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# Growing Importance of Modelling and Simulation: Professional and Ethical Implications

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## ABSTRACT

Examples to the growing importance of modelling and simulation (M&S) are given. The implications are highlighted in three categories: (1) Professional implications, (2) Ethical implications, and (3) Desirable research and development (R&D) areas in science, methodology, and technology of modelling and simulation; trustworthiness, reliability, quality, and efficiency in modelling and simulation; application areas; consolidation and dissemination of modelling and simulation knowledge; and modelling and simulation professionalism.

## 1. GROWING IMPORTANCE OF M&S

Simulation is goal-directed experimentation with dynamic models, i.e., models with time-dependent behavior. It is an enabling and very important technology in many application areas. Examples on the usages of simulation in training (to enhance motor and operational as well as decision making skills) and education are given in Table 1 [1]. Table 2 [1] provides examples in other application areas such as evaluation of alternative courses of actions, acquisition, operational support, engineering design, prototyping, diagnosis, proof of concept, and understanding. To underline the importance of simulation, examples are given for the implications of negative consequences, if simulation is not used properly.

Growing importance of modelling and simulation oblige us to reflect on professional and ethical implications, as well as desirable research and development areas of modelling and simulation.

## 2. PROFESSIONAL IMPLICATIONS

Major components of professionalism in modelling and simulation, are shown in Fig. 1; they can be grouped in three categories: Knowledge, activities, and behavior. *Knowledge* is essential to perform the *activities* which in turn should be based on acceptable *behavior*.

*Knowledge* – There are five groups of knowledge:
- M&S body of knowledge (BoK)
- Science
- Technology
- Knowledge of the application area(s)
- Code of professional ethics

The last one is needed for professional and ethical conduct.

*Activities* – Basically there are two groups of activities:
- Knowledge generation and dissemination (academia, R&D)
- Wealth generation and problem solving (industry)

*Behavior* –
- Professional and ethical conduct
- Certification

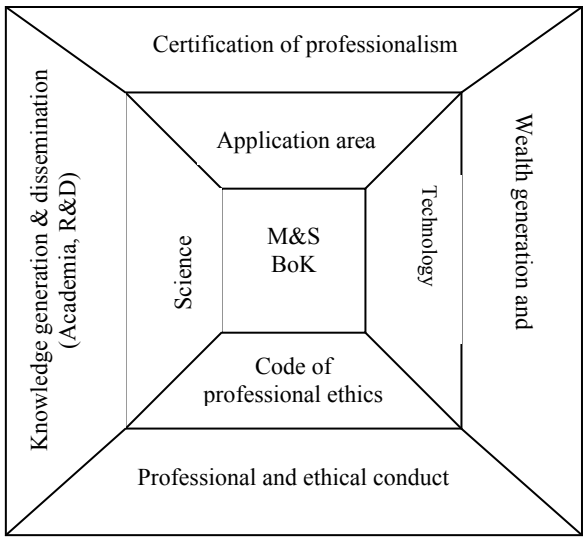


**Fig. 1** Major components of professionalism in M&S

**Table 1** Examples of usages of simulation in training and education

| Usage of simulation | Examples: | Implications of negative consequences, if simulation is not used properly |
|---|---|---|
| Training to enhance *motor and operational skills* (and associated decision making skills) | - virtual simulation (i.e., using virtual equipment and real people (human-in-the-loop) in a simulation study)<br>- aircraft simulator for pilot training<br>- augmented reality simulation (such as in-flight pilot training with additional artificial intelligence aircrafts)<br>- virtual body for medicine<br>- nuclear reactor simulator<br>- power plant simulator | - ill-prepared operators (civilian as well as military) for *regular operating conditions*<br>- ill-prepared operators (civilian as well as military) for *rare emerging conditions* |
| | - simulators for the selection of operators (such as pilots) | - recommending unfit personnel for jobs requiring high dexterity |
| | - live simulation (use of simulated weapons along with real equipment and people) | - false sense of achievement |
| Training to enhance *decision making skills* | - constructive simulation (war gaming simulation)<br>- simulation for operations other than war (non-article 5 operations, in NATO terminology): peace support operations; conflict management (between individuals, groups, nations)<br>- business gaming simulations | - ill-prepared decision makers (civilian as well as military) for *regular operating conditions*<br>- ill-prepared decision makers (civilian as well as military) for *rare emerging conditions* |
| | - agent-based simulations<br>- holonic agent simulations (to explore benefits of cooperation between individuals, companies (mergers), nations) | - "dehumanization" of decisions |
| Education | - simulation for the teaching/learning of dynamic systems (which may have trajectory and/or structural behavior): simulation of adaptive systems, time-varying systems, evolutionary systems, … | - missed opportunity to better learn the subject matter<br>- misinformation |

**Table 2** Examples of usages of simulation in areas other than training and education

| Usage of simulation | Examples: | Implications of negative consequences, if simulation is not used properly |
|---|---|---|
| Evaluating alternative courses of actions | - simulation in business<br>- use of simulation to provide predictive displays (in economy, in other complex systems)<br>- policy modelling and simulation<br>- drug modelling and simulation | - missed opportunity to gain insight in the subject matter<br>- insufficient or incorrect advice<br>- interpretation of results influenced by desired (political) outcome<br>- models used beyond their scope of applicability<br>- not enough evidence to evaluate results |
| Acquisition | - defense acquisition | - acquisition of equipment not fully fit for the purpose |
| Operational support | - operations management | - wrong recommendation or explanation<br>- insufficient representation of reality |
| Engineering design | - virtual ship (per se and as a platform to integrate several components)<br>- earthquake simulation to design better structures: buildings, bridges, … | - equipment malfunctions<br>- unreliable structures<br>- neglect of engineering knowledge and regulations<br>- numerical inaccuracies<br>- incomplete models |
| Prototyping | - chip prototyping<br>- engine prototyping | - recall of thousands of defective units<br>- deficient representation of novel technologies |
| Diagnosis | - on-line use of simulation to compare real-system's behavior and simulated behavior to detect anomalies in the functioning of an equipment | - false alarms<br>- inability to detect "faint" alarms |
| Proof of concept | - simulation of safe disposal of nuclear fuel waste (for tens of thousands of years) | - burden to future generations<br>- unwarranted extrapolation of present knowledge |
| Understanding | - scientific simulations to understand reality | - missed opportunity to have proper understanding<br>- modelling and simulation used as 'proof of concept' rather than as 'investigation of concept' |

## 3. ETHICAL IMPLICATIONS

Several professions have codes of ethics [2, 3]. However, simulation is one of the few professions which does not have a professional code of ethics. Due to growing importance of modelling and simulation, a code of professional ethics is prepared [4]. Since World Federation of Simulation Societies does not exist yet, it is hoped that international, regional, and national simulation societies will adopt the prepared "Professional Code of Ethics for Simulationists" as a token of their assuming responsibilities of simulationists as professionals. Background information for the necessity of ethics in simulation are given in [1] and [5].

Certification studies already started in modelling and simulation [6]. This is an important step in the maturity of the profession. One of the conditions of certification may be allegiance to the code of professional ethics. Hope that this step will also be added to the certification process.

## 4. DESIRABLE R&D AREAS IN M&S

"Simulation has been instrumental in the success of many application areas. As such, simulation is an important enabling technology" [7]. Progress is not possible by maintaining the status quo. There are yet several growth potential for modelling and simulation. Some of them are elaborated on in [8, 9]. Here, a summary of the growth areas presented in [7] are summarized. The views are not limited to trend analysis; they are rather, author's normative views which may include some trends.

As summarized in Table 3, these areas are grouped as follows:

- Science, methodology, and technology of modelling and simulation,
- Trustworthiness, reliability, quality, and efficiency in modelling and simulation,
- Application areas,
- Consolidation and dissemination of modelling and simulation knowledge, and
- Modelling and simulation professionalism.

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**Table 3** Promising Development Areas in Modelling and Simulation

| | Categories | | Challenges (or desirable developments) |
|---|---|---|---|
| 1 | Science, methodology, and technology of modelling and simulation | | Methodologies and technologies for: |
| | | 1.1 | Multimodels |
| | | 1.2 | Multiaspect, multistage, multiperspective, multiresolution, and multiparadigm modelling |
| | | 1.3 | Variable structure models |
| | | 1.4 | Mixed formalism simulation |
| | | 1.5 | Multisimulation |
| | | 1.6 | Concurrent simulation |
| | | 1.7 | Goal processing in modelling and simulation |
| | | 1.8 | Automation of design of experiments |
| | | 1.9 | Agent-directed simulation |
| | | 1.10 | Holonic agent simulation (for cooperative systems) |
| | | 1.11 | Specification languages and environments for interoperability |
| 2 | Trustworthiness, reliability, quality, and efficiency in modelling and simulation | 2.1 | Built-in reliability prior to validation and verification |
| | | 2.2 | Proper documentation of simulation studies (including assumptions) |
| | | 2.3 | Reuse libraries |
| | | 2.4 | Taming and monitoring software agents –to have (self-)inhibited quasi autonomous versus autonomous behavior– in order for agents to behave in a civilized way |
| 3 | Application areas | | Use of simulation to enhance (training): |
| | | 3.1 | Cooperation (business, defense, …) |
| | | 3.2 | Conflict management (avoidance, resolution, …) |
| | | 3.3 | Peace support / peace assurance |
| | | 3.4 | Human behavior |
| | | 3.5 | Societal systems |
| | | 3.6 | Use of simulation to train systems with learning abilities |
| 4 | Consolidation and dissemination of modelling and simulation knowledge (for reference / education) | 4.1 | Systematization of the body of knowledge in M&S |
| | | 4.2 | Curriculum development for graduate M&S studies |
| | | 4.3 | Modelling and simulation dictionary |
| | | 4.4 | Electronic textbook |
| | | 4.5 | Dissemination of modelling and simulation knowledge (an e-clearinghouse) |
| 5 | Professionalism | 5.1 | Code of professional ethics for simulationists |
| | | 5.2 | Certification |