Chapter 4
Over Fifty Years of My Involvement in Simulation

Tuncer Ören

Those –be it an individual, an institution, or a country– unable to surpass themselves cannot exceed others. Therefore, in achieving progress, what is difficult is to supersede oneself.
(*Ören* 1995).

Abstract Author's involvement and witnessing the advancements of modeling and simulation over 50 years are highlighted. Some concepts are outlined: inputs, data, quality and failure avoidance in simulation, ethics, machine understanding, synergies of simulation with several disciplines, intelligence and simulation, agent-directed simulation, simulation terminology, modeling and simulation body of knowledge, big picture of simulation, bigger picture of similarity, and some of the aspirations of the author for the future of simulation.

4.1 Introduction

Recently, two important proceedings cast light on the past and the evolution of simulation: One is on the 30 years of the European Council of Modeling and Simulation (ECMS) (Al-Begain and Bargiela 2016); the other one goes farther back and documents the "Seminal Research from the 50 Years of Winter Simulation Conferences" (Tolk et al. 2017).

I have been involved in simulation since 1965, had well over 500 publications including over 45 books and proceedings, and have been active in over 500 conferences and seminars in 40 countries. I had several opportunities of documenting historic aspects of my involvements in modeling and simulation. The first occasion was on the 25th anniversary of SCS (Society for Modeling and Simulation International); I wrote "Simulation—as it has been, is and should be (Ören 1977a). Some of my wishful thinking for the future of simulation were:

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1. “Simulation models will be comprehensible.” Later, during 1980–1996 when I was a member of the Technical Advisory Committee (TAC) of the Atomic Energy of Canada Ltd. (AECL) on the Nuclear Fuel Waste Management Program as the Representative of the Canadian Information Processing Society (CIPS) and Chairman of the System Analysis Subcommittee of TAC, I realized how important it was the comprehensibility of simulation programs by non-programmer scientists.
2. “If a simulation program is to be used several times, a list of questions answerable by the model will be part of the documentation provided to the user.” It seems the problem persists.
3. “Advanced modelling concepts will be used to simulate complex phenomena. For example, behaviorally anticipatory models have definite advantages over classical feedback models.”
4. “New simulation software implementing advanced concepts in modelling and model manipulation will be part of computer-assisted model building, handling, and documentation systems. Some of the algorithmic model manipulations may be done for consistency checks, decomposition, simplification, coarsening, elaboration, or comparison of models.” Currently, it is comforting to see the advent of simulation model engineering (Zhang et al. 2019)

The following year, on another occasion, I wrote: “A Personal View on the Future of Simulation Languages” (Ören 1978b). On the 50th anniversary of the SCS, it was “SCS and Simulation: Fifty Years of Progress” (Ören 2002a). On the 60th anniversary of SCS, Bernie Zeigler and I wrote: “System Theoretic Foundations of Modeling and Simulation: A Historic Perspective and the Legacy of A. Wayne Wymore” (Ören and Zeigler 2012). (My intellectual pedigree which goes back to Gauss is documented in this article.) The same year, I also wrote: “Evolution of the Discontinuity Concept in Modeling and Simulation: From Original Idea to Model Switching, Switchable Understanding, and Beyond” (Ören 2012). A recent article documents the nine evolution aspects of modeling and simulation (Ören et al. 2017).

The kind invitation from the editors of this book gave me an occasion to concentrate on some aspects of the history and advancement of modeling and simulation intertwined with my witnessing; and in some areas, with my involvements. Since, I have contributed –with talented colleagues or alone, to well over 500 publications, including 46 books and proceedings –mostly in modeling and simulation, in this chapter I would like to concentrate on the threads of advancements and on some anecdotes.

4.2 The Beginnings

Normally, I don’t remember when I heard a word for the first time. The only exception is “simulation.” In 1965, while working as a systems engineer at IBM in my native Istanbul, Turkey, I decided to enrol the Ph.D. program at the Technical

University of Istanbul. I asked a theme for doctoral studies to Prof. Faruk Akün, the then head of the Industrial Engineering Department of the Mechanical Engineering Faculty. He suggested "simulation" a concept which intrigued me then and which continues to interest me with increasing zeal after over half a century.

In the mean time, I had applied for a scholarship to a US government agency. Considering that I was an IBM systems engineer, the Agency chose the then Systems Engineering Department (later it became, Department of Systems and Industrial Engineering) of the University of Arizona in Tucson, Arizona. The department was established by Prof. Albert Wayne Wymore, one of the founding fathers of systems engineering. I went to Tucson in 1967, the year Dr. Wymore published his seminal book "A Mathematical Theory of Systems Engineering: The Elements" (Wymore 1967). In 1967, Dr. Wymore was spending his sabbatical in Hawaii. I enrolled in many courses. With my background as mechanical engineer, some of them such as finite state machines appealed to me very much as abstract machines.

My scholarship was for one year. The Agency's handbook had the following note: "It is seldom possible to approve a request to extend the time limit of a quest to extend the time limit of a training program." However, thanks to two favorable brief notes from my professors on annual evaluation forms, my scholarship was extended twice.

The second year Dr. Wymore returned to Tucson –albeit after a surf accident. He kindly accepted to be my thesis advisor. My thesis work was to develop a simulation model specification language based on his systems theory.

At the end of 1970, I satisfied all requirements for my doctoral studies. The thesis: "GEST: General System Theory Implementor, A Combined Digital Simulation Language," was submitted to the University (Ören 1971a). There was a position at the newly established Computer Science Department of the University of Ottawa in the Canadian national capital. I communicated with the founding chair, Prof. Louis G. Birta and joined the department on December 1970.

4.3 The Reviewers Were Not Ready

After getting my Ph.D., I thought I was ready to disseminate my views; however, soon I realized that the reviewers were not. Here is a sequence of some initial failures (of the reviewers): Before I left Tucson, I prepared an article on GEST and I submitted it late 1970 to Simulation, the Journal of the Simulation Councils –SCi (Later became SCS—The Society for Modeling and Simulation International). That was the time of high success of CSSL (Continuous System Simulation Language) (SCi Software Committee 1967). The reviewers who were accustomed to CSSL –a simulation *programming* language– and its variants, flatly rejected my article which was the first *model specification language* based on a systems theory. I wrote several letters to SCi to persuade them; to no avail. Finally –after about two dozen letters– John McLeod, the founder of SCi wrote me to announce that the article is not accepted for Simulation. As I clarified elsewhere, I never blamed John for the refusal of my article; I realized, to my dismay, that the referees couldn't appreciate it (Ören 2002a). Three years later, I was an Associate editor of Simulation. Over the years, I was honored several times by SCS as SCS McLeod Founder's Award for Distinguished Service to the profession, SCS Fellow, SCS Hall of Fame, Distinguished Service Award, and Distinguished Professional Achievements Award (SCS-AR). And early 1980s after a NATO Advanced Study Institute in Ottawa, John wrote very favourably:

> This summer (July 26-August 6) Suzy and I participated in the NATO Advanced Study Institute "Simulation and Model-Based Methodologies: An Integrative View" held at the University of Ottawa, Ottawa, Canada; I now know vastly more about modeling and simulation (or the possibilities thereof) than I did before. I also learned that there is a lot more to learn!
>
> Well, the 58 lecturers and participants from 18 countries at the Institute, organized under the direction of Dr. Tuncer Ören of the University of Ottawa's Computer Science Department, are certainly doing their best to remedy that. In fact, the degree of mathematical abstraction (which seems necessary to develop theory) was so advanced that this writer found it difficult at times to relate it to reality.
>
> Dr. Ören was the first speaker. After an appropriate greeting he presented a lecture on 'Computerization of Model-Based Activities: A Paradigm Shift and New Vistas.' Although he covered the 'fundamental elements of a simulation study; models and behaviour; elements of a model-based simulation software system; synergies of simulation, software engineering, artificial intelligence, and general system theories; knowledge-based modeling and simulation systems; and highlights of desirable research in simulation,' Tuncer's main thrust, it seemed to me, was 'to place simulation in a central position for several scientific disciplines by a shift of paradigm' (McLeod 1982).

John McLeod's last observation about my motivation is still valid. In early 1980s, it was time to promote model-based approach; currently simulation-based approach appears to be a viable way to enhance many disciplines.

Not having a publication in a refereed journal in early 1970s did not help me to get non-trivial research grants from the Canadian research granting agency in natural sciences. Luckily, I realized that I didn't need funding to generate ideas.

However, after being accepted by other colleagues, the agency asked me later to review some of the submitted research proposals. I gladly did the reviews.

Another lack of understanding occurred in Switzerland. My colleague Prof. François Cellier organized an International Symposium on Simulation—SIMULATION '80, during June 25–27, 1980 in Interlaken, Switzerland and honored me by asking me to be the keynote speaker. I chose the following theme for my talk: "Computer-Aided Modelling Systems." After my presentation, a Canadian scientist criticized me heavily, refusing strongly the concept of computer-aided modeling. Since, this was an open criticism, I had the opportunity to reply with even stronger zeal. The book (Cellier 1982) and my contribution were published (Ören 1982a). Today, nobody needs to promote the concept of computer-aided modeling systems, since it is the only obvious way to do it. However, at that time, somebody had to promote the concept to programmer-simulationists. I am glad I did it.

4.4 The Trio

Bernie Zeigler, Maurice Elzas, and I often referred to ourselves as the trio. In one of our activities we also had George Klir. Let me outline how we got together and what we did:

During 1976–83, I was a member of the Board of Directors and Delegate to Canada of the International Association for Cybernetics (Namur, Belgium). During September 6–11, 1976, the association had its 8th International Congress on Cybernetics. Within the congress, I organized a symposium on the application of cybernetics and general system theoretic concepts to the simulation of large scale systems. As it can be seen in the proceedings of the symposium (Ören 1978b), I had several eminent scientists as speakers. One of them was Prof. Bernie Zeigler who had published his first seminal book (Zeigler 1976).

During my first sabbatical leave (1977–78), I was a senior research fellow at the Computer Science Department of the Agricultural University, Wageningen, The Netherlands. The chair of the department was Prof. Maurice Elzas whom I met in 1976 at the 8th AICA (International Association for Analog Computing) Congress which was held in Delft, the Netherlands. I had the pleasure of introducing Bernie to Maurice. The Trio organized four main conferences. The titles of the books reflect our themes:

1. First one was in 1978 in Rehovot, Israel while Bernie was at the Weizmann Institute of Science. He was the editor-in-chief of the volume titled: "Methodology in Systems Modelling and Simulation." In this conference, Prof. George J. Klir joined us (Zeigler et al. 1979).
2. Second one was a NATO Advanced Study Institute (ASI) held in 1982 in Ottawa. The book was titled: "Simulation and Model-based methodologies: An Integrative View" (Ören et al. 1984).
3. The third one was held in 1985 in Papendal, Arnhem, The Netherlands, very close where Maurice was (Wageningen). At the NATO Advanced Study Institute, we had funding from NATO. Furthermore, NATO sent an observer to our ASI. In this third conference, we didn't require funding and we invited the same observer all expenses paid. The title of the book was: Modelling and Simulation Methodology in the Artificial Intelligence Era" (Elzas et al. 1986).
4. The fourth conference was held in Tucson, Arizona, in 1987 while Bernie was established at the University of Arizona (my Alma Mater for my Ph.D. studies). The book was titled: "Modelling and Simulation Methodology: Knowledge Systems' Paradigms" (Elzas et al. 1989)

In addition to these four conferences and the books, we had several other joint activities. Some of them are:

In 1977, while Bernie was at the Weizmann Institute of Science in Rehovot, Israel, extended me an invitation to write a joint article. We decided the theme of the article in Rehovot and finished it in a week. However, the then editor-in-chief of the transactions of SCS could publish it only in 1979 (Ören and Zeigler 1979).

The article was an iconoclast; it started as follows:

> Conventional simulation techniques have three shortcomings when applied to large-scale modelling: They provide an inadequate man-machine interface, they provide a poor conceptual framework, and they lack needed tools for managing data and model. These shortcomings may be ameliorated by developing new simulation languages that differentiate the functional elements of simulation programs and by recognizing the goals of these functional elements. This paper provides concepts for the design and implementation of such advanced simulation methodologies.

In 1979, Bernie, Maurice, and I organized the Sorrento Workshop for the International Standardization of Simulation languages. The Workshop papers were published later (ACM SIGSIM Digest 1984). One of the articles, by Bongulielmi and Cellier: "On the usefulness of deterministic grammars for simulation languages" was categorically different than the then usual ad hoc definition of simulation languages (Bongulielmi and Cellier 1984).

One of the highlights of the Sorrento Workshop was that one of the invited colleagues was Dr. Harry M. Markowitz. His article was titled: "Proposal for the standardization of status description" (Markowitz 1984). Dr. Markowitz is known by the simulationists as the designer and developer of SIMSCRIPT, a discrete simulation language, widely used before Bernie developed long needed theoretical basis to specify discrete systems (DEVS—Discrete Event System Specification) (Zeigler 1984). Dr. Markowitz is the only simulationist who is a Nobel laureate – albeit in a different domain, namely in portfolio theory. His collected, selected works on portfolio theory, sparse matrices, as well as on the SIMSCIPT are available in a comprehensive volume (Markowitz 2009). Dr. Markowitz was the keynote speaker at the 1981 Winter Simulation Conference (Markowitz 1981).

4.5 Basics: Inputs and Data

In 2001, I was invited to deliver a plenary talk in a conference held in St. Petersburg, Russia. My talk was titled: "Software Agents for Experimental Design in Advanced Simulation Environments." In this talk (Ören 2001a), I also provided a classification of inputs which are normally considered to be exogenous, namely, generated outside of the system of interest. In this classification, I also introduced endogenous inputs, namely, internally generated inputs as outlined in Table 4.1.

Endogenous inputs are important especially in the simulation of cognitive systems. Any computationally intelligent system should be able to perform introspection; and generate questions, hypotheses, and goals.

Nowadays, the importance of big data analytics is properly acknowledged. In 2001, I was also invited to deliver a plenary talk at the Eurosim conference held in Delft, The Netherlands. My talk was titled: "Impact of Data on Simulation: From Early Practices to Federated and Agent-Directed Simulations." I started with a well-known milestone example and pointed out the importance of Tycho Brahe's meticulous data collection activities in the second half of the 16th century (Ören 2001b):

> 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). 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.

My interest in the importance of data still continuous, especially with one of my diligent young colleagues; i.e., Dr. Mayank Singh (Singh et al. 2017; Gupta et al. 2019).

4.6 Quality and Failure Avoidance in Simulation

Considered from the knowledge processing perspective, simulation is a model-based knowledge processing activity; hence similitude of the simuland and a model to represent it is important. Validation in modeling and simulation deals with the assurance of goal-directed similitude of models. Another issue is verification which deals with the proper computerization of simulation models and associated

Table 4.1 Internally generated inputs

(1) Active perception of endogenous inputs:
    Introspection □ perceived:
    - Internal facts, events; or realization of lack of them
(2) Generation of endogenous input:
    - Anticipated facts and/or events (anticipatory systems)
    - Internally generated questions
    - Internally generated hypotheses by:
        -- Expectation-driven reasoning (Forward reasoning, bottom-up reasoning, data-driven reasoning)
        -- Model-driven reasoning
    - Internal goals: internally generated goals

experimentation as well as model behavior generation conditions. Sargent and Balci contributed extensively to the validation and verification in simulation (Sargent 1991, 2011 (with extensive references to previous publications); Balci 1987, 1998; Balci and Sargent 1984). For a historic review of verification and validation theories, see: Sargent and Balci (2017) and Durst et al. (2017).

My activities on reliability and quality assurance in modeling and simulation (over 60 publications and over 20 activities in meetings) started in mid 1970s with a study of the syntactic errors of the original formal definition of CSSL 1967 (Ören 1975). In 1981, I published: “Concepts and criteria to assess acceptability of simulation studies: A frame of reference” (Ören 1981). During 1980–1996, I served as a member of the Technical Advisory Committee (TAC) of the Atomic Energy of Canada Ltd. (AECL) on the Nuclear Fuel Waste Management Program as the representative of the Canadian Information Processing Society (CIPS) and as Chairman of the System Analysis Subcommittee of TAC.

As a novel paradigm in reliability of modeling and simulation, my first article on failure avoidance was published in 2009: “Failure Avoidance in Agent-Directed Simulation: Beyond Conventional V&V and QA” (Ören and Yilmaz 2009a). Along this line, the following sources of errors in decision making should also be taken into consideration:

(1) dysrationalia –inability to think and behave rationally despite adequate intelligence (Stanovich 1993);
(2) cultural biases, i.e., the tendency for people to judge the outside world through a narrow view based on their own culture (Worldatlas; Hofstede 2001),
(3) as well as drawbacks of rule-based intelligent systems, and misunderstanding (Ören et al. 2013).

4.7 Ethics in Simulation

Ethics can be considered as the top link of reliability in simulation-based studies (as in many human activities), Several colleagues were influential in pointing out the need for development, and adoption of a code of ethics for simulationists. Ethics for simulationists was recommended for the first time by John McLeod (1983). (My special thanks and appreciation to Prof. Helena Szczerbiska for pointing it out.) A special symposium was organized in Wageningen, The Netherlands on the 65th birthday of Prof. Maurice S. Elzas (July 2, 1999). Maurice selected the theme as: Simulation and Ethics. As one of his close colleagues, I was invited to talk. This was my first talk on the topic. In 2001, Dr. Bruce Fairchild, the then President of the SCS asked me whether I would like to develop a code of ethics for simulationists. In 2002, two articles were presented at the Summer Computer Simulation Conference; one, on the rationale for a code of professional ethics for simulationists (Ören 2002b); the other, a code of professional ethics for simulationists (Ören et al. 2002). Our late and distinguished colleague, W. Waite was behind the resolution of SimSummit “that a Code of Professional Ethics should be one of the four pillars –along with Science, Technology and Applications– for Modeling and Simulation to be considered as a profession" (Ören 2014). The code is adopted by the SCS (SCS SimEthics) and for the member organizations of two umbrella organizations of SCS, namely, M&SNet and MISS, as well as by influential simulation organizations such as CMSP (Certified Modeling & Simulation Professional) certification program of M&SPCC (Modeling and Simulation Professional Certification program) (CMSP-Ethics).

4.8 On Machine Understanding

In late 1980s and early 1990s, a large Canadian company offered a substantial research funding for understanding simulation software. This very favorable funding was the initial impetus first to develop reverse engineering tools to understanding simulation programs (Ören et al. 1990). Table 4.2 depicts an outline of how my research on understanding evolved over the years. With my colleagues, I have published over 20 articles on machine understanding and had about the same number of presentations in meetings.

I consider machine understanding as one of the pillars of computational intelligence including computational emotional intelligence and wonder how a knowledge processing system without understanding ability could be considered intelligent.

4.9 Synergies

The relationships of several entities can be one of the following types:

1. They may co-exist without any reaction. This may be, for example, the essence of *co-existence pacific*.

Table 4.2 An outline of how my research on understanding evolved over the years

1990-1995	Understanding simulation software; Program understanding
1997-2006	Understanding systems in general
2006-2008	Systems with understanding ability and Understanding agents
2009-	Agents with ability to understand emotions; Switchable understanding
2011-	Avoidance of misunderstanding
2015-	Enriching machine understanding paradigm
2016-	Exploring the synergy of machine understanding and all three aspects of agent-directed simulation (ADS)
2017-	Computational awareness; Computational consciousness

2. They may be living together. This is the essence of *symbiotic relationship* (or *symbiosis*) which can be mutualistic, commensalistic, or parasitic relationship.

   2.1 In a mutualistic relationship "two organisms of different species exist in a relationship in which each individual fitness benefits from the activity of the other. Similar interactions *within* a species are known as co-operation. Mutualism can be contrasted with interspecific competition, in which each species experiences *reduced* fitness (Wikipedia—mutualism)
   2.2 In a commensalistic relationship "in which members of one species gain benefits while those of the other species neither benefit nor are harmed" (Wikipedia—commensalism)
   2.3 In a symbiotic relationship, some may exploit some others. This is the case of parasitic relationship.

3. They may unite to form a new entity, such as hydrogen and oxygen forming water. This is *systemic relationship* (Checkland 1993).
4. They may have two types of *synergistic relationship*.

   4.1 Synergy generally means working together to have an extended effect larger than the total of the individual effects.
   4.2 Another way of expressing "working together" can be one enhancing others; or entities may enhance each other. In this type of *synergistic relationship*, each entity conserves its identity, is enhanced by the influence of other entities, and may enhance other entities.

The difference between synergy and symbiosis lies in the fact that symbiosis implies living together. The difference between synergy and systemic relationship is important: In systemic relationship the component entities form a new entity with characteristics different than the characteristics of the component entities; while in a synergy, entities enhance each other while retaining their identities.

Over the years, I had (or initiated) occasions to elaborate on synergies of simulation with several disciplines (Ören 1978b, 1982b, 1984a, 1996; Ören and Yilmaz 2006, 2009b, 2012; Ghasem-Aghaee et al. 2017; Yilmaz and Ören 2009).

In early 1980s, while I was the editor of SIMULETTER, the publication of the ACM Special Interest Group on Simulation, I even elaborated on a possible forum for the synergy of ACM Special Interest Groups (Ören 1984b). I wrote: Simulation as an important model-based activity:
can have two-way interaction with almost all the fields of knowledge represented by ACM Special Interest Groups: … I would like to publish in SIMULETTER two articles for each SIG group under the following categories:

1. Contributions of SIGSIM to SIGxxx: One article would survey the current and possible contributions of simulation in the field represented by this particular SIG. An additional bibliography would be also very useful.
2. Contributions of SIGxxx to SIGSIM: This article would cover just the opposite, i.e., it would be a survey of the current and possible contributions of the specific

field of knowledge to any aspect of simulation. In this case also an additional bibliography would be very useful.

There was no interest to this suggestion. However, once done, it could document the central role simulation can play to empower many disciplines. After two publications, namely, "Guide to Simulation-Based Disciplines: Advancing our Computational Future" (Mittal et al. 2017) and "The Evolution of Simulation and its Contributions to Many Disciplines" (Ören et al. 2017), the time is ripe to finally elaborate on this topic.

4.10 Intelligence and Simulation

The synergy of simulation and computational (artificial, machine) intelligence played an important role even at the beginning of computational intelligence which started by simulation of human cognitive abilities in 1950s. My first publication on the synergy of simulation and computational intelligence was in 1982 (Ören 1982b). In the editorial of the January 1985 issue of SIMULETTER, I wrote:

> … As expected from the inertia of human intelligence, however, some of the shifts of paradigms were not easily achieved. … For a long time, simulation contributed to the field of artificial intelligence by making possible the cognitive simulation studies. Now, simulation can benefit from the advances in artificial intelligence (as well as from advances in general system theories, software and computer engineering, and mathematical modelling and experimentation techniques).

The question is not whether or not to have artificial intelligence in simulation, but rather how to have it? at which level? how reliably? how soon? and above all how intelligently? …

The quotation on the cover of this issue would well summarize an attitude: " … *unintelligent computerization is not enough* (Ören 1985)".

4.11 Agent-Directed Simulation

Agent-directed simulation (ADS) refers to the full possibilities of the synergy of simulation and agents as outlined in Fig. 4.1. The first publication about ADS was in 2000 (Ören et al. 2000). Afterwards Prof. Levent Yilmaz has been contributing tremendously to ADS (Yilmaz and Ören 2005, 2009). Another colleague who has been contributing to ADS is Prof. Yu Zhang (Zhang et al. 2010, 2012).

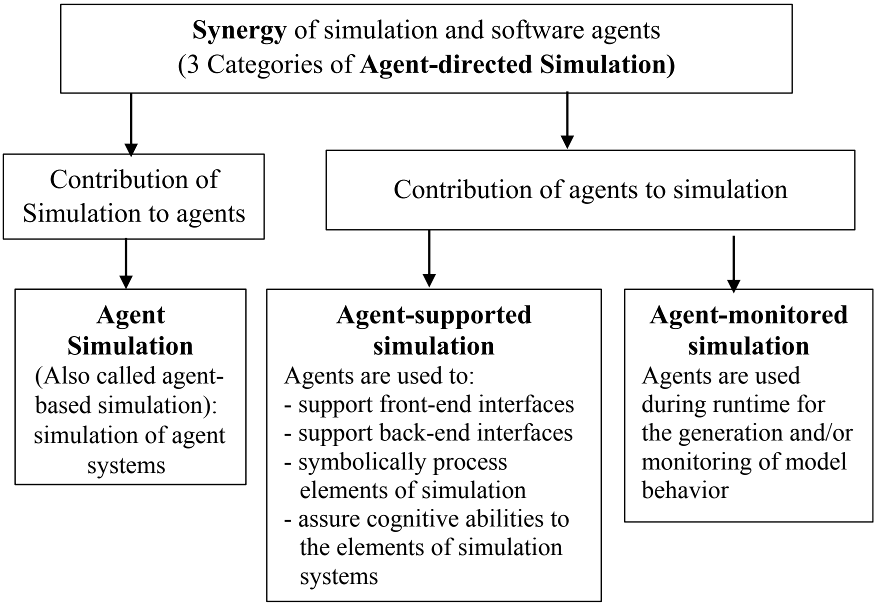

Fig. 4.1 Synergy of simulation and software agents

4.12 Simulation Terminology

As it is also the case for simulation, the conceptual richness of a field can be seen in its terminology. My first elaboration about simulation terms was in late 1970s (Ören 1977b). The list included about 800 terms and at that time, it looked rather long.

In 2006, colleagues at the Université Paul Cézanne—Aix-Marseille III, and I had the pleasure of seeing in print, our first tri-lingual (English, French, and Turkish) modeling and simulation dictionary (Ören and the French team 2006). The French team comprised of 14 colleagues and Mme. Lucile Torres was the co-ordinator. The dictionary had about 4500 English terms that I gleaned over the years. The support of late Professor Norbert Giambiasi and Professor Claudia Frydman for the preparation of the French terms and the publication in Marseille as well as the valuable contributions of dedicated colleagues in the French team are gratefully acknowledged.

In 2012, with the contribution of 30 Chinese colleagues, the first version of the Chinese-English and English-Chinese modeling and simulation dictionary with about 9000 English terms were published (BoHu Li et al. 2012). Currently, a Chinese team under the leaderships of Prof. Bo Hu Li and Prof. Guanghong Gong are finalizing the second edition which comprises about 13 000 English terms that I compiled.

Time permitting, I will revise the French, Italian, and Spanish terms and continue co-operating with colleagues for the respective editions of the modeling and simulation dictionary.

Ontology-based dictionaries combine taxonomy of the relevant terms and their definitions. An example is ontology-based dictionary of about 80 machine understanding terms (Ören et al. 2007).

4.13 M&S Body of Knowledge (Bok)

My first publication about the Body of knowledge of modeling and simulation was published in 2005 (Ören 2005a). Over the years I had over 30 publications and/or presentations on modeling and simulation BOK as well as on integrative view of modeling and simulation.

Currently, an SCS Technical Committee is working to finalize the M&S Body of Knowledge (SCS-M&SBOK).

4.14 Big Picture of Simulation

Simulation provides a very rich paradigm (Ören 2010). And as clarified by Ören (2011a), M&S can be perceived from the following perspectives:

(1) Purpose of use
(2) Problem to be solved
(3) Connectivity of operations
(4) Types of knowledge processing and
(5) Philosophy of science

However, our perspective acts as a filter in our perceptions. Accordingly, nine focus areas of about 100 definitions of simulation are given in the sequel (Ören 2011a). Number of definitions are given within parentheses.

Group 1 experiment (24), training (experience) (9), game (experience) (1)
Group 2 modeling (12), model implementation/execution (14), technique (8)
Group 3 similarity/imitation (19), pretense/imitation (14), other (7)

A critical review of these definitions is given in (Ören 2011b). Seeing the big picture of simulation is essential to appreciate the many possibilities that it offers. A recent publication lists about 750 types of simulation (Ören et al. 2018).

4.15 Bigger Picture of Relationships: Similarity and Veracity

Simulation is based on the similarity relationship of a model (or a representation) with an—existing or non-existent– system; hence it is related to many other disciplines which are also germane to similarity. Relationship of a model (or a representation) with reality is the essence of veracity which is also relevant for simulation; hence validation and verification are essential aspects of simulation. Figure 4.2 outlines the relationships aspects of similitude and veracity.

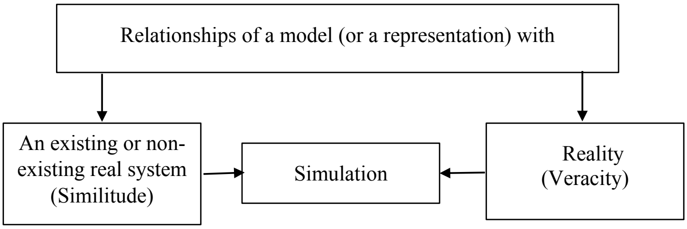

Fig. 4.2 Relationship of simulation with similitude and veracity

Table 4.3 Examples to similarity and veracity in different areas

--Similarity--
affinity
alike
analog
analogical
analogous
analogy
consimilitude
correspondence
homogeneity
like
likeness
match
pose (v)
resemblance
resemble (v)
resembled
resembling
sameness
self-similar
similar
similarity
similitude
simulacra
simulacrum
verisimilitude

--Behavioral similarity--
mimesis
mimetic
mimicry
pantomime
pretend (v)
role playing

--Functional similarity--
emulate (v)
emulated
emulating
emulation
emulative
emulator

--Similarity in art--
imitate (v)
imitation
inverisimilitude
likeness
pastiche
replica
verisimilitude

--Similarity in linguistics--
alternative
assimilation
equivalence
equivalent
homograph
homographic
homography
homonym
homonymous
homonymy
homophon
homophonous
homophony
isomorph
isomorphism
synonymous
synonymy
tautology

--Similarity in literature--
metaphor
metaphoric
pastiche
pataphor
pataphoric

--Similarity in mathematics--
automorph
automorphic
automorphism
automorphous
congruence
congruent
congruently
congruity
congruous
conjugate
endomorph
endomorphic
endomorphism
endomorphous
equivalence
equivalent
homolog
homologic
homology
homomorph
homomorphic
homomorphism
homomorphous
homomorphy
homothecy
homothetic
homothetic
transformation
homothetism
homothety
isomorph
isomorphic
isomorphism
isomorphous
map (v)
noncongruent
noncongruently

--Similarity in medicine--
biosimilar

--To be alike--
assimilate (v)
assimilated
assimilatingly
assimilation
assimilationism
homochromy
homotypy
mimesis
mimetic
mimetism
mimicry
verisimilar
verisimilitude

--Indistinguishableness--
indistinguishable
indistinguishableness
indistinguishably
undistinguishing
to be mistaken for

--Imitation--
copy
imitate
imitate (v)
imitated
imitation
imitative
imitator

--Hiding similarity--
dissimular
dissimularity
dissimulate
dissimulate (v)
dissimulation
dissimulative
dissimulator

--Dissimilarity--
dissimilar
dissimilarity
dissimilarly
dissimilate (v)
dissimilation
dissimilitude
non-similar
semblance
unalike
unique
uniqueness

Table 4.3 displays similarity terms in many groups such as: similarity, behavioral similarity, functional similarity, similarity in art, similarity in linguistics, similarity in literature, similarity in mathematics, similarity in medicine, to be alike, indistinguishableness, imitation, hiding similarity, and dissimilarity.

The similarity concept in simulation and painting or sculpture are amazingly opposite. For a painter or a sculptor, the product of their activity is called a painting or a sculpture; the real system that they use as inspiration is often called "a model." For simulationists, the source of inspiration is often called the real system, while the product of their activity is simply a model. Other types of art often provide an esthetic experience (Devey 1934). As posited by Devey (1934, p. 272), "esthetic experience is imaginative." Thought experiments as non-computational simulations are also imaginative as expressed by Brown (2014): "Thought experiments are devices of the imagination used to investigate the nature of thing." In fiction (including science fiction), an existing or fictional reality is the source of inspiration for the author and the product provides an esthetic experience to the reader or the viewer if the topic of the book is visualized for theater, opera, movie, or TV.

Simulation used to provide experience can be used for training to enhance three types of skills: motor skills (virtual simulation, simulators), decision making skills (constructive simulation, gaming), or operational skills (operational simulation); as well as for entertainment as in simulation gaming. One can find many other similarities between simulation and other disciplines based on similarity and veracity of a model (or a representation).

4.16 My Aspiration for The Future of Simulation

Many advancements of simulation have been achieved by talented colleagues active in simulation in many continents. Simulation has been maturing for a long time at several fronts (Ören 2005b) including theoretical advancements and maturity (Zeigler 1976; Zeigler et al. 2018). Several groups expressed their views to explore enhancing use, usefulness and advancement possibilities of modeling and simulation. A recent book, based on a workshop (Jan. 13–14, 2016), where participation was by invitation only, documents recent challenges in modeling and simulation for engineering complex systems (Fujimoto et al. 2018). One of the important issues is still model reuse. In a very old article the concept of model bases was recommended for this purpose (Ören and Zeigler 1979).

After over 50 years of involvement, and closely following advancements such as quantum simulation (Bramüller 2018), in addition to some wishes expressed in previous sections, I am still hoping to see realization of the following possibilities:

1. To witness simulation-based decision making by advanced computationally intelligent systems, such as software agents, robots, advanced cyber-physical systems, and intelligent cities.

2. Use of personality, emotional, and cultural filters in human behavior simulation for decision making.
3. Simulation-based approach to be the base for large number of application areas in physical and social sciences, engineering, and technologies (Ören et al. 2017).
4. Widespread simulation education at every level for the preparation of future generations for whom simulation-based decision making may be common practice. A recent publication on this topic is by Niazi and Temkin (2017).
5. Extensive simulation-based education, including simulation-gaming for education at several levels to enhance education in several disciplines (Ören et al. 2017).
6. As the theory-based simulation for discrete systems DEVS (Discrete Event System Specification) formalism provides a solid background, its use with GEST (General System Theory implementor) (Ören 1971a, b; 1984c) to represent combined continuous and discrete-change systems.
7. Similar to the maturity levels of software engineering companies, establishment of maturity levels of simulation companies.
8. Establishment of SII (Simulation Industry Initiative) on Business Ethics and Conduct like DII (Defense Industry Initiative) on Business Ethics and Conduct (DII-ethics).

4.17 Epilogue

A professional autobiography may also necessitate a clarification of "why one did what one did?" Maslow's hierarch of needs (with several updated versions) has at the top level "Self-actualization" (Maslow 1998). I acted as if this level consists of three sub-levels:

(1) at the lowest sub-level, achieve one's full potential (this is why, in 1966, I quit a very successful career as an IBM systems engineer to start my Ph.D. studies and afterwards switch to an academic career);
(2) to assist others to achieve their full potential (I have been available to anyone who would ask my advice); and
(3) to contribute to my professional discipline (which happens to be simulation) to achieve its full potential.

Prof. Levent Yilmaz, with the volume he edited (Yilmaz 2015) and all the colleagues who contributed not only honored me but also proved that shared worthwhile ideas might be amplified and made available to others who might benefit from them.

I would like to finish this professional autobiography with what I wrote in 2005 on the publication of IBM Canada on their thoughtful consideration of honoring some of us as "IBM pioneers of computing in Canada":

The early days of computers remind me of the rich girl who was asked to write an essay on a poor family: She started her essay by stating, 'this family was so poor, even the driver, the cook, and the gardener were very poor.' … When I started my career, the world was so poor that nobody had personal computers, nobody had laser printers, and nobody had Internet, because even the concepts did not exist.

What a wonderful experience it was to witness all the developments and to have had the chance to contribute to some aspects of computerized modeling and simulation (IBM 2005).

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