AUTOMATED GRADING OF FIRST YEAR STUDENT CAD WORK

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Abstract

Introductory CAD courses typically have a large enrollment. This results in considerable grading for the faculty and thus slow feedback for the student. As a solution to this problem, a program has been created to automatically grade students' work that is submitted in a text file format. The program receives students' files by email, and returns grading feedback to the students through email as well. The effectiveness of the program is demonstrated using a survey of the students as well as improvement of the students test scores compared to the previous year when the program was not used. An additional benefit of using the program is the instructor's time grading is dramatically reduced.

Introduction

Introductory level Computer Aided Design (CAD) courses typically have large enrollment. This presents a problem for both the instructor and the student. The sheer volume of material to be graded occupies the professor's time and leads to long return times for graded homework. By the time the students receive feedback about their mistakes, they no longer care. This leads to a desire for automated grading of CAD work.

One approach to automated grading is seen in an online CAD course [1]. In this approach, students are given a drawing assignment. After students have completed the drawing, they are given a set of multiple choice questions based on the completed drawing properties. Grading is done based on geometric properties such as distances and geometric center of the object. This provides a method to determine if the drawing was completed accurately. This approach has a limitation of not clearly showing the students their mistakes.

A similar approach is taken by Hamade *et. al.* in their work in assessing CAD competence using learning curves. [2] In addition to technical accuracy based on geometric parameters, students are also evaluated on the time it takes them to construct a 3D solid model.

An improved approach is seen in work at San Diego State University [3,4] where in two masters' theses, they created an electronic grading program for CAD files based on the AutoCAD DXF (Drawing Interchange Format) file format [5]. The DXF format is an ASCII method of saving the drawing information. The first thesis consisted of programing the front end user interface for faculty and students and also worked with network interfacing. The second thesis consisted of the parsing of the DXF files. The parsing program was able to recognize lines, arcs, ellipses, and circles and provided only textual feedback for the student's errors. The work was expanded in two later masters' theses to allow students to submit their work via a web based application. [6,7]

The research done at San Diego State provides the framework for electronically grading CAD files but is proprietary. It also is limited in elements it can interpret and provides no graphical feedback for the students. There is clearly a need for a program providing improved feedback for the student.

The rest of the paper is organized as follows: The first section presents a description of the development and operation of the program. The next section presents the survey given to the students in which they are asked to evaluate the effectiveness of the program in helping them learn AutoCAD. In addition, the results of the survey are presented in that section. In the following section, the effectiveness of the program is evaluated by comparing the students'

grades on the first AutoCAD test between the semester using program and the semester before using the program. Possible future improvements to the program are presented in the next to last section. The final section contains a summary and conclusions for the work.

Program Development and Operation

Because of the grading possibilities of the series of programs at San Diego state, a program has been written to extract geometric objects (lines, circles, arcs, etc.) from two drawing files which graphically and textually highlights the differences between the files. Based on the differences between the files, the program determines a grade for the student's work. Grading is done based on the number of each type of object as well as numerical accuracy of these objects' geometries. In addition, the layer of an object can be compared as part of the grading rubric.

The program is used in a freshman level CAD class at a California Baptist University, a midsized private university. Much of the time in the classroom devoted to AutoCAD instruction is allotted for students to work through tutorials in their textbook. During the class, the professor is then free to help students when they need help. In addition, students are also encouraged to work together, helping each other out when they have problems. However, each student is required to submit his or her own drawing for grading. After students receive their score, they are allowed to correct there drawing and resubmit their work.

Program Version 1

The program is written in the graphical programing language LabVIEW. In the first generation of the program, students would download an installer to install the program on their own Microsoft Windows computer. Student solution files were provided to the student using a binary format so that students could not copy the solution directly. Students could then instantly see the score that they would receive on their assignment as well as graphical and textual feedback for their mistakes. This allowed them to correct their work prior to submitting the drawing to the online course management system.

The instructor would then download the students' drawings to his own computer. A script file was constructed to convert the students AutoCAD DWG files to the ASCII DXF file format. The instructor could then grade all of the DXF files for one answer key in a batch format. The program would store the results in a file that could be uploaded into the course management system.

After the first semester of using the program, students were asked if they used the program. If they indicated that they used the program their opinions were solicited. If they did not use the program, they were asked why they did not. From the 6 responses received, none of the students had used the program. Half said it was too complicated and the other half said that it did not run on a Macintosh computer.

Program Version 2

Based on the struggles of the students, the grading program was improved over the summer. In the second version, students submit their drawings by emailing them to a dedicated Gmail account with their DXF file attached. Students indicate which answer key they want the grading program to use in the subject line of the email. This makes the program platform independent for the students, therefore solving the problem of not being able to use it on a Macintosh computer.

The grading program is configured to check the email every two minutes, and grades all of the new drawings that have arrived in that time frame. If the program does not recognize the subject line as a problem for which it has a key, it sends an email to the student with the list of known solution files and the general grading program instructions. If the subject line is

recognized, students then receive email feedback on their work consisting of a list of discrepancies between their drawing and the answer key (Figure 1), and two jpg files containing pictures contrasting the two solutions (Figure 2).

Figure 2A shows the students drawing, with the errors highlighted using different colors and line weights. Figure 2B shows the corresponding drawing of the key. Each drawing shows the front view of an object on the left side and the side view of the same object on the right side. On the side view it shows the middle line was incorrectly drawn as a hidden line when it should be a visible line. The figure also highlights some grading confusion in the program. Because the exact starting point of the drawing is not specified, the program uses the Δx and Δy of the lines in comparing the student's submission and the answer key. Because of this, it incorrectly matches the top line in the front view of the solution with the bottom line of the side view of the student's

work, since these two lines have the same length and orientation in the solution.

The second version of the program also allows the professor to allow for alternate versions of the correct solution. This could include indicating that one long line could be drawn as two shorter lines. This allows greater flexibility in the students' solutions which addresses a complaint from the first students testing the program.

As seen in Figure 1, the program has the capability of checking for lines, circles, arcs, ellipses, polygons, text, dimensions, hatches, and multi-leaders. The program also checks which layer each object is on and whether the item is on the Model or Layout. Grading is scored based on one point for having a perfect match, and a half of a point for each matching number of item type (e.e., the solution has 3 non-matching lines and the student work also has 3 non-matching lines). A half of a point is deducted for each extra item in the student's work that is not found in the solution.

```
Score: 90.6

Item                # in Key              # of Matches
Line                   16.0                   13.0
Circle                  0.0                    0.0
Arc                     0.0                    0.0
Arc Radii               0.0                    0.0
Ellipse                 0.0                    0.0
Polygon                 0.0                    0.0
Text                    0.0                    0.0
Dimension               0.0                    0.0
Hatch                   0.0                    0.0
MLeader                 0.0                    0.0


Extra Items:
Solution Line Extras
Page    Layer    X Start Y Start X End    Y End    Delta X  Delta Y
Model   VISIBLE  5.9642  2.5990  7.9642  2.5990   2.0000   0.0000
Model   VISIBLE  6.9642  3.5990  7.9642  3.5990   1.0000   0.0000
Model   VISIBLE  6.9642  4.5990  7.9642  4.5990   1.0000   0.0000
Student Line Extras
Page    Layer    X Start Y Start X End    Y End    Delta X  Delta Y
Model   HIDDEN   6.9642  3.5990  7.9642  3.5990   1.0000   0.0000
Model   VISIBLE  1.9687  4.5990  4.2147  4.5990   2.2460   0.0000
Model   VISIBLE  4.2147  3.5990  4.9687  3.5990   0.7540   0.0000
```

Figure 1: Example email response sent to the student from the grading program.
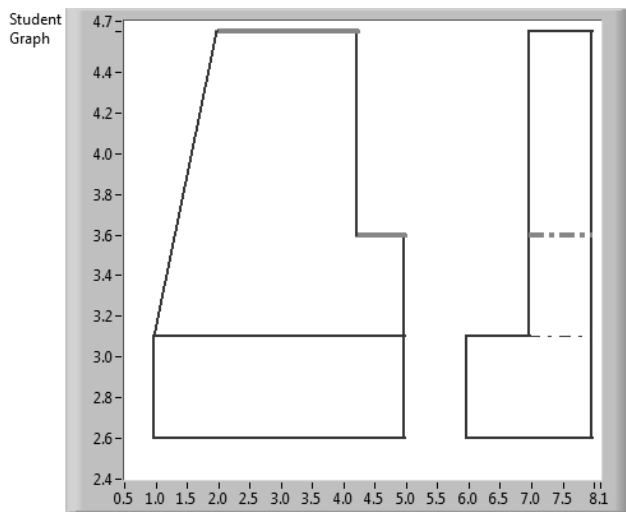
A
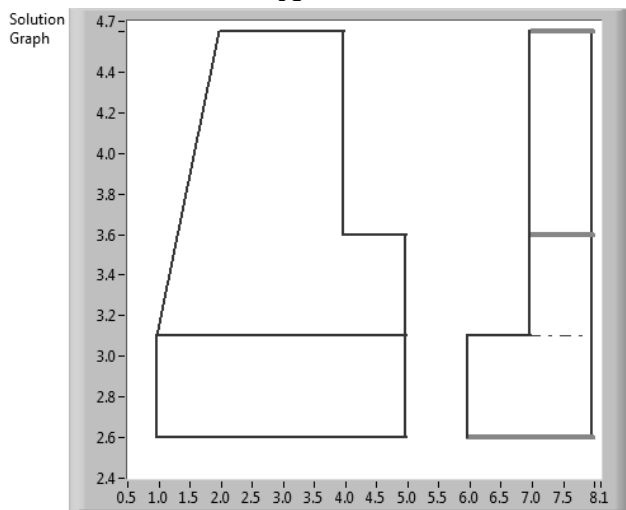
B

Figure 2: JPG files sent to the student from the grading program.

For each submission, the program updates a CSV (comma separated variable) file which records the score, the time of submission, and the creation time of the file in a grid format based on the email address of the submission to identify the student. The student ID associated with each email had been entered into the file previously. The student's score is only saved if it is better than the one previously submitted. The program also checks the creation time of each file submitted and compares it to the other files from other students that have been submitted for the same assignment. If a match is found, the instructor is alerted by email that plagiarism may have taken place.

A separate program has been written which takes a grade book download from Blackboard, matches the student ID with the student ID in the email grades file, and adds the grade from the grades file if it is better than the one in the Blackboard grade file. This file can then be uploaded into Blackboard to let the student and instructor know the students' grades on the assignment.

There were several challenges faced with the implementation of the program. One challenge was that initially the campus email system flagged the program response as spam, causing the grading response to be delayed to a twice daily spam report. Having the program's email flagged as spam is not surprising since it is an off campus email address sending email to multiple recipients in rapid succession. It took a couple tries before the dedicated homework email address was permanently added as an approved sender.

Another challenge was that checking email too rapidly caused the Gmail server not to allow the program to log in. Through trial and error it was discovered that two minutes would allow the program to not cause Gmail to no longer allow remote email checking.

Yet another challenge encountered was that different email programs use different coding methods for attachments. The program had to be modified to account for different methods. It was never determined why a Hotmail attachment causes the program to crash.

A final challenge faced was that during the semester Gmail changed the way it allows emails to be deleted remotely. Code that worked at the beginning of the semester to delete files after they were graded stopped working in the middle of the semester.

Student Survey and Results

A voluntary survey was administered to the students at the end of the second semester, in which the program was required to be used.

Students were asked to rank on a Likert scale (Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, or Strongly Disagree) the following statements:

1. I found the program helpful.

2. I found the email report easy to understand.

3. I found the program easy to use.

4. The program helped me improve my drawing skills.

5. The grading reply from the program came in a timely manner.

6. I would prefer that it had a web interface where you upload your file for grading.

7. I would like to be able to download the grading program and run it on my own computer to get instant feedback.

In addition, students were given an area to respond to "How would you recommend improving the program?"

Between the two sections, 34 students (54%) filled out the survey. The results of questions 1, 3 and 4, concerning the utility of the program, are displayed in Figure 3. For question 1, 88% of the students either agreed or strongly agreed that the program was helpful, with an average 4.26 on a 5 point scale. For question 3, 88% of the students either agreed or strongly agreed that the program was easy to use with an average of 4.26 as well. For question 4, 79% of the students either agreed or strongly agreed that the program helped them improve their drawing skills with an average of 4.09.

Figure 4 displays the mechanics of the program interaction, as seen in the results of questions 2 and 5. For question 2, 62% of the students either agreed or strongly agreed that the email report was easy to understand, with an average 3.41 on a 5 point scale. For question 5, 79% of the students either agreed or strongly agreed that the email report came back in a

timely manner, with an average 3.97 on a 5 point scale. In reviewing the comments, most of the comments were regarding confusion in the grading report, as well as timeliness of the feedback.
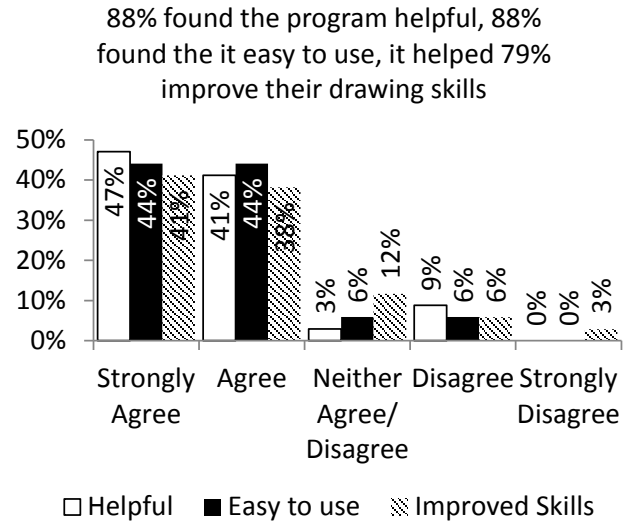

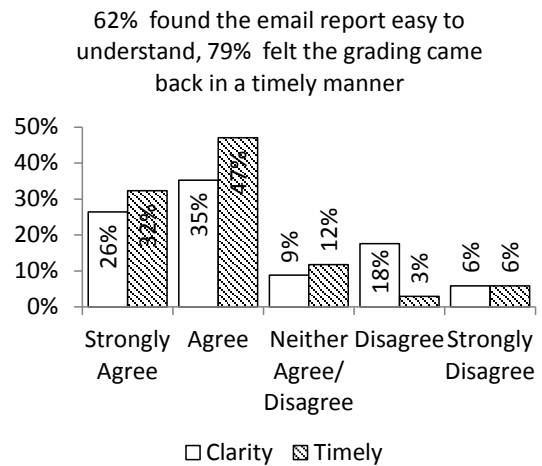Figure 3: Program utility survey results from questions 1,3 and 4.

Figure 4: Email report survey results from questions 2 and 5.

Figure 5 shows the results of questions 6 and 7 which concerns possible improvements in the program for future semesters. For question 6, 41% of the students either agreed or strongly agreed that they would prefer a web interface with an average of 3.50 on a 5 point scale. For question 7, 62% of the students either agreed or strongly agreed that they would like to be able

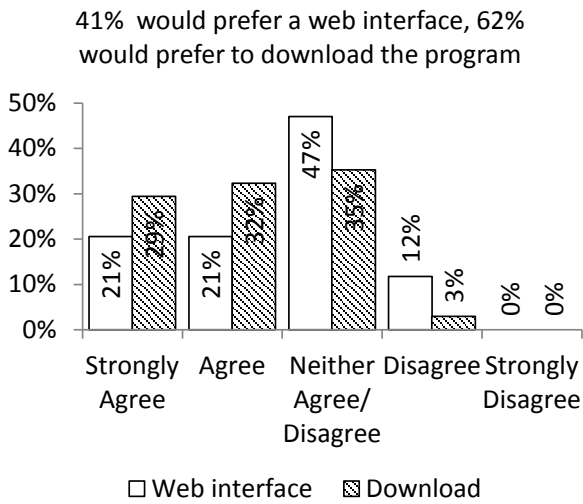to download the program, with an average 3.88 on a 5 point scale.

Figure 5: Program possible improvement survey results from questions 6 and 7.

Student Grades Improvement

In addition to surveying the students, the grades on the first AutoCAD test, covering orthographic projections were analyzed for Fall 2011, the year before the program was used, and Fall 2012 where students were required to use the program to submit their homework for grading. Figure 6 shows that the students' scores improved from using the program. Fall, 2011 was based on a class size of 30 students while Fall 2012 is the compiled average from three sections of 29, 34, and 12 students respectively. The median grade improved a step from a B+ to an A- while the mean grade did not increase significantly, since the people not doing the homework are still scoring very low.

To better understand the usefulness of the program, the students' test scores were plotted verses their corresponding homework scores. Figure 7 shows the results for the homework before the first test which covered drawing orthographic projections. Figure 8 only uses the homework scores directly related to orthographic projection, and did not include the AutoCAD introduction homework. Both plots are divided into four regions. Region B is the area where students demonstrated sufficient mastery of the material (>=80%) both on the homework and on the test. It is this region that one would hope all students are in. Region C is also to be expected, where students are not doing their homework and also not doing well on the test.
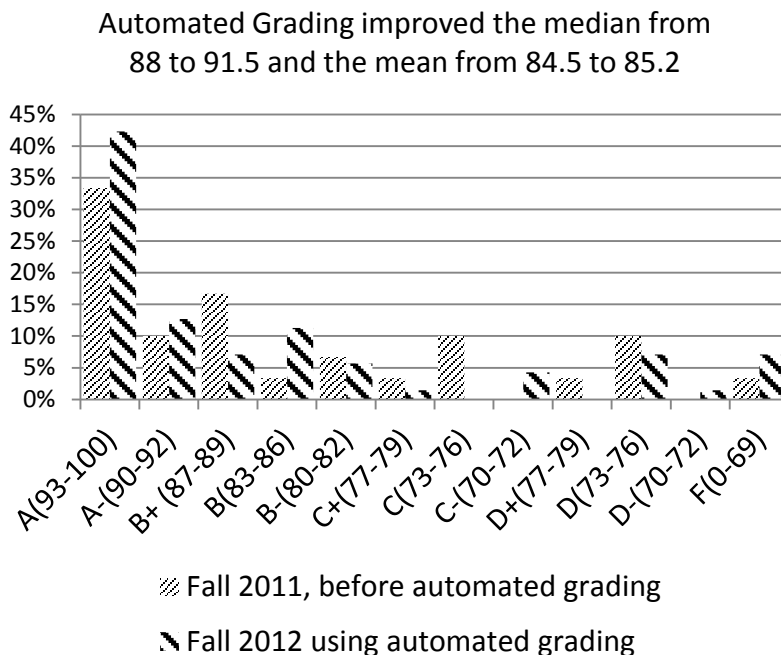

Figure 6: AutoCAD students' test results before and after students used the program.

Without program 23% of the students earned
a B- or greater on the HW and not on the test,
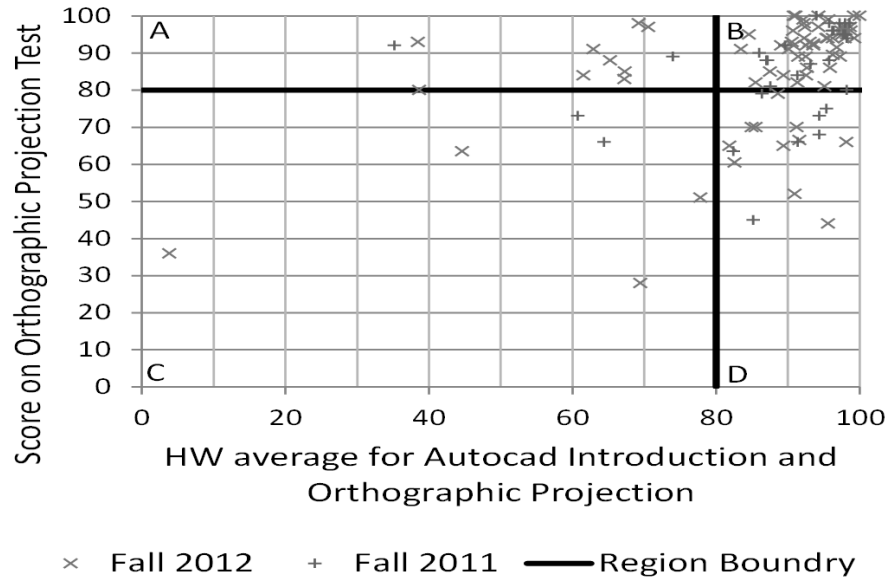while using the program it was 15%

Figure 7: Students' results on the first test contrasted with their prior AutoCAD homework.

Without program 17% of the students earned
a B- or greater on the HW and not on the test,
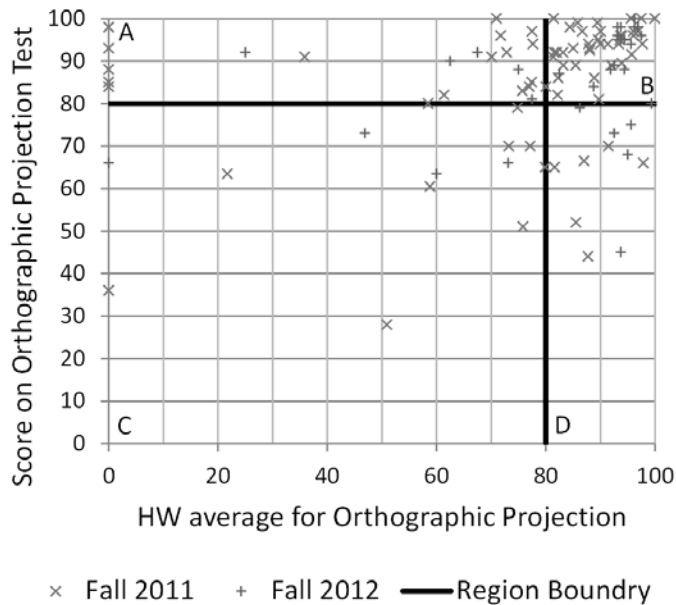while using the program it was 8%

Figure 8: Students results on the first orthographic projection test
contrasted with their orthographic projection homework.

Region A consists of students who demonstrated sufficient mastery on the test, but not on the homework. The concern for this group of students is why they are not doing their homework, and if it is related to the program and not their motivation. For all the homework this was 7% of the students in 2011 and 13% of the students for 2012. For just the orthographic

projection, this was 17% of the students in 2011 and 25% in 2012. Six students did not submit any homework, but were able to do well on the test, probably from previous knowledge of AutoCAD.

Region D is the last area of interest, which is students who did well on the homework, but not on the test. This could relate to a lack of retention of the skills, slow test taking ability, or only being able to solve the homework with additional assistance. For the complete homework set, this group was 23% of the students without the program, but only 15% of the students using the program. For the orthographic projection chapter, where the homework most closely resembled the test, it was 17% of the students not using the program, but only 8% of the students using the program. This seems to indicate that students had a better retention of the material after using the program.

It was expected that with the opportunity to resubmit their homework, students' scores on their homework would improve. However, the scores went down slightly. For the fall semester, the average homework score for the first two chapters of AutoCAD was 88.3% and the median score was 93.6%. Using the grading program, the average score was 86.2% and the median score was 91.6%. This can be explained by the fact that a human grader is more lenient than the grading program, since the grading program takes into account that the scores can be corrected on a later submission.

Future Improvements

Based on student feedback and our experience, the program can be improved in a few ways. From the students' perspective, clarity can be added to the user feedback. The simplest improvement would be to use larger images of the grading feedback, as drawings become more detailed. Another improvement, graphically, would be to include one image for the Model and one for the Layout, to more clearly indicate where the errors lie.

Creating a program for the students to download would provide students the ability to work at home even if they did not have reliable internet access. The user interface would have to be improved, but LabVIEW provides an easy way to provide an installer to install the program on a PC without LabVIEW.

From an administrative perspective the program can be improved as well. The most useful addition would be a way to have the students' link their student ID number associated with their email, as this currently needs to be done manually by the professor. This is necessary, as all students were not using their university email address due to the slow response of campus email.

Conclusion

An automated grading program has been implemented in a first year AutoCAD course at California Baptist University. The program allows students to submit their files by email, and provides rapid textual and graphical feedback to indicate their drawing errors. From a survey of the students it was found that it was useful and helpful. In addition, the median grade on the first AutoCAD test improved from a B+ to an A-, and retention of the students drawing skills increased as indicated by the reduction in the number of people who did well on the homework and not on the test. Besides the benefits to the students, the instructor's grading time has been greatly reduced. Future improvements to the program could increase clarity of the feedback to the students and simplify administration of the grading.

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