development, two phases of which have been already received at SD Conferences (Piattelli *et al.* 1994, Piattelli and Coyle 1995). According to the aim of this paper, relevant features of these two steps are the dual-built-in model for simulating the behaviour before and after the saturation of soil resources, and the treatment of discrete events together with a continuous transient submodel for solving the discontinuities.

The POLIS extension presented here[2], deals with the dynamics of war-vessel type, providing a cue for considerations about conceptual distance, discrete events and structural changes. Briefly, the rationale of this extension pre-sets four vessel types in the simulated period and some constraints for each transformation. It appears useful for a general consideration because:

- there is a socio-cultural model at the macrolevel of aggregation, which offers a flexible scenario for treating specific processes, such as the above one, at the microlevel;
- both levels include discrete events as start and end points of the transient;
- the war-vessel type is a state variable, which changes its quality and produces quantitative changes in the parameters.

The discussion on these items leads to a suggestion for approaching complex systems in the simulation practice.

2. About conceptual distance

All the above items deal with conceptual distance in modeling. The structure at the aggregation macrolevel is obtained by the maximum distance, which however includes the most significant processes.

In POLIS these processes concern the dynamics of population classes and their savings, also due to produce, consumption, trade and war, but the war-vessel number is not treated as a level. The distance has been reduced for simulating more polises in a conflictual scenario, mainly addressing the transient from the migration to the birth of a new polis and the outcoming naval battles. This last model requires the vessel number as a level.

For focusing on the dynamics of vessel type, the conceptual distance is again reduced and four new levels, the considered types, are introduced[3]. *Plot N. 1* shows the related example. In this case there are two changes in vessel type. At this microlevel of aggregation, the dynamics in the merchant fleet is also necessary for the evaluation of sea power, i.e. the relations of the city-state with the sea. Therefore two other variables are added: number and average size of ships. The resolution is evident in *Plot N. 2*, considering that the number of ships is double-smoothed by the information on trade and transportation demand[4]. At the end of simulation the economic crisis causes the disappearance of both war and merchant fleets.

Obviously the microlevel submodels are not included in the main model if not relevant for the purpose of the simulation.

3. Discrete events and the dynamics of war-vessel type

Some authors, R.G. Coyle (1985) for example, show that SD is usually far more flexible than FORTRAN in modeling discrete and random events. However, a discrete event in an SD model is considered, according to the continuity principle stated by Forrester, as the signal of a wrong choice in the conceptual distance.

The POLIS rationale treats migration as a discrete event because migration and its outcome, the birth of a new polis, are historical discrete happenings. From a more general point of view, if the modeling process is conceived in a hierarchy of different aggregation levels, surely there are levels where discrete events must be considered.

Furthermore, POLIS treats the discreteness by a starting event and an end event, connected through a continuous transient submodel. When the transient is over, the model returns to the main one with initial values different from the final ones at the starting event and eventually with different parameters.

The evolution of socio-cultural systems can be explained (Dechert 1968) by periods of continuous trend, between which a discontinuity changes rules and parameters. The fundamental problem of uniqueness in history could then be approached by saving both the deterministic path of the past and the open *multi-furcation* of the future.

The literature about the related models deals with "self-organizing" systems, i.e. capable to change their structure. POLIS appears to be a very preliminary step in this way.

The theoretical and practical problem now becomes if and how the structural changes could be preset in the model.

Let us now reconsider the cue example. The starting event for the type change depends on some constraints: a minimum number of vessels of the current type according to the naval strategy; the disappearance of the type preceding the current one; and the technological level.

Then a transient begins, during which only the new type is built. This is over when the old type disappears due to the seasonal war loss (the expected life of a war-vessel is here about ten years). The parameters change continuously during the transient, until new steady values are reached. The change is asymmetrically reversible: if the current type is no more supported by the technological level, the cycle starts again from the first type.

4. A comparison with the Kuhnian models

Let us compare our case study type (war-vessel types) with the Kuhnian models of science paradigms (Sterman and Wittemberg 1993). Plots for each war-vessel type show the same qualitative behaviour of the paradigm. The following differences are found: first of all, paradigms are not simulated in a plausible scenario, they are isolated variables the birth of which only depends on random noise; furthermore there are no submodels for managing the transients; finally, there are no changes in the model due to a new paradigm.

Surely the Kuhnian models are conceptual experiments, but the POLIS approach seems to be more useful in simulation of socio-cultural systems.

However, our example still appears limited because both type changes and their sequence are preset; therefore this predetermination prevents us from obtaining news by simulation. In general simulation practice, however, it seems to be very difficult, if not impossible, to avoid change predetermination, while presetting sequences can be avoided.

As an example, let us consider that there are few basic political systems and, even if some sequences appear to be more probable, however from history, the future sequence can be obtained without predetermination.

The discontinuity or critical point or start event can be produced in the continuous evolution by endogenous or exogenous causes or by both.

In POLIS a new colony is an event due to endogenous causes in the mother city-state and the whole model; however it acts as exogenous input for the enemy city-state model. In this case there is a double bifurcation: whether the conflict occurs or nor; if so, only one party is the winner. Even this simple example produces three possible sequences, among which the resulting one is not preset.

In this case, however, at the end of the sequence there are no changes in the model structure, but in its parameters only.

The continuous transient between two discrete events depends on the final model to be reached, but this can also be provided by exogenous or random inputs during the transient itself. That is again a matter of conceptual distance: by reducing it, the transient can be treated by the same approach suggested for the whole evolution in the presence of discontinuities.

5. Conclusions

The literature on SD offers mainly tailor-made applications related to particular jobs, together with theoretical approaches, as in the Kuhnian models case. There are no examples of discontinuities in evolution, which changes the structure of the model.

The POLIS modeling process has been conceived as a laboratory for experiments on complex systems by taking into account both discrete events and structural changes. For clarifying the topic, the following step will concern the political transformations in the ancient city-states. SPARTA and ROME will be simulated in comparison, because both show a similar behaviour: a former period of growth, according to the general POLIS conceptualization, after which a discontinuity produces a change. SPARTA becomes a closed system characterized by high social stability, while Rome reaches a similar stability by an imperialistic behaviour. However, in both cases, the key of stability concerns the war activities and their social effects.

6. Notes

1. Nicola Bianchi <bianchi@cst.ge.cnr.it> is with the Center for the History of the Technology of the Italian Research Council (CNR), where he is running the research project "Modelling and Historiography".
2. The POLIS model written in COSMIC (a DYNAMO-like language) is downloadable from this URL: <ftp://area.ge.cnr.it/pub/cst/M&S/Polis/src/>.
3. The considered war-galley types are: triaconter, penteconter, bireme and trireme; the last one does not appear in the example.
4. Peculiar feature is the transformation of money values of produce and consumption into the burden transportation demand, solved by data from Forbes (1956, second part, chapter 4).

7. Bibliographical references

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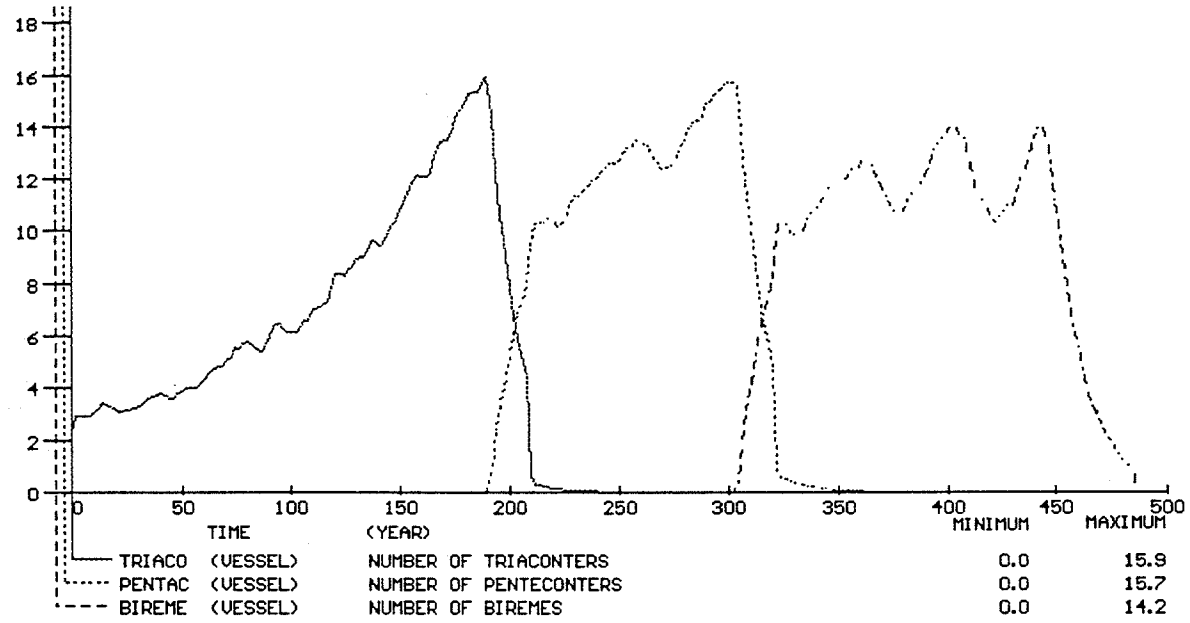
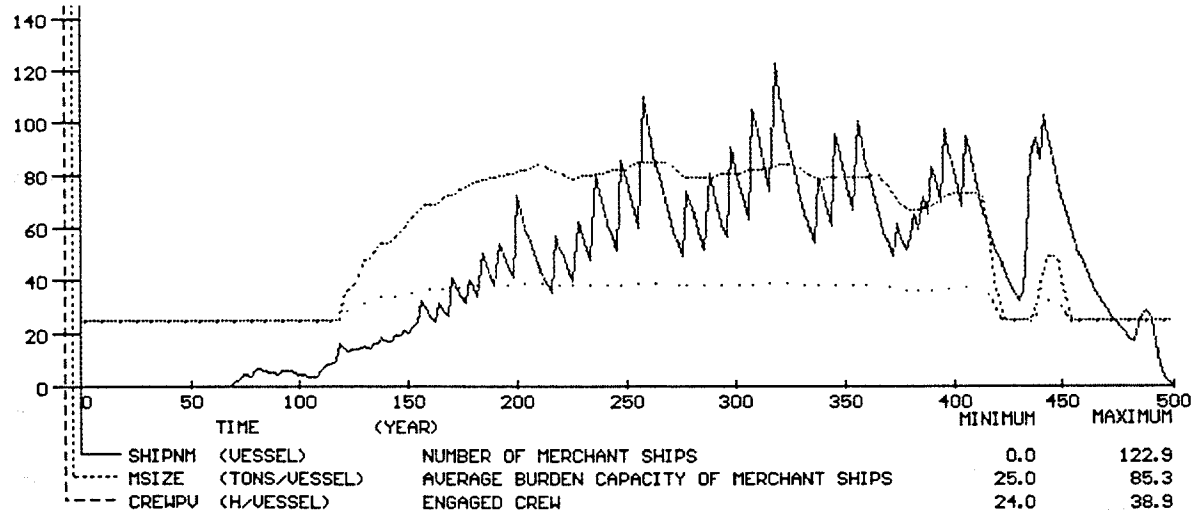
8. Figures



Plot n. 1: Changes in war-galley type



Plot n. 2: Merchant fleet dynamics