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Mini Review

On the Advantages of Simulation based Approach in Engineering

Tuncer Ören*

School of Electrical Engineering and Computer Science, University of Ottawa, Canada

***Corresponding author:** Tuncer Ören, School of Electrical Engineering and Computer Science, University of Ottawa, Ontario, K1N 6N5 Canada

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Abstract

This brief note highlights the vital role of simulation-based experimentation and simulation-based experience in several aspect of engineering. Only the outlines and several references are given where additional references can also be found.

Keywords: Computational experiments; Computational experience; Advantages of simulation-based engineering; Emulation; Pretention; Counterfeit; Cyber-Physical Systems; Cognitive; Dynamic models; Cybernetics; Artificial intelligence; Simulation-based paradigm; Decision support; System theories; Synergies; Virtual prototyping; Testing; Planning; Acquisition; Proof of concept

Introduction

The term simulation is based on the concept of similarity and has many meanings. As an everyday word, the similarity may represent a positive or negative relationship with reality. In a positive relationship, simulation may mean "imitation" or "pretention." For example, in a training session of a new employee, a senior sales representative may simulate (or pretend to behave like) a tough customer. In a negative relationship, simulation may be used to denote deliberate misrepresentation of reality such as "counterfeit." A related but different concept is emulation where a system can be used in lieu of another system. For example, a dialysis machine may emulate the functioning of a kidney.

Simulation

In science, engineering, and technology, simulation is related with experimentation and experience.Often these two aspects of simulation can be considered separately, and two specific definitions can be as follows: For the experimentation aspect: Simulation is using dynamic models to perform goal-directed experiments. A dynamic model has time-dependent variables and/or structure. For the experience aspect: Simulation is using dynamic models to gain experience: (1) to enhance three types of skills, namely motor, cognitive, or operational skills, or (2) for entertainment. Hence, a concise definition of simulation is: Simulation is using dynamic models to perform goal-directed experiments or to gain experience to enhance three types of skills or for entertainment. Simulation used for entertainment is called simulation gaming. Simulation has been used in a large number of application areas for many reason [1]. Hence, some existing definitions of simulation have focused views. For a review of 100 definitions of simulation and their critical review [2,3]. In this article, the focus is the use of simulation for experimentation and for gaining experience to enhance three types of skills.

Simulation-Based Approach

For a long time, model-based engineering has been accepted as de facto approach for science, engineering, and technology aiming "at increasing the effectiveness of engineering by using models as key artifacts in the development process" [4]. Model-based simulation was first promoted by Ören and Zeigler [5] and later by Ören et al. [6]. However, advances in modeling and simulation and its many synergies with several disciplines [7] such as computation, software engineering, system theories, cybernetics, artificial intelligence, and software agents make it a valuable infrastructure for many disciplines. [8] and for engineering [9]. A recent article clarified the benefits of a shift from model-based to simulation-based paradigm [10]. In this article, the benefits of the shift of paradigm from model-based to simulation-based approach are elaborated on. Experimentation possibility of simulation-based approach allows decision support, understanding, and can enhance education.

So far as decision support is concerned, simulation allows [11]:

1. Prediction and evaluation of behavior and/or performance of the system represented by a model under the experimental conditions.

2. Evaluation of alternative models, parameters,

experimental, and/or operating conditions on model behavior or performance.

3. Sensitivity analysis of behavior and/or performance of the system of interest based on granularities of different models, parameters, and experimental and/or operating conditions.

4. Virtual prototyping.

5. Testing.

6. Planning.

7. Acquisition (simulation-based acquisition).

8. Proof of concept.

Furthermore, experiments can be performed:

i. When the real system does not exist yet (at design level).

ii. When real environments are not accessible or very difficult to access

iii. Under dangerous and/or extreme conditions.

iv. To provide convenience of time for very fast or very slow phenomena.

Another possibility is to have integrated or symbiotic simulation where the operations of the real system and its simulation are connected. Two class of advantages are possible:

i. The system of interest and the simulation program operate simultaneously to enrich system's operation for (1) on-line diagnostics (when there is discrepancy between their behaviors) or (2) for simulation-based augmented or enhanced reality.

ii. To support real systems operations by allowing parallel experiments while system is running. In this case the system of interest and the simulation program can operate alternately to provide simulation-based predictive displays.

In reverse-engineering of a complex system as in most analysis problems of science, simulation can help understanding the system. Simulation-based learning and education is widely used [12].

Simulation-based experience is vital to enhance three types of skills:

a. To enhance motor skills (by simulators or by virtual simulation).

b. To enhance decision making and communication skills (by constructive simulation or gaming simulation).

c. To enhance operational skills (by live simulation).

Conclusion and Future Work

Model-based approach has been very beneficial for several applications in many disciplines. Simulation, being model-based, provides many advantages of experimentation and gaining experience for them as well as engineering. A recent reference [13] has valuable chapters on simulation-based engineering [14] simulation-based systems engineering [15], simulation-based Cyber-Physical Systems [16], Simulation-based Software Engineering [8], and simulation-based military training [17]. The exponential increase of simulation studies in social systems is also very promising in simulation-based social systems engineering [18].

Cyber-physical systems engineering is another important application area [19]. Advances of computation brings new possibilities for simulation-based advanced applications. Some such possibilities include simulation on wearable computers [20] and quantum computer simulation [21-23].

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