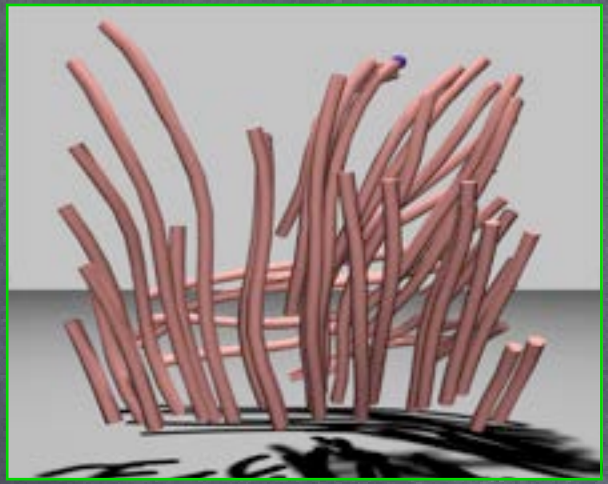
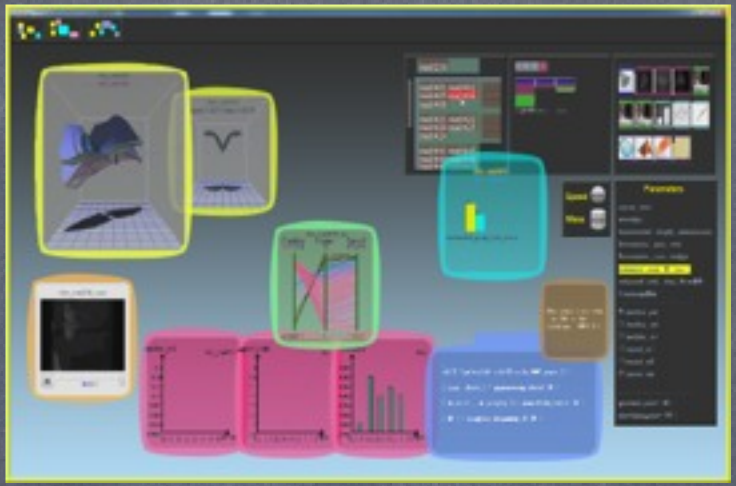
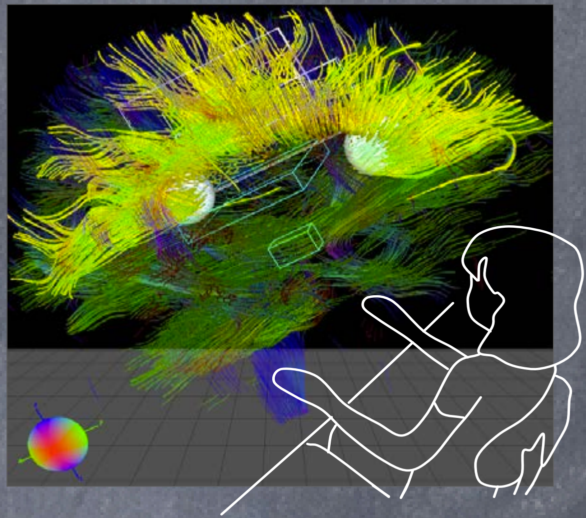
A Visualization Language

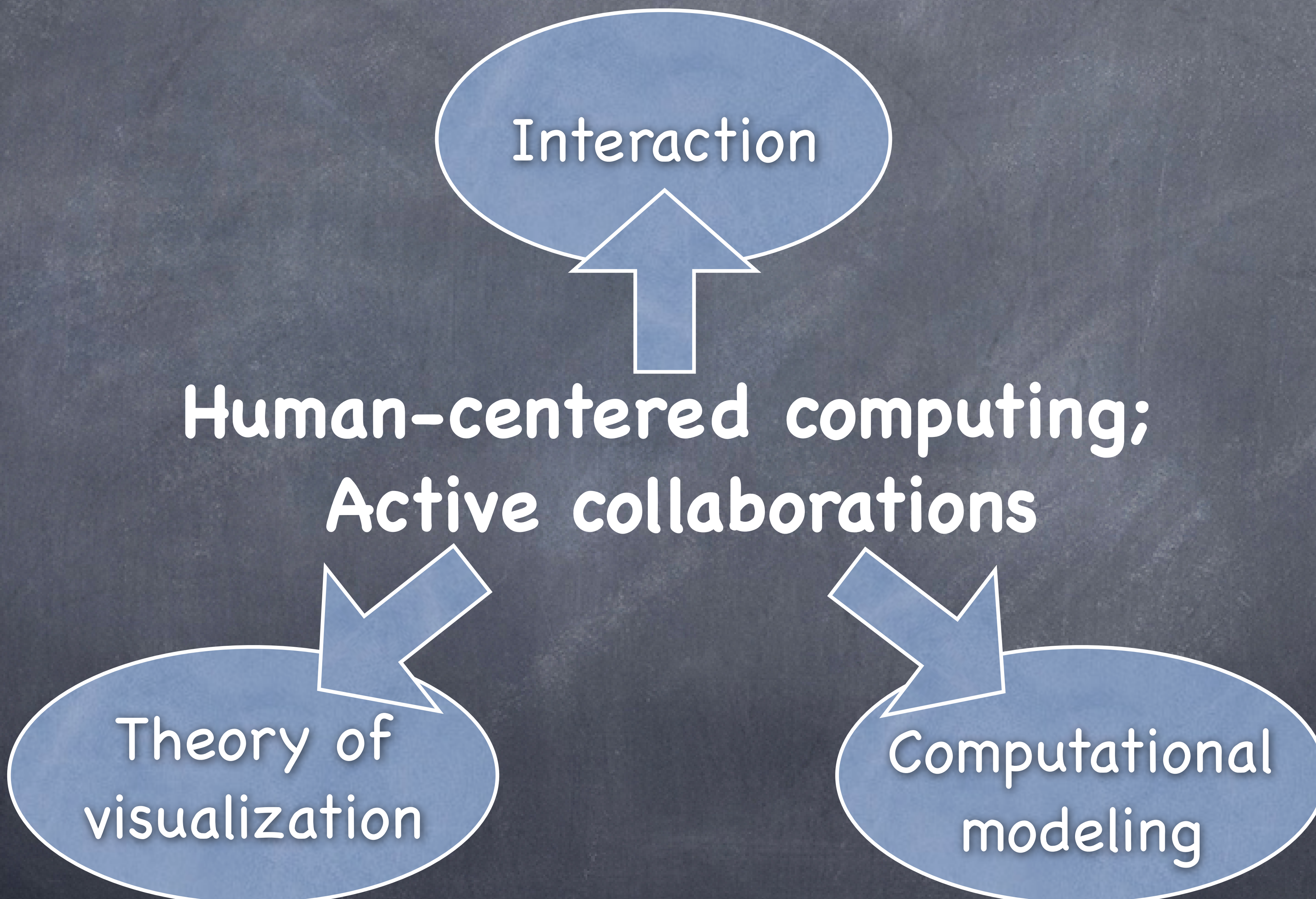




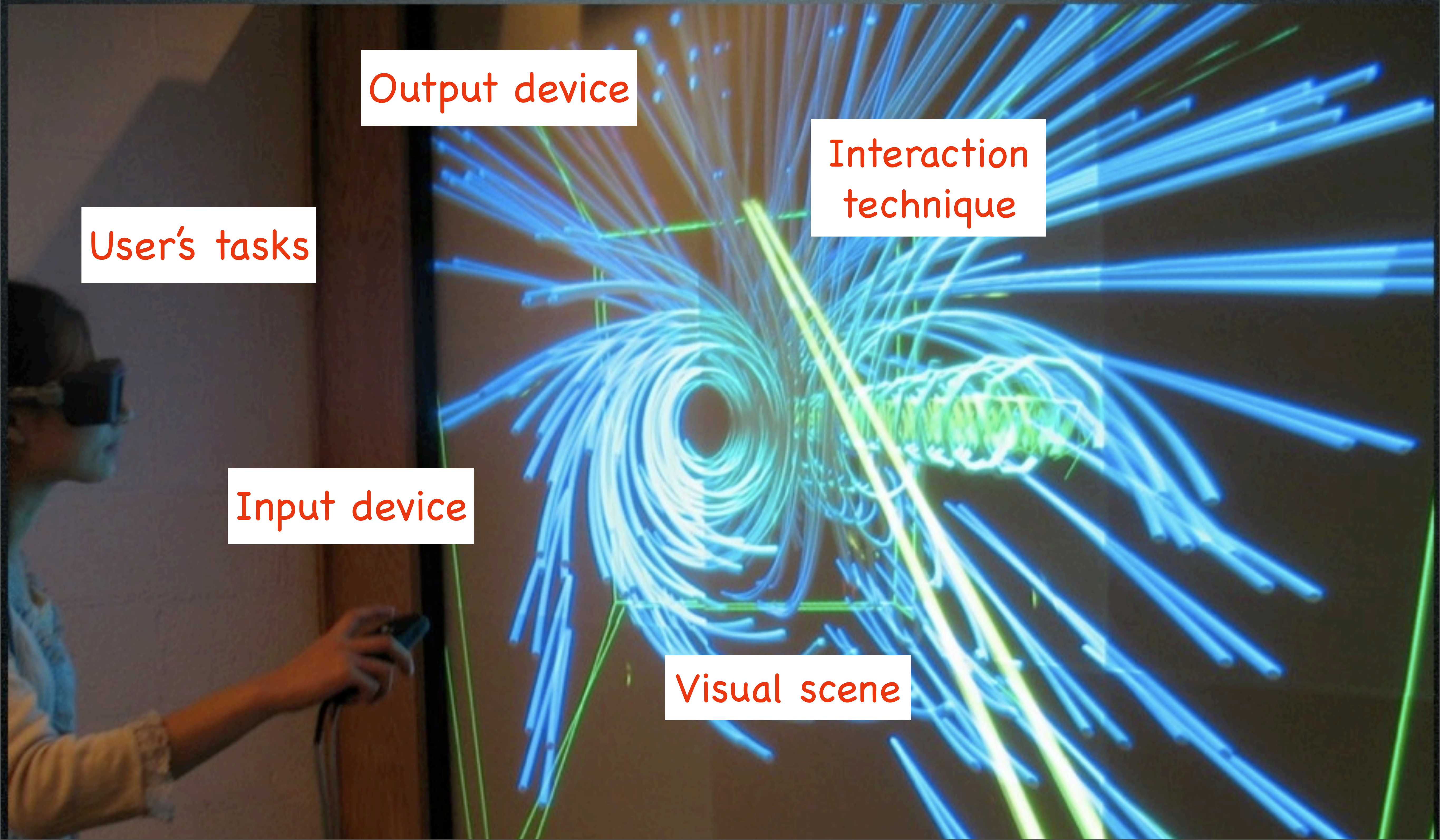


Jian Chen, PhD
http://www.csee.umbc.edu/~jichen
the DaVinCI lab (Data visualization, computing, interaction)

Research Program



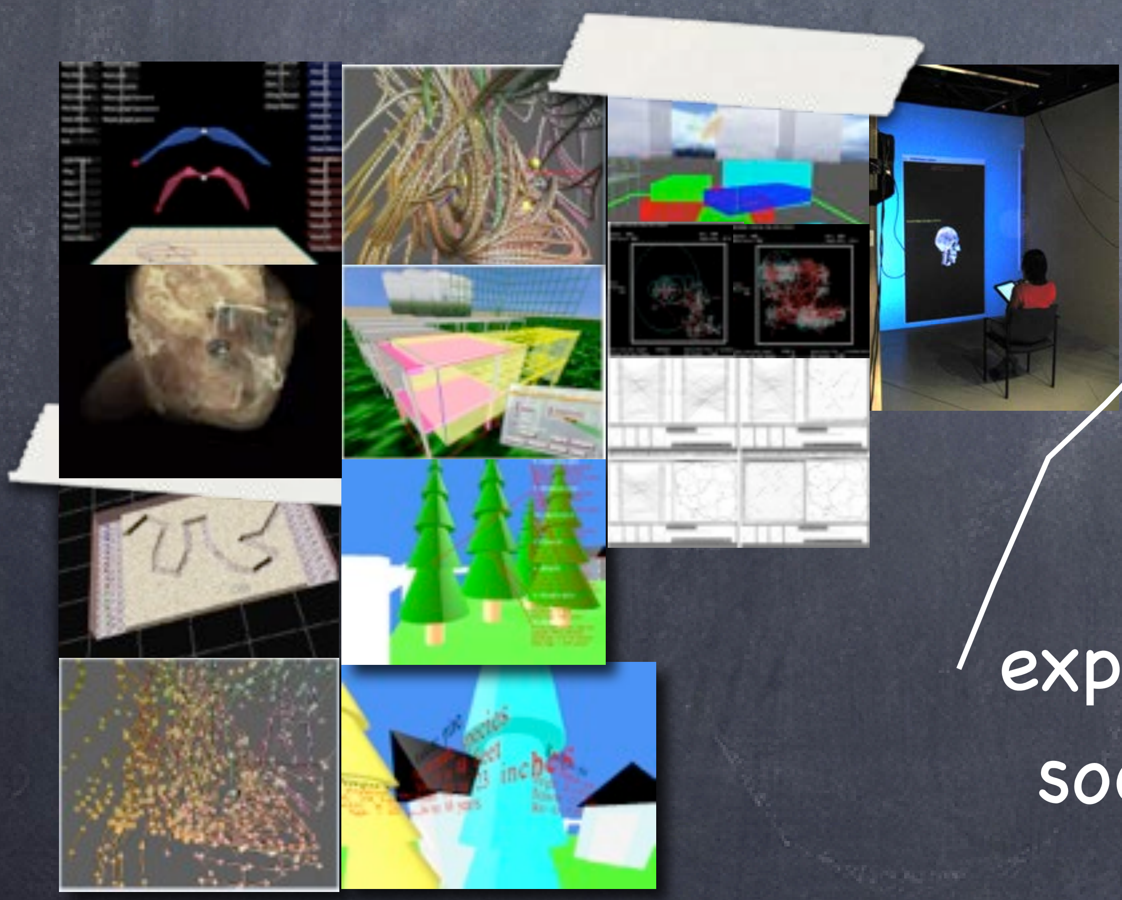
An interactive environment



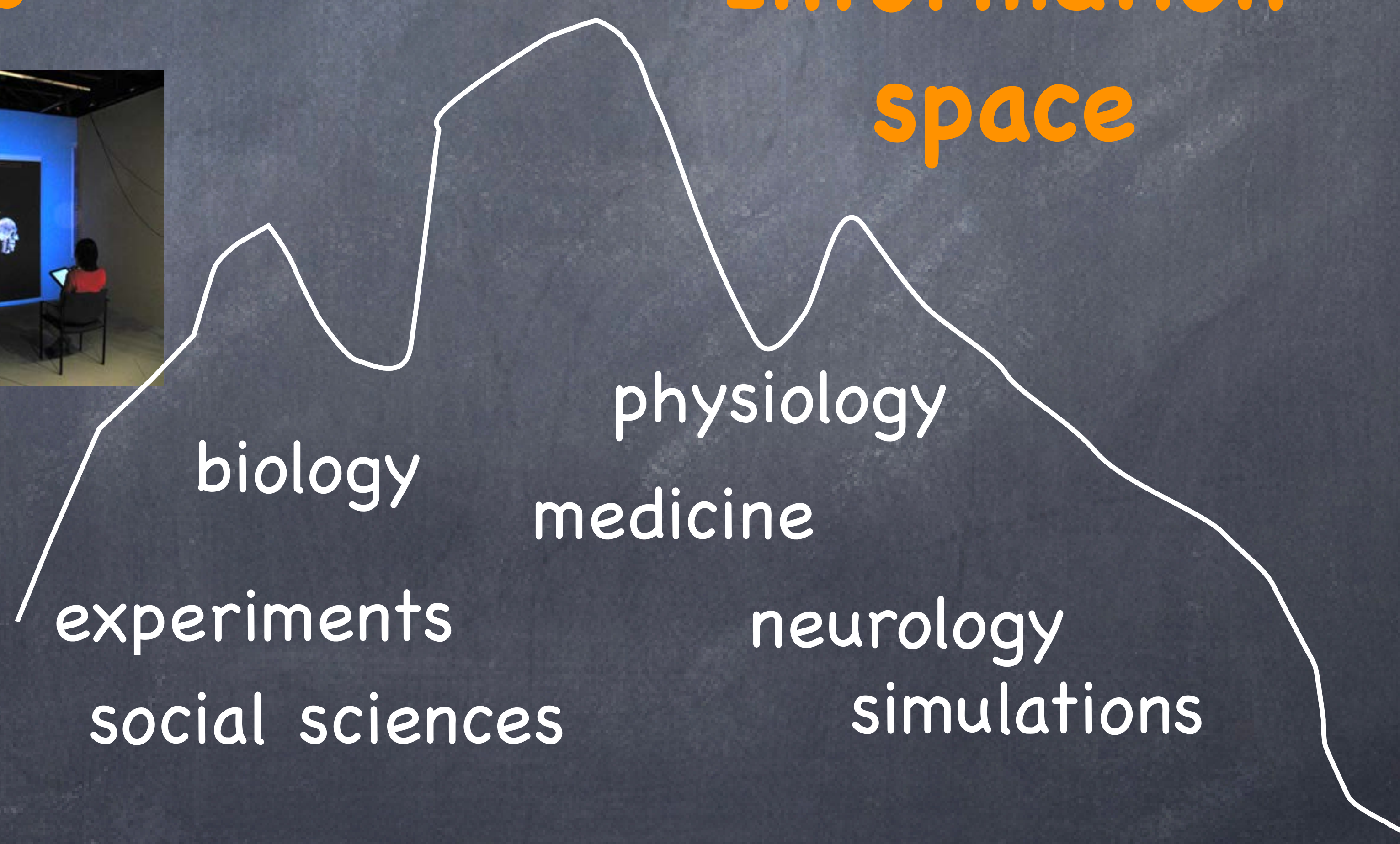
Problem statements

- Urgent needs to understand how to design visualizations to support understanding of the amount of information from complex systems.

Visualizations



Information space

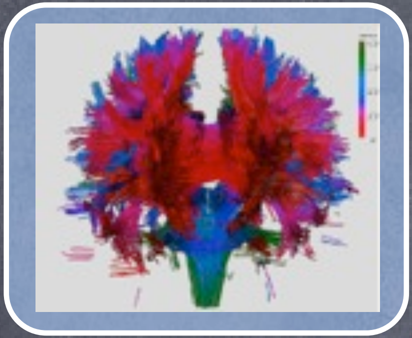


- How does visualization support **seeing**? and what do scientists **see** from mountains of data?

Theory of visualization

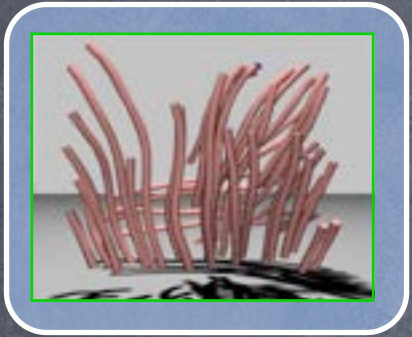
- How to enable more effective **knowledge discovery process** in large information space?

Interactivity



1. A scientific visualization **language** for diffusion-tensor MRI visualization

Descriptive framework of seeing

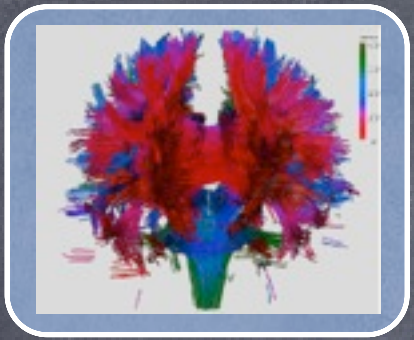


2. **Experiment**: understanding illumination models

Experiments

3. Workflow-driven design for time-varying bat flight **analysis**

Knowledge discovery

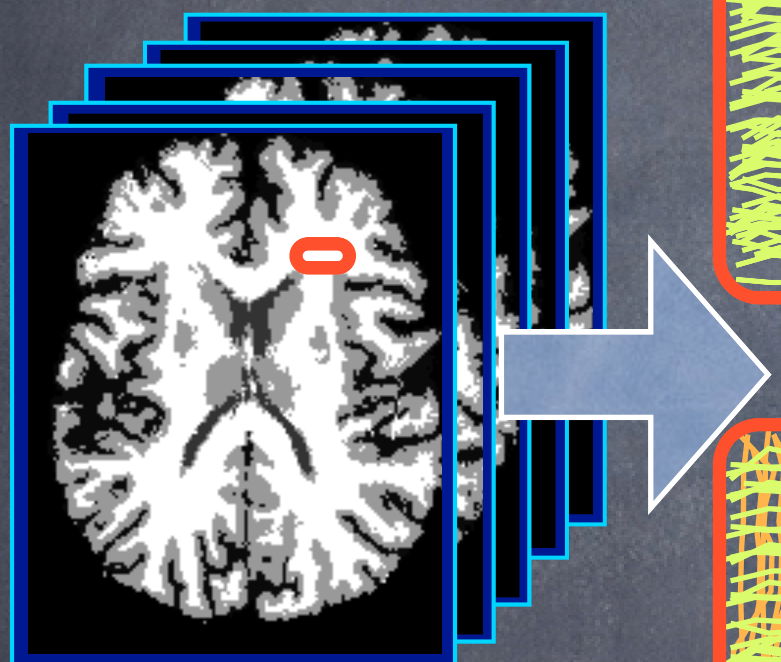


1. A scientific visualization **language** for diffusion-tensor MRI visualization

Collaborators:

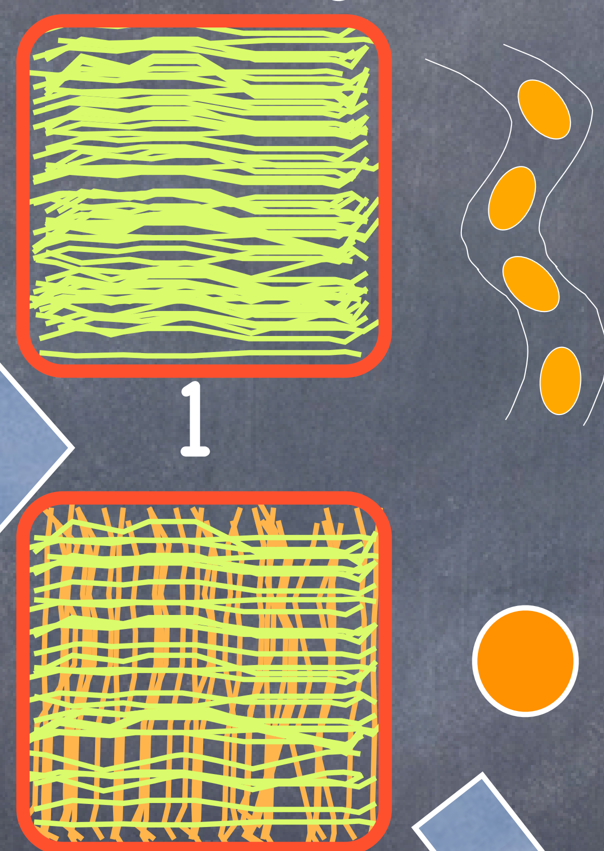
- **Computer science**: David H. Laidlaw (Brown)
- **Neurology**: Alexander P. Auchus (UMMC)

Diffusion-tensor MRI



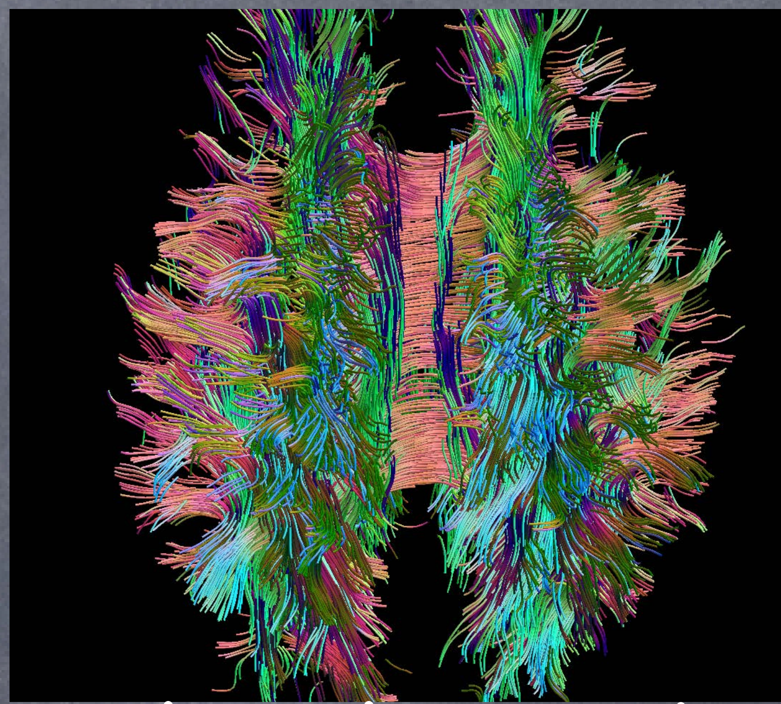
MRI

tensor shapes

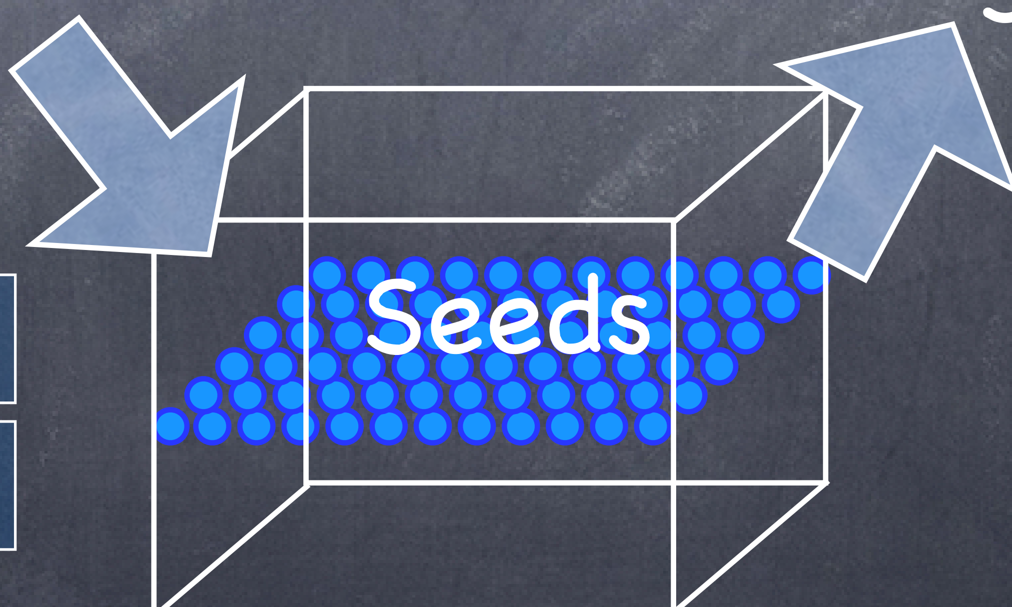


1

2



tractography



More measurement matrices

Not real-time (data intensive)

“General” graphics theory

Semiotics: the study of sign (Bertin 1967)

data -> graphics signs

- Angular separation
- Retinal variables
  - position
  - size
  - value
  - texture
  - color
  - orientation
  - shape

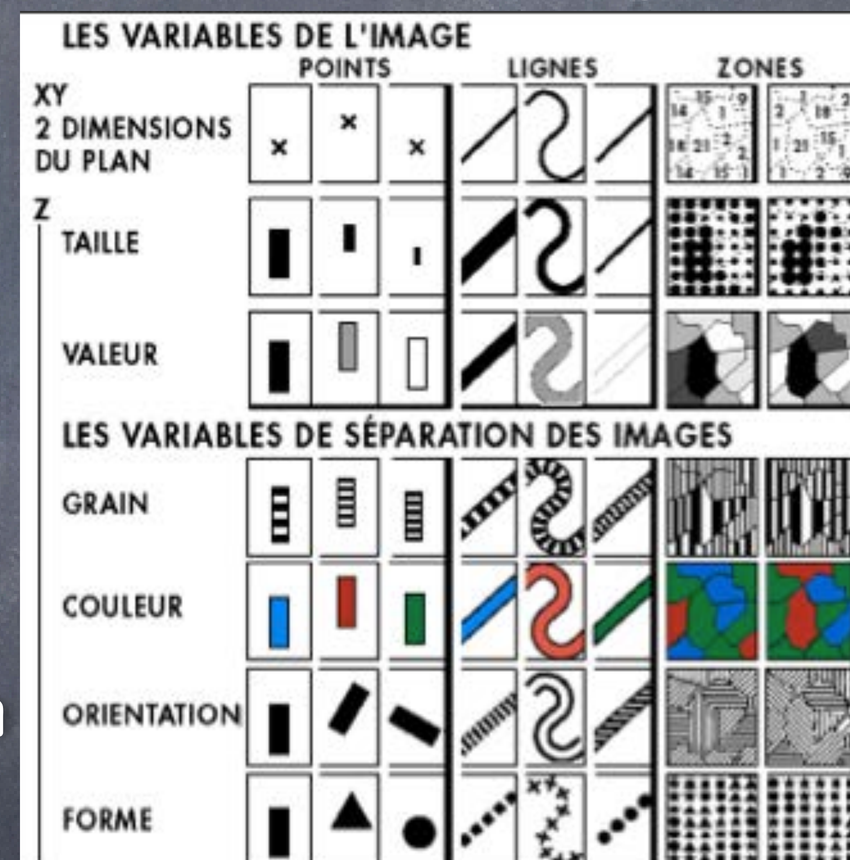
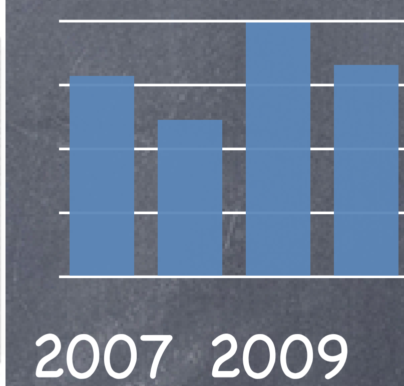
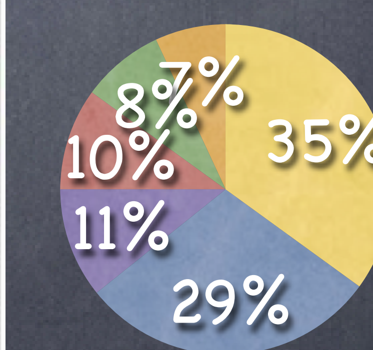


Figure courtesy of Bertin 1967



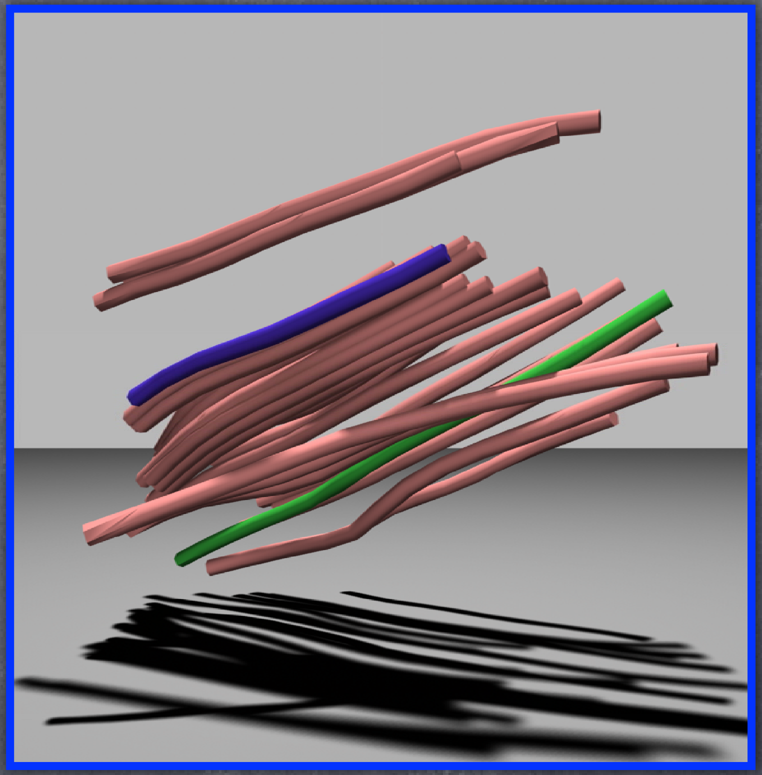


Applied to InfoVis by Mackinlay (Stanford, 1986), Fry (MIT/Harvard, 2006), and Heer (Berkley 2007).

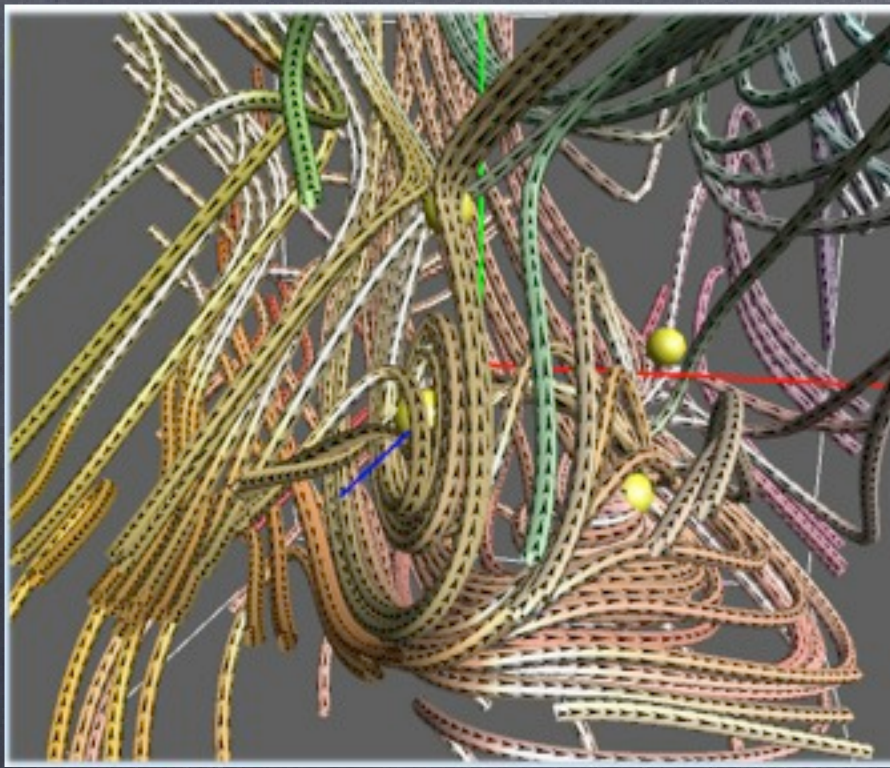
Our 3D semiotics theory

point, line, area, **volume**

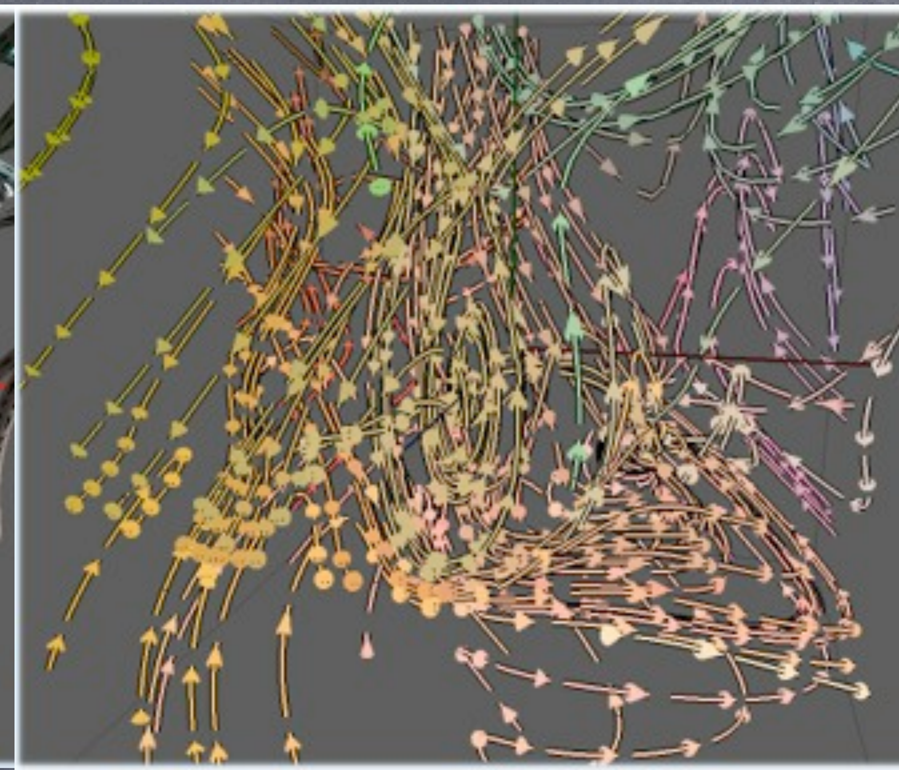
- Angular variables
  - **depth**
- Retinal variables
  - position
  - size
  - value
  - texture
  - color
  - orientation
  - shape
  - **rendering style**



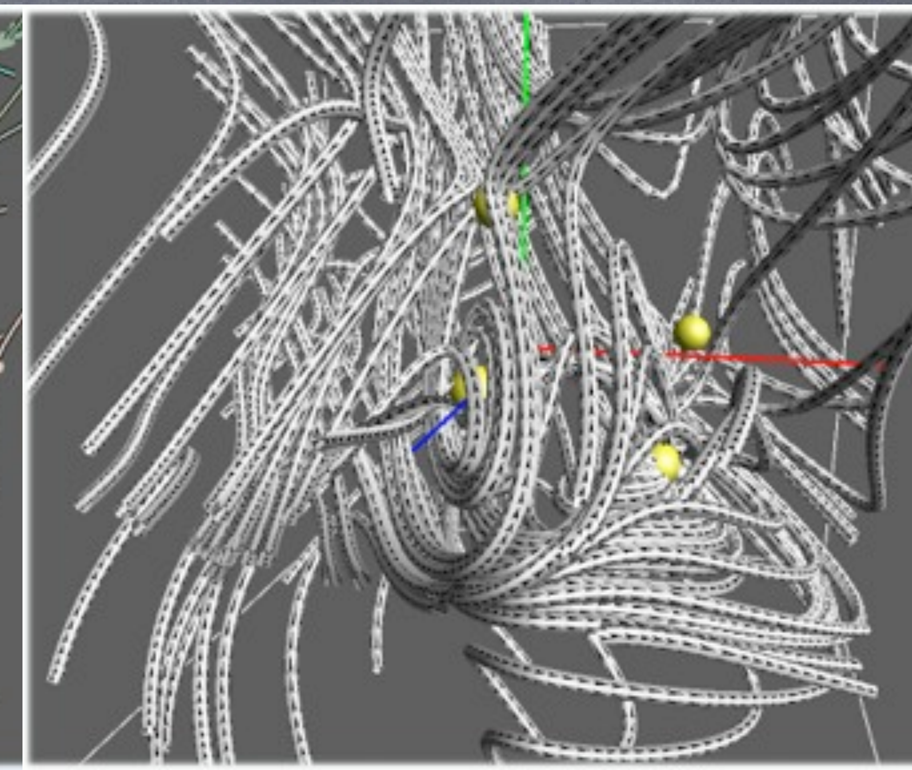
J. Chen, On the semiological analysis of diffusion tensor field visualizations, IEEE TVCG (in progress).



flow direction -> color
flow speed -> texture
size



flow direction -> color
flow speed -> shape



flow speed -> texture
size

How to study these dimensions?

- Design space must inform design (visualization technique and problem solving environment)

point, line, area, **volume**

Angular variables

depth

Retinal variables

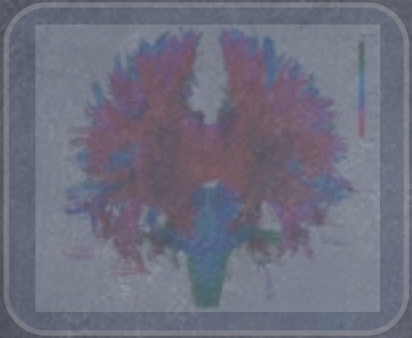
- position
- size
- value
- texture
- color
- orientation
- shape
- **rendering style**

Which dimensions are most important?

Are these the right level of representation in a problem solving environment?

Our approach

- Strongly hypothesis-driven experimentation
- End-to-end, breadth-first reciprocal research strategy
- Corpus collection & data-driven research



1. A scientific visualization **language** for diffusion-tensor MRI visualization

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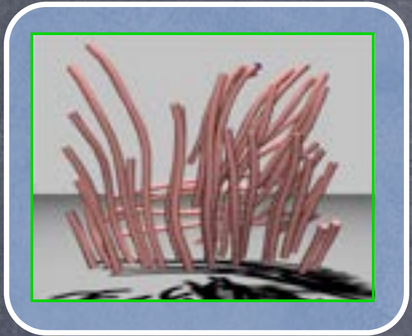


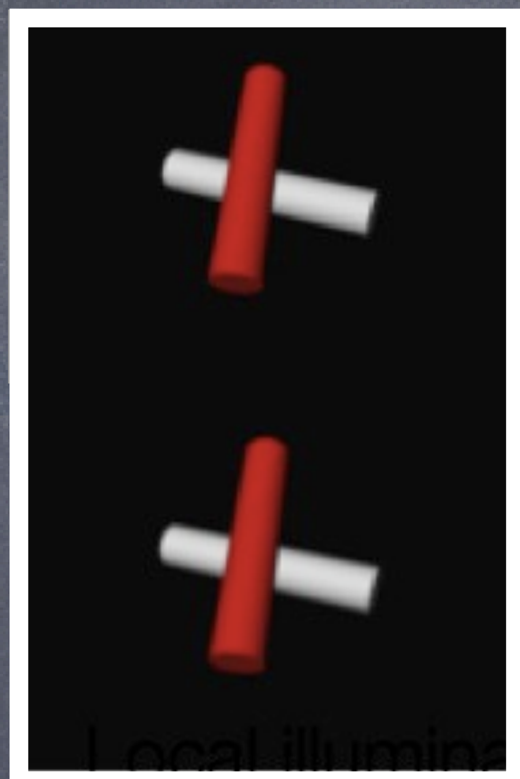
2. **Experiment**: understanding illumination models

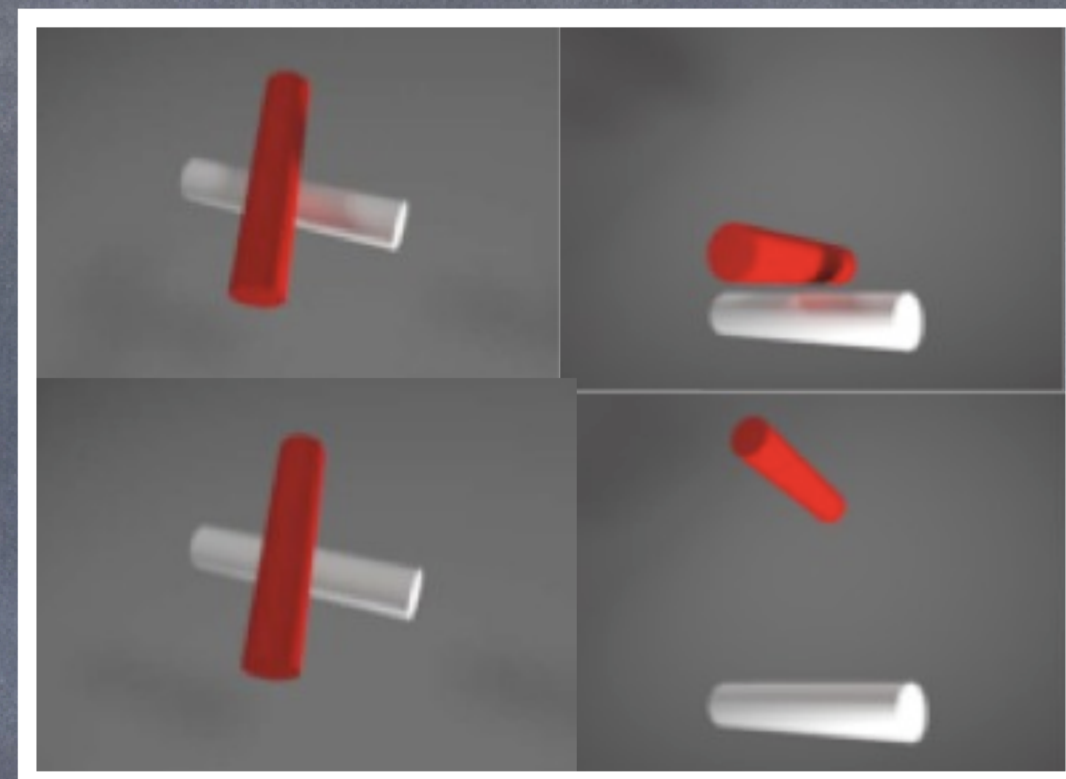
Experiments

Goal: study the effect of global illumination on task performance in complex visual scenes.

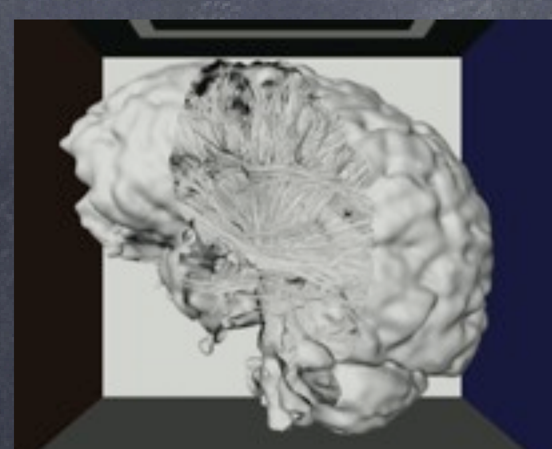
Motivation: Illumination Models

Image courtesy of David Banks (Harvard / U. of Tennessee)

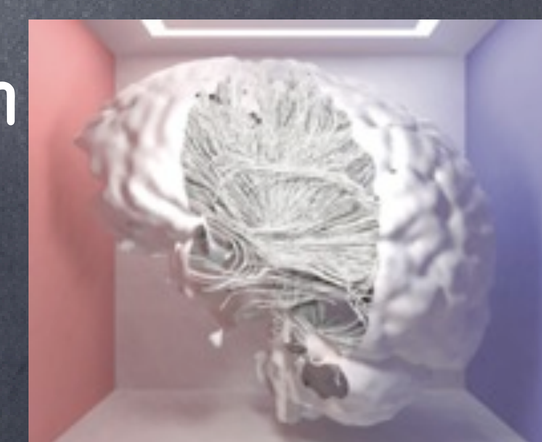




Local illumination model (OpenGL)



Global illumination model (GI)



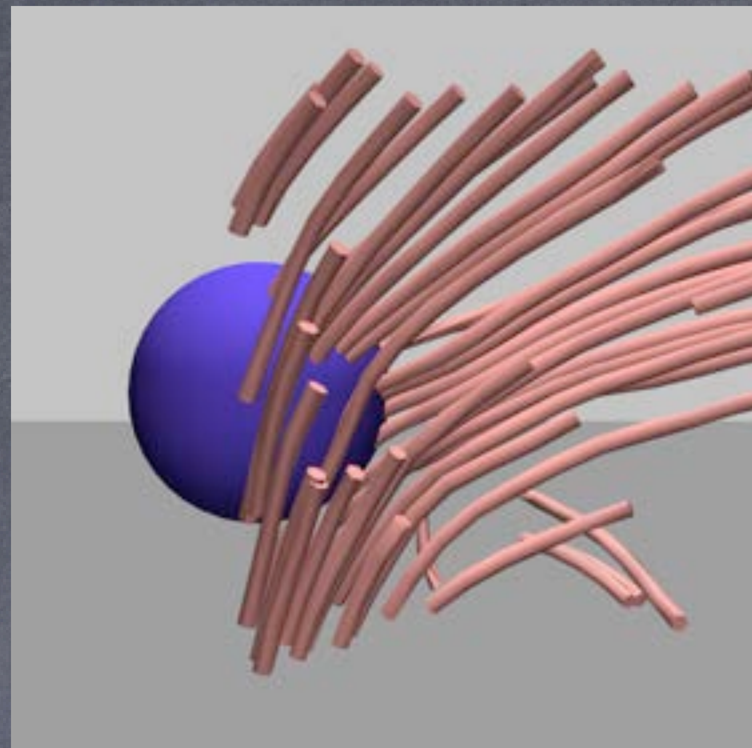
Hypotheses

- Independent variables:
  - illumination model, texture, motion, and scene complexity
- Depend variables
  - Time and error rate

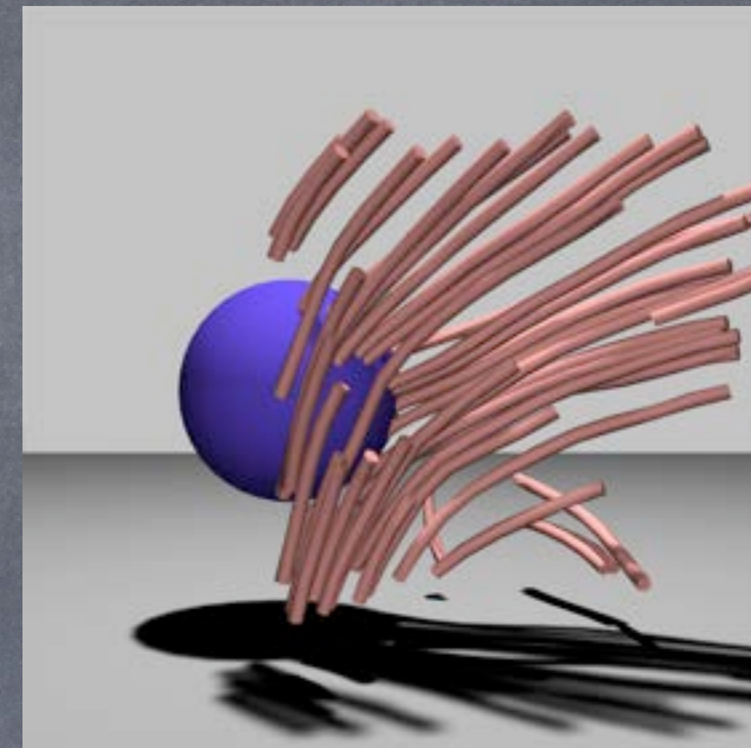
GI > OpenGL

Motion > No motion

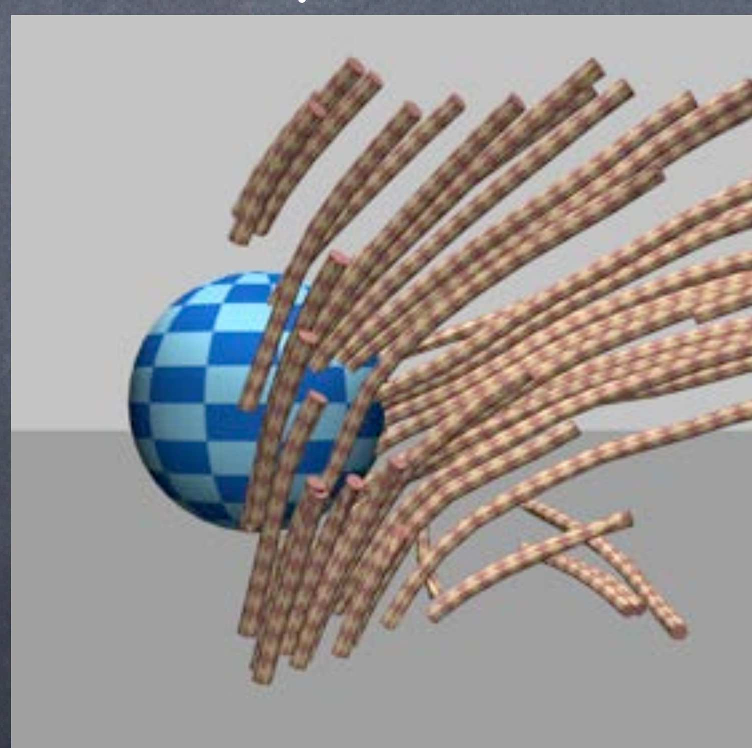
Texture > No texture



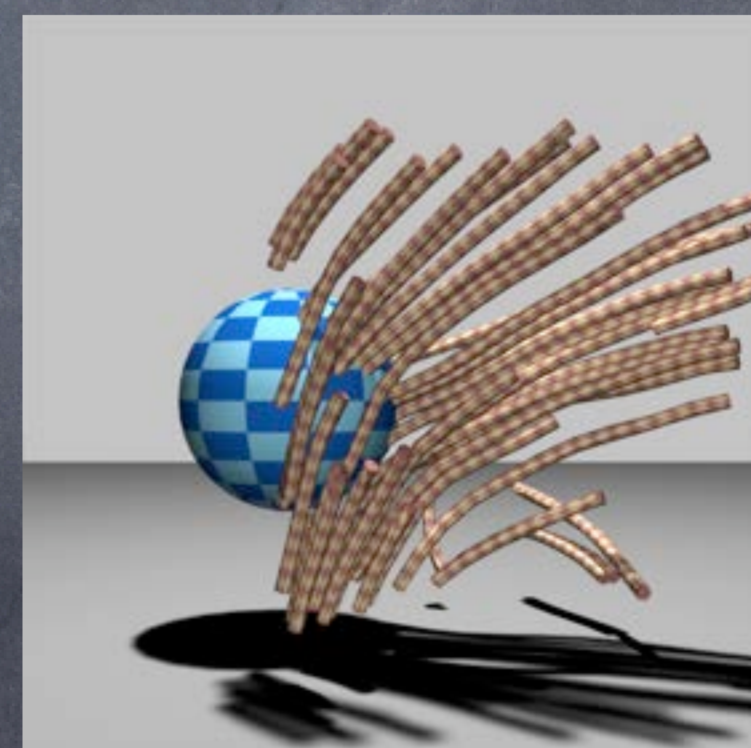
OpenGL



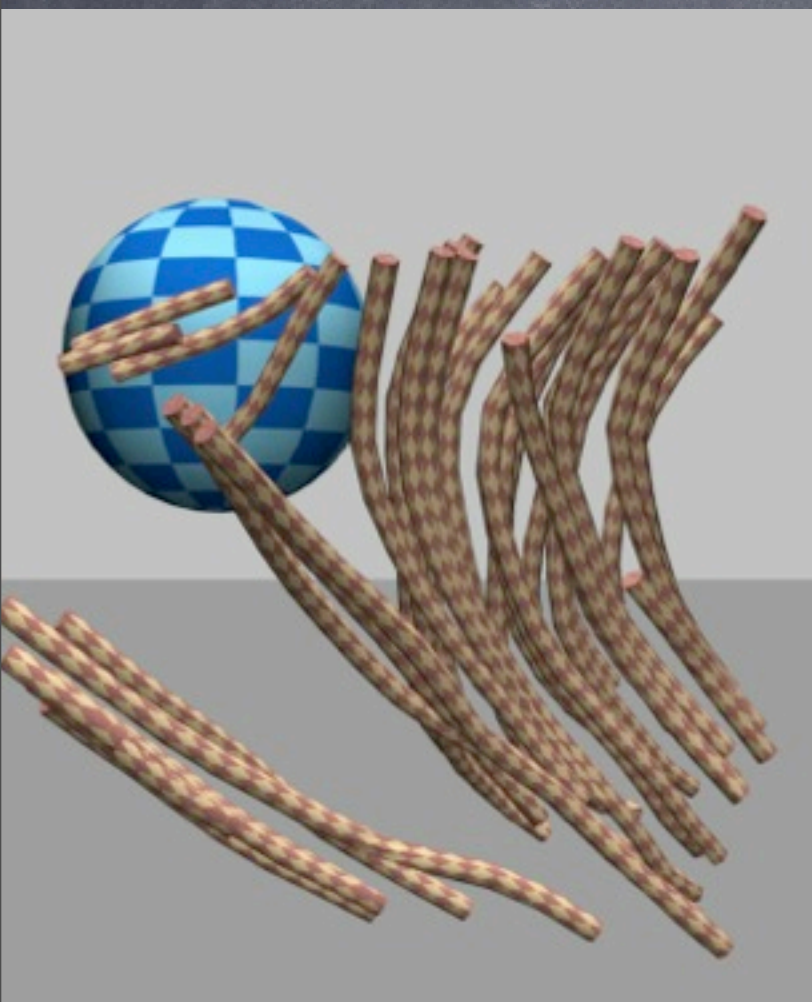
GI



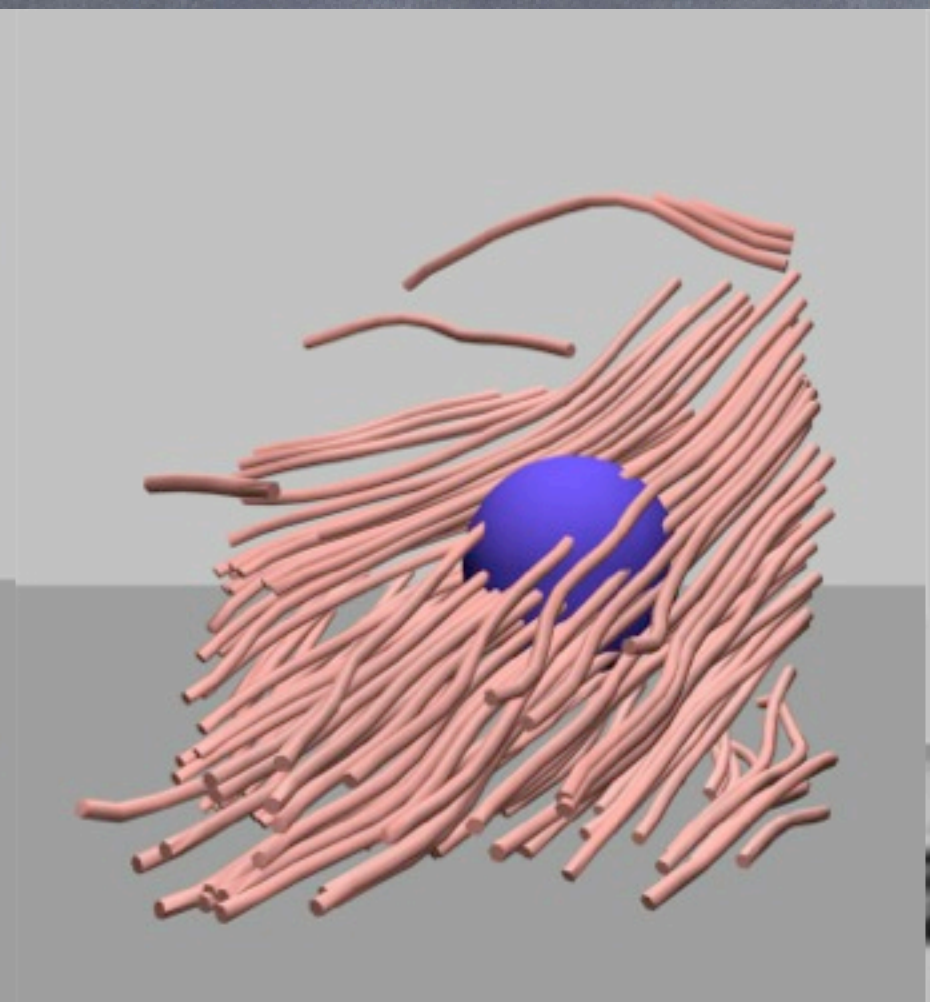
OpenGL+Texture



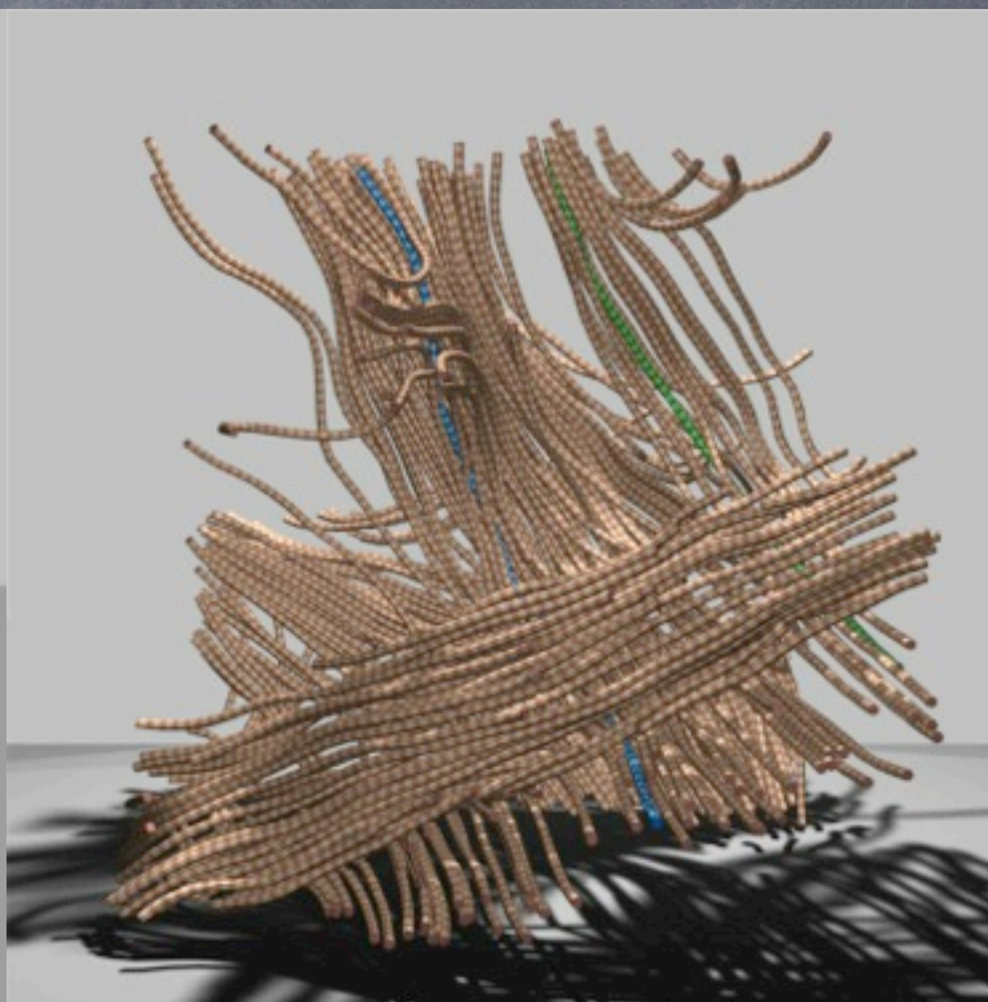
GI + Texture



small

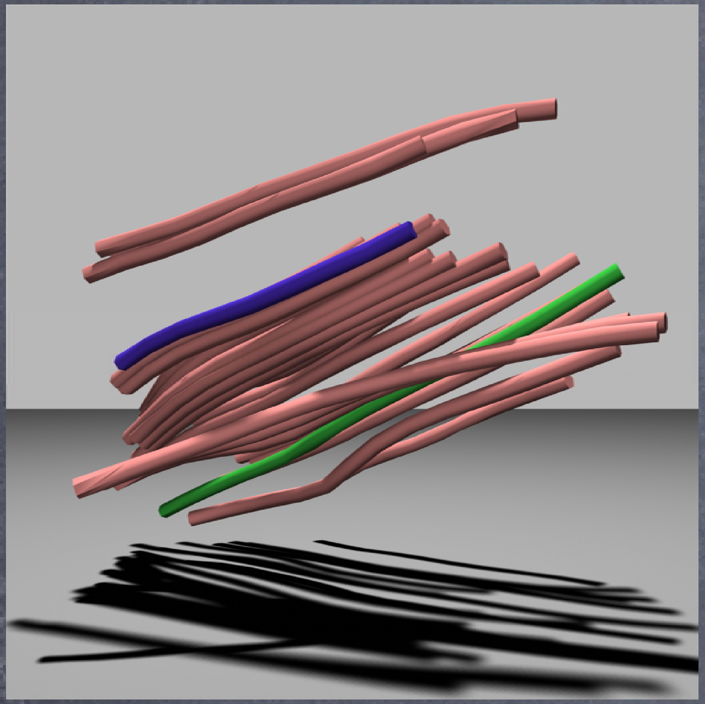


medium

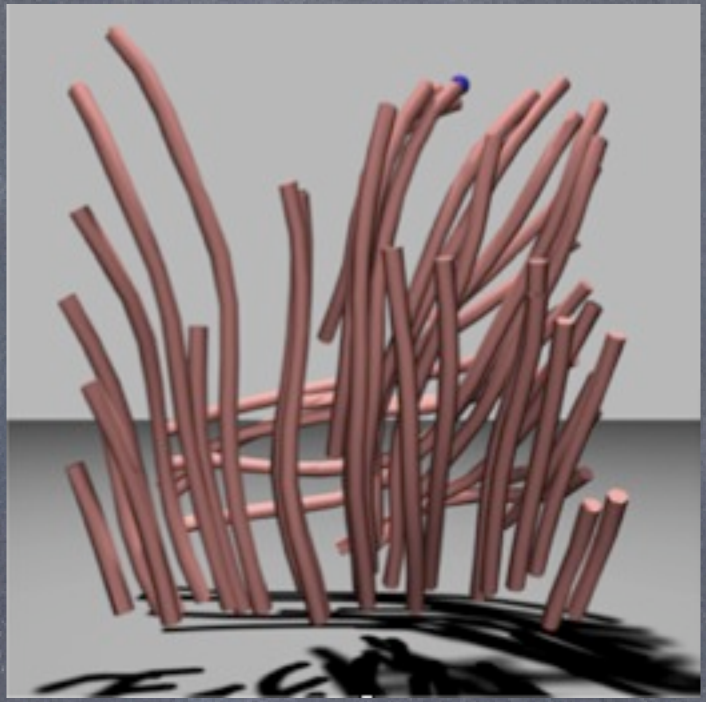


large

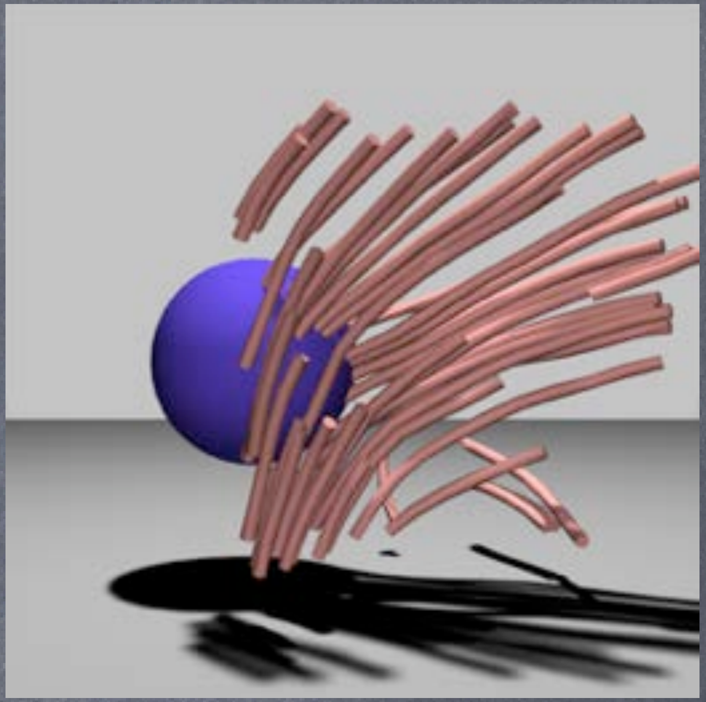
Task Conditions



Depth Judgment



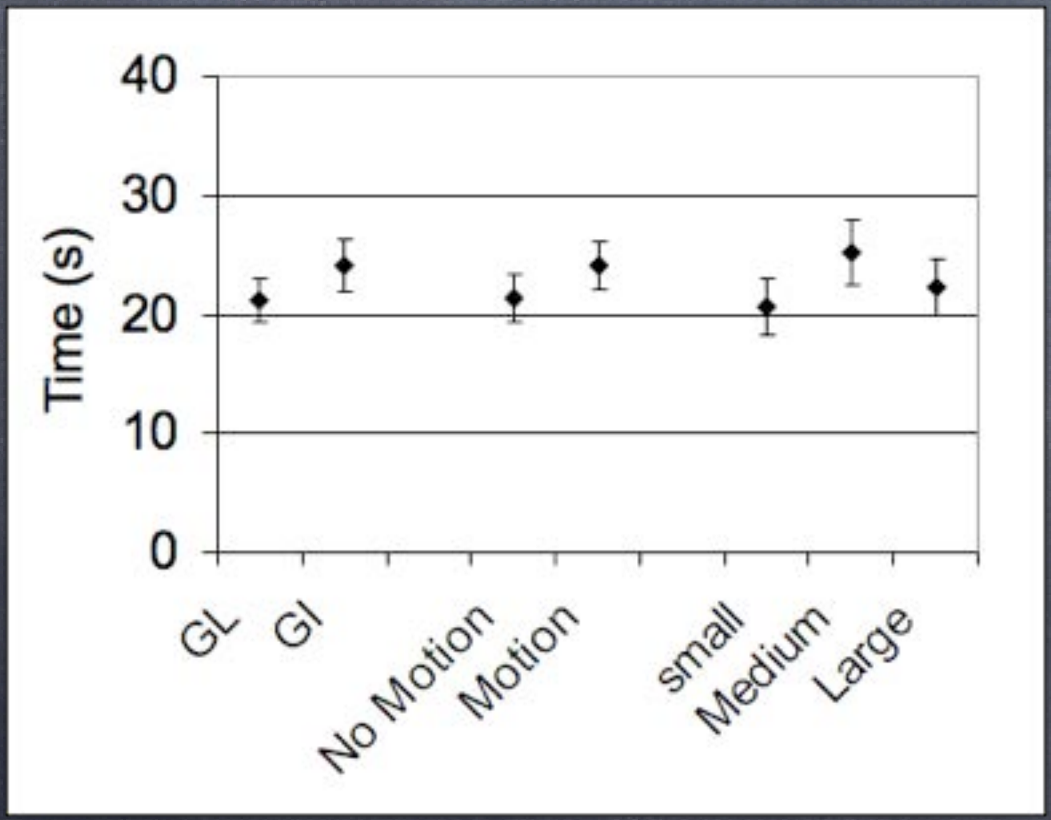
Visual Tracing

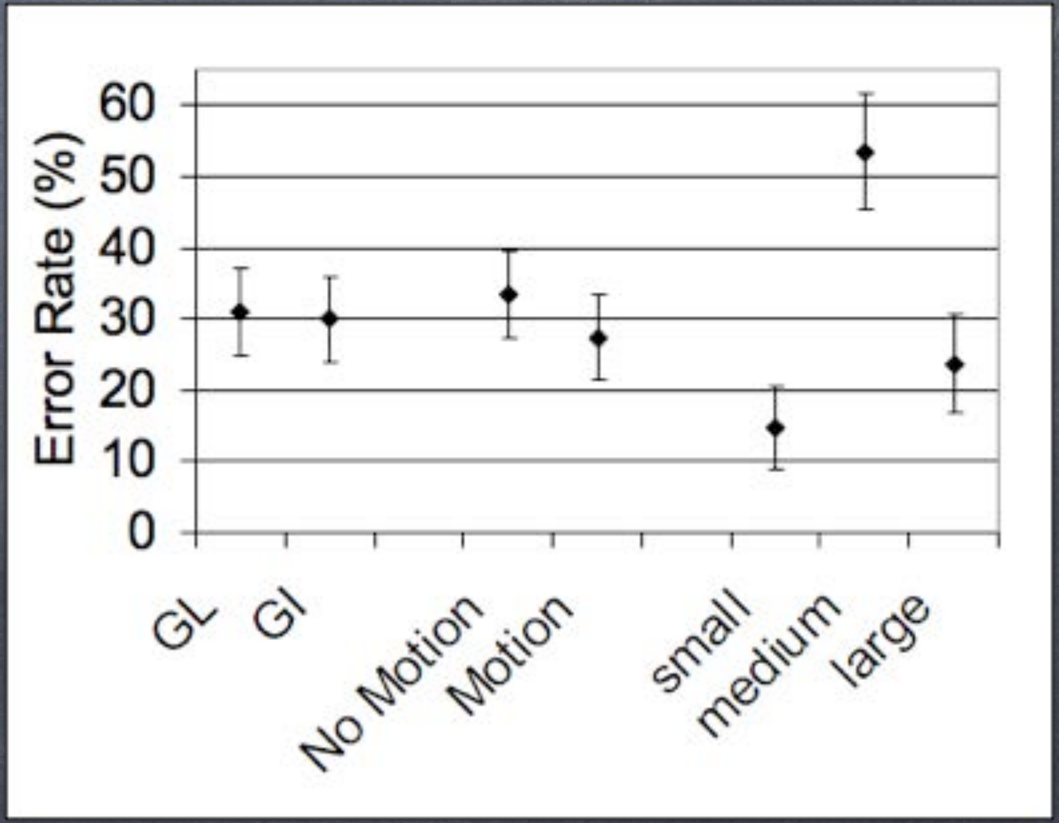


Contact Judgment

Results: Motion on Performance

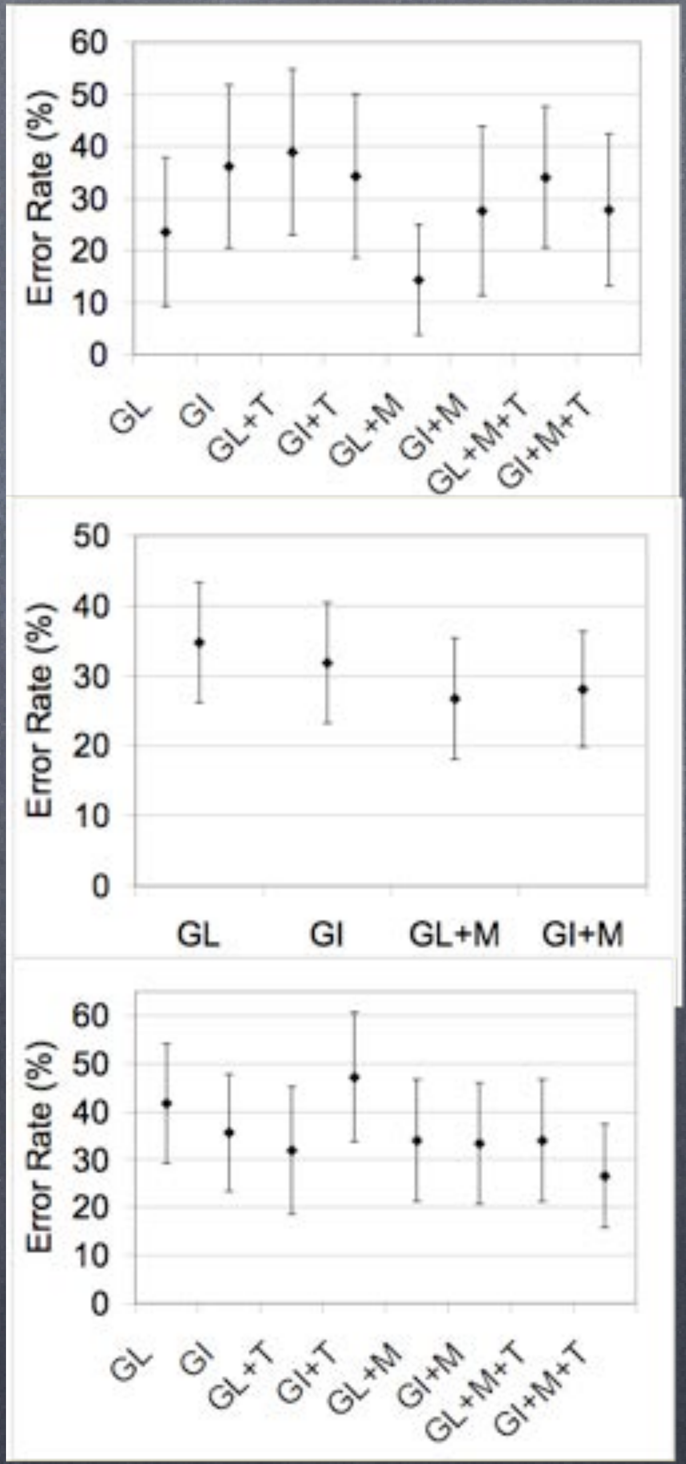
- Motion reduced error rate but at the cost of longer task execution time.

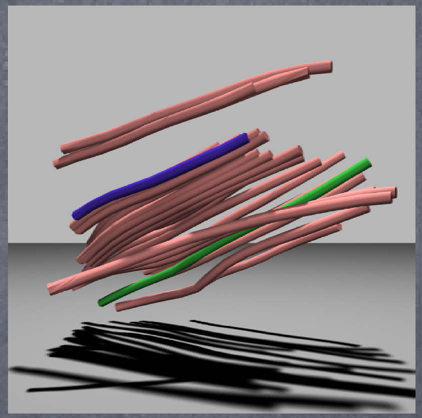


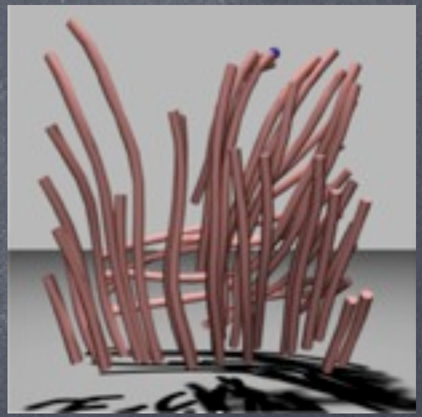


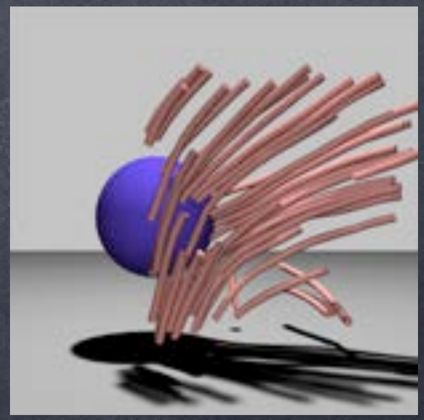
Results: Illumination Model on Performance

- GI -> higher error rate | global tasks
- GI = GL on error rate | local tasks
- GI -> lower error rate (not significant)



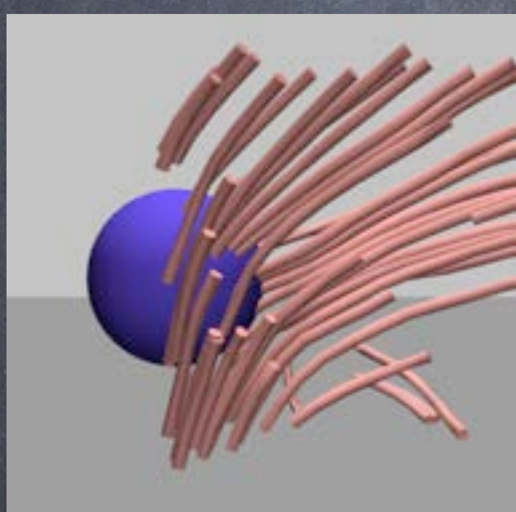






Results: Subjective Responses

- More cues = higher score



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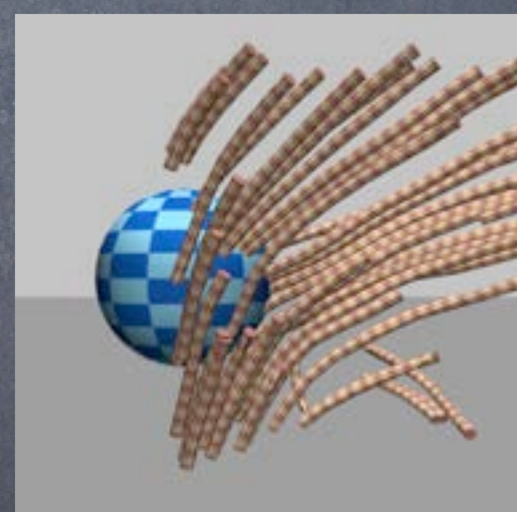

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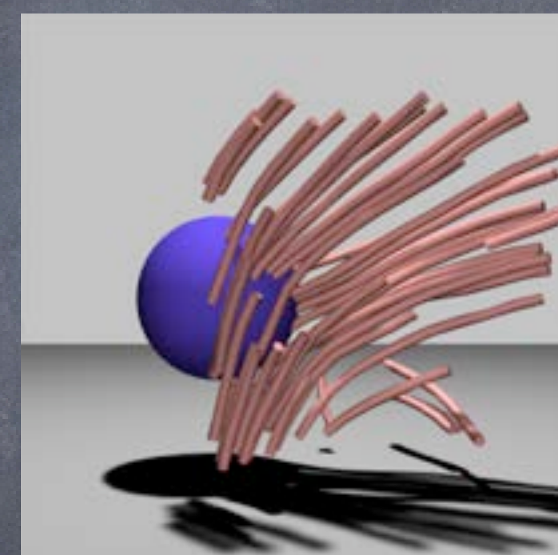

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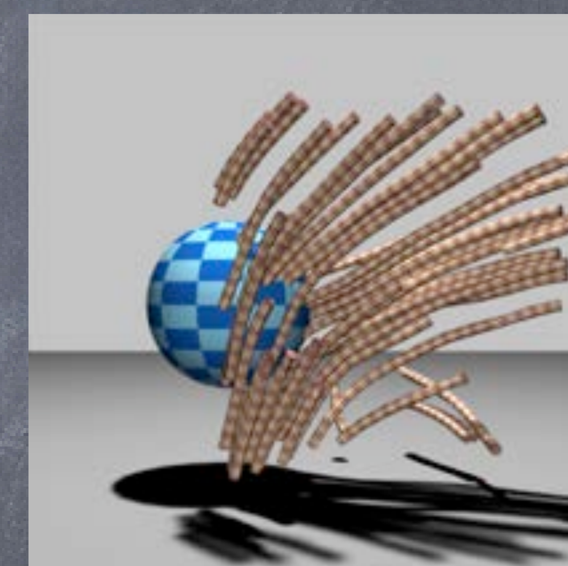


- Beautiful things are useful.

point, line, area, **volume**

- Angular variables
  - **depth**
- Retinal variables
  - position
  - size
  - value
  - texture
  - color
  - orientation
  - shape
  - **rendering style**

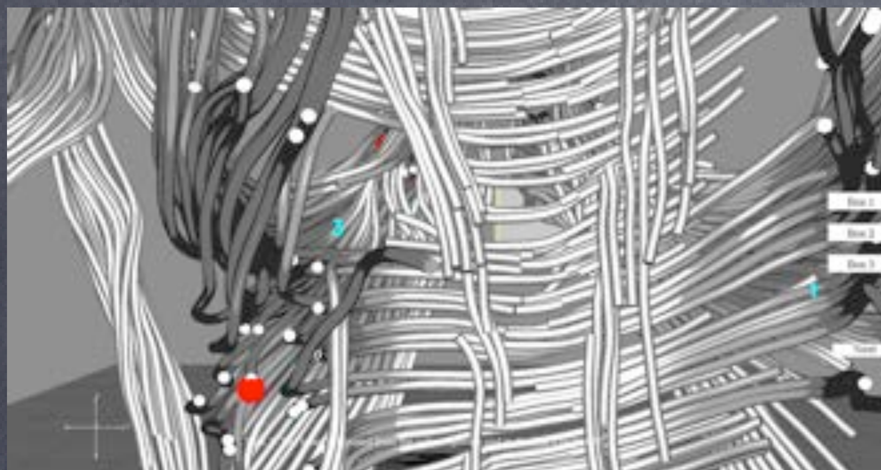
Which dimensions are most important?

Are these the right level of representation in a problem solving environment?

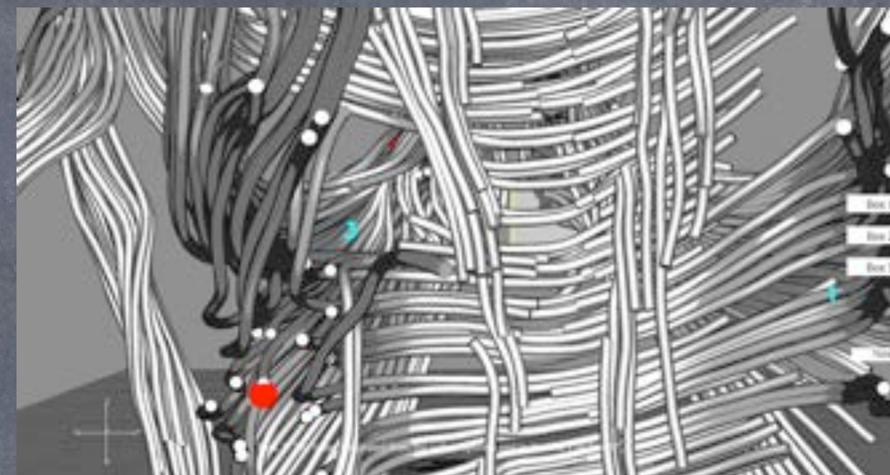
Contributions

- Significant first step
  - understanding how illumination model and motion -> time, error rate
- Functional value and perceived value are not equivalent
- Results could have impact on other types of 3D vector / tensor field visualizations

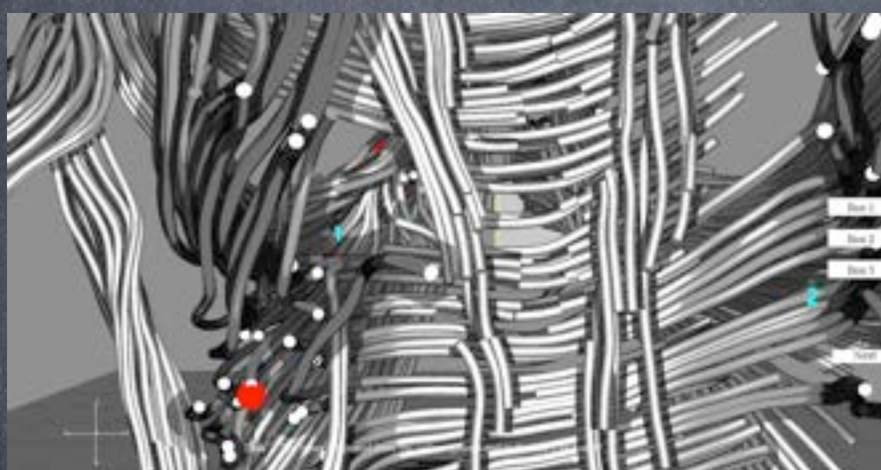
Current work: rendering style comparison



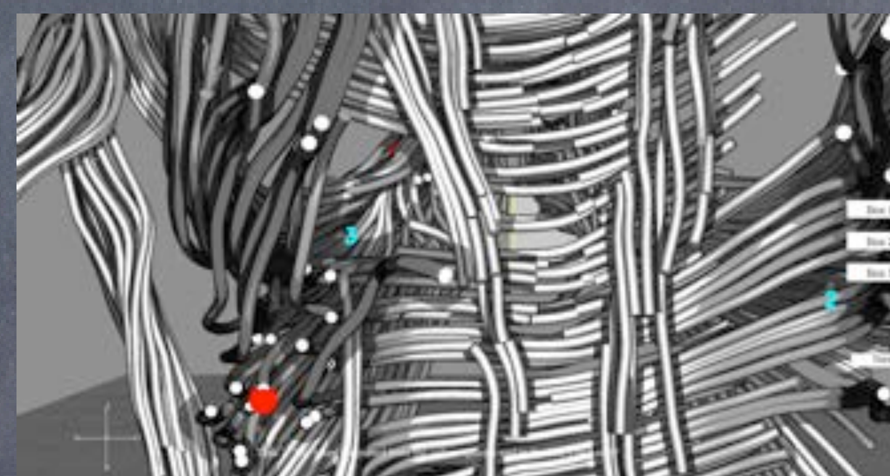
tone



tone+halo



tone+shadow



tone+shadow+halo

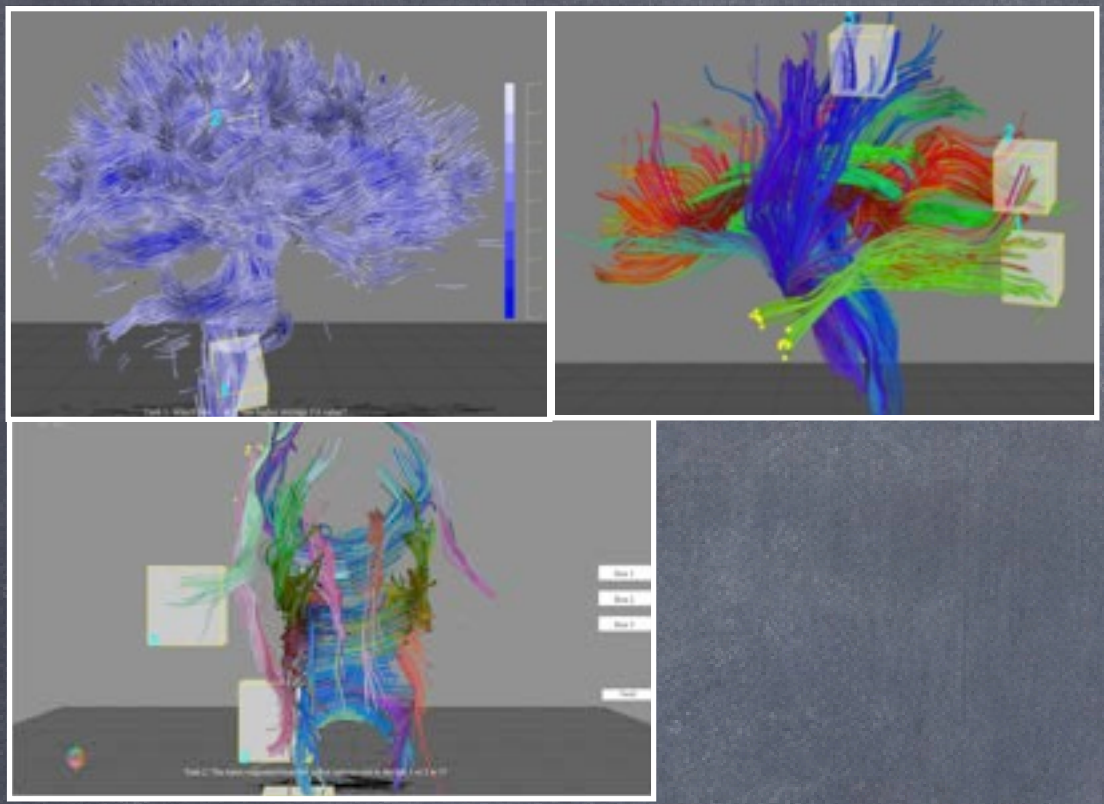
Research questions:

1. Are there any differences in accuracy and efficiency when we use artistic rendering?
2. Can artistic rendering replicate the cueing effects in realistic rendering?
3. Does the rendering style influence preferences and reassuring brain scientists' confidences?

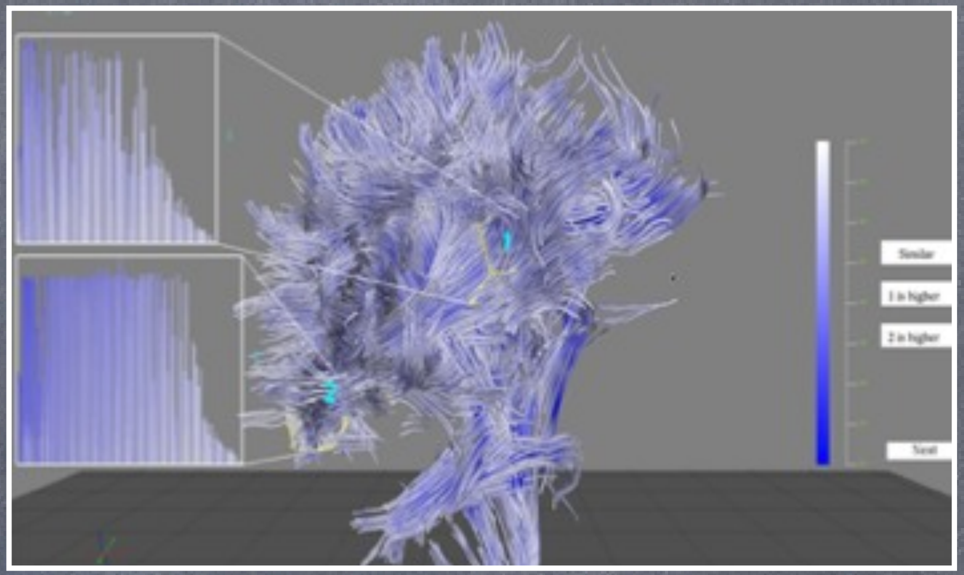
Results:

- abstract tone shading works exceptionally well.
- we did not find significant main effect of halos on task performance
- depth-dependent shadows have a detrimental effect on accuracy and task completion time.

Current work: color encoding for legibility



Boy's surface



2D and 3D integration

goals:

- Effects of color to represent selective / associative / quantitative visual dimensions
- Quantify the effectiveness of combined 2D/3D displays

Current work: optimal density





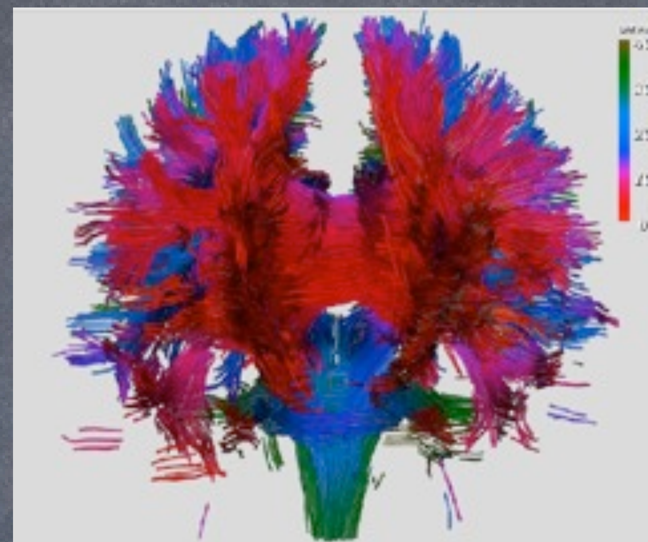
Research question: what is the optimal seeding resolution?

Major results: 2x2x2

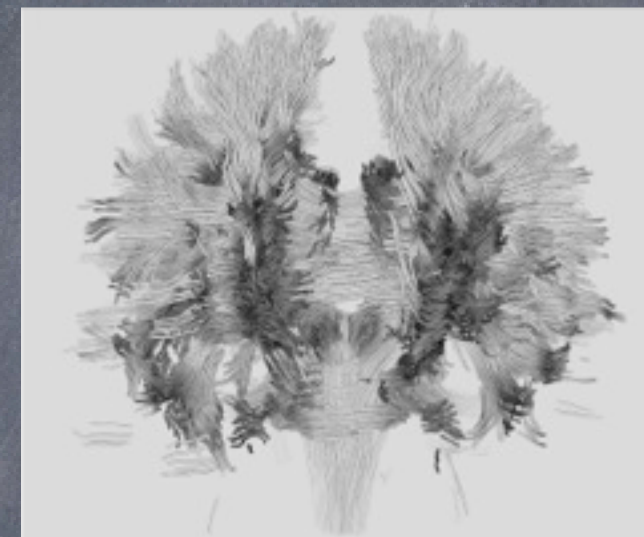
J. Chen, H. Cai, et al., “Efficacious Graphics Density of Diffusion Tensor MRI Visualizations”, (under review).

Current work: ranking encoding for legibility

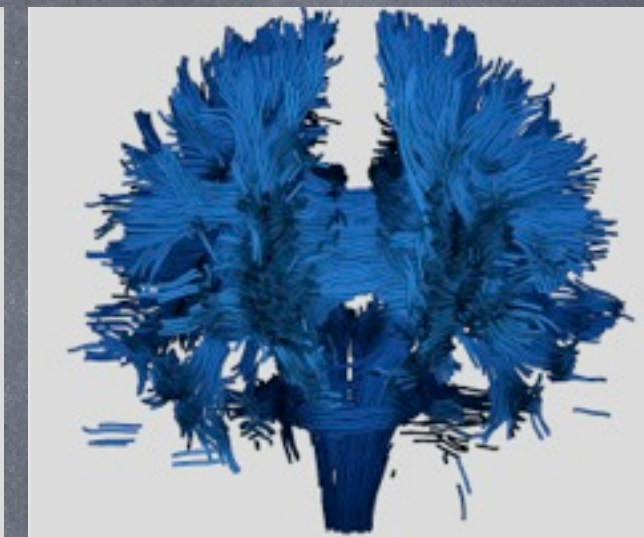
size



color



transparency

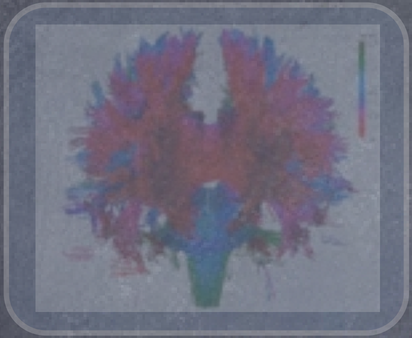


value

Method:
- depth->encoding
- color > (transparency = value) > size

```
LOAD ``/tmp/allfb_tagged.data''
SELECT ``CC''
SELECT ``FA in [0.2,0.25]'' IN ``IFO''
UPDATE color BY FA IN ``CC''
SELECT ``LA > 0.35'' IN ``CST''
UPDATE shape BY line IN ``CC''
UPDATE shape BY tube IN ``IFO''
UPDATE size BY FA WITH 0.1,20 IN "IFO"
```

H. Cai, J. Chen, et al., Depth-dependent parallel visualization with 3D stylized dense tubes. (under review).
J. Chen, H. Cai, et al,, Gryphon: A scientific visualization language for diffusion MRI tractography visualizations. (under review)



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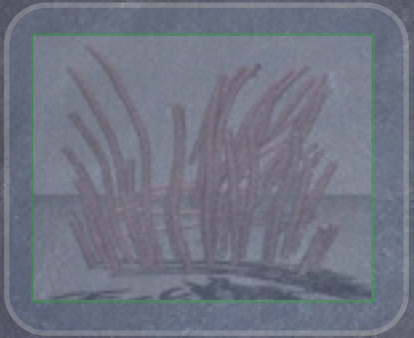


2. **Experiment**: understanding illumination models

3. Workflow-driven design for time-varying bat flight **analysis**

Knowledge discovery

Goal: invisible visual interfaces for knowledge discovery

Collaborators:

Computer science: Andrew Bragdon (Microsoft Research), Andy van Dam, David H. Laidlaw

Biology: Sharon M. Swartz, Rhea von Busse

Problem Domain

- Kinematics
  - Complex wing bone interaction
  - Time-varying wing deformation
- Kinetics
  - Unmanned vehicle design

Recording @ 1000 fps
Playback @ 30 fps
~ 33x slow down

Video courtesy of Brown University

Conventional problem solving approach

Downstroke Upstroke

- Observations (bio)
- Matlab feature extraction (bio, cs, math)
- Visualization (cs)
- Hypothesis formation (bio, eng)
- Comparison (cs, bio)

Work in multiple environments

Extremely complex and dynamic process

Barriers to knowledge discovery

- Observations (bio)
- Matlab feature extraction (bio, cs, math)
- Visualization (cs)
- Hypothesis formation (bio, eng)
- Comparison (cs, bio)

Error-prone computing

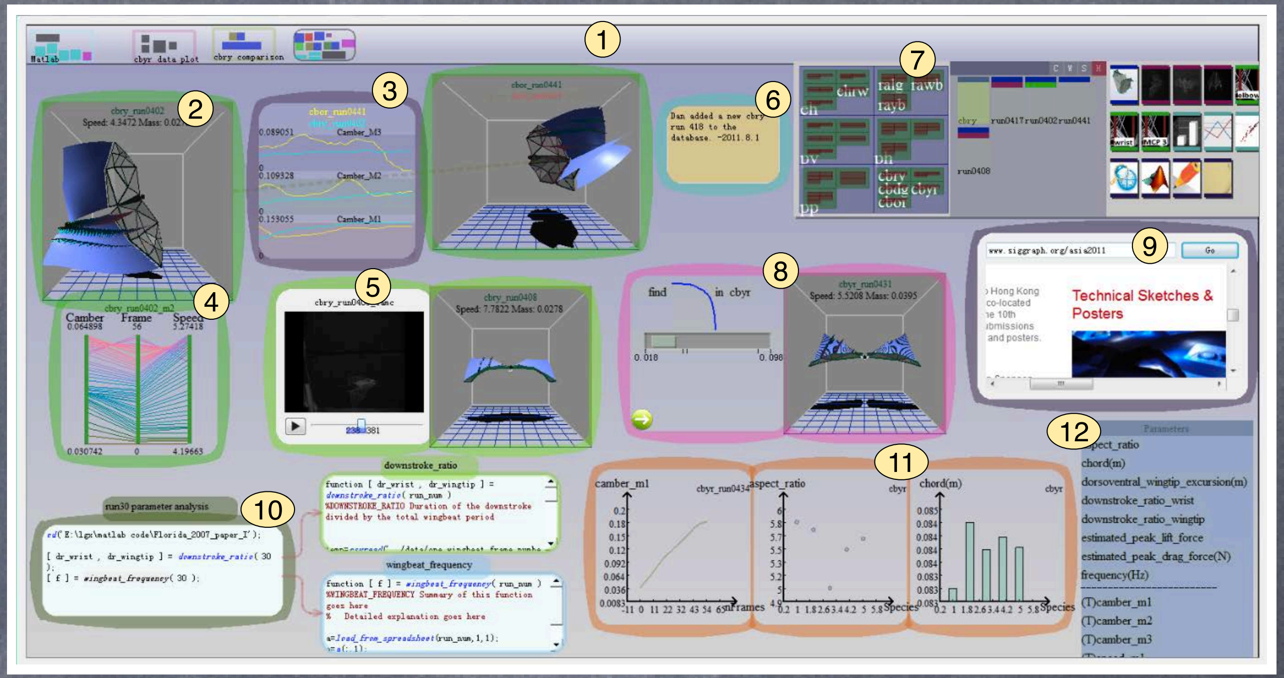
Inefficient collaborative social dynamics

Education

Difficulties in visualization

Our solution: VisBubbles

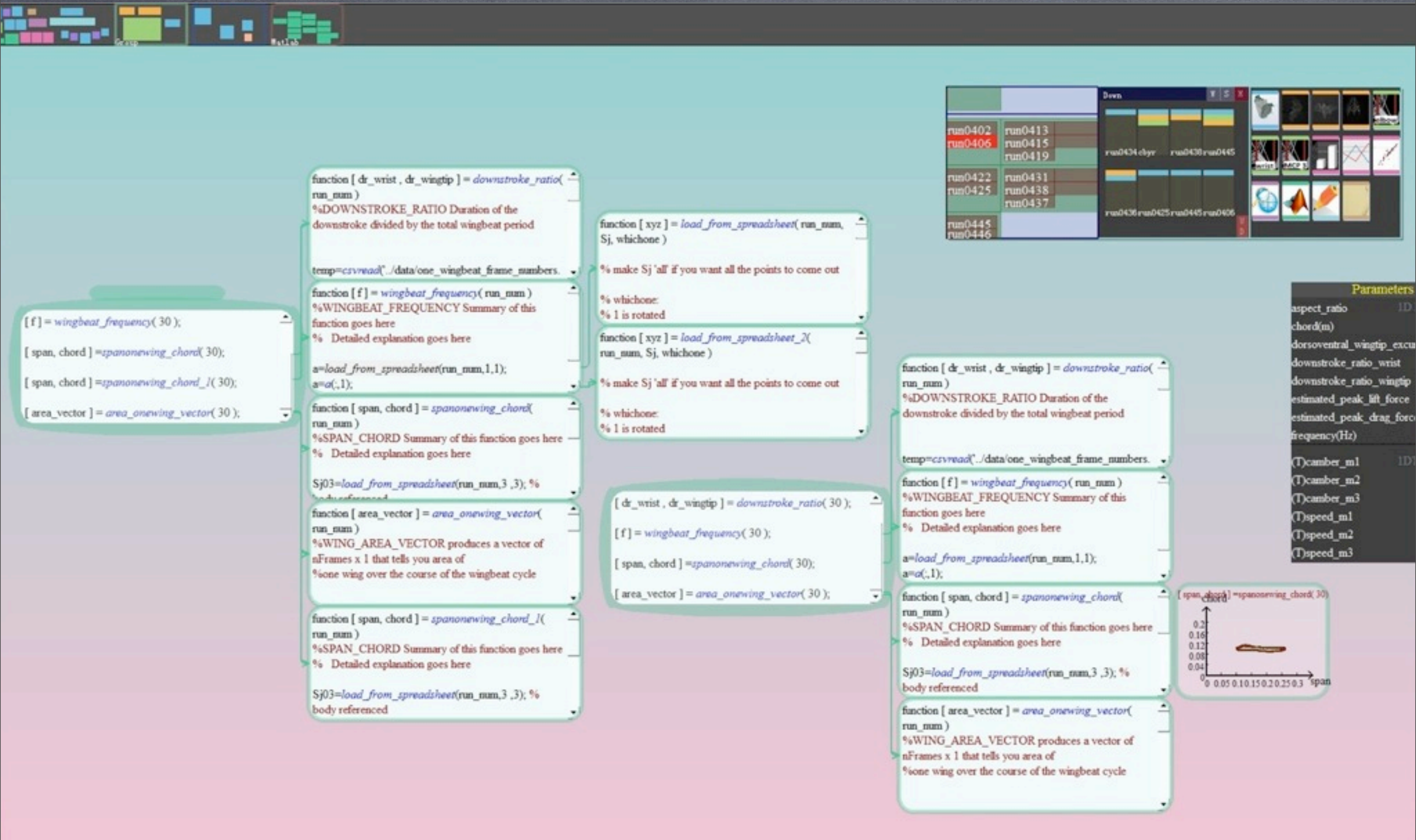
- In the nutshell, it is
  - A multiple-view UI with bubbles (Bragdon et.al 2010)
  - A programming environment for data handling cross-linked to visualization
  - A rapid visualization prototyping (2D/3D rendering)
  - An asynchronous collaborative environment
  - Interactivity



Error-prone computing

Difficulties in visualization

Inefficient collaborative social dynamics / education


[f] = wingbeat_frequency(30);
[span, chord] =spanonewing_chord(30);
[span, chord] =spanonewing_chord_1(30);
[area_vector] = area_onewing_vector(30);
function [dr_wrist , dr_wingtip] = downstroke_ratio(run_num)
%DOWNSTROKE_RATIO Duration of the downstroke divided by the total wingbeat period
temp=csvread('../data/one_wingbeat_frame_numbers.
function [f] = wingbeat_frequency(run_num)
%WINGBEAT_FREQUENCY Summary of this function goes here
% Detailed explanation goes here
a=load_from_spreadsheet(run_num,1,1);
a=a(:,1);
function [span, chord] = spanonewing_chord(run_num)
%SPAN_CHORD Summary of this function goes here
% Detailed explanation goes here
Sj03=load_from_spreadsheet(run_num,3 ,3); %
function [area_vector] = area_onewing_vector(run_num)
%WING_AREA_VECTOR produces a vector of nFrames x 1 that tells you area of
%one wing over the course of the wingbeat cycle
function [span, chord] = spanonewing_chord_1(run_num)
%SPAN_CHORD Summary of this function goes here
% Detailed explanation goes here
Sj03=load_from_spreadsheet(run_num,3 ,3); %
body referenced
function [xyz] = load_from_spreadsheet(run_num, Sj, whichone)
% make Sj 'all' if you want all the points to come out
% whichone:
% 1 is rotated
function [xyz] = load_from_spreadsheet_2(run_num, Sj, whichone)
% make Sj 'all' if you want all the points to come out
% whichone:
% 1 is rotated
[dr_wrist , dr_wingtip] = downstroke_ratio(30);
[f] = wingbeat_frequency(30);
[span, chord] =spanonewing_chord(30);
[area_vector] = area_onewing_vector(30);
run0402
run0406
run0413
run0415
run0419
run0422
run0425
run0431
run0438
run0437
run0445
run0446
Parameters
aspect_ratio
chord(m)
dorsoventral_wingtip_excu
downstroke_ratio_wrist
downstroke_ratio_wingtip
estimated_peak_lift_force
estimated_peak_drag_forc
frequency(Hz)
(T)camber_m1
(T)camber_m2
(T)camber_m3
(T)speed_m1
(T)speed_m2
(T)speed_m3
chord
span

Design principles

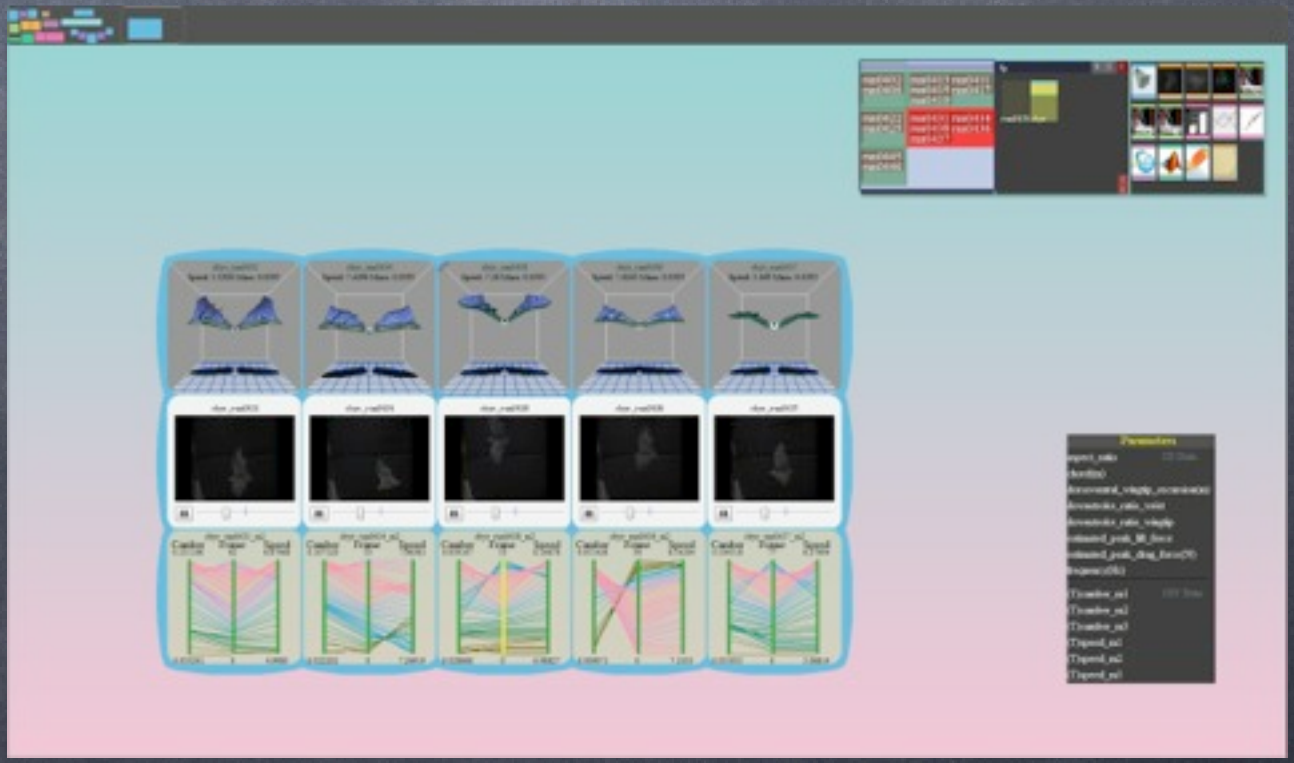
- How to make people more creative?
  - memory sequencing (spatial locations, predicting next step)
    - e.g., put socks on before the shoes
  - forming schema (Barlett 32) mental structure representing knowledge)
    - e.g., put shirt on before my jacket

Reduce interruption

Consistency

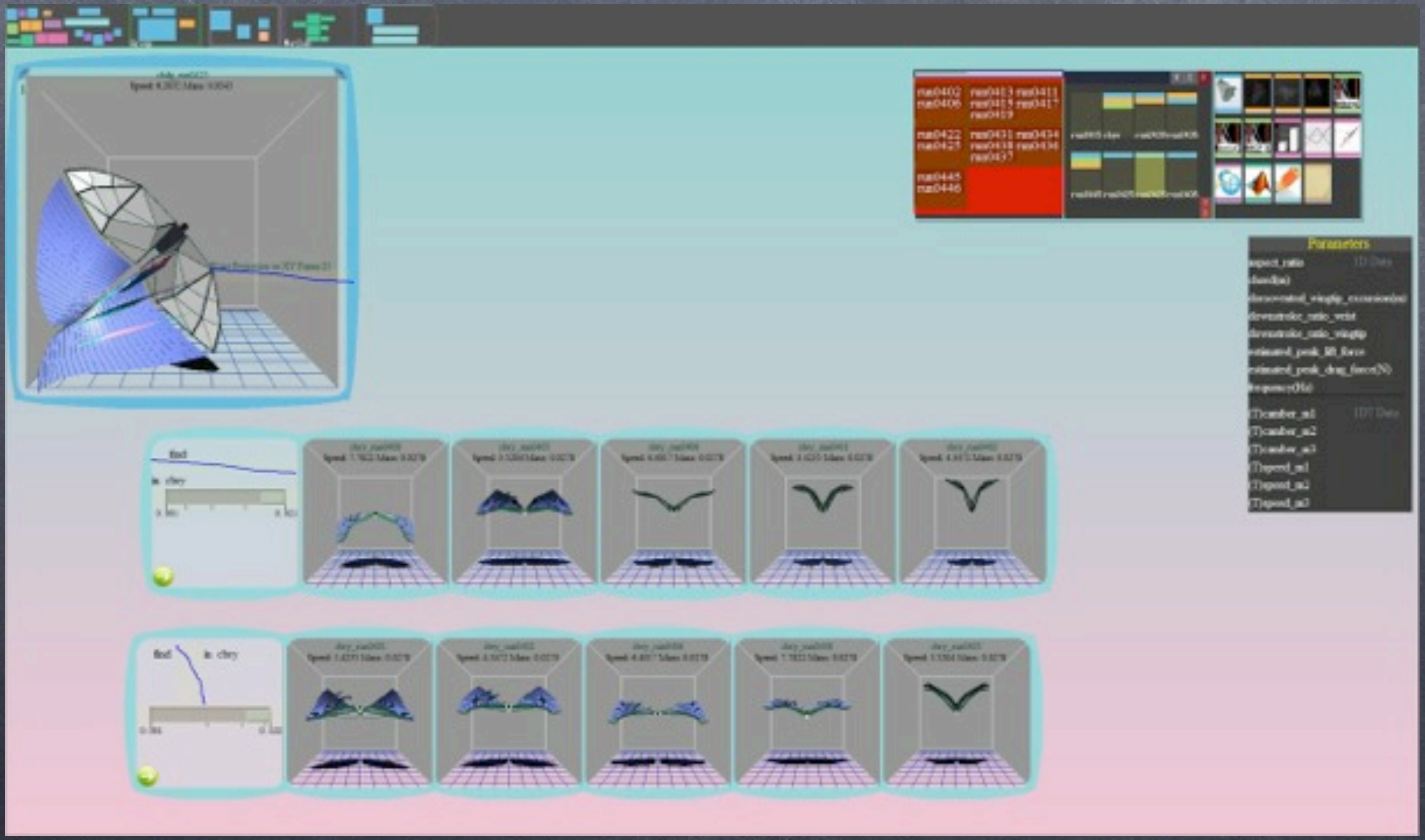
Forming schema

- Bubbles interface (Bragdon et al. 2010)
- User behavior -> interface action
  - grouping -> linking
- New schema
  - Asynchronous collaboration



Support memory sequencing

- Reducing cognitive distances between programming and visualization
  - Right representation level for visual analysis



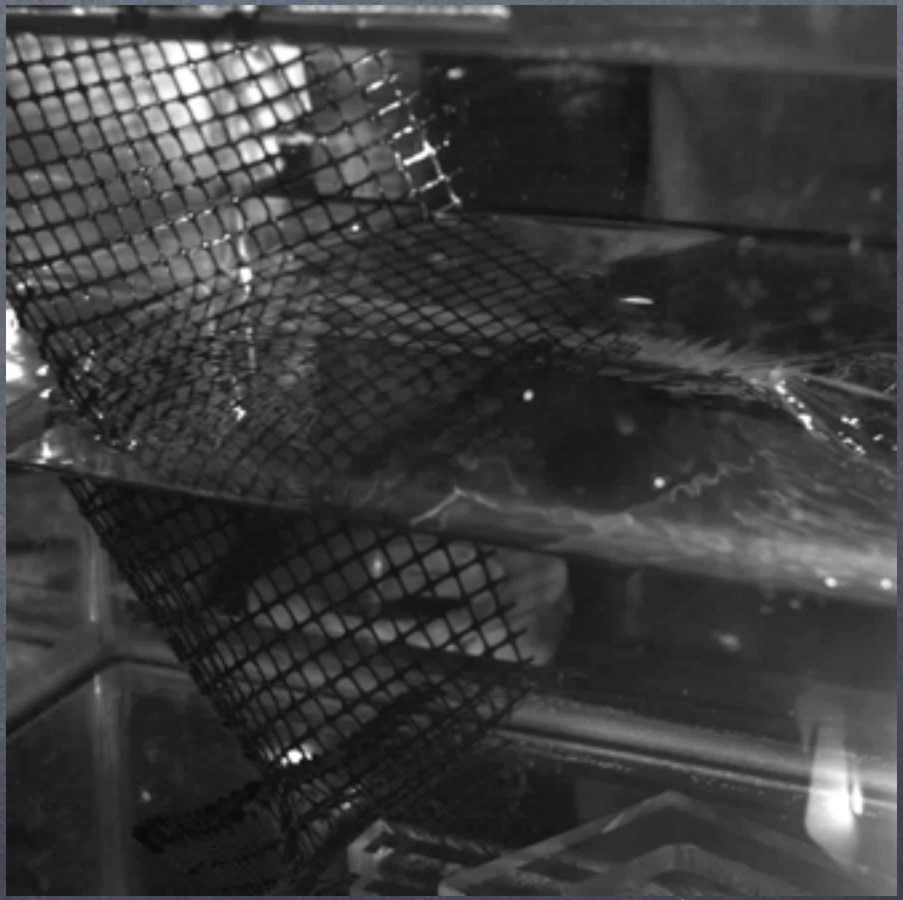
Contributions

- Memory-driven design for enhancing knowledge discovery
- Integrated problem solving environment

Current work: interaction discourse analysis

Deeper analysis

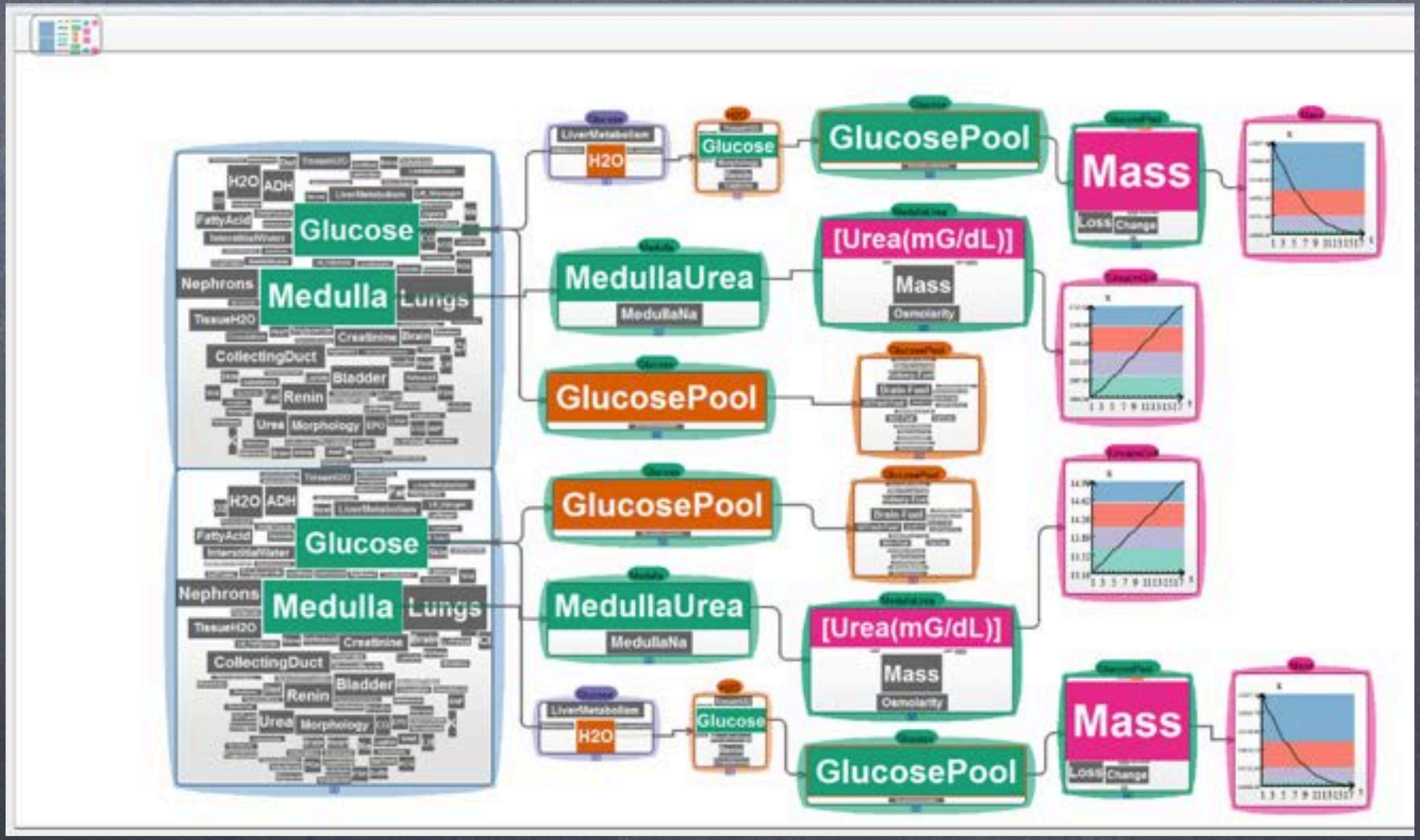
- Is there an accessible structure in space usage pattern within the knowledge discovery discourse?
- How might one exploit this?
- Answering these questions?
  - Is inherently multidisciplinary
  - Requires expansive effort and vision
  - Promising great rewards
- A key component is mental imagery in discourse.



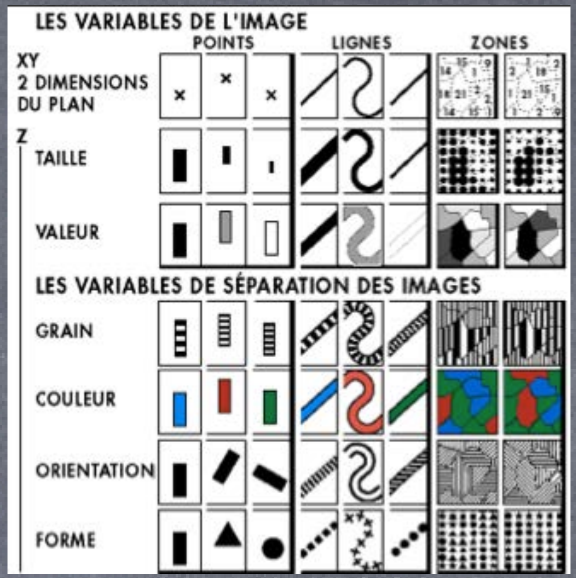
A swimming bat @ Brown (Video courtesy of the Swartz lab)

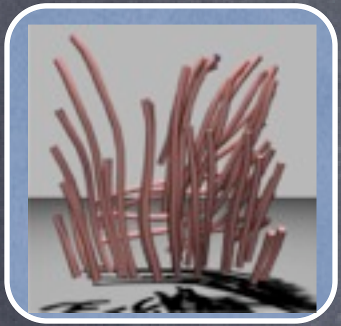
Current work: Pathway and physiology data analysis

New applications

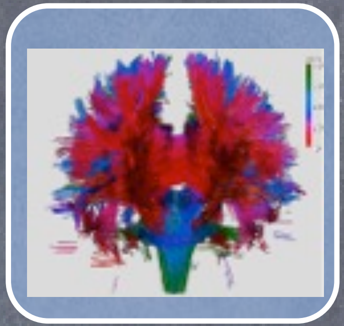


Conclusions

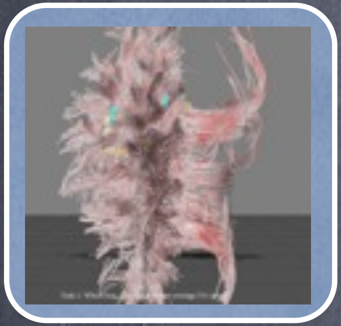




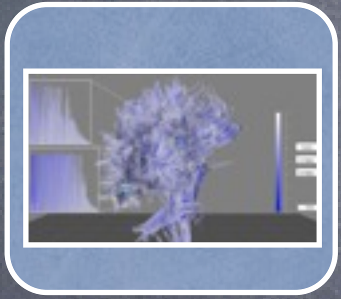
Global illumination resulted in similar task performance as local illumination



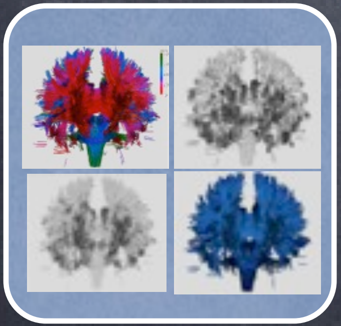
Ranking encoding



The just-noticeable difference for dense tube visualizations



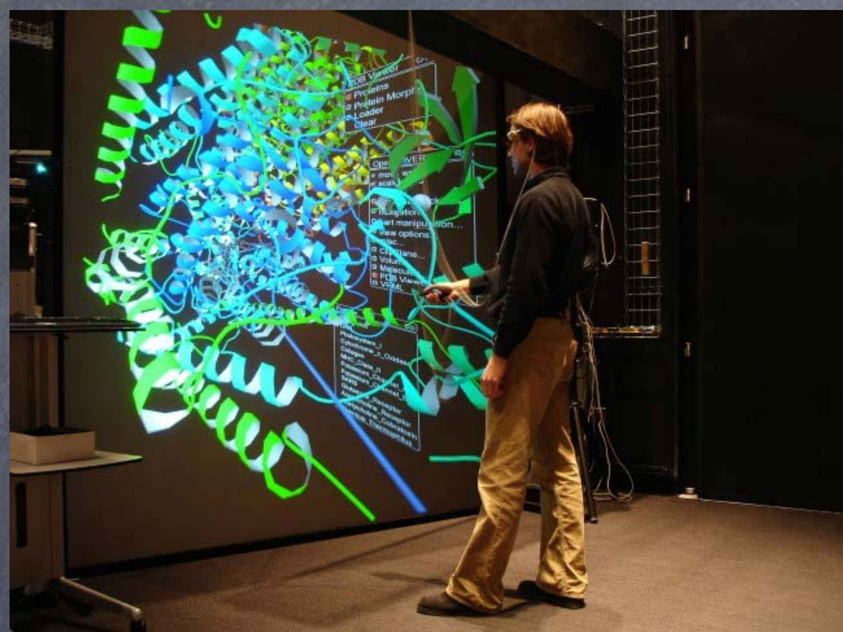
Color encoding

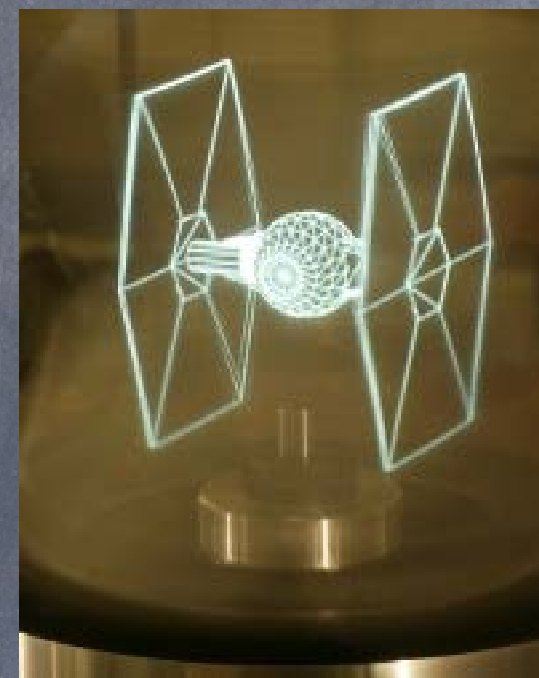


Legible dimensions: color worked the best.

Workflow driven interface design

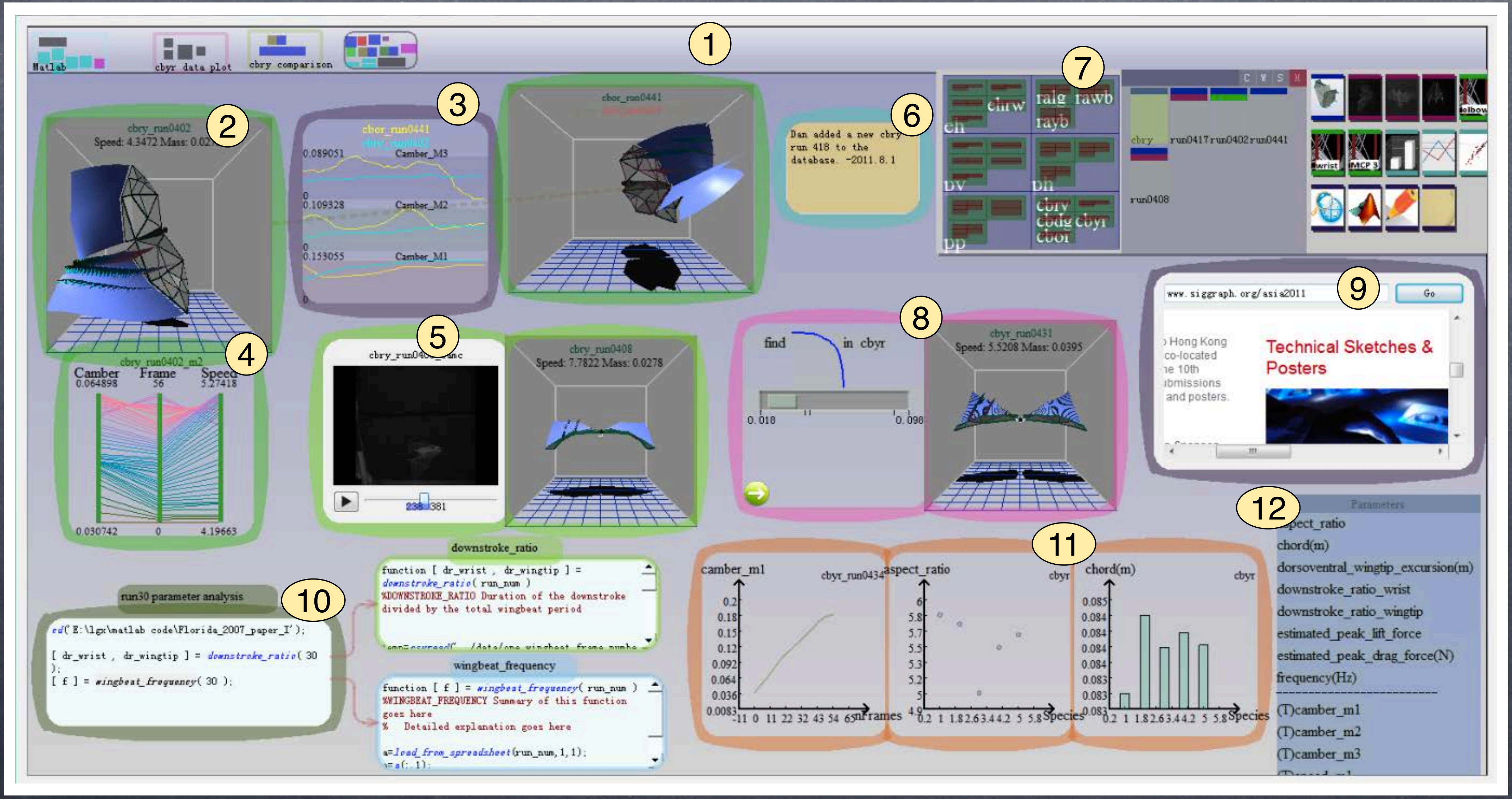
Trend: rapid advances in interactive technologies





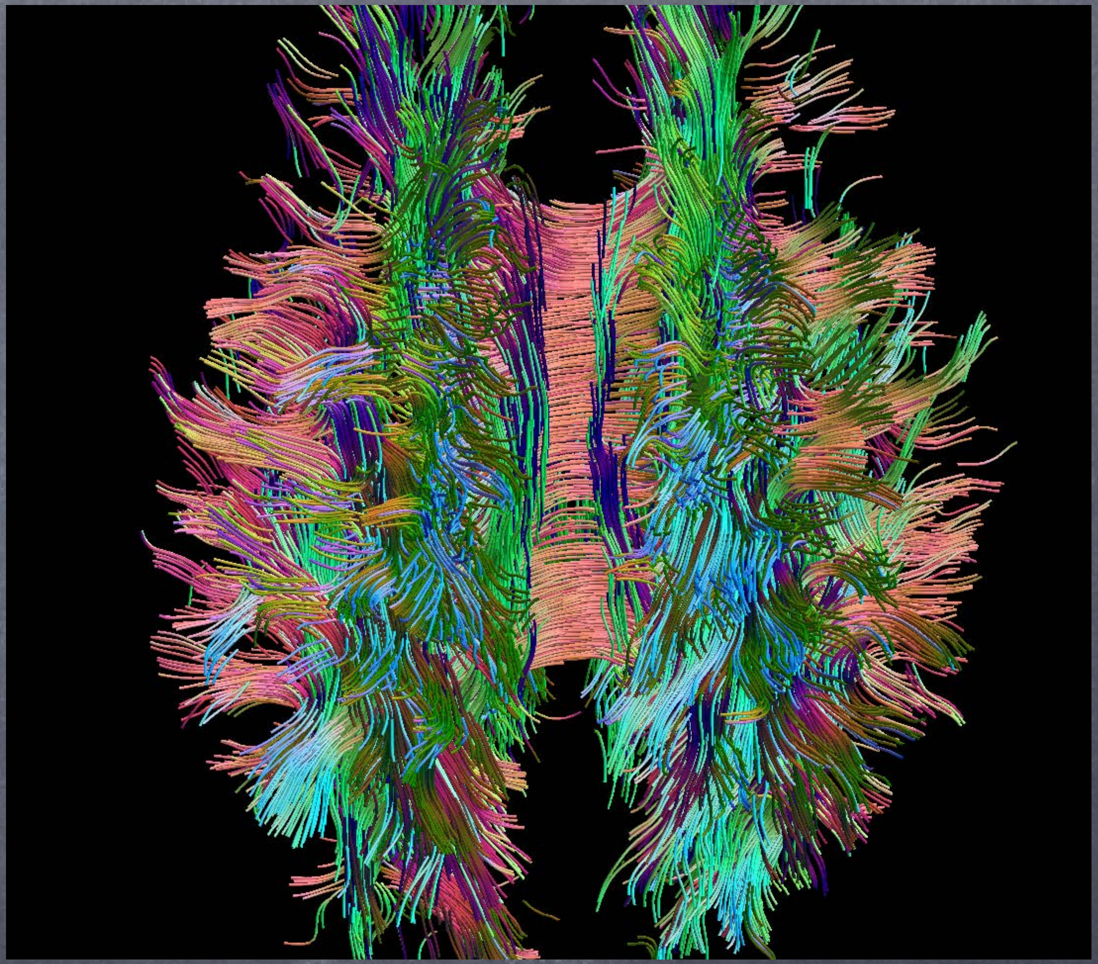
Trend: increased importance of design process (tools, practice and teaching)

- Storytelling, creativity, integrating infoVis + sciVis



Trend: understand uncertainty

- Error bars on Measurement errors?



Trend: into the cloud

- Visualization will make use of the resources in the cloud.
- Physiological sciences
- Health care and Med student training in the cloud?

Robert Hester

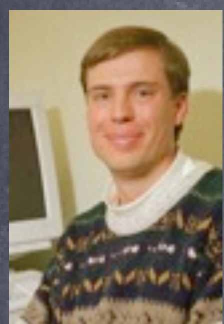
David H. Laidlaw
(Brown)

Alexander P. Auchus
(UMC)

Kenneth Breuer
(Brown)

Magenta
(Harvard)

Carl Schmidt
(Delware)



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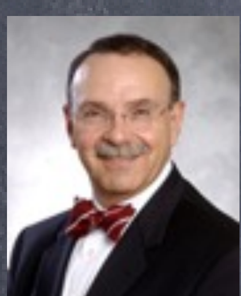

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- NSF:EPSCoR:Sole-PI: "Storytelling Bubbles: integrating symbolic representation, data ink manipulation, and metaphorical interface for fluid time-varying biological data analysis."
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Thank you!

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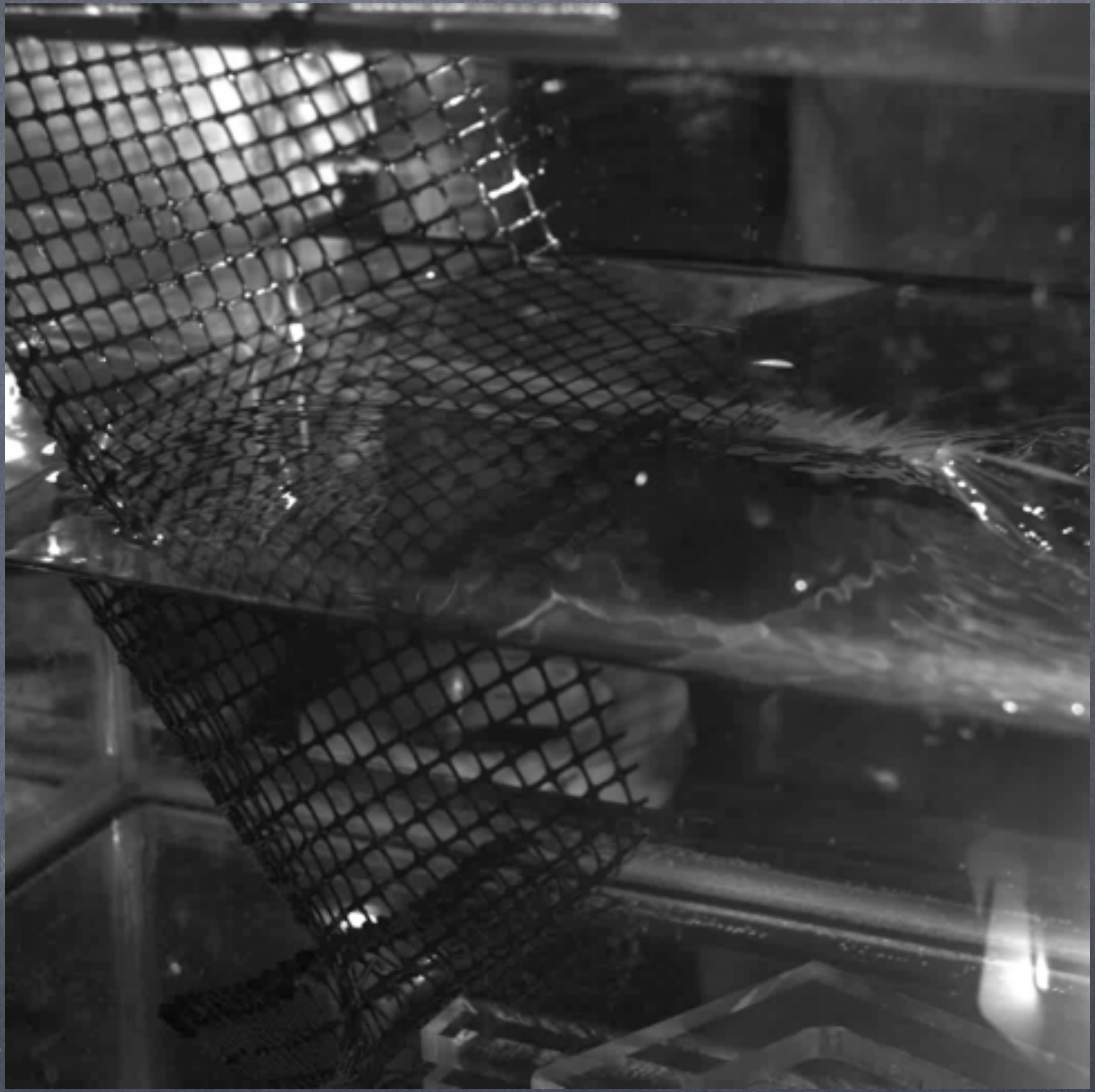

A swimming bat @ Brown (Video courtesy of Swartz lab)