Anna Latawiec

The notion of simulation - philosophical aspects

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ANNA LATAWIEC

THE NOTION OF SIMULATION – PHILOSOPHICAL ASPECTS*

1. The Notion and Types of Simulation. 2. The Essence of Simulation. 3. The Methodological Aspects of Simulation.

The notion of simulation appeared in scientific literature 30 years ago. However, in publications presenting practical examples of simulation the explanation of the notion itself is often omitted. Supposedly, such a situation results from an intuitive perception of the notion and the authors' concentration on the process and its final results.

1. THE NOTION AND TYPES OF SIMULATION

The term *simulation* comes from the Latin word *simulatio* which means the representation or imitation of the behaviour of an object, group of objects or the course of a process through the use of another object, group of objects or process.

1.1. OBJECTIVE APPROACH TO SIMULATION

The objective approach to simulation is an approach that is based on identification of a simulation with the material or formal object.

The objective approach to simulation includes the following interpretations:[1]

1) model (operational model: C.S. Greenblat 1990; special model: D. Crookall, R. Oxford 1986; C.S. Greenblat 1990)
2) actualisation of the simulator (D. Crookall, R. Oxford 1986)
3) tool (G.M. Weinberg 1979, R.F. Barton 1974, A.A.B. Pritsker, C.D. Pegden 1976, T. Ryś 1981, A. Pełech 1984)
4) technique (numerical: T.H. Naylor 1966; experimental: W. Switalski 1987; problem solving: G. Gordon 1969, 1975, T. Ryś 1981)

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[1] Pełny wykaz publikacji zawierających omawiane określenia pojęcia symulacji znajdują się w pracy: A. Latawiec, *Pojęcie symulacji i jej użyteczność naukowa*, Warszawa 1993.

5) representation (J.M. Proth, H.P. Hillion 1990, A.A.B. Pritsker, C.D. Pegden 1976)
6) computer program (H. Stanislaw 1986, J.M. Proth, H.P. Hillion 1990)
7) operation (G. Bonham, E. Carter, J.W. Harbaugh 1969)
8) method of confirming that the rules of functioning of the material object are known (G.M. Weinberg 1979)
9) natural behaviour (A. Pełech 1984)
10) social phenomenon (A. Pełech 1984)

Of special interest is the often observed identification between the notion of simulation and the method of confirming that the rules of functioning of the material object have been understood. It is obvious that the correct construction of a system representing the original one requires profound knowledge about the original. If we know the input and the resultant output states, then it is possible to learn about the interior of the simulated object. In other words, by changing the input parameters it is possible to obtain the output states that agree with the real behaviour of the system. This is a method of learning about the system's interior. As G.M. Weinberg puts it, we "discover" the system's interior. Therefore, if we succeed in construction of a system that response to the given input parameters is in accordance with our expectations, we may say that the essence of the object's behaviour has been discovered, and the simulation was fruitful.

Let us put together and consider the proposals identifying the notion of simulation with some of its interpretations, i.e. the numerical, experimental and problem solving techniques or the method of confirming that the functioning of the material object is understood. As a result we have a numerical method, a method or technique of conducting experiments, a method of solving problems or a method of confirming that the rules of functioning of the system under examination have been understood.

To sum up, we may say that the objective approach to simulation inevitably leads to its identification either with a material object (tool, physical model) or a "formal" object (mathematical model, method, approach, representation, sociological phenomenon, operation).

1.2 OPERATIONAL APPROACH TO SIMULATION

Hereinafter, by the term *operational approach to simulation,* a certain activity or proceeding will be assumed. Simulation research and analysis made by their authors, enable underlining of the following activities :

1. modelling (by wide range of means), namely : making use of the model itself, computer–aided modelling and computer–aided research and analysis
2. programming (widely understood), namely : a computer program execution, making use of computers' hardware and software tools and resources, computer–aided modelling
3. representing (or transforming): imitation, emulation, tracking, monitoring, duplicating
4. reality's fragment research and analysis : behaviour analysis, individual cases analysis
5. activity
6. experimenting

Similarly with the object approach and the operational approach, more information might be included indirectly or in a hidden form.

Therefore, the operational approach of simulation, results in its equivalence with one of the following activities :

1. Creating and making use of the model
2. Research, analysing and experimenting (also computer–aided)

1.3 SYMBOLIC APPROACH TO SIMULATION

Hereinafter, by the term *symbolic approach to simulation*, its formal description based upon the notation of rules set within a certain domain, will be assumed.

Many authors recognise the fact that formalising of notation, its consideration, etc. – proves the understanding of mentioned domain. Actually, an extensive knowledge on the essence and functioning of the notion is necessary for its formalising. In case of the notion of simulation, a try to define a simulation process itself has taken place. It is not, however, the one symbolically seen and expected by us.

The proposals of M. Bunge, F. Pichler and M. Lubański illustrate the third type of the simulation approach.

The first approach stresses analogies' relation, a sort of similarity between the objects. It is assumed that the original and its model should be "infection–like" analogous. Having said that, we state that a high level of similarity and adequacy between them should take place, but mentioned adequacy should not be meant as an identity. We talk on simulation in terms of creating the real model, for example a small model of a ship, so still the adequacy is provided when function graphics are presented. Bunge assumes that the simulation is an unsymmetrical, reciprocal and transitional relation.

A mathematical description makes a point of the original object and its behaviour emulation, and in a formal way expresses an idea – that the simulation is a construction of the model's status history

– as it would have been the original's one. That is an example of the emulation by a simulating process. It does not address special situations concerning, for instance, a factor of time gone. Nevertheless, we can easily see that both versions of symbolic simulation descriptions are just a formal set of expressions, appearing in two previously mentioned type proposals.

2. THE ESSENCE OF SIMULATION

Descriptions presented above give us a picture of views and their changes, which are dependent on other science and technologies' progress. As far as new technologies become available, particularly the microcomputers, the simulation method itself, although heterogeneously seen, comes into wider areas of technology and science. It becomes a method or a tool, which is more and more willingly and efficiently used – since its superiority over other scientific research methods and tools has been recognised. The simulation process in conjunction with the time and purpose aspects is underlined in many views and analysis.

One of the important factors of the simulation notion, seems to be its relation with the time aspect. It gives a possibility of monitoring the results, tracking and recording the changes in status of the simulated system — within certain time frames. In consequence, it may be seen as a source of data to predict the results of the real system itself.

Another aspect coming from the simulation, concerns the inviolability of the real system. Since the simulation process makes use of its model only, the real system remains unchanged. This very feature, plainly specific, is often understood as the primary criterion in choosing the method of simulating the reality. There exist a number of cases, when simulation is the only applicable method of getting to know the reality. When researched object, for example a human brain, a company business administration, etc. – is to be monitored in terms of its reactions on certain stimulation, then the only proper way to handle that is the simulation, mainly computer–aided.

Now, let us consider whether notional role of simulation has any important impact on its value, particularly when computer–aided. It seems that it is not the case, since the symbolic models are commonly used in the scientific research.

One can say the computer–aided simulation is not really a simulation in terms of its word exact meaning, or even that it has nothing in common with that. Such an opinion is shared mainly by the physical simulation supporters, who take into account its intuitive aspect. In the light of mentioned proposals, a purely notional computer–aided processing of the symbolic model, expressed in a certain programming language, is a simulation, too. The only difference is that the computer–aided simulation is of another type, in the sense of its intuitive understanding.

Having agreed that the simulation is a form of representing, transforming, emulating or imitating – it is allowed to do that in any possible way – as long as the relations between the original and its model remain compatible. That is why, we shall agree that the symbolic representation is one of many possible ways.

There also exists quite opposite opinion saying the simulation addresses mainly the relations between the models and the computer. It is believed that in such a case, a purely notional simulation is seen as an exactly meant method. Furthermore, we shall stress the fact that the simulation is an artificial representation of the reality.

It has been suggested that a full understanding of the simulated object or system behaviour is needed before you proceed with the simulation. Certainly, a knowledge of the system is necessary to construct its simulation model, but in many cases the simulation is performed in order to get more information on its original, like its behaviour, for instance. Sometimes, before getting started, our knowledge might be partial or just very poor — anyway, there is a need to know researched object on a minimal level, so you will be able to construct its approximate model first. More data about the object can be found by comparing the simulation results, taken from and based upon various values of entered parameters. If the results are those of expected before processing, it will show our good knowledge of the original, and then we may recall G. M. Weinberg words : "the black box is ours and we can read it". It will also mean we proved our understanding of the original object.

If, however, the results do not feet to our expectations, it will show a wrong construction of the model. Then, according to the simulation method rules, we will have to modify the model, so next time the results should be positive. Of course, constructing and improving the model, we will extend our knowledge of its original.

Searching for the essence of simulation, we discover that all recalled expressions and descriptions, carrying the most important information in a hidden or direct way, divide its stress on the objective, operational and symbolic approach. All types of approaching:

1. relations between the simulation and the model (of different types)
2. the status changes' dynamics
3. inviolability of the original
4. a precise description of a purpose

In both symbolic approaches, an existence of similarity relation – or just analogy – has been underlined. A certain tool is needed to illustrate such a relation, and it can be the model, which is to capture those similarities and analogies. Symbolic approaches mentioned before, above present the fundamental ideas of simulation in a different way. From now on, we will exclude the symbolic approach as a different way of presenting the notion of simulation in both objective and operational versions.

The objective approach of simulation often shows its certain aspects in a hidden way and at the same time — the same aspects are very clear in terms of the operational approach — and vice versa. For example, when the objective approach clearly addresses the model, then the operational approach includes the same model just in terms of representation. As we well know, the representations take place by making use of some tools, mainly by the properly prepared models.

That is why, we should admit that both approach types reciprocally complement each other in highlighting the most important aspects of the notion of simulation. To summarize, we agree that searching for the essence of the simulation notion, we should take into account all its elements, put in a clear or hidden form – and expressed by both objective and operational approaches.

The dynamics of the simulation, stressed many times already, shows decreasing or increasing of the time scale. It is one of the most important conditions for performing the simulation process. There exist many different processes, which are difficult or even impossible to research and analyse, due to the length of their time scale. In other words, the real processes last for a very long period of time, like for example the evolution process demanding a macro time scale. There are examples of a very short time scale, as some genetic phenomena – and it is simply impossible to track them in the real–time scale – from purely technological reasons. Therefore, there exists a possibility to represent or just simulate the real–time scale during the simulation process, and a suitable time scale variable is needed for that. Similar situations take place when simulating the original object of a size that disables their direct analysis. It means we use the process of simulation when the original object size (put in micro– or macro–scale) makes it impossible to monitor, experiment or research the original object, for instance the evolving galaxy, gens, biology (pol. Biocenoza).

Now, taking into account our considerations of this chapter, we will try to form a consolidated definition of the simulation, by both its approach and its essence.

The simulation is a usage of a material or formal object (objective approach) in order to construct and operate or research and experiment its model (operational approach), which guarantees the inviolability of the real system and provides the status changes' dynamics, by representing decrease or increase of the time scale and the object size – and by doing so – leads to achieving precisely described purpose.

3. THE METHODOLOGICAL ASPECTS OF SIMULATION

We can address the simulation in both "personal" and social–cultural terms. The first one covers any events of individual human life. Those are the unconscious situations from the early childish forms of behaviour, like "playing home", imitating the parents, playing roles in various games, etc. Later on, a person learns to have "new faces", manners, habits, so she/he can better meet other persons' expectations. Actually, she/he simulates a good employee, a politician, a parent — always when it does not (fully) take place in reality. Such a "personal" aspect of the simulation is analysed by psychologists, psychiatrists (when the simulation becomes a sickness / illness) and sociologists.

As far as the social–cultural simulation aspects are concerned, the simulation means intentional forms of behaviour, but first of all — a heuristic and anticipation method. That is why, it is used to monitor the results of taken decisions and to track the progress of certain activities.

Some of the methodological aspects will be shown in this part of article now.

3.1. SIMULATION AS A METHOD

For the majority of authors, the simulation is a method of system research and analysis. By the term *method*, we mainly understand a rule or a way to reach researched reality, or a way to analyse that. To put it differently, it is a repeated action, sort of algorithm based upon a certain set of rules.

It should be stressed that a certain constant algorithm is being formed – and the separate steps are executed according to it – a problem specification, a model description, creating a program, execution of that program, its verification, its validation, results interpretation and the conclusions. Each of mentioned steps may be more complex.

The simulation is then not only an objective system research method, but also the entry point for further methodological procedures.

3.2. SIMULATION AS THE ENTRY POINT FOR THE DESCRIPTION

The simulation model is constructed in such a way that it allows to monitor researched system's changes, the activities' progress and researched object's structure itself. On the one hand – the algorithm includes a knowledge of the simulation model and the object's description, on the other hand – the running program illustrates the activities' progress and the object's status. In this sense, we can even stress that simulation is a description. The simulation models describe the reality in its closest way.

When we research the model of a gigantic bubble–leaf (pol. pęcherzo–listek), then at the same time its description is available; when we proceed with the model of how the weather influences on a certain insect type, we are able to have a description of any events captured by the experimenter – and by changing the model parameters, we get a full picture of any possible situations. In this way, we use the description to construct the model – and in parallel, thanks to the simulation's results, we can share its description with other users.

When we recall the steps of the simulation process, then we will pay attention to a need of given research precise description. There must be a purpose in any scientific activity. One of them, as mentioned before, can be a clarification of the process or event. At the same time, it becomes clear that the necessary condition for such a clarification is just a precise description, expressed in a suitable language. So the description is a sort of the stage of scientific research, in which the results are recorded, and mentioned stages correspond with the scientific problems to solve.

The nature's description takes place indirectly, namely in the light of research methods and is expressed in more and more specialised language. So we may say that the simulation method is a sort of an explorer's preparedness to describe the real world. The simulation model behaviour's monitoring is the entry point for the description of reality.

The simulation might be treated as the entry point for a natural or artificial, real or hypothetical reality's description – and thanks to that – it is a first stage in creating theory concerning certain process or reality. On the other hand, the simulation plays a role of confirmation of previously formed theories.

3.3. EXPERIENCE AS A SIMULATION

The science often recalls the experience, treating it as a specific type of connection between a human being and the reality.

An experiment is a cognitive procedure, assuming a sensual information as a way to solve a problem – but the information itself is insufficient.

The experiment is a kind of a dialogue between us and surrounding reality. Dialogue done by the experiment is a very special type of procedure, when the reality is cross-examined by us. The answers for all raised questions are carefully recorded. Their importance is evaluated according to the rules set up during a design phase of the experiment. The reality often rejects given hypothesis, but still remains the main criterion of the answers' acceptance.

An experimenter tries to check the circumstances, under which the process goes on – and when he succeeds – he takes a certain advantage over the observer, who just looks at the running process, having no influence on that. Since the experimenter may interfere with the process whenever he wishes to, he can properly prepare himself for observation. He is able to repeat his research many times and then compare its results. He also can systematically change the conditions and then analyse their impact on the results' changes.

A theoretician raises certain questions to the experimenter, who is tries to find out the answers by his experiments. The theoretician shows the way of research to the experimenter, although the later is partly a theoretician himself, since he uses theory from the beginning of its design. The experimenter may exclude certain questions due to his research, and those questions are not important to him anymore in terms of the scientific experiment. This reciprocal relation between the theory and experimenting is particularly powerful and clear in practice. Each experiment is based upon certain theory and is processed for its needs. When experimenter undertakes the research, he has to prepare it in accordance with certain knowledge and theory.

Comparing our knowledge of the simulation with our knowledge of the experiment, we may find out that the simulation is a form of the scientific experiment, which is heuristic, does some checking and is practically useful. Any problem faced by experimenter is also faced by the simulator. The simulative experiment has to be carefully designed and processed in accordance with certain knowledge (and certain theory). Simulators themselves treat the simulation as a type of experiment. It is worth to note that also in case of the simulation, it happens that during the experiment, by chance, a discovery of another phenomenon or certain correlation may take place.

Therefore, it may seem to someone that there is no difference between simulation and experiment. However, the deeper analysis shows a number of significant differences. The most important one is a possibility of repeating any number of the simulative experiments, all of them processed under unchanged circumstances with the parameters required by the experimenter. In case of experiments held in laboratories, there is a possibility of very minor conditions' changes, which may return significant changes of the results and their interpretation.

A possibility of repeating is one of the aspects of the experiment and the simulation. Another, equally important one, is the inviolability of researched object. The scientific experiment (both heuristic one and decisive one) is limited to the events, which neither ethical doubts of the experimenter nor technical difficulties appeain. We mean by those all such situations when researched object may be changed or even damaged (for instance a human brain), or situations when the time scale or the size scale has to be changed. The simulative experiment is then the only possible to proceed with. The researched object has a significant influence on choosing a type of the experiment. All the experiments may be processed on a living or lifeless, natural or artificial object – only when it will not interfere with the system that might change the essence of researched object. It is obvious that in many cases the research may, on purpose, change system object's essence.

Our considerations on the simulation and the experiment can be summarised as follows : there is a clear analogy between the simulation and particular types of experiments, namely scientific and practically useful ones. As in case of the scientific experiment, the simulation is based upon the same heuristic and verifying purposes. Practically useful experiments and simulation are processed in order to find out optimal applicable solutions. Having agreed on certain differences between the experiment and the simulation, we may however admit those two are reciprocally complementary methods.

3.4 SIMULATION AS THE ENTRY POINT FOR THE THEORY

Now, let us consider the relations between the simulation and the theory.

The first meaning of the term *theory* is understood as a hypothesis used to resolve a certain research problem and it suggests an existence of a link between the simulation and the hypothesis, leading to find out the resolution. The theory is treated just as a verified hypothesis, and it is crucial to get an answer for "what – if" questions, thanks to and based on the simulation. Rasing such a question, we base on the previously expressed hypothesis concerning the considered problem. The entire simulative experiment, at its initial stage, is processed according to certain hypotheses that are taken due to the rules of searching for a confirmation or rejecting of a proposed answer.

In case of the term *theory*, meant as methodologically and notionally coherent system of theorems, the simulation related with it does not seem to fulfil the criteria set. That is because the simulation is not a system of theorems. The simulation is, however, related with a suitable notional apparatus, like : a model, a scheme, a program, a verification, etc.

These notions come from other domains, mainly from the computer science and cybernetics, but also from other areas linked with particular simulation models, so for example – with the economics, biology, medicine, etc. – or with particular theories, like the Theory of Decisions, of Graphs and of Games – which are used as the auxiliary tools. No rules are set in the definition of a theory, so the simulation can not be seen as a theory in terms of the second approach.

A comparison of the theory and the practice, shows the first one as a systematised knowledge clarifying a given domain of reality, which is much more convenient due to the scientific theories. The theory is a logical scheme allowing to present a consolidated set of various facts, supported by the empirical results. However, a suitable clarification of those results is required, in which the theory should be expressed in accordance to them – giving a possibility to conclude a certain nature of predictions and to compare that with the results. Such an approach to the theory does not comply with the notion of simulation, either.

It is supposed that the simulation can be looked at from two different angles. Since the simulation bases on modelling of a given fragment of reality, the obtained results and descriptions are kind of a theoretical approach to their prototypes. That is why, a language of the simulation is a first–level–language, called an objective language. At the same time, the simulation models themselves can be a subject to research, certainly in a second–level–language, called a meta–language. Such a meta–language can be a System Theory language, a Set Theory language, a Cybernetics' language or any other language. You can find those kinds of approaches in various publications.

From a practical point of view, the simulation is equally treated with other scientific methods. Above all, it is seen as a method having a very important stage of verification.

To sum up, the subjects considered and presented above, constitute just a sector of a huge area to be faced by the philosophers who intend to undertake deeper analysis of the notion of simulation. All issues related to the problem of simulation fascination with the simulation method, its improper use or treating a human being as a subject or object of the simulation process itself – seem to be the most interesting ones.

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