SIMULTECH'19

Prague, Czech Republic, July 29-31, 2019

Opening Keynote:

The vital role of simulation for many disciplines:
A desirable shift of paradigm
from model-based paradigm to **simulation-based paradigm**

Tuncer Ören, University of Ottawa, Canada

http://www.site.uottawa/~oren/y/2019/07-29_ Prague-keynote.ppsx

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A **Question**:

As a simulationist, do you think that
proper use of simulation

(i.e., **experimentation** and/or
experience to enhance any of three types of skills)

may be beneficial

for several applications in many disciplines ?

As a researcher in simulation, your answer can be:

Yes or No

As a researcher in simulation, if your answer is:

Yes:

- We are on the right track.
- Please elaborate on it for the benefit of several application areas in different disciplines.

As a researcher in simulation, if your answer is:

No:

(1) Please elaborate on why and how simulation cannot have a vital role.

Your points may be beneficial for other researchers.

(2) Do you think you can recommend ways to improve simulation so that it may have vital role for some application areas?

Concepts for advanced simulation methodologies

by

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An example.

The article started as:

"Conventional simulation techniques have three shortcomings when applied to large-scale modelling"

Ören, T.I., Zeigler, B.P. (1979). Concepts for Advanced Simulation Methodologies. (SCS) Simulation, 32:3, 69-82.

The Essence of Simulation:

Experiments and **experience** are the essence of modeling & simulation (M&S).

- Simulation is performing goal-directed **experiments** using a model of a dynamic system.

- Simulation is gaining **experience,** by use of a representation of a system,
  - ***to enhance*** any one of three types of **skills**:
    - -- *motor skills* (by virtual simulation, or simulators),
    - -- *decision making and communication skills* (by constructive simulation, gaming simulation),
    - -- *operational skills* (by live simulation)
  - *for* ***entertainment*** purposes (simulation games)

A brief history of **experimentation**:

Aristotelian logic:
The traditional system of logic by Aristotle (384 BC – 322 BC), concerned chiefly with **deductive reasoning**"
(Expressed in his "**Organon**")

Francis Bacon, as a reaction to Aristotle's Organon:
New Organon (Novum Organum, 1620).

Francis Bacon promoted **experimentation** which is one of the pillars of scientific method.

Experimentation

(as one of the pillars of scientific method):

- Using the real system
    - in vivo
    - in vitro (under lab. conditions)
- Using a model: simulation
    - in silico

Consider

- Advantages and
- Disadvantages of all

“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 variables are known.”

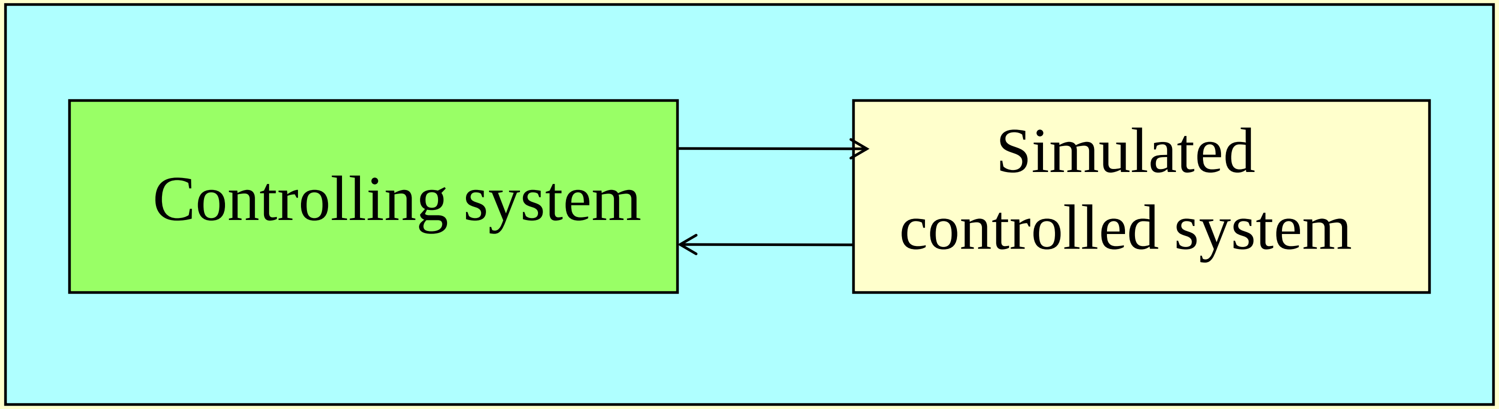
(Walter Karplus, 1976)

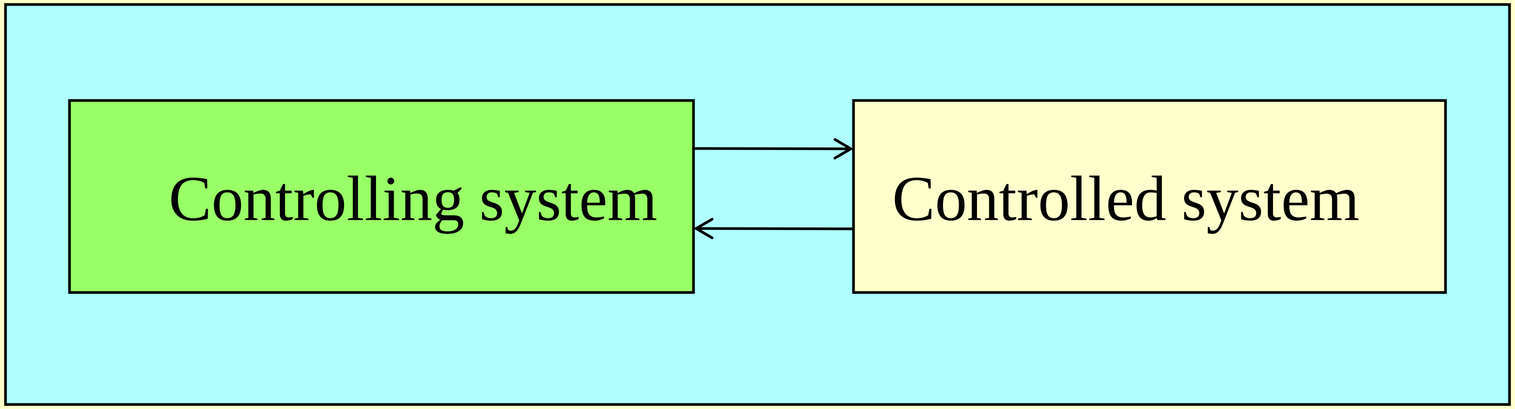
Type of problem:		Given		Find
Analysis	input	state		Output
Design	input		output	State
Control		state	output	Input

Challenge:

Simulation-based software development

- for control systems, for example





Possibilities for Enriched (Augmented) Reality:

		Equipment	
		Real	Virtual
Operator	Real	**- Live simulation** (a human operator uses *real equipment* (laser/gun)	**Virtual simulation** - Simulator - Virtual simulator
	Virtual	**- Automated vehicles** (auto pilot, aircraft without pilot; vehicle without driver)	e.g., **an AI aircraft** (in dogfight)

Simulation and Real System:

2 categories of simulation:

(with respect to **connectivity** of operations)

- **Stand-alone simulation**
  (operations of the simulation and the system of interest are **independent**)
- **Integrated simulation** (**symbiotic simulation**)
  (operations of the simulation and the system of interest are **interwoven**)

(Operations of simulation and the system of interest are interwoven.)

(**Integrated simulation/symbiotic simulation**)

Simulation **enriches** real-system operation.

(Real-System Enriching Simulation)

Simulation **supports** real-system operation.

(Real-System Support Simulation)

Simulation and Real System:

Integrative simulation (symbiotic simulation)

To (enrich) augment reality

In enriched **(augmented or mixed) reality simulation,** real and virtual entities (that can be people or equipment) and the environment can exist at the same time.

Hence, operations can take place in a richer *augmented reality environment*.

Simulation **supports** real-system operation.

Real-System Support Simulation

The SOI and the simulation program

operate alternately

and provide predictive displays for:

- Decision support
- On-the-job training

About 750 types of simulation
About 120 types of inputs to simulation models

Ören, T., S. Mittal, U. Durak (**2019** Invited Chapter).
Modeling and Simulation:
The Essence and Increasing Importance.

Chapter 1 in the book: Modeling and Simulation of Complex Communication Networks (M. A. Niazi, ed.), pp. 3-26. IET Book Series on Big Data.

(Appendix A: A list of over **750 types of simulation**,

Appendix B: A list of **120 types of input**)

Types of inputs

Source of input	Mode of input	Type of input
Exogenous input (externally generated input)	**Passive acceptance** of exogenous input (imposed or forced input)	**Type of access to input**: coupling, argument passing, knowledge in a common area, message passing. **Nature of input**: - ***Data*** *(facts)* - *Forced* ***Events*** - ***Sensation*** (converted sensory data: from analog to digital; single or multi sensor: sensor fusion) -***External goals*** *(imposed goals)* - ***Online knowledge***
	Active perception of exogenous input (perceived input)	- ***Perception*** (interpreted, sensory data and detected events) -- includes: decoding, selection (filtering), recognition, regulation - ***Perceived goals*** - ***Evaluated inputs*** -- evaluation of inputs (acceptability) -- evaluation of source of inputs (reliability, credibility)

Source of input	Mode of input	Type of input
Endogenous input (internally generated input)	**Active perception** of endogenous input	- ***Introspection*** (perceived internal facts, events; or realization of lack of them)
	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)*

Challenge: Use endogenous inputs in simulation

A personal view:

(Some aspects expressed previously:

Lectures at Beijing and Changsha, China, September 2011

"**Future** of Modeling and Simulation:

Normative Views, Desirable **Growth Areas** & **Challenges**")

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

Confucius, 551-479 BC

Consider advances in **:**

(1) Simulation

(2) Other disciplines by simulation-based approaches

M&S from the **Tool Hierarchy:**

	Types of tools		
Levels	Physical tools	Software tools	M&S tools
Manual tools			
	Additional features		
Power tools			
	Additional features		
Cybernetic tools			

Level	Physical tools	Software tools	M&S tools
Manual tools	• stone tools • metallic tools • …	• hand-coded programs • non-automated documentation (including specification & processing of requirements)	• hand-coded M&S programs (simulation is an art / craft era)

Level	Physical tools	Software tools	M&S tools
Manual tools	• stone tools • metallic tools • …	• hand-coded programs • non-automated documentation	• hand-coded M&S programs (simulation is an art / craft era)
Additional features	• ***(Energy)*** **Ability to perform work**	• *Computer-aided* programming • *Computer-support* in software life cycle	• *Computer-aided* M&S programming • *Computer support* in M&S (in areas other than model behavior generation)
Power tools	• simple power tools • machine tools • integrated machines (transfer machines)	• software tools • software tool kits • software environments • integrated computer-aided software engineering tools	• M&S tools (e.g., program generators, symbolic processors of models & other M&S components) • M&S tool kits • M&S environments • integrated environments for M&S • computer-aided design and/or problem solving environments with simulation abilities

Level	Physical tools	Software tools	M&S tools
Manual tools	• stone tools • metallic tools • …	• hand-coded programs • non-automated documentation	• hand-coded M&S programs (simulation is an art / craft era)
Additional features	• *(Energy)* Ability to perform work	• *Computer-aided* programming • *Computer-support* in software life cycle	• *Computer-aided* M&S programming • *Computer support* in M&S (in areas other than model behavior generation)
Power tools	• simple power tools • machine tools • integrated machines (transfer machines)	• software tools • software tool kits • software environments • integrated computer-aided software engineering tools	• M&S tools (e.g., program generators, symbolic processors of models & other M&S components) • M&S tool kits •.M&S environments • integrated environments for M&S • computer-aided design and/or problem solving environments with sim. abilities
Additional features	• ***Knowledge processing***	• ***Advanced** knowledge processing* ability - Artificial Intelligence (**AI**), Software **agents**	
Cybernetic tools	**Knowledge processing (kp) machines** • Machines for kp: Computers • Machines with kp abilities (smart machines)	• AI in software • AI in software environments	AI-directed simulation • Simulation of intelligent entities • AI for simulation - AI- supported simulation - AI-based simulation
		• Agents in software • Agents in software environments	Agent-directed simulation • Simulation for agents: - agent simulation • Agents for simulation: - agent-supported simulation - agent-monitored simulation

Agent-directed simulation (**ADS**)

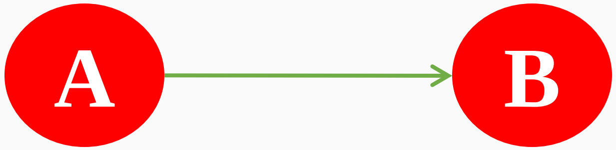
- Simulation for agents:
  - agent simulation (simulation of agent systems)
- Agents for simulation:
  - agent-supported simulation (agents for interfaces)
  - agent-monitored simulation (agents at run time)

Synergies of simulation with some disciplines

Synergies between 2 entities A & B can be:

- **First order synergy:**

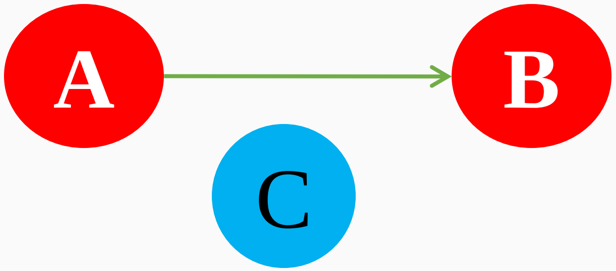
  Direct contributions between them



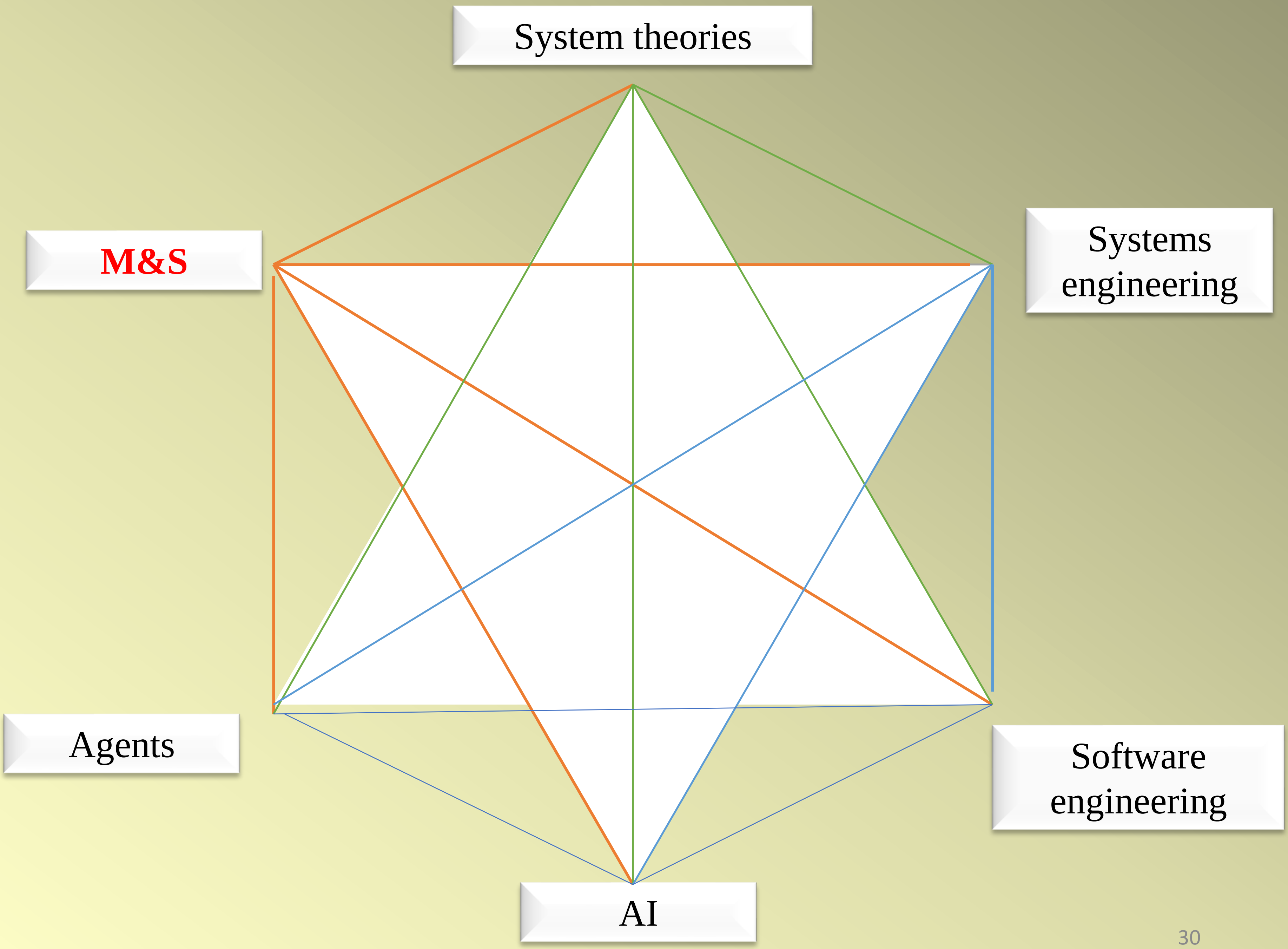
B is enhanced due to contributions of A to B

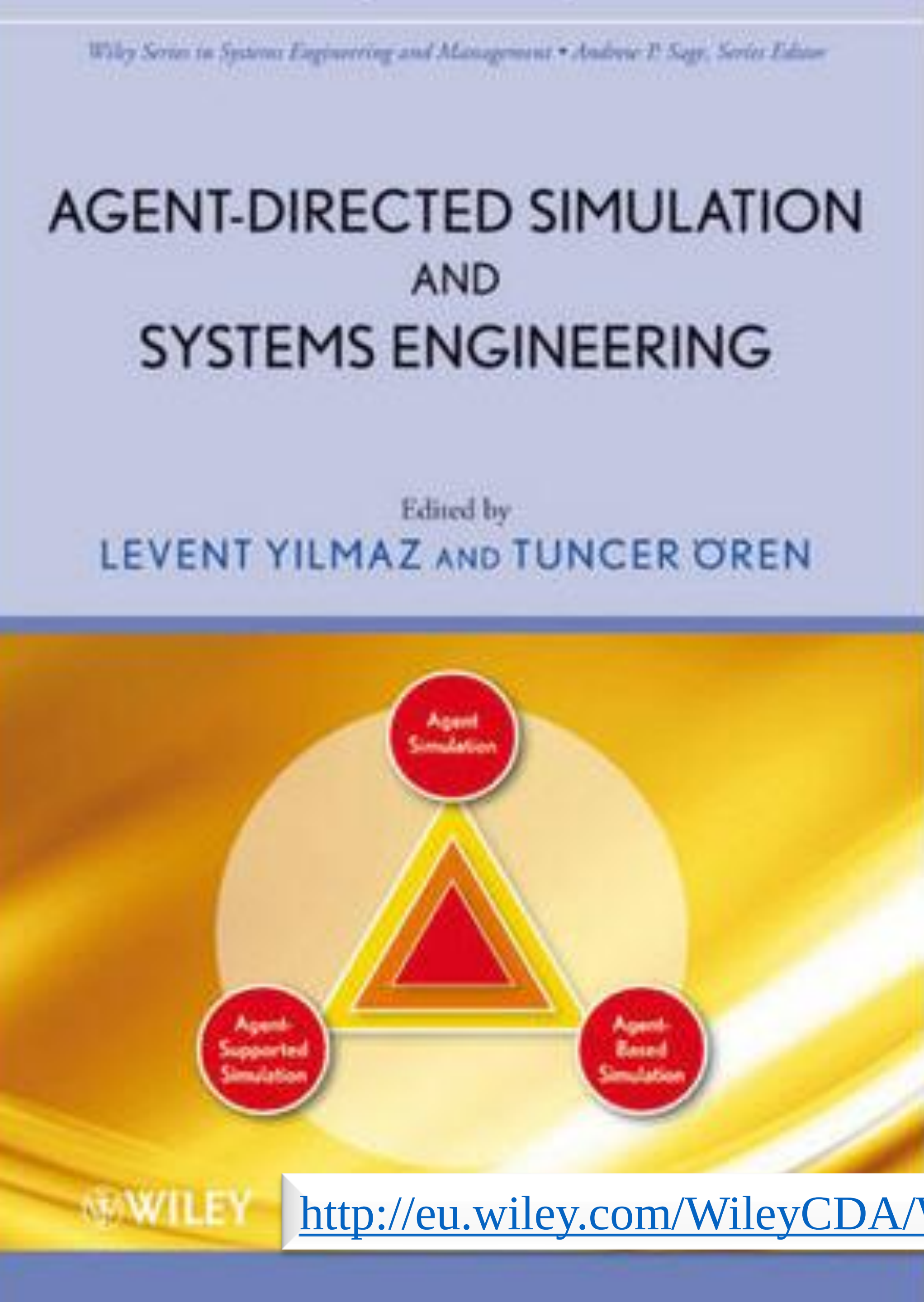
- **Higher order synergy:**

  Indirect contributions between them



B is enhanced due to contributions of enhanced A to B

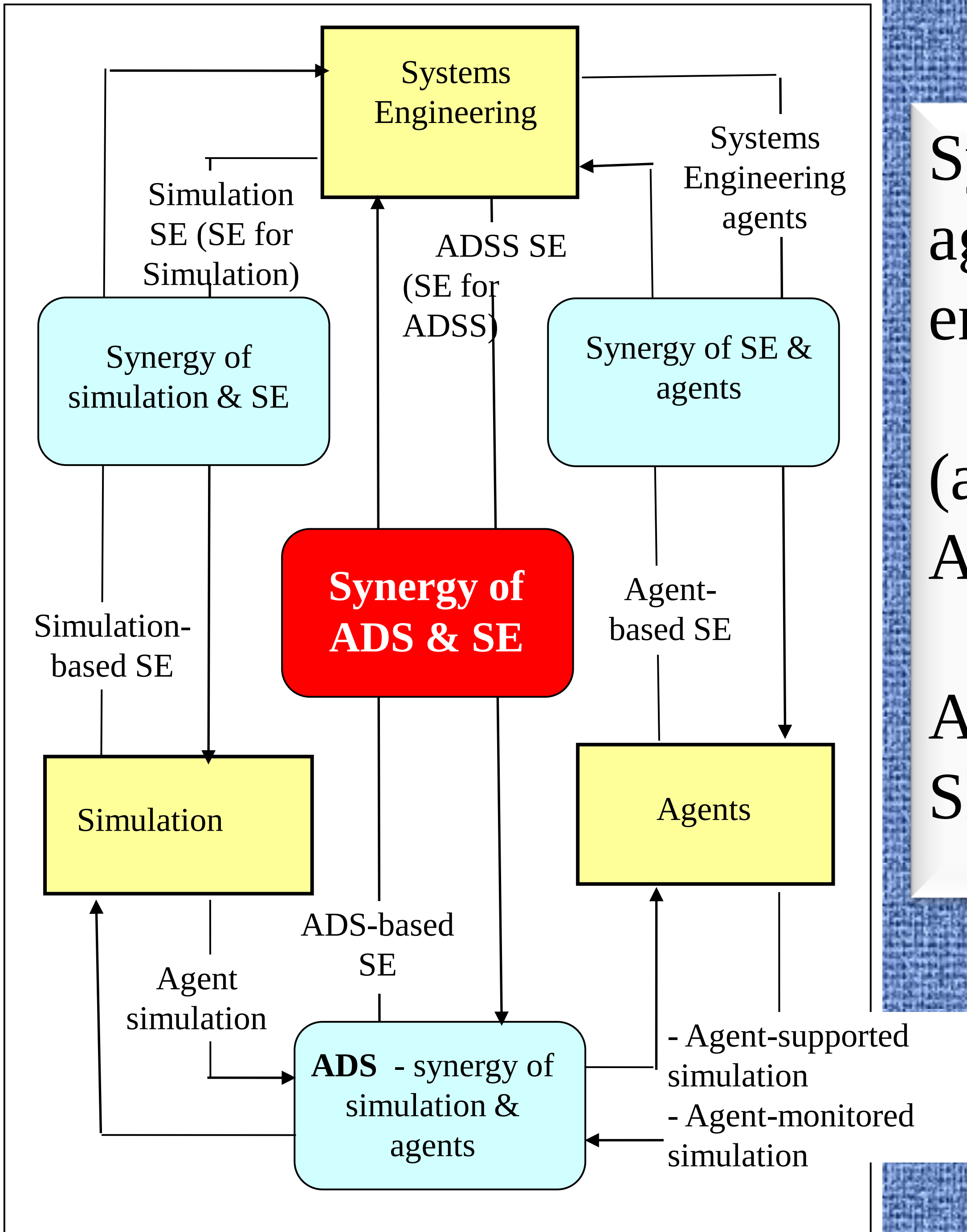

System theories
M&S
Systems engineering
Agents
Software engineering
AI



"The only book to present the synergy between modeling and simulation, **systems engineering**, and **agent**. . ."

550 pages
September **2009**

http://eu.wiley.com/WileyCDA/WileyTitle/productCd-3527407812.html



Synergies of simulation, agents, and systems engineering

(abbreviations:
ADS: Agent-directed simulation
ADSS: ADS systems
SE: Systems engineering)

Challenges

- Develop simulation systems engineering for social systems

- Consider use of simulation (simulators) for pilot training;

  & remember that most social systems –even though somehow more resilient– are much more complex.
- Decision skills can be enhanced by simulation-based experiences.

An increasing number of social system simulation conferences is a very promising development.

We have also

- Cognitive simulation
- Emotive simulation
- Including representation / simulation of human personality, emotions, understanding, misunderstanding, computational awareness.

Challenges:

- Use **conceptual models** to be transformed to computational (programmed) models.
- Model bases to store conceptual models.
- Maintenance of conceptual models instead of computational (programmed) models.
- Develop concepts and tools for interoperability of conceptual models

Another possibility

Add virtual gauges (measurement devices) (with or without threshold controls) to simulation systems

Abdullah, B., Ören, T., (**1997**). Enhancement of a Simulation Environment with IMAGES (Intelligent Multi-Agent Based Virtual Gauges). In: Proceedings of the 1st World Congress on Systems Simulation, Singapore, Sept. 1-4, 1997, pp. 359-363.

Model-based Approaches:
A Brief History

Concepts for advanced simulation methodologies

by

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and

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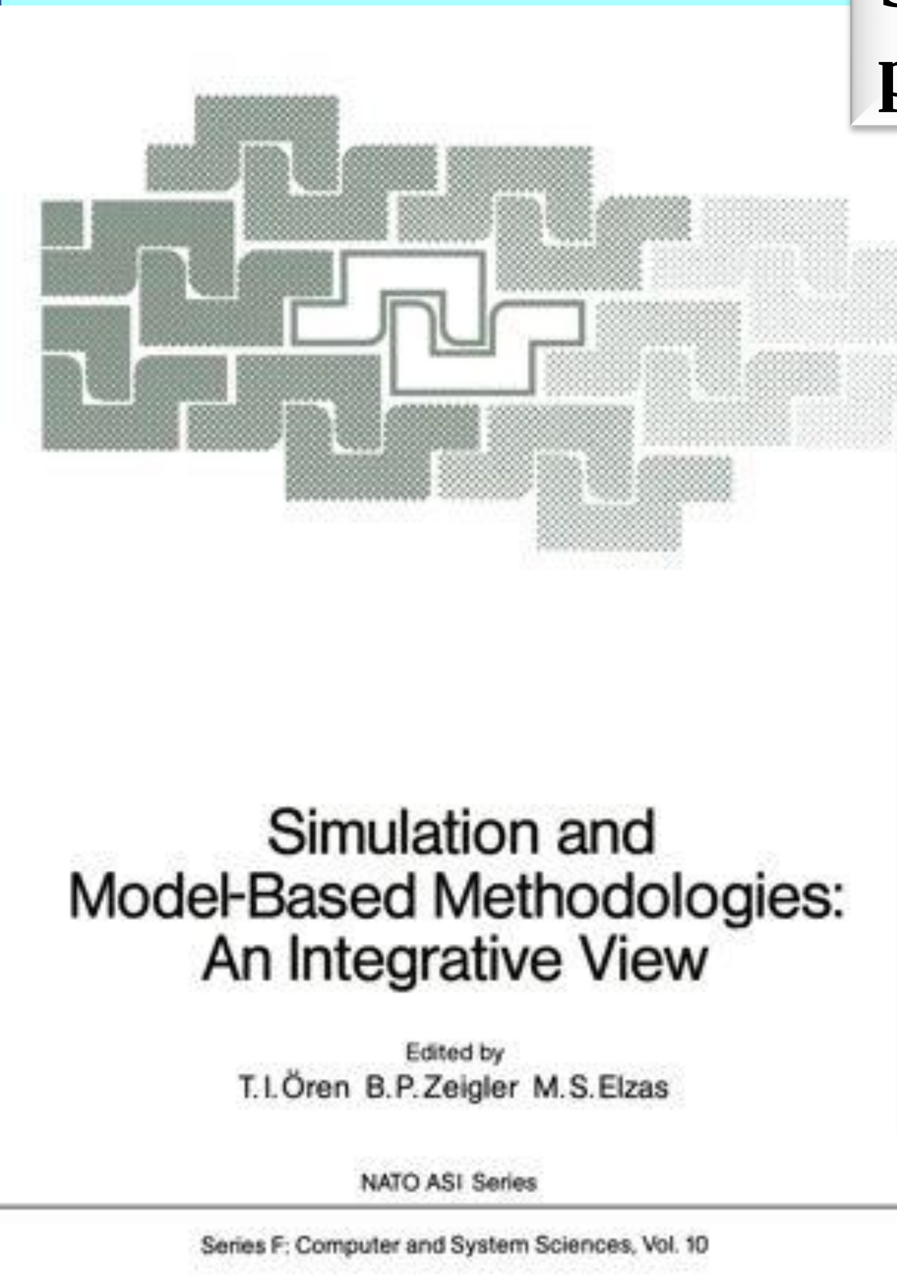
The first article where model and experimentation (as well as several components of experimentation) were separated.

Leading to model-based simulation

(and hence to **model-based approaches**) .

Ören, T.I., Zeigler, B.P. (1979). Concepts for Advanced Simulation Methodologies. Simulation, 32:3, 69-82.

Simulation has been **the starting point** for **model-based activities**:



Ören, T.I. (**1984**). **Model-Based Activities: A Paradigm Shift**.

In: Simulation and Model-Based Methodologies: An Integrative View, T.I. Ören, B.P. Zeigler, M.S. Elzas (eds.). Springer-Verlag, Heidelberg, Germany, pp. 3-40.

The first declarative simulation language:
"GEST: General Systems Theory* implementor"
Doctoral dissertation, T. Ören (**1971**)
Univ. of Arizona, Tucson, Arizona.

*Based on: of Dr. A. Wayne Wymore (1967).
A Mathematical Theory of Systems Engineering:
The Elements. Krieger, Huntington, NY.

And one of the first model-based approach studies:
A. Wayne Wymore (**1993**).
Model-Based Systems Engineering, CRC Press, Boca Raton.

Currently,
Model-based approach is widely used:

model-based **systems engineering**
model-based
model-based **testing**
model-based **design**
model-based **reinforcement learning**
model-based **software engineering**
model-based **clustering**
model-based **machine learning**
model-based **active exploration**
model-based **engineering**

Simulation-based Approaches:

Gianni, Daniele; D'Ambrogio, Andrea; Tolk, Andreas, eds. (December **2014**). **Modeling** and **Simulation-Based Systems Engineering Handbook** (1 ed.). USA: CRC Press. ISBN 9781466571457

SIMULATION AND MODELING AS THE ESSENCE OF COMPUTATIONAL SCIENCE

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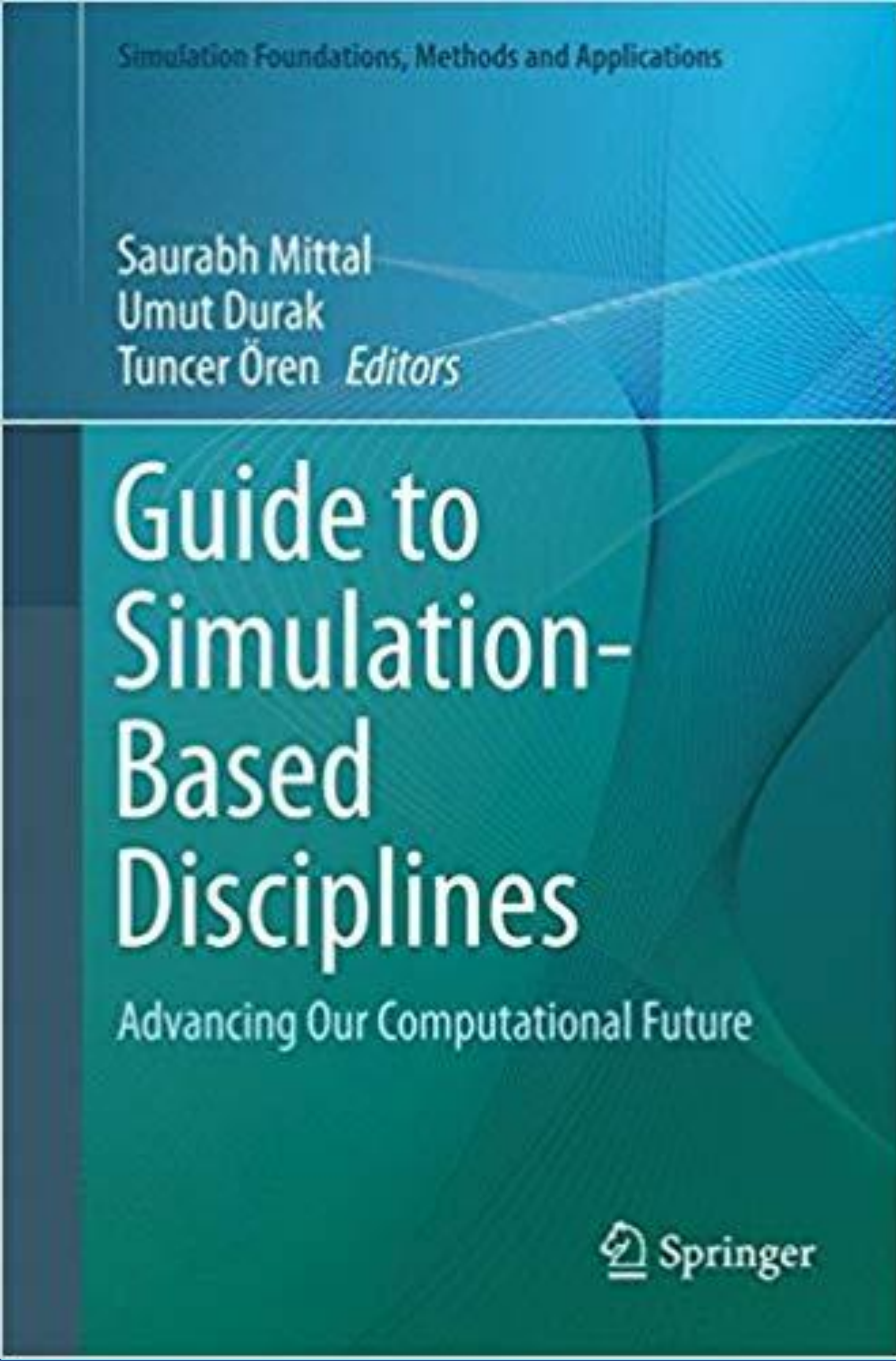
SummerSim-SCSC18; **2018**, July 9-12, Bordeaux, France



Contemporary view:

Simulation-Based Disciplines

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

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

ToC

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Contemporary view: Simulation-Based Disciplines

Ören, T. (**2018** July). On the Advantages of Simulation-based Approach in Engineering.

COJ Electronics & Communications, vol. 1, issue 1. COJE

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. Vol:3, issue: 1.

Contemporary view: Simulation-Based Disciplines

Ören, T., S. Mittal, U. Durak (**2019** Invited Chapter).

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Chapter 1 in the book: Modeling and Simulation of Complex Communication Networks (M. A. Niazi, ed.), pp. 3-26.

IET Book Series on Big Data.

(Appendix A: A list of over **750 types of simulation**,

Appendix B: A list of **120 types of input).**

Challenges:

- Simulation-based problem-solving environments

- Simulation-based Computer-aided design (CAD)
- Simulation-based (several types of) engineering
- Simulation-based science
- Simulation-based education
- Simulation-based social science
- Simulation-based training:
  for conflict management

Airline disasters:

- In October (2018), Lion Air Flight 610 crashed just minutes after taking off from Jakarta, Indonesia, killing 189 people.
- In March (2019), another Boeing 737 Max, Ethiopian Airlines Flight 302, crashed minutes after takeoff; all 157 people on board died.
- Inquiries into both crashes are continuing, but black box data immediately pointed similarities between the two accidents:

A system designed to help the plane avoid stalling appears to have malfunctioned, pushing down the nose of the plane.

https://www.nytimes.com/interactive/2019/business/boeing-737-crashes.html

Question:

Wouldn’t simulation be useful in the following cases?

Simulation-based experiments to **test** the effects of the sensors under several experimental conditions.

Simulation-based experience to **train** pilots for the aircrafts equipped with new sensors.

We have seen outlines of:

A question
Essence of simulation
A personal view
- tools
- synergies
- challenges

Model-based approach
Simulation-based approach
Two disasters and a question

For the researcher in you:

No progress is ever possible

by keeping the state-of-the-art,

no matter how advanced it is.

Welcome to the **Simulation-based Era!**

Thank you for your attention!

Q / A