Inverse Design Process: Generating the BIG DATA to Efficiently Visualize a Complete Design Space

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Purpose:

Develop a methodology to produce hundreds of unique parameterized simulations of a medical device design for visualization and comparison of design variations to select an appropriate final design.

Background:

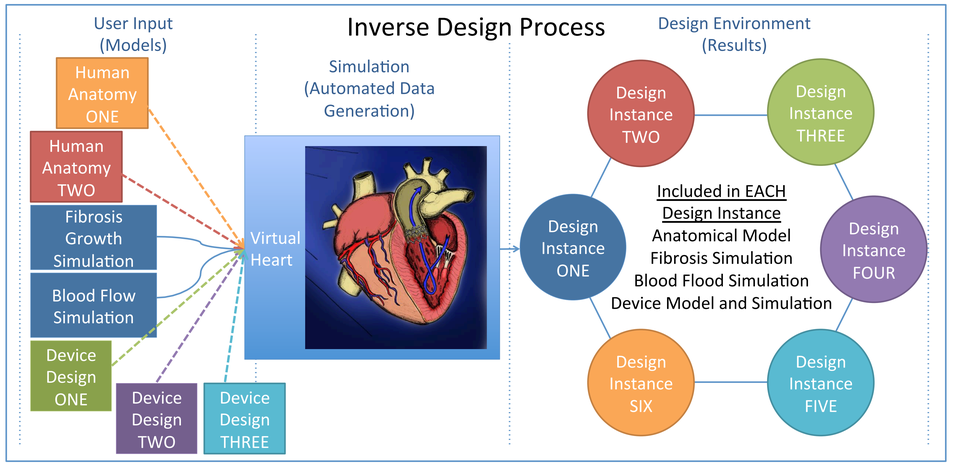
Each year millions of dollars are spent on medical devices to improve individual patient health. These devices came to fruition through a linear design process with many idea variations eliminated without complete consideration for the potential variations of the design. Mean while, many final designs never make it to market due to efficacy evaluations. A linear process limits and significantly bounds the design space by discouraging exploration of all design variations.

Inverse Design Process:

Inverse design is a process that through the use of computational technology enables a designer to explore hundreds of design variations and simulated testing of each design. The process includes all of the possible design variations into one design environment. The bounds (maximum and minimum) of each parameter can be adjusted to the user preference, enabling the inclusion of a designer's intuition and previous experience with similar designed devices. The inverse design process enables the designer to intuitively narrow down the design space and select a better device based on simulated testing and environmental constraints.

Proof-of-Concept Device:

In order to use this inverse design process for a medical device, the first step is to generate the data. Producing the data has previously been the limiting factor, however with current computational technology and the appropriate software hundreds of model variations can be rapidly created. A cardiac lead for a pacemaker was selected as the proof of concept because of the opportunity to vary the model complexity. For this proof of concept, a simplified cardiac lead was modeled with three parameters; length of cardiac lead in the heart cavity, diameter of the cardiac lead, and stiffness of the cardiac lead. The parameter bounds were selected based on cardiac leads available in industry.



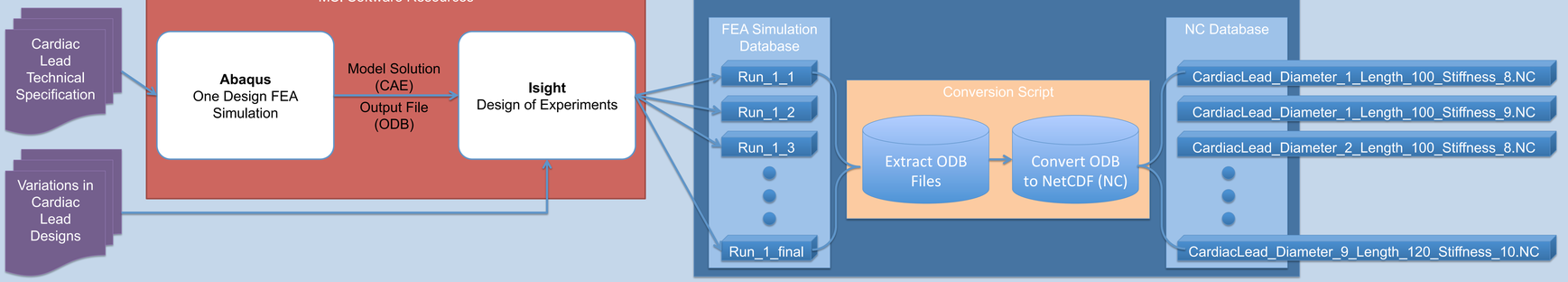
Methodology:

A cardiac lead was modeled in Abaqus 6.13-2 and the job was compiled. The data was imported into Isight 5.8 and a full factorial design of experiments (DOE) was computed to produce 729 design variations (nine variations in diameter, nine variations in stiffness and nine variations in lead length). Created files were stored and a script was used to parse and reformat the data for visualization.

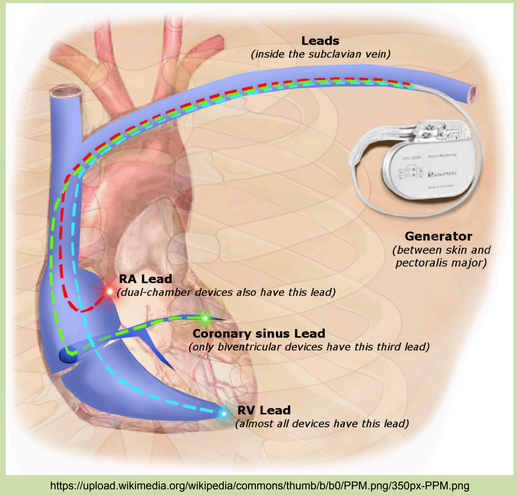
Results:

This methodology reduced the time to create the models by 98.1% and computational resource time by 33.3%. Overall, the time to complete the models was reduced from 364.5 hours to 85.5 hours, with most of those hours being computational time.

Parameter	Input
Length	110 mm
Diameter	6 Fr (2 mm)
Stiffness	9 N/mm
Attachment	Appendage



Parameter	Minimum	Maximum	Interval	Variations
Length	102 mm	118 mm	2 mm	9
Diameter	5.2 Fr (1.74 mm)	6.8 Fr (2.26 mm)	0.2 Fr 0.067 mm	9
Stiffness	8.2 N/mm	9.8 N/mm	0.2 N/mm	9
	Location 1			**Variations**
Attachment	Appendage			1
			Total Variations	729



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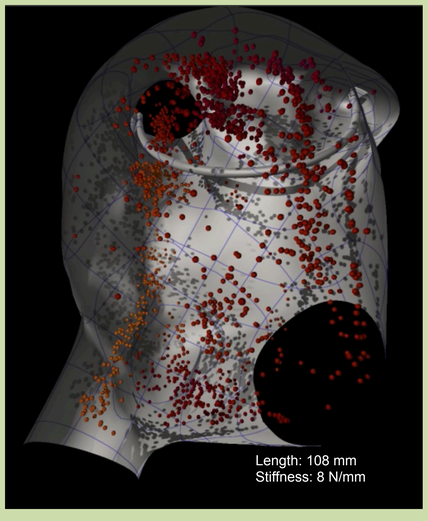

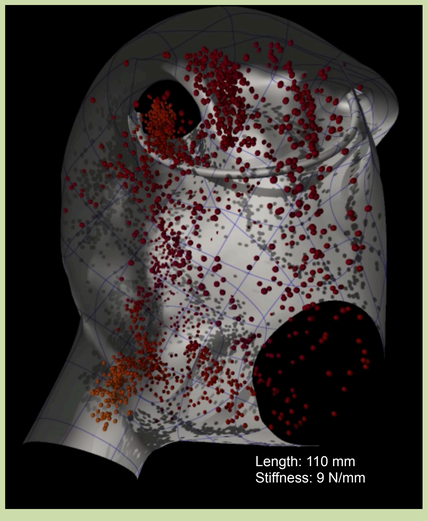

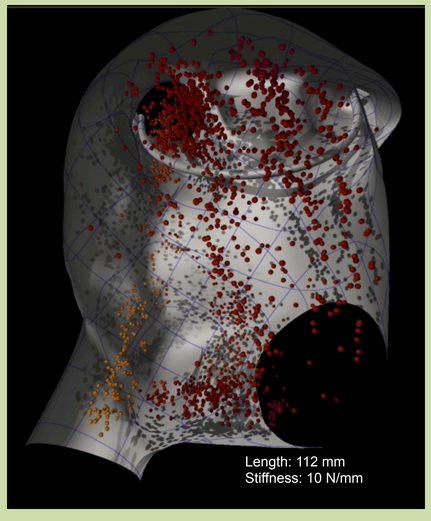

Methods for Model Generation

Abaqus						
	Time per Model (mins)	Num Models	Mins	Hours	Work weeks	Attention Needed
Human Time	20	729	14,580	243.0	6.1	Every 30 minutes
Computer Time	10		7,290	121.5	3.0	
		Total	**21,870**	**364.5**	**9.1**	

Abaqus plus Isight						
	Time per Model (mins)	Num Models	Mins	Hour	Work weeks	Attention Needed
Human Time	20	9	270	4.5	0.1	Every 9 hours
Computer Time	540	729	4860	81	2.0	
		Total	**5130**	**85.5**	**2.1**	

MSI Contribution:

Access to the resources available at the Minnesota Supercomputing Institute (MSI) is essential to the development of the inverse design process, through storing, computing, processing and visualizing the data for this project. The use of these resources, enable our research team to explore using a complete design space in the design of every medical device to open doors to solutions that will efficiently complete the FDA evaluation and better serve the patients receiving the treatment.

Discussion:

This ongoing collaborative interdisciplinary work hopes to answer both medical engineering questions related to device design and large data visualization questions in computer science. Time has been the limiting factor in developing the the amount of data necessary to explore these larger research goals. Accessing computing resources that enables rapid data generation helps advance this research to explore data visualization techniques and understand complex simulations.

Conclusion:

A process has been developed to generate a large number of parameterized datasets. These datasets will be used to interactively explore complex coupled simulations about medical device design. The resources available at the Minnesota Supercomputing Institute are invaluable to the advancement and exploration of this research.

Future Work:

Encapsulate this process into a larger software application. This would allow a design to upload their medical device design, define the parameterization and submit, returning hours later to a parameterized design space that could be explored and conclusions drawn.

References:

Bethany Tourek, Daniel Orban, Lingyu Meng, Hakizumwani Birali Runesha, Daniel Keefe, and Arthur Erdman. "Review of Cardiac Pacemaker Lead Designs for Computational Models in a VR Environment." Journal of Medical Devices. 2017.

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