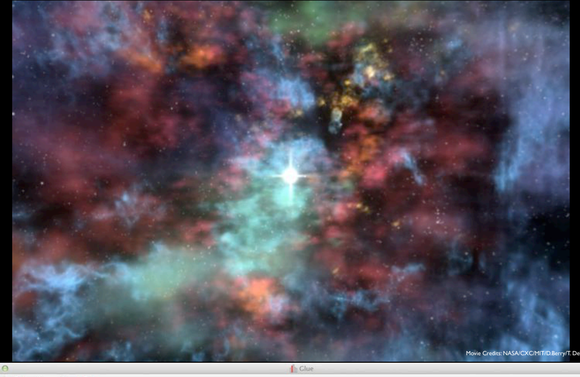
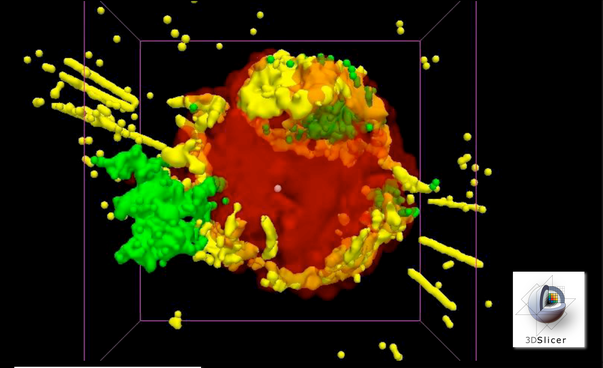
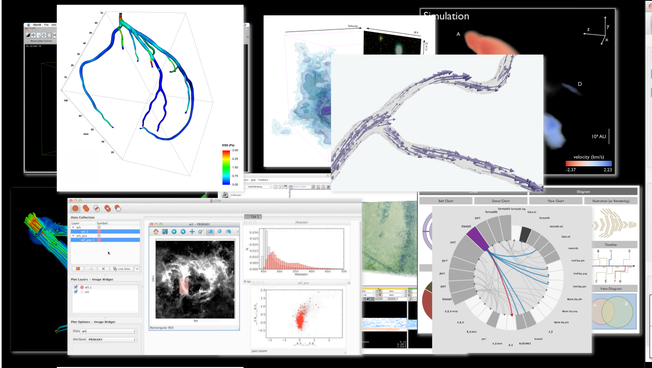
Perception, Cognition, and Effectiveness of Visualizations with Applications in Science and Engineering

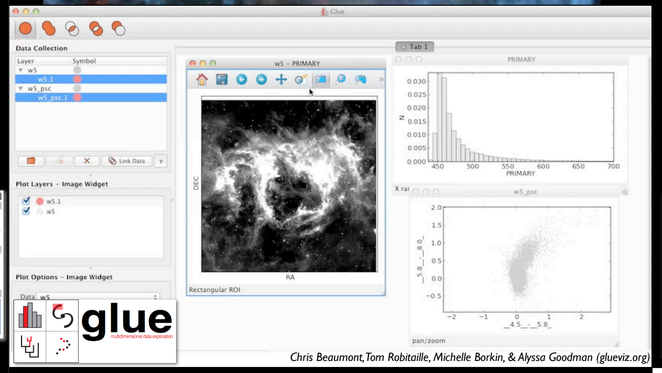
Michelle Borkin
(University of British Columbia & Harvard University)

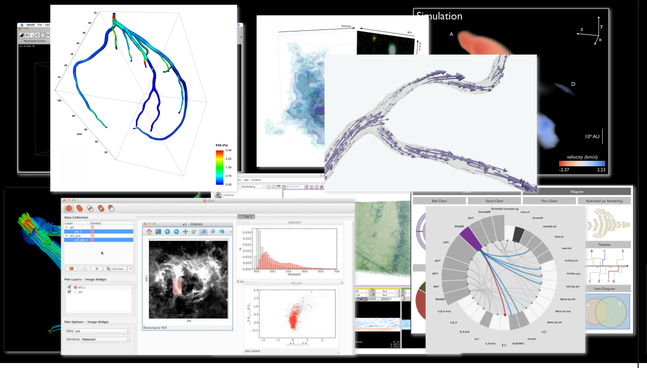
CPSC 547, UBC - September 24, 2014

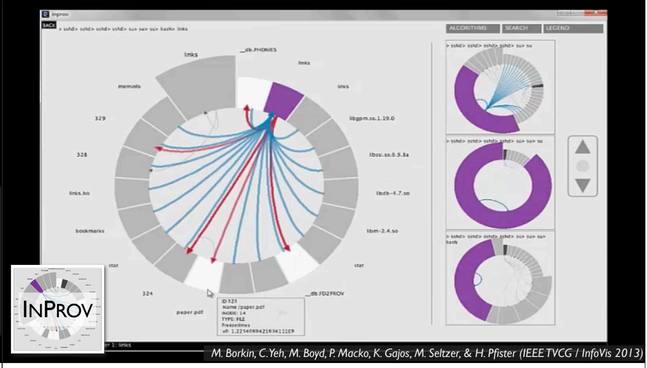


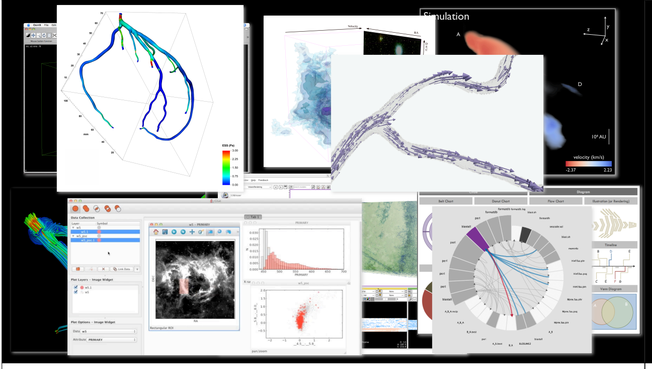


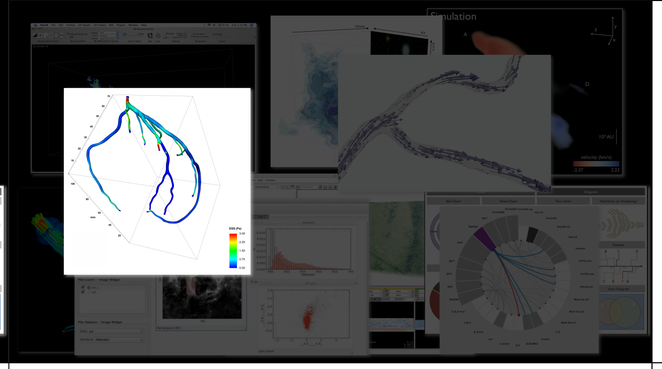


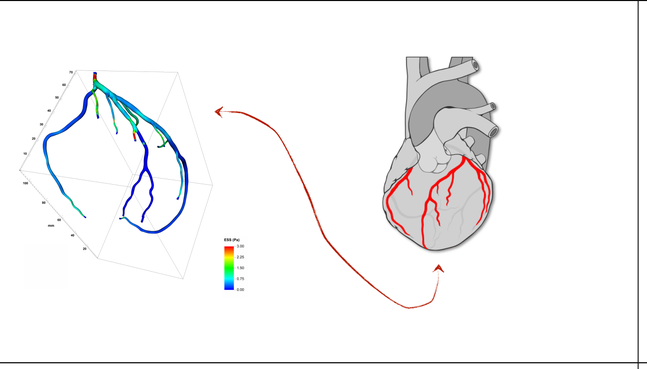


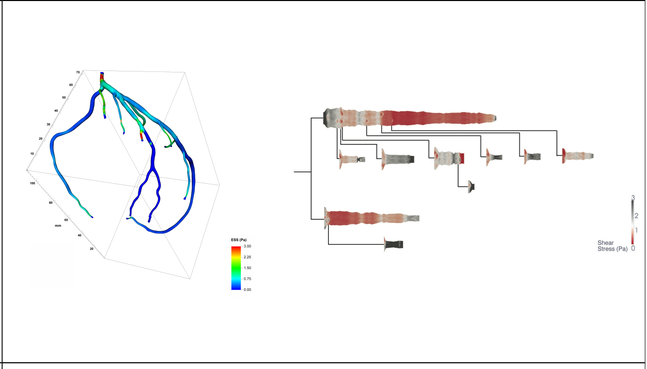


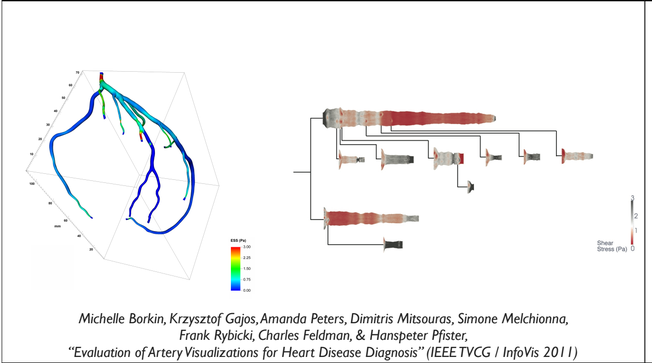








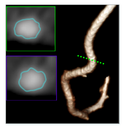




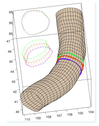
Michelle Borkin, Krzysztof Gajos, Amanda Peters, Dimitris Mitsouras, Simone Melchionna, Frank Rybicki, Charles Feldman, & Hanspeter Pfister, "Evaluation of Artery Visualizations for Heart Disease Diagnosis" (IEEE TVCG / InfoVis 2011)

Non-Invasive Diagnosis

Obtain patient CT data



Segment arteries



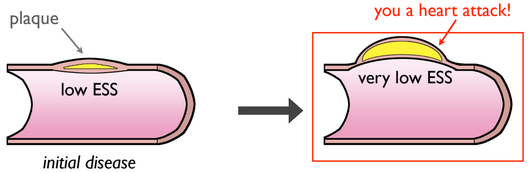
Generate patient geometries

Patient specific blood flow simulation

Visualize and analyze data

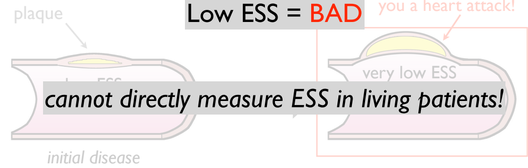
Clinical decision

Data



ESS = endothelial shear stress
(i.e., frictional force from blood flow)

Data



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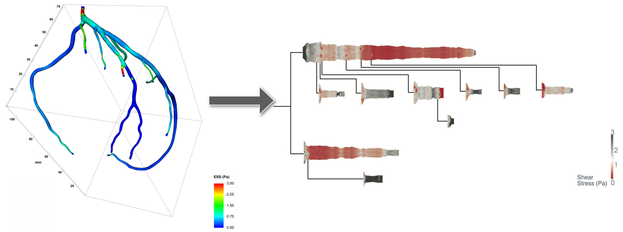
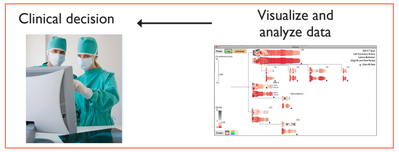


Formative Qualitative Study

- Semi-structured interviews
- 10 medical doctors and researchers
- Brigham & Women's Hospital (Boston, MA)



Task Taxonomy

Task	Abstraction

Task Taxonomy

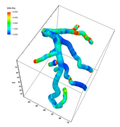
Task	Abstraction
"Identify regions of low ESS"	find extrema

Task Taxonomy

Task	Abstraction
"Identify regions of low ESS"	find extrema
"Identify stenosis or blockage"	find extrema

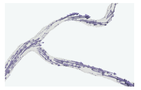
Task Taxonomy

Task	Abstraction
"Identify regions of low ESS"	find extrema
"Identify stenosis or blockage"	find extrema
"View all ESS data for patterns"	cluster



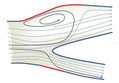
Task Taxonomy

Task	Abstraction
"Identify regions of low ESS"	find extrema
"Identify stenosis or blockage"	find extrema
"View all ESS data for patterns"	cluster
"Study blood flow velocity patterns"	find anomalies



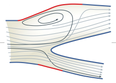
Task Taxonomy

Task	Abstraction
"Identify regions of low ESS"	find extrema
"Identify stenosis or blockage"	find extrema
"View all ESS data for patterns"	cluster
"Study blood flow velocity patterns"	find anomalies
"Identify regions of blood recirculation"	find anomalies



Task Taxonomy

Task	Abstraction
"Identify regions of low ESS"	find extrema
"Identify stenosis or blockage"	find extrema
"View all ESS data for patterns"	cluster
"Study blood flow velocity patterns"	find anomalies
"Identify regions of blood recirculation"	find anomalies
"Investigate other physical variables of blood flow"	find anomalies



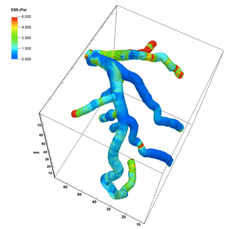
Task Taxonomy

Task	Abstraction	Clinical	Research
"Identify regions of low ESS"	find extrema	X	X
"Identify stenosis or blockage"	find extrema	X	X
"View all ESS data for patterns"	cluster	X	X
"Study blood flow velocity patterns"	find anomalies		X
"Identify regions of blood recirculation"	find anomalies		X
"Investigate other physical variables of blood flow"	find anomalies		X

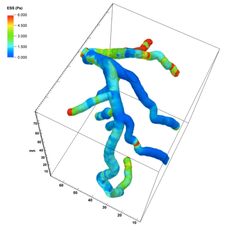
Task Taxonomy

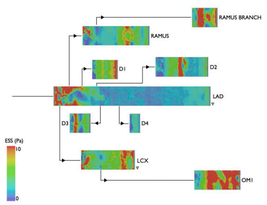
Task	Abstraction	Clinical	Research
"Identify regions of low ESS"	find extrema	X	X
"Identify stenosis or blockage"	find extrema	X	X
"View all ESS data for patterns"	cluster	X	X
"Study blood flow velocity patterns"	find anomalies		X
"Identify regions of blood recirculation"	find anomalies		X
"Investigate other physical variables of blood flow"	find anomalies		X

3D vs. 2D

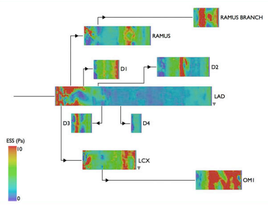


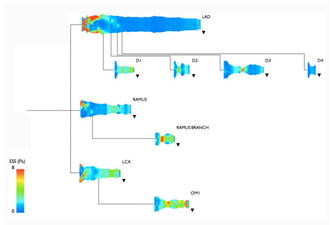
3D vs. 2D

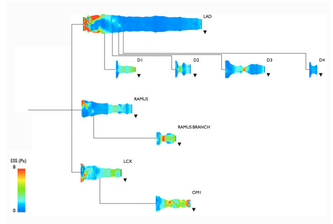


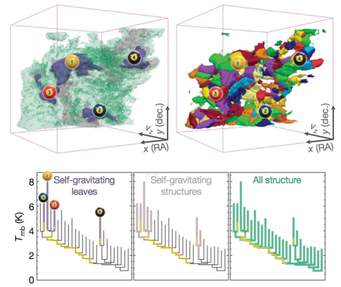


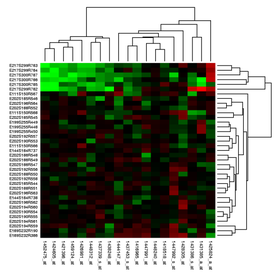
Layout and Projections

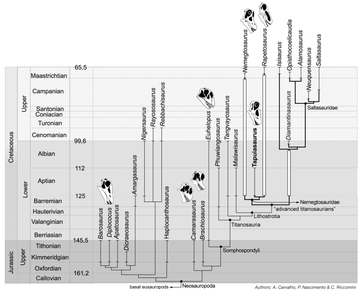


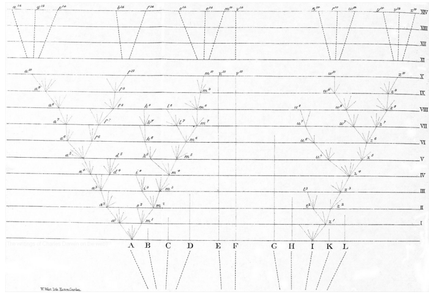


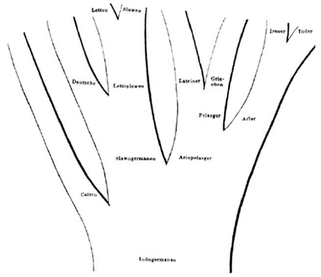


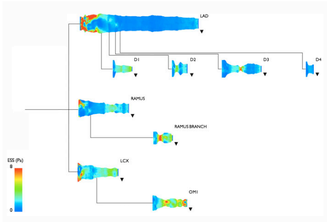




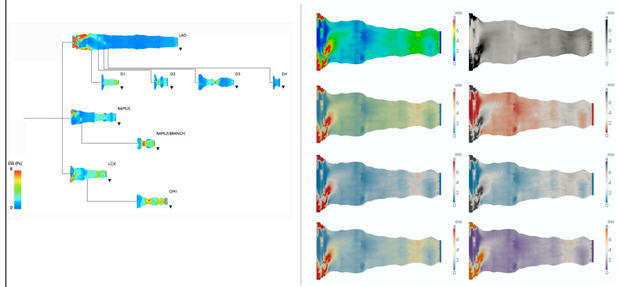




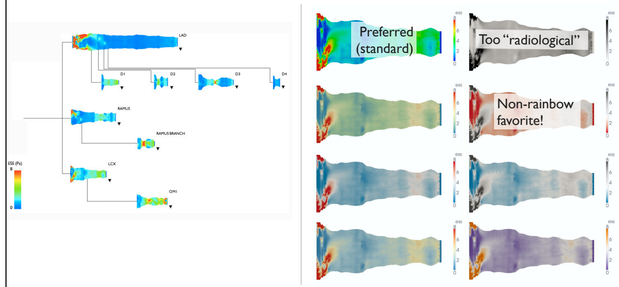




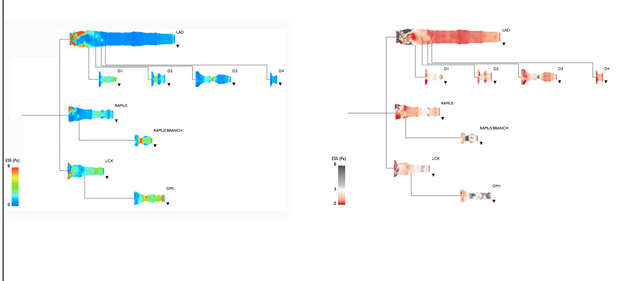
COLOR

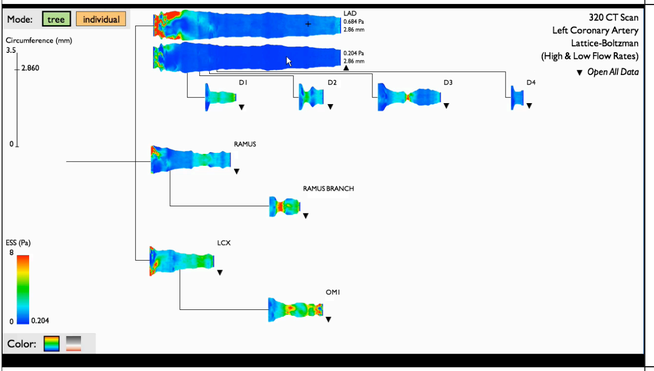


COLOR



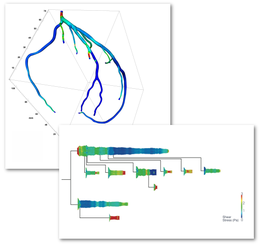
COLOR



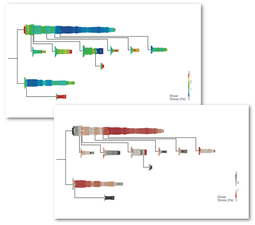


QUANTITATIVE STUDY: GOALS

3D vs. 2D

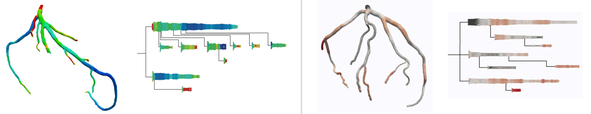


rainbow vs. diverging



QUANTITATIVE STUDY

- 21 Harvard Medical students (12 women and 9 men)
- Mixed within-subject and between-subject design:
  - *within* = dimensionality of representation (2D or 3D)
  - *between* = color mapping (rainbow or diverging)

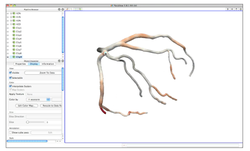


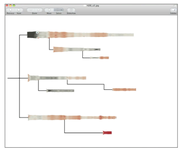
e.g., Participant A

e.g., Participant B

QUANTITATIVE STUDY

- Dependent measures:
  - fraction of low ESS regions identified
  - number of false positives (i.e., non-low ESS regions identified as low ESS)
  - time to complete a diagnosis





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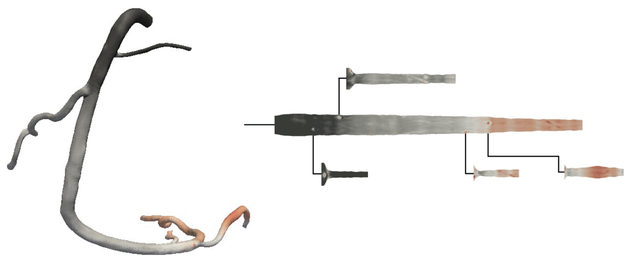

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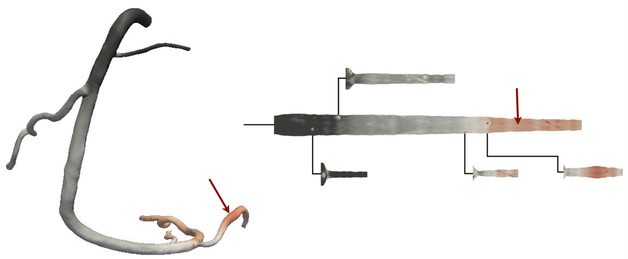

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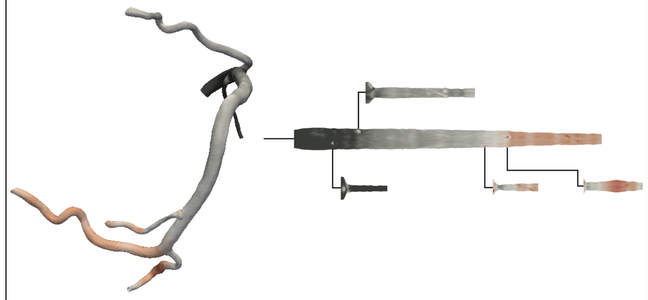

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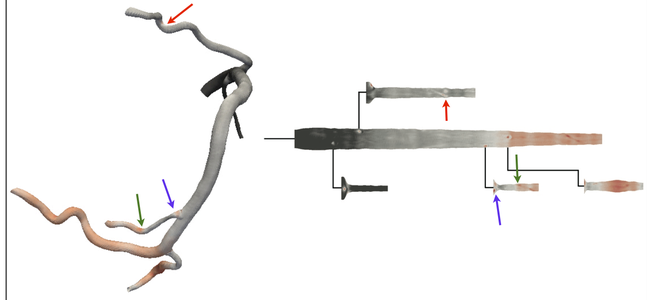
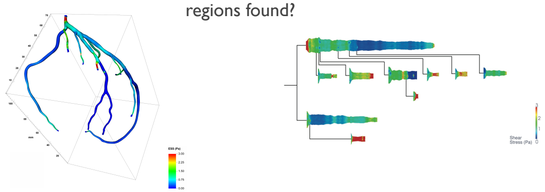


Results

Accuracy

Strong effect of **dimensionality** on accuracy

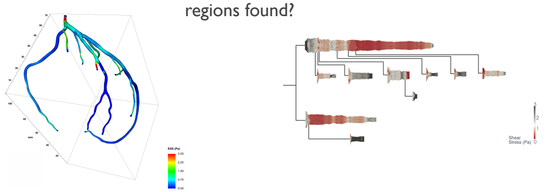
39% How many low ESS regions found? 62%



Accuracy

Strong effect of **dimensionality** on accuracy
...as well as **color**

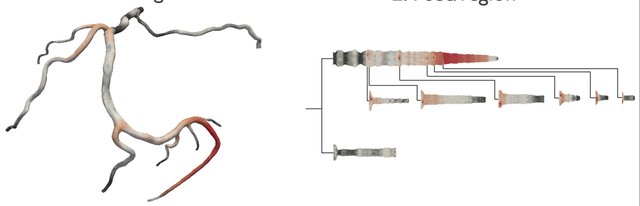
39% How many low ESS regions found? 91%



Efficiency

Participants more **efficient** in **2D**.

5.6 sec/region 2.4 sec/region



Efficiency

Participants more **efficient** in **2D**.

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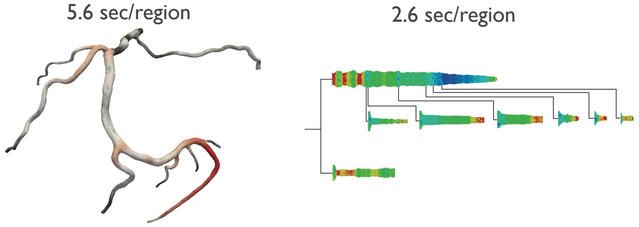
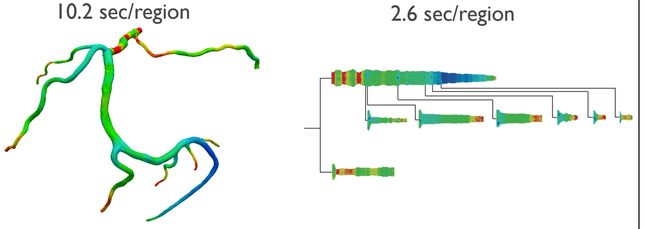


Efficiency

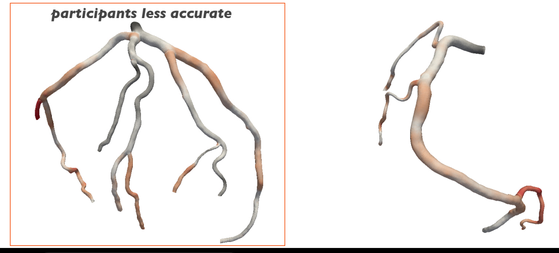
Participants more **efficient** in **2D**.
Rainbow color map has greater effect on efficiency in 3D.

10.2 sec/region 2.6 sec/region



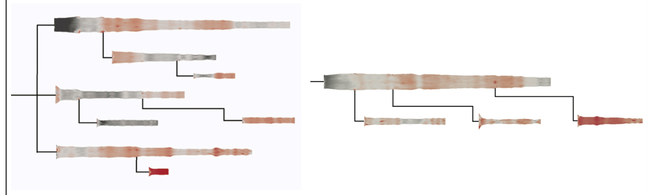
Complexity

Accuracy decreases with increased data complexity in 3D



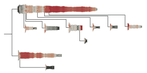
Complexity

Accuracy decreases with increased data complexity in 3D
(not true in 2D!)

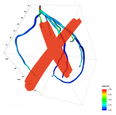


Findings Summary

- Even for 3D spatial data, a **2D** representation is
  - more **accurate** for spatial tasks
  - more **efficient** for spatial tasks

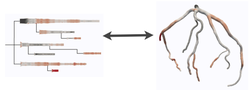


- Rainbow color map
  - is **not accurate** and **not efficient**
  - has adverse effects even greater in 3D

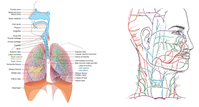


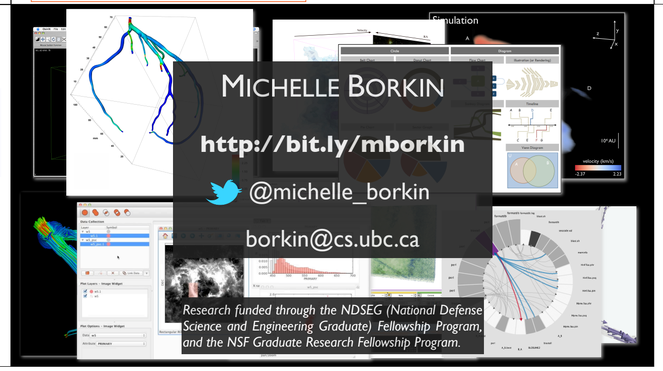
Final Remarks

- 3D representation is still essential for surgical planning



- 2D tree diagram applicable to other applications





Michelle Borkin
http://bit.ly/mborkin
@michelle_borkin
borkin@cs.ubc.ca

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