# A System for Optimizing Medical Device Development Using Finite Element Analysis Predictions

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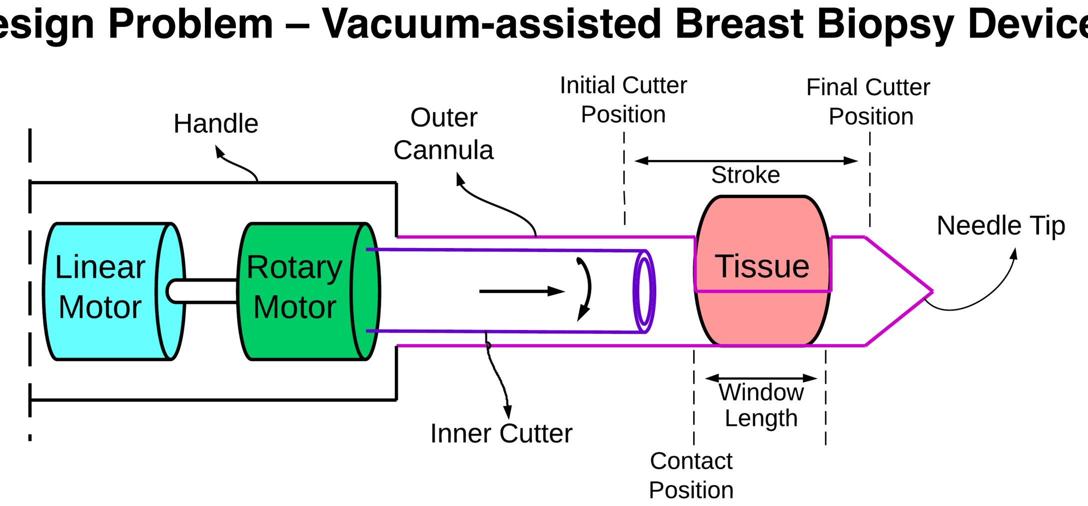
## Introduction

We propose a system to allow computational tools to work effectively with big data and to ultimately achieve simulation-based medical device design. The system

- provides finite element analysis (FEA) predictions for design problems.
- takes advantages of high performance computing (HPC) to largely reduce the time to predicted results.
- equipped with interactive interfaces to enable creative forward and inverse design searches over design spaces.

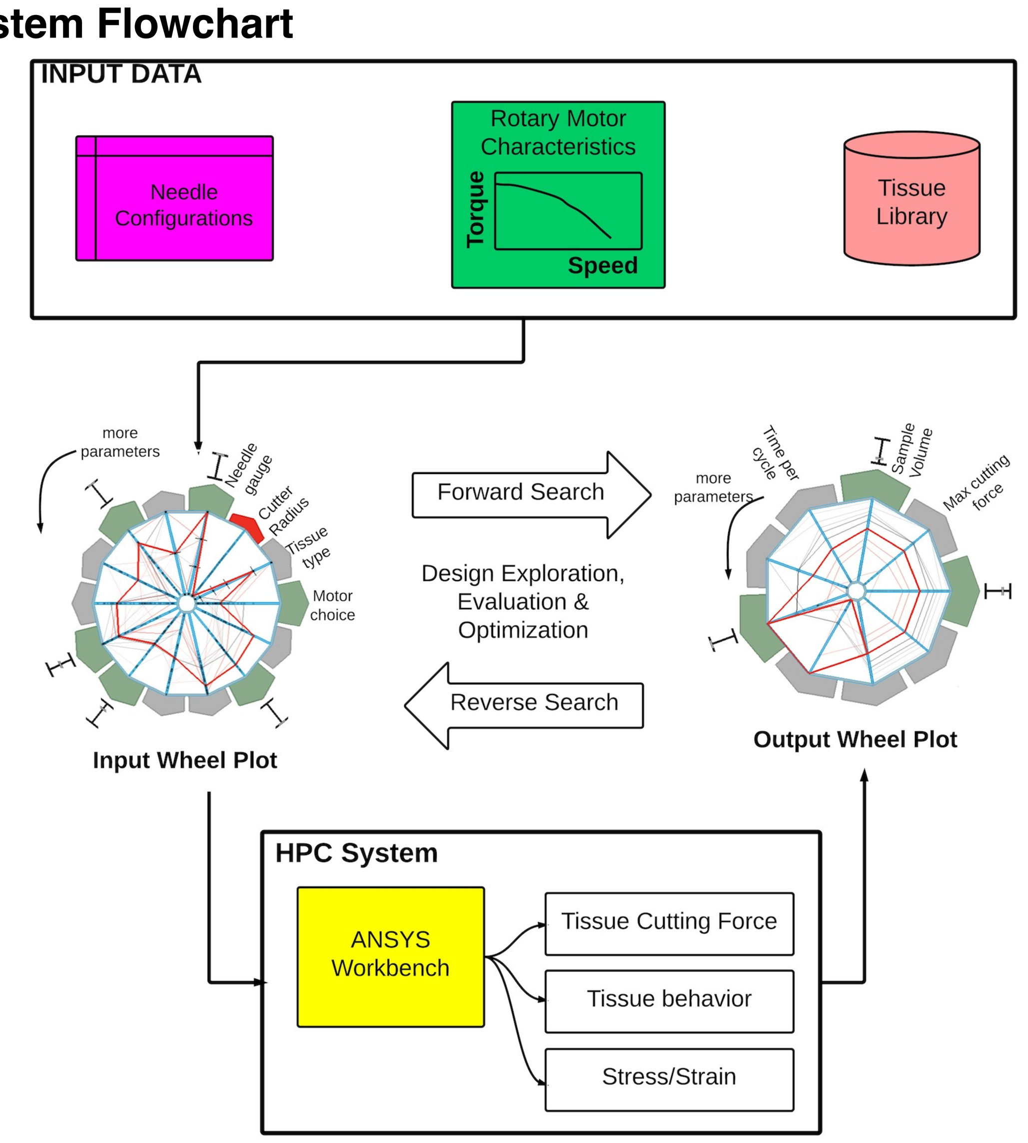
## Methods

### Design Problem – Vacuum-assisted Breast Biopsy Device




| Input parameters | Output Variables |
|---|---|
| Needle Configurations | Maximum cutting force |
| Rotary cutting speed | Motor overload |
| Tissue Types | Tissue sample volume / sec |
| Motor choices | Mechanical system weight |

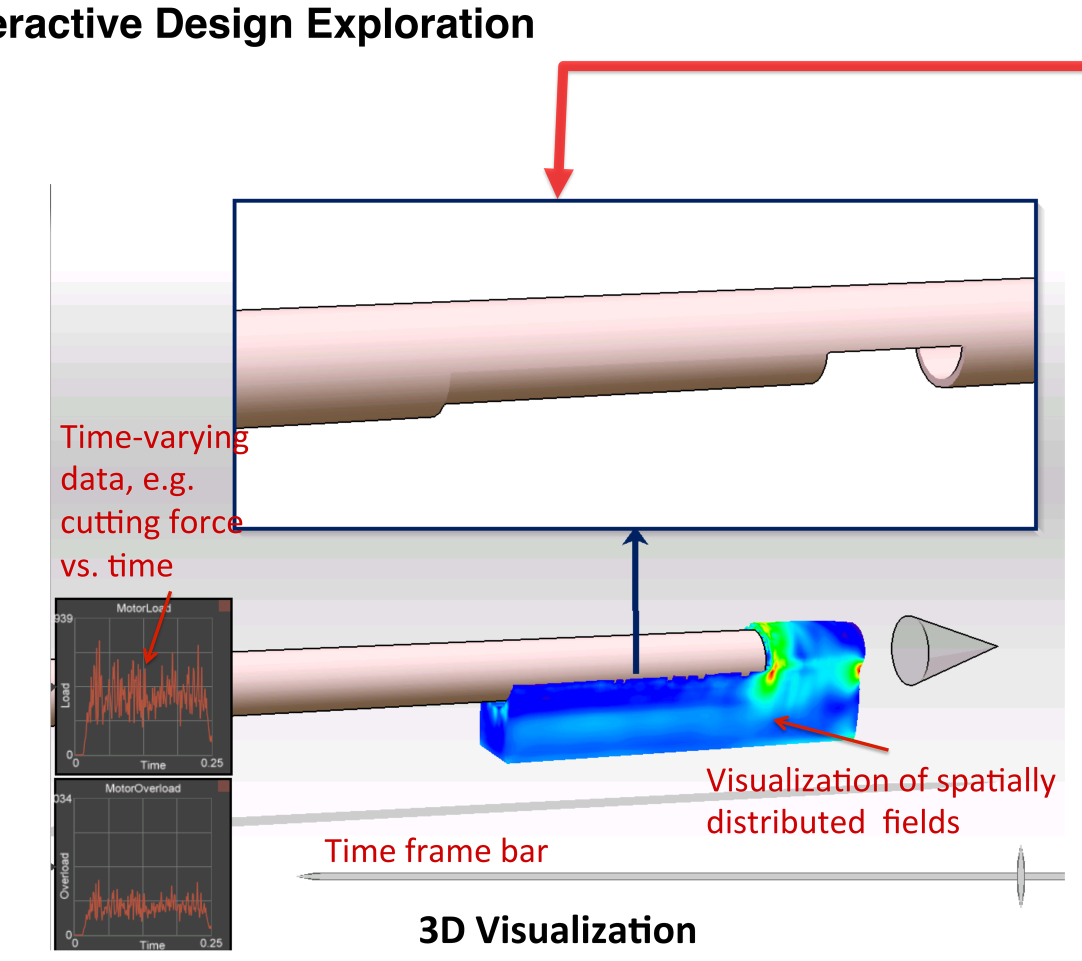
### System Flowchart




The proposed system provides interfaces to allow input data and FEA output data to fill into the design space. The FEA output data is generated using ANSYS Workbench with HPC. The designer can change design parameters and evaluates device performance or in an inverse way in the integrated design environment.

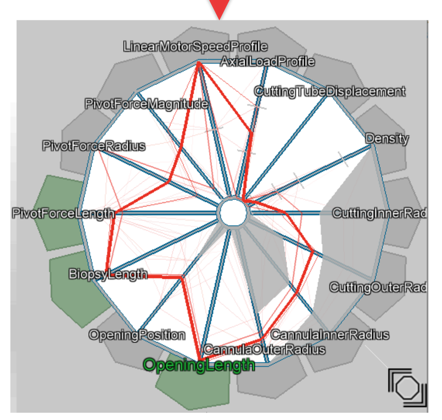
## Results

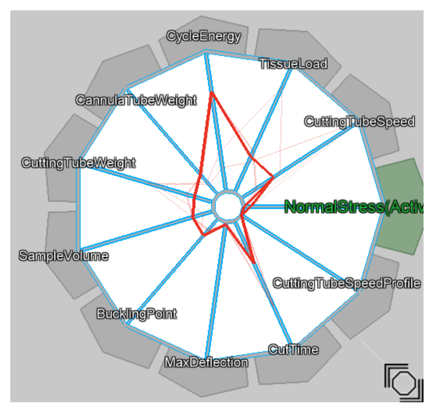
### Interactive Design Exploration




#### Human-in-the-loop Design Process

- Efficiently explore through the design space by interacting with the 'wheels.'
- Change/specify design parameters, variables or constraints and see how the others are affected.
- Quickly identify critical design parameters by interacting with the design environment.


Input Parameters


Output Variables

#### Forward Design Search

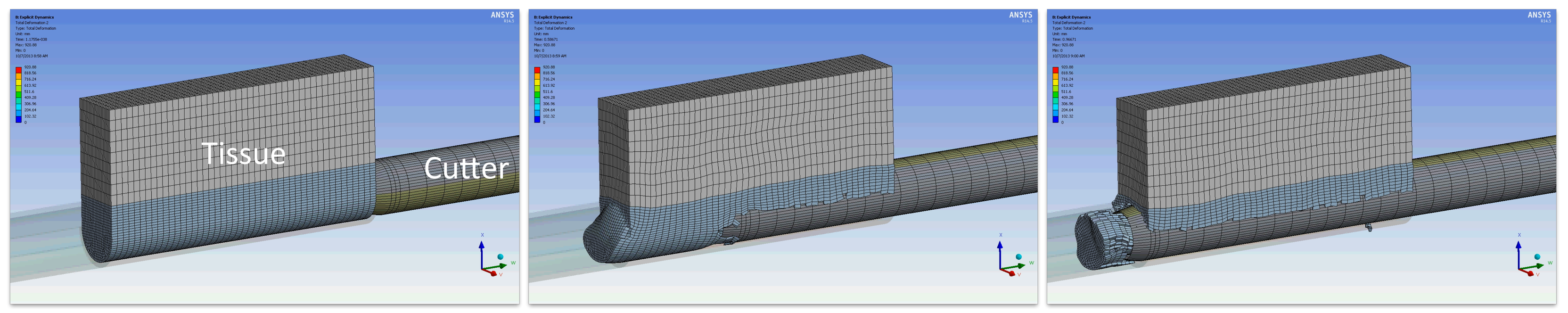
- Specify desired input values
- Ex: Find a design with **7G needle** that can retrieve largest **volume per time** when sampling **fat tissue**

#### Inverse Design Search

- Specify target output values
- Ex: What are the designs that weigh **~300g** and can reach above **100 mg/s** of sampling capability?

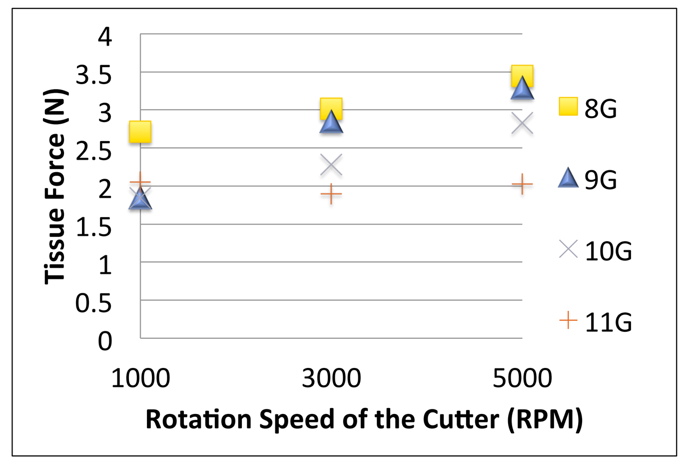
### FEA Predictions using ANSYS Explicit STR in HPC Clusters

60 design points are created using ANSYS Workbench. Explicit dynamic solves are performed using ANSYS Explicit STR. With parallel computation and HPC, the design points are solved much more efficiently.

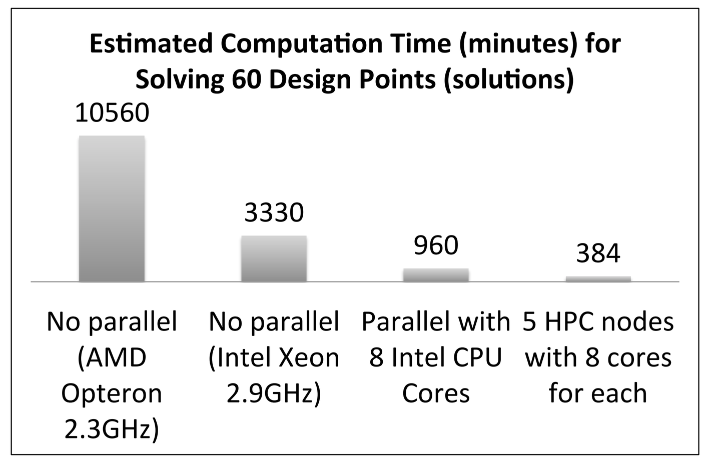



A. 0% cutting progress B. 50% cutting progress C. 100% cutting progress

Explicit dynamic simulations predict the tissue behavior during cutting. The output data is used for 3D visualization and tissue sample volume computation. Note that The outer cannula is suppressed from the view.




Predictions of maximum cutting forces with different needle sizes and rotation speeds. The results are used for motor evaluation.




Parallel computation in HPC significantly reduces time to results for expensive simulations

## Conclusions

**The proposed system**

- integrates computational simulations into the early stages of device design.
- provides with multiple data sources, such as input data, FEA output data and motor evaluation results, in an integrated design environment.
- enables interactive and efficient design exploration in a large design space.
- can provide more design insights before producing physical prototypes for animal and human tests.

**Future work includes**

- improving the accuracy of the cutting model.
- building a more comprehensive tissue library.
- adding predictions with multiple levels of resolutions, such as analytical and experimental data.
- creating design scenarios and conducting user study of this system.

## Acknowledgements

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## Further Information

More information about our 3D visualization system can be found at IV/LAB's website: http://ivlab.cs.umn.edu/project_meddev.php

Contact for questions regarding the system integrations, modeling and simulations of the tissue cutting: linxx691@umn.edu