Model Curriculum and Case Study Projects of Simulation in Undergraduate Education Initiative in Electrical Engineering

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ABSTRACT
Computational modeling and simulation (M&S) continues to be one of the areas in demand by many in the public and private sectors. While the demand is high, there is no established or agreed upon educational program to enable universities to offer a degree in this area. Recently, much attention has been focused on what constitutes a proper educational program for a career in M&S. This paper presents a first version of a possible M&S educational program as well as several case study examples. Such a program, when approved by the University of Nebraska, will be offered in the Electrical Engineering Department as an area of specialization at the undergraduate level. This program is part of a course, curriculum, and laboratory improvement project called Undergraduate STEM Education Initiative in Creative Educational Innovations for Electrical Engineering Students (USE-ICE).

1. Introduction
The increased demand for computational modeling and simulation professionals necessitates that academic institutions provide solid educational and research opportunities for a career in modeling and simulation. At the 2000 Western Simulation Conference, Dr. Roy Crosbie [1] and Dr. Vakilzadian [2] proposed the development of a model curriculum for a Master of Science degree in M&S to assist schools in planning new programs in this field. This work [1] was based on their experience in developing a new Bachelor of Science program in Computer Engineering in the 1980s, a task that was greatly facilitated by the availability of a model curriculum for Computer Science and Engineering (CSE) published by IEEE-CS and ACM.

The task of defining a curriculum for an MS degree in M&S is difficult. This is partly because M&S is not normally recognized as a discipline in its own right at most universities. This field is usually regarded as a fragmented subject with components in a range of disciplines including, but not limited to, computer science, mathematics, and the student’s field of specialization, which may be engineering or science. Furthermore, the range of M&S applications is so wide that almost any university department could potentially offer a course on M&S applied to its particular discipline.

One way of organizing these individual courses, as proposed in [1], is through the establishment of a Department of Interdisciplinary Studies degree which is the mechanism used at California State University at Chico (CSCU). This offers a flexible MS degree in Interdisciplinary Studies (MSIS) that allows a student, with faculty support, to devise a program of study from the course offerings of multiple departments that can address specific academic goals not addressed by the regular graduate programs of a particular department. The MSIS program at CSUC requires 9 semester units (3 courses) of M&S fundamentals that cover methodology, tools and techniques, and a comprehensive project of at least 3 semester units.

Another approach for developing elements of an interdisciplinary M&S program is to identify the list of skills that industries are looking for in a graduate of an M&S program using a criteria and qualifications list. These criteria can be met by an evaluation program developed by an ABET-like organization [3] as has been reported by Vakilzadian/Moeller [4]. The various components of the required skills can be used to develop a curriculum that encompasses those skills.

No matter which approach is used for curriculum development, the M&S curriculum will include a number of credit hours (courses) of M&S fundamentals, covering methodology, tools, and techniques; fundamentals of electrical engineering, covering passive and active circuits, electronics, and electromagnetics; fundamental courses in computer programming and math; courses in probabilities and statistics; and some M&S design projects as well as a capstone design project that will include substantial M&S. The curriculum should also provide written and oral communication and project management skills. The student will select the remaining courses with no restriction as to department or discipline as long as they conform
to the student’s academic goals and receive faculty committee approval.

2. Basic M&S Curriculum Structure

The M&S program will require at least 12 semester units (equivalent of 4 courses) of M&S fundamentals, covering continuous and discrete systems and their tools, some topics related to simulation of real-time systems, distributed systems, object-oriented simulation, and emergency simulation that can be part of the fundamentals or higher level courses as electives, at least 3 units on an M&S topic in EE, and a project of at least 3 units on an electrical engineering topic in the student’s area of specialization which contains a great deal of M&S. The following is a set of M&S study area subjects (SAS) that will be offered as part of the M&S study program in EE:

1. SAS-1: Fundamentals of computational modeling and simulation of continuous time systems and discrete time systems.
2. SAS-2: Fundamentals of M&S tools, techniques, special application areas related to EE as well as their pitfalls for both continuous and discrete systems.
3. SAS-3: Seminar on electrical engineering applications related to computational modeling and simulation.
4. SAS-4: Small applied electrical engineering projects related to computational modeling and simulation.
5. SAS-5: Capstone design project in electrical engineering that includes a great deal of M&S.

Each SAS includes a number of subareas (SA) that can be regarded as a module or a basis for a course. The study area subject material for SAS-1 to SAS-4 will be available as both face-to-face (F2F) and blended learning (BL). The education modules/packages related to BL can be downloaded from the web.

Blended learning provides students with flexibility and convenience. It includes various modes and models of delivery and styles of learning. This method can also make use of laboratory work as part of an embedded collaborative virtual lab [5, 6] and modeling and simulation [7, 8]. Proposing this approach may raise several questions as to what is actually meant by this approach and what gets blended with what.

A BL approach is Internet-based learning accompanied or enhanced by F2F learning. It takes advantage of the resources provided by online technology which substitute for pure F2F learning. This method:

- Facilitates the collaboration of students and instructors and provides support for communication between tutors and learners and among the learners.
- Provides a content delivery system which blends different technologies.

The following topics provide a brief description of the issues one needs to consider when proposing a course for offering as F2F or BL.

**Topic No. 1:**
On deciding how much of an M&S course should be offered via traditional learning (F2F) and how much via e-Learning, one needs to consider the didactic strategies and the technologies that are used for the e-Learning and F2F learning modules. That is:

- Implementing communication facilities—news groups, chat, video, F2F—not always necessary to combine e-Learning with F2F learning.
- Assessing the demand an instructional method poses on the learners.
- Meeting these demands in specific communication settings might necessitate implementing F2F phases within the BL process, or it might be sufficient to combine various e-Learning facilities.

**Topic No. 2:**
Issues to be considered for arrangement of a course for blended learning consist of more than combining online and F2F options. Approximately 65% of online learning should be self-paced learning, group collaboration, and mentoring and tutoring (teaching on the web). The remaining 35% should be F2F, including laboratories, seminars, and exams.

**Topic No. 3:**
One important consideration for designing a course for a BL offering is the collaboration of students. Various benefits can be ascribed to group collaboration. The students working as a group usually achieve better results than those working individually because group discussion helps reinforce concepts qualitatively and/or quantitatively. In addition, since group members coordinate their activities, they achieve better results and acquire a wider knowledge than those working individually. Multiple perspectives allow:

- Less knowledgeable group members to learn from more knowledgeable ones.
- More emphasis on the individual member activities such as communication about instructional material, e.g. explaining it to others.
- Support of restructuring and elaboration of learning contents.
Furthermore, it permits development of social skills because team success relies on the successful learning and on the commitment of the individual team members. The focus will be on
• Helping each other.
• Explaining concepts to each other.
• Encouraging each other to achieve.
• Working and supporting each other.
• Exchanging of experiences.

As a group, students will be highly motivated because they will be faced with challenging and interesting tasks. The process of group work itself is highly rewarding and will lead to:
• Motivation of individual members.
• Rise in the efforts to achieve tasks.

3. Courseware and Case Studies on Simulation in Electrical Engineering

Computational modeling and simulation is an iterative process consisting of model building and computer-assisted simulation. Through simulation, the model structure and/or its parameters may be changed in an attempt to match the system, component, or process model created. The life cycle of a derived model is over when an optimal match is obtained between the simulation results and the data obtained from the test of a prototyped system or component. This requires that students become well acquainted with M&S of continuous time systems as well as discrete time systems in order to derive the respective valid model.

Thus, in terms of courseware, one has to expose the undergraduate students to the use of M&S as a base for developing an understanding of the response characteristics of the broad class of real-world systems, components, and processes. While the analytical techniques and mathematical models are based on systems theory and provide complete solutions, it is difficult to get a sense of the system behaviour when the models are complex. The simulation methodology is the tool to provide a better understanding of the time-dependent and transient behavior of these models, which is related to the behaviour of the system.

The subject matter of the courseware forms an introduction to the methodology of M&S of real-world systems, components, and/or processes as well as to simulation software packages/systems to gain experience, which results from the different electrical engineering application domains that are introduced later as case study examples.

The nature of the courseware material can be more or less difficult, if the student is new because of the multidisciplinary domain of M&S. The course material—in the form of F2F or BL—may not be understood easily. Therefore, specific case study examples from various application areas of electrical engineering or related topics of system theory will be embedded in the courseware to help ease the understanding and reinforcement of the concepts. This assumes that the students have a background in mathematics that includes calculus, differential equations, Laplace transform, and matrix fundamentals. The background will also permit the introduction and use of the common simulation software packages for evaluation of the performance of the case study examples.

Since the real systems (in the form of a component and/or processes) are often ill defined as the important parameters which should be known for developing a model may not be available and/or measurable. This will call for parameter identification methods to estimate unknown parameters, which are also part of the courseware.

It doesn’t matter what the basis is for an M&S program in electrical engineering as the program can be established by a set of generally agreed upon guidelines, such as those in ABET criteria for accrediting engineering programs [3]. Hence, it will be important to specify course contents in the form of subareas rather than complete courses. This modularization approach will allow mixing and matching of different SAs to produce individual courses that best fit the needs and resources of a particular M&S program in electrical engineering.

Students entering this program will need to have adequate background (prerequisites) in basic topics in mathematics, science, computer programming, and their primary electrical engineering discipline.

3. Case Study Examples

As a result of the previous explanations, two examples will be presented in order to illustrate two objectives. The first objective is the reinforcement and understanding of the fundamentals of electrical engineering based on building a respective model; and the second provides an introduction into the respective tool to simulate the model.

Case Study No. 1:
Modeling and simulation of a metal oxide semiconductor field effect transistor (MOSFET), 1) to determine its performance as a switch and 2) to find the operating point of the transistor.

MOSFET is a four-terminal device where gate (G) acts as the base, source (S) acts as the emitter, drain (D) functions as the collector in a Bipolar Junction Transistor (BJT), and body (B) is the silicon in which MOSFET is fabricated. This terminal must be held at a nonconducting voltage (usually tied to S) for MOSFET to operate.

In an n-channel MOSFET, source and drain are doped with electrons. The substrate is doped with holes. Figure 1 shows the schematic diagram of a MOSFET followed by its symbol representation in Figure 2.
The circuit in Figure 3 is an electronic switch that is realized with an n-channel MOSFET. The output voltage $U_{DS}$ can be written as:

$$ U_{DS} = U_0 - I_{DS} \cdot R_D $$  \hspace{1cm} (1)

In the saturation mode the current $I_{DS}$ can be derived as:

$$ I_{DS} = \frac{K}{2} \cdot (U_{GS} - U_{TH})^2 $$  \hspace{1cm} (2)

where $U_{TH}$ is the threshold voltage (voltage between gate and source) at which drain current begins to flow. Inserting expression (2) in (1) results in

$$ U_{DS} = U_0 - \frac{R_D \cdot K}{2} (U_{GS} - U_{TH})^2 $$  \hspace{1cm} (3)

which can be transformed into the required Gate-Source-Voltage

$$ U_{GS} = \sqrt{-\frac{2(U_{DS} - U_0)}{R_D \cdot K} + U_{TH}} $$  \hspace{1cm} (4)

With $U_{DS} = 3V$, $U_0 = 5V$, $U_{TH} = 1V$, $R_D = 1k\Omega$ and $K = 4 \times 10^{-3} A/V^2$, $U_{GS} = 2V$!

**Simulation of the Model:**

Let’s assume that we would like to get a DC-sweep of the input-voltage using PSpice to determine the operating point. Starting with the values given above, we want to determine and explain:

1. What will happen when the values of $U_0$ and $R_D$ are changed.
2. What will happen when $U_{TH}$ and $K$ are varied.

Figure 4 shows the schematic circuit diagram of MOSFET with its bias components. Figure 5 is the same circuit described in PSpice.

As the simulation results in Figure 5 show the output voltage is at high level and vice versa while the input voltage is at a low level.
Case Study No. 2:
Let’s model and simulate a MOSFET NAND Gate.

A circuit diagram of this gate is given in Fig. 6; and its schematic in PSpice is provided in Fig. 7, followed by its simulation results in Figure 8.

4. Conclusion
A first version of a model curriculum for an undergraduate degree in M&S in electrical engineering is proposed. Parts of the coursework are realized as blended learning modules with embedded case study examples and the remaining parts in F2F. The blended learning of the case study modules contains the theoretical background, the schematic circuit diagram description, and their representation in PSpice. The F2F part will include the discussion of the result with the instructor.

5. References

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