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The Richness of Modeling and Simulation & its Body of Knowledge

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Plan

1. **Introduction**
2. Importance of M&S
3. M&S & Education
4. Richness of M&S
5. Professionalism in M&S
6. Stakeholders of M&S
7. M&S Body of Knowledge
8. Conclusion

Possible opportunities & challenges

Some Motivations to see the **Big** Picture:

"The smaller a man, the closer his horizon"

(John McLeod, founder of SCS)

"The greater a person, the larger his horizon"

(Tuncer Ören)

Having a large horizon is desirable; **but not sufficient.**

Two important factors (biases):

- **Where we are** (***local bias***): At the North Pole, all directions point out the South!
- **Our perspective** (***cultural bias***):

- "Horizon" is relevant if we are outside of a sphere;
- When we are within a sphere, our **perspective** (**point of view**) & our **ability to discern** are relevant.

Simulation has well over 100 definitions!

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.

For any discipline, having that many definitions is not necessarily a testimony of richness.

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.

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 providing **experience**,
  by use of a representation (a model) of a system,
  - ***to enhance*** any one of three types of **skills** (**training**):
    -- *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)

Plan

1. Introduction
2. **Importance of M&S** ★
   - 2.1 Simulation-based Science & Engineering
   - 2.2 Simulation-based Social Sciences
   - 2.3 Computational Neuroscience
   - 2.4 Impact of Extreme-scale Computing in M&S
   - 2.5 ★

2. Importance of M&S

2.1 Simulation-based Science & Engineering

"Simulation-based engineering science (SBES) is a well established and important concept" (Oden et al., 2006).

"*Meaningful advances in SBES will require dramatic changes in science and engineering education*" (p. 56).

2.2 Simulation-based Social Sciences

Simulation-based social sciences include anthropology, archaeology, economics, geography, government, linguistics, management, political science, and sociology.

2. Importance of M&S

2.3 **Computational Neuroscience**

Computational neuroscience is a subfield of neuroscience that uses mathematical methods to simulate and understand the function of the nervous system (Scholarpedia).

"A *connectome* is a comprehensive map of neural connections in the brain" (Wiki-connectome).

"The *Human Connectome Project* aims to provide an unparalleled compilation of neural data, an interface to graphically navigate this data and the opportunity to achieve never before realized conclusions about the living human brain" (HCP).

Advanced simulation is an integral part of the connectome project.

2. Importance of M&S

2.4 Impact of **Extreme-scale Computing** in M&S

Extreme scale computers are high-speed computers such as *teraflop*, *petaflop*, or *exaflop* computers.

They perform, respectively,

10^{12} (i.e., one thousand times one billion),

10^{15} (i.e., one million times one billion), or

10^{18} (i.e., one billion times one billion) floating point operations per second.

Simulations performed on these types of computers are called, *extreme-scale simulation*, *terascale simulation*, *petascale simulation*, or *exascale simulation*.

USA is working to realize an exascale computer.

2. Importance of M&S

2.4 Impact of **Extreme-scale Computing** in M&S

As *a practical importance of:*

• ***petascale simulation,*** one can point out that,

if one billion entities are represented in a simulation model,

every second, over a million fp operations can be performed for each object represented.

• **exascale simulation**, one can point out that,
if 100 billion entities (e.g., all neurons in a brain) are represented in a simulation model,
every second, over 10 million floating point operations can be performed for each object represented.

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3. M&S & Education

Education for simulation

Simulation for education

For simulationists
- Degree programs:
  - -bachelar, MS, PhD
- Professional training
- . . .

Practically in any field
- In Degree programs:
  - -bachelar, MS, PhD
- Professional training
- . . .

Uniform curricula

Benefits of M&S for Ed.

Opportunities & Challenges for both:

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3. Richness of M&S

Over 500 terms denoting several types of simulation

3d simulation	biologically-inspired simulation	continuous simulation
A--	bio-nano simulation	continuous-change simulation
ab initio simulation	block-oriented simulation	continuous-system simulation
abstract simulation	bond-graph simulation	continuous-time simulation
academic simulation	branched simulation	conventional simulation
accurate simulation	built-in simulation	convergent simulation
activity-based simulation	**C--**	cooperative simulation
ad hoc distributed simulation	case-based simulation	coopetition simulation
adaptive simulation	cellular automaton simulation	co-simulation
adaptive system simulation	classical simulation	coupled simulation
adiabatic system simulation	closed-form simulation	credible simulation
advanced simulation	closed-loop simulation	critical event simulation
advanced distributed sim.	cloud simulation	customizable simulation
advanced numerical sim.	cloud-based simulation	customized simulation
agent simulation	cluster simulation	**D--**
agent-based simulation	coercible simulation	data-driven simulation
agent-based participatory sim.	cognitive simulation	data-intensive simulation
agent-controlled simulation	cokriging simulation	decision simulation
agent-coordinated simulation	collaborative component-based simulation	degree 1 simulation
agent-directed simulation	collaborative distributed sim.	degree 2 simulation
agent-initiated simulation	collaborative simulation	degree 3 simulation
agent-monitored simulation	collaborative virtual sim.	demon-controlled simulation
agent-supported simulation	collocated cokriging sim.	descriptive simulation
aggregate level simulation	collocated simulation	detached eddy simulation
	combined continuous-discrete	deterministic simulation
		DEVS simulation
		digital analog simulation

Table 3. An Ontology-Based Dictionary of Understanding

Based on the Understanding **Process** and the **Metamodel** Used

Criteria		*Types of understanding*	Definitions & (explanations)
understanding **process**	**directness**	*apprehension (direct understanding)*	*Apprehension* is direct understanding or self-evidence.
		comprehension (indirect understanding) (mediated understanding)	*Comprehension* is indirect or mediated understanding.
		- logical understanding	*Logical understanding* is indirect understanding where logical inference is used as a means for the attainment of an understanding.
	direction	*top-down understanding*	*Top-down understanding* starts with background knowledge (meta-model) about an entity to gather knowledge about it.
		bottom up understanding	*Bottom up understanding* starts with an analysis or perception of an entity and maps relevant knowledge to a meta-model of it.
	Precedence	*sequential understanding*	Understanding done in sequence.
		parallel understanding	Understanding done in parallel.
	modality	*unimodal understanding*	Understanding one modality at a time. (e.g., text, picture, or gesture.)
		multimodal understanding	Understanding more than one modality simultaneously.
	dependability	*robust understanding*	Understanding by a system that has the ability to recover gracefully from the whole range of exceptional inputs and situations in a given environment.
		brittle understanding	Understanding by a system which is functional but easily broken by changes in operating environment or configuration, or by any minor tweak to the software itself. (Also, any system that responds inappropriately and disastrously to abnormal but expected external stimuli.)
	accumulation of knowledge	*tabula rasa understanding (re-initialized understanding)*	*Tabula rasa understanding* does not depend on the results (products) of previous understanding process(es). (At the beginning of an understanding process, any remnant understanding from previous understanding process(es) is ignored.)
		cumulative understanding	*Cumulative understanding* builds up an understanding on top of previous understanding(s).

3. Richness of M&S

- ***Number of terms in the M&S domain***:

- an early (English-French-Turkish) M&S dictionary had about 4000 terms. 2006, Marseille, France.

- The English-Chinese M&S dictionary has over 9000 terms. (In Press, Beijing, China) (with contributions of 30 Chinese scholars)

- The English-French-Italian-Spanish-Turkish version which is being prepared has over 10000 terms and contributions of about 80 volunteers.

3. Richness of M&S

- There are many articles about comprehensive views of M&S.

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

- **Gaming simulation** can also be combined to explore experimentation for scientific research. An example is eyewire project of MIT which is gamified for crowdsourcing to have large cooperation of simulation game players to explore how connectomes of retina work
(Anthony, 2012; eyewire).

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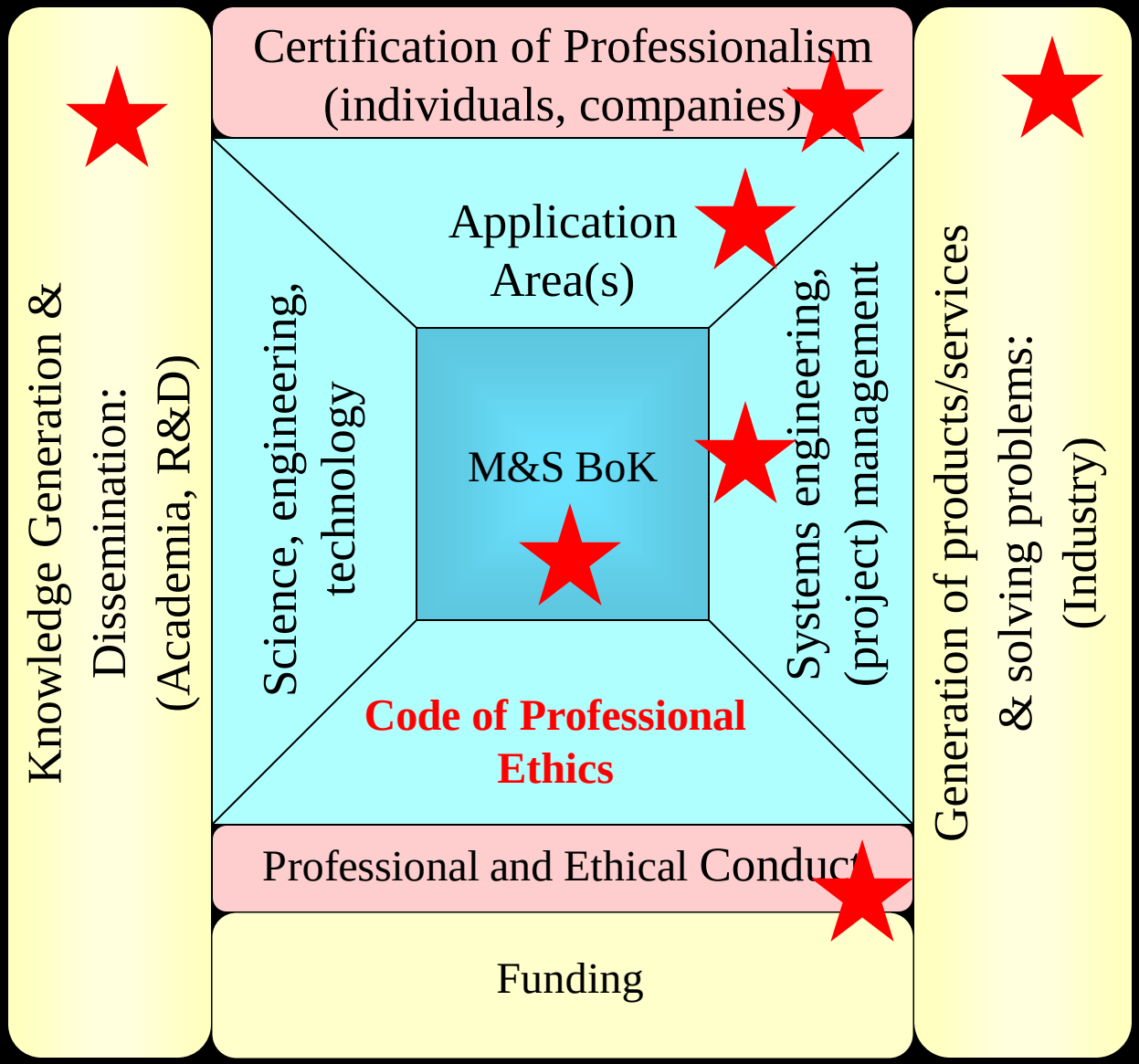
3 Aspects of Professionalism in M&S:



1. Knowledge:

1.1 To solve problems:

- M&S BoK
- Science, Eng., technology
- Systems Eng., management
- Application Area(s)

1.2 How to behave as a simulationist

- Code of Professional Ethics

2. Activities:

1.1 Knowledge Generation & Dissemination: (Academia, R&D)

1.2 Generation of products /services & solving problems (Industry)

1.3 Funding

3. **Monitoring**:

3.1 Professional and Ethical Conduct

3.2 Certification of Professionalism

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6. Stakeholders of M&S

Table 1: Stakeholders of M&S

Stakeholders of M&S BoK	
Individuals	• Researchers / educators
	• Practitioners
	• Experienced learners
	• Novice learners
	• Customers / users of products / services
	• People (to be) affected by simulation projects (done or not yet done)
	• Industrialists
Institutions	• Government organizations
	• Non-profit organizations
	• Agencies for licensing or certification (of individuals / organizations)
	• Funding agencies
	• Professional societies
	• Standardization organizations
	• Educational institutions
	• Industrial / professional groups / centers
	• Commercial organizations
Discipline and market	
Countries	

International Federation of M&S

SIEI (similar to DII)
(Simulation Industry Ethical Initiative)

Urgently needed

http://www.site.uottawa.ca/~oren/links-MS-AG.htm

Importance of Modeling & Simulation (M&S)

USA
The Senate declared it as a critical technology

- **High Level Recognition of M&S:**
  US Congressional Modeling and Simulation Caucus (News) (Congressman J. Randy Forbes)

- **As a testimony of high level recognition of M&S see:**
  USA - House Resolution 487 (2007 July 16)
  USA - Enhancing SIMULATION (Safety In Medicine Utilizing Leading Advanced Simulation Technologies to Improve Outcomes Now) Act of 2009 – H.R. 855/S. 616 (2009 February 4)
  USA - A companion bill - S. 616 (2009 March 17)

Importance of Modeling & Simulation (M&S)

China

- Since 1985, most universities in China have master and Ph.D programs on the direction of modeling and simulation technology under related discipline such as computer science, mathematics, mechanical engineering, and automation.
- According to the investigation of CASS (China Association for System Simulation), during the last decade, there are 85,964 master students and 19,657 Ph.D students graduated from system modeling and simulation technology in the top 100 universities in China.
- Modeling and simulation technology is being considered to be established as a first class discipline by the Ministry of Education of China under the proposal of most Chinese universities and CASS [1].

Bo Hu Li, Lin Zhang, Zongji Chen, Tianyuan Xiao and Jingye Wang (2010)
Simulation Science and Technology in China
SCS M&S Magazine, vol. 1, issue 3 (July)

Stakeholders of M&S: Countries / Unions

USA: declared M&S as a critical discipline

China: acknowledges M&S's importance ★

European Union ★
may benefit from

- **the declaration of M&S as a critical area for the well being of Europeans**

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7. M&S Body of Knowledge (BoK)

7.1 **Preliminary**

- A body of knowledge (BoK) of a discipline is "structured knowledge that is used by members of a discipline to guide their practice or work" (Ören, 2006).

7. M&S Body of Knowledge (BoK)

7.1 **Preliminary**

- A **BoK Index** is a set of systematically organized pointers to the content of a BoK.
- Desired BoK Index features include:
  - Supporting a variety of users within the M&S Community of Practice (CoP)
  - Identifying and providing access to BoK topics/content
  - Providing configuration-managed views to content that changes over time"

(Lacy and Waite, 2011)

Among other benefits, M&S BoK would allow us **systematic exploration** of many **opportunities** and **challenges**. ★

Cartesian approach may be useful!

Cartesian Approach:

René Descartes: “Discours de la méthode pour bien conduire sa raison, et chercher la verité dans les sciences” (1637).
(However, when needed we can also be pragmatic. Remember for a camera, infinity is about after 20 meters.)

- The first was *to never accept anything as true which I could not accept as obviously true*; that is to say, to carefully avoid impulsiveness and prejudice, and to include nothing in my conclusions but whatever was so clearly presented to my mind that I could have no reason to doubt it.

Cartesian Approach:

Furthermore,
avoid the trap of single-vision understanding
which may lead to **dogmatic understanding**.

(More on several **types of understanding**:

Ören, T.I. (2000 – Invited Opening Paper). Understanding: A Taxonomy and Performance Factors. In: D. Thiel (ed.) Proc. of FOODSIM'2000, June 26-27, 2000, Nantes, France. SCS, San Diego, CA, pp. 3-10.)

Cartesian Approach:

- The second was to **divide each of the problems** I was examining in as many parts as I **could**, as many as **should** be necessary to solve them.
- The third, to **develop my thoughts in order**, beginning with the simplest and easiest to understand matters, in order to reach by degrees, little by little, to the most complex knowledge, assuming an orderliness among them which did not at all naturally seem to follow one from the other.

Cartesian Approach:

- And the last resolution was to make my **enumerations so complete** and my **reviews so general** that I could be assured that I had **not omitted anything**.

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   - 7.2 BoK of Other Disciplines
   - 7.3 Previous & On-going Studies/Activities
   - 7.4 Being developed by the author

7. M&S Body of Knowledge (BoK)

7.2

Body of Knowledge of Other Areas

Business/Management

BA - Business Analysis Body of Knowledge

EA - Guide to the Enterprise Architecture Body of Knowledge

IT - Information Technology Body of Knowledge

UR - Utility Regulation Body of Knowledge

Civil Engineering

CE (Civil Engineering) Body of Knowledge

Database

Towards a Database Body of Knowledge

Family and Consumer Sciences

Body of Knowledge for Family and Consumer Sciences

Geography

Geographic Information Science and Technology Body of Knowledge

Mechanical Engineering

Body of Knowledge for Mechanical Engineering

Medicine

Guide to the Body of Knowledge for Medical Practice Management

Building the Drug Safety Body of Knowledge

7.2 BoK of Other Disciplines

Project Management

NPD - New Product Development Body of Knowledge

PM - Project Management Body of Knowledge

PM-APM - Project Management Body of Knowledge (APM)

PM - Project Management Body of Knowledge: Guide

Quality

Q - Body of Quality Knowledge

QPI - Body of Knowledge in Quality and Performance Improvement (database)

NBICE - Body of Knowledge for National Board Inspector Commission Examination

ASQ (American Society for Quality) Six Sigma Body of Knowledge

ASQ (American Society for Quality) Quality Technician Certification Body of Knowledge

TT - Towards Building a Solid Body of Knowledge in Testing Techniques

7.2 BoK of Other Disciplines

Safety

Beginning of Define a Body of Knowledge for Safety Practitionners

White Paper of the Body of Knowledge of the American Society of Safety Engineers Council on Practices and Standards

Software Engineering/Computer Science

SE - Guide to Body of of Knowledge of Software Engineering

PSP (Personal Software Process) Body of of Knowledge

SQM - Body of of Knowledge for Software Quality Measurement

SA - Creating a Software Assurance Body of of Knowledge

CST - Common Body of of Knowledge for the Certified Software Tester

SRT - Replicated Studies: Building a BOK About Software Reading Techniques

CS - Overview of the Computer Science Body of of Knowledge

Systems Engineering

SE - Guide to Systems Engineering Body of Knowledge

ISE - Towards an Information Systems Engineering Body of Knowledge

DISE - (US Department of Energy) Departmental Information Systems Engineering (DISE):

Lifecycle: vol 1, Guidance: vol 2

ISSEP (Information Systems Security Engineering Professionals Body of Knowledge

Usability

Usability Body of Knowledge

Utility Infrastructure

BoKIR - Body of Knowledge on Infrastructure Regulation

7. M&S Body of Knowledge (BoK)

M&SBOK: Early and Contemporary Studies

Due to its importance and timeliness, several studies on M&SBOK preparation have been under way. Some of them are:

An early study was developed by the Technical Committee on Simulation of the IEEE Computer Society (CS-TCSim-BOK). However, this study did not have an impact on the discipline.

One of the on-going efforts is the establishment of a clearinghouse as well as contribution to the M&SBOK studies by an avid supporter of the M&SBOK studies, i.e., B. Waite (Aegis Docushare). Many Workshops are organized (e.g., Waite and Skinner 2003, Waite 2004).

Fairchild (2002) presented his version of M&SBOK by partitioning it in four areas:

(1) Simuland: What is simulated,

(2) Purpose: Why it is simulated,

(3) Technique: How it is simulated (solution method, execution control, interfacing –inputs and outputs–, classical mathematics, and soft computing),

(4) Programmatics: How it is controlled (technology and management).

Birta published an M&SBOK (Birta, Birta 2003) which caused Elzas to publish a critique (Elzas).

Studies elaborating on an "ideal simulationist" such as reports (Madewell and Swain 2003, Rogers 1997) and their critiques also contain valuable information.

A section at the references –titled M&SBoK – Early Studies & Other Contributions– is dedicated for this purpose.

7. M&S Body of Knowledge (BoK)

M&SBOK - Early Studies & Other Contributions

Banks, Catherine M. (2006). Academic Night Spring SIW 2006, 2006 Spring Simulation Interoperability Workshop,Huntsville, AL 2006.

Birta, L.G. (2003). The Quest for the Modelling and Simulation Body of Knowledge. Keynote presentation at the Sixth Conference on Computer Simulation and Industry Applications, Instituto Tecnologico de Tijuana, Mexico, February 19-21, 2003.

Birta, L.G. A Perspective of the Modeling and Simulation Body of Knowledge. Modeling & Simulation, vol. 2, number 1, pp. 16-19.

Elzas, M.S. The BoK Stops Here. Modeling and Simulation, Issue 7.

IEEE CS – Technical Committee on Simulation. Body of Knowledge

Loftin, B.R. et al. (2004). Modeling and Simulation Body of Knowledge (BOK) and Course Overview

Petty, M. and B.R. Loftin (2004). Modeling and Simulation "Body of Knowledge" Version 5b(17 April 2004).

Waite, W. (2004). V&V Education Initiatives. Foundations '04.

Waite, W., Skinner, J. (2003). Body of Knowledge Workshop, 2003 Summer Computer Simulation Conference.

Zeigler, B.P. and T.I. Ören (2003). Scientific Exploration of Simulation Phenomena – Supplementary Material– On a More In-Depth View of the Body of Knowledge. Aegis Docushare.

Zeigler, B.P.(2005). The Need for a Theory of Modeling and Simulation to Support the M&S COI Mission.

7. M&S Body of Knowledge (BoK)

7.3 Previous & On-going Studies/Activities

http://www.msco.mil/documents/_25_M&S%20BOK%20-%2020101022%20Dist%20A.pdf

Department of Defense

Modeling and Simulation Body of Knowledge (BOK)

- Interwoven with Bloom's taxonomy of learning.
- Limited usefulness

Plan

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   - 7.4 Being developed by the author
     - Background
     - Core Areas of the M&S BoK
     - Supporting Domains
     - References

7. M&S Body of Knowledge (BoK)

7.4 Being developed by the author

- **Background**

Publications, Presentations and
other relevant activities of Dr. Tuncer Ören on:

- Modeling and Simulation ***Body of Knowledge*** (M&S BoK) &
- ***Comprehensive and Integrative View*** of M&S (Big Picture)
  http://www.site.uottawa.ca/~oren/pubsList/MSBOK.pdf

(Since 2005, 20 publications & 14 presentations)

Modeling and Simulation Body of Knowledge (M&S BoK) - Index

Draft Version 11b

(In version 11, major changes have been made;
In version 11b, some minor changes are made and some links are updated)
updated and © by: Dr. Tuncer Ören - 2012-04-03 (yyyy-mm-dd)

(The format is especially chosen to reveal the structure and the content of the M&SBOK index)

Please also consider:
Modeling and Simulation Body of Knowledge Index:
An Invitation for the Final Phases of its Preparation,
M&S Magazine of SCS, Vol. 1, Issue 4 (October 2010), by Tuncer Ören and Bill Waite
Publication and Presentations of Dr. Tuncer Ören on M&SBOK

Index

http://www.site.uottawa.ca/~oren/MSBOK/MSBOK-index.pdf

Part 1. Background

(Preliminary, Introduction, Terminology, Comprehensive View)

1.1 Preliminary

M&SBOK Development Project
Version History and Milestone Reports
Members of the Review Committee
Recommendations by Members of the Review Committee

1.2 Introduction

Some Vision Quotations
High level Recognition of M&S
- US Congressional Modeling and Simulation Caucus
- US House Resolution 487 (2007 July 16)
- M&S in China

Stakeholders and Possible Interests for M&SBOK
- M&S Associations and Organizations
- For a comprehensive World Medical Simulation Centre Database click here then select the region on the map
- Individuals, Certified Simulationists
- Workforce Development

- Professional Certification for:
  --CMSP (Certified Modeling and Simulation Professional) designation:
    M&SPCC – M&S Professional Certification Commission

Professional Concerns

(Professionalism, Achievements, Progress, and Challenges)

Why an M&SBOK? Rationale and Possible Usages - Some Views

M&SBOK: Early and Contemporary Studies

Presentation Formats of: Other BOK studies, as well as M&S BOK studies

1.3 Terminology

Background: Definitions of "Definition"

Some M&S Definitions: On Internet:

From Defense-Related Sources and From Civilian Sources, Suggested in this Study

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 Mode and Simulation. SCS M&S Magazine, 2:3 (July), pp. 142-151.

Collections of Special Terms

- An Inventory of over 8400 M&S Terms
- Terms and Concepts Related with Simulation and Similarity
- Terms Related with Experiment, Experience and Training

M&S Dictionaries

- List of M&S Dictionaries
- M&SNet's M&S Dictionary Project
  - -- version 1: English-French-Turkish (over 4000 terms)
  - -- version 2: English-French-Italian-Spanish-Turkish (over 10 000 terms, in preparation)
  - -- version 3: English-Chinese (about 9000 terms, in press)

Ontology-Based Dictionaries

- Ontology-Based Dictionary of V&V (rationale and an example)
- Ontology-Based Dictionary of Understanding
- Ontology-Based Dictionaries of Other M&S Terms

1.4 Comprehensive View

Challenges and Benefits of a Comprehensive and Consolidated View of M&S

Different perspectives, Domain-independent Application Areas

Ören, T.I. (2010). Simulation and Reality: The Big Picture. (Invited paper for the inaugural issue) International Journal of Modeling, Simulation, and Scientific Computing (of the Chinese Association for System Simulation - CASS) by the World Scientific Publishing Co. China. Vol. 1, No. 1, 1-25. (Based on the keynote speech of the 2009 International Simulation Multiconference of SCS and SISO, July 13-16, 2009, Istanbul, Turkey.)

Ören, T.I. (2009). Modeling and Simulation: A Comprehensive and Integrative View. In L. Yilmaz and T.I. Ören (eds.). Agent-Directed Simulation and Systems Engineering. Wiley Series in Systems Engineering and Management, Wiley-Berlin, Germany, pp. 3-36

Simulation and Reality: The Big Picture and Challenges

Keynote of ISMC'09 (International Simulation Multiconference)
Sponsored by SCS and SISO, 2009 July 13-16, Istanbul, Turkey

Ören, T.I. (2007). The Importance of a Comprehensive and Integrative View of Modeling and Simulation. Proceedings of the Summer Simulation Conference. San Diego, CA, July 15-18, '07.

Part 2. M&S BOK Core Areas

Science / Methodology
Types of simulation
Life cycles of M&S
Computers & Computation
Technology
Infrastructure
Reliability
Ethics,
Maturity

History
Trends
Challenges, and Desirable Features
Enterprise

2.1 Science / Methodology

Data

Issues

(types of data and terms related with data) (over 260 terms)

Variables (types of variables and terms related with variables) (over 160 terms)

-- Input Variables (types of inputs and terms related with inputs) (over 110 terms)

Values (types of values and terms related with values) (over 90 terms)

Models & Modeling Formalisms

Models (types of models and terms related with models) (over 1100 terms)

Issues: Reusability, Interoperability, Composability, Dynamic composability

Conceptual models and Conceptual modeling

Taxonomy of simulation models

Modeling formalisms (list of modeling formalisms)

Modeling physical systems

(By Prof. Dr. Fançois Cellier (in English, in German, in Spanish)

Modeling qualitative systems

Model Building

Modeling

Model composition (and dynamic model composition)

Model-base Management

Model search, semantic model search

Model integrity

Model Parameters and Parameter-base Management

Parameters, Auxiliary parameters

Deterministic parameters, Stochastic parameters

Model Characterization (Descriptive model analysis)

for Model comprehensibility

-- Model documentation (static and dynamic documentations)

-- Model ventilation (to examine its assumptions, deficiencies, limitations, etc.)

for Model usability

-- Model referability

Model Evaluation (Evaluative Model Analysis)

Model evaluation with respect to:

A Modeling Formalism (Consistency of model representation)

Evaluation of:

(Static structure of: component models, Coupled models, Models of system of systems)

(Dynamic structure of: state transitions, Output function(s),

Structural change, Dynamic coupling)

Model robustness

Another Model (Model Comparison)

Structural model comparison

-- Model *verification* (Types of and techniques and tools for model verification)

-- Model checking (for homomorphism, isomorphism, endomorphism)

-- Model equivalencing

Behavioral model comparison (under same or different scenarios)

Real System (For Analysis Problems)

Technical System Specifications (For Design and Control Problems)

Model qualification (model realism, model adequacy, model correctness analysis)

Model *validity*

(Types of and techniques and tools for model validity)

Goal of the Study

Model relevance (domain of intended application(s),; range of applicability of a model)

Model Transformation

Types of model transformation (copying, reduction, pruning, simplification, elaboration, isomorphism, homomorphism, endomorphism)

Experimentation (Main issues related with experimentation)
(types of experimentation and terms related with experimentation) (over 100 terms)

- Statistical Design of Experiments
- Computer-Aided Systems for Design of Experiments
- Computer-Aided Systems for Execution of Experiments
- Data compression techniques (deterministic, stochastic)
- Analysis of simulation data

Model Behavior (Main issues related with model behavior)
(types of model behavior and terms related with behavior) (over 120 terms)

- Types of Model Behavior
- Generation of Model Behavior
- Processing of Model Behavior

2.2 Types of Simulations (types of simulation and terms related with simulation) (over 850 terms)

2.3 Life Cycles of M&S

for Experimentation

to Gain Experience for Training to enhance

motor skills (virtual simulation: simulators, virtual simulators)

to Gain Experience for Training to enhance:

decision-making and communication skills

(constructive simulation - serious games: business gaming, war gaming, peace gaming)

to Gain Experience for Training to enhance:

operational skills (live simulation)

for Entertainment (simulation games)

2.4 Technology

M&S languages

M&S tools and environments

Computer-Aided Problem Solving Environments

(for Modeling, Model Processing, Program Generation, Experimentation, and Problem Solving)

2.5 Infrastructure

Standards
Code of Best Practice
Lessons Learned
Resource Repositories

2.6 Reliability & QA of M&S and types of:

Errors (types of errors and terms related with errors) (over 200 terms)
Validation (types of validation and terms related with validation) (over 50 terms)
Verification (types of verification and terms related with verification)
Built-in Quality Assurance
Failure Avoidance

2.7 Ethics

(at SCS) (at Tuncer Ören's site)

2.8 History

2.9 Trends, Challenges, and Desirable Features

2.10 Enterprise

2.11 Maturity

M&S: Ethics

- **http://www.site.uottawa.ca/~oren/pubsList/ethics.pdf**
- **http://www.scs.org/ethics/**

A **Code of Ethics** (**by SCS**) for Professional Simulationists exist . The **Code is adopted by**:

- Society for Modeling and Simulation International
- Mcleod Institute of Simulation Sciences
- McLeod Modeling and Simulation Network
- Simulation Interoperability Standards Organization
- Alabama Modeling and Simulation Council
- Student Chapters of the SCS
- NATO Modeling and Simulation Group
- DLM . . .

M&S: History

Hardware:

- Analog simulation: Differential analyzer
- Hybrid simulation
- Digital simulation

Software: languages, tools, techniques, environments

- M&S languages: Early languages and their critique
- M&S environments: Conventional, AI support

Applications

- Canon ball problem
- Simulators: First pilot trainer of Link (1929)
- Early applications: Space flight simulations

Techniques:

Visualization for simulators, synthetic environments

Part 3. M&S BOK:
Supporting Domains (Independent of the Application Areas)

Computers and Computation, Science Areas, Engineering Areas, Management Areas
Mutual Contributions of M&S

3.1 Computers and Computation

Impact of Computers

- -Digital, hybrid, analog; mobile, cloud
- -Extreme scale computers (petascale simulation, exascale simulation)

Synergies **Soft Computing** and M&S

- -Fuzzy logic and simulation
- -Neural networks and simulation

Synergies of **Artificial Intelligence & M&S**

Agent-Directed Simulation

- -Agent-based models
- -Agent simulation (and agent-initiated simulation)
- -Agent-supported simulation
- -Agent-based simulation

3.2 Supporting Science Areas

Systems Science
Physics
Mathematics (Differential Equations, Numerical Analysis, Probability, Statistics)
Queuing Theory

3.3 Supporting Engineering Areas

Systems Engineering
Visualization

3.4 Supporting Management Areas

Enterprise Management
Project Management
Product Management

3.5 Education

Education

Part 4. References

(See also: M&S BoK Sharepoint of SimSummit)

M&S Portals
Social Network - Ning by Prof. Dr. Gabriel Wainer
M&S Blogs
Google News on Simulation

References by Authors
References by Application Areas
References by Topics including:

Body of Knowledge
- BOK of Other Areas
- M&SBOK - Early Studies & Other Contributions
- M&SBOK - Recent Contributions
- Dr. Tuncer Ören's publications and activities on M&SBOK

M&S
- Master Plans
- Dictionaries
- Epistemology
- Ontologies
- Taxonomies
- Standards

- Composability
- Reusability
- Interoperability
- Conceptual Models

M&S &
- Systems Engineering
- Simulation Professionals & Needed Qualifications

Plan

1. Introduction
2. Importance of M&S
3. M&S & Education
4. Richness of M&S
5. Professionalism in M&S
6. Stakeholders of M&S
7. M&S Body of Knowledge
8. **Conclusion**

8. Conclusion

M&S offers
many opportunities & challenges
to solve problems of
unprecedented complexities.

As simulationists, we can continue to:

1. **sharpen our tools,**
2. **abide by ethics, &**
3. **offer our services.**

We have seen

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Thank you for your attention!
Q & A