NON-NUMERIC SIMULATION

Steven Evans

Carnegie-Mellon University

Abstract

This paper introduces the concept of non-numeric simulation, a viewpoint which emphasizes the simulation possibilities among parameters associated relationally rather than numerically. One purpose of non-numeric simulation is presented as a means of evaluation of theoretical frameworks or systems of axioms that a researcher may be considering. By way of example, an essentially non-numeric simulation is sketched, also showing how it may evolve into a more classic, numeric form. Some types of results that may arise are discussed including detecting stable, oscillating, and steady-state processes and conditions. Finally our hypothetical example is related to an instance of research in organizational behavior, with two other applications briefly noted.

Introduction

Simulation is often considered a means by which extremely complicated interactions may be considered and evaluated, especially when the interactions, variables, or relationships are large in number and complicated in structure. There may not even be any way to organize the phenomenon other than by a simulation effort due to a lack of theory, framework, or mathematical power. In such cases simulation becomes the means by which the complexity is handled for us.

We wish to suggest another aspect of simulation that is often ignored. This aspect of simulation is its use as a framework evaluator. In this application, simulation is a methodology to experiment with frameworks or conceptualizations. Its focus is on relations rather than on numeric interdependance. We shall call such simulation non-numeric simulation. We shall consider some characteristics of this methodology and present a somewhat pure example.

Under different conditions and formulations, methods with some of the same characteristics of non-numerical simulation have been used. This has been true especially in the behavioral sciences where numerous interrelated models have been presented such as the simulation of verbal learning behavior (6) and behavior in the binary choice experiment (7). Other recent efforts also represent basically a semantic approach (1), (2), (10). In this sense, non-numerical simulation has not been new to some researchers, but its essential differences from usual simulation have often been obscured. This paper initiates an explicit effort in exploring such methodology. In this context, this paper is also a contribution to complex problem-solving in ill-structured problem domains. It is typically these domains that benefit from such an approach rather than the more structured and well-developed problem domains.

The essential idea of non-numeric simulation is an analogue to the development of heuristic programming with special emphasis on list processing (rather than numeric-algebraic manipulation). However it is advantageous to discriminate in the methodology of simulation rather than draw extensive parallels through analogy to the heuristic programming, artificial intelligence domain. Hence we shall only note the surface similarity between list processing and non-numeric simulations.

List processing involves the manipulations of lists with operators that are suited for lists (as removing the first or last items from a list). It does not rely on explicit numeric relations. Often the relations that are crucial are the semantic ones that relate to the actual items on the lists. In such applications, the essential relational operators are semantic. In non-numeric simulation, when an undefined or poorly defined phenomenon is considered, the relational operators of interest involve the separate parts of the phenomenon, usually with such relations as "follows in time sequence", "is adjacent to", "precedes", "follows". etc. Such non-numeric relations have no arithmetic counterpart, in the ill-structured environments about which we shall be interested (in those cases where there are such numeric relations, we have a numeric simulation). Hence non-numeric simulation involves relations that are typically weak rational as we shall call them, rather than strongly functional (in the mathematical sense). The purpose in such weak-relational cases is to explore such sets of relations further, via the non-numeric simulation, to ascertain their merit for future exploration, numeric evaluation, etc. Non-numeric simulation, then, simulates the set of relationships, rather than just the effect of such relationships already defined (and usually accepted). Thus instead of being in the case of having axioms in whose consequences we are interested, we are in the case where we wish to explore the choice of axioms themselves. Shortly, we shall explore one such example of non-numeric simulation.

Though we shall speak of the pure case of non-numeric simulation, there is rarely if ever an absolutely pure instance. Rather we are typically in a mixed case where there are at least some incidental numeric relations that are available (or can reasonably be approximated for the sake of the example), but incidental or subsidiary to the main issues and actions. In fact, the mixed case itself is a summary of the fact that the actual condition is a continuum from the totally mathematically explicit case to the mixed case, the mainstream of simulation, to the relational case where non-numeric simulation in its purer form takes place. As our example will note, some numeric relations will arise, just as in list processing, we may restrict the number of members in a list, count membership and act accordingly; keep lists of associated probabilities that relate some members to others, etc. However one measure of the minimal interest in numeric relations in list processing is reflected in the difficulty and (computer system) expense in performing any type of arithmetic at all. Similarly, we shall focus on the other end of the continuum than numeric simulation traditionally has. The following example shall reflect this non-numeric emphasis. All the relations are purely hypothetical but are representative of the kinds of information that can be dealt with.

A Hypothetical Example of Non-numeric Simulation: Effects of Job Strategies

In this example, we shall postulate four strategies that describe the motivation of the job holder or seeker: these motives are security, status, power, and money. We shall not pursue all strategies nor completely orthogonal strategies. Rather, for the purposes of the example as well as a hypothetical researcher, we assume that we wish to concentrate on these four types. Given the four, we hold that various relations can be expected to follow under certain conditions. We shall be interested in the consequences of such relations when we "run" the non-numeric simulation.

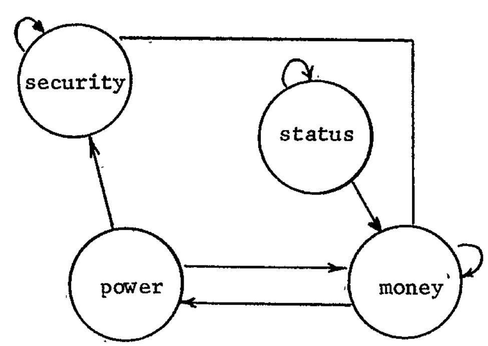
Before giving the first proposition however, we emphasize that all such relations that follow are purely arbitrary; no claim whatsoever is made for their actual validity. They were merely formulated for the example, while the "justifications" for the relations that are sometimes given merely attempts to make the example more plausible to the reader. In practice, we presume that a researcher has relations he is interested in and that he wishes to test the effects of such sets of suppositions (including some he may consider false) under a simulation run.

The first set of relations we shall arbitrarily postulate concern the hiring propensities of people who operate under different strategies. Though we do not argue that all the "people" in the simulation shall hire someone directly, we shall consider their selection and choice of new job candidates, as well as their general influence, to effectively affect the kinds of people they will prefer and hence choose to work with. Since jobs are also filled by recommendation, this effect corresponds to the real world in its effect, if not in manner of implementation. For our first arbitrary relation, posited simply for the sake of example, we shall suppose that people who prefer security shall tend to hire others who prefer security. People who do not rock the boat prefer others with the same strategy. Status-minded people will hire their own type as well as those who are after money, since the money often can be confused, at an initial level, with status. People looking for power will hire those looking for security (no threat) as well as the money-makers (to enhance their own vicarious contribution to the organization). They do not hire other power-oriented people since these will be threats. Money-types hire others of the same sort since they see a successful organization as one that can pay better. They also will hire power-types since these can be confused with money-types who want the presidency for the money rather than the power. A summary of these relations is given in Illustration 1, where the arrow indicates that a person of the strategy indicated at the tail of the arrow will hire a person of the type listed at the head of the arrow.

ILLUSTRATION 1

Hiring Propensities

Under Different Strategies

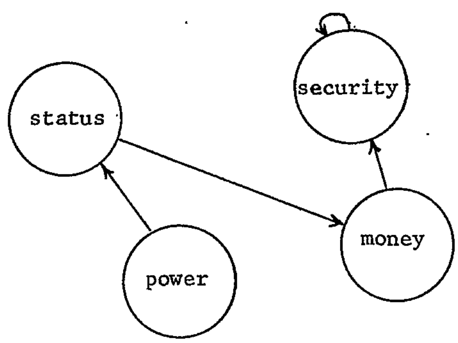


We shall consider four shifts of strategies relating to (1) time (that is, evolution of the person), (2) environment (the type of fellow-strategists one is immersed in), (3) success with any one strategy (its effect on one's subsequent strategy) and finally (4) failure of one's strategy (its effect on one's subsequent strategy).

Looking at shifts of strategy over time, we shall also posit that the security minded becomes moreso. The status seeker tends to settle for money (all the other symbols perhaps becoming finally monotonous), the power seeker tends toward status (whether he has gotten power and now wants status or has not gotten power and settles for status as an alternate), and the money-minded gravitates toward security as he feels he is "maturing" (or simply aging). A summary of these relations is found in Illustration 2.

ILLUSTRATION 2

<u>Strategy Evolution Over Time</u>

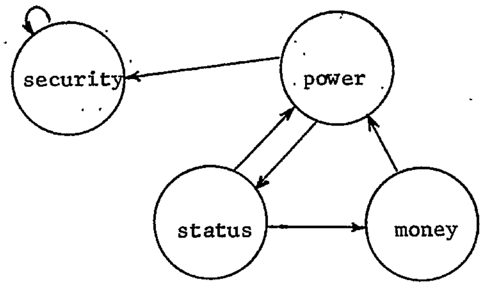


In an environment of security minded people, the security-minded individual moves toward security too. Status seekers together move toward either power or money strategies as ways to distinguish themselves (higher status) from the others. Power seekers together either shift toward a status strategy as a way to gain more power (all things being equal) or move toward a security strategy in order to prevent being trampled by the other ladder climbers. Money minded types move toward power as a way to enhance their success amidst other similar strivers. These relations are summarized in Illustration 3.

We now consider shifts of strategy when the former strategy was successful. We further hypothesize that security minded people who achieve security will tend to move toward a money-strategy, seeking the benefits they can, once they feel secure. On the other hand the money-type will seek security after successfully achieving financial gain, in order to secure such gain. In addition he may pursue a status strategy, as the proper result of having achieved such financial success. Similarly the power strategist who is successful pursues a status strategy, to properly complement his power. The successful status seeker on the other hand pursues money to reflect the status he has achieved.

ILLUSTRATION 3

<u>Strategy Evolution Over Environments</u>



In the case of failure, the security minded seeks power to provide the means by which he may acquire security. Similarly the status seeker pursues power as a means by which he may force status. The unsuccessful power type resorts to a money strategy as a substitute. The financial failure seeks security as a substitute for his failure. These relations are summarized in Illustrations 4 and 5 on the following page.

In our simulation, we shall begin with a mix of individuals of various strategies permitting each person to affect the hire of someone at the end of the year's period. Each new person has equally likely opportunity to go into any division of the company. This hiring effect, defined by the hiring propensities transformations, ends for each individual after he has served five years, and presumably delegates such responsibilities (and interest) elsewhere. At the beginning of each year, after the first, an environment effect applies: if the majority of any division are of one strategy, then someone who is in the minority is shifted to the type of the majority. If this results in a pure environment, the environmental evolution applies to the group, according to Illustration 3. For each individual, at the end of every other year, beginning with the second, his success or failure transition is activated (where success or failure depends on the division he is in). At the end of each person's fourth year, the time evolution transformations are applied to him. Then at every fourth year (absolute time), the system recomputes which divisions are successful or not. To structure the simulation, all the changes are applied in the order as given above.

We shall propose two simulation runs. The first is with a company with four divisions,

ILLUSTRATION 4

Strategy Transition Under Success

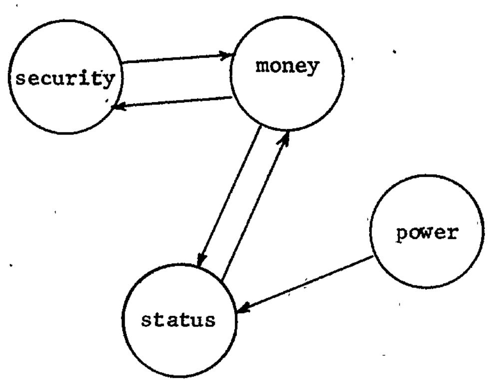
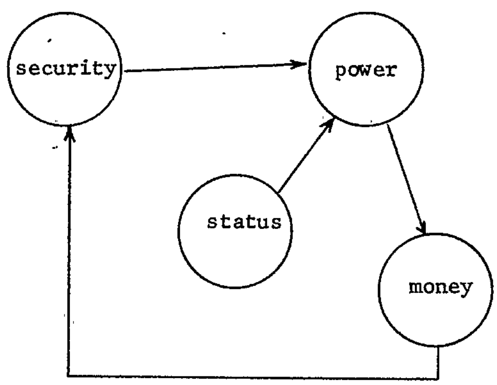


ILLUSTRATION 5

Strategy Transition Under Failure



three of which are successful. The individual has equal chance of being in any one of the divisions, and in so being, his success or failure is determined. Each year he may be shifted to any division. The company is considering operating under three meta-strategies. First it will hire people with either security or money strategies figuring that it wants to continue a good thing (success) while still expanding. The second possibility is to hire just money-types thinking it should go for growth (or aggresive) types. Finally it can take a conservative approach and hire only security minded types, thinking it should continue on its successful course. Hence, this first run has three separate meta-strategies which we are testing in the environment described.

The second simulation involves a company with three of four of its divisions failing. It considers hiring only power-strategists hoping that each one's "wanting to become president" will turn the company around. On the other hand it also is considering hiring only money strategists feeling that this will prompt growth, and hence success. Finally they are considering a mixed strategy of some of each. The question is: What will be the results of such meta-strategies on the overall makeup of the firm over an eight year period? This example is ready for simulation in non-numeric terms. In virtually a metric free environment, we may see the results of these suppositions under such conditions with such hypothetical initial conditions. Over a longer time frame (of shorter time periods like months but the same total time horizon of eight years) we have too complicated a problem to calculate by hand; simulation is the natural methodology. In particular, the simulation of course is essentially non-numeric.

Relaxing that condition, we could add several evaluation parameters as we move to a more numeric simulation style. We could cast the effects of different types of strategies as operators on the growth of the firm. To exemplify this transition toward the numeric, we shall posit some purely hypothetical, though reasonable, operators for each of the four strategies. Let the value, g, of the firm be set at 100 units. For each security strategist in each division, the growth of that division of the firm remains constant:

$$s(g) = g$$

where s(g) is an individual in the firm with a security strategy. For the status strategy, we calculate for each division the effects of a status strategy on growth:

$$st(g) = g + .04g - N(st)/2$$

where N(st) is the number of individuals with that status strategy. This indicates that the status minded adds about 4% growth to the company, which is necessary to maintain his status of being in a growing company but also detracts, by a factor of one-half, from the company as the number of workers become more and more just status-seekers. For the power strategy, we assume that this leads to a bit more growth but detracts as there becomes too many chiefs and no indians.

This is given as

$$p(g) = g + .05g - N(p)$$

Finally we have the money strategy which benefits the company on the short term but is a hindrance (in net profit) in the long run as the salary of such highly paid management far exceeds their income producing potential. This is given by

$$m(g) = g + .08g - 2N(m)$$

where again N(m) is the number of such money types in a particular division.

This added measure, of course, moves us farther along the simulation continuum to the numeric style.

Some Types of Results Such Simulation Can Yield

One simulation of the first case under the strategy of hiring only money-minded types resulted in the following after four years: one of each type in successful division #1, 75% security-types in unsuccessful division #2, only power types in successful division #3 (which would all converge to security types under environment evolution in another year), and about half of status and half money types in successful division #4.

Though the suppositions in the example were purely for explication purposes, it appears that the assumptions were strong enough to at least imply a "ghetto-ization" in some divisions, along types. Obviously this single partial run in no way suggests, or was meant to suggest, research results in effects of employment strategies. Nonetheless the convergence of types over time in divisions is the kind of result that could suggest further research. One could then see to what extent which suppositions affected the convergence, by altering or relaxing some conditions. One can survey industry to determine if such convergence of types occurs, which would then provide a data area to further refine the simulation assumptions.

Another kind of investigation would involve looking at the differences of meta-strategies in successful versus unsuccessful companies as well as intra-departmental differences (successful versus unsuccessful divisions). Hence such simulation provides, among other benefits, a way to explore initial conceptualizations and formulations of problems. Relational assumptions can be studied before they are acted on.

Finally, focusing on the relations, we shall introduce three performance characteristics that can typically arise in a non-numeric simulation with which one may be concerned. The first is stability. This condition is simply the observation that within some partition of the program (e.g. - a division of the company in our example), the members of that partition remain essentially the same after some point in time of the simulation. In our case, if we were to eliminate success/failure transitions after the first two years for an individual, one meta-strategy in a simulation run leads to security-minded types dominating a section and perpetuating themselves. With the success/failure transition included, we get an oscillating characteristic, where some division is ghetto-ized under first one then another type, and these types proceed together through the system, following the same rules. An interesting case is when the simulation settles down to some steady-state description, or at least statistically so. More precisely, this steady-state condition occurs when the stable and oscillating conditions are identical. In such a case the simulation can be said to converge. An alternate interest can be to isolate particular time periods (or intervals) where the simulation has some stable, oscillating, or steady-state description. The researcher of course, depending on his desires, manipulates the relations (or perhaps some subset) to ascertain the effects of shifts of hypotheses on (simulation) outcome. In general, information about stable, oscillating, or steady-state conditions can be quite important or useful.

An Example From Organizational Behavior

We shall remark on recent research in organizational behavior, to show how one such work lends itself to this methodology. One research effort by Hunt (8) attempted to find relationships between such organizational parameters as structure and technology and the impact of these factors on worker satisfaction and subsequently on organizational conflict; in turn these variables were evaluated as to their effect on personality factors and the concomitant interplay between structural, environmental, and technical variables and dissatisfaction. Some results (9) were of the nature of propositions of relations:

> "an increase in attitude strength for external pressures will lead to a strengthening of attitudes about the technical system."
>
> "a strengthening of attitudes about the technical system will be accompanied by a strong, positive change in attitudes about the formal structure...".
>
> "if attitudes about the formal structure strengthen, then there will be a positive change in the strength of attitudes about destructive conflict and need dissatisfaction."
>
> "if attitudes about destructive conflict are strengthened, then there will be a positive strengthening of attitudes about the formal structure..."

The nature of these propositions are essentially the analogue to our example and would have provided the transitions of interest. A diagramatic representation of the proposition would yield figures analogous to the diagrams in our hypothetical example. This example from the literature shows just one instance where there is a natural candidate for non-numeric simulation.

Other Examples of Non-numeric Simulation

We shall briefly mention two other applications explicitly conceived to take advantage of a non-numeric simulation viewpoint; both involve framework evaluation. The first concerns research into computer constructed education (3), in particular the construction of a computerized educational assembly system for student executed educational design (4).

In this effort, very large collections of educational goals were assembled where each of the goals described some educational learning effort. The description included a specification of the subtasks necessary to accomplish some particular educational goal. The various subtasks, being learning efforts, were also described. The purpose of the system was to create a complete curriculum for the student, satisfying his initial goal. Thus, given a particular student involved in the system with some desired goal, the matching of his goal with a stored goal generated a series of subgoals needed to be accomplished. In turn, given such subgoals,each of its sub-subgoal represented some implied set of requirements necessary to accomplish the subgoal. At times, some subgoals of subgoals... of subgoals implied a higher goal due to the nature of the encoding process of the goals. In addition, over time, the student would acquire some subgoal list of accomplishments from an earlier period, thus causing other subgoals to be unnecessary in some subsequent time period. This universe of implications of learning materials represented an enormous framework of assumptions concerning a set of educational materials. Since the collected universe of goals was so large, and the variety of students who might use it was great, only a non-numeric simulation that evaluated this total framework could have given adequate information about the educational assumptions embedded in it. The various transitions of our earlier example in organizational behavior correspond to the transitions implied in the connection between educational subgoals. Different backgrounds of the students as well as evolving backgrounds as they accomplish goals and subgoals are analogous to the various strategies in our former example. The goal of the simulation was to ascertain the extent to which the universe of goals (and their implied goals) represented a coherent set of relationships that could generate appropriate sets of curricula.

Oscillating conditions are especially important in this example since this usually implies that some subgoal is so similar to a higher goal that the satisfaction of the subgoal repeats the efforts of the original goal,and thus an infinite cycle is formed. A stable condition arises when some subgoal inadvertently indicates itself as a necessary subgoal, thus causing the infinitely recurring satisfaction of the same goal to arise. In general however, this educational application is a typical case where a large framework of assumptions have been collected, too numerous to handle directly, and are all non-numeric in character. A non-numeric simulation viewpoint makes the testing of this framework a straightforward effort.

The final application will only be briefly noted. The example involves an effort to describe the cognitive map of the medical doctor involved in diagnostic work (5). Given a particular human physiological system, certain tests and expectations are assumed by the researchers to be implied for diagnostic evaluation. These in turn point to other systems depending on the positive or negative results of the test. For certain disorders, a limited set of systems may be explored and a limited set of tests and conditions considered. The system implications resulting from a test, implying other systems and tests, are the corresponding transitions of interest in this example. The framework being evaluated is a set of transitions, a series of suggested next steps that follow, given a system, a test applied to that system, and a condition that may hold for that system. These are, again, a large number of non-numeric, semantic evaluations whose consequences can be determined for a large set of patients via a non-numeric simulation approach.

Conclusions

We have drawn a distinction between three types of simulations. The strictly numeric, which predominates, the mixed case where some relational elements were involved with numeric relations but usually were a result of ignorance rather than choice, and what we chose to call the non-numeric case which can be persued for its own merit. Typically such styled simulation involved weak-relational associations between elements. This latter case was described more explicitly, with an example. By explicitly describing the non-numeric case, its familiarity should increase to other researchers unfamiliar with such a possibility. This distinction and elaboration could contribute to the development of efforts in other domains as well as influence the development of future simulation languages and simulation methodology.

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