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Title: Development of educational computer tools for enhancing 3D spatial visualization skills in engineering graphics curriculum

Abstract: *Three-dimensional spatial visualization is one of vital skills required by many engineering curricula and future careers for many engineering students. Studies show that the skills can be learned, and the students with higher spatial skills tend to make successful academic achievements. Traditional paper-based engineering graphics textbooks, however, have inherent limitations in illustrating the three-dimensional contents. A web-based educational software tool for engineering graphics utilizing three-dimensional graphics technology and a sketch-based interface is proposed. The proposal is expected to address the STEM area of the student retention and success. A new paradigm of engineering graphics curriculum based on the tools will be developed for seeking external funding opportunities.*

Description of the scope of the project and its outcomes

According to many engineering curricula, engineering freshmen students must take an engineering graphics course in which students learn how to interpret and visualize various three-dimensional (3D) objects. They also learn how to represent 3D objects from two-dimensional (2D) drawings conforming to certain standards for effective global engineering communications.

Visualizing and understanding 3D shapes from 2D drawings (and vice versa) is a vital skill in many engineering careers. Numerous studies prove that well-developed spatial skills have been shown to lead to success in many fields of engineering, including computer science, chemistry, mechanical and construction engineering, and computer aided design. A long-term study shows that engineering students with higher spatial skills give better average GPA's. A similar study also shows statistically significant improvements in retention rates after educating the spatial visualization skills, especially more significantly to women engineering students. The engineering graphics course is also significant because it is usually the first engineering course for most students. Any experiences in the course affect the students' decisions in continuing their engineering studies. Unfortunately, however, many students seem to have negative experiences. In the mechanical engineering department in CSUS, for example, we have seen too many students failing or dropping the course (ENGR 6), and eventually quitting their engineering careers.

Studies also show that the spatial skills can be learned and improved through proper education. But many universities do not pay enough attention to the course, and many courses rely on two-dimensional figures and drawings in traditional textbooks in teaching the 3D spatial visualization skills. Without many hours of face-to-face instructions using various examples and explanations, some students find it very hard to understand the concepts from static 2D figures. With large class sizes as in most freshmen courses, instructors rarely find time to pay individual attentions.

I propose developing a set of educational software tools based on 3D computer-graphics to address the above issues. Many students are familiar with 3D computer graphics by playing computer and video games. Students will learn spatial reasoning and engineering graphics contents by interactively rotating, viewing the 3D virtual objects. Many existing software tools have been built using multimedia authoring tools such as Macromedia Flash, which are not usually based on true 3D technology. They can only present the contents that are pre-programmed by the instructors. Instead, the proposed method will implement true 3D models that are dynamically generated via student's interactive learning activities. Unlike existing multimedia methods that

require solutions and contents to be provided by the instructors, students can create their own problems and the solutions will be automatically generated. Students will learn the spatial skills through dynamic graphics and textual feedback; hence instructors' time can be saved. I have been developing such a software tool for the past few years. An immediate objective of this proposal is to extend the software to cover most of the activities included in the standard spatial visualization test suites. A long-term goal is to develop a new paradigm of engineering graphics curriculum based on the tools. Current engineering graphics textbooks have become quickly obsolete, as the 3D computer graphics technology is rapidly developed. Significant portions of thick engineering graphics textbooks are no longer taught and they need to be replaced by new concepts and methods.

Benefits to STEM Activities

The impacts on CSUS STEM activities will focus on student retention and success. The immediate goal is to increase the retention rate of engineering graphics course in the mechanical engineering curriculum. If the studies quoted in the previous section are correct, I expect the success in the course will give positive impacts on students' future academic performances and careers. The web-based tools will be open to other departments and other universities in the future. I expect that many universities will welcome to accommodate the tools in their engineering graphics curricula, and CSUS will be recognized.

Potential Funding Sources

I have identified following funding sources relevant to the proposal.

- **Higher education HP technology for Teaching Grant Initiative - Digital Learning Environment** – This is an annual grant by HP company. The proposed work includes research in alternative user interface such as sketch-based computer interface. HP can provide required hardware solutions including tablet PC and others.
- **NSF grants**
  - Grants from the division of Undergraduate Education such as Course, Curriculum and Laboratory Improvements (CCLI)
  - Innovations in Engineering Education, Curriculum, and Infrastructure (IEECI)

Current/Anticipated Support

With my background as a professional programmer of commercial CAD systems, I have been developing a software tool for a specific problem of interpreting orthographic engineering drawings. Using the software, students draw an isometric view of objects represented in orthographic multiviews, and the 3D object is automatically generated so that the students can confirm their work by interactively viewing and visually matching the 3D object with the corresponding 2D drawings. I have presented some preliminary results of the work at a conference organized by a special group on engineering graphics in ASEE, and the responses were overwhelmingly positive.

I have been recently awarded the Pedagogy Enhancement Award for 2009-2010. Using the award, the current windows-based software will be converted to a web-based tool for wider accessibility to the tool. If an additional 3-unit release time is granted, I plan to extend the software tool in breadth and depth such that the tool can cover the whole areas of the standard spatial visualization skill test suite that is currently administered on paper with 2D drawings.