SYSTEM DYNAMICS AS A TOOL FOR HISTORIANS:
The Role of Software[1]

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ABSTRACT

This paper intends to explore the potential of the System Dynamics approach as a new auxiliary science for the historical analysis. To this end a portable DYNAMO-like package, called STEC, has been developed.

The paper, first, describes the peculiarities of the System Dynamics method as a tool for historical research, and gives an outline of the project; second, it argues that the scanty diffusion of System Dynamics might be due, among other factors, to the lack of a public domain software; third, it asserts that the "old style" data processing (command line interface and batch mode) can prove itself still usable and fruitful; and last, it shows the STEC main features.

I. INTRODUCTION

Over the last thirty years some significant models relevant to historiographic research have been built according to the criteria of the System Dynamics methodology[3]. Most of these works

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[1] This work has been developed in cooperation with DIST, University of Genova.

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[3] The topics covered by these works include: the Anasazi settlement in the Colorado Plateau [12], the Russian Revolution [17], the Maya collapse [10], Ortega y Gasset's ideas [28], the industrial Revolution [8], Ancient Rome's urban dynamics [31], the pastoral societies of West Africa [18], the industrial city of Lowell [1], the Kuhn's theory of scientific revolutions [26], population control mechanisms of New Guinea aborigines [25], the sociolinguistic interactions in the Basque Country [6], and the urban growth of the last two centuries in Britain [15]. In this paper we refer to "social sciences" and "human sciences" in a most comprehensive manner, as they raise similar issues in the formalization process.

raised methodological and epistemological issues that apparently should have persuaded many historians to use System Dynamics in their studies. However, few archaeologists[4] excepted [10, 31], no professional historian ever adopted the System Dynamics approach so far.

Renfrew [22] argues that archaeologists' interest in qualitative modelling is due to the *mute nature* of their available data; this type of data calls for some kind of coherent explanation as a part of an overall conceptual framework. Instead, historians are to process a large quantity of data made up of written records. As a consequence, they make an increasing use of quantitative methods based on statistics and econometrics. Specialistic journals covering this domain (*Historical Methods, Computers and the Humanities, Histoire & mesure*), frequent articles based on *cliometrics* in such a prestigious journal as the *Annales*, and the recent constitution of the *Association for History and Computing*: all this testifies to the establishment of "Quantitative Methods" as a new auxiliary science for the historical analysis[5].

II. QUALITATIVE MODELLING FOR HISTORIANS

Following the opinion of such a well-distinguished historian as Voltes Bou [29], it is our conviction that not only archaeologists, but also historians working on more recent ages might take advantage of qualitative modelling both in a technical task like data organization and in conceptual phases ("explanation", "evaluation" and "methodological verification"). In fact, the model building stage, by casting light on the causal relationships among the system variables, helps to gain a better insight into the specific problem under consideration. Simulation runs[6] enable the dynamic behavioural hypotheses testing; while by sensitivity analysis procedures [27] one can isolate the critical model parameters and point out the data which may need extreme accuracy.

In addition, we think that the interdisciplinary training required by the qualitative approach is not heavier than the strong mathematical nucleus inherent in quantitative methods.
In our opinion System Dynamics may result of better use than other qualitative methodologies since from its inception it has taken into account many of the features that could make it a

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[4] System Dynamics is marking time in archaeological research, too (as it can be noted in Renfrew [21]).

[5] The so called traditional *auxiliary sciences* are: librarianship, heraldry, sphragistics, numismatics, palaeography, metrology, etc.

[6] For our purpose system behaviour over time may resemble, to some extent, historical narrative.

discipline: clear principles [5, 30]; very good introductory text books [2, 23]; exercises [7]; both guidelines [13, 20] and diagramming tools [16] for model conceptualization; a mass of fully documented applications, and a special simulation language [19]. This last item enables the user to formalize in a smart and quick way such difficult concepts as non-linearities and delays.

III. THE RESEARCH PROJECT

We started from the conviction that, in order to obtain a positive impact on the historians' community, it was necessary to issue a far-reaching systematic work including methodological guidelines, epistemological reflections and paradigmatic case studies. Of course this work was to be based on strong interaction between system dynamicists and historians. Since it is crucial that final results meet the actual requirements of this humanistic field, historians' real time specifications can prevent the project from leading towards too abstract directions. Furthermore, by working side by side with historians, it is easier to single out the most suitable case studies and it is possible to check the ongoing scholars' adjustment to their new tools.

On a pure theoretical level, dozens of historians of our department could have been the potential cooperators. Yet we found out that to equip even only some of them with an orthodox software like Professional DYNAMO[7] would result too expensive. So we decided to develop a clone of the traditional System Dynamics simulation language; we called it STEC, which is the acronym of our Institution. This would enable us to provide any possible cooperator with such a tool, on a machine-independent basis, without drawing on our limited budget.

We were aware that this undertaking would considerably slower our original work schedule. But we were induced to do that also by the opportunity of inserting such features as, for example, a phase plane plotting routine, that is crucial to any *chaos* analysis, or a full batch processing. It was our hope that we might lay the foundations for an original historians oriented language.

IV. THE ROLE OF SOFTWARE IN SYSTEM DYNAMICS DIFFUSION

The problems we singled out as far as historians are concerned are just part of a more general difficulty that the System Dynamics is presently confronted with. In our opinion the overall

[7] DYNAMO and Professional DYNAMO are trademarks of Pugh-Roberts Ass., Inc.

scanty diffusion of the System Dynamics methodology[8] has to do, among other factors, with the lack of a public domain software. This, in turn, triggers a kind of vicious circle: not being freely available and already well-known among potential users, the System Dynamics software cannot induce them to search for it. While, on the contrary, other methodologies, that are available on a freeware basis, increasingly allure scientists and students.

We think that shareware and professional packages are not mutually exclusive, since users might upgrade after the testing period to a more powerful and more easily usable product of the same kind. In any case, if our construction of the problem is correct, the positive feedback loop constituted by testability, reputation and diffusion would result in a rapid growth of System Dynamics as a field and a consequent increase in the turnover of the software houses and consulting firms concerned with.

So we deem it advisable to add a stable and well tested simulation language, based on the System Dynamics concepts, to the most popular software-banks and to SDNET [9].

V. EFFECTIVENESS OF "OLD STYLE" DATA PROCESSING

We realize that nowadays a package without an integrated environment, user friendly interface, on-line help, and (colour) graphics may be easily dismissed as nonsensical. However in developing this package we endeavoured to take into account our own need for design simplification, as well as our basic ideas on the way it may be used. First of all, we wish to ensure portability and avoid memory waste. Second, we are convinced that working straight through operating system command line is neither a tremendous undertaking nor a task that people would tend to reject. In fact, one has to bear in mind that:

a) the aforementioned task involves the same type of skill -organizing a sequence of commands/operations according to the manual's instructions- required by a user friendly package if a high level outcome is expected from it;

b) with the help of such contrivances as the use of commands in batch files and memos at desk, operations would be quick and safe;

c) of late PC's magazines have started carrying recommendations about the need for a comprehensive learning of the operating system [3];

d) there is an increasing education in computer science at school.

We think that batch processing is the most suitable remedy for such slow computers as the early personals. Moreover, by separating man from machine it may help to develop a

[8] This topic was matter of discussion in previous System Dynamics Conferences. Unfortunately, an adequate re-appraisal of that debate goes beyond the scope of this paper.

"meditative" attitude on the part of the user, with positive effects on the steps of validation and modification of a simulation model.

The lack of such typical features of an integrated environment as, for example, a source programs editor and a high quality graphics for plotting can be obviously overcome by the use of powerful packages available also as shareware.

VI. THE STEC PACKAGE.

STEC (**S**toria della **Tec**nica) is a DYNAMO-like *to* C translator. It has been written in the C language [11] and its internal structure is based on recursive linked lists. This saves us from establishing in advance the maximum size of the source to be processed. The translator preserves basic features of early DYNAMO versions including macros, reruns and boxcar train. A special algorithm for reordering the equations makes the specification of their type optional. In order not to confuse our scholars the *timescript* driven computational sequence follows the original rules.
Simulation final output may be redirected to disk files for further reference and elaboration.

Now STEC is running under MS-DOS environment not only on *true* IBM compatibles but also on any generic PC, according to the Rosenblum's definition [24]. The C choice should ensure a large portability. To this end, we are contacting some institutions, that have workstations, minis and mainframes, for installing our package on their machines.

As far as performances are concerned, it does not seem advisable to present *benchmark* comparative tables since there are too many variables involved in making data meaningful[9]. In addition, our software is not to be considered in competition with professional packages. Indicatively, STEC shows clear higher performances than Micro-DYNAMO[10]; whereas, in comparison with Professional DYNAMO, it is three-four times slower in compiling (including translating and linking) and up to five times faster in the simulation step.

Presently we are preparing two more releases of STEC. The first one provides only some slight improvements and the second one is a simplified version without macros (SmallSTEC) suitable to smallest systems.

Furthermore, *backcasting* computational problem [4, 14] is under consideration.

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[9] We are referring to model size, C compiler, math libraries, precision, (floppy, fixed or RAM) disk files, math coprocessor, etc.

[10] Micro-DYNAMO is copyrighted by Addison-Wesley Publishing Co., Inc.

We are waiting for the first results of our research in order to decide whether such important features as array variables, automatic integration step, parameters optimizer, dimensional analyzer, sensitivity testing procedures, expert system environment, etc., should be added to STEC or to a new language to be devised.

VII. CONCLUSIONS

After completing the STEC package, our research project can finally start. The good performances shown by this package seem to make it especially suitable to medium-large models and low-powered machines. These performances should ease the development of our work.

Should the final outcome be positive, two scientific communities could take advantage of it: on one hand, historians would have a useful and convenient supplementary tool and, on the other hand, system dynamicists would increase their prestige and eventually reap new fruits in such traditional domains for their activity as industry and business.

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