Title:
Retrieval of Solid Models based on Assembly Similarity

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Objective:
The objective of this research is to extend existing solid model retrieval algorithms to aid in assembly process planning. Specifically, a new algorithm is developed using geometric information from components and assemblies to enable the reuse of assembly work instructions. The hypothesis tested in this research is that similar geometric models of assemblies will have similar assembly work instructions. This research enables manufacturing engineers to reuse existing assembly work instructions (based on solid model similarity) in a systematic manner, thus reducing the effort expended in the assembly planning process.

A two-level solid model similarity algorithm is developed and validated. At the first level, the geometric similarity of between two assemblies is computed by determining the similarity of the individual components in each assembly. At the second level, the similarity is computed between the two assembly models. This two level approach is justified because the individual components within an assembly may be configured differently. It is hypothesized that the two-level approach will increase the accuracy of retrieved assemblies as compared to the existing algorithms for computing similarity between solid models. The algorithm developed in this research combines existing shape histogram similarity [1,2] and surface area similarity [3] with tessellation density differences. Additionally, tessellation density differences are computed by comparing

- the number of tessellations, between two solid models, that had unique values for area, and
- the L1 Minkowski difference [7,2] of tessellation area distribution plots.

Methodology:
A survey was conducted where each question consisted of standard geometric models of two components and the solid model of their assembly. There were seven questions in all. Respondents were asked to rate the similarity of five other models presented as options for each question. 75% of the respondents have 1 to 3 years industry experience related to process engineering and dealing with assembly work instructions.

Results:
To validate the responses, Fleiss' Kappa for each question in the survey is calculated. The results are in Table 1. Question 2 had a negative Fleiss' Kappa indicating slight disagreement among raters [5]. Therefore, this question and its associated results are ignored from this point on.

Question Number	**Fleiss' Kappa Value**	**Level of Agreement**
Question 1	0.34	Fair Agreement
Question 2	-0.02	No Agreement
Question 3	0.37	Fair Agreement

Question Number	Fleiss' Kappa Value	Level of Agreement
Question 4	0.62	Good Agreement
Question 5	0.23	Fair Agreement
Question 6	0.26	Fair Agreement
Question 7	0.24	Fair Agreement

Tab. 1: Fleiss' Kappa for each question.

The survey results and the two-level algorithm results are compared on two key aspects. First, between results from the survey and results from the algorithm that includes similarity of assembly models. The second comparison is between results from the survey and results from the algorithm where similarity of assembly models was not considered. The correlation coefficient for each comparison will allow us determine if similarity of assembly models must be considered or not. To compute correlation, Kendall's tau rank correlation coefficient was used [4].

A statistical test was used to compare the results obtained. The null and alternative hypothesis are stated below.

Null Hypothesis: There is no correlation, or there is a negative correlation between the entities being compared.

Alternative Hypothesis: There exists a positive correlation between the two entities being compared.

A significance level of 0.01 is used. Based on the comparison, results (Table 2) show that considering similarity of components of an assembly alone will not suffice. Similarity of the assembly model must also be considered. The p-value in both cases of Table 2 indicates allows us to reject the null hypothesis and therefore state that there exists a significant positive correlation between the entities being compared. However, the comparison of survey results with results from algorithm using component and assembly similarity yields a higher correlation coefficient value.

	Correlation Coefficient	p-value
Survey, Algorithm with assembly similarity	0.70	< 0.01
Survey, Algorithm without assembly similarity	0.53	< 0.01

Tab. 2: Correlation coefficient results.

To test whether there is any improvement over an existing method of computing solid model similarity; the rankings obtained from the survey are compared to Osada and colleagues' [7] solid model similarity algorithm rankings. Note that for shape histogram similarity algorithm, only assembly models were considered while computing similarity. The results from this comparison are juxtaposed with the results from the comparison of survey results to the proposed algorithm that considers both component, as well as assembly model similarity.

The p-values in Table 3 show that there is sufficient evidence to reject the null hypothesis in the case of comparison between survey results and proposed algorithm (using component and assembly model similarity). However, in the case of comparison between survey results and results obtained from shape histogram similarity algorithm [7], the p-value is greater than 0.01. Therefore, we fail to reject the null hypothesis. This implies that there is insufficient evidence to show that there exists a positive correlation between the survey results and the results obtained from shape histogram similarity algorithm [7].

	Correlation Coefficient	p-value
Survey, Algorithm with assembly similarity	0.70	< 0.01
Survey, Shape histogram similarity	0.07	> 0.01

Tab. 3: Correlation coefficient results.

Closure and Future Work:
The comparisons presented above show the following:
1. Component solid model similarity must be used in conjunction with assembly solid model similarity to determine similarity of components from an assembly process perspective.
2. The combined method of using shape histogram similarity [7], surface area differences [3] and tessellation density differences, yields better results than use of overall shape similarity alone.

The results from this research will be used as a method to assist in retrieval of assembly work instructions. Original Equipment Manufacturers who have a database that relate solid models to assembly work instructions can benefit from this research. Manufacturing engineers can use existing, similar assembly work instructions as a template to develop new/revised assembly work instructions. This reuse of design knowledge will reduce the number of iterations [1,8,6] in process design and lead to a more efficient process planning method.

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