

ORGANIZATIONAL DECISION CHEMISTRY ON A LATTICE[◦]

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ABSTRACT

We use *NetLogo*¹ to design a simple multi-agent environment to explore organizational decision processes. Our work builds on the original insight of the "Garbage Can Model" of organizational choice (GCM) proposed by M. Cohen, J. March, and J. Olsen (1972). In this model organizations are viewed as crossroads of time-dependent flows of four distinct classes of objects: "problems," "solutions," "participants" and "opportunities." Collisions among the different objects generate events called "decisions." In our NetLogo-based reconstruction of the GCM, the type of decision is determined by the relative levels of energy accumulated by "participants" and "opportunities" up to the moment of collision. We make no attempt to reproduce all the features of the original model. Some features of our representation are not present in the original model and are included to cast new light on specific aspects of decision processes in organizations. The model is a highly preliminary attempt to represent organizational decision processes when agents live in a structured socio-physical space, and are capable of reproducing, i.e. of creating identical copies of themselves. In its current state of development the model serves mainly didactic purposes and as an illustration of the value of the *NetLogo* programming environment for representing complex organizational systems. The general learning point that the model can be used to illustrate is that dynamic complexity at the organizational level does not depend on complexity at level of individual agents. This conclusion suggests a conceptual link between aspects of social organizations and the study of emergence in natural and artificial systems.

1. INTRODUCTION

Social organization can be studied at many different levels of abstraction and analysis. For example, in the analysis of organizational decision making processes a common strategy is to reduce a complex social activity to an individual constrained optimization problem. Understandably, this analytical strategy emphasizes the information properties of alternative organizational arrangements (Burton and Obel, 1995) and the capacities of decision makers (individually and in teams of variable size) to find, assemble, exchange and process the various pieces of information that formal organizations produce and make available to its

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¹ The NetLogo software, models and documentation are distributed free of charge for use by the public to explore and construct models. The most recent version of NetLogo can be downloaded from: <http://ccl.northwestern.edu/netlogo/>.

participants (Miller, 2001). Typically – but not invariably – organizational decision processes are assumed to follow a “logic of consequence” according to which the outcomes of decisions are evaluated in terms of personal preferences (March, 1994). Within a logic of consequence framework, a number of coherence assumptions are needed for inferring from the observable consequences of decisions, an implicit decision rule such that the organization as a whole can be said to behave as if it were following that rule (McFadden, 1976).

An alternative way of thinking about how decisions happen in organizations, concentrates on the aggregate flows of problems, solutions, opportunities and decision makers through organizational networks (Padgett, 1980). This perspective focuses on how aggregate regularities are produced and reproduced through the interaction of elementary components (“agents”) defined at lower levels. Such a view starts with a very different position on what the term “organization” means when referred to socially constructed entities. Organizations are seen as regulated and partly self-maintaining flows emerging from the interaction of elementary agents (Fontana, 1998). Organization “structure” is patterns in these flows that may take the form, for example, of routines – systematic connections between actual or potential “problems” and “solutions.”

Within the broadly defined field of “Organization Science,” a prominent example of this second strategy to make sense of organizational decision processes is the Garbage Can Model of Organizational Choice (GCM), originally proposed by M.D. Cohen, J.G. March and J.P. Olsen (1972). The motivating claim behind the GCM is that: “[A]lthough organizations can often be viewed conveniently as vehicles for solving well-defined problems [...] they also provide sets of procedures through which participants arrive at an interpretation of what they are doing and what they have done while in the process of doing it. From this point of view, an organization is a collection of choices looking for problems, issues and feelings looking for decision situations in which they might be aired, solutions looking for issues to which they might be the answer, and decision makers looking for work” (Cohen, March and Olsen, 1972: p. 2).

In the model that we present below, we start from this definition of “organizations” as containers of transformation rules (Padgett, Lee and Collier, 2003). We try to extend the basic GCM representation by bringing to light and developing its more constructive features that are implicit in the tendency of the basic constituent elements of organizations (“problems,” “participants,” and “solutions”) to (i) reproduce by creating copies of themselves and (ii) give rise to new entities through interaction.

Our effort is based on the intuition that - within the original GCM - the representation of “organizational decisions” as outcomes of quasi-random collisions among “participants,” “problems,” and “solutions” invites development of a more explicit bio-chemical metaphor for organizational decision process (Fontana and Buss, 1994). In this view, new constituents of an organizational system are generated from within by the interaction of elementary “agents” following different laws of composition (Padgett, Lee and Collier, 2003).

The present work is not the only or the first attempt to reconstruct the GCM. Other examples are available that have emphasized and developed different aspects of the original model (Masuch and LaPotin, 1989; Warglien and Masuch, 1995). Since its appearance, the implications of the GCM have also been explored in a number of empirical contexts (Carley, 1986; Cohen and March, 1974; Levitt and Nass, 1989; March and Olsen, 1976; March and Weissinger-Baylon, 1986) and theoretical elaborations (March, 1978). In its current state of development the model serves mainly didactic purposes. For example, the simulator could be used as a computer-based learning environment to introduce students with an interest in institutions to central issues in the study of organizational decision processes, and to discuss the corresponding representation problems that are typically associated with these issues. For

further discussion of these and related themes we refer interested users to March (1994), March and Olsen (1989), and March, Schultz and Zhou (2000).

2. MODEL DESCRIPTION and DESIGN

Consider a stylized organizational world inhabited by three types of entities (or objects) called "Problems," "Solutions" and "Participants." A fourth type of object called "Choice Opportunities" - or simply "Opportunities" - emerges from the collision among individual "Problems" and "Solutions."

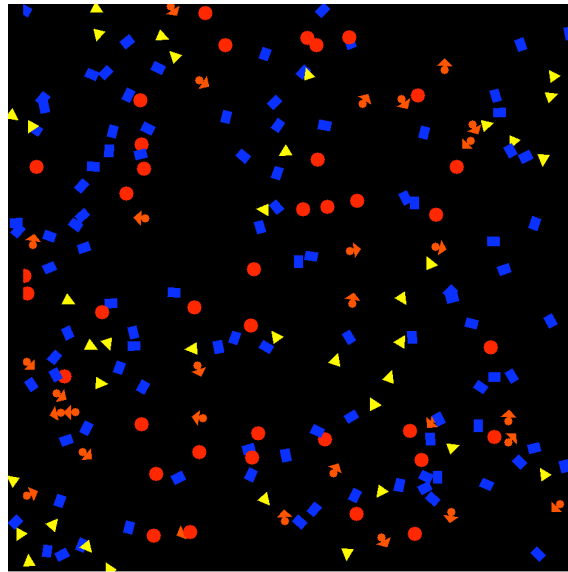


Figure 1. Initial distribution of objects on the lattice

Suppose that each object is randomly allocated to sites in a two dimensional lattice with periodic boundary conditions (see the Figure 1). Assume that objects are endowed with an initial level of energy. During their life on the lattice, objects dissipate energy by moving around, as described below. Objects move following a random walk through the lattice. An entity expires when its energy level is zero. Objects can also increase and exchange their energy levels through collisions. When a maximum (exogenously set) level of energy is reached, participants and opportunities reproduce by splitting, i.e., by forming identical copies of themselves.

In keeping with the original formulation of the model, both participants ("decision makers") and choice opportunities are characterized in terms of energy levels. Energy exchange among the different types of objects is regulated by the collision rules described below. Collisions between "Participants" and "Opportunities" give rise to three possible outcomes, each inducing specific types of "decisions."

1. If (Energy-of-Participant > Energy-of-Opportunity), then the participant destroys the opportunity. As a consequence the opportunity disappears and the participant increases its own energy level (new-energy-of-participant = old-energy-of-participant + energy-of-opportunity). The outcome of this collision is called decision by "Resolution."
2. If (Energy-of-Participant < Energy-of-Opportunity), then the opportunity destroys the participant. As a consequence the participant disappears and the opportunity increases

its own energy level (new-energy-of-opportunity = energy-of-participant + old-energy-of-opportunity). The outcome of this collision is called decision by "Flight."

3. If - within a given range - (Energy-of-Participant = Energy-of-Opportunity), then the opportunity separates into its component elements: a problem and a solution. In this case the "problem" and the "solution" retain the energy level of the opportunity. The energy level of the participant remains unchanged. The outcome of this collision is called decision by "Oversight."

3. SELECTED NETLOGO FEATURES

The NetLogo User Manual reads (2003): "NetLogo is a programmable modeling environment for simulating natural and social phenomena. It is particularly well suited for modeling complex systems developing over time. Modelers can give instructions to hundreds or thousands of independent "agents" all operating in parallel. This makes it possible to explore the connection between the micro-level behavior of individuals and the macro-level patterns that emerge from the interaction of many individuals." These characteristics of the NetLogo modelling environment make it particularly useful as a way to represent a number of central issues in the study of organizational decision processes, and facilitate decentralized experimentation with the model.

In particular – for the purposes of the present model - note the use of "breeds" to model four different kinds of "turtles": solutions, problems, opportunities and participants. Furthermore look at the use of "turtles-own [var1 var2 ...]" and "breed-own [var1 var2 ...]" to describe the features of all agents and the ones of single breeds, respectively. Finally, consider the use of "hatch" in combination with "breed" to create new agents with the general features of the parent-agent (for example: position, energy etc.) and specifically breed (for example: energy values, grabbed?). In some case the breed of the child may be the same of the parent (split function). Note the use of the RANDOM-ONE-OF agentset command to select an opportunity to be energy-exchanged by participants and to select a problem to be transformed into an opportunity.

4. A QUICK GUIDE TO THE GRAPHICAL INTERFACE

The graphical interface that we designed for the model is displayed in Figure 2. In this section we provide a brief guide to the simulator. The SETUP button establishes the initial configuration of objects in space. Users may specify the number and the attributes of the three primitive (i.e., non-composite) objects: problems, solutions and participants. The specific attributes can be set through the INIT-SIZE sliders (which control the initial population size) and the INIT-ENERGY sliders (which control the initial maximum energy level of the objects). The slider RANGE-RESOL controls the range within which the energies of "participants" and "opportunities" are considered equal. The sliders FRICTION-PAR and FRICTION-OPP control the amount of energy that participants and opportunities dissipate through movement. For participants this can be interpreted as a search cost. For opportunities, friction defines their duration or "timing."

The initial energy endowments are randomly assigned and vary between zero and INIT-ENERGY. The objects are randomly distributed across the lattice. If the objects present in the same site are a "solution" and a "problem," an "opportunity" is created. The energy level of the new "opportunity" is the average energy level of its generating elements (solutions and problems). If a participant and an opportunity come to occupy the same site, a decision happens whose outcome is determined by the set of collision rules described above. The MAX-ENERGY slider sets the "reproduction threshold" - the maximum possible level of

energy that participants and opportunities can accumulate before splitting. If the SHOW-ENERGY switch is "ON" the energy values of individual objects are written to screen. Users might find that this option slows down the simulation considerably. GO sets the simulation in motion. By clicking GO UNTIL, the simulation will run until a halting condition is met (for example there is no participant left). Users may click GO STEP to advance the simulation by one time step only. Clicking GO UNTIL again while the simulation is running halts the execution.

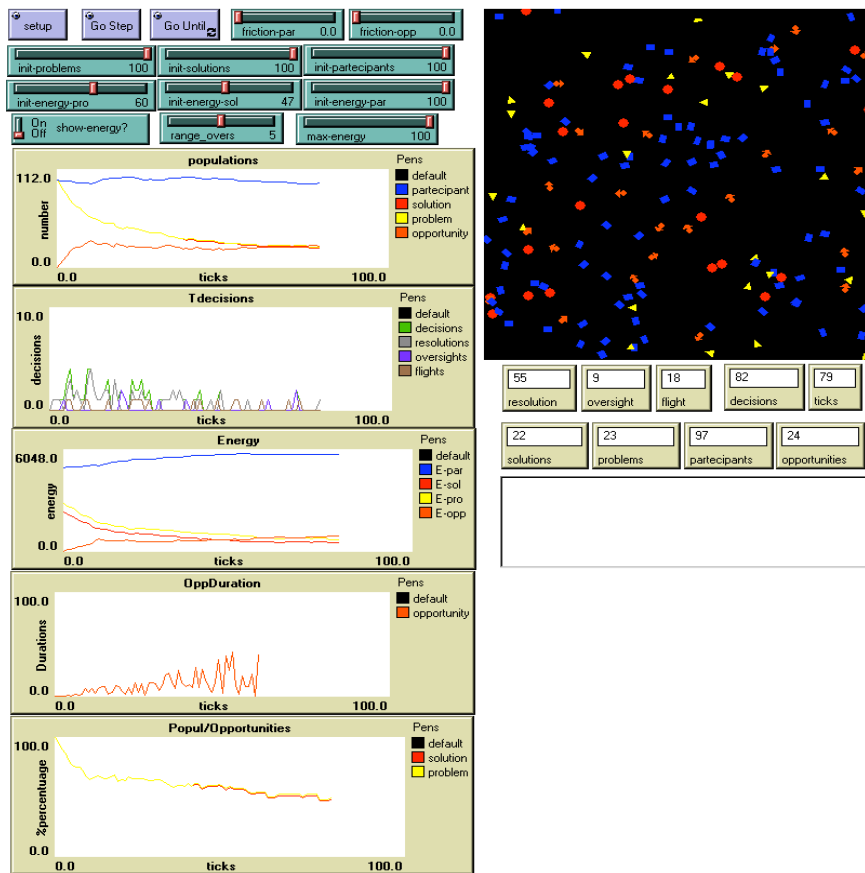


Figure 2. A snapshot of the NetLogo graphical interface

Five time series plots provide information about the qualitative behavior of the system. The first plot simply reports the number of entities over time. The second reports the number and types of decisions that are being made. The third plot reports the aggregate energy accumulated by the various entities. The fourth plot reports an estimate of the time between the emergence and the disappearance of individual opportunities. Finally the last time series graph reports the number of problem and solutions that are not converted into opportunities.

These plots provide information on specific aspects of organizational decision processes. According to the original model formulation, the performance of garbage can decision processes can be assessed in terms of problem activity (the amount of time that problems spend attached to choice situations without solution), problem latency (the amount of time problems spend activated but not linked to choices) and decision time (the amount time that choices remain unmade).

According to March (1994; 203): “Presumably a good organizational structure would allow problems to appear and be solved and decisions to be made quickly, reducing problem activity, problem latency and decision time as choices are made and problem

move quickly to resolution. In a garbage can situation, it is hard to improve on all three measures simultaneously.” These various considerations can be used to explore a variety of issues related to the performance of garbage can-like organizational systems.

5. EXPERIMENTS

We illustrate the typical behaviors of the model starting from a baseline configuration. Figures 3 (a), (b) and (c) report the results of baseline runs. Above each time series plot we have reported the relevant sliders through which users can manipulate the parameters of the model. To provide numerical information about the model behavior, Figure 3 also reports the various monitors.

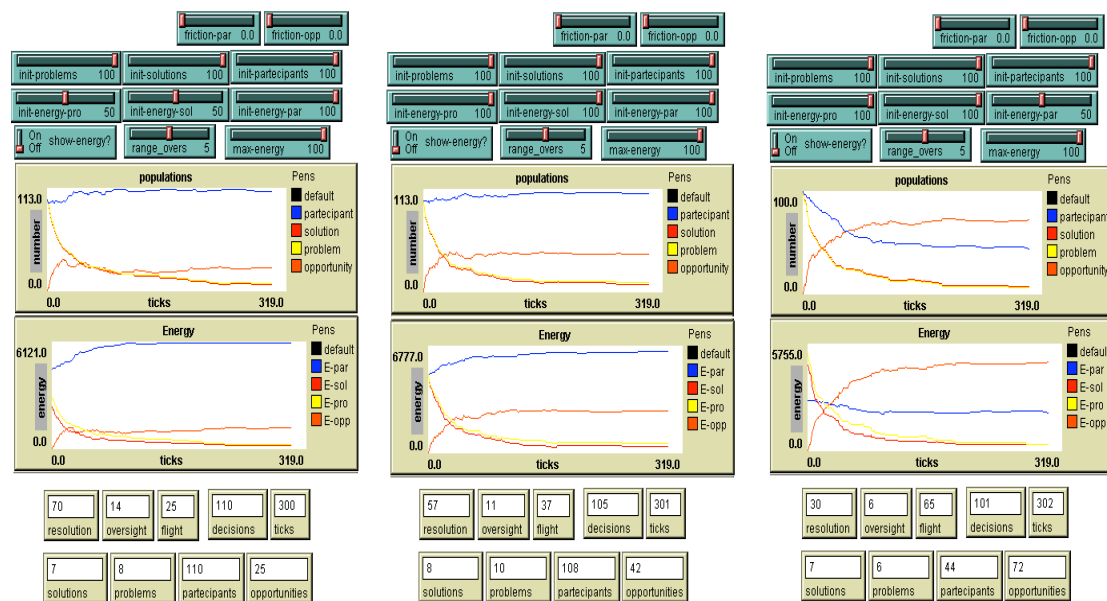


Figure 3. (a), (b) and (c). Baseline runs of the model

For example, the INIT-ENERGY sliders in Figure 3(a) imply that most of the participants are endowed with an initial energy level that is greater than that of solutions and problems. Because the energy of an opportunity is computed as the average of the energy of its parent objects (problems and solutions) in this configuration the energy of participants will tend to be higher than the energy of opportunities. Thus when a participant and an opportunity collide, the “decision style” prevalent in the system is likely to be “by resolution.” As the various monitors illustrate, after 300 time periods (“ticks”), the number of decisions “by resolution” (70) is more than twice the number of “decisions by flight” (25), and five times the number of “decisions by oversight” (14). In the second baseline run illustrated in Figure 3 (b), the energy level is likely to be the same across all types of entities. In this case, when participants and opportunities collide, we have little prior information to guide our prediction about the decision style that will be prevalent in the system. After 301 periods (or “ticks”), the number of decisions “by resolution” (57) is again somewhat greater than the amount of flights (37), and is five times greater than the number of decisions “by oversight” (14). Number of participants, problems and solutions in case 3(b) are comparable to the corresponding numbers in of Figure 3(a), but the number of opportunities in the system has almost doubled (42 vs. 25). Decisions “by resolution” are less frequent in this system (70 vs. 57) and the number of decision “by flight” is higher (37 vs. 25). Finally in the situation illustrated in

Figure 3(c) it is likely that the most of solutions and problems will be endowed with a level of energy that is higher than that of participants. In this case, when a participant collides an opportunity the resulting decision will be likely to be “by flight.” After 302 simulation steps, the number of decision “by flight” (65) is more than twice the amount of decisions “by resolution” (30), and eleven times greater than the number of decisions “by oversight” (6). The number of participants surviving in this system has dropped dramatically (44 vs. 108). These simple experiments confirm a considerable degree of sensitivity of the system to changes in initial conditions in predictable directions.

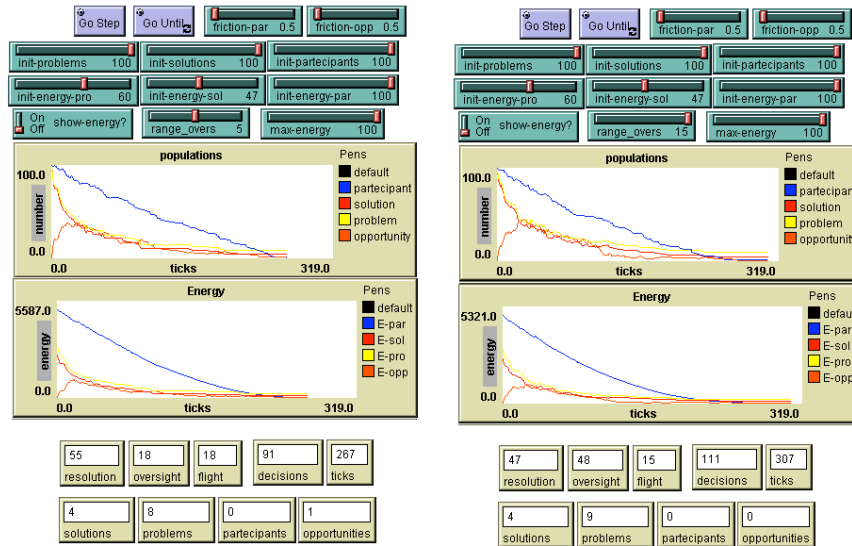


Figure 4. (a) Baseline runs with friction, and (b) baseline runs with different values of the RANGE_OVERS slider

So far we have experimented exclusively with conservative model configurations. The model is very sensitive to friction that we can manipulate experimentally by setting the corresponding sliders to desired levels (that can be interpreted as “search costs” for participants and “timing” or “duration” for opportunities). Figure 4a illustrates what happens when dissipation of energy through movement is allowed. After 267 time periods we have no participants left, only 4 solutions, 8 problems and 1 opportunity. The system halts because it is no longer possible to take decisions. As expected, the value of RANGE_OVERS controls the number of decisions “by oversight” that will be taken. This is illustrated in Figure 4(b).

6. CONCLUDING REMARKS AND FUTURE WORK

We have discussed a highly preliminary attempt to represent organizational decision processes when agents live in a structured socio-physical space, and are capable of reproducing, i.e., of creating identical copies of themselves. In keeping with the original “Garbage can model of organizational choice” (Cohen, March and Olsen, 1972) on which our model is based, three different species of agents populate the organizational space: “problems,” “solutions” and “participants.” A fourth species – “opportunities” - is produced endogenously as a combination of “problems” and “solutions.”

The model is based on rather minimalist assumptions about how agents behave. While we make no claim that actual social agents should conform even remotely to these assumptions (Carley and Newell, 1994), we note that in our representation complexity at the system level does not seem to depend on complexity at level of the agents’ architecture. In its current form the simulator serves mostly didactic purposes. For example, it could be used as a

computer-based learning environment to introduce students of social and economic institutions to a number of central issues in the study of organizational decision processes, and to the related representation problems.

We see at least two directions for future research. The first involves treating the model as a quasi-experimental observation-generation mechanism. Information on the states that the various objects occupy at any given time, and on the duration of the objects in these states can be produced and treated as empirical data. Under certain assumptions statistical models could be estimated to explore patterns of state and time-dependence of the different objects on the lattice as a function of different combinations and levels of experimental parameters. The main idea behind such an analysis would be to arrive at a characterization of “organizational performance” in terms of patterns of duration dependence of problems, participants, solutions and opportunities. For example, stochastic models of state transition with multiple destinations could be estimated to explore conditions under which “problems” might tend to transform themselves into opportunities. In this perspective, the analysis of the conditions affecting the survival of “problems,” “participants,” and “solutions” on the lattice could reveal interesting aspects of the underlying model. A similar strategy has recently been followed by March, Schultz and Zhou (2000) in their detailed empirical study of rules in organizations.

A second avenue for further research that we are currently pursuing, involves additional programming work to inject elements of stability into Garbage Can decision making processes. Since its appearance, a historical criticism of the GCM has been based on its apparent inability to represent elements of stability, inertia and routinization and therefore to capture adequately what many consider to be the most obvious feature of organizations (Cyert and March, 1963; Hannan, and Freeman; 1989; Nelson and Winter, 1982; Padgett, 1980). In an attempt to address this problem, we are currently working on a new and considerably more complex version of the model in which “routines” – stable and recurrent sequences of problem solving activities – are produced endogenously within the model as emergent, and partly self-reproducing entities.

The model that we have presented in this paper is nothing more than a first step in a search for more constructive representations of organizational decision processes, i.e., for representations that do not presuppose the existence of entities that are meant to be explained (Fontana and Buss, 1996). Even as a first step the model falls short of its own promises in many respects. Perhaps the most obvious shortcoming involves the fact that the boundaries around primitive objects in the model are not allowed to change or evolve. In our model, entities are capable of reproducing, but their structure is kept constant throughout the simulation. In other words, the entities in the model might change quantitatively (e.g., their energy level may change), but they are capable of limited qualitative change as a consequence of their encounters with other objects (this is particularly true for participants, perhaps less so for “problems” and “solutions”). As a consequence – and as a reflection in part of the original formulation of the Garbage Can Model - the state space of the model depends almost exclusively on a set of exogenous conditions with extremely limited scope for innovation, learning and the development of novelty at scales not specified at the level of individual entities (Crutchfield, 1994). In the context of our continuing modeling efforts, we believe that the main challenge ahead will be to remove these limitations, without increasing the complexity in the architecture of individual entities that populate the organizational landscape.

DISCLAIMER

Permission to copy or modify this *NetLogo* model and its documentation for educational and research purposes only and without fee is hereby granted, provided that the authors' names

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