Ören, T.I. (2001 – Invited Paper). Impact of Data on Simulation: From Early Practices to Federated and Agent-Directed Simulations. In: A. Heemink et al. (eds.) Proc. of EUROSIM 2001, June 26-29, 2001, Delft, the Netherlands.

Impact of Data on Simulation: From Early Practices to Federated and Agent-Directed Simulation

Tuncer Ören
Professor Emeritus (University of Ottawa, Ottawa, Ontario, Canada) and
Tübitak-Marmara Research Center, Information Technologies Research Institute
Gebze-Kocaeli, Turkey oren@site.uottawa.ca

ABSTRACT

Data has strong impact on different aspects of scientific thinking. The article starts with a milestone example of the impact of data. Then clarifications are offered for some basic concepts such as, belief, fact, data, information, and knowledge. Three perceptions of simulation, namely non-scientific, scientific, as well as military views are outlined. Concurrency of simulation and real system operations are elaborated on and four possibilities for augmented reality are clarified. Where data matters in simulation it is highlighted. Unity in diversity of simulation is pointed out.

1. INTRODUCTION

A discussion on the impact of data on simulation can benefit from elaborations on the characteristics of data as well as the types of simulation.

1.1 Impact of Data: A Milestone Example

Data is essential and provides a conceptually rich paradigm for many types of discourse including scientific inquiry. As a milestone example, one can cite the fact that relevant data had an impact in the history of ideas in Western civilization, as reflected in the works of Ptolemy and his predecessors to the works of Galilei; with Copernicus, Brahe, and Kepler, in between. As Riley summarizes: "Kepler's work is an example of the deduction of general laws from a mass of observations—the essence of science. But it was primarily his attempt to apply physical principles to astronomical data that marks his break with ancient astronomy." (Riley, 1992, pp. 185-186.) Claudius Ptolemy (100-175) who dominated the Western world for 15 centuries advocated the previously known earth-centric (i.e., Ptolemaic) world view. Nicolaus Copernicus (1473-1543), leading to the Copernican revolution, (i.e., sun-centric world view), argued just the contrary. However, his "methods of arguments were still distinctly medieval." (Hall, 1992, p. 178). Thus, what Kepler (1571-1630) achieved was based on his master, Tycho Brahe's (1548-1601) relentless observations of the planetary system. (Brahe also advanced astronomical apparatus that was needed for the observations). Furthermore, Kepler's abstraction of relevant data and Galileo Galilei's (1564-1642) own observations led Galileo to promote the Copernican world view with well known consequences.

1.2 Basic Concepts: Belief, Fact, Data, and Knowledge

A brief overview of the terms belief, fact, data, information, and knowledge can be useful as a background:

“*Belief* is a hypothesis about some unobservable situation” (Hayes-Roth et al. 1983, p. 399). Beliefs do not need to be true.

“A *fact* is what makes a belief true or false.” (Russell, 1921). Webster dictionary defines “fact” as a thing known to be true or a statement about something which has occurred. The word fact is derived from Latin factum, a thing done, and exists in English since 1539 and predates the word data by over a century.

The word *“data*” exists in English since 1646 and can also be used as a singular word. It is the plural form of the Latin word datum which has also another plural form as datums. As explained in Webster, data means factual information given or admitted, as measurement or statistics, to be used as a basis for reasoning, inferencing, discussion, or calculation.”

A synopsis of the definitions of *knowledge* taken from Ören (1990) –which also provides a taxonomy of about 500 types of knowledge and knowledge processing knowledge– follows: “A limited-scope definition of knowledge is ‘facts, beliefs, and heuristic rules’ (Hayes-Roth et al. 1983, p. 401). Russell defines knowledge as ‘a sub-class of true beliefs’ (Russell, 1948, p. 170). Ayer states that ‘the necessary and sufficient conditions for knowing that something is the case are first that what one is said to know be true, secondly that one be sure of it, and thirdly that one should have the right to be sure’ (Ayer, 1956, p. 35). Minsky summarizes these views by saying: “Some philosophers have argued that ‘knowing’ must mean ‘true’ and ‘justified’ belief” (Minsky, 1988, p. 302).

Denning provides a concise contradistinction of the terms data, information, and knowledge: “(1) Data are symbols inscribed by human hands or by instruments. (2) Information is the judgment, by an individual or group, that given data resolve questions, disclose or reveal distinctions, or enable new action. In other words, information is data that makes a difference to someone. Information thus exists in the eyes of the beholder; the same data can be nonsense to one person and gold to another. (3) Knowledge is the capacity for effective action in a domain of human action” (Denning, 1997, p. 276). Another contradistinction of fact, data, knowledge, and related concepts is given by Wildberger. “Data are facts. … Information is data organized for some human purpose. … Knowledge is information and how to use it. … Judgment is knowledge and when and where to use it. … Creativity is the selective invention of new information and/or new knowledge. … Skill is the focused application of knowledge to some specific task.” (Wildberger, 2000, p 110-111). And “’Deciding’ means acting on information.” (Penzias, 1989).

Data can be numerical, textual, or graphical. It can be a point; can be given in a tabular form or as a function. A list of types of data is given in Table 1 where about 150 types of data are listed. Data are grouped as datasets and can be stored in databases and data warehouses. Table 2. is a list of basic database-related terms. Table 3. –where over 200 other data-related terms are listed– testifies the richness of concepts associated with data.

2. IMAGES OF SIMULATION

Taxonomies of types and elements of simulation can be useful to systematically explore impact of data on simulation. Some taxonomies of conventional simulation and related fields are as follows: simulation (Ören 1987a), simulation models (Ören 1987b), and simulation model behavior (Ören 1987c). A taxonomy of artificial intelligence directed simulation (i.e., cognitive simulation, AI-based simulation, and AI-supported simulation) is given by Ören (1994).

2.1 Three Perceptions of Simulation

The term simulation is derived from Latin simulacre with two connotations: appearance and action; both beeing fake. Currently, simulation has three images as reflected in non-scientific view, scientific view, and military view.

In *non scientific view*, the term simulation means fake, a sham object, counterfeit, or imitation (as for example, simulated leather, simulated pearl). The term simulation has been used in English with these derogatory meanings since 14^{th} century. Even in this use, there is a confusion of the terms simulation and emulation. Emulate means "to strive to equal or excel." (Webster). Therefore emulation means "ambition or endeavor to equal or excel others (as in achievement)" (Webster). For example, a child may emulate her parents; and by doing so she does not simulate them.

The *scientific view* of simulation leads to the following definition: Simulation is goal-directed experimentation with dynamic models. With this perception, simulation is the contemporary sine qua non technique for Francis Bacon's (1561-1626) scientific method which is based on experimentation, as he advocated it in his Novum Organum published in 1620. When experimentation cannot or should not be done on the real system, one can perform it using a dynamic model and hence use simulation. From a systemic point of view, simulation can be used to find the values of output, input, or state variables of a system; provided that the values of the two other types of the variables are known. Correspondingly, simulation can be used in analysis, control, and design problems. The reasons to use simulation were systemaized by Karplus (1976). His spectrum ranged from arousing public opinion to designing products; and also covered: gaining insight, testing theories, experimentation with control strategies, prediction for action, and prediction of performance. In scientific parlance, emulation is the use of a system in lieu of another system. For example, hardware emulation connotes use of a hardware in lieu of another one. In this sense, use of the term simulation would be wrong. Hardware simulation should mean performing experiments using a model of this hardware.

Military perception of simulation can be summarized as "All but war is simulation." Due to this fundamental difference of perception of simulation, one of the military applications of simulation is called "live simulation;" the two others are labelled "constructive simulation" and "virtual simulation."

In *live simulation*, experimentation is performed with simulated ammunition and real system acting in real environment. Real people and real equipment are both augmented with special sensors to act as target designators.

Constructive simulation is war gaming –forces, equipment, and environment are all represented by appropriate models. At decision points, decision makers inject their decisions to the simulation system.

Virtual simulation is a military simulation where virtual equipment –namely, a physical model of the system– is used.for training purposes. In non-military applications the term simulator is used when a physical model of the system is used. When the physical model has a man-in-the-loop, simulators are usually used for training purposes.

Constructive and virtual simulations fit to the scientific definition of simulation with war gaming and simulator connotations, respectively. Live simulation can best be conceived as a special case of augmented reality simulation..

2.2 Simulation and Real System: Concurrency

There are two basic possibilities: Stand-alone simulation and on-line simulation.

Stand-alone simulation is use of simulation independent of the real system. There are three purposes for such use: pure experimentation, training to develop skill in hardware use, and training to enhance decision making skill.

Pure experimentation is the most common purpose in the use of simulation for both civilian and military applications. This usage supports planning, design, logistic operations, simulation-based acquisition, and simulation-based evaluation of products or processes.

Use of simulation for *training to develop skill in hardware use* corresponds to virtual simulation in military terminology. A human operator uses a virtual equipment (a simulator) to develop skills to use the equipment. This is the case of simulators, such as a submarine simulator or an aircraft simulator.

Use of simulation for *training to enhance decision making skill* is done by gaming simulation. For professional use is examplified by business games and by war games, in civilian and military applications, respectively. War games are labelled constructive simulation, in military terminology. There are also other types of gaming simulation such as peace support simulation and conflict management simulation.

On-line simulation is use of simulation concurrently with the real system. There are three goals of usages: To support the operation of the real system, to foster on-line diagnosis, and to augment reality.

Simulation can be used *to support the operation of the real system*, especially by providing *predictive displays*. A predictive display can be realized by having a model of the system that can be used for simulation. The environmental inputs to the system can be transformed as inputs to the model –by using sensors if necessary. The values of the decision variables are also fed to the simulation model. The behavior of the model can then be displayed before the real system's behavior. If necessary, the values of the decision variables can be modified to get desirable model behavior. Corresponding values of the decision variables can then be inputted to the real system.

Use of simulation to foster *on-line diagnosis* can be done to run a simulation model and a real system concurrently and to compare their behaviors. A difference may indicate a mulfunction in the real system.

Another use of simulation is to augment reality. In *augmented-reality simulation*, real and virtual entities (that can be people or equipment) and the environment can exist at the same time; therefore, operations can take place in a richer augmented reality environment. For example, combat pilots can use helmets to perceive virtual rival aircrafts in an in-flight training session. Augmented-reality simulation reinforces an old saying among simulationists that "Reality is a special case of simulation." In virtual and augmented reality, amimation may necessitate fidelity and accuracy of input data. Data acquisition problems for animated talking faces is reported on Internet (Haskins).

The definition of simulation based on scientific view covers every type of civilian applications as well as constructive and virtual simulation of the military applications. Live simulation is a hybrid type of experimentation where real and virtual entities (such as virtual guns) are used together.

2.3 Possibilities for Augmented Reality

There are four groups of possibilities in augmented reality. Both equipment and operator can be real or virtual.

Real operator using *real equipment* corresponds to *live simulation* where a human (real operator) uses real equipment and virtual guns.

Real operator using *virtual equipment* corresponds to *simulators* or *virtual simulation*.

Virtual operator using *real equipment* corresponds to automated vehicles such as auto pilot – in cars or aircrafts: aircrafts without pilot, and vehicles without drivers.

Virtual operator using *virtual equipment* corresponds to an artificial intelligence aircraft used in an in-flight training. Real (human) operators can interact with such equipment with head mounted displays.

2.4 Levels of Perceptions of Simulation

Levels of perception of simulation also have an implication on the impact of data on simulation. Three levels are clearly identified: Simulation as a computational activity, simulation as a model-based activity, and simulation as a knowledge generation activity.

In the conception of simulation as a *computational activity*, the emphasis is on the generation of model behavior. Hence, this is the essence of conventional simulation. Almost all explanations on input data are applicable within this category of applications.

In the conception of simulation as a *model-based activity*, in addition to the generation of model behavior, computer-aided modelling, model-base (and parameter-base) management, and model processing are considered. The role of data in modelling and parameter-base management is primordial.

At the third level, namely, in the conception of simulation as a *knowledge generation activity*, the scientific definition of simulation can be interpreted as follows: simulation is model-based experiential knowledge generation (Ören 1990, 36-43). This abstraction facilitates the synergy of simulation with other knowledge processing techniques. Hence, simulation can be combined with different types of experiential as well as non-experiential knowledge generation techniques such as optimization, statistical inferencing, reasoning, hypothesis processing (some of which leading to artificial intelligence applications). The role of data in most of these applications is evident. For example, in reasoning, the initial conditions of a rule-based system have to be specified by facts.

2.5 Some Advanced Types of Simulation

Some relatively recent trends of advanced types of simulation are: federated simulation, agent-directed simulation, holonic simulation, and holonic agent simulation.

Federated simulation is an example of interoperability of several simulation studies; each called a federate. It is based on the military requirements of DoD of the USA as well as joint forces of NATO. Current realization relies on HLA (High Level Architecture). For HLA education, see for example, Morse (2000). For use of HLA with a methodology-based simulation approach, see Zeigler et al. (1999).

"*Cooperation* is becoming an important paradigm for both civilian and military applications. Holonic systems are excellent candidates to conceive, model, control, and manage dynamically organizing cooperative systems. A *holonic system* is composed of autonomous entities (called *holon*s) that can deliberately reduce their autonomy, when need arise, to collectively achieve a goal. A *holonic agent* is a multi-agent system where each agent (called a holon) acts with deliberately reduced autonomy to assure harmony in its cooperation in order to collectively achieve a common goal.

Agent-directed simulation is very promising and consists of agent simulation, agent-based simulation, and agent-supported simulation. *Agent simulation* allows simulation of natural or engineered entities with cognitive abilities. Therefore, agent simulation is very appropriate for the simulation of intelligent entities. *Agent-based simulation* is use of agent technology to generate behavior of models. (Parallels with AI-based simulation are knowledge-based simulation, qualitative simulation, and rule-based simulation.) *Agent-supported simulation* is use of agent technology to support simulation activities; they comprise front-end and back-end activities of a modelling and simulation environment, agent-supported validation and verification, as well as agent-supported program generation, program integration (as it would be the case in the formation of federations using HLA), and program understanding for documentation and/or maintenance purposes.

Holonic agent simulation or *holon simulation*, in short, is an important type of agent simulation where agents represent holons. Some military applications include use of simulation for preparedness for conflict management including conflict avoidance, conflict resolution, and conflict deterrence. Civilian applications include modelling and simulation of cooperation of different business entities." (Ören, 2001).

3. Where Data Matters in Simulation

In simulation, if the results have serious implications to others then the simulation results should also be considered from an ethical point of view (Ören 2000b). Furthermore, to have meaningful and credible results from a simulation study, one must have relevant and correct data. Initialization bias is a well-known phenomenon (Schruben, 1982). Hence relevance and correctness of data can become of paramount importance, as it was elaborated on in a recent article:

"Simulation is used to support important policies and decisions. For example, in nuclear fuel waste management systems, simulation is used to study (even several millenia) long-term behavior of nuclear fuel waste. Simulation of safety-critical systems is one of the important application areas of simulation. Currently, simulation is also used in simulation-based acquision as well as simulation-based prototyping affecting millions of dollars of investments. Simulation has the potential of surpassing its own abilities of being an off-line decision making tool to be also an on-line decision support tool for complex and important problems. Existence of several validation, verification, and accreditation (VV&A) techniques and tools also attest the importance of the implications of simulation (Davis, 1992)." (Ören 2000).

Data can occur in several phases of a simulation study: In formulating a model, in formulating an environment (static or dynamic) where the model resides in providing input to excite the model, and as the behavior of the model. Some of the data related issues are: leaving out significant variables and associated data, not having enough relevant data, using inappropriate data, and using data beyond its applicable range. An example of use of data in formulation of an environment is SEDRIS (Synthetic Environment Data Representation and Interchange Specification) (Hunsucker, 2000). Furthermore, lack of proper documentation of explicit and implicit assumptions about data and data sources is also a serious issue.

The behavior of the model can be structural or trajectorial. Most of the simulations are trajectory simulations where successive values of the descriptive variables can be generated. In structural simulation, successive structures of a model, such as growth of cancerous cells can be generated. The scope of this article, i.e., impact of data on simulation, does not include the simulated output data; except the situations where a simulation study provides input to another one.

In modelling, data is needed for parameter fitting and parameter calibration. Afterwards, data is needed for validatating the model and experimental conditions. As Sadowski ascerted in the "data requirements" section of his article, "Acquiring accurate data in the right form often is the modeler's most formidable task." (Sadowski, 1991, p. 52). Sadowski later argued that too much data can cause problems as too little data would (Sadowski, 2000). In some cases model constants and parameters can be very large. For example, in nuclear fuel waste management, simulation of the impact of the buried used fuel necessitates use of several thousands of constants and parameters. In this particular example, the uncertainty in the values of some of the parameters even dictate the use of several replications of simulation to have a probabilistic estimate of the result. In cases where large simulation data should be kept in datasets, datasets need to be reliable, validatable, auditable, and replacable. Depending the importance of the results of a simulation study, dataset integrity may be monitored by specialized tools. Replacing an input probability distribution by its perceived mean as well as using the wrong distribution can be causes of errors in simulation studies (Law and McCowan, 2000).

Sensitivity of the model behavior to the values of the parameters is important since it may lead to misuse of the simulation result, by simply choosing inappropriate combination of the parameter values. Use of neural nets may allow learning the values of data coming through sensors. When data or theory lack, then using simulation, or any other method, may not produce reliable result.

3.1 Providing Input to Simulations

Inputs to a simulation can be input data, sensory input data, learned data, and intersimulation data (Fig. 1). A taxonomy for input models is developed by Leemis (2000). Sensory input data comes from sensors that filter and convert analog data into digital data. Neural nets may capture sensory data and convert it into learned data. In federated simulations, a simulation system may provide input to another one, thus intersimulation data becomes an issue. Dynamic linking between distributed simulations can be achieved by mobile agents. As part of agent-supported simulation, Wilson et al. (2000) report an agent-based framework for dynamically linking distributed simulations and remote data sources. An important data-related issue in federated simulation (with current technology, in HLA-compatible simulation) is to minimize marginal data transfer between federates.

4. UNITY IN DIVERSITY

Simulation, with a myriad of applications and methodological implications, has a coherent unity like a polyhedral gem; each plane face representing a methodological or an application aspect –many having distinct sources. This richness is well represented in the topics of the invited presentations of the EUROSIM 2001 Congress (Figure 2). They are outlined here, since they are relevant to the subject matter of this article and vice versa. The articles can be grouped in two categories: Applications and methodologies/techniques.

Application areas include societal models, atmospheric modelling, and integrated water management. (The application areas of simulation can better be categorized by using the classification scheme of Karplus (1976)).

-*Societal problems* are somes called ill-defined problems. Appropriate modelling formalisms to model such systems and appropriate simulative educational tools are urgently needed also for the following purposes: (1) Simulation for education; and (2) Simulation for the education of (future) decion makers for conflict resolution and for co-operation. Needless to mention, knowledge and data to adequately characterize societal problems are very important. Some resources, once thought to be aboundant, are becoming alarmingly scarce or polluted and devoid of their original characteristics.

-*Atmosphere*, for example, including its problems at the ozone layer, has green house effect and cannot protect us fully from cancer prone ultra violet radiations.

-Drinking and/or irrigation water is already so scarce that it is a source of conflict, or peaceful trade, between nations and/or states. *Integrated water management* is part of a solution to some societal problems.

Methodologies/techniques represented in the invited presentations include: art of simulation, evolution of computing technology, emerging trends, validation, simulation environments with adaptive behavior, and visualization/animation.

-*Art, science, and technology of simulation* subsumes critical system thinking and simulation which is a fundamental area in thinking, reasoning (Cartesian as well as non-Cartesian, e.g., Schrödinger), systems approach in problem solving, system theories, cybernetics, sociocybernetics, and the like. In inductive system theories, observations, i.e., data provide the starting point in the formulations. Systems view in simulation is important to provide a solid background in conceiving, perceiving, and representing (i.e., modelling) reality for analysis, design, or control problems as well as for symbolically processing models.

-Simulation has to be conceived as part of larger system problems. Computer-aided problem solving systems can be enhanced with simulation abilities to have simulation-based design environments (or simulative design environments) as well as computer-aided and simulation-based problem solving. Some of the simulation environments would have *adaptive behavior*.

-*Validation*: Whether or not a model is an appropriate representation of the reality, for a clearly specified goal, is the essence of model validation. Similarly, there are other relevant questions to be asked –such as acceptability of the goal of the study and the experimental conditions

-*Visualization/animation*: They are usually important components in back-end functionalities of user/system interfaces of simulation environments.

5. CONCLUSION

Experimentation —as advocated by Francis Bacon in early 17th century— is the backbone of scientific thinking and allows us to go beyond the limits of Aristotelian logic. Use of models to perform experiments is the essence of simulation. With the advent of computers, simulation and associated knowledge processing are performed with the assistance of computers. Several theories, methodologies, and techologies are available (and opportunities still exist to further develop them) to solve problems in diverse application areas. However, without relevant, correct, reliable, and timely data, none of them can be solved.

REFERENCES

Ayer, A.J. (1956). The Problem of Knowledge. Penguin, Harmondsworth, Middlesex, England.
Davis, P.K. (1992). Generalizing Concepts and Methods of Verification, Validation, and Accreditation (VV&A) for Military Simulations, RAND, R-4249-ACQ.
Denning, P.J. (1997). How We Will Learn. In: P.J. Denning and R.M. Metcalfe (eds.) Beyond Calculation – The Next Fifty Years of Computation. Copernicus (Springer Verlag). New York, 267-286.
Hall, D.E.(1992). Galileo Galilei. In: Great Thinkers of the Western World, I.P. McGreal (ed.). Harper-Collins, New York, pp. 178-181.
Haskins: http://www.haskins.yale.edu/haskinsHEADS/KBSkbsav.html
Hayes-Roth, F., Waterman, D., and D.B. Lenat (1983). Building Expert Systems. Addison-Wesley, Reading, MA.

Hunsucker, M. (2000). SEDRIS in the Real World. In Proc. of the Summer Computer Conference, W.F. waite (ed.) July 16-20, 2000, Vancouver, B.C., Canada, pp. 245-248.
Karplus, W. (1976). The Spectrum of Mathematical Modeling and Systems Simulation. In: Simulation of Systems – Proc. of the 8th AICA Congress, L. Dekker (ed.), August 23-28, 1976. Delft, The Netherlands, pp. 5-13.
Law, A.M. and M.G. McComas (2000). How the Expertfit Distribution-Fitting Package Can Make Your Simulation Models More Valid. In: Proc. of the 2000 Winter Simulation Conference, J.A. Jones et al. (eds.), Dec. 10-13, 2000, Orlando, FL., pp. 253-258..
Leemis, L. (2000). Input Modeling. In: Proc. of the 2000 Winter Simulation Conference, J.A. Jones et al. (eds.), Dec. 10-13, 2000, Orlando, FL., pp. 17-25.
Minsky, M. (1988). The Society of Mind. Simon & Schuster/Touchstone, New York.
Morse, K.L. (2000). Taking HLA Education to the Web. In: Proc. of the 2000 Winter Simulation Conference, J.A. Jones et al. (eds.), Dec. 10-13, 2000, Orlando, FL., pp. 1619-1623.
Ören, T.I. (1987a). Simulation: Taxonomy. In: Systems and Control Encyclopedia, M.G. Singh (ed.), Pergamon Press, Oxford, England, pp. 4411-4414
Ören, T.I. (1987b). Simulation Models: Taxonomy. In: Systems and Control Encyclopedia, M.G. Singh (ed.), Pergamon Press, Oxford, England, pp. 4381-4388
Ören, T.I. (1987c). Model Behavior: Type, Taxonomy, Generation and Processing Techniques. In: Systems and Control Encyclopedia, M.G. Singh (ed.), Pergamon Press, Oxford, England, pp. 3030-3035.
Ören, T.I. (1990). A Paradigm for Artificial Intelligence in Software Engineering. In: T.I. Ören (ed.) Advances in Artificial Intelligence in Software Engineering, JAI Press Inc., Greenwich, Connecticut.
Ören, T.I. (1994). Artificial Intelligence and Simulation. Annals of Operations Research, vol. 53. pp. 287-319.
Ören, T.I. (2000). Responsibility, Ethics, and Simulation. Transactions of the SCS, San Diego, CA., 17:4, 165-170.
Ören, T.I. (2001). Advances in Computer and Information Sciences: From Abacus to Holonic Agents. Elektrik (Special Issue on Artificial Intelligence, published by TUBITAK). 9(1).
Riley, M.T. (1992). Johannes Kepler. In: Great Thinkers of the Western World, I.P. McGreal (ed.). Harper-Collins, New York, pp. 182-186.
Russell, B. (1921). The Analysis of Mind.George Allen & Unwin, London, England.
Russell, B. (1948). Human Knowledge. George Allen & Unwin, London, England.
Sadowski, R.P. (1991). Avoiding the Problems and Pitfalls in Simulation. In: Proc. of the 1991 Winter Simulation Conference, B.L. Nelson et al. (eds.), Dec. 8-11, 1991, Phonix, AZ, pp. 48-55.
Sadowski, R.P. and M.R. Grabau (2000). Tips for Successful Practice of Simulation. In: Proc. of the 2000 Winter Simulation Conference, J.A. Jones et al. (eds.), Dec. 10-13, 2000, Orlando, FL., pp. 26-31.
Schruben, L.W. (1982). Detecting Initialization Bias in Simulation Output. Operations Research: 569-590.
Webster (1985). Webster's Ninth New Collegiate Dictionary. Merriam-Webster, Springfield, Mass.
Wildberger, A.M. (2000). AI & Simulation, Simulation, 74(2 - Feb. 2000): 110-111.
Wilson, L.F., D. Burroughs, J. Sucharitaves, and A. Kumar. (2000). An Agent-Based Framework for Linking Distributed Simulations. In: Proc. of the 2000 Winter Simulation Conference, J.A. Jones et al. (eds.), Dec. 10-13, 2000, Orlando, FL., pp. 1713-1721.
Zeigler, B.P., S.B. Hall, et al. (1999). Exploiting HLA and DEVS to Promote Interoperability and Reuse in Lockheed's Corporate Environment. Simulation, 73(5): 288-295.

Table 1. Types of data

abnormal data	internal data	software metrics data
abstract data	internally defined data	sorted data
actual data	internally described data	spatial data
affected data	internally generated data	stochastic data
alphabetic data	intersimulation data	stolen data
alphanumeric data	intrasimulation data	stored data
altered data	legacy data	structural data
ambiguous data	legible data	structure data
analog data	local data	structured data
analog input data	logical data	symbolic data
available data	lost data	test data
background data	malicious data	text-based data
biased data	mapped data	textual data
certain data	marked data	time series data
certified data	matched data	time-varying data
complementary data	model data	transferred data
conditional data	national security data	unaffected data
confidential data	noisy data	unambiguous data
contradictory data	nonlogical data	unavailable data
conventional data	nonmalicious data	unbiased data
corrupted data	non-understandable data	uncertain data
customizable data	non-unified data	uncertain data
discrete data	non-uniform data	uncertified data
divided data	normal data	unconditional data
domain-dependent data	numeric data	unconventional data
domain-independent data	operational data	uncustomizable data
dynamic data	ordered data	understandable data
dynamical data	outgoing data	undivided data
dynamically-changing data	output data	unencripted data
electronic data	packed data	unformatted data
empirical data	perceptual data	unhiden data
emulated data	pragmatic data	unified data
encripted data	predictable data	uniform data
endogenous data	program-described data	universal data
evidential data	protected data	unmapped data
exogenous data	qualitative data	unmarked data
external data	quantitative data	unmatched data
externally defined data	random data	unordered data
externally described data	raw data	unpacked data
externally generated data	real data	unpredictable data
factual data	real-world data	unprotected data
formatted data	recoverable data	unrecoverable data
global data	recursive data	unreliable data
heterogenously stored data	relational data	unsafe data
hidden data	reliable data	unsorted data
hierarchical data	replacable data	unstable data
historic data	safe data	unstructured data
homogenously stored data	scanner data	unusable data
illegible data	select data	usable data
illogical data	sensor data	validatable data
immediate data	serial data	virtual data
incoming data	simulated data	voice data
input data	simulation data	Web data

Table 2. Database-related terms

analytical database	database server	open database connectivity
assertional database	database software	parallel database
associative database	database wizard	real-time database
common database	decentralized database	relational database
conceptual database	decisional database	relational database language
database format	deductive database	rule database
database grid	distributed database	scenario-specific database
database independence	dynamic database	semantic database
database integrity	expert database designer	spacial database
database management	expert database system	static database
database management system	external database	statistical database
database manager	fuzzy database	tabular database
database mining	hierarchical database	temporal database
database organization	informational database	textual database
database query language	intelligent database	Web-enabled database
database replication	lexical database	
	object-oriented database	

Table 3a. Other data-related terms

abstract data type	data dictionary	data insert
abstract data type theory	data directed	data integrity
administrative data processing	data directed generalization	data integrity analyst
analog data channel	data directed reasoning mechanism	data intensive
analytical data compression	data dispenser	data intensive application
automatic data processing	data display	data interactivity
burst data transfer speed	data distribution	data interchange
computerized data analysis	data distribution management	data interchange format
conceptual data model	data document	data interchange standard
constrained data-directed generalization	data driven	data item
context-based data organization	data driven learning system	data item description
data acceptability	data driven processing	data link
data access	data driven programming	data log
data access tool	data element	data logging
data acquisition	data encryption	data management
data acquisition strategy	data entry	data manipulation
data administration	data error	data manipulation language
data administrator	data exchange	data mart
data analysis	data export	data member
data assimilation	data file	data memory
data augmentability	data filtering	data mining
data authenticity	data flip-flop	data model
data availability	data flow	data modelling
data bank	data flow acyclic graph	data network
data based	data flow algorithm	data network language
data bus	data flow analyser	data node
data bus architecture	data flow analysis	data object
data center	data flow analysis tool	data organization
data certification	data flow diagram	data oriented
data channel	data flow functional graph	data processing
data collection	data flow graph	data processing center
data collection strategy	data flow guided test	data processing manager
data collection terminal	data flow image processing	data protection
data commonality	data flow language	data query
data communication	data flow machine	data rate
data communication equipment	data flow network	data receiver
data compression	data flow test generator	data record
data conversion	data fork	data recovery
data creation	data format	data recovery technique
data definition	data fusion	data reduction
data definition language	data gathering	data reference
data deletion	data generation	data reference line
data dependency	data generator	data refreshment
data dependency graph	data graph	data refreshment speed
data description	data handling	data related
data description language	data impact	data reliability
	data impact parameter	data repository

Table 3b. Other data-related terms (continued)

data representation	data transmission speed	legacy data structure
data representation model	data type	location-based data organization
data representation system	data uncertainty	marginal data transfer
data resource	data unit	massive data processing
data retrieval	data update	meta-data
data security	data validation	output data
data semantic language	data validity	physical data model
data sensitive	data visualization	predefined data type
data sensitive process	data visualizer	protocol data unit
data sensitive rule	data warehouse	random test data generator
data set	data warehousing	recursive data structure
data sharing	datafile	relational data model
data signalling rate	dataglove	relational data structure
datasink	dataset	remote data source
data sonification	dataset flexibility	sampled-data system
data sonification tool	dataset replaceability	semantic data compression
data source	dataset validity	semantic data model
data space	datasheet	serial data bus
data state	datashow	static data member
data storage	digital data communication	static data resource
data storage density	distributed data processing	static dataset
data storage unit	dynamic data exchange	statistical data compression
data structure	dynamic data member	symbolic data structure
data system	electronic data exchange	test data
data tablet	functional data model	test data generation
data text	general data representation	test data generator
data text merge	general data structure	training data set
data trading	heteregenous data structures	unconstrained data-directed generalization
data transcription	historical data validation	unifying data structure
data transfer	historical data validity	universal serial data bus
data transfer rate	homogenous data structures	voice-data integration
data translation	input data	
data transmission	irreducible data model	

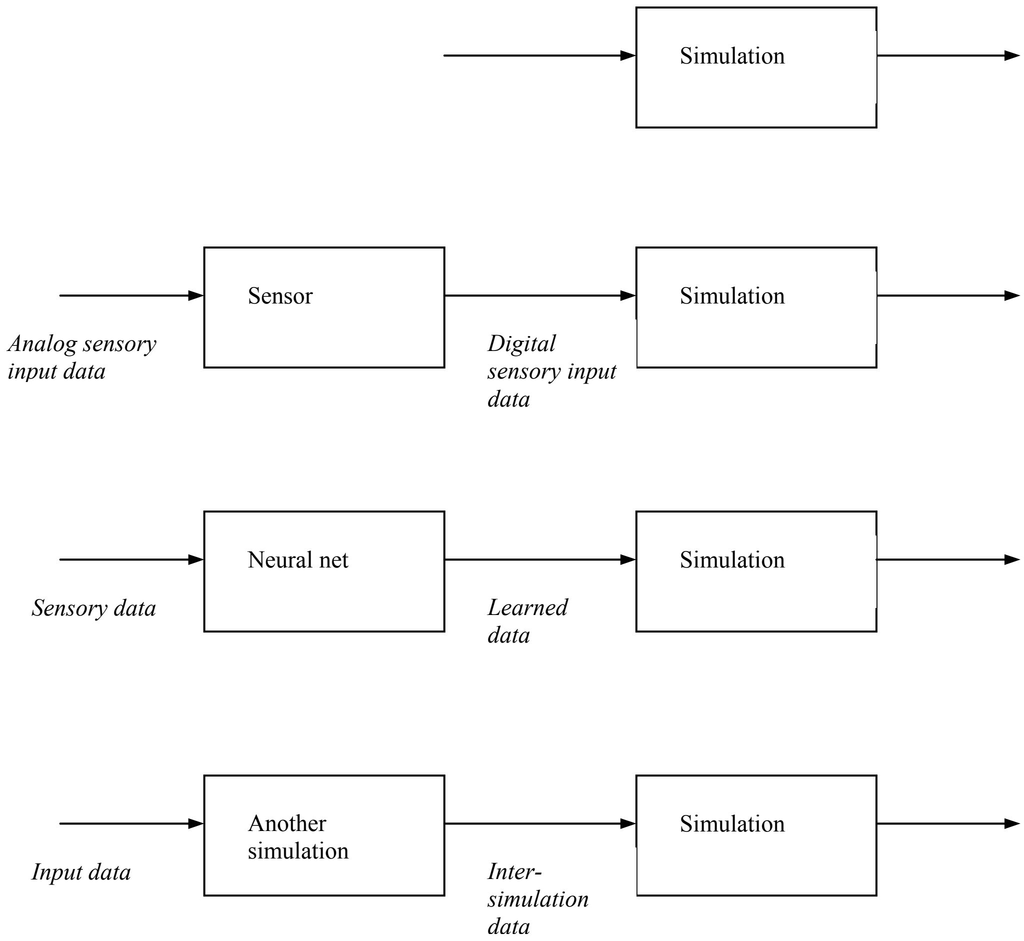

Figure 1. Types of Simulation Input Data

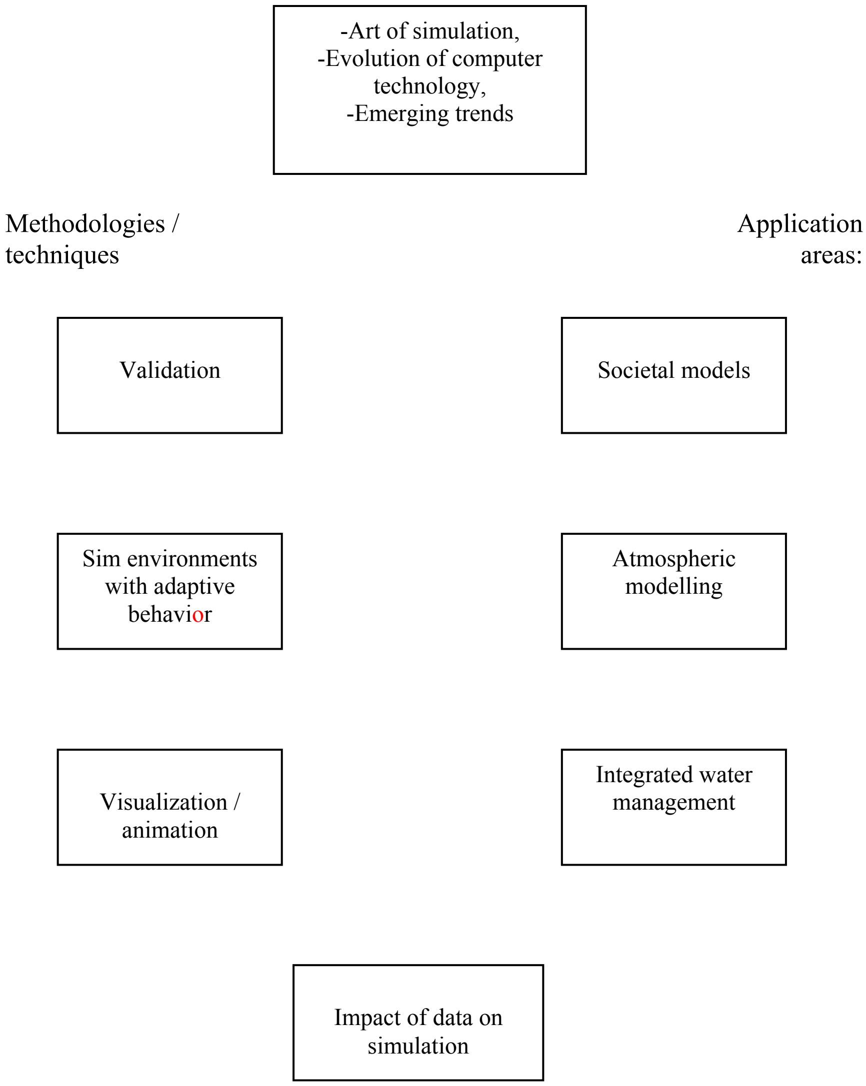

Figure 1. A view of the topics of the invited presentations at the EUROSIM 2001 Congress