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Towards a Modelling Formalism for Conflict Management and for Sociocybernetics

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1 Introduction

Conflicts are worth studying because they affect quality of life everywhere. They have been common throughout the human history. National and international conflicts are ubiquitous (Balencie and de La Grange, 1999). They have been common during the 20th century (Grant, 1992) and they are at least as worthy of study as during the cold war (Arquilla and Ronfeldt, 1997; Khalilzad and Lesser, 1998). Even more important, perhaps, is the study of conflict management, i.e., conflict avoidance, and conflict resolution (Rupesinghe and Anderlini, 1998). For example, Davis and Arquilla (1991), based on behavioral science's prospect theory, assert that "possible opponents are likely to become increasingly and unreasonably risk-accepting as they become emotionally more dissatisfied with current situation and trends." Game theory has been applied to social problems (Shubik, 1964). Schelling's pioneering work of analytical game theory recommends identification and consideration of focal points which are the perceived mutual expectations, obsessions, sensitivities, appreciation, and the like for conflict resolution in search of win-win conditions (Schelling, 1960).

Several aspects of conflict management are already studied. Searches in RAND Corporation's Web site reveal over 800 documents on conflict (RAND-1) and 70 RAND documents on the same subject (RAND-2). A search in amazon.com reveals that nearly 10000 books related with several types of conflict exist.

The aim in this paper is to explore whether or not a modelling formalism – such as multistage modelling formalism– and associated simulation formalism, i.e., multisimulation, can be developed for the simulation of conflict avoidance

and conflict resolution. Such modelling and simulation formalisms might also be useful in modelling other social phenomena and hence may be useful for sociocybernetics studies.

We need appropriate paradigms and modelling methodologies to perceive, conceive, and foresee conflicting situations to ideally avoid them and –if they are inevitable– to resolve them. Regardless of their type and origin, conflicts, are parts of social systems; similar to other social phenomena, they are difficult to model. Social systems are sometimes labeled in the literature as soft systems or ill-defined systems where the usefulness of traditional mathematical representations is questioned (Spriet and Vansteenkiste, 1982, p. 42).

A major effort (Davis, 1986) used the structure of war gaming, and included artificial intelligence models (rule-based systems) to represent national and international leaders and commanders. This and other works were described by Zeigler (1990) as an example of the more general approach of variable-structure agent-based simulation. The studies of a special type of conflict, namely war gaming has been numerous. In war gaming, military decision-makers (i.e., commanders at different levels) can get “war experience” basically at peacetime. Nowadays, war gaming studies use computers extensively although such studies predate computers. For example, in a bibliography on professional war gaming, early studies date back the second half of the 1880s (Riley and Young, 1957). There are two types of war games, for professionals and for hobbyists. In war gaming, it is much easier to model equipment than humans. Recently, there are studies to remedy the situation (Pew and Mavor, 1998).

It is argued that conflict avoidance and conflict resolution deserve levels of efforts similar to war gaming. Similar to war gaming experience, military and civilian decision-makers can enhance their conflict management skills through conflict management simulation studies.

Conflict systems are complex social systems. Some already available modelling approaches based, for example, on different types of game theories (e.g., sequential games, differential games, evolutionary games, and hyper games) as well as several other approaches such as bounded rationality, deterrence theory, and crisis destabilization are used for their solutions. Some novel simulation modelling formalisms, not conflicting with already proven theories and approaches may be useful for the proper formulations and resolutions of conflicts.

Some references on complexity are Waldrop (1993) and Kaufmann (1996). There are examples in conceiving complexity in elegant ways. For example, by using fractals (Barnsley et al., 1988), a complex system can be generated based on simple initial knowledge. An L-system (Prusinkiewicz and Hanan, 1980; Vitanyi, 1980) can be used to model the growth of a plant at different stages (or steps). A catastrophic manifold (Casti, 1979) can represent interesting (sometimes contradictory) patterns of behavior.

Cybernetics has been considered as a source of paradigm for simulation of complex systems including social systems (Knight, Curtis, and Fogel, 1971;

Ören 1978). For a bibliography on contemporary sociocybernetics studies see Geyer and van der Zouven (1998).

In developing a modelling formalism for conflict management, one should take into account the bias and limitations of classical scientific thinking toward Newtonian way of perceiving reality which is well documented in the literature (e.g., Prigogine and Stengers, 1984; Marshall and Zohar, 1997). Toffler even expresses this in more vigor: “Most phenomena of interest to us are, in fact, *open* systems, exchanging energy or matter (and, one might add, information) with their environment. Surely, biological and social systems are open, which means that the attempt to understand them in mechanistic terms is doomed to failure.” (Toffler, 1984, p. XV). Newtonian paradigm is indeed very powerful and useful, in engineering and most of the scientific studies (except of course in quantum physics and the domain of relativity). However, Newtonian paradigm is not well suited to complex human-related disciplines. The suggested modelling and associated simulation formalisms, i.e., multistage modelling, and multisimulation formalisms, respectively, would allow experimenting with different –even contradictory– aspects of reality simultaneously. For computational convenience, they can also be executed sequentially, in depth-first search mode. Results of the experiments with multistage models can be simultaneously displayed by taking advantage of the possibilities offered by virtual and augmented realities.

2 Towards a Modelling Formalism and an Associated Simulation Formalism

It is a philosophical issue whether or not as humans we can deal with reality directly. It is paramount that we develop aids to perceive and to conceive reality properly. The question is whether we can develop a modelling formalism to conceive and to perceive such soft systems in a more systematic way. When properly developed, such a modelling formalism could be useful to model conflicts and associated events. It could be used to develop appropriate models to be used in simulation gaming to provide simulation-based experience for future decision-makers. Such models could be used in getting experience to develop and sharpen abilities to steer the events to achieve desired states to achieve and maintain desirable social order. Since all the details of such a modelling formalism are not yet ready, the term “towards” is used in the title of this article where the concepts are discussed for the first time.

The simulation modelling formalism can benefit from the synergies of conventional simulation and artificial intelligence techniques. For war gaming, use of artificial intelligence, more specifically, rule-based knowledge processing techniques was advocated by Davis (1986). However, a systematic treatment of the subject reveals also other possibilities of application of artificial intelligence in simulation studies (Ören, 1995). Zeigler elaborated on the use of intelligent

software agents to represent high autonomy systems (Zeigler, 1990). The relevance of this and another important concept, called endomorphy by Zeigler will be discussed in Section 2.5.

2.1 Background for Multistage Modelling Formalism

In this section, two modelling formalisms are reviewed to provide background knowledge for multistage models. They are multimodel and evolutionary models.

2.1.1 Multimodels

A multimodel is a modular model where only one model module is active at a certain time. Each model module is an *alternate model*. The “multimodel” formalism was introduced as a generalization of discontinuity in piece-wise continuous systems (Ören, 1987; 1991). However, the concept is applicable to continuous, discrete, and memoryless models, as well as to other modelling formalisms such as rule-based models and software agents, including intelligent agents and mobile agents. The models can be atomic or coupled (Ören, 1993). An extension of the multimodel formalism to combined discrete event and differential equation specified systems (DEV & DESS) as well as coupled multi-formalism system formalism is developed by Praehofer (1992).

Figure 1. depicts a multimodel M composed of three component models M_i , $i = 1, 2$, and 3 . At the beginning, one of the M_i is the initial model to represent M . The inputs of M are connected to the inputs of the initial model. The outputs of the initial model are connected to the outputs of the initial model. While the initial model is running, its behavior is generated through its state transition function and output function. There is a monitoring done at the same time. Model selection (or model transition) conditions are checked to decide whether another module model will represent the multimodel M .

In general, the dynamics of each alternate model is represented by three distinct sections to represent state transition function, output function, and model selection or model transition specifications. Some special cases are as follows: Memoryless models do not have a state transition function. In some other special cases, some/all state variables can be outputted directly. This corresponds to the situation where output function(s) are reduced to identity function(s). If a model transition section does not exist, instead of a multimodel, there is only a conventional model, which can be represented by any appropriate modelling formalism. Two essential characteristics of multimodels are: (1) before the beginning of the behavior generation phase of a simulation study, all the alternate models are known; and (2) only one alternate model is active at a given time.

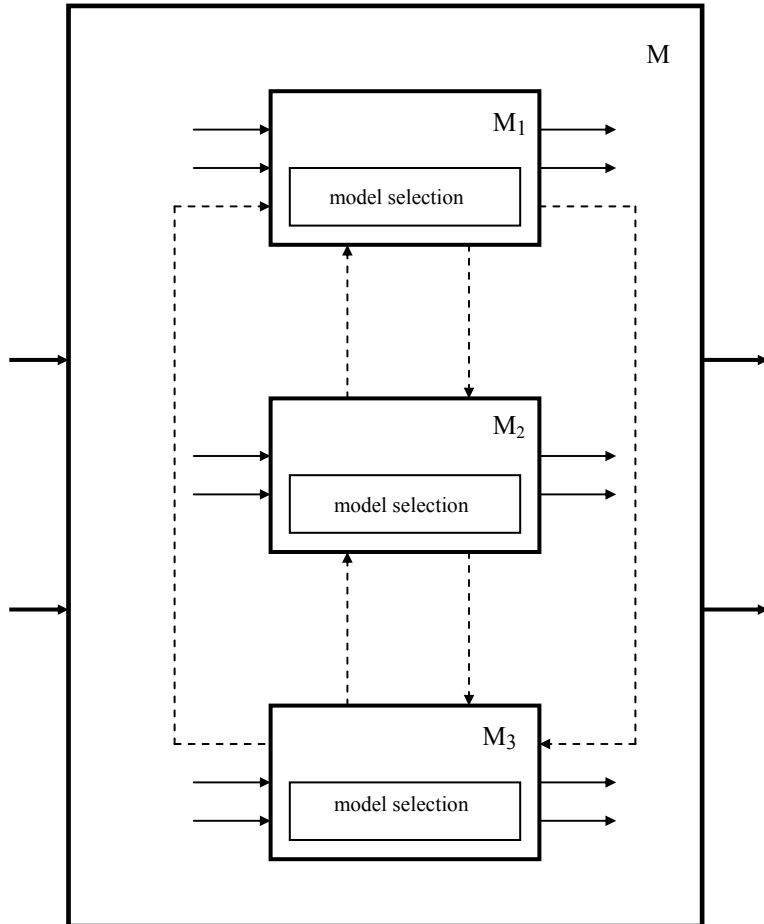


Figure 1. A multimodel.

As an example, the simulation study may start with model M_1 , then at a model selection instant, model M_3 can be selected. Then model M_2 can represent the model M ; afterwards model M_1 can be used again. In all these transitions, all the alternate models are known a priori as well as the transition conditions. During the behavior generation of a simulation study, the model selection conditions have to be monitored to cause interrupts for model selections. In systems with learning abilities, rules for model selection can be learned, hence can be time varying. In the latter case, consistency checks should be done at appropriate times; to assure acceptability of learned knowledge.

With multimodels, similar to any conventional simulation study, only one aspect of reality can be simulated at a given time.

2.1.2 Special Cases of Multimodels

Two special cases of multimodels are metamorphic models and multiaspect models. A metamorphosis can be represented by a *metamorphic model* which, in turn, can be represented as a special case of a multimodel. For example, alternate models can represent egg, larva, pupa, and butterfly; alternate models can be selected, under well-defined conditions. However, in this case, there is a predefined sequence for the alternate models; i.e., transitions from alternate models would be rather limited.

A *multiaspect model* is another special case of a multimodel where the condition of having only one alternate model active at a given time is relaxed. An example usage might be representation of solid, fluid, and vapor phases of the same mass of material (e.g., ice, water, and vapor) and the transitions from one phase to another. The transitions can include sublimation, i.e., passing from solid to vapor state and vice versa. In the example, alternate models representing both water and vapor can exist concurrently with a mass transfer from one to another alternate model. The direction of the transfer of an entity, in the example, water, or vapor, depends whether or not energy is given to, or taken from the multimodel itself.

2.1.3 Evolutionary Models

Evolution is irreversible change in an open system (Salthe, 1985). At each phase of its evolution, an open system can be represented by a different model. Hence, *evolutionary models* would start with an initial model and a mechanism would alter the current model based on some external and internal conditions.

An evolutionary model is represented by the series of variant models m_i where i is not repeated. Evolutionary models –or *mutational models*– consist of *variant models*. Not all variant models are known a priori. In an evolutionary model, an initial model and the mechanism to generate variant models are known a priori. In a *simulation with evolutionary models*, only one variant

model is active at a given time. Furthermore, only one aspect of reality is simulated at a given time.

2.2 Multistage Models and Multisimulation

The multistage model formalism is suggested as a simulation modelling formalism for sociocybernetics systems in general and for conflict management such as conflict avoidance and conflict resolution in particular. Figure 2 is given as an example of multistage models where component models are M_i , $i = 1, \dots, 8$. For example, the following multistage models are identified: M_1 , M_1M_2 , $M_1M_2M_5$, $M_1M_2M_6$, M_1M_3 , $M_1M_3M_7$, $M_1M_3M_8$, M_1M_4 , and $M_1M_4M_8$. A model, which can be used after another one in a multistage model, is a successor model.

In a multistage modelling formalism, several aspects of the reality can be formulated by sets of components models. Normally all the multistage models may not be known a priori. For example, only the initial model M_1 may be known. In this case, one can attempt to model alternative models to get ready for contingencies. Supposing that M_2 and M_3 are also modelled, one can have two multistage models: M_1M_2 and M_1M_3 . One can perform a simulation study with each multistage model to find out for example, the outcomes of having M_2 or M_3 . Accordingly, one can try to control the conditions to facilitate transition to a specific model module and/or to make it difficult the transition to another one. If the status of a module of a multistage model is not acceptable or desirable, one has to generate successor model(s) and facilitate transition to that module model.

If all or some of the component models of the multistage models are known a priori, one can use only relevant component models and several simulations can be performed. Multistage model formalism can allow *multisimulation*, or *multisim*, in short. A multisimulation can be in parallel, to experiment with several aspects of reality simultaneously. For computational convenience, it can also be executed sequentially, in depth-first search mode. When some previously unforeseen conditions arise, i.e., under *emerging conditions*, one can add *emerging successor models* to existing models to explore behavior of alternative system models.

Multisim may be the simulation paradigm to experiment with Schrödinger's cat –which can be alive *and* dead at the same time (Marshall and Zohar, 1997). In non-quantum theoretic realm, it is argued that ability to experiment with several –even contradictory aspects of reality may bring new vistas in conflict management.

Similar to war gaming (or business gaming) one can have experience in conflict avoidance and/or resolution by using appropriate computerized simulation systems. As it is the case with war gaming systems, knowledge about several types of conflict avoidance and conflict resolution can be made available to the user of computerized simulation system.

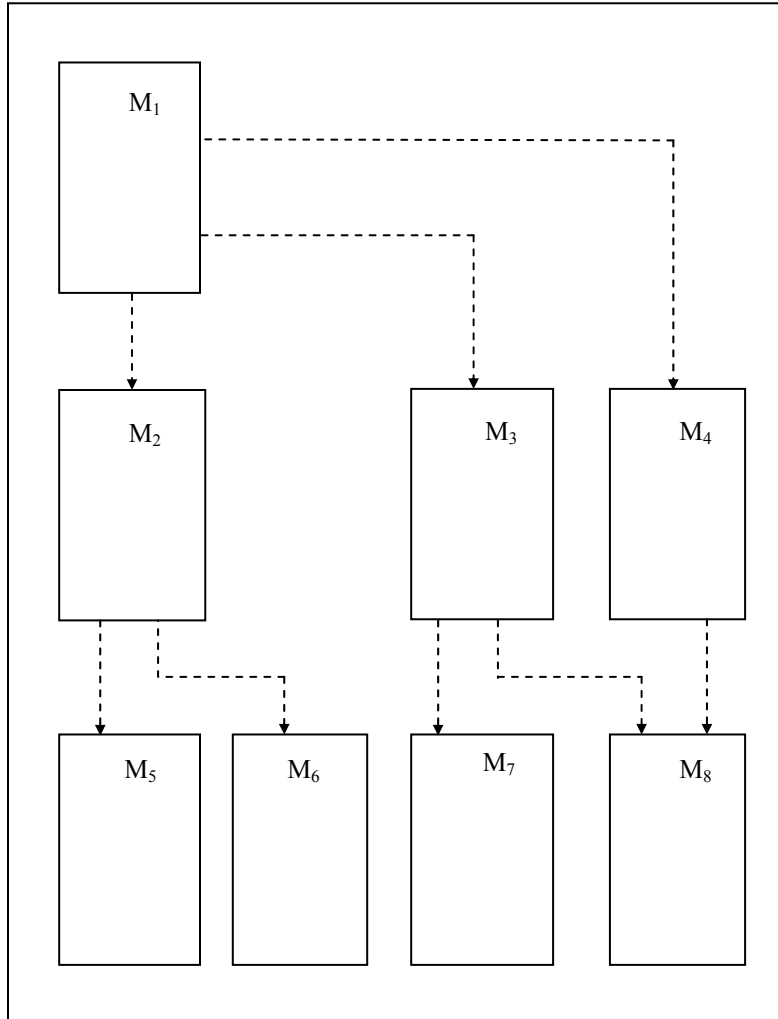


Figure 2. An example to multistage models.

2.3 State Machines

State machine formalism (SM) can be used as an example to develop model modules for multistage models. However, the concept of multistage model is not bound with SM formalism.

Let us start our discussion by reviewing the basic finite-state machine formalism. In a Moore or Mealy machine (Gill, 1962; Hartmanis and Stearns, 1966) there are three sets and two functions. These sets define finite number of state, input, and output values. A state transition function defines how next state value can be obtained based on current state and current input. The two types of the finite state machine formalisms differ in their output functions. In Moore machine, current output depend on current state; in Mealy machine, current output depends on the current state and current input. The transition and output functions of finite state machines are specified in tabular and/or in graphic notations. In the later, circles depict states, arrows between circles, depict transition between states. Outputs are represented as associated with states or as the labels of the arrows. In Moore machines, current output depend on current state; hence, outputs are associated with corresponding states. In Mealy machines, current output depend on current state and current input; hence, outputs are associated with transitions.

Finite state machine formalism, as a classical modelling formalism, can be used in depicting well defined modules of systems where all the values of the state, input, and output variables as well as state transition and output functions are known a priori. Inputs and outputs may also include events. With the knowledge about the initial state and the values of the input variable, it is possible to generate the state and the output of the system at every update time.

2.4 Multistage State Machines

A *multistage state machine* is a multistage model that is based on state machine formalism. In a multistage state-machine formalism, each component model is a state-machine. With this generalization, it is possible to represent at any stage known states, inputs, and outputs as well as known transitions and output functions –by using the finite state machine formalism. More importantly, we can add new (emerging or desirable) states, inputs, and outputs. Given the current state, one can identify the possible next states and the needed inputs for each of them. Considering the inputs as the conditions for the associated transitions, one can nurture some conditions to avoid transitions associated with others and hence one can force transitions to desirable state(s). The transitions can involve several intermediary states, some of which can be induced to facilitate transition to desirable one.

In some social cases, the conditions are often very fluid and the equilibrium, if any, is very unstable. In these cases one needs a clear picture of the status, and systematic exploration of the possible states and the conditions to nurture (or the necessary inputs) to reach each one of them. According to the desired state, one would block some conditions to be satisfied or one would steer the conditions to realize the transition to a desirable state. Often, at every state, one would need to explore possible next states and the conditions to reach them. That means the system description is not know a priori but the system can evolve in a fluid way.

In a finite-state machine, there is only one state that is active at any time. In social systems, not only reality, but also the perceptions of the reality by different groups or individuals are also important. Therefore, a system can be perceived by different observers/players to be at different states at the same time. Hence, different images (models) of a real system may be active at the same time. This can be represented as a multistage model or as a multiaspect model.

Once a modelling formalism is developed, one can develop a high-level specification language and a computer-aided environment to model systems graphically and with the assistance of a knowledge-based system. Maintenance of the model base can be managed by system entity structure (SES) developed by Zeigler (1990). A program generator can translate the specifications given in this high-level specification language into a compilable simulation gaming program. The simulation gaming program can be used to enhance conflict management abilities of by current or future decision-makers.

2.5 Some Other Multistage Modelling Formalisms

Multisimulation can be associated with several modelling formalisms. FSM formalism is used to illustrate the concept. Some other possibilities can be the use of Petri nets –especially to represent deadlocks and synchronization, or use of linguistic variables such as the case in fuzzy logic. The synergy of artificial intelligence techniques with simulation can be explored systematically (Ören, 1995).

The concept of endomorphic models introduced by Zeigler (1990) is directly applicable. To take into account different perceptions of an opponent, model(s) of an opponent can be embedded in a model. In less technical terminology, the embedded models are also called ghost models. If an entity –represented by a model– has an internal model of itself, this embedded model can be called an introspective model.

In conflict situations, opponents are often autonomous (or quasi autonomous) under operating constraints. Software agents are the most natural computerization possibilities for autonomous or quasi-autonomous entities. Furthermore, they are also open to more powerful formalisms such as multiagent formalism where an agent can be represented by several agents only one of them being active similar to a multimodel. Therefore, in simulation studies used for

conflict management, one should explore possibilities offered by intelligent agents. Gelenbe (1999) investigates and evaluates novel paradigms for simulation of intelligent behavior and learning in interacting autonomous agents. In his work, each agent's external control mechanism can be a FSM or a set of rules. FSM transitions or rules can change through learning which proceeds by observing the environment and of other agents. A systematization of the possibilities offered by the synergies of simulation, artificial intelligence, and software agents was discussed by Ören (1999). Furthermore, endomorphic models –both ghost models and introspective models– can be expressed as intelligent agents.

3 Conclusion and Challenges

It appears that appropriate formulation of complex social phenomena may improve our perception of reality and may provide a paradigm to conceive innovative solutions. Hence, we may learn ways, which might be useful in steering the course of the events in such a way as to achieve desirable or at least acceptable states. In the article, an attempt for such a challenging task is presented. Especially the concept of multisimulation is explored to experiment with different perceptions of reality simultaneously. Intelligent and knowledge-based conflict management simulation environments should be developed to provide extensive experience to decision makers for conflict avoidance and conflict resolution as well as peace keeping. Not taking advantage of the power of simulation in these vital issues would be similar to a hypothetical case where pilot training is not completed by using aircraft simulators.

Acknowledgment

Invitations are often honorific and sometimes inspirational. I considered this invitation, in honor of my good friend and colleague Prof. Bernie Zeigler, to be both honorific and inspirational; hence, I wanted to introduce a new concept as we did so many times working together. The invitation reminisced the time when he was an invited speaker in a symposium I organized in Namur, Belgium, in 1976 (Ören, 1978). Then in 1978, he invited me, to the Weizmann Institute, Rehovot, Israel, to conceive and write an article in one week –we delivered, and the editor took almost a year to comprehend and to accept it (Ören and Zeigler, 1979). Thereafter, we worked together in our series of symposia and many other projects to advance the state of the art of modelling and simulation. It is a great pleasure to notice that after a quarter of a century, we still find each other's contributions inspirational for our own research.

I would also like to express my pleasure to return to Tucson, AZ, the hometown of the University of Arizona, one of my alma maters. There I had the

privilege to work in late 1960s, with Dr. A. Wayne Wymore on the synergy of system theories –and especially his own theory (Wymore, 1967)– and modelling and simulation. Getting a Ph.D. degree for these pleasurable moments was a rewarding excuse.

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