IMPACT OF CHAINING METHOD AND LEVEL OF COMPLETION ON ACCURACY OF FUNCTION STRUCTURE-BASED MARKET PRICE PREDICTION MODELS

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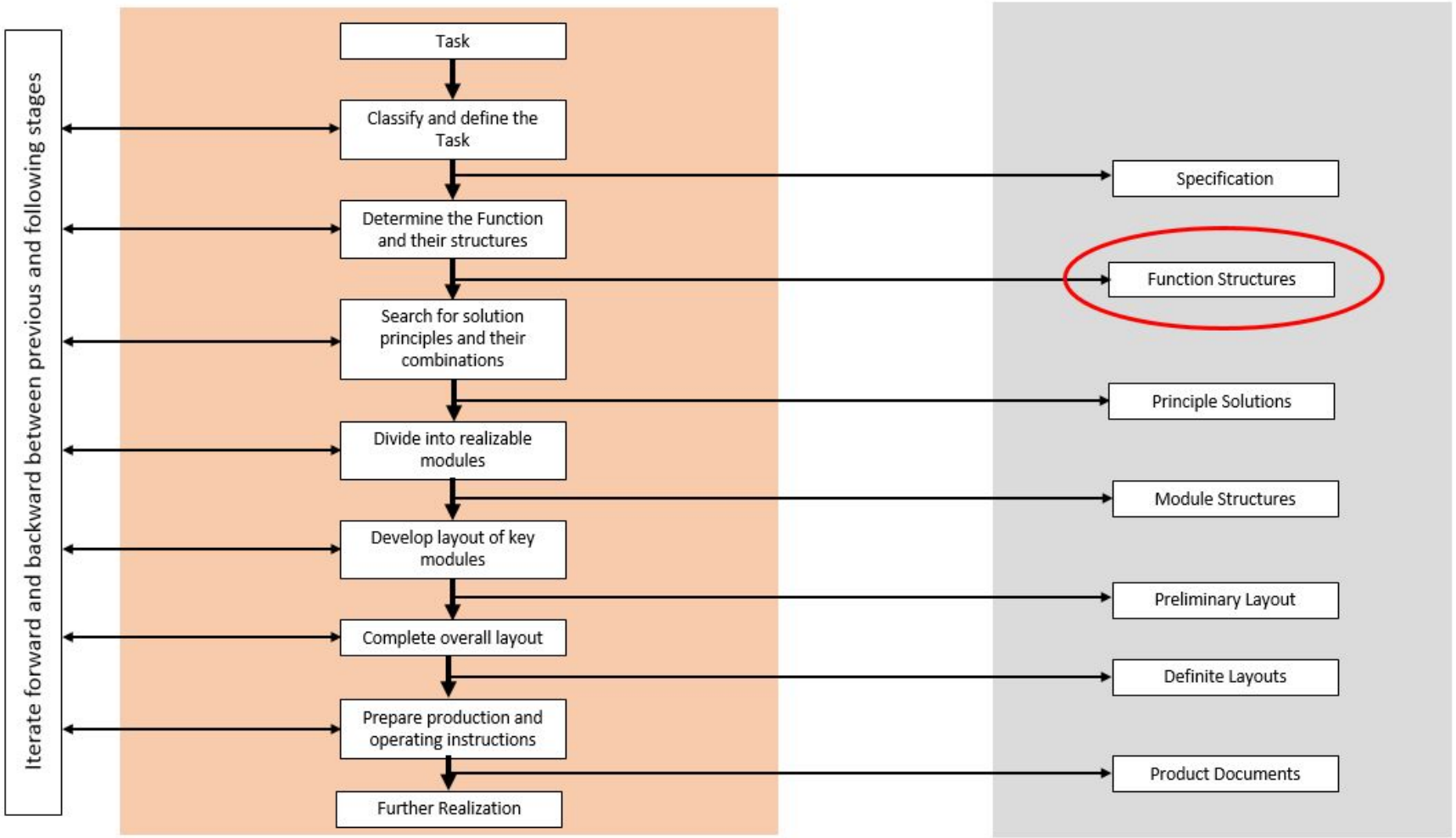
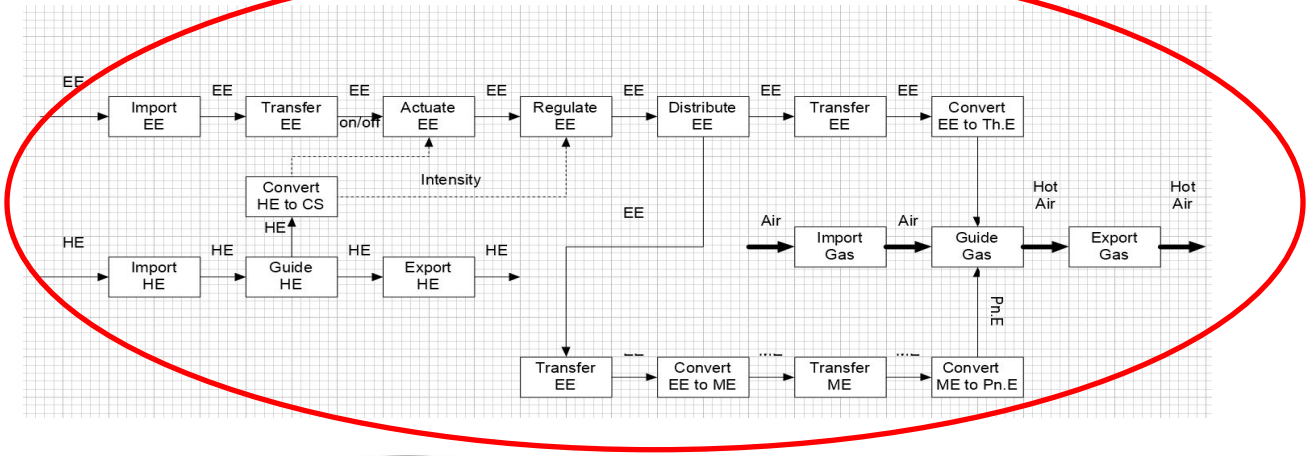
Design Process and Design Representation

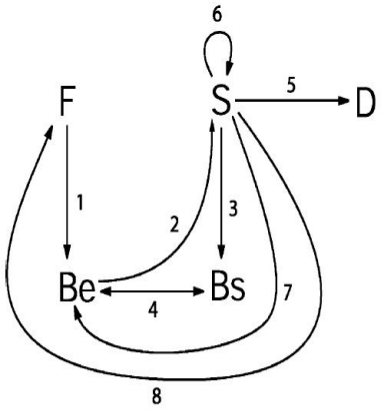


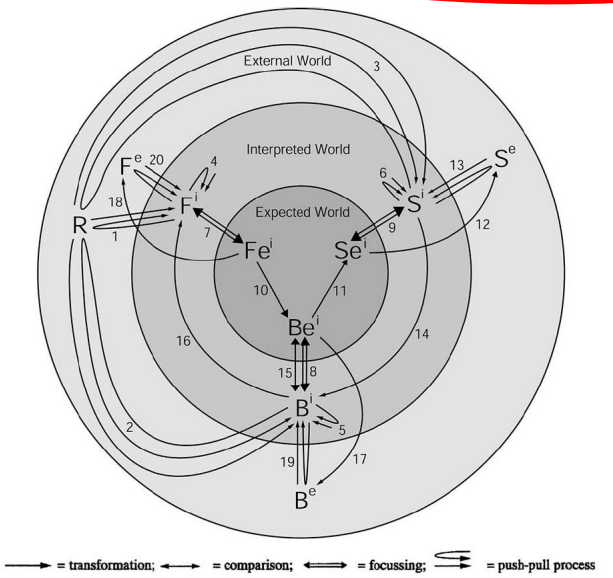
1.) Pahl, Gerhard, and Wolfgang Beitz. *Engineering design: a systematic approach*. Springer Science & Business Media, 2013.

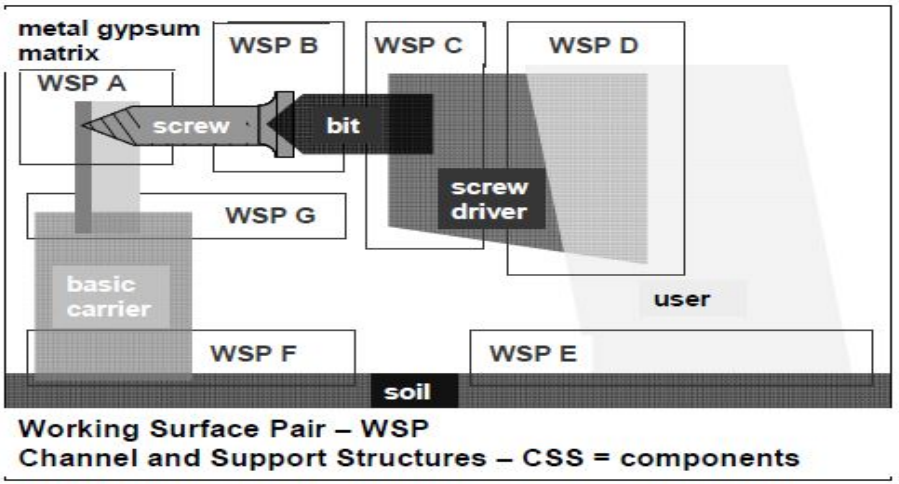
Types of Representation

- Early phase of design (first 5%) is of importance to researchers because of the cost implication on deciding the total cost of product development (70%)
- Different methods to model the functions in the conceptual design phase
- Different models suited for different areas of application have been developed over the years







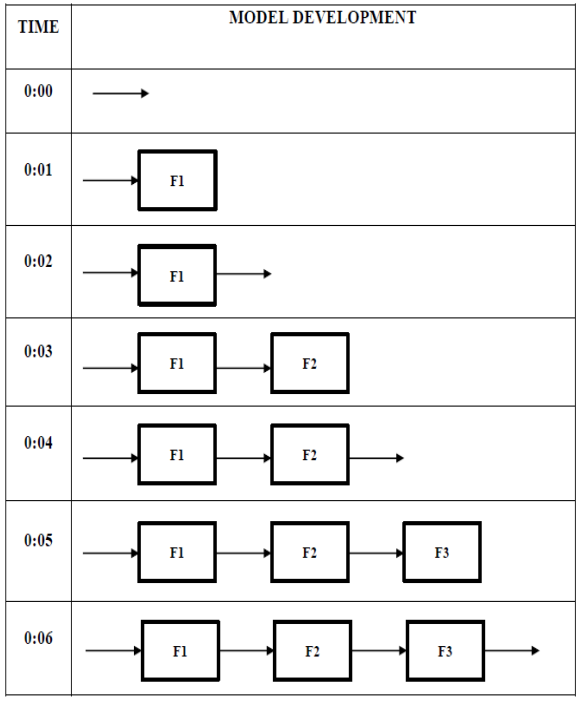


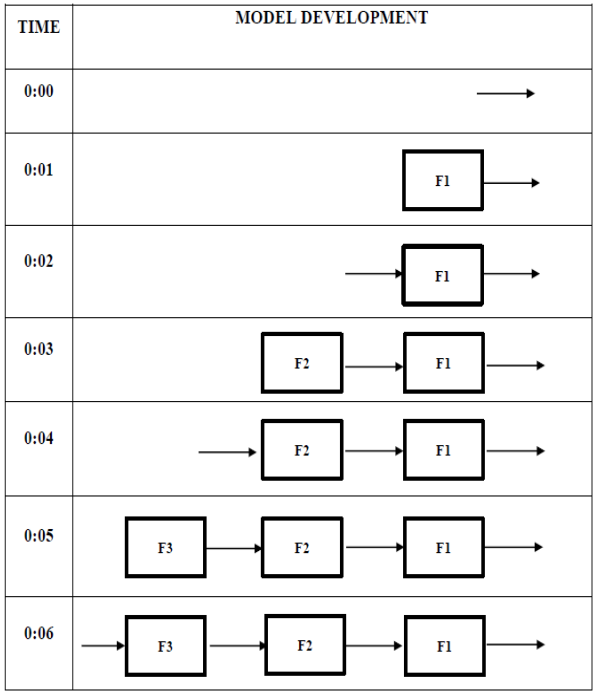
Motivation - 1

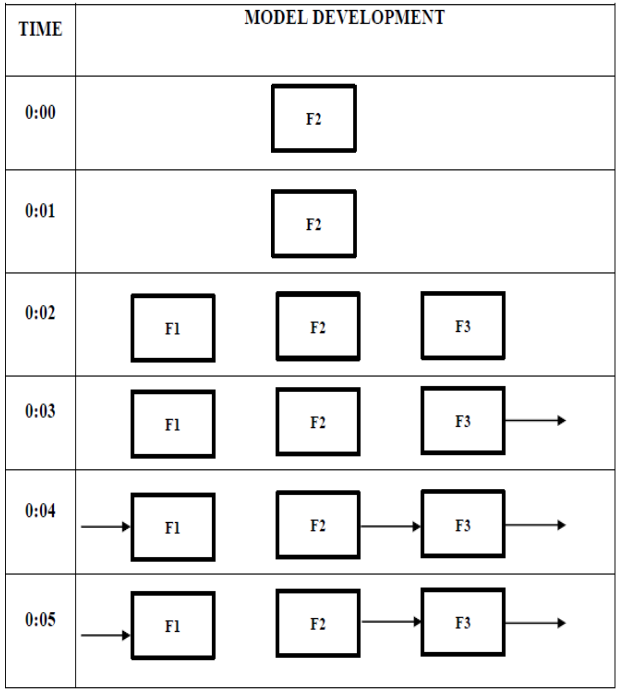
- Function structure modelling is a designer/human centric knowledge representation
- Different designers end up with different function models even though they are describing the same product as is revealed by protocol studies (Sen 2014; Thiagarajan 2017; Nagel 2015; Patel 2016)
- Hence, researchers tried to standardize the elements of the function models
- Knowledge Collection & Standardization Efforts: design repository, functional basis; functional basis hierarchy; composition rules; quantification of information content; impact of level of detail; impact of level of detail on information content
- Calls for benchmarking

Motivation - 2

- Understand how designers create function structures – how are the function blocks and the function flows created
- Videotaping – Sequence, Patterns, Pauses – Code
- Three modelling strategies identified – Forward Chaining, Backward Chaining, and Nucleation





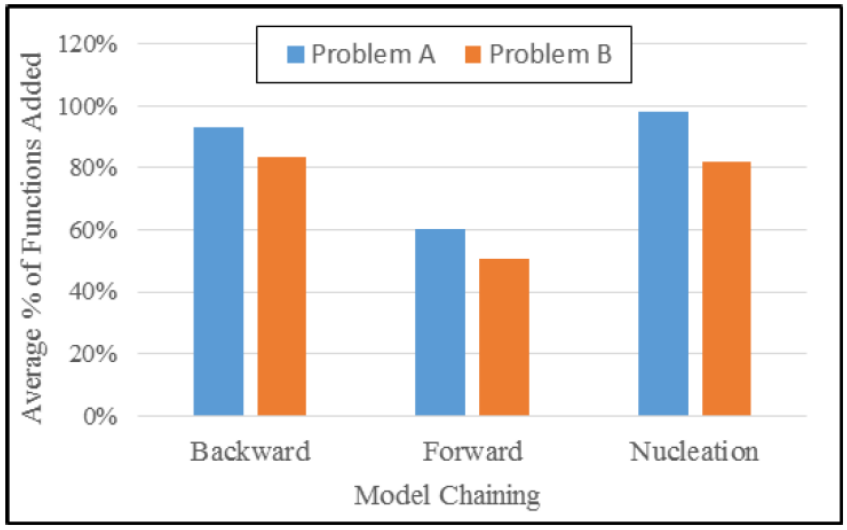


Motivation - 3

PARTICIPANT NO	FORWARD CHAINING	BACKWARD CHAINING	NUCLEATION
P1			
P2			
P3			
P4			
P5			
P6			
P7			
P8			

	>50%
	>10% and <50%
	<10%

- Coding results from Thiagarajan
- Mixture of the three schemas used by each individual
- Bias in favor of forward Chaining



- Protocol study results from Patel et al
- Number of functions added by students when seed function structure is created using one of the three methods
- Forward chained seed results in the least number of functions added

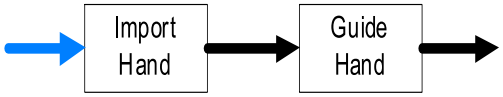
Research Questions

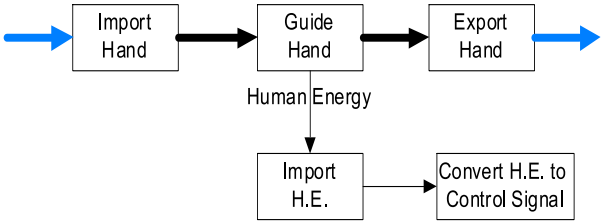
- What is the amount of information content in each of the three chaining methods at various stages of chaining completion?
- At what level of completion do the chaining methods yield a significant difference in their ability to accurately and precisely answer specific query like Market Price?
- Can guidelines be developed to select the chaining method based on amount of completion and computational accuracy?

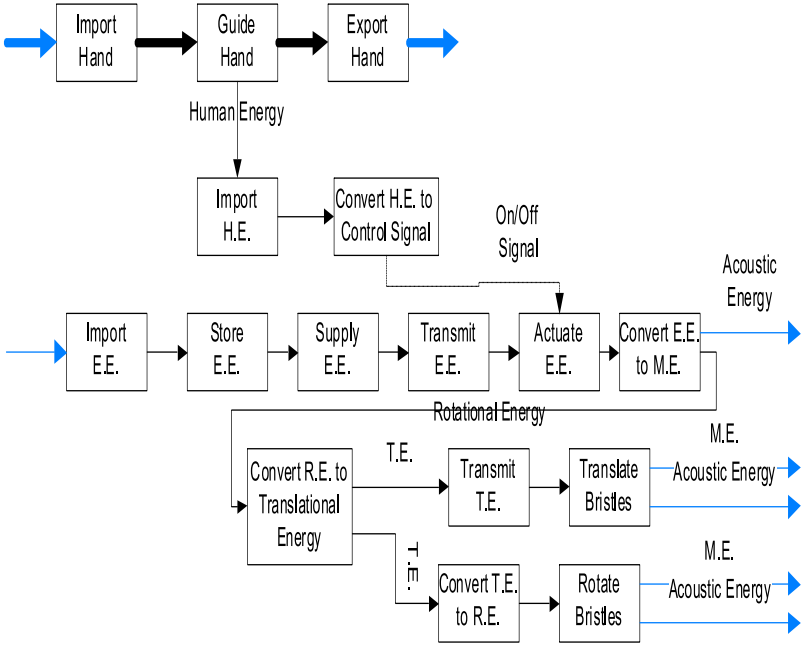
Experimental Procedure

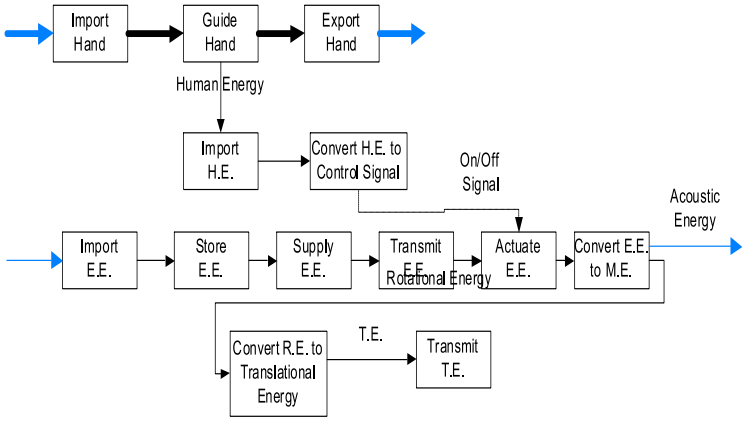
- The three different levels of completion in this study were chosen for each chaining method: 10%, 40% and 80%
- Some of the smaller function models may not be able to add even a single a block if the completion percentages are placed too close to each other
- Twenty different electro mechanical consumer products were chosen from the Oregon State University Design Repository
- These function structure were recreated using the following chaining methods and completion rate combinations: F-10, F-40, F-80; B-10, B-40, B-80; N-10, N-40, N80
- 29 complexity metrics were calculated for each of these function structures and ANNs were trained using these inputs

Forward Chaining

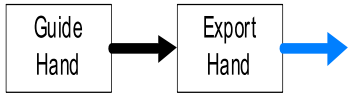


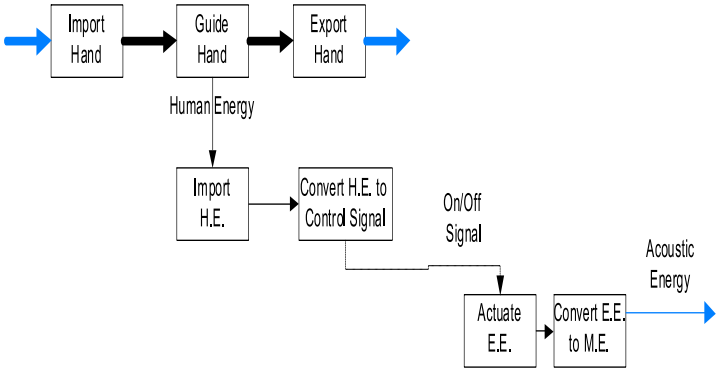


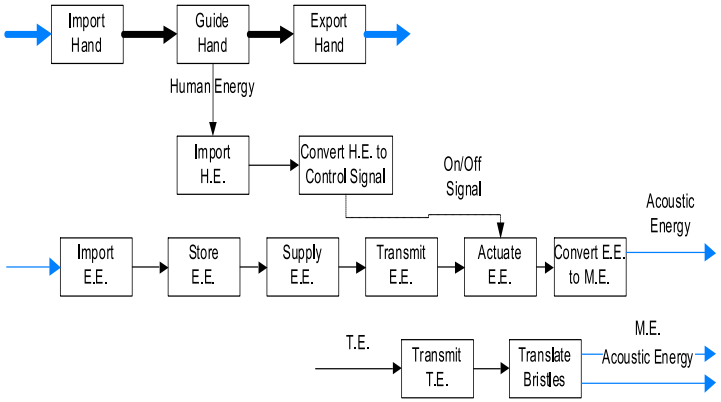


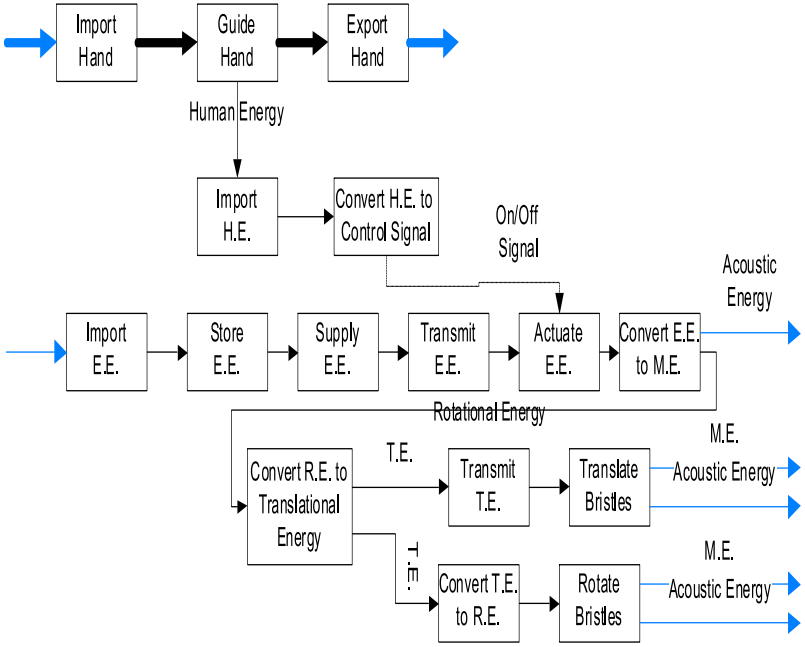


Backward Chaining

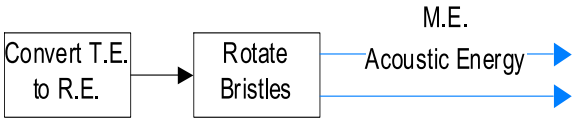


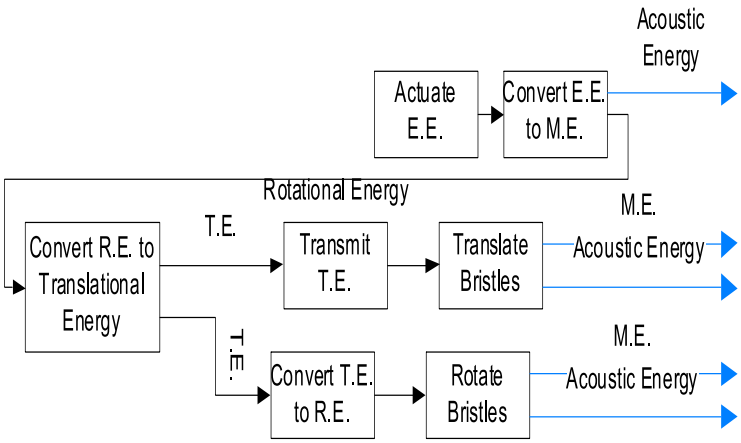


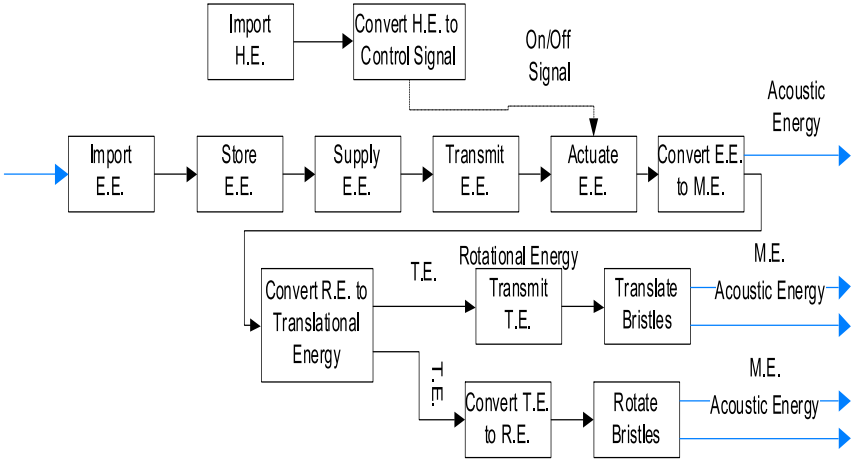


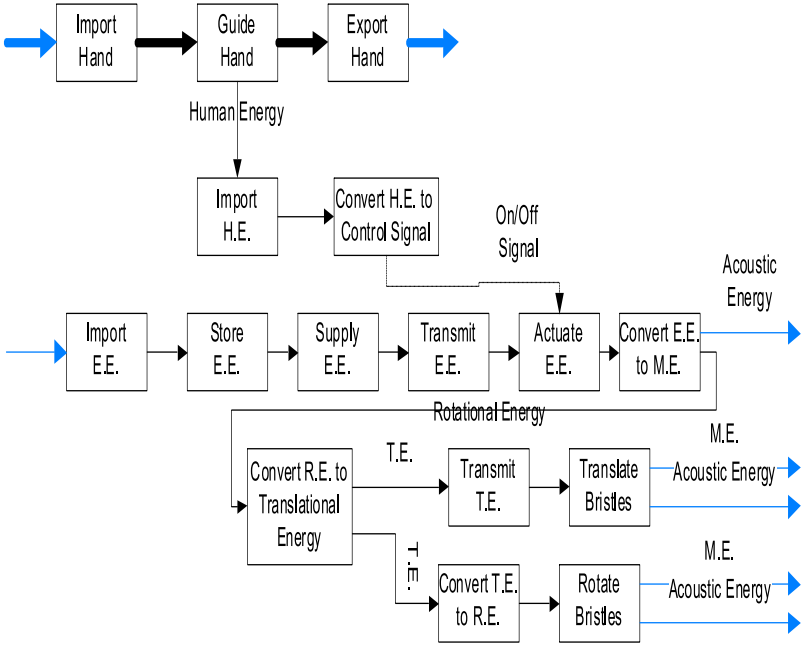


Nucleation

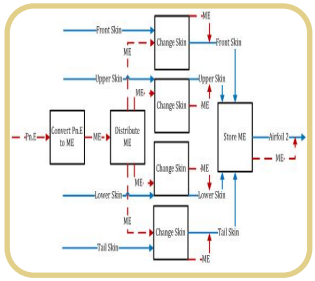

Convert T.E. to R.E.
Rotate Bristles
M.E.
Acoustic Energy


Acoustic Energy
Actuate E.E.
Convert E.E. to M.E.
Rotational Energy
Convert R.E. to Translational Energy
T.E.
Transmit T.E.
Translate Bristles
M.E.
Acoustic Energy
T.E.
Convert T.E. to R.E.
Rotate Bristles
M.E.
Acoustic Energy

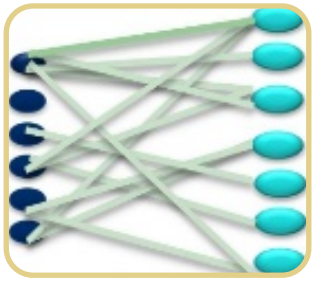

Import H.E.
Convert H.E. to Control Signal
On/Off Signal
Acoustic Energy
Import E.E.
Store E.E.
Supply E.E.
Transmit E.E.
Actuate E.E.
Convert E.E. to M.E.
Rotational Energy
Convert R.E. to Translational Energy
T.E.
Transmit T.E.
Translate Bristles
M.E.
Acoustic Energy
T.E.
Convert T.E. to R.E.
Rotate Bristles
M.E.
Acoustic Energy


Import Hand
Guide Hand
Export Hand
Human Energy
Import H.E.
Convert H.E. to Control Signal
On/Off Signal
Acoustic Energy
Import E.E.
Store E.E.
Supply E.E.
Transmit E.E.
Actuate E.E.
Convert E.E. to M.E.
Rotational Energy
Convert R.E. to Translational Energy
T.E.
Transmit T.E.
Translate Bristles
M.E.
Acoustic Energy
T.E.
Convert T.E. to R.E.
Rotate Bristles
M.E.
Acoustic Energy

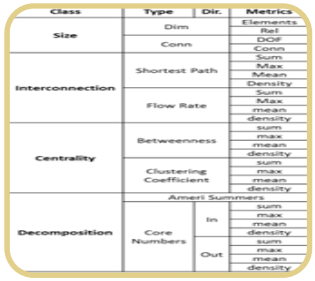
Computational Procedure



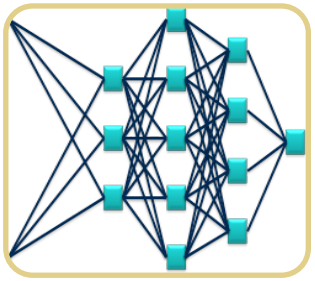
Collect Training Models (Function Structures and Market Price)



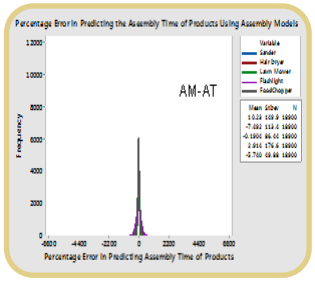
Convert assembly models to connectivity graphs



Convert connectivity graphs to complexity vector



Create predictive models (18,00 ANN models)



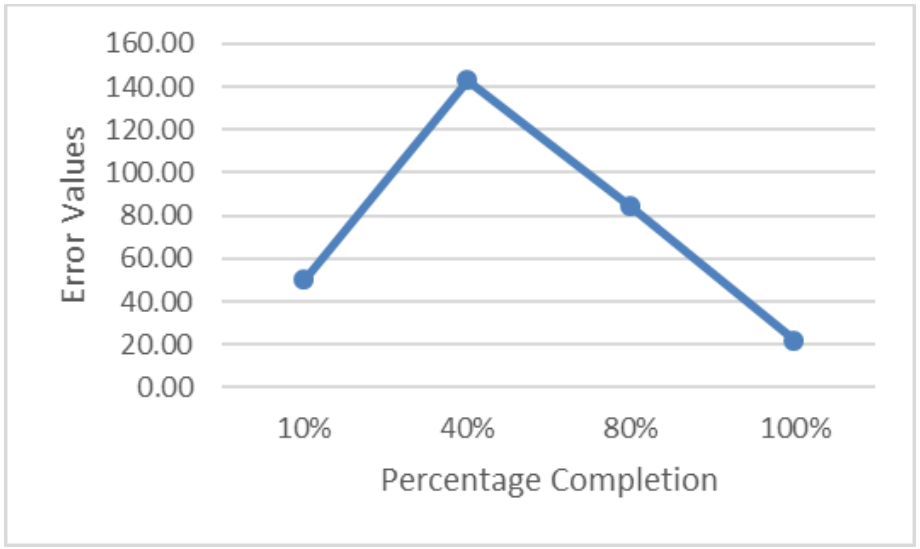
Averages and variance returned to user with respect to info predicted

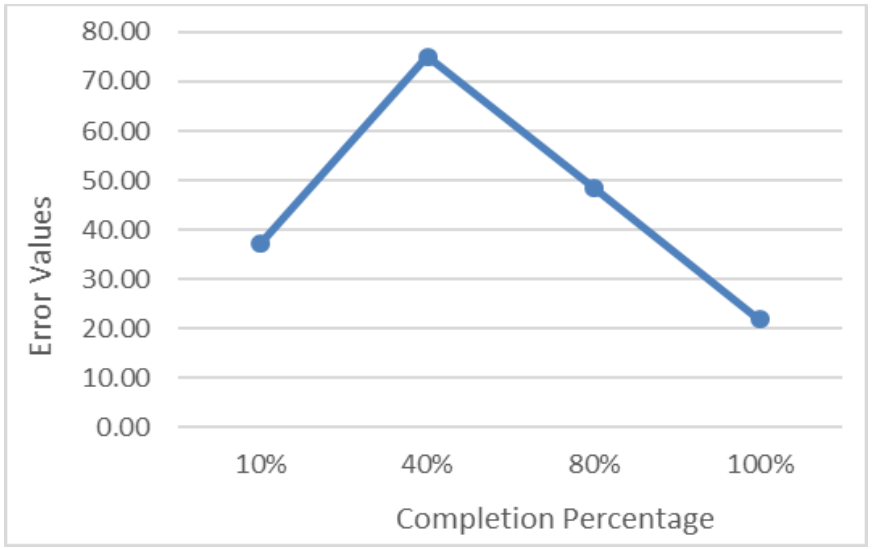
$$Residual\ Error = Target\ Value - Predicted\ Value$$

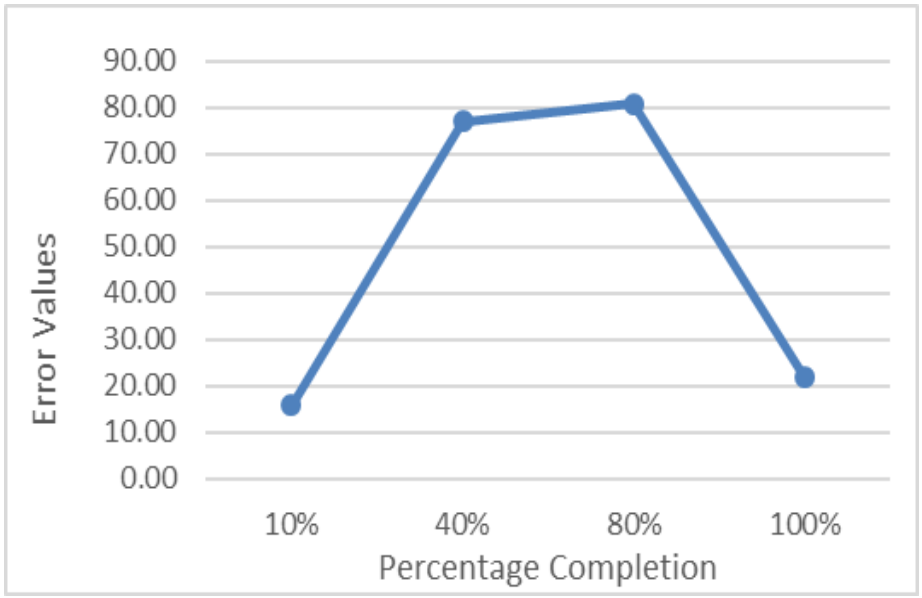
$$Standard\ Error = \frac{Target\ Value - Predicted\ Value}{Target\ Value}\ X\ 100$$

$$Normalized\ Error = \frac{|Target\ Value - Predicted\ Value|^2}{|Target\ Value\ X\ Predicted\ Value|}\ X\ 100$$

Results & Interpretation







- Clockwise: (Bottom Left to Top Right): Residual Error Values for a) Nucleation b) Forward Chained c) Backward Chained
- Pattern Emerges

Interpretation and Conclusion

- The study also runs counter to the previous understanding that the more function blocks and flows are added, the more amount of information a function structure has and consequently should end up with better prediction capability as compared to a function structure that has a lesser amount of information

- Possible Explanation: for 10% completion, there is a lot more homogeneity in the way that the chaining methods select the function blocks. There is a loss of this homogeneity as the completion percentage reaches 40%. Some of this homogeneity is again visible as the function structure is almost complete at 80%

- There is also a lot more room for how the user chooses to grow a function structure while using nucleation

- Inherent bias in the construction of the function models used

- ***Future work***: Quantify and understand the effort involved in construction of the function structure; develop tradeoffs

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QUESTIONS … ?