Development of an Application for the Automatic Evaluation of the Quality of 3D CAD Models

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Abstract. In the 3D modeling of products, the use of an adequate methodology that ensures the capture of the design intention is very important. The sequence of operations is key, like for instance, the sketches have to be completely restricted and the references of the modelling functions have to be correctly chosen without generating unwanted dependency relationships, among others. In the best of cases, the team leader dictates best practice manuals and then supervises the design work, ensuring that quality, which will facilitate future modifications or new designs based on existing models. However, this is not an established process, causing multiple failures in cascade when modifying or reusing the models is approached. This work has consisted of the development of an application that allows the automation of the quality analysis process in the models and has been developed for the Autodesk Inventor application using its iLogic tool. This work is the result of a Master's Thesis, where for the evaluation of the developed application, the examination models of the students of the subject of Graphic Engineering of the 4th year of the Degree in Engineering in Industrial Technologies of the Universitat Politècnica de València have been used.

Keywords: Design · Quality evaluation · 3D CAD models

1 Introduction

More and more companies are using 3D modeling tools. However, how do companies know that their designers make proper use of these tools? It would be necessary to ensure that the methodology followed is adequate through some type of control [1, 2]. Are those controls carried out efficiently? Let us see two examples of this in the industry to help focus the problem that has been tried to solve in this Master's Thesis (Project from now on). The first example company manufactures radiators for the automotive industry where some of their parts are very problematic, because further modifications are tough to work (see Fig. 1a). In order to solve or minimize this process, the company collaborated with the local University through a national research project (Ref.: 1FD97-0784) to identify the key aspects of the design process and developed Best Practices manuals for their designers to follow when modeling these products.

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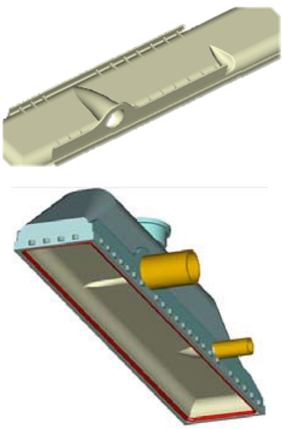
The second company manufactures molds for the automotive industry, where the first author of this work did her traineeship. In order to verify that its designers meet the design requirements set by the company, the person in charge reviews each model manually using a 75-point checklist (see Fig. 1b). This process is very laborious and represents one of the bottlenecks of the technical office department of the company. In the checklist, things such as collisions, diameters, and some general characteristics of the model are checked over. Despite this supervising control, failures in the molds are still found, which implies remaking the molds from the scratch, representing many hours of work.



(a)

1	USE COLLISION FILTER. NON UNJUSTIFIED COLLISIONS SHOULD APPEAR.
2	USE DRILL ALIGNMENT FILTER. NON UNJUSTIFIED DRILL SHOULD APPEAR.
3	CHECK THAT NO PART OF THE MODEL TREE IS ON ALERT.
4	CHECK THE BELT ELEVATION [H=46mm – STRIP-EXTRACT] (H=331 mm BELD-BENCH)
5	CHECK THE FASTENER OF THE BELT ELEVATION.
6	CHECK FOR FALLING OFF REMNANTS (INTERFERENCE), SCRAPPING.
7	GLUED STOPS [SPLIT BETWEEN TOP AND BOTTOM].
8	DESING THE PART EJECTOR.
9	CHECK THE ADVANCE. MUST BE EQUAL TO OR LESS THAN QUOTED. (89 mm)
10	CHECK THE BOBBIN WIDTH. MUST BE EQUAL TO OR LESS THAN QUOTED. (171 mm)
11	ADVANCE SENSORS. THE FINAL SENSOR IS PRIORITISED AGAINST THE NON-RETURN SENSOR, IF POSSIBLE.
12	CHECK THAT THE OUTPUT OF PARTS IS SUITABLE FOR THE PRESS. MANUAL
13	CHECK BELT DRIVE.
14	CHECK THE SAFETY ROUTE OF NITROGEN GASES (10%). RV 170-15 (C-10)
15	CHECK LIQUID EVACUATION AREAS IN NITROGEN GAS ACCOMMODATION.
16	CHECK CHAMFERS OF PRESSPLATE, KEYHOLE TOOL, CUTTER-SHAPER, FOR SHEET METAL DEFORMATION IN CAP MOLDS.
17	CHECK THAT ALL INTERNAL ELEMENTS HAVE AIR OUTLETS.
18	CHECK DIRECTION OF CUTTING BURRS.
19	CHECK TOTAL HEIGHT OF CLOSED MOLDS AND VERIFY WITH MACHINE MOTION. 344mm CLOSED DIE – MOTION ~130
20	CHECK FLANGED GROOVES ARE IN ACCORDANCE WITH THE STANDARD AND PRESS. IT IS FLANGED WITH FLANGES.
21	CHECK THAT COMPONENT CHANGES ARE APPROPIATE, SAFE AND QUICK.
22	CHECK THAT THE COMPONENT CHANGES HAVE 2 M6 THREADS FOR EASY REMOVAL.
23	CHECK CRITICAL TOLERANCES TO ACHIEVE PLANE' TOLERANCES.
24	CHECK PENETRATION OF THE PUNCHES INTO THE CUTTING PLATE. 6mm
25	CHECK THE PROTRUSION OF THE DIE-HOLDERS WITH RESPECT TO THE PUNCHES. 2mm
26	CHECK THE PATH OF THE DIE-HOLDERS IN RELATION TO THE PUNCHES (TRAIL TRM). 10 mm
27	CHECK THE SHAPER GAP BETWEEN THE MALE CUTTER-SHAPER AND THE CUTTER PLATE (CAPS MOLD)
28	CHECK THE HEIGHT DIFFERENCE BETWEEN THE DIE-HOLDER AND THE CUTTER-SHAPER PLATE (CAPS)
29	CHECK THE NUMBER AND DIAMETER OF THE KEYHOLE TOOL IN RELATION TO THE WORKPIECE PLANE.
30	CHECK THAT THE INNER EXTRACTOR IS ABOVE THE OUTER EXTRACTOR AND THE MALE CUTTER-SHAPER.
31	CHECK PART EXTRACTION. Manual

… (up to 75 key-points)

(b)

Fig. 1. a) Radiator components subject to good practice manuals; b) Key-points checklist during the mold design process.

Thus, despite best practices' manuals have been developed and applied or some type of control is done during the process of design, normally the evaluation of the CAD model is still subjective and done manually, which hinders the reuse of the models or makes their modification a laborious task [3, 4]. The work presented here is the Project carried out in the Master's Thesis of the first author of this paper and has consisted on the development of an application that allows automatically assessing the quality of the geometric 3D CAD models [5]. More specifically, the main objective was to develop an application aimed to assess the exams of the students of the 4th course subject Graphic Engineering of the Degree in Engineering in Industrial Technologies of the UPV (Universitat Politècnica de València). Attempting in turn to reduce the correction time and to suppress the variability among the professors since, due to the high number of students in the subject, this task is commonly carried out by several professors.

2 Materials and Methods

In this section, the materials and methods used for the development of this Project are briefly described.

2.1 CAD Tools

The Autodesk Inventor application has been chosen since it is the modeling application used in the laboratory classes in the subject Graphical Engineering of the 4th course of the Engineering in Industrial Technologies degree, and also in the 2nd course of the Industrial Engineering Master degree, in the subject of Industrial Applications of Solid Modeling. The Autodesk Inventor iLogic programming tool is the platform where the application has been developed (Fig. 2), which uses the VisualBasic.NET as programming language, allowing the development of specific applications using rules and forms to be executed inside Inventor.

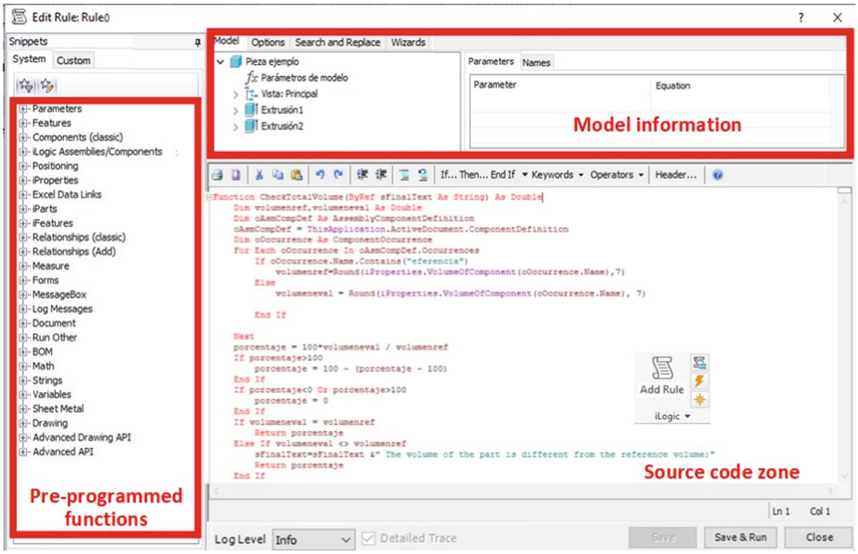
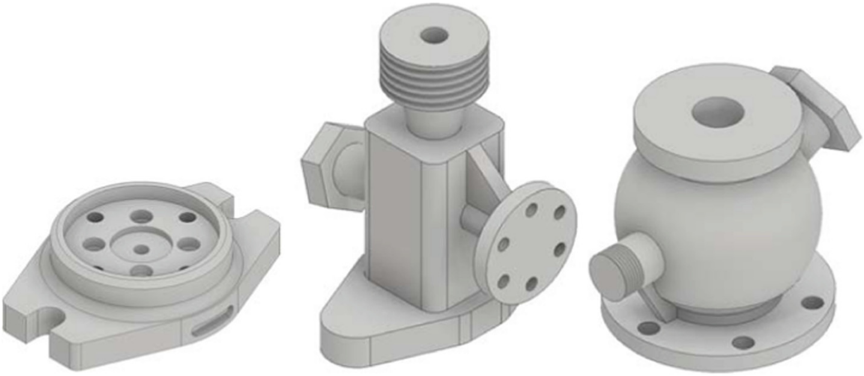


Fig. 2. Autodesk inventor iLogic tool.

The Forms allow interacting with the user to enter parameters or a specific configuration, whereas Rules are functions that are created with a programming language to perform specific tasks. The iLogic tool already provides basic pre-programmed functions contained in libraries, that can directly access to the internal database of the model [6].

2.2 Models

The 3D CAD models used for this work are those used in the subjects previously mentioned. Figure 3 shows some examples of the parts modeled as part of the laboratory exams of the students.



(a) (b) (c)

Fig. 3. Examples of 3D CAD models used in the exams.

The functions/features that can be found in the model tree of the 3D models used in this project are extrusions, revolutions, ribs, holes, patterns, symmetries, threads, fillets, chamfers and work features.

2.3 Quality Specifications Under Evaluation

Although the quality of the 3D CAD models depends on many aspects and it is also very dependent on the model itself, these aspects have been organized into the following three differentiated blocks: (1) general considerations, (2) functions/features used, and (3) sketches; which usually are always taken into account in more or less depth, when quality is evaluated. More specifically, the aspects checked inside each of the three main blocks are:

- Block-1. General considerations: orientation and model sequence, what means that main features have to be at the beginning of the model tree and the secondary features have to be located at the end of the model tree.
- Block-2. Functions/features: the use of specific suitable features instead of "any" similar feature.
- Block-3. Sketches: should be fully constrained with no crosses between geometric entities or superimposed entities.

For this first approach developed in this Project, the application operates comparing two models, the reference model consisting on the model that the professor creates as the solution of the exam, and the student model. Regarding the general considerations, the orientation and location of the two models (reference and student model) have to match, including the total volume. Additionally, the main features are checked to be in the upper half of the model tree and secondary features (like fillets, chamfers, threads, and ribs) are checked to be in the bottom half of the model tree. Regarding the use of suitable features to create specific geometry, the students were asked to rename some functions with a certain name, so the application can identify them in the student model and check the type of feature used and its parameters. With regards to the sketches, the items checked out are the number of dimensional restrictions, the number of some geometric constraints (like tangencies), and also if the contained profile is unique (no crosses or superimposed geometric entities) and if it is fully constrained.

3 Results and Discussion

In order to study the performance of the application developed, named EVALUATE, it was tested on several student models. More specifically, the exam chosen for the tests was the one of the first partial exam (December 2020) of the 4th course of the subject Graphic Engineering of the Degree in Industrial Technologies (Figs. 4 and 5).

Fig. 4. 3D model resulting of the exam statement in Fig. 5.

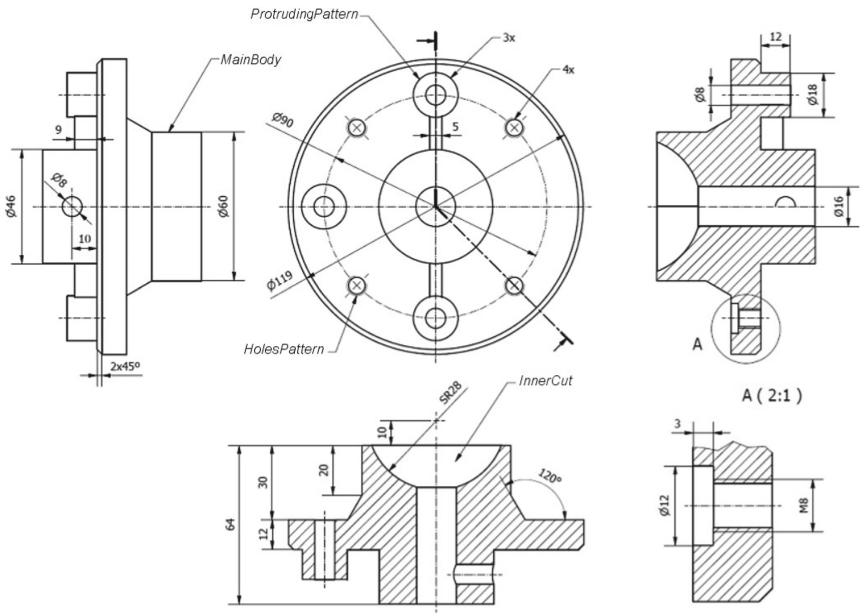


Fig. 5. Statement of the exam used for the tests (first partial exam December 2020).

In general, it is a good practice and highly recommended to label the features with logical names to find them easily by designers when modeling or modifying. In the statement of the exam, students were asked to label some features with a certain name in order to find them and later inspect them properly.

3.1 Application Developed

Figure 6 shows the general flowchart of the application developed. EVALUATE loads the reference model from the professor and interacts with the user to weight the items considered in each of the three blocks to assess the student models. Later on, EVALUATE dumps a global numeric mark and some comments in an Excel file. On the other side, two professors marked each of the student models attending to a standard criteria set for the exams of the subject, which served as reference.

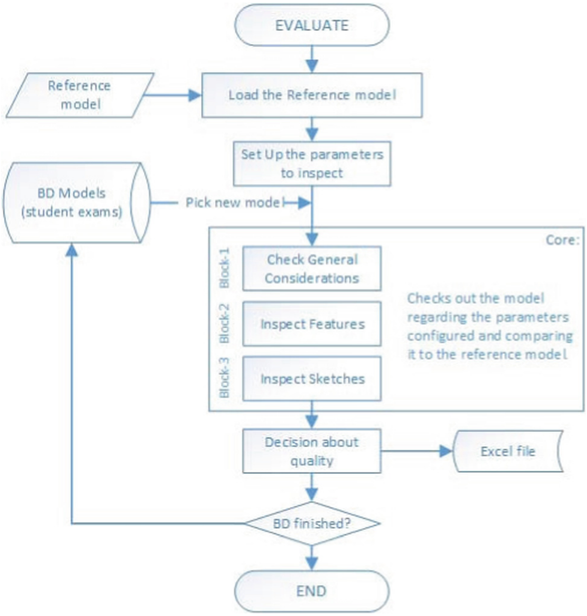


Fig. 6. General flowchart of the application EVALUATE.

3.2 Validation

As we can see in Figure 7, the differences between the professors' marks are similar to those obtained between the average of both professors and the result of the application developed.

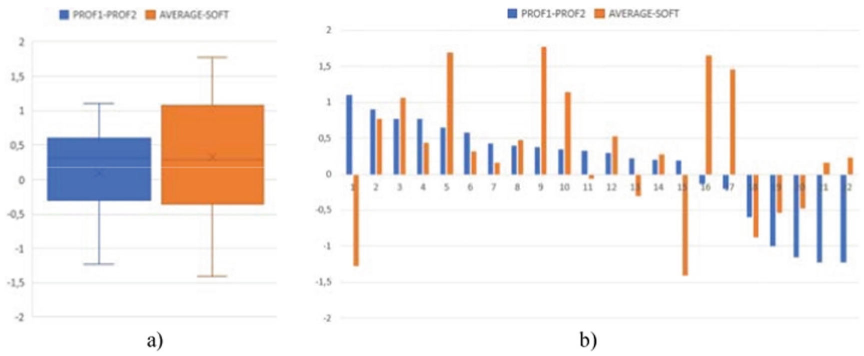


Fig. 7. For each student exam: a) differences between global marks of the two professors (blue); and differences between the professors' average and the application mark (orange). (Color figure online)

However, we can also see that there is a greater deviation between the results of the application and the average of the professors (Fig. 7a), which may be because the criteria used by the professors are much more detailed or rigid than those configured in this first approach of EVALUATE. It also should be noted that, in those cases where the differences between professors are minimal, the system penalizes more, and when the difference between professors is more dissimilar, the result obtained by the application is close to the average between professors, which can be taken as a goodness (Fig. 7b).

4 Conclusions

As this first approach to automate the assessment of the quality CAD models demonstrates, it is possible to create automated strategies to check whether student exams meet minimum quality standards. Additionally, the application developed has shortened the correction time considerably, also suppressing the subjectivity due to the long correction time (fatigue) or to the variability among professors. Besides, the results obtained have proved a more objective and unified result for all students.

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