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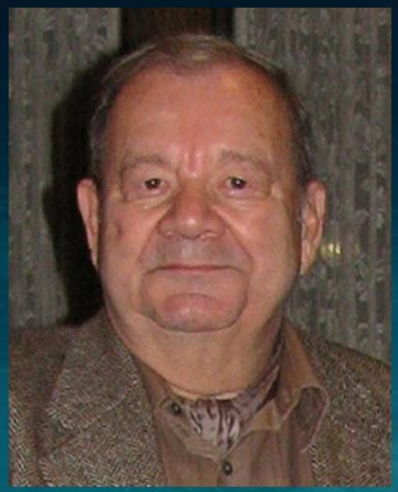


Professor Tuncer Ören, Univ. of Ottawa, Canada
Fellow of SCS
Past Vice President for Publication of SCS
Recipient of SCS Hall of Fame Award- Life Time Achievement Award

Grand Challenges in Modeling and Simulation: What M&S can do and what we should do for M&S?

http://www.site.uottawa.ca/~oren/pres/2020-CCCI.ppsx

Grand Challenges in Modeling and Simulation
(What happens to them):

- **Most early challenges** *became past features*, *after some time lags.*

- **Some very early challenges** *are part of the folklore* of M&S; *despite strong initial opposition*.
(An example to follow)

- **Some challenges** *are still not met*.
(I will refer to some of them)

- **Some very early challenges** *are part of the folklore* of M&S; *despite strong initial opposition*.

(An example to follow)

1980 June 25-27, Interlaken, Switzerland
International Symposium on Simulation - SIMULATION '80
Keynote paper: *Computer-Aided Modelling* Systems*

Ören, T. (1982). Computer-Aided Modelling Systems. In: Progress in Modelling and Simulation, F.E. Cellier (ed.). Academic Press, London, England, pp. 189-203.

*At the conference, a simulationist strongly criticized the idea!

No progress is ever possible by keeping the status quo!

Emulate nature; keep blooming!

He that would perfect his work
must **first sharpen his tools**.

Confucius, 551 – 479 BC

Hence, we may hope to find solutions to more complex problems by advancing M&S concepts, methodologies, technologies, and using them ethically and wisely.

Our activities should serve a worthwhile goal.

However, even (and especially) our goals need to be scrutinized.

Ref: Ören, T. (1981). Concepts and Criteria to Assess Acceptability of Simulation Studies: A Frame of Reference. CACM, 24:4, 180-189.

Peter Drucker (1909 – 2005):

"**Efficiency** is doing things right;
effectiveness is doing the right things."

We may aim:
to be efficient while being effective.

Why we need to see the Big Picture of the M&S:

- For practitioners
- For methodologists and other professionals

- We also need to consider & contrast **short- and long-term needs**:
- Example: in an operating room
  - Short term (immediate) need
  - Long term developments (the need & importance to start ahead of time)

From:
Invited talk at SIREN: M&S & Interoperability (on September 27, **2010**)
DIPTEM, University of Genoa, Savona, Italy.
"Simulation: The Big Picture - A Comprehensive and Integrative View"

A recap: Aspects of M&S (Modeling and Simulation)

1. Experimentation

2. Experience

- to gain / enhance 3 types of **skills**
  - motor skills
  - decision making skills
  - operational skills
- for **entertainment**

Imitation

From:

Ören, T.I. (2011). A Critical Review of Definitions and About 400 Types of Modeling and Simulation. SCS M&S Magazine, 2:3 (July), pp. 142-151.

Ören, T., S. Mittal, U. Durak (2017). The Evolution of Simulation and its Contributions to Many Disciplines. Chapter 1 of: S. Mittal, U. Durak, T. Ören (eds.), Guide to Simulation-Based Disciplines: Advancing our Computational Future, Springer, pp. 3-24.

A recap: Aspects of M&S (Modeling and Simulation)

Imitation:

Etymology – Simulation:

Since mid 14th century

From: Latin: “simulare” (**imitate**); “similis” (**like, resembling**)

(On-line Etymology Dictionary)

Imitation (purpose):

(-): → fake

(+): → simulated leather, simulated pearl

The concept "**similitude**" provides a very rich paradigm:

From: Ören, T., S. Mittal, U. Durak (2017). The Evolution of Simulation and its Contributions to Many Disciplines. Chapter 1 of: S. Mittal, U. Durak, T. Ören (eds.), Guide to Simulation-Based Disciplines: Advancing our Computational Future, Springer, pp. 3-24

Appendix 1.1 – Terms related with similitude
Under 14 categories:

Appendix 1.1 – Terms related with similitude (Under 14 categories)

(1) Simulation concept
(2) Model
(3) Analogy
(4) Imitation
(5) Behavioral similarity
(6) Functional similarity
(7) Similarity in mathematics
(8) Similarity in linguistics
(9) Similarity in literature
(10) Similarity in art
(11) To be similar
(12) Indistinguishableness
(13) Disguise similitude under a false appearance
(14) Non-similarity

A recap: Aspects of M&S (Modeling and Simulation)

1. Experimentation

2. Experience

- to gain / enhance 3 types of skills
  - motor skills
  - decision making skills
  - operational skills
- for entertainment

Ören, T.I. (2011). The Many Facets of Simulation through a Collection of about 100 Definitions. SCS M&S Magazine, 2:2 (April), pp. 82-92.

Ören, T.I. (2011). A Critical Review of Definitions and About 400 Types of Modeling and Simulation. SCS M&S Magazine, 2:3 (July), pp. 142-151.

A recap: Aspects of M&S (Modeling and Simulation)

1. Experimentation

"Simulation is **performing goal directed experiments** with models of dynamic systems."

From: Ören, T.I. (2011). A Critical Review of Definitions and About 400 Types of Modeling and Simulation. SCS M&S Magazine, 2:3 (July), pp. 142-151.

"Simulation **is used for**:
- behavior prediction and performance analysis;
- analysis of alternatives;
- sensitivity analysis;
- engineering design;
- virtual prototyping;
- planning;
- acquisition; and
- proof of concept."
- understanding in analysis problems
- control problems

From: Ören, T., S. Mittal, U. Durak (2017). The Evolution of Simulation and its Contributions to Many Disciplines. Chapter 1 of: S. Mittal, U. Durak, T. Ören (eds.), Guide to Simulation-Based Disciplines: Advancing our Computational Future, Springer, pp. 3-24.

A recap: Aspects of M&S (Modeling and Simulation)

2. Experience

"Simulation is providing experience under controlled conditions for training, i.e., for **gaining /enhancing competence** in one of the three types of skills:

(1) motor skills (virtual simulation),

(2) decision and/or communication skills

(*constructive simulation*; *serious game*), and

(3) **operational skills** (*live simulation*)."

From:
Ören, T.I. (2011). A Critical Review of Definitions and About 400 Types of Modeling and Simulation. SCS M&S Magazine, 2:3 (July), pp. 142-151.

A recap: Aspects of M&S (Modeling and Simulation)

Entertainment

- gaming simulation

"Simulation is providing experience for entertainment purpose (*gaming simulation*).
Some aspects of gaming simulation make it a source of inspiration for serious games used for training purposes. These include advanced visualization techniques and specification of environments and scenarios."

From: Ören, T.I. (2011). A Critical Review of Definitions and About 400 Types of Modeling and Simulation. SCS M&S Magazine, 2:3 (July), pp. 142-151.

- The best simulator games for 2020, Jacob Roach, October 17, 2020
- Browse games, Origin
- PC Simulation Games

Grand Challenges in Modeling and Simulation:

1. Previous grand challenges

1.1 By colleagues

1.2 By Tuncer Ören

2. Can we enhance M&S to make it:

2.1 more powerful?

2.2 more reliable?

3. What M&S can do?

3.1 Existing possibilities

3.2 Are there application areas which could benefit from M&S?

1. Previous grand challenges

1.1 By colleagues

1.2 By Tuncer Ören

2019: Robinson, S. (2019). Conceptual Modelling for Simulation: Progress and Grand Challenges, Journal of Simulation, 14(1),1-20.

2016: Workshop on Research Challenges in Modeling & Simulation for Engineering Complex Systems, January 13-14, 2016 at the National Science Foundation in Arlington, Virginia.

2015: Simon Taylor, Azam Khan, Katherine Morse, Andreas Tolk, Levent Yilmaz, Justyna Zander, Pieter J. Mosterman, Grand challenges for modeling and simulation: simulation everywhere—from cyberinfrastructure to clouds to citizens, SIMULATION: Transactions of The Society for Modeling and Simulation International, **91**:7, 2015.

2013: Taylor, S.J.E., Khan, A., Morse, K.L., Tolk, A., Yilmaz, L., Zander, J. (2013). Grand Challenges on the Theory of Modeling and Simulation. In Proceedings of the Symposium on Theory of Modeling & Simulation - DEVS Integrative M&S Symposium (DEVS 13). Society for Computer Simulation International, San Diego, CA, Article 34.

2004: Fowler, J.W., Rose, O. (2004). Grand Challenges in Modeling and Simulation of Complex Manufacturing Systems, SIMULATION: Transactions of The Society for Modeling and Simulation International **80**(9):469-476

2004: Pegden, C.D. (2004). Future Directions in Simulation Modeling.
Also: In: Proceedings of the 37th Winter Simulation Conference, Orlando, FL, USA, December 4-7, 2005.

2002: Fujimoto, R.M, Lunceford, D, Page, E. Grand Challenges for Modeling and Simulation, August 25 – 30 , 2002, Dagstuhl Seminar 02351.

2002: Future Modelling and Simulation Challenges, NATO RTO Meeting Proceedings, #73, 2002. *Papers presented at the RTO NATO Modelling and Simulation Group (NMSG) Conference held in Breda, Netherlands, 12-14 November 2001.*

2002: Chapter 5. Modeling and Simulation Research and Development Topics. In: Modeling and Simulation in Manufacturing and Defense Acquisition: Pathways to Success, 2002, pp. 77-102. The National Academies Press, Washington, DC.

1. Previous grand challenges

1.1 By colleagues

1.2 By Tuncer Ören

(Normative views, future, directions to explore)

	0	1	2	3	4	5	6	7	8	9	total
1970s									3		3
1980s			1	5	4	1	1	2		1	15
1990s			1								1
2000s			1								1
2010s	1	2	1		1		1				6
2020s	1										1
											27

http://www.site.uottawa.ca/~oren/pubsList/challenges.pdf

1978: Ören, T. (1978). (Member of the panel on): Methodology of the Future, Symposium on Modelling and Simulation Methodology, August 13-18, Rehovot, Israel.

1978: Ören, T. (1978). A Personal View on the Future of Simulation Languages (Keynote Paper). Proceedings of the 1978 UKSC Conference on Computer Simulation, IPC Science and Technology Press, Chester, England, April 4-6, 1978, pp. 294-306.

Simulation programming languages
→ Model specification languages
(and generation of simulation programs by program generators)

1983: Ören, T. (1983). (Invited Lecture): Directions for the Future of Computer-Aided Modelling and Simulation, Department of Systems Science, School of Advanced Studies, State University of New York, April 12, Binghamton, NY.

1986: Ören, T. (1986). (Invited Discussant in the Panel on): Artificial Intelligence and Simulation - The State-of-the-Art and Future Directions. Workshop on AI and Simulation, in conjunction with AAAI-86, August 11, Philadelphia, PA.

1992: Ören, T. (1992). (Invited Presentation) Knowledge-Based Simulation Environments: State-of-the Art and Challenges for the Future. National Research Council Canada - Institute for Information Technology, January 28, Ottawa, ON, Canada.

2014: Ören, T.I., L. Yilmaz and N. Ghasem-Aghaee (2014). A Systematic View of Agent Supported Simulation: Past, Present, and Promising Future. In: M.S. Obaidat, J. Kacprzyk and T. Ören (eds.) Proceedings of the 4th International Conference on Simulation and Modeling Methodologies, Technologies and Applications (SIMULTECH'14), Vienna, Austria, 28-30 August, 2014, pp. 497-506.

2016: Ören, T., L. Yilmaz, N. Ghasem-Aghaee, M. Kazemifard, and F. Noori (2016). Machine Understanding in Agent-Directed Simulation: State-of-the-art and Research Directions. (Keynote article of the 2016 Modeling and Simulation of Complexity in Intelligent, Adaptive and Autonomous Systems (MSCIAAS) Symposium of the SpringSim'16), Proceedings of the SpringSim'16, Umut Durak and Murat Günal, (eds.), April 3-6, 2016, Pasadena, CA, (SCS – The Society for Modeling and Simulation International), San Diego, CA, pp. 848-855. (presentation)

Grand Challenges in Modeling and Simulation:

1. Previous grand challenges

1.1 By colleagues

1.2 By Tuncer Ören

2. Can we enhance M&S to make it:

2.1 more powerful?

2.2 more reliable?

3. What M&S can do?

3.1 Existing possibilities

3.2 Are there application areas which could benefit from M&S?

3. Can we enhance M&S to make it:

3.1 more powerful?

3.2 more reliable?

Some useful possibilities may be synergy of simulation with:

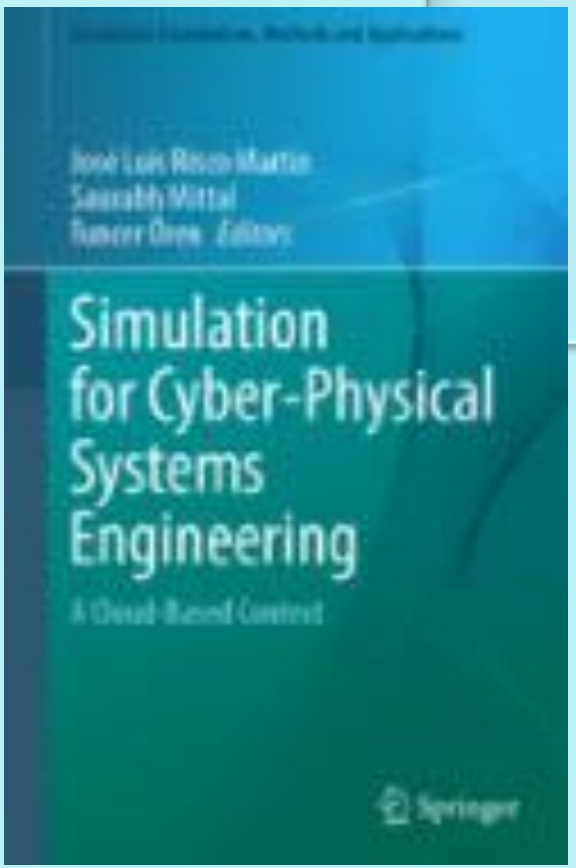
- **computational awareness**

As part of synergy of machine intelligence and simulation.
Along with:

- intelligent agents and simulation
- machine learning
- machine understanding
  - emotion understanding

Some useful possibilities may be **synergy of simulation** with:

- **nature inspired modelling** and **nature-inspired computation**.



Ören, T. (2020 – In Press). Agent-directed Simulation and **Nature-inspired Modeling** for **Cyber-Physical Systems Engineering**. Chapter 7 in: Risco-Martin, J.-L., S. Mittal, T. Ören (Eds.) (2020 – In Press). Simulation for Cyber-Physical Systems Engineering: A Cloud-based Context. Springer.

Holonic simulations may be helpful to appreciate how cooperation can be useful to solve problems.

"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 holons) 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."

From: Ören, T.I. (2001). Advances in Computer and Information Sciences: From Abacus to Holonic Agents. Special Issue on Artificial Intelligence of Elektrik (Turkish Journal of Electrical Engineering and Computer Sciences - Published by TUBITAK - Turkish Science and Technical Council), 9:1, 63-70.

Refs for holonic simulation:

Gaud, N. et al. (2007). Holonic multiagent multilevel simulation application to real-time pedestrians simulation in urban environment. IJCAI'07: Proceedings of the 20th international joint conference on Artifical intelligence, January 2007 Pages 1275–1280.

Integrated use of simulation to support real systems:

- For predictive displays
- For on-line diagnosis abilities

From: Ören, T. (2004). Invited Presentation: Growing Importance of Modelling and Simulation: Professional and Ethical Implications, at: EPUM (Ecole polytechnique Universitaire de Marseille), Departement du Genie Industriel et Informatique, Universite de Provence-Aix-Marseille I, September 15, Marseille, France. (presentation)

Predictive displays

During the operation of a real system, a simulator of the system,

- gets the time-varying information about the environment of the system, directly through sensors and A/D convertors,
- gets the values of the control variables, from the system through transducers, and
- displays the predicted state (trajectory) of the system.

By using a predictive display,

Decision maker/operator can base his/her decision(s) on:

- system characteristics (as represented in the model) and
- facts as generated by the simulator;

Instead of using an undocumented mental model.

On-line diagnosis abilities can be provided by comparing the outputs of the real system and the simulator working under same conditions.

A discrepency may indicate a misfunction of the system.

3. Can we enhance M&S to make it:

3.1 more powerful?

3.2 more reliable?

In modeling and simulation studies:
- Validation & Verification
- Quality Assurance (QA)
- Failure Avoidance (FA)*

*Ören, T.I. and L. Yilmaz (2009). **Failure Avoidance** in Agent-Directed Simulation: Beyond Conventional V&V and QA. In L. Yilmaz and T.I. Ören (eds.). Agent-Directed Simulation and Systems Engineering. Systems Engineering Series, Wiley-Berlin, Germany, pp. 208- 239.

Some Sources of Failures in M&S

Common mistakes in
- modeling
- experimentation
- computerization
- project management
- expectations of users

Multi-paradigm approach for successful M&S projects

V&V Paradigm
QA Paradigm
Failure Avoidance Paradigm for
- M&S
- agent-based modeling
- rule-based systems
- autonomous systems
- agents with personality, emotions, and cultural background
- input (externally generated, internally generated)
- systems engineering

A coalition of M&S companies committed to **ethical conduct** would be useful.
MSII (Modeling and Simulation Industry Initiative)

Defense Industry Initiative
On Business Ethics and Conduct (DII) (USA)

Ref.: Kurland, N.B. The Defense Industry Initiative: Ethics, self-regulation, and accountability. *J Bus Ethics* **12,** 137–145 (1993). https://doi.org/10.1007/BF00871933

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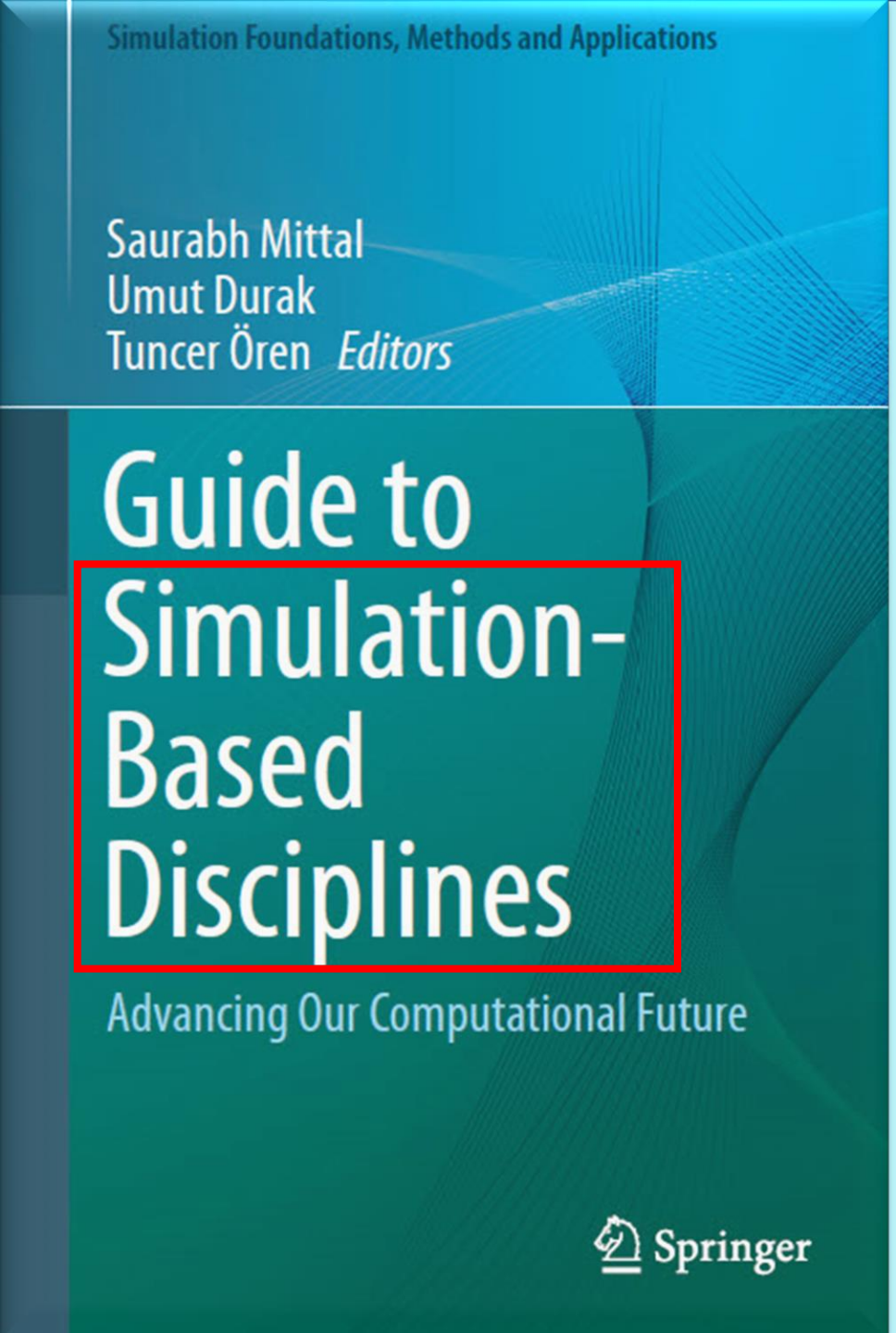
Ören, T.I. (2011). A Critical Review of Definitions and About **400** Types of Modeling and Simulation. SCS M&S Magazine, 2:3,142-151.

Appendix A
Over 400 terms representing
Types of Simulation

abstract simulation
academic simulation
accurate simulation
activity-based simulation
adaptive simulation
adaptive system simulation
adiabatic system simulation
advanced distributed simulation
advanced numerical simulation
advanced simulation
agent-based participatory simulation
built-in simulation
case-based simulation
cellular automaton simulation
classical simulation
closed-form simulation
closed-loop simulation
cloud computer simulation
cluster simulation
co-simulation
coercible simulation
coercion simulation
cognitive simulation
cohersing simulation
collaborative component-based simulation
convergent simulation
cooperative simulation
coopetition simulation
coupled simulation
credible simulation
critical event simulation
customizable simulation
customized simulation
data-driven simulation
data-intensive simulation
descriptive simulation
deterministic simulation
DEVS simulation
digital analog simulation
digital computer simulation

peer-to-peer simulation
perceptual simulation
petascale simulation
Petri net simulation
physical simulation
physical system simulation
plan simulation
portable simulation
predictive simulation
prescriptive simulation
process-based discrete event simulation
process-oriented simulation
process simulation
proof-of concept simulation
proxy simulation
pseudo simulation
serial simulation
serious simulation
shape simulation
simulation
simultaneous simulation
single-aspect simulation
single component simulation
single processor simulation
smoothness simulation
spreadsheet simulation
stand-alone simulation
static simulation
steady-state simulation
stochastic simulation
strong simulation
structural simulation
structure simulation
variable fidelity simulation
variable resolution simulation
virtual simulation
virtual time simulation
virtual training simulation
visual interactive simulation
visual simulation
weak classical simulation
weak simulation
wearable computer-based simulation
Web-based simulation
Web-centric simulation
Web-enabled simulation
yoked simulation
zero sum simulation



Ören, T., S. Mittal, U. Durak (2017). The Evolution of Simulation and its Contributions to Many Disciplines. Chapter 1 of: S. Mittal, U. Durak, T. Ören (eds.), Guide to Simulation-Based Disciplines: Advancing our Computational Future, Springer, pp. 3-24.

2017

Table 1.10 Simulation-based disciplines (examples)

Areas	Disciplines
Engineering	Simulation-based (all types of) engineering (Chaps. 3, 4, 7, 8) Simulation-based cyber-physical systems (Chap. 5) Simulation-based complex adaptive systems (Chap. 6)
Natural science	Simulation-based (all types of) Science (Chap. 9) Simulation-based cosmology Simulation-based astronomy
Health science	Simulation-based Health Care (Chap. 10) Simulation-based pharmacology
Social science and management	Simulation-based Social Science (Chap. 11) (Behavioral science, psychology, demography, sociology, public administration, political science, archeology, environmental studies, …) Simulation-based economics Simulation-based enterprise management (Chap. 12) Simulation-based planning and scheduling Simulation-based optimization Simulation-based policy improvement
Information Science	Informatics Artificial intelligence (machine intelligence) Software agents Communication Library science
Education/training	Simulation-based Education (Chap. 13) Simulation-based training (Chaps. 10, 14) (including health care and military training)
Entertainment	Simulation-based games

From: Mittal, S., U. Durak, T. **Ören** (eds.). (2017). Guide to Simulation-Based Disciplines: Advancing our Computational Future, Springer.

Upgrading from model-based activities **to simulation-based activities** has all the advantages that simulation can provide.

Ören, T., S. Mittal, U. Durak (2018 – Invited Paper). A Shift from Model-Based **to Simulation-Based Paradigm**: Timeliness and Usefulness for Many Disciplines.
International Journal of Computer & Software Engineering. **3**:1. (article-IJCSE-126) (at ResearchGate)

3. What M&S can do?

3.1 Existing possibilities

3.2 Are there application areas which could benefit from M&S?

"Would you tell me, please, **which way I ought to go from here**?"

"That depends a good deal on where you want to get to," said the Cat.

"I don't much care where –" said Alice.

"Then it doesn't matter which way you go," said the Cat.

"– so long as I get *somewhere*," Alice added as an explanation.

"Oh, you're sure to do that," said the Cat, "if you only walk long enough."

Alice's Adventures in Wonderland (1865)

Lewis Caroll (Pen name of Charles Lutwidge Dodgson (1832-1898) English author, mathematician, logician, Anglican deacon and photographer.) (from Wikipedia)

From: Ören, T. (2010). (Keynote speech at the awards banquet), Old Dominion University, VMASC

M&S can be useful for **fact-based rational decision making**!

Experience is very valuable in fact-based rational decision making.

- on-the job
- using simulation / simulators

Pilots get their experience

- using simulators (a vital type of experience)
- on-the-job (and become seasoned pilots)

Social systems are much more complex than aircrafts!

Hope one day,
similar to training of pilots on simulators,
education/training of public decision makers
(including those at the highest levels)
will include experience with predictive displays
based on simulation and multisimulation.

From: Ören, T. (2012). Trends and Challenges in Modeling and Simulation. Presented at the Panel, SIMULTECH, Rome, Italy, September 28, 2012. (presentation).


Thank you for your attention!
Q & A