Statistical Analysis to identify the significant design complexity metrics in the estimation of product assembly time and market value

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Background
Previous research focused on developing four prediction models:
1. Assembly time estimation based on assembly models
2. Market value estimation based on function structures
3. Market value estimation based on assembly models
4. Assembly time estimation based on function structures

Motivation
1. Identify the complexity metrics which are significant predictors of assembly time and market value
2. See whether the set of significant metrics improves the prediction accuracy as compared to the original set of metrics
3. Analyze the metrics which are significant across all the four models
4. Figure out which characteristics make them significant independent of the output being predicted
5. These metrics can be used as the fundamental predictors for other design applications

Experimental Method
1) Generate function structures and assembly models of products
2) Create bi-partite graphs of these structures and models
3) Build the 29 complexity metric vector metric using these graphs
4) Store Assembly Times and Market Values of Products as Target Values
5) Train Artificial Neural Networks (ANNS) using Complexity Metrics and Target Values
6) Test the five selected products against the trained Artificial Neural Networks
7) Analysis of the test results

Analysis
Parameters:
Confidence level for all intervals: 90 (i.e. Alpha= 0.1)
Type of confidence interval: Two-sided
Method: Stepwise selection
Software used: Minitab

Results

<table>
<thead>
<tr>
<th>AT</th>
<th>MV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric no. 1, 4, 9, 10, 11, 12, 14, 25, 29</td>
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</tr>
<tr>
<td>FS</td>
<td>AM</td>
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<tr>
<td>Size-2</td>
<td>Size-2</td>
</tr>
<tr>
<td>Interconnection-4</td>
<td>Interconnection-3</td>
</tr>
<tr>
<td>Centrality-1</td>
<td>Centrality-3</td>
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<tr>
<td>Decomposition-2</td>
<td>Decomposition-2</td>
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</tbody>
</table>

Conclusions
- Interconnection is a significant predictor across all the four prediction models
- In AM prediction models, centrality and interconnection have the most number of significant metrics
- In FS prediction models, interconnection has the most number of significant metrics
- AMs comprises of parts which are connected to other parts whereas FS is like a tree wherein you have different levels. So not every source/sink will have multiple connections.
- Centrality is significant for AMs as the more central a component is to the others makes the assembly either easier or difficult

Advantages
- Using this information, designers can develop multiple design solutions with more focus on the significant metrics
- Helps channelize design concept development efforts in the right direction
- Reduces computation time and effort

New research questions identified
- Can this experimental method be applied to predict other design parameters such as quality
- Find out which characteristics make certain metrics significant across all the four models
- Would the significant predictors be the same for a different set of training and test products

Acknowledgements
5. Farhad Ameri, Joshua D. Summers, Gregory M. Mocks, Matthew Porter, “Engineering design complexity: an investigation of methods and measures”,
6. Koehler Sifta, ”Structural complexity quantification for engineered complex systems and implications on system architecture and design”, ASME IDETC/CIE, 2013