THE ROLE OF VIRTUAL ENGINEERING AND EMERGING VISUALIZATION TOOLS IN NUCLEAR ENGINEERING EDUCATION AND TRAINING AT THE UNIVERSITY OF UTAH

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ABSTRACT

The University of Utah Nuclear Engineering Program is emerging as one of the most modern curricula in the US. The program emphasizes experiential learning based on a virtual engineering practicum, novel visualization tools, and hands-on experience through nuclear engineering laboratory practices. In collaboration with the Scientific Computing and Imaging Institute, we have developed unique educational and training tools based on advanced and novel visualization techniques and methods. For example, the students in the *Neutron-Based Engineering* class (where they learn about neutron transport phenomena and its application in nuclear power and nuclear medicine) can visualize the abstract concepts of neutron flux, current, and interactions, directly on their cell phones. A key aim of three-dimensional educational visualizations applicable to any electronic platform is to engage the students' capacity for complex evaluation, problem-solving and higher-order thinking. We are developing a student-centered virtual nuclear engineering practicum. It is based on interactive tools for improved comprehension of engineering concepts. For example, today the problems of nuclear power plant simulation and radiation treatment planning both require extensive off-line setup, calculation, and iteration. Providing the students with interactive analysis/simulation/problem-solving tools early-on in their education encourages them to establish a dynamic thinking process with analytical exploration of the "what-if" questions essential to any engineering discipline. The University of Utah Nuclear Engineering Program has well-established nuclear engineering laboratories, which provide the students with hands-on experience. All three components of our modern nuclear engineering curricula -- the virtual engineering practicum, multi-platform visualization tools, and laboratory practices -- are interconnected, enabling the students to explore, discover and maintain focus on the engineering concepts at hand.

1. Introduction

The mission of the recently revitalized Utah Nuclear Engineering Program (UNEP) is to advance education and promote R&D in supporting nuclear science and engineering in line with the Department Of Energy – Nuclear Engineering's (DOE-NE's) mission and the nation's nuclear energy challenges. The University of Utah has recognized the recent increase in demand for nuclear energy in the United States and worldwide. With the hope that the natural disaster in Japan and its unfortunate consequences on nuclear power plants that took place in March of 2011 will not affect national and worldwide plans to continue with the nuclear *renaissance,* the University of Utah continues to identify the need for nuclear power. The nuclear renaissance will require an increased knowledge in nuclear science and technology, especially in practically trained personnel. University programs such as the one at the University of Utah with the TRIGA (research reactor) and associated facilities are resourceful in meeting these expectations.

With a mission to provide higher quality hands-on education and training for aspiring nuclear engineers, scientists, and policy-makers, in both graduate and undergraduate studies, the University of Utah established the state's only undergraduate minor in nuclear engineering and modernized its graduate program in 2010. All core courses in the nuclear engineering minor include up to ten laboratory practices where students are trained to use various equipment and associated software tools. In addition, the graduate program at UNEP has recently modernized the methods through which it exposes students to laboratory practices and experimental training as well as training in using nuclear engineering codes. The University of Utah TRIGA Reactor housed in the Utah Nuclear Engineering Facility and operated by UNEP is established as a university-wide facility to promote research, education and training in nuclear engineering, radiation science and health physics. The UNEP graduate curriculum includes two consecutive graduate level classes in preparing students for the reactor operation license. Practical training to operate the research reactor gives the students experiential understanding of the "how" and "why" pertaining to reactor physics. UNEP laboratory infrastructure and the virtual engineering practicum at UNEP support, maintain, and enhance the program's capacity to attract and teach high quality students interested in nuclear energy-related studies.

2. *Higher Order Thinking* – From "Words" to "Images"

The University of Utah nuclear engineering program is building a modernized curriculum with the goal of strengthening disciplinary depth in students' education. The UNEP education infrastructure has recently been revised to incorporate experiential learning tools (exposure to and training in laboratory practices and nuclear engineering codes) as an integral part of on-going courses. All efforts support the goal that all students build a sufficient level of nuclear engineering literacy in order to be able to contribute productively to the nuclear engineering work force or continue their education toward doctoral degrees, [1].

In moving away from a classical lecture setting, in which the teacher is focused on the most efficient time-constrained delivery of abstract knowledge to the students, we combine methods and techniques to increase students' involvement in lectures and avoid the "rote memory" approach. As a result, the students expected to just 'remember' are guided to 'understand' the key concepts and 'think to higher levels' rather than just restating facts. By definition, the "higher order thinking (HOT) requires that we do something with the facts. We must understand them, connect them to each other, categorize them, manipulate them, put them together in new or novel ways, and apply them as we seek new solutions to new problems." The homework sets, class projects and class laboratory practices are therefore designed to provide the students with innovative visual techniques, laboratory experiments and computational applications with the goal of engaging critical thinking processes. A comprehensive set of the web-based interactive tools equipped with many visual interpretations of the learning concepts allow students to practice and think about the facts presented in class. The use of these web-based interactive tools are not limited by time, space and resources, thus the students are given much more flexibility and opportunities to 'apply', 'analyze' and 'evaluate' the concepts learned during the class lecture. The tools also allow the students to 'create' novel scenarios other than those in which the concepts were introduced in the class lectures. In Bloom's Taxonomy, for example, the skills involving analysis, evaluation and creation are considered to be of higher order. These skills are more valuable because they are more critical in problem-solving and innovation. Our virtual engineering practicum (described in the following section) not only meets the requirements of instilling technical proficiency and analytical skills, but also encourages, capacity for higher order thinking.

Examples:

Reactor physics topics are usually found to be difficult for students due to their abstract nature. Visualization of the reactor physics and transport phenomena is one interesting and inspirational way to teach it more effectively. To ensure students' broad understanding and competence, the visual learning modules have been verified to be motivating, convenient and inspiring. As a part of regular instruction, the students also learn how to run different reactor physics and numerical transport codes, and thereby how to connect theoretical course materials with direct applications. Through extensive graphical visualizations students obtain a better understanding of the major reactor concepts. In developing the reactor physics and transport visual and interactive modules we are taking advantage of our TRIGA research reactor to test all of our new modules and tools. Students are familiar with the reactor characteristics and operation presented to them in the lab-courses and by seeing the characteristics of the reactor through numerical models again we reinforce a conceptual learning of the reactor engineering, [1]. As an example, Fig. 1 shows the demonstration of heat transfer in a TRIGA reactor, while Fig. 2 shows the scalar neutron flux distribution in the core of a TRIGA reactor.

In collaboration with the Scientific Computing and Imaging Institute at the University of Utah (developers of the mobile volume rendering system, "ImageVis3D Mobile", which allows visualization on iOS devices), we recently developed novel interactive and attractive tools in teaching and demonstrating aspects of reactor physics, [1]. The "ImageVis3D Mobile" program generates volume renderings of gridded scalar data, such as for example 3D medical CT data; the same approach was used for rendering the complex images obtained as a result of reactor physics and transport simulations (of research or power reactors). One useful feature of that software is the ClearView rendering mode [3], which allows fast and informative data set mining for extremely large data. Figure 3 illustrates a fission rate in TRIGA visualized using ClearView. Such images are used in teaching to point to specifics of the reactor design, reactor physics and other aspects involved in neutron transport.

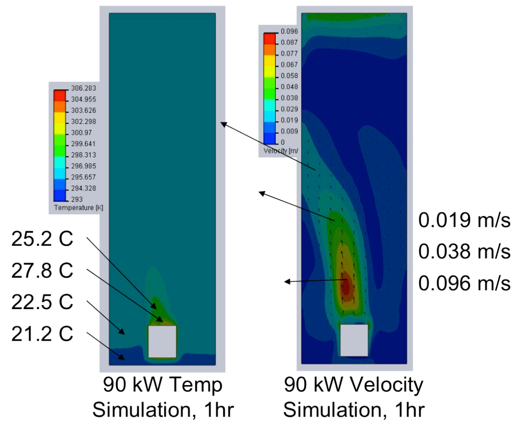

Figure 1 Heat Transfer in TRIGA (SolidWorks code), [2]

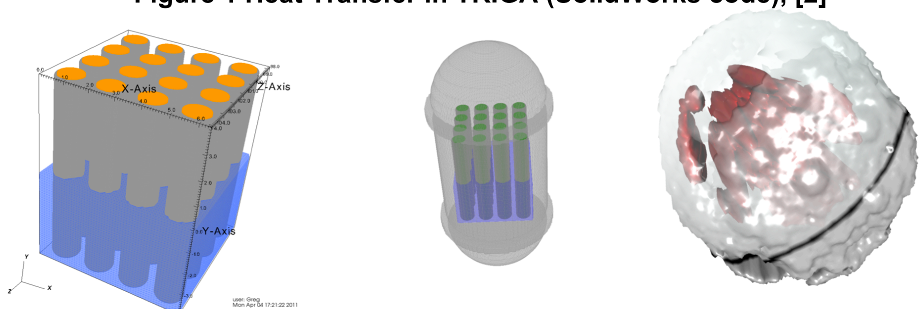

Figure 2 Scalar Neutron Flux in Arbitrary Reactor (AGENT code), [4]

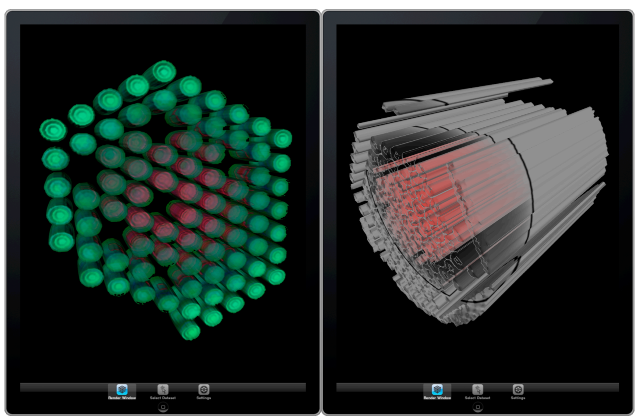

Figure 3 Fission Rates in TRIGA (AGENT code) visualized on an iPad

3. Virtual Nuclear Engineering – *iPhones - Based Nuclear Engineering Practicum*

The virtual engineering practicum under development at UNEP includes a variety of computing platforms. The most interesting sessions are deployed into iPhones, iPods and iPads. Based on “ImageVis3D Mobile”, all visuals produced by running any of engineering codes are uploaded into iPhones for easy access to a rich set of data; it is a motivating tool for the students to practice class materials, and complete homework in novel environments, thus providing extended flexibility in their study schedules. A mobile nuclear engineering practicum allows students to work on a real world problem in order to put the theoretical concepts learned and the analytical skills developed into the context of students' future homework and assignments. Work is currently under way to develop the full working version. Figure 4 illustrates two sessions of the iPhone-based practicum in helping students analyze the facts learned in class through advanced visual images.

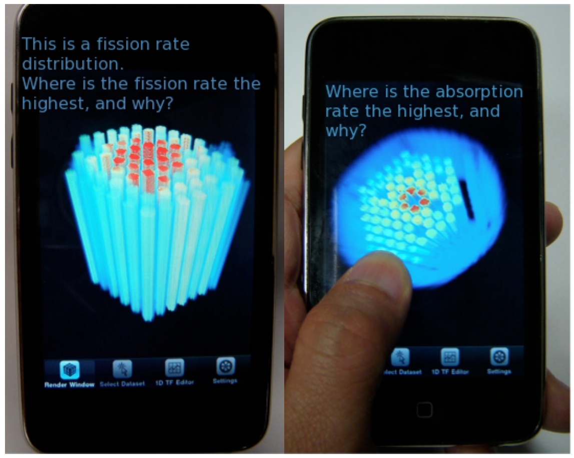

Figure 4 iPhone-Based Practicum Sessions (TRIGA images produced with the AGENT code)

4. Conclusion

The fast development of new and improved computation and visualization technologies have been the driving force behind creating flexible virtual engineering based class lecture practices. This includes the laboratory practices, training, and also the web-based and mobile-based exercises with interactive tools. All these approaches enrich our curriculum in that they provide an effective environment in which students can gain understanding and build the competency in their skills. Work is currently under way to develop the full working version of virtual nuclear engineering practicum delivered on iPhones.

5. References

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