Assessing Design Intent in an Introductory-Level Engineering Graphics Course

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Abstract

*This paper describes an assessment strategy used in an introductory engineering graphics course to help introduce the concepts of 3D solid modeling and design intent. The assessment strategy incorporates immediate feedback for students on 3D solid modeling assignments using self-checks (formative assessment) as well as limited "automatic" post-*submission grading *(summative assessment).*

Introduction

The increased emphasis on dynamic rather than static CAD models has changed the rules of assessment in engineering graphics education. It is no longer acceptable to merely look at student CAD models or printouts and compare them to the instructor's static answer key. The assessment criteria today not only include dimensional accuracy, but also modeling strategies and the overall robustness of the CAD model. Many instructors are now required to manually interrogate each CAD model submitted by students to probe the design intent that was built in to the model (Ault & Fraser, 2013; Branoff, Wiebe, & Hartman, 2003; Branoff, 2004). Assessment of student work in this new paradigm is proving to be a very laborious and time consuming activity for instructors, making it very difficult to provide timely feedback to students. Instructors are therefore searching for tools to help assess student CAD models with efficiency and consistency. This paper will describe a "low-tech" assessment strategy used in an introductory engineering graphics course to help introduce the concepts of 3D solid modeling and design intent. The strategy incorporates immediate feedback for students on 3D solid modeling assignments using self-checks (formative assessment) as well as limited "automatic" post-submission grading (summative assessment).

Literature

It is important that assessment of student competencies be measured in a venue that will provide students with the opportunity to demonstrate the knowledge and skills that they possess.

Self-assessment from in-class exercises provides formative assessment that is essential to the learning process. Formative assessment that includes feedback to the student is necessary for students and without it the learning opportunity is minimized (Brown et al., 1997). In-class assessment during the practice phase (i.e. lab activities) provides formative feedback that reinforces student learning. Formative assessment encourages students to seek answers to difficult problems they face, and practice in an environment where they obtain constructive feedback to enhance the learning process. In-class studies have shown that students' self-assessment has raised student achievement significantly (Black & William, 1998; Chappuis & Stiggins, 2002; Rolheiser & Ross, 2001; White & Frederiksen, 1998).

With the prevalence of parametric solid modelers today, the assessment criteria for student CAD work not only include dimensional accuracy, but also modeling strategies and the overall robustness of the CAD model. In response, several innovative assessment approaches have been presented in the literature. Branoff, Wiebe & Hartman (2003) described the use of a simulated Engineering Change Notice (ECN) to assess the robustness and design intent of student CAD models. Branoff (2004) described the use of grading rubrics that explicitly make students aware of the design intent that should be built in to the model. The instructor then assesses the student model by manually modifying the CAD model as outlined in the grading rubric. Baxter (2002) and Baxter & Guerci (2003) developed innovative software that automatically assessed student models. And Ault & Fraser (2013) described the early stages of their work to develop an automatic grading system for Pro-Engineer models.

The message in the literature is clear; assessment of parametric solid models should include some manner of exercising/modifying the CAD file in order to assess if the model was created using appropriate methods. Towards that end, the authors are using an assessment strategy that requires students to assess the design intent, robustness, and overall accuracy of their own models for both formative and summative assessment purposes. In this instance of assessment students apply knowledge, skills, and abilities to prepare a model from set criteria, and manipulate the model per instructions to achieve new results. The result of the model dimensional changes demonstrate the level of competency the student has achieved through verification of the constraints and procedures used to create the model. Students are provided feedback through practice exercises to reinforce modeling concepts, and confirmation of accurate completion of the assigned task.

Overview of Assessment Strategy

The TEC116 Introduction to Technical Drawing and Constraint-Based Solid Modeling course is an introductory-level engineering graphics course that is designed to introduce students to a variety of engineering graphics topics including 3D solid modeling. Because students having prior experience with solid modeling are not required to take this course, it is assumed that students in the course have very limited prior experience in the field. The solid modeling software used in the course is Autodesk Inventor and the class meets two days per week for 1 hour and 50 minutes in combined lecture/lab class periods.

During each class period a new solid modeling topic is discussed and demonstrated. After the brief demonstration, students are given a lab assignment that is to be completed during class. The lab assignments typically include assignment instructions and dimensioned part drawings for two to three parts to be modeled. Students are provided two self-check opportunities for each assigned model where they are required to measure one 3D distance, one face area, and the total face area of each part. The self-check includes the correct values for the measurement checks, so students have immediate feedback regarding the geometric accuracy of their model. This first set of measured values correspond to the initial part dimensions and as such help the students verify that they have read the dimensions for the part correctly and have accurately created a solid model of the original part design.

The second self-check requires students to change several dimensions on the part. The dimensions are purposefully selected by the instructor to require students to modify several features in the history tree as opposed to a single sketch. Students are again given the correct dimensions for the three geometry checks so they can get immediate feedback regarding their choice of modeling strategies to achieve the required design intent.

Once students have made any required corrections to their models and the self-check exercises are successful, the work is electronically submitted for evaluation using a learning management system (LMS). To submit their work students must change the self-check dimensions to yet another specified value and make the same dimensional measurements they did in the two self-check exercises. This time the correct measurements are not provided for the students who must manually enter the measured values into an assessment screen in the LMS to be automatically graded for accuracy. Students are also required to upload their CAD models into the LMS as well.

In addition to the lab exercises, students are required to complete a daily homework assignment that is identical in format and relative complexity to the lab exercise they completed in class. The use of self-check exercises and submission procedures for the homework exercises are exactly the same as for the lab, thus providing additional opportunities for student practice. Periodic in-class performance exams use the same format and procedures that are used in the lab and homework assignments.

Conclusion

Before the authors implemented the assessment strategy described above, all student models were graded manually using printouts containing one set of distance checks and a screen-captured image of the part. The model dimensions were not modified by the students and student design intent skills were understandably poor in more advanced courses. This initial assessment process was woefully inadequate and was changed to the strategy described in this paper.

Although the strategy presented in this paper is decidedly “low tech”, it does incorporate many of the CAD assessment attributes recommended in the literature. These attributes include:

- a grading rubric so students understand exactly what they are expected to do and how they will be graded;
- immediate feedback for students in the form of formative assessment;
- verification of design intent using model manipulation;
- reduced assessment time for instructors; and
- improved assessment consistency.

This assessment strategy also has several notable shortcomings. For example, the self-check feedback provided to the students is very limited. Students receive a go/no-go check on the correctness of their measurements but are not told why their measurements are wrong. Furthermore, the dimensions of the model may be correct even though the overall quality of their model may be less than ideal. These limitations are mitigated by the fact that this is a face-to-face course with instructors present at all times. Students are given individual, detailed feedback by the instructor when they have difficulty determining why their dimensions to not match the answer key. Furthermore, students submit their models electronically, thus allowing instructors to browse student work looking for problems.

While the assessment strategy presented in this paper is not the assessment “magic bullet” that we are all looking for, it has proven to be a low-cost tool to assess introductory level design intent and instructors have observed improved student modeling performance in advanced modeling courses. Perhaps this strategy will be helpful for other instructors until a more elegant assessment solution had been developed.

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