A Review of File Comparison Utilities for Assessing Student Work

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Abstract

In academia, CAD file utilities and comparison tools have been used in attempts to speed grading and feedback delivery, decrease workload and human error, and increase grade reliability. Most current CAD packages contain some built-in capability to examine and compare solid models. For those who want something beyond the capability of the stock software utilities, custom software can be created. This paper reviews the capabilities of currently available tools for the assessment and grading of student work.

Previous Attempts at Automated Grading of CAD Files

In perhaps the first attempt at the automated grading of CAD files, Baxter and Guerci (2003) described a computer program to automate the grading of SolidWorks files, notify students via e- mail, and update grade databases. The program compared key data from the student file to that of the instructor file. However, grading algorithm details and results were not presented nor published. Hekman and Gordon (2013) described automated grading efforts of 2-D AutoCAD files.

Students submitted files by email and within minutes, without human intervention, a computer program compared the AutoCAD text descriptions of a student sketch to those of the corresponding instructor-created sketch and delivered feedback consisting of text and an image that pointed out deficiencies in the student work.

In a proof-of-concept pilot study to automate the grading of Creo files, Ault and Fraser (2013) created a computer program to evaluate one specific part. The program compared information from the student file to that from the instructor file, such as volume, the presence or absence of critical dimensions, and the existence of specific features. The computer code was created and owned by PTC and was not available to the university collaborator, so the code could not be easily reused for other applications. Because the program was looking for the existence of specific features, it allowed limited freedom in the creative and strategic planning aspect of part creation.

Currently, there is only one publicly available program to assist with the grading of CAD files, and it works only with SolidWorks files (Graderworks from Garland Industries LLC). An attempt at the automated grading of NX CAD files has been demonstrated at conference presentations (Kirstukas, 2016 and 2018). Finally, in this same conference, co-author Morris (2019) details a method of detecting the integrity (absence of plagiarism) in NX CAD files. That work is part of a bigger project involving a customizable .NET application that also automatically grades Siemens NX files. In the following text, the computer programs that are either already available or currently under development will be compared using a test part that was similarly constructed in both Dassault SolidWorks and in Siemens NX.

Test Part

The test part has been used to demonstrate the capabilities of Graderworks and the drawing is available at their webpage. The part can be created by several perfectly acceptable methods and various points could be used as the origin. The Graderworks-provided solution file for this part (Solution_To_A10.SLDPRT) was constructed using four sketches, three extrudes, a datum plane, and a rib. For comparison, two additional good and bad models of the part were created in both SolidWorks 2018-2019 and in Siemens NX 12. These parts were created using different modelling strategies than that of the Graderworks-supplied part, and involved symmetric extrudes and the hole feature. This modeling approach was used virtually unchanged in both NX and in SolidWorks.

The good and bad parts have the same volume and surface area, but the bad part has incorrect orientation. The bad part contains one unconstrained internal sketch that results in the hole being in the wrong position. The bad part is not changeable per the design intent in the original drawing as it is missing some dimensions, and contains unwanted and repeated dimensions. The bad part also has a sketch that does not contribute anything to the part. A number of built-in tools and add-in programs were used to try to assess these parts.

Siemens NX Built-in Tools

Check-Mate is a built-in tool in NX that can perform a series of tests on a part to verify that the model conforms to various standards. For this investigation, a total of 24 pre-defined tests were selected, including the tests “Sketch Fully Constrained?” and “Sketch with Auto Dimensions.” When the Check-Mate analysis was performed on the good part, all tests passed, as expected. However, when the same set of tests was performed on the bad part, all tests also passed. Check- Mate failed to notice a sketch internal to the hole feature that had two auto dimensions.

Model Compare is a built-in tool in NX that can compare the geometries of two different bodies. Three graphics windows are displayed, showing the two individual parts and a view that is useful in highlighting differences in the parts. By default, parts are displayed relative to the absolute coordinate system (Fig. 1a). After realignment of the good and bad parts, the resulting overlap view (bottom of Fig. 1b) showed that the two parts were identical except for hole position. This tool is useful to visually confirm orientation, and shape similarity. However, Model Compare cannot be automated so it can be a time-consuming manual process to align and visually compare parts.

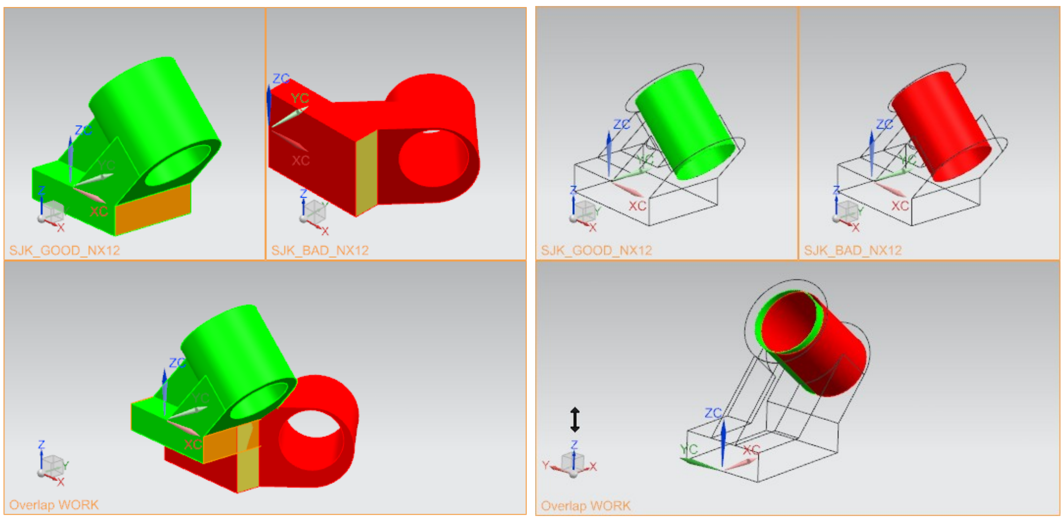

Figure 1: the good and bad parts before and after alignment. When aligned, it is clear that the geometry is the same, except for hole placement.

It is possible that Check-Mate used together with Model Compare could identify non-fully- constrained external sketches and verify part orientation, shape, and size. But these tools do not seem capable of evaluating some of the issues that new solid modelers have trouble mastering, such as constraining internal sketches, building models that honor design intent, or eliminating unused sketches. Perhaps most important, it does not appear that these tests can be automated to allow many student files to be examined and graded quickly.

Dassault SolidWorks Built-in Tools

SolidWorks Design Checker verifies design elements such as dimensioning standards and sketches to ensure that SolidWorks files meet pre-defined design criteria, similar to Siemens NX Check-Mate. However, SolidWorks Design Checker is available only in the Professional and Premium editions, not in the Education Edition that most educators use.

The SolidWorks Compare Geometry tool is similar to NX's Model Compare. However, it requires that both parts have the same origin and orientation. When the parts are misaligned as often happens with student files, there is an option to align geometry with respect to individual coordinate systems within each part. However, student-created files will not in general contain a properly situated internal coordinate system to allow alignment.

Even if these two tools were available in the Education Edition and worked as desired, their use would require a rather lengthy manual process that would not greatly aid the instructor in time- efficient assessment of student files.

Custom Tools

Because the built-in tools are unable to aid in the timely assessment of student files, various add-on programs have been developed by interested third parties. These work only with specific CAD packages and require the ability to write a computer program that can interface with a vendor- provided application programmer interface (API) to allow the program to conduct comparisons between the student file and an instructor file, which is assumed to be perfect.

Dassault SolidWorks Custom Tools

Graderworks has been available for several years and is freely available for a 30-day evaluation period. Graderworks version 3.17 for SolidWorks 2018-2019 compares the geometry of a student part to that of an instructor part and assigns a score based on adjustable weight factors. Various parameters are examined, such as volume, material, shape, and the presence of non-fully- constrained sketches.

A test of Graderworks was made by comparing the good and bad test part files to the Graderworks-provided solution file "Solution_To_A10.SLDPRT". In Run 1, although the good part had the same shape, size, volume, surface area, and orientation as the provided solution part, it scored slightly less than perfect, presumably due to different part origin. The bad part scored just a couple of points lower (Table 1). Although the bad part had the correct volume and surface area, it had different orientation, it was not changeable due to missing, unwanted, and repeated dimensions, it had an unused sketch, and it had the hole in the wrong place due to an under-defined internal sketch. On a second grading run (Run 2), the incompletely defined quantity "Shape Check and Shape Composite Score" scored differently for both good and bad parts, with the bad part actually out- scoring the good part by a small margin for unknown reasons.

Table 1: "Shape Check and Shape Composite Score" scores differently on subsequent grading runs, and causes the final grade to be different

	Run 1		Run 2	
FileName (*.SLDPRT)	Shape Score	File Grade	Shape Score	File Grade
a10_sjkbad_part	94.10	95.57	97.11	97.84
a10_sjkgood_part	96.15	97.11	96.33	97.24

The Graderworks software can evaluate many files quite quickly. However, subsequent runs can produce different shape scores and different grades, which should not happen in an automated grading scheme. Additionally, internal sketches are not evaluated, there is no attempt at accessing model changeability, and there is no orientation detection.

Siemens NX Custom Tools

Kirstukas (2016 and 2018) has described work toward the automated grading and plagiarism detection of student files created with Siemens NX. The program is designed to catch common mistakes of beginning modelers and encourages the creation of simple, changeable part models. The program attempts to write feedback in human language, similar to what an instructor may provide after a manual analysis. When the NX version of the bad part was compared to the good part, the bad part was noted for incorrect geometry, incorrect orientation, missing, unwanted, and repeated dimensions, the unconstrained internal sketch, and the unneeded sketch. Program output is a text file designed to be cut and pasted into Moodle, a learning management system (Table 2).

Table 2. Output from the grading program of Kirstukas

deduction values from gui: 4 / 6 / 3 / 3 / 4 / 2 / 4 / 4 / 6 / 30 / 1 / 0 / 100.
gold master filename = sjk_good_nx12.prt

<p>filename = sjk_bad_nx12.prt
Your model has incorrect shape and/or size, and has incorrect orientation.
Your model is missing 2 dimensions from the original drawing: 4.5, 48.
Your model has 2 repeated dimensions: 1, 3.
Your model has 2 dimensions not from the original drawing: 1.22014465515, 2.35510792391.
Use fewer numbers and more geometric constraints!!!
Sketch(6) which is internal to Simple Hole(6) is not 'Fully Constrained' as it contains 2 auto dimensions.
Replace auto dimensions with geometric constraints!!!
Sketch(7) is not used and should be deleted.
Score = 52</p>

Total Time Elapsed: 0 minutes, and 4 seconds.

In this same conference, co-author Morris (2019) details a method of detecting the integrity (absence of plagiarism) in NX CAD files. That work is part of a bigger project involving an application that also automatically grades Siemens NX files. The automated grading aspect is currently functional and is to be published later in 2019. The program uses a similarity algorithm that currently examines five factors: Volume, Surface Area, Number of Edges, Number of Faces, and Moment of Inertia values. Parts are scored on a scale of 0–5. Morris's program does not identify specific missing or incorrect dimensions, nor does it provide guidance for healthier modeling or sketching practices.

After analysis of the good and bad NX versions of the part, program output is viewable in Excel (Table 3). The model similarity (SIM %) scores shape independent of orientation, placement, or build method, and currently do not factor into the grading. The bad part scored 2.75/5 (55%) due to different moment of inertia values, number of sketches not fully constrained (SNC), number of unused sketches (SNUS), and number of auto dimensions (AUTO). These quantities are shaded in pink and red. The good part was selected as the solution file and checked against itself, scoring a perfect 5/5 (100%).

Table 3. Morris's program output for bad and good parts vs. solution (good part).

SOLUTION >		sjk_good_nx12	IN.	1	30.6451	100.9643	37	16	2.8605	0	1.7289	21.6183	30.9789	22.2778
TOTAL	SIM %	FILENAME	UNITS	NBOD	VOL	SA	EDGE	FACE	COG-X	COG-Y	COG-Z	MOI-X	MOI-Y	MOI-Z
2.75	98.181	sjk_bad_nx12	IN.	1	30.6451	100.9643	37	16	2.8594	1.7275	-0.1072	21.225	21.8962	30.9155
5	100	sjk_good_nx12	IN.	1	30.6451	100.9643	37	16	2.8605	0	1.7289	21.6183	30.9789	22.2778

SOLUTION >		sjk_good_nx12	2	0	0	0		0	5	0
TOTAL	SIM %	FILENAME	STOT	SNC	SEMP	SNUS	SINV	AUTD	ACTD	FIX
2.75	98.181	sjk_bad_nx12	4	1	0	1		2	7	0
5	100	sjk_good_nx12	2	0	0	0		0	5	0

Discussion and Conclusion

Due to the inability of the built-in tools to aid in the time-efficient assessment of student CAD files, various add-on programs are necessary. These programs work only with specific CAD packages. In this paper, one such program has been reviewed that works with Dassault SolidWorks, and two with Siemens NX. Some comparison of features is shown in Table 4.

	FEATURES	NX Kirstukas	NX Morris	SW Graderworks
Sketch	Incorrect Dimension Values	Flagged	N/A	N/A
	Fully Constrained	Flagged	Flagged	External only
	Unused	Flagged	Flagged	N/A
Solids	Origin Location	Flexible	Flexible	Rigid
	Orientation	Compared	Compared	N/A
	Volume and Surface Area	Compared	Compared	Compared

Table 4. Grading summary of the bad test part using different add-on programs.

Graderworks is the only automated grading program available for general use and works only with SolidWorks files. Some of the other automated grading solutions have been demonstrated at conferences but have not been evaluated by others. For grading purposes, Graderworks uses material density, volume, surface area, center of mass, and constraint status of external sketches to develop a grade score. However, these quantities tell us little about the modelling strategies used and the changeability of the model.

The custom program written by the first author to analyze NX files performed best here. It caught all issues of the bad file. There is certainly some bias here. The bad file was specifically created by the first author to mimic a file that a struggling beginning student may create and contained issues that his program was designed to catch. However, this program is still under development and testing and has not been released for general use.

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