UIC UNIVERSITY OF ILLINOIS AT CHICAGO

Visual Computing at the Electronic Visualization Laboratory

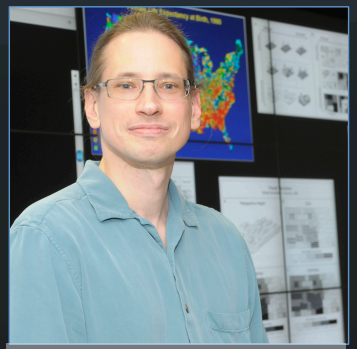
G. Elisabeta Marai

Electronic Visualization Lab
University of Illinois at Chicago

UIC Electronic Visualization Laboratory (EVL)

UIC UNIVERSITY OF ILLINOIS AT CHICAGO

Maxine Brown,
EVL Director, CS

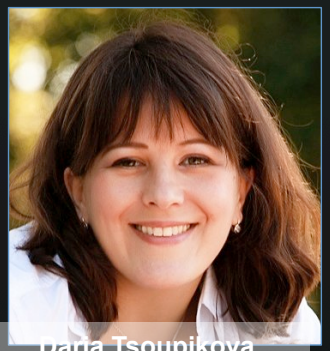


Andy Johnson,
Associate Professor, CS

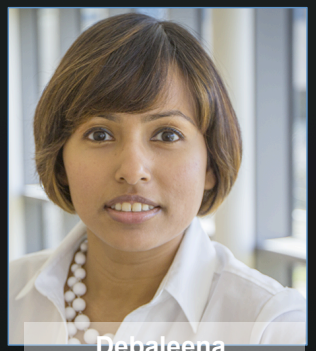
Robert Kenyon,
Professor, CS

G. Elisabeta Marai,
Associate Professor, CS

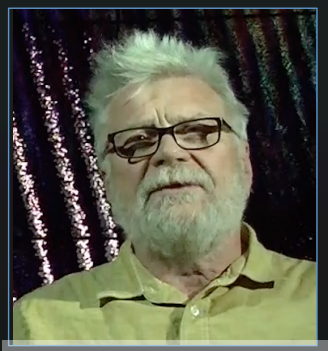
Luc Renambot,
Assoc. Research Professor, CS



Daria Tsoupikova,
Assoc. Professor, Design



Debaleena Chattopadhyay, Assistant Prof., CS



Dan Sandin,
Professor of Art, Senior Research Professor, CS

Funded through research grants from:
- NIH
- NSF
- DARPA
- NASA
- NIDRR
- ANL

and partial support from:
- UIC, State of IL

EVL's Visual Computing and Virtual Reality Hardware and Software Help Teams Manage "Big Data"

UIC UNIVERSITY OF ILLINOIS AT CHICAGO


"Star Wars" 1977


CAVE 1992


TacTile 2008


SAGE (2004-2014) and SAGE2 (2014-present)


CAVE2 2012

Rat fetus using SAGE2

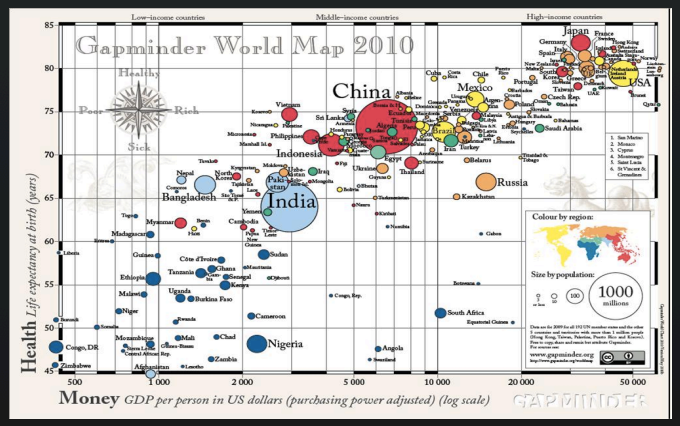
UIC UNIVERSITY OF ILLINOIS AT CHICAGO

High-resolution optical scan of a near-mid-section of a rat fetus at 19 days, acquired by the Monash Histology Platform, Monash University. At low magnification, this 123K x 74K pixel image shows the entire organism and its central organs and anatomy, yet there is sufficient resolution sufficient to identify, at high magnification, the nuclei of red blood cells forming in the liver.

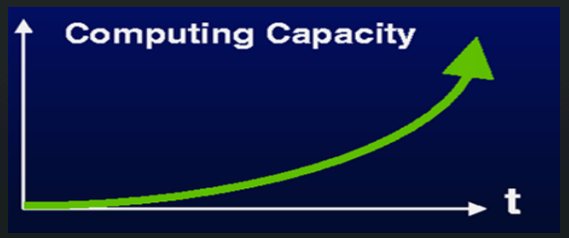
Visual Computing

UIC UNIVERSITY OF ILLINOIS AT CHICAGO

- Computing over images and 3D models, including the processes at the interface between (visual) data and humans



visualization of human development
http://tools.google.com/gapminder/



- Systems that provide *visual representations of datasets* designed to help people carry out tasks more effectively.

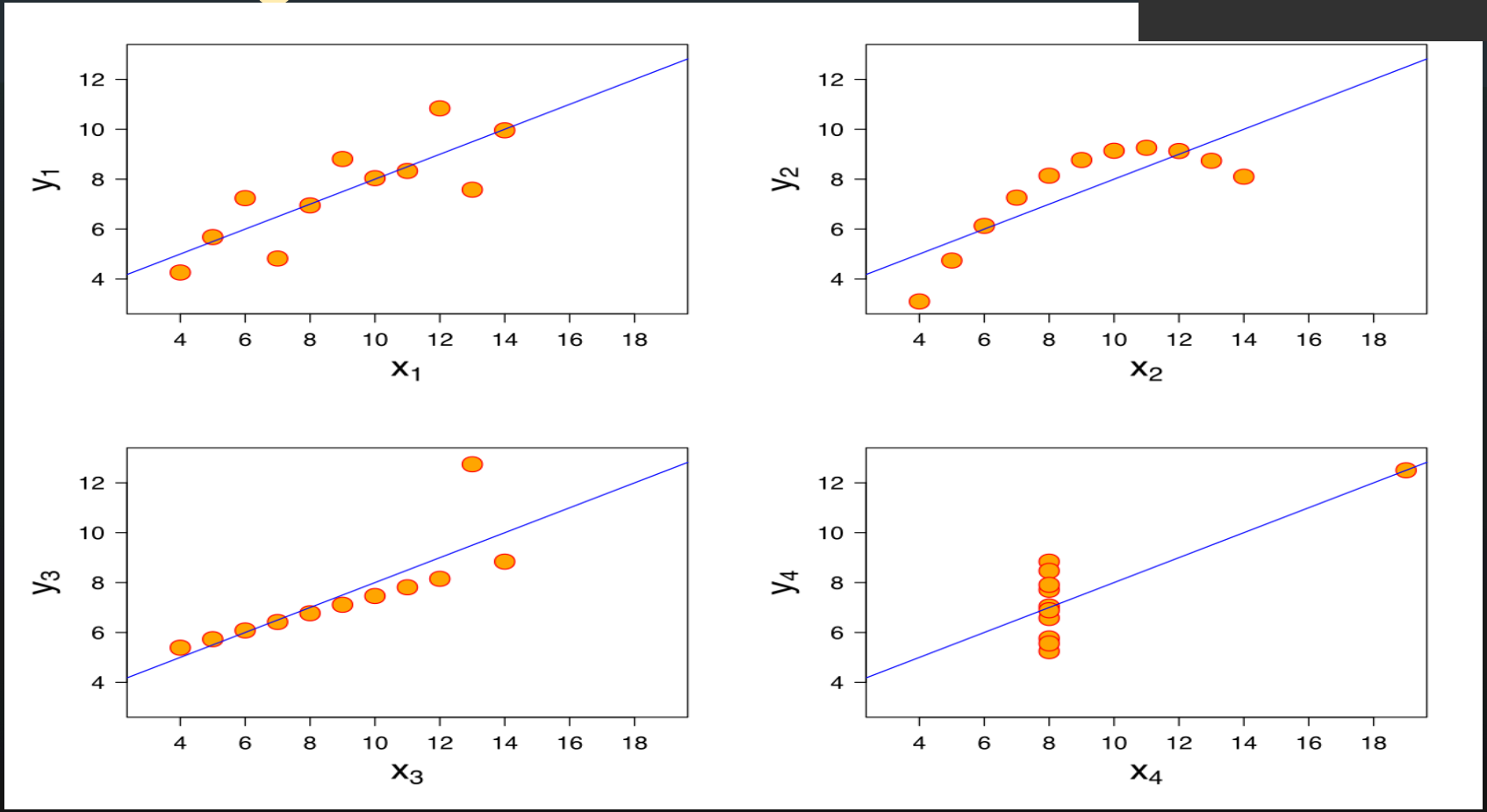
Anscombe's Quartet

UIC UNIVERSITY OF ILLINOIS AT CHICAGO

	I		II		III		IV	
	x	y	x	y	x	y	x	y
	10	8,04	10	9,14	10	7,46	8	6,58
	8	6,95	8	8,14	8	6,77	8	5,76
	13	7,58	13	8,74	13	12,74	8	7,71
	9	8,81	9	8,77	9	7,11	8	8,84
	11	8,33	11	9,26	11	7,81	8	8,47
	14	9,96	14	8,1	14	8,84	8	7,04
	6	7,24	6	6,13	6	6,08	8	5,25
	4	4,26	4	3,1	4	5,39	19	12,5
	12	10,84	12	9,13	12	8,15	8	5,56
	7	4,82	7	7,26	7	6,42	8	7,91
	5	5,68	5	4,74	5	5,73	8	6,89
SUM	99,00	82,51	99,00	82,51	99,00	82,50	99,00	82,51
AVG	9,00	7,50	9,00	7,50	9,00	7,50	9,00	7,50
STDEV	3,32	2,03	3,32	2,03	3,32	2,03	3,32	2,03

Visualizing Anscombe's Quartet

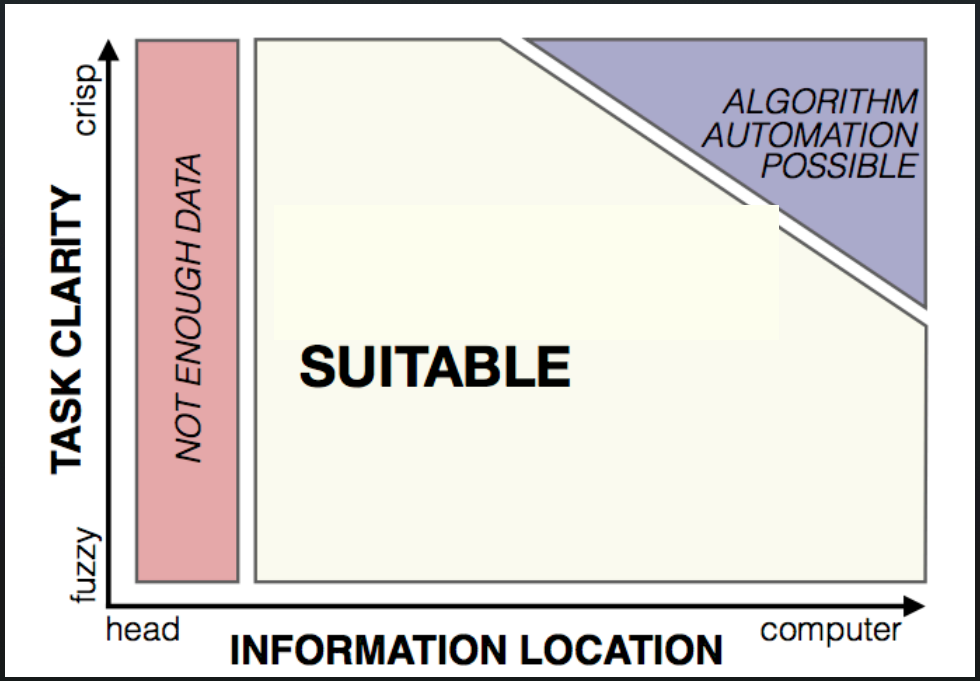
UIC UNIVERSITY OF ILLINOIS AT CHICAGO



Visual representations (Visualization) also not always appropriate

UIC UNIVERSITY OF ILLINOIS AT CHICAGO

- Use when there is a need to augment human capabilities rather than replace people with computational decision-making methods.



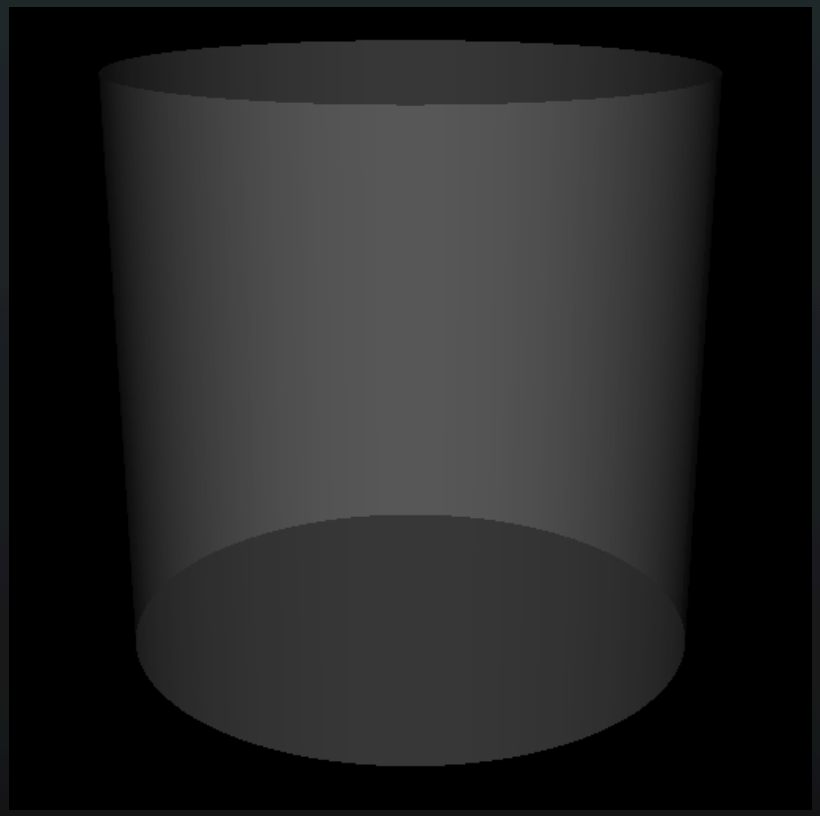
Roadmap

UIC UNIVERSITY OF ILLINOIS AT CHICAGO

- EVL and Visual Computing
- Beyond ParaView
- Precision Medicine
- Bioinformatics

Viscous finger evolution

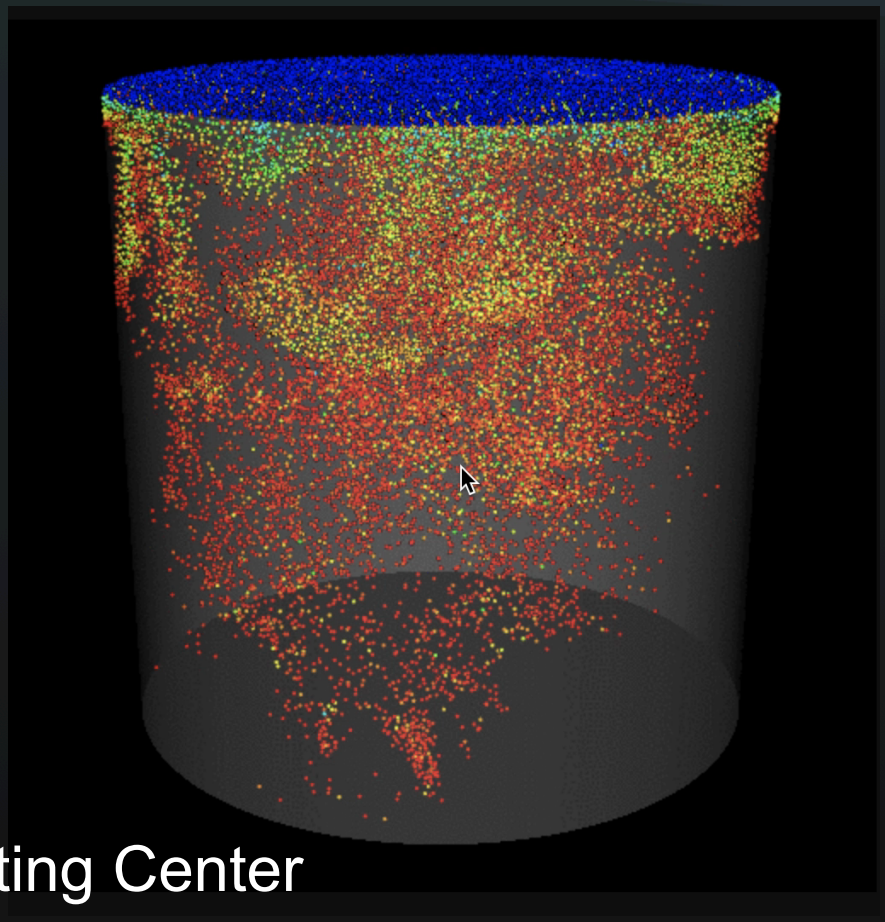
UIC UNIVERSITY OF ILLINOIS AT CHICAGO



SciVis Contest 2016
San Diego SuperComputing Center

Viscous finger evolution

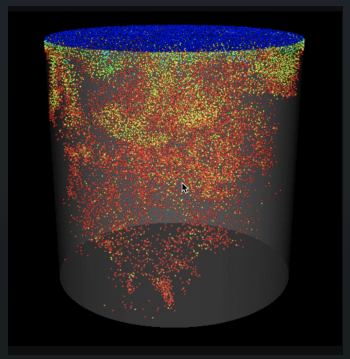
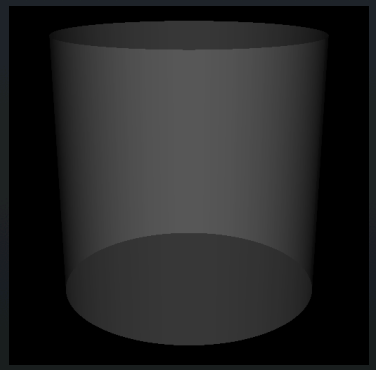
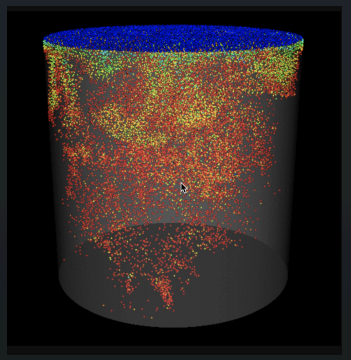
UIC UNIVERSITY OF ILLINOIS AT CHICAGO



SciVis Contest 2016
San Diego SuperComputing Center

Many stochastic simulations

UIC UNIVERSITY OF ILLINOIS AT CHICAGO



...


- Results in a simulation ensemble, to be analyzed

CFD in general: two processes

UIC UNIVERSITY OF ILLINOIS AT CHICAGO

Process 1

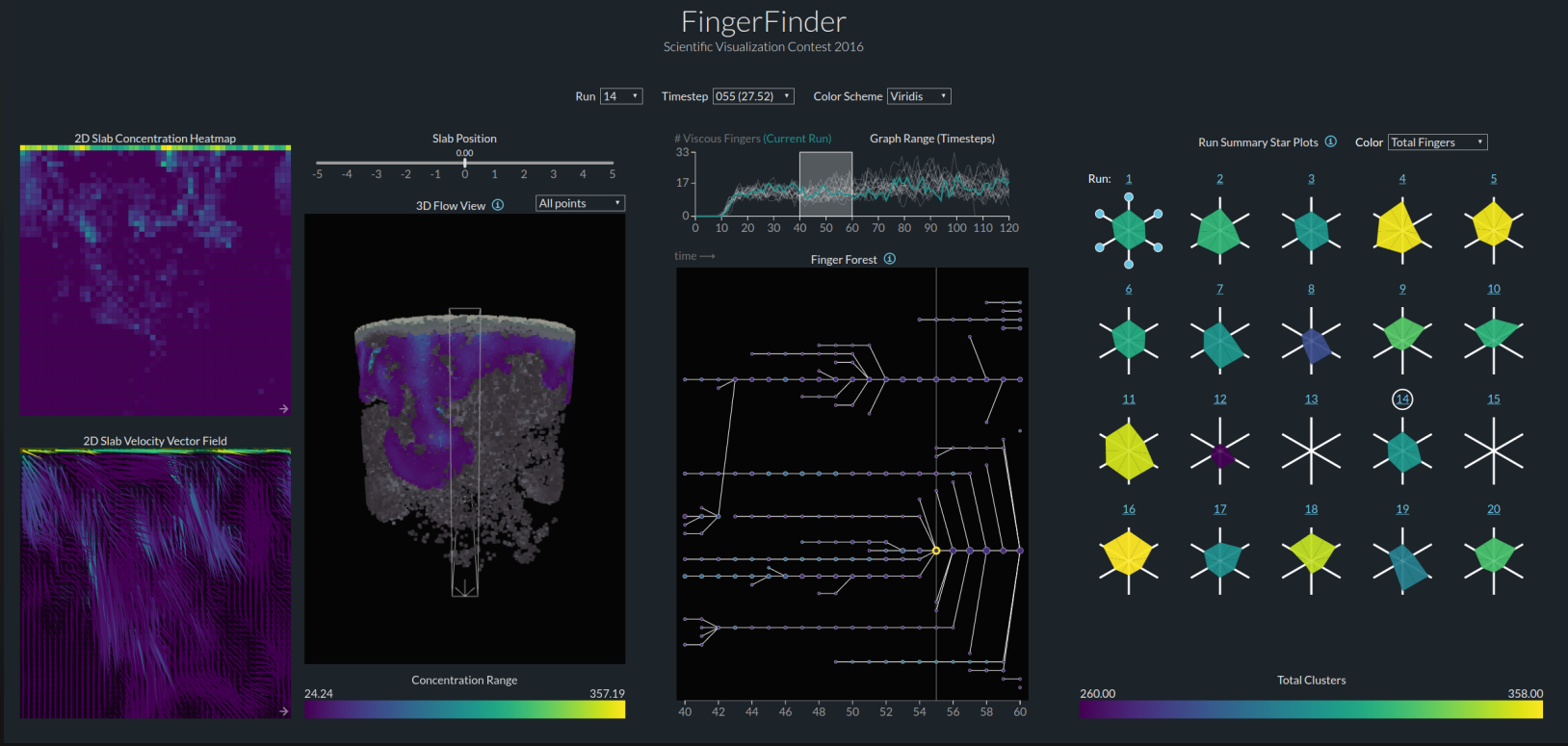
- Identify somehow features of interest
  - *"[The feature] is hard to define, but when you see it, you recognize it immediately"*
- Summarize the features somehow (e.g., mean and stddev)

Process 2

- Explore summarization looking for unusual patterns

Unified process using D3 and other web technologies

UIC UNIVERSITY OF ILLINOIS AT CHICAGO

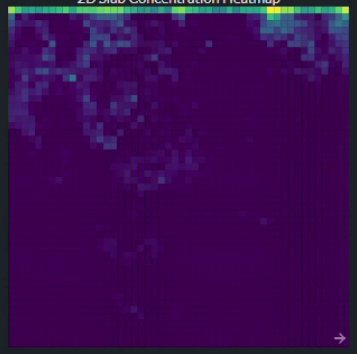


FingerFinder

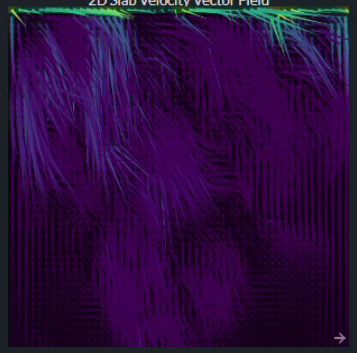
Scientific Visualization Contest 2016

Run 01 ▾ Timestep 044 (22.00) ▾ Color Scheme Viridis ▾

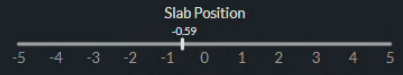
2D Slab Concentration Heatmap



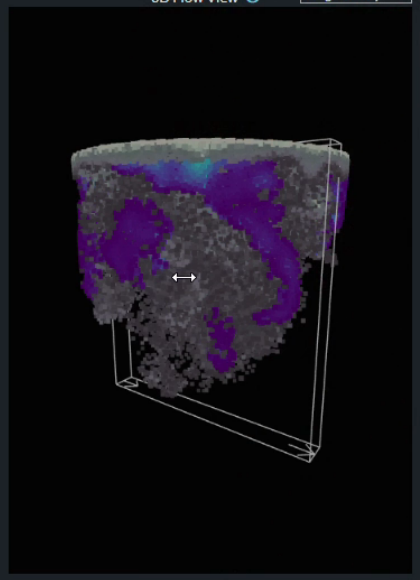
2D Slab Velocity Vector Field



Slab Position

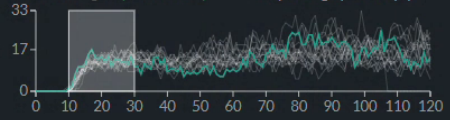


3D Flow View ⓘ Fingers only ▾

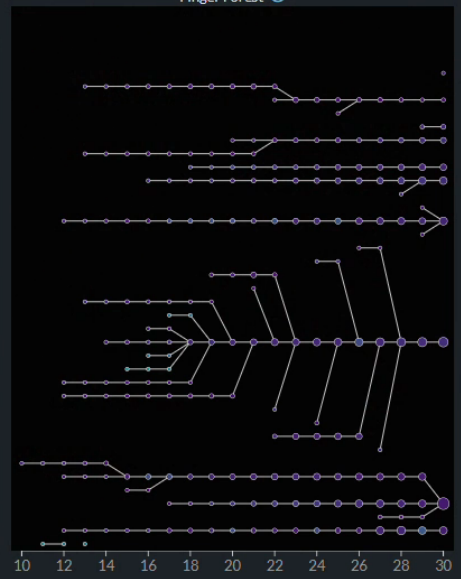


Concentration Range

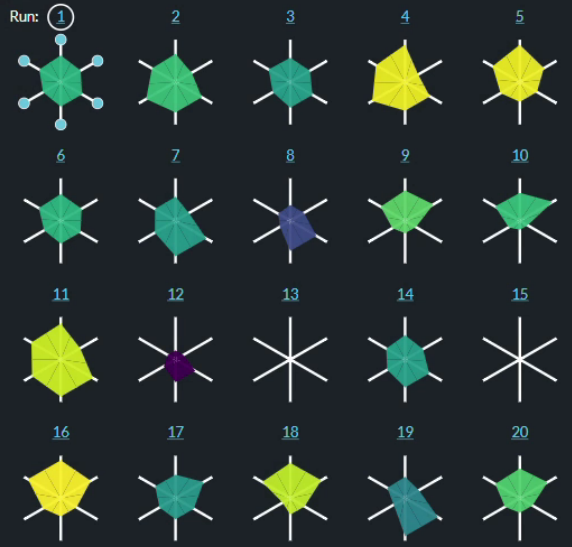
Viscous Fingers (Current Run) Graph Range (Timesteps)



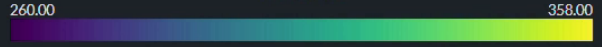
time ⟶ Finger Forest ⓘ



Run Summary Star Plots ⓘ Color Total Fingers ▾



Total Clusters

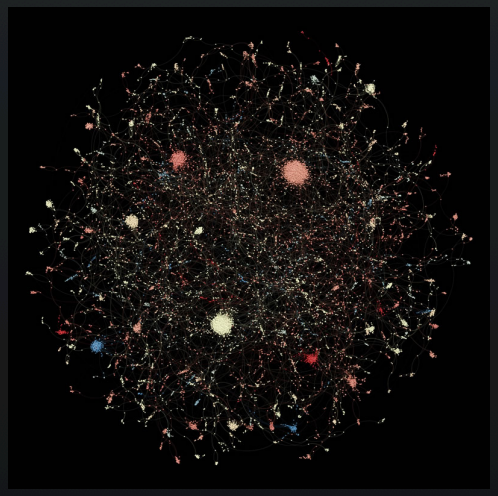


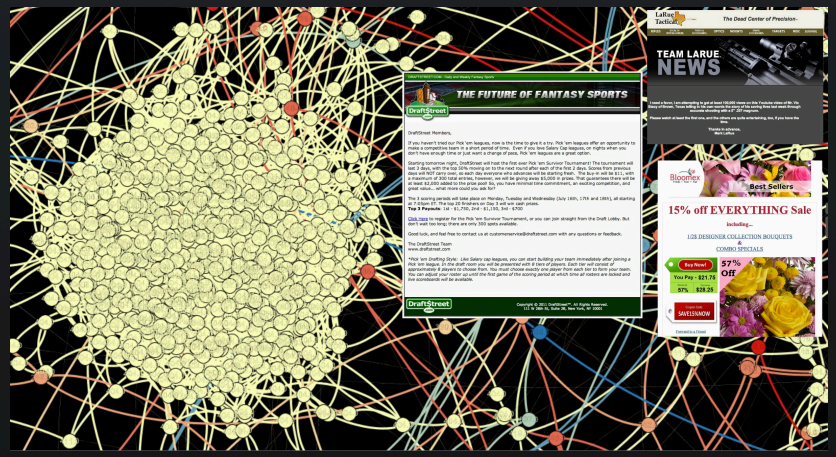
At the human-data interface

UIC UNIVERSITY OF ILLINOIS AT CHICAGO

- The Shneiderman (or Visual Info Seeking) Mantra:

"Overview first, Zoom in and Filter, then Details on demand"





https://www.recordedfuture.com/information-seeking-mantra/

Shneiderman, Ben. "The eyes have it: A task by data type taxonomy for information visualizations." Visual Languages, 1996. Proceedings., IEEE Symposium on. IEEE, 1996.

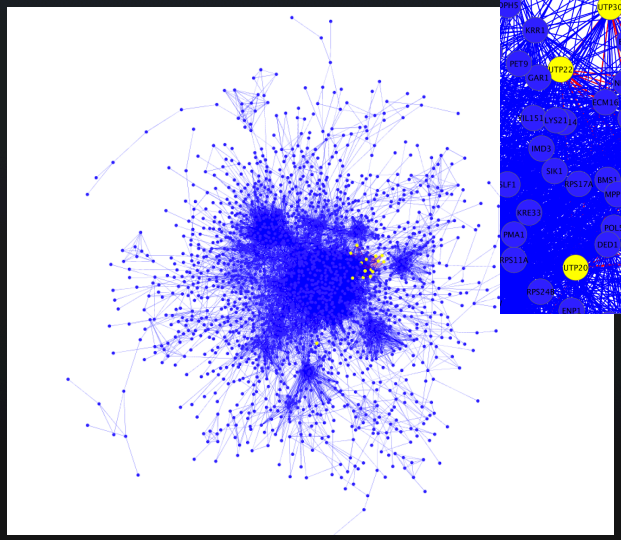
At the human-data interface

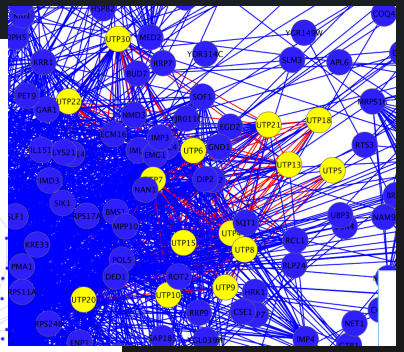
UIC UNIVERSITY OF ILLINOIS AT CHICAGO

- The van Ham and Perer Mantra:

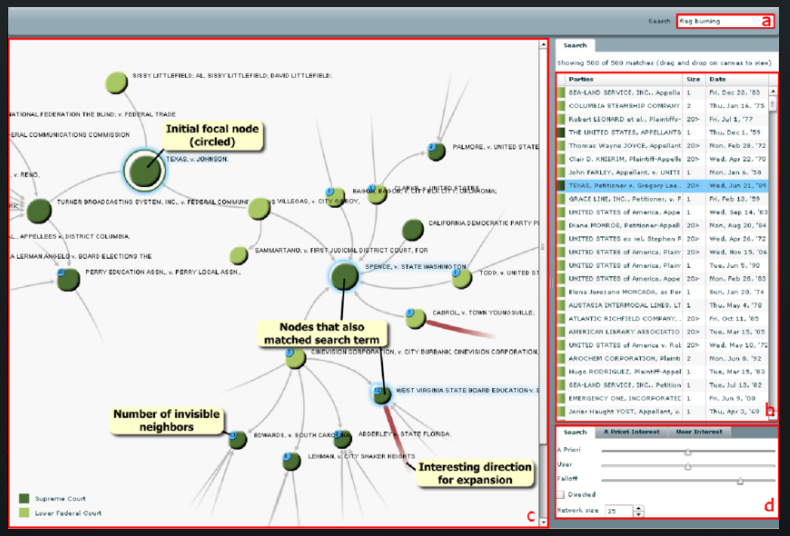
"Search first, Show Context, Expand on demand"

aka NOT THIS





BUT THIS



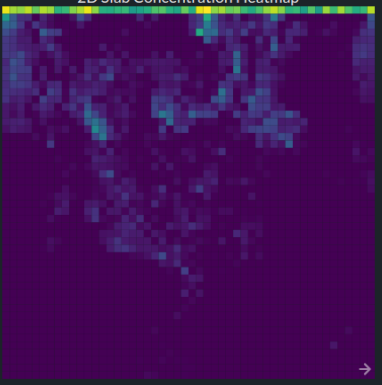
Van Ham, Frank, and Adam Perer. ""Search, show context, expand on demand": Supporting large graph exploration with degree-of-interest." IEEE Transactions on Visualization and Computer Graphics 15.6 (2009).

FingerFinder

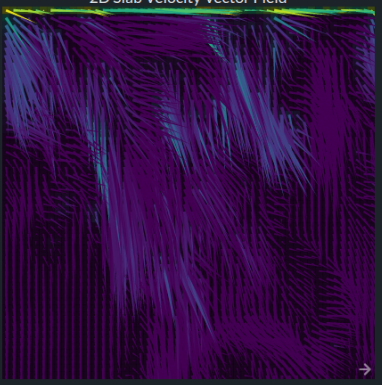
Scientific Visualization Contest 2016

Run 14 Timestep 055 (27.52) Color Scheme Viridis

2D Slab Concentration Heatmap



2D Slab Velocity Vector Field

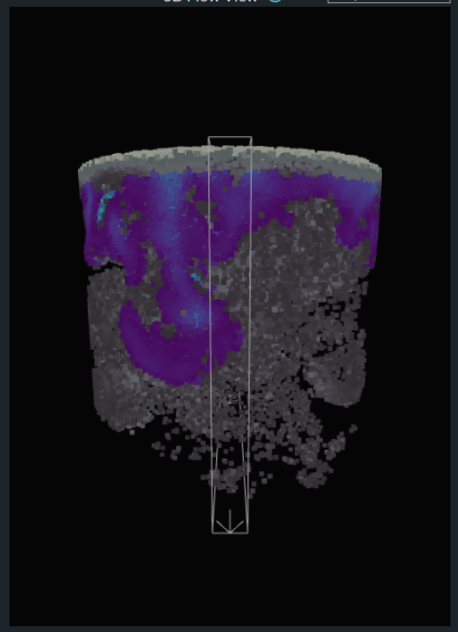


Slab Position

0.00

-5 -4 -3 -2 -1 0 1 2 3 4 5

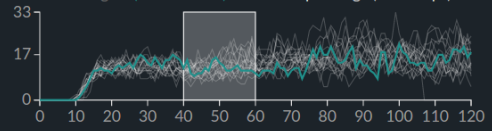
3D Flow View ⓘ All points



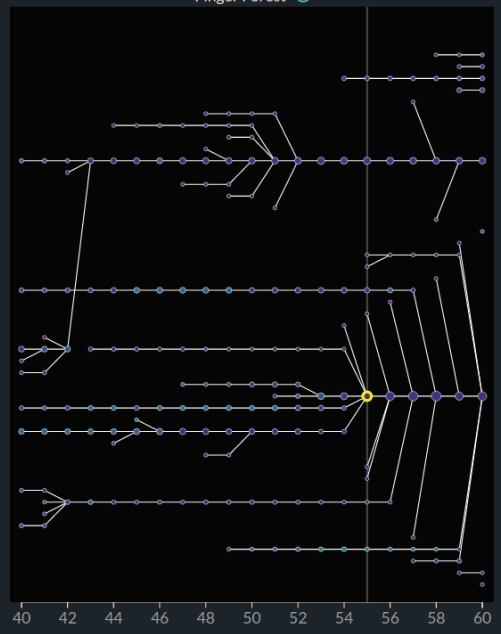
Concentration Range

24.24 357.19

Viscous Fingers (Current Run) Graph Range (Timesteps)

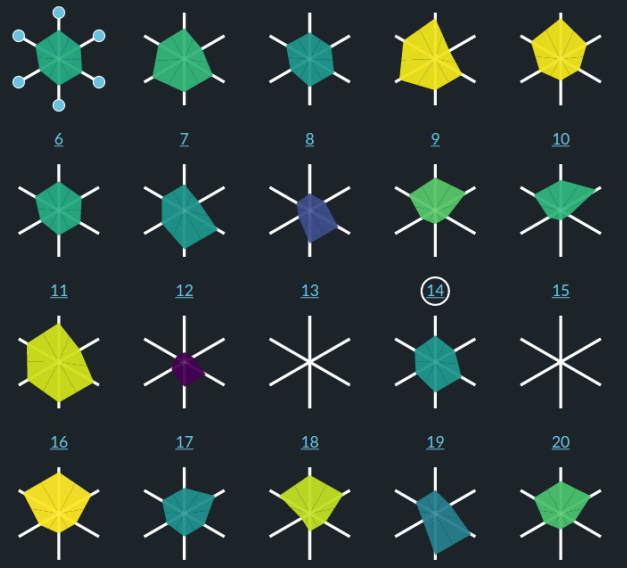


time ⟶ Finger Forest ⓘ



Run Summary Star Plots ⓘ Color Total Fingers

Run: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

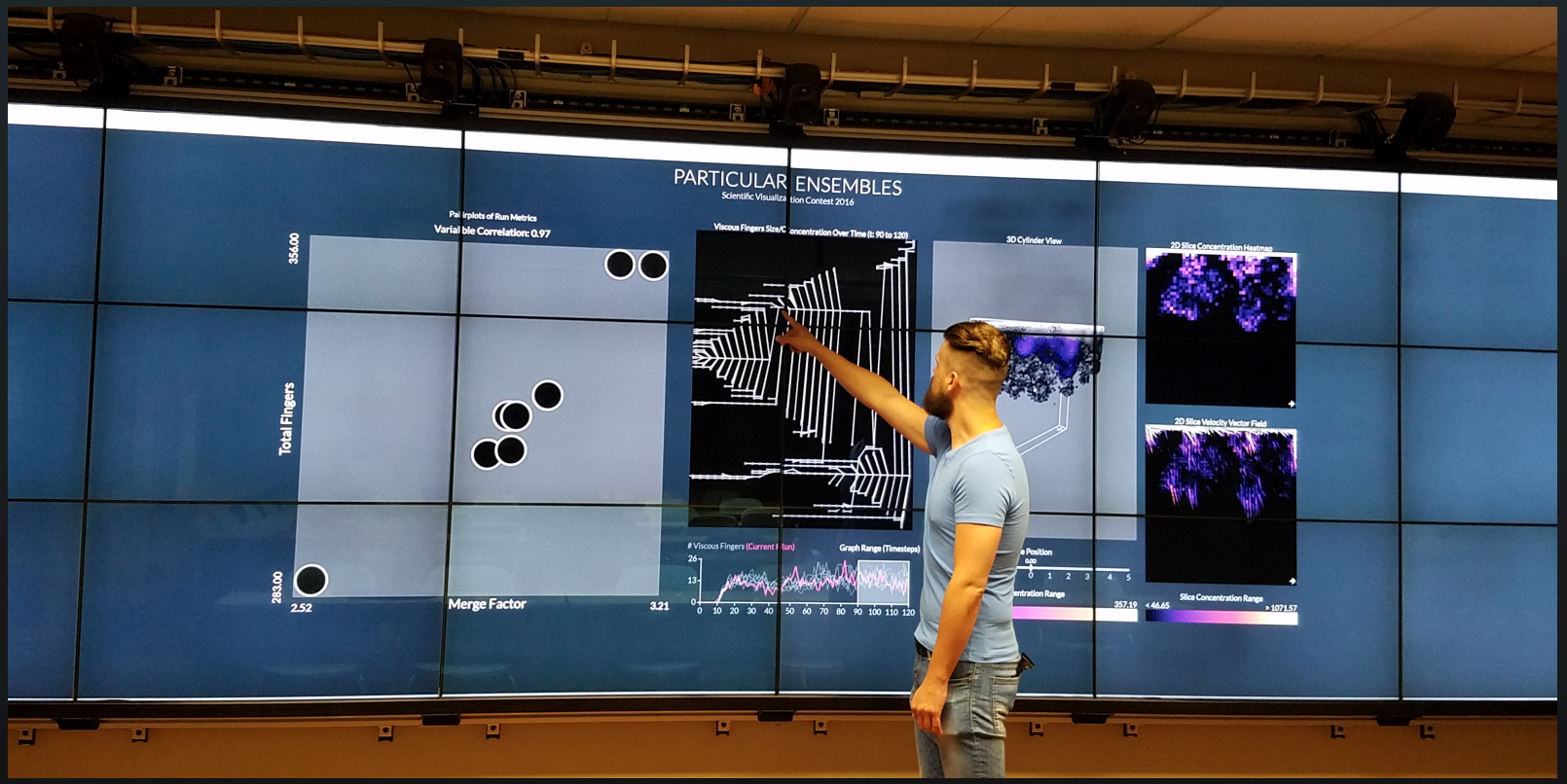


Total Clusters

260.00 358.00

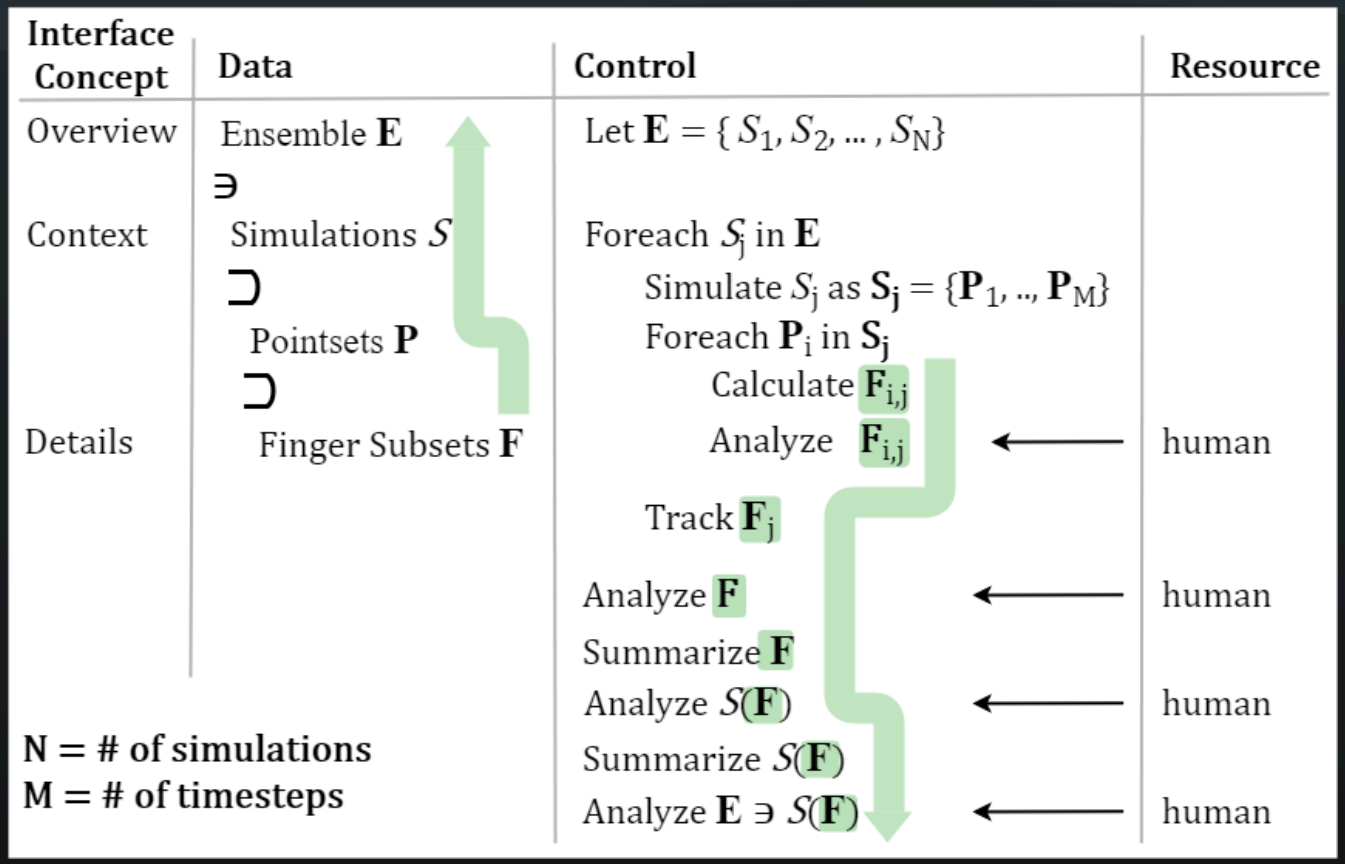
Wall displays

UIC UNIVERSITY OF ILLINOIS AT CHICAGO



Scientific Workflow theory

UIC UNIVERSITY OF ILLINOIS AT CHICAGO



A third theoretical guideline

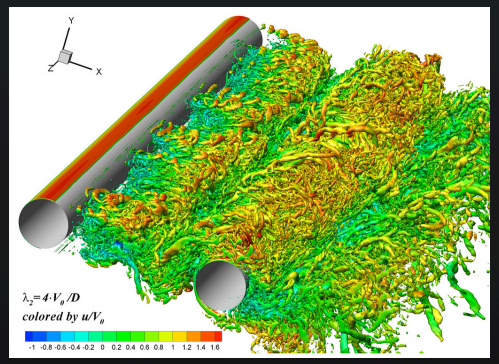
UIC UNIVERSITY OF ILLINOIS AT CHICAGO

Luciani, Burks, Sugiyama, Komperda, Marai

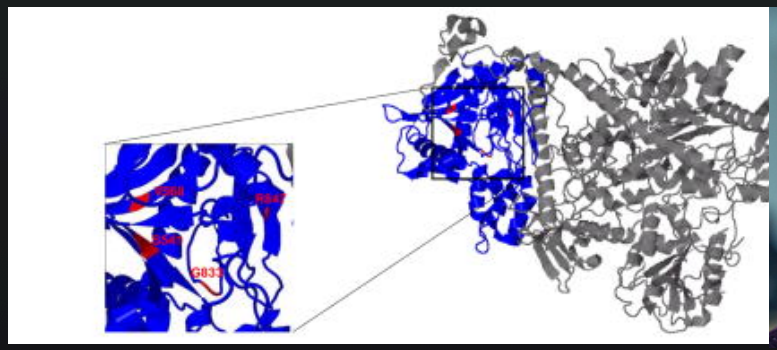
- “Details first, Show context, Overview last”

IEEE VIS’18, TVCG 2018

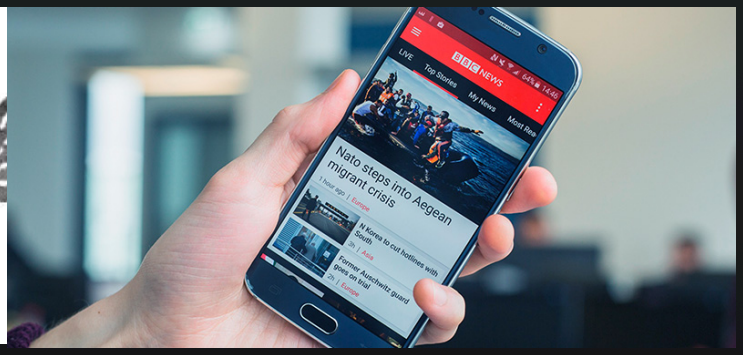
- Details-first in the wild: eng, bio, journalism



Garbaruk et al 2010



Chapman et al 2011



https://www.psafe.com/en/blog/next-step-big-data-humanize/

Theory of VIS

UIC UNIVERSITY OF ILLINOIS AT CHICAGO

- Not a general critique of Shneiderman mantra, but of its sometimes inappropriate application, w/out due consideration to the user workflows, interests, and data flow

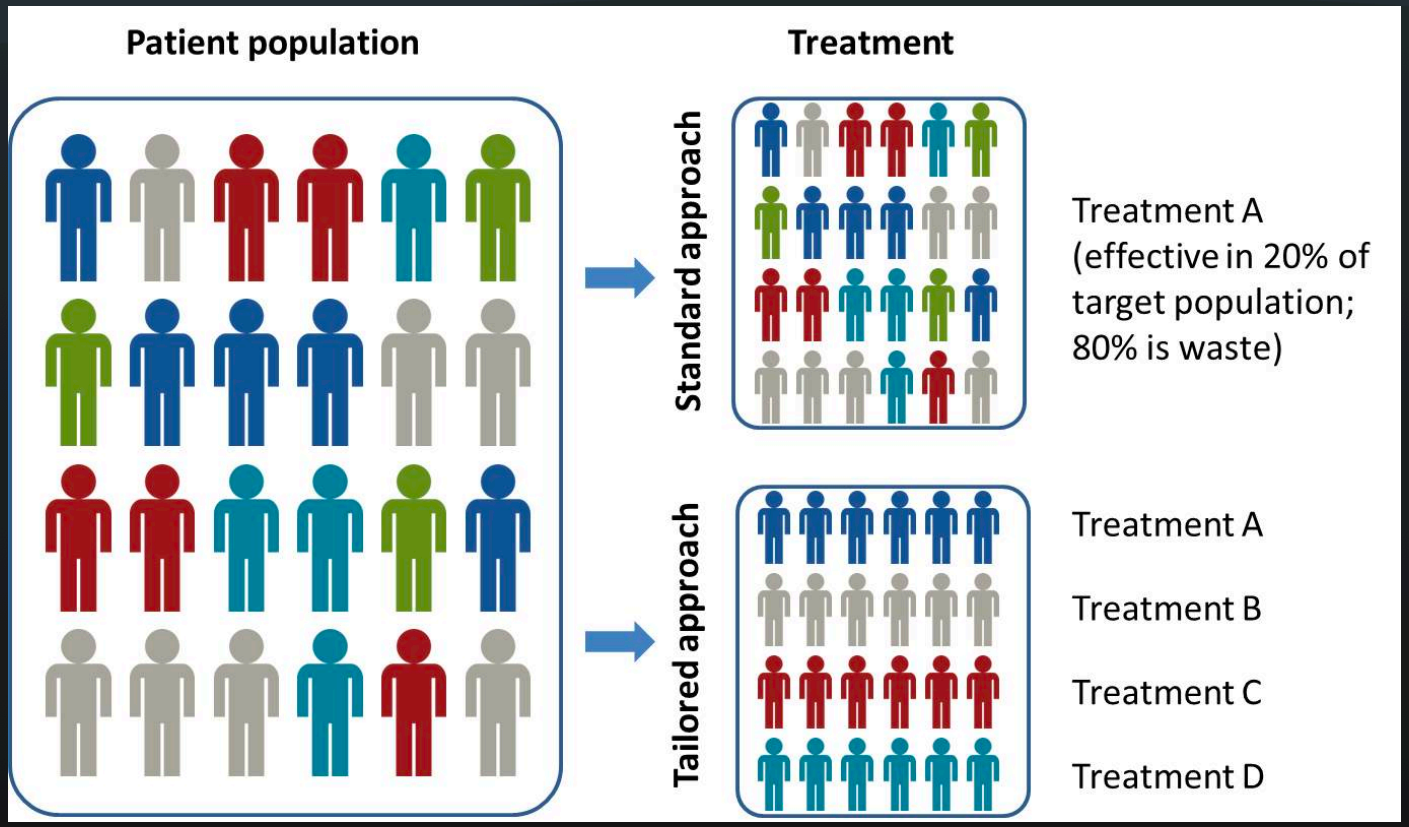
- How do we figure out what the domain expert needs?
  - "Activity-Centered Domain Characterization", Marai, TVCG 2018

UIC UNIVERSITY OF ILLINOIS AT CHICAGO

Visual Computing in Precision Medicine

Precision Medicine

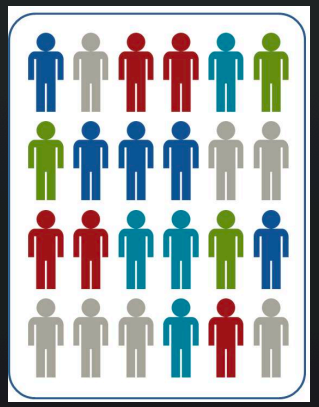
UIC UNIVERSITY OF ILLINOIS AT CHICAGO



[http://www.questdiagnostics.com/]

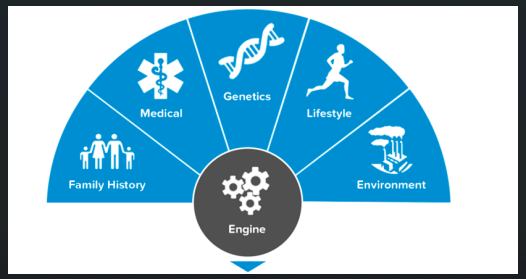
Data science in medicine

UIC UNIVERSITY OF ILLINOIS AT CHICAGO

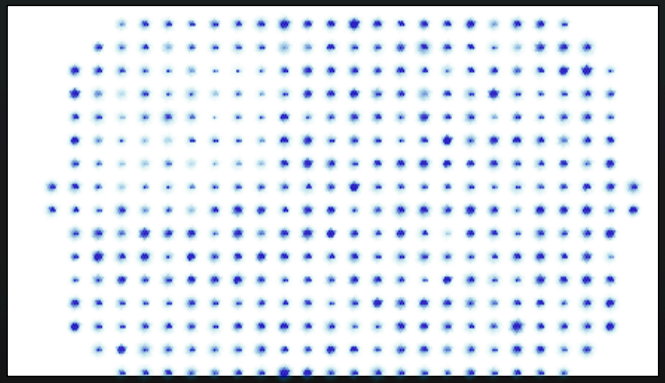


High-dimensional data

+

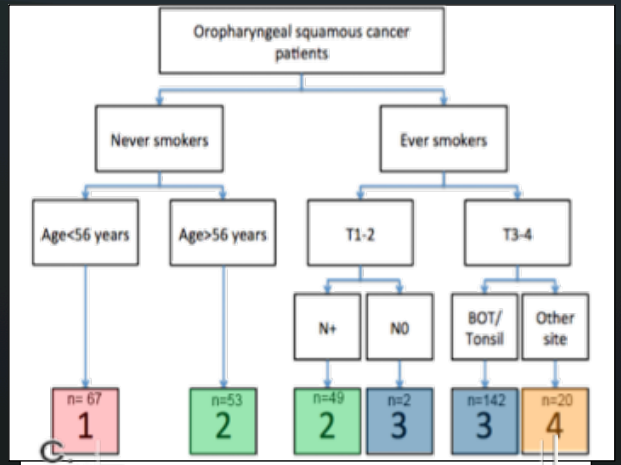


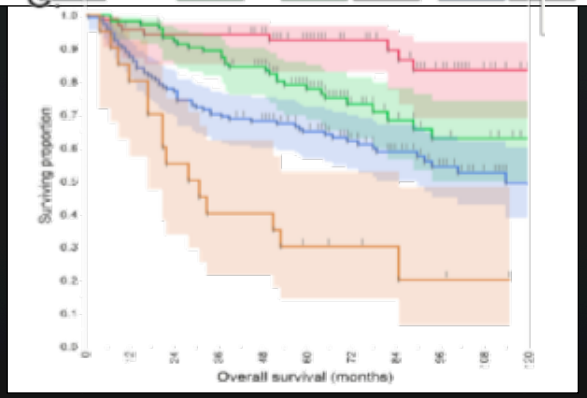
Heterogeneous data



Locally-sparse data

+

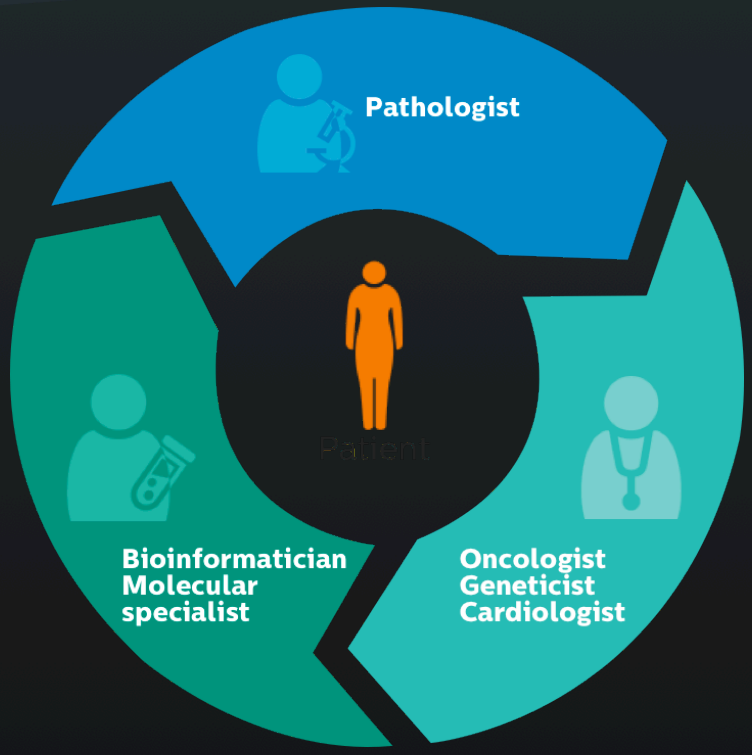




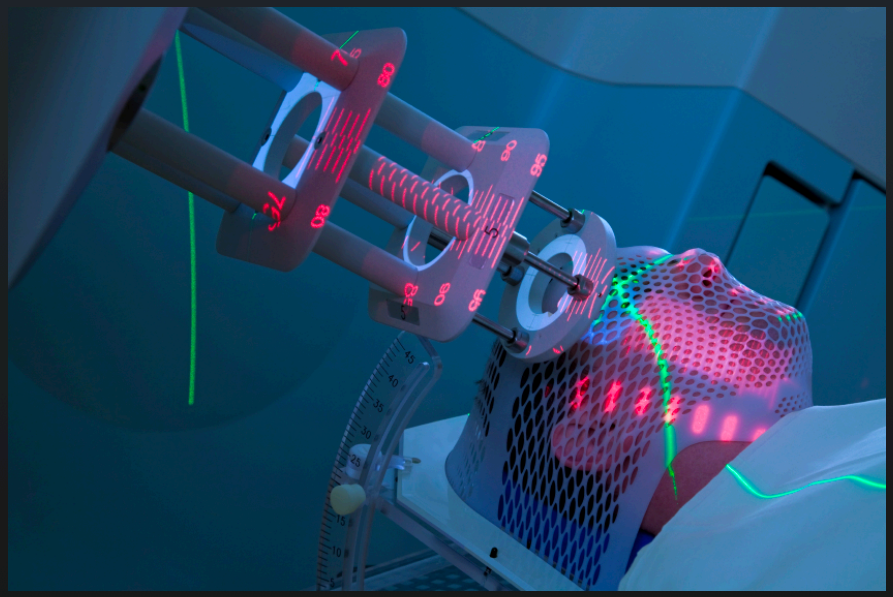
Dynamic data

Head & Neck Oncology

UIC UNIVERSITY OF ILLINOIS AT CHICAGO



[http://hitconsultant.net/]

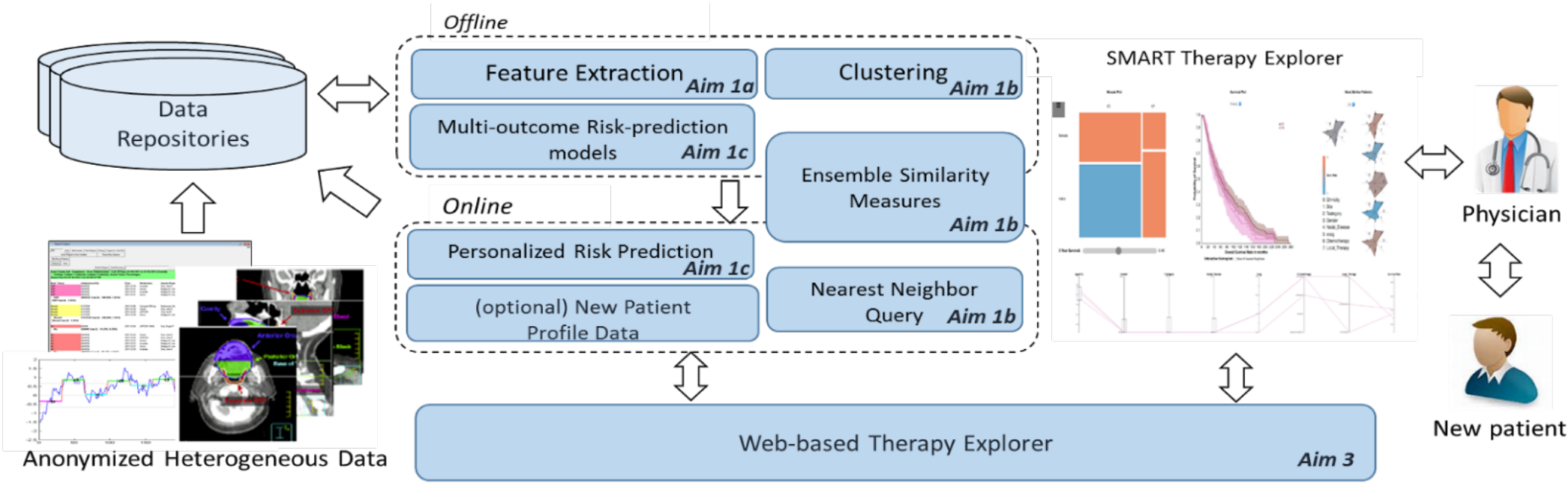


[headandneckcancerguide.org]

SMART-ACT

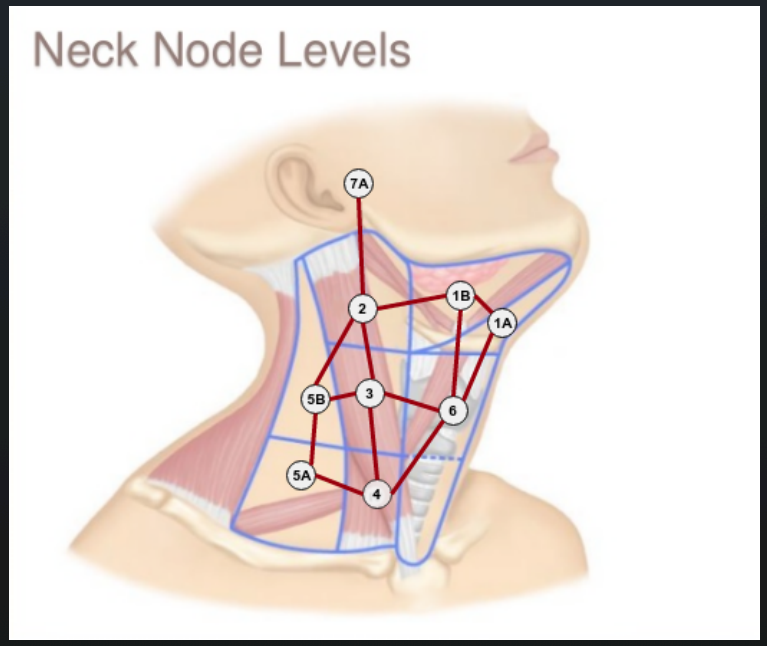
(G.E. Marai, G. Canahuate, C.D. Fuller, D. Vock)

UIC UNIVERSITY OF ILLINOIS AT CHICAGO



Lymph-node similarity

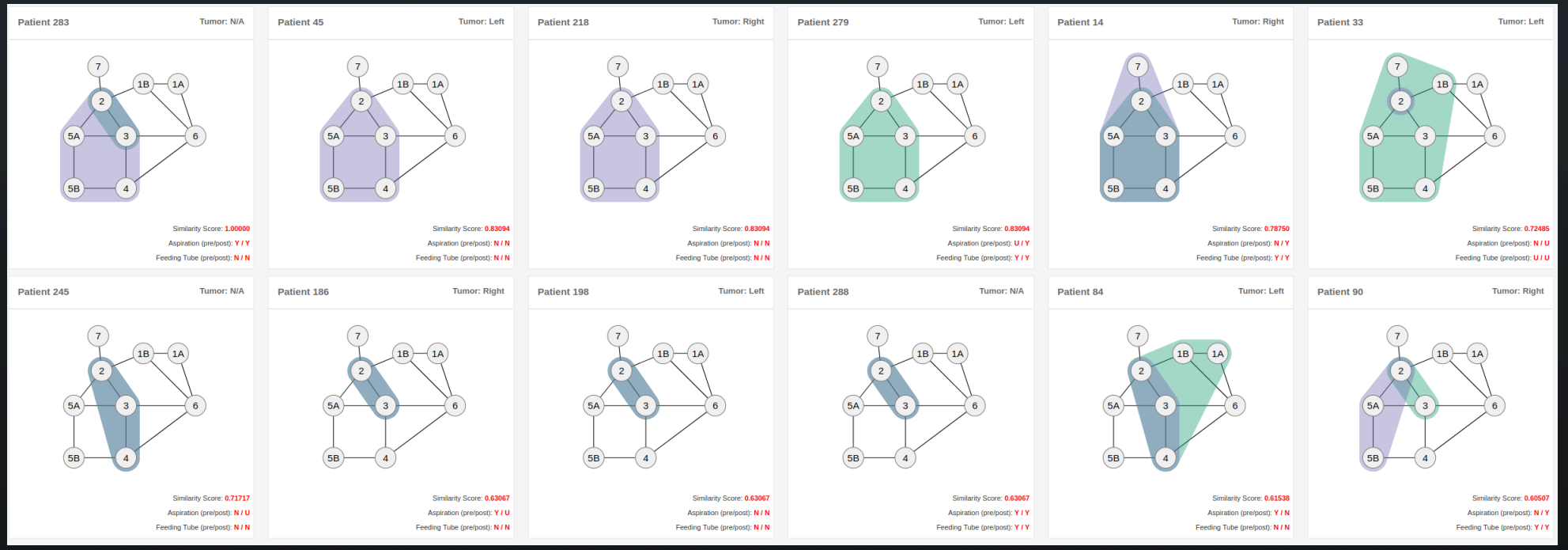
UIC UNIVERSITY OF ILLINOIS AT CHICAGO



NCI-R01: SMART-ACT Spatial Methodological Approaches for Risk Assessment and Therapeutic Adaptation in Cancer Treatment
(Lead PI on multi-site project: UIC, MDACC, U Iowa, UMN)

Lymph-node similarity

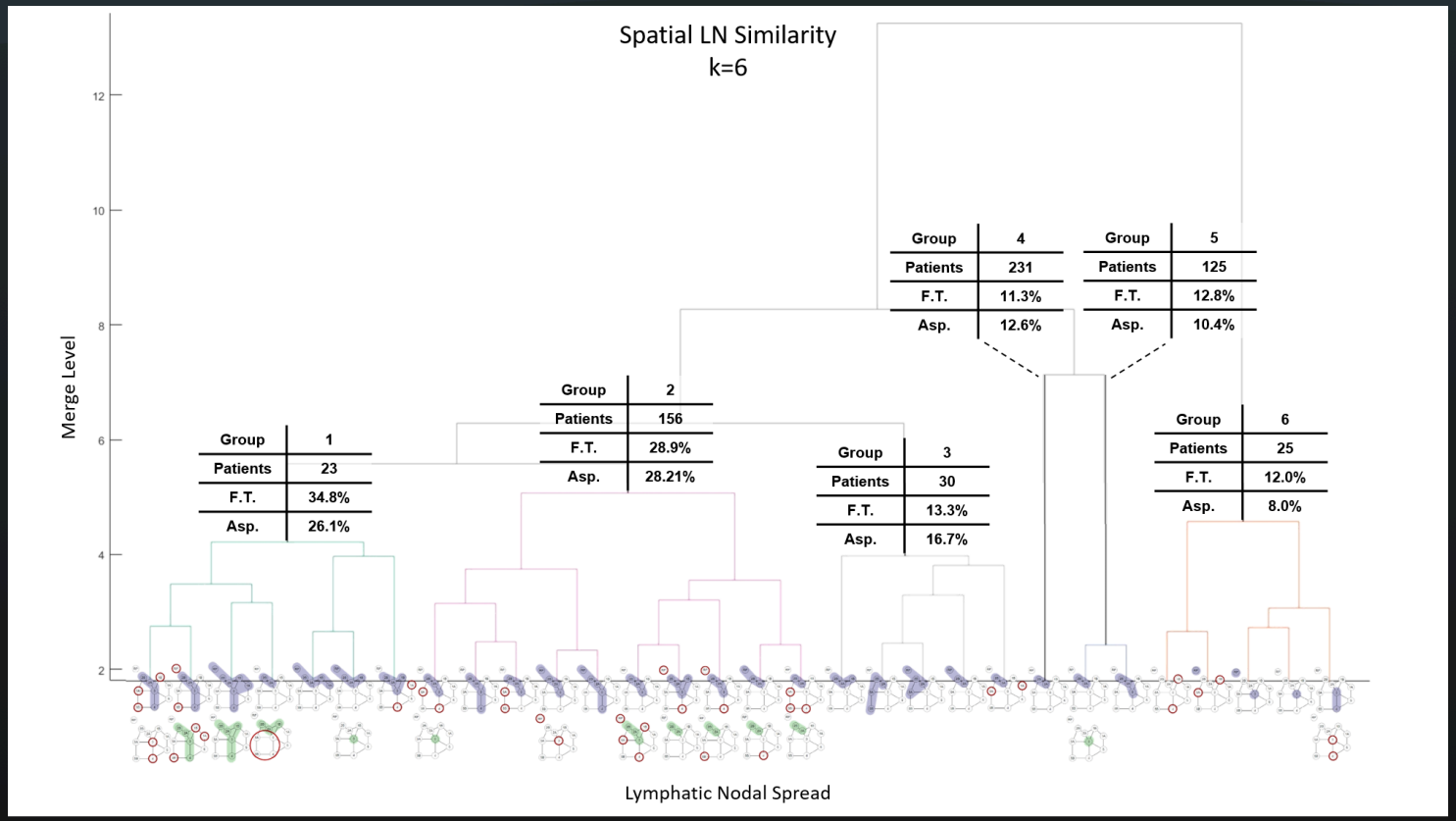
UIC UNIVERSITY OF ILLINOIS AT CHICAGO

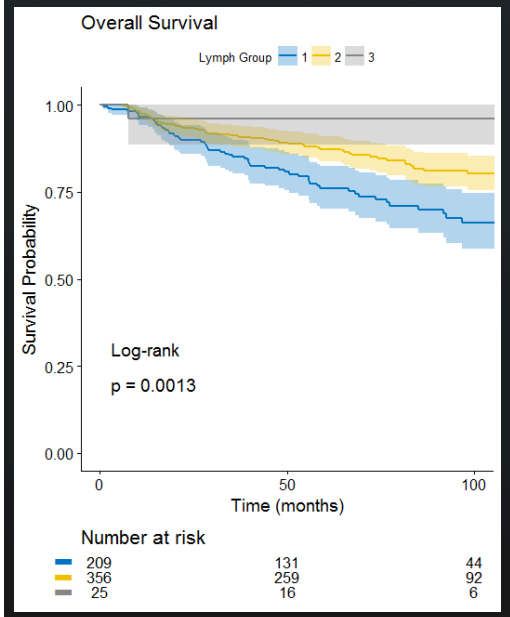


w/ T.Luciani

Correlates w/ toxicity

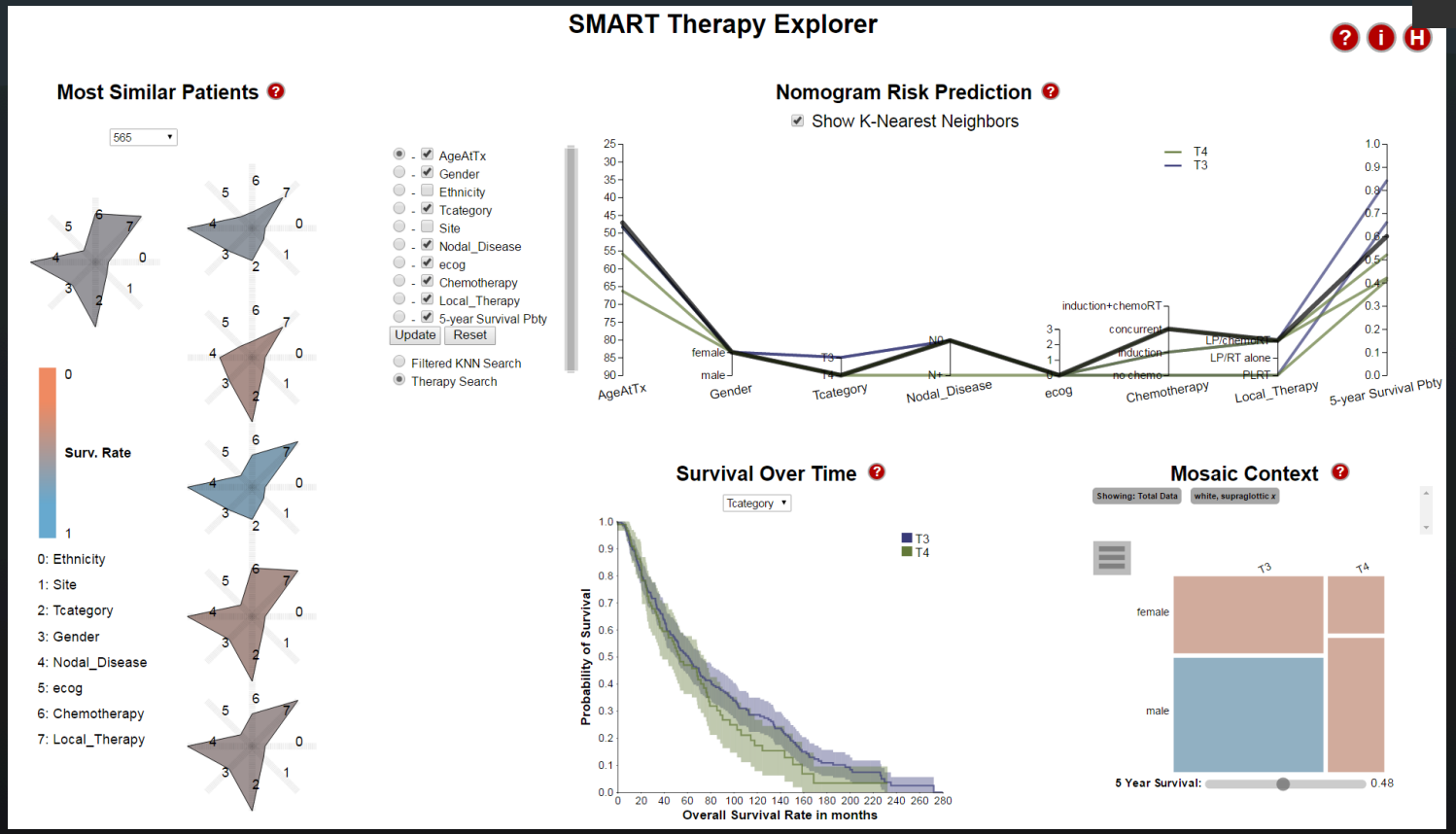
UIC UNIVERSITY OF ILLINOIS AT CHICAGO





Sharing the results

UIC UNIVERSITY OF ILLINOIS AT CHICAGO



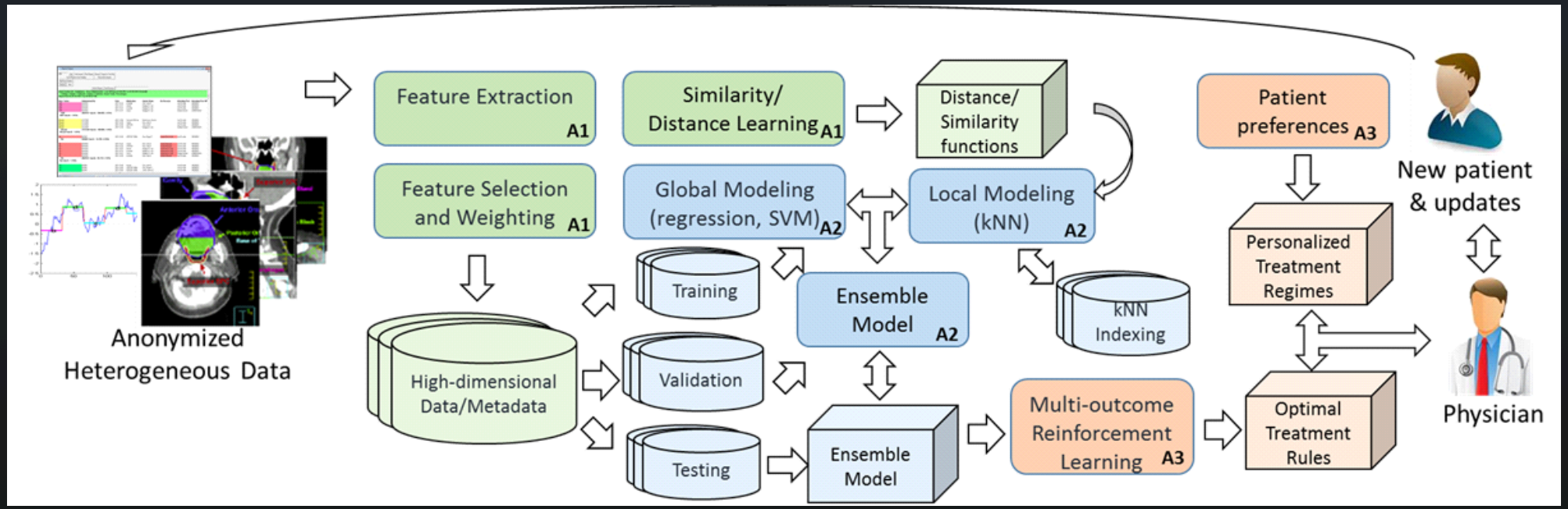
TVCG 2018, Precision Risk Analysis, Marai et al

w/ C.Ma, A. Burks, F.Pellolio, ASR Mohamed, G. Canahuate, CD Fuller, D. Vock

E-Radiomics

(Marai, G. Canahuate, C.D. Fuller, D. Vock)

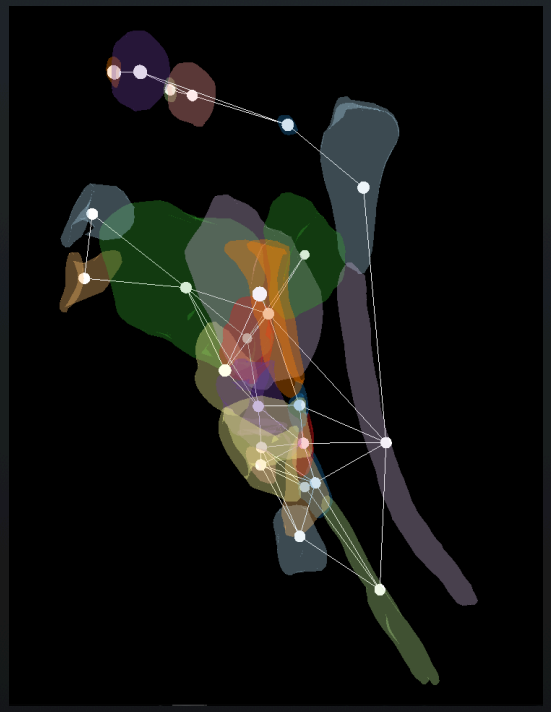
UIC UNIVERSITY OF ILLINOIS AT CHICAGO

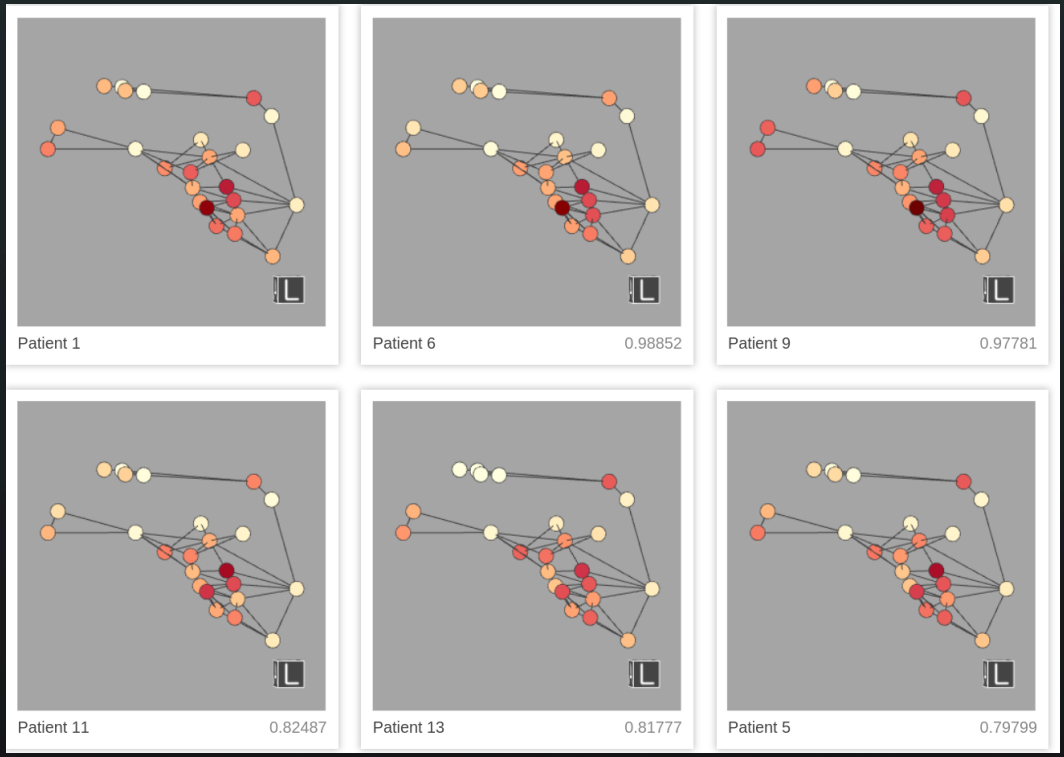


NCI-R01: QuBBD Precision E –Radiomics for Dynamic Big Head & Neck Cancer Data
(Lead PI on multi-site project: UIC, MDACC, U Iowa, UMN)

Radiation Therapy

UIC UNIVERSITY OF ILLINOIS AT CHICAGO

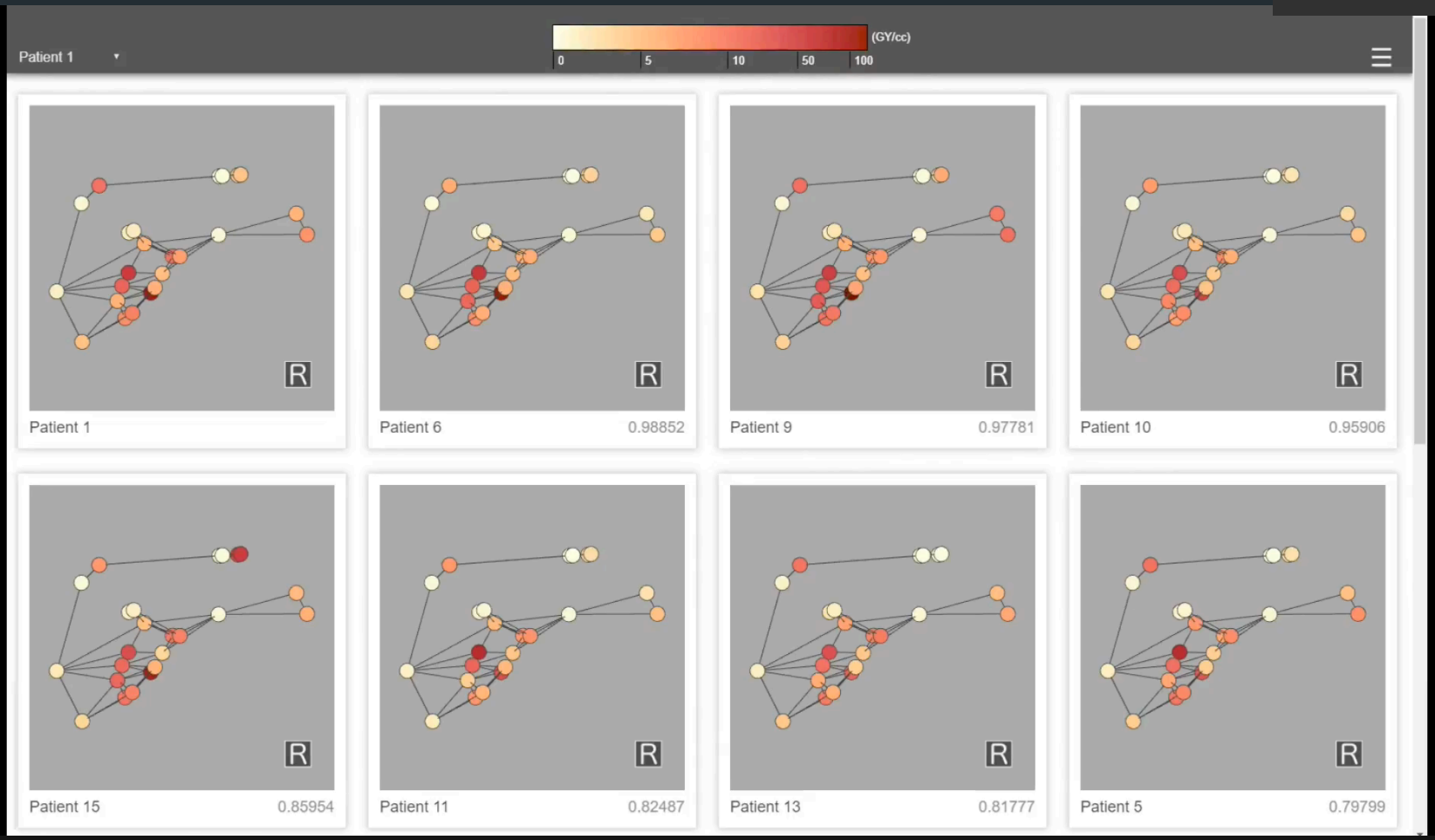


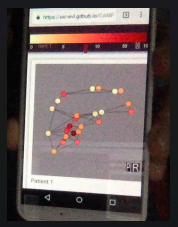


w/ T. Luciani, P. Hanula, B. Elgohari, ASR. Mohamed, CD. Fulle

RT plan similarity

UIC UNIVERSITY OF ILLINOIS AT CHICAGO





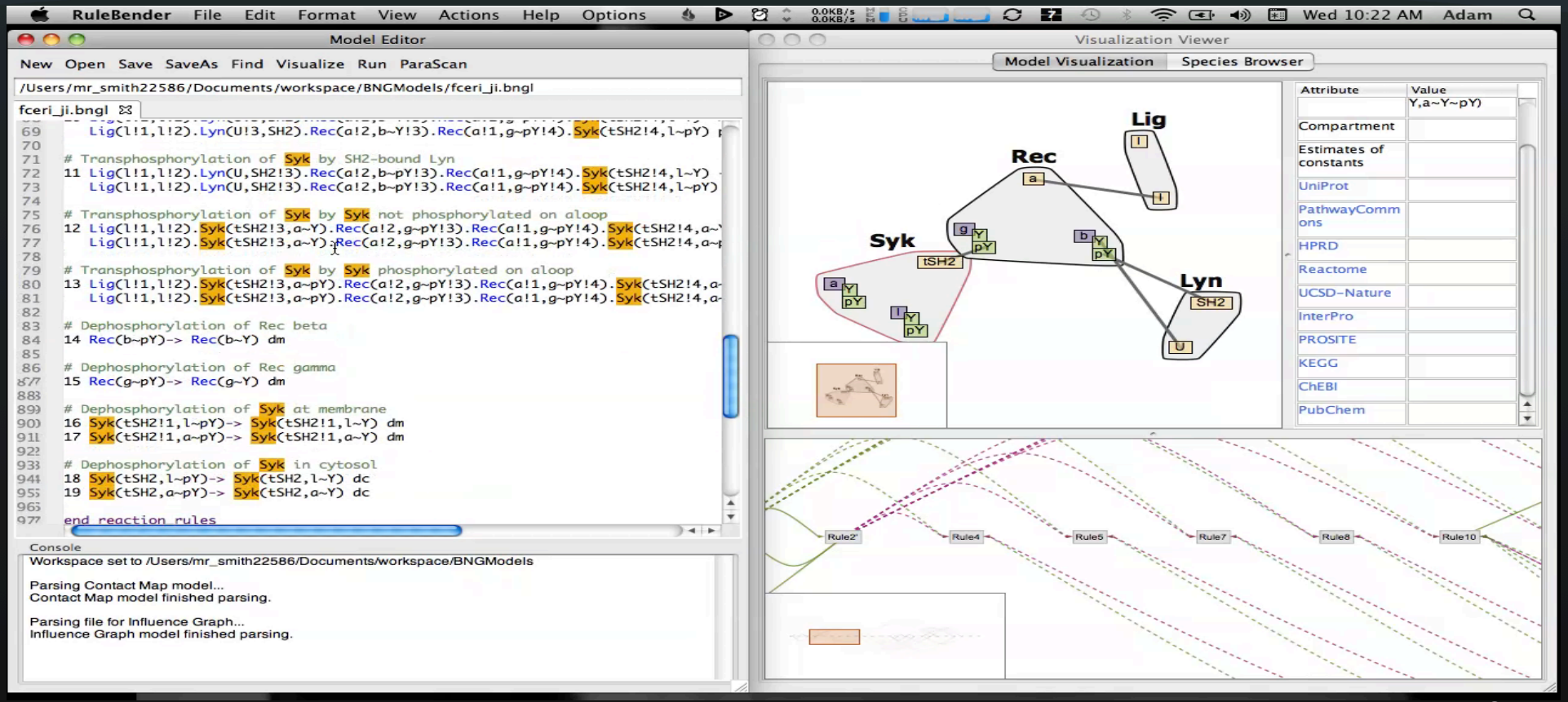
UIC UNIVERSITY OF ILLINOIS AT CHICAGO

Visual Computing in Bioinformatics

RuleBender: scientific software with thousands of users

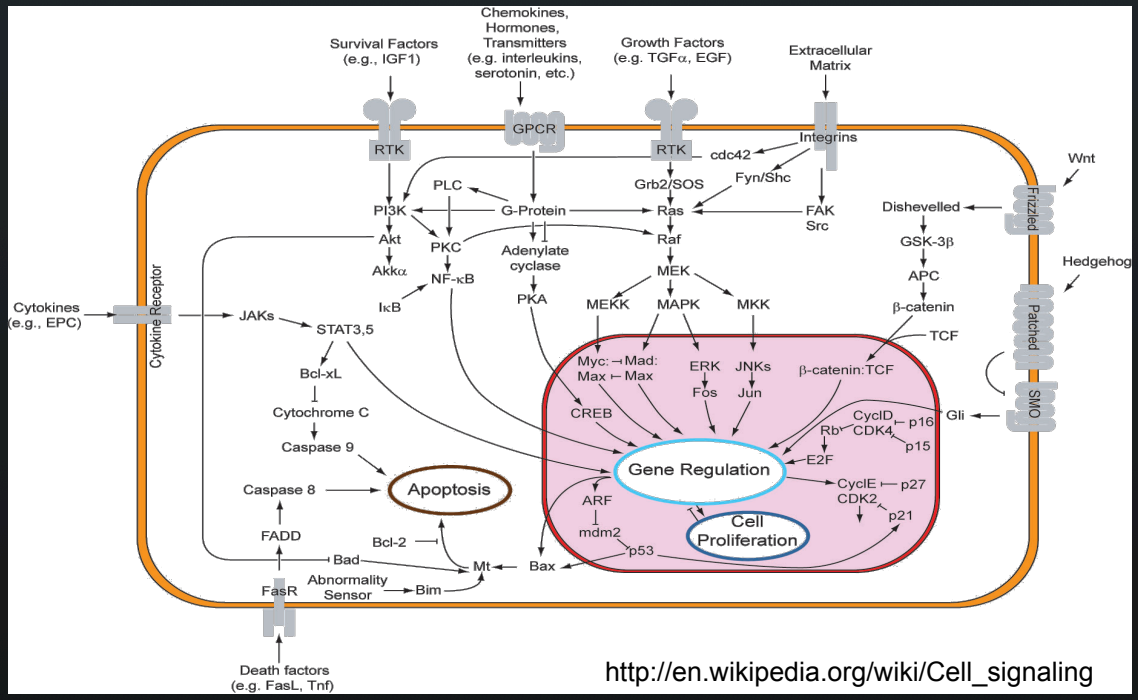
[Vis BioVis 2011] Best Paper Award
[BMC J Bioinformatics 2012]
[J Bioinformatics 2011] w/ J.Faeder, A.Smith, W.Xu

UIC UNIVERSITY OF ILLINOIS AT CHICAGO



Cell Signaling

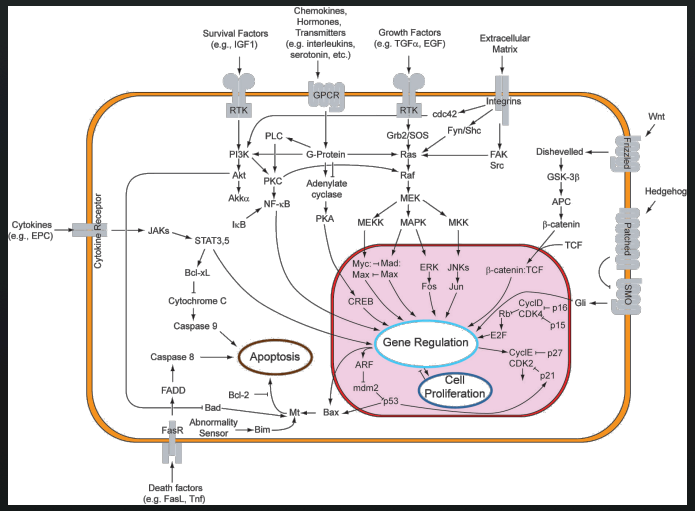
UIC UNIVERSITY OF ILLINOIS AT CHICAGO



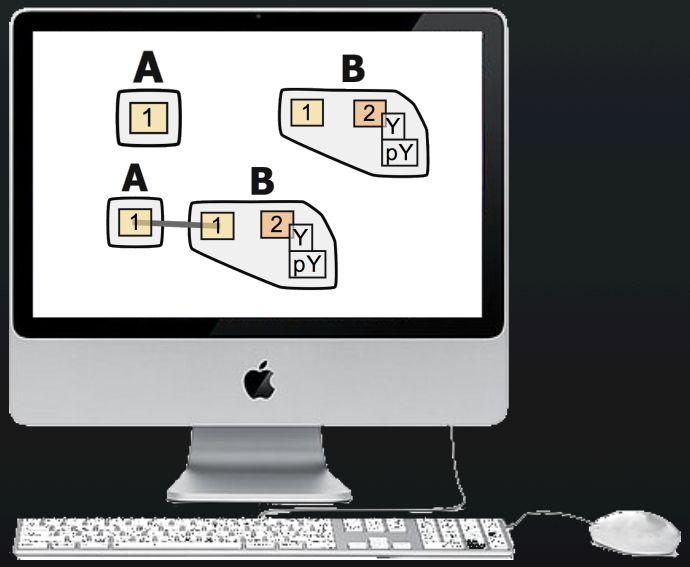
http://en.wikipedia.org/wiki/Cell_signaling

Cells as electric circuits

UIC UNIVERSITY OF ILLINOIS AT CHICAGO

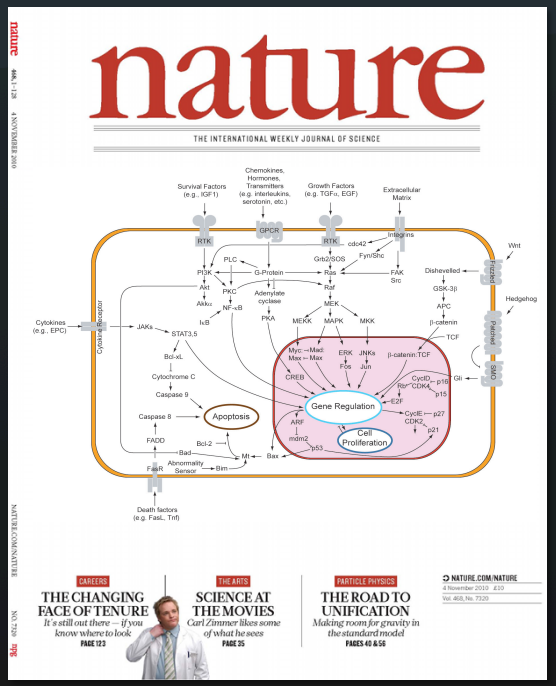


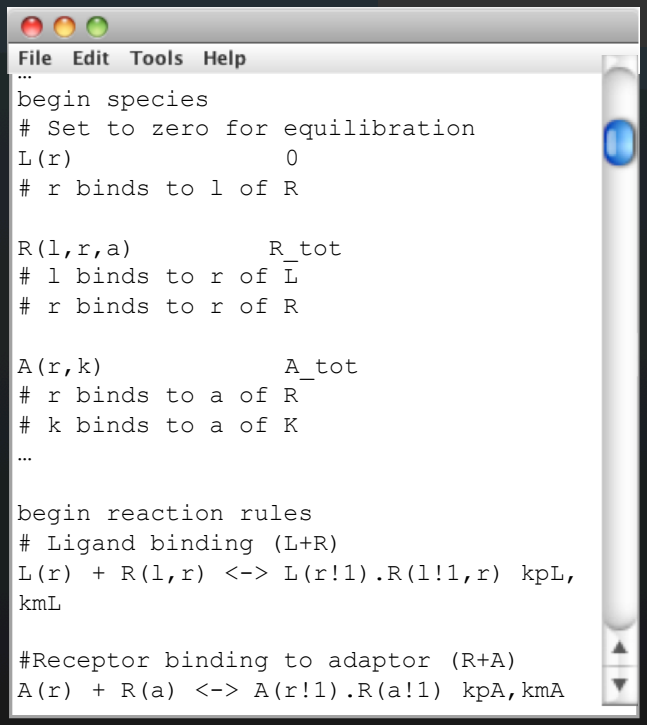
?



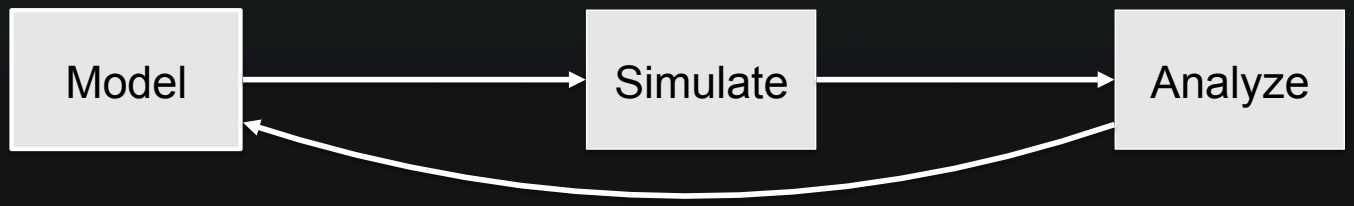
Modeling workflow

UIC UNIVERSITY OF ILLINOIS AT CHICAGO



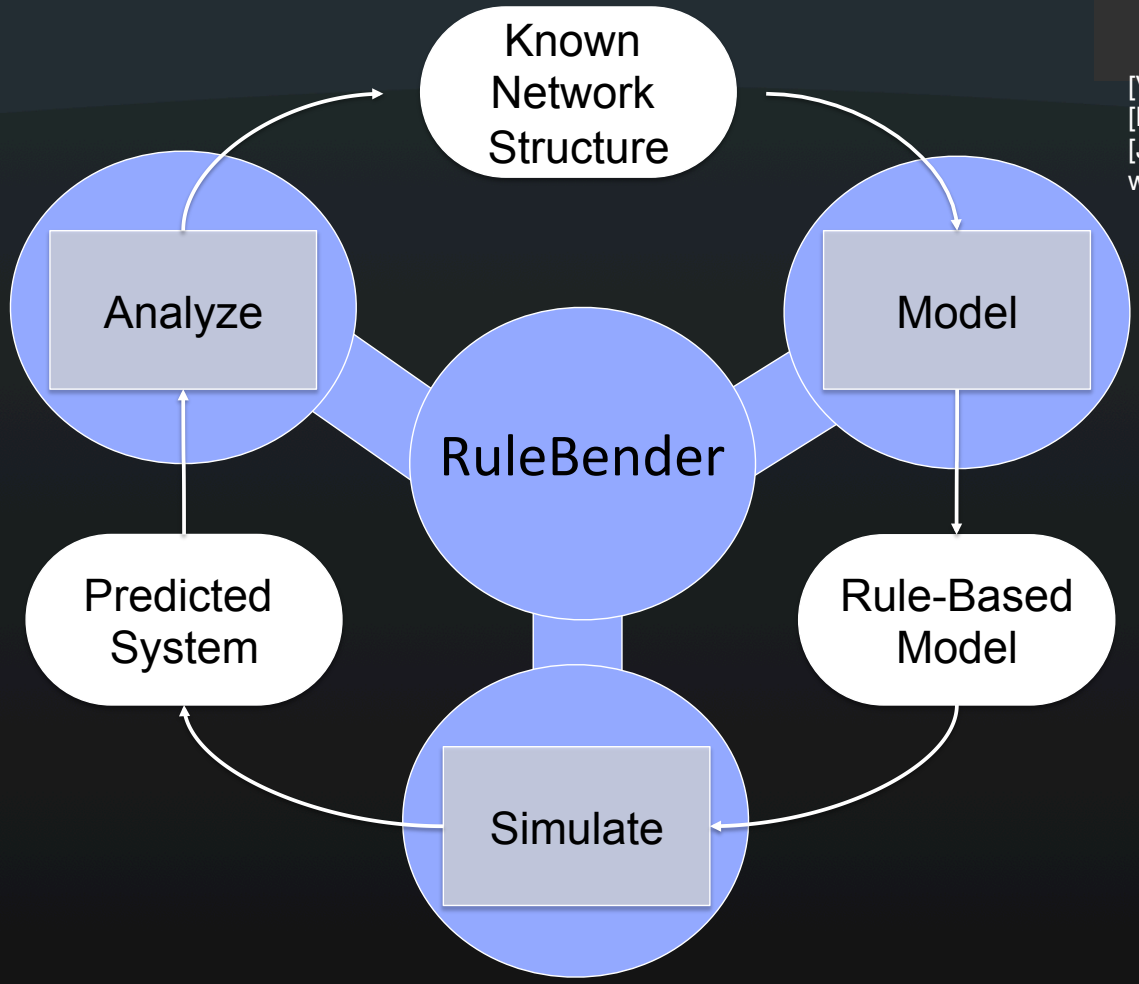


```
File  Edit  Tools  Help
…
begin species
# Set to zero for equilibration
L(r)                0
# r binds to l of R

R(l,r,a)          R_tot
# l binds to r of L
# r binds to r of R

A(r,k)              A_tot
# r binds to a of R
# k binds to a of K
…

begin reaction rules
# Ligand binding (L+R)
L(r) + R(l,r) <-> L(r!1).R(l!1,r) kpL,
kmL

#Receptor binding to adaptor (R+A)
A(r) + R(a) <-> A(r!1).R(a!1) kpA,kmA
```



UIC UNIVERSITY OF ILLINOIS AT CHICAGO

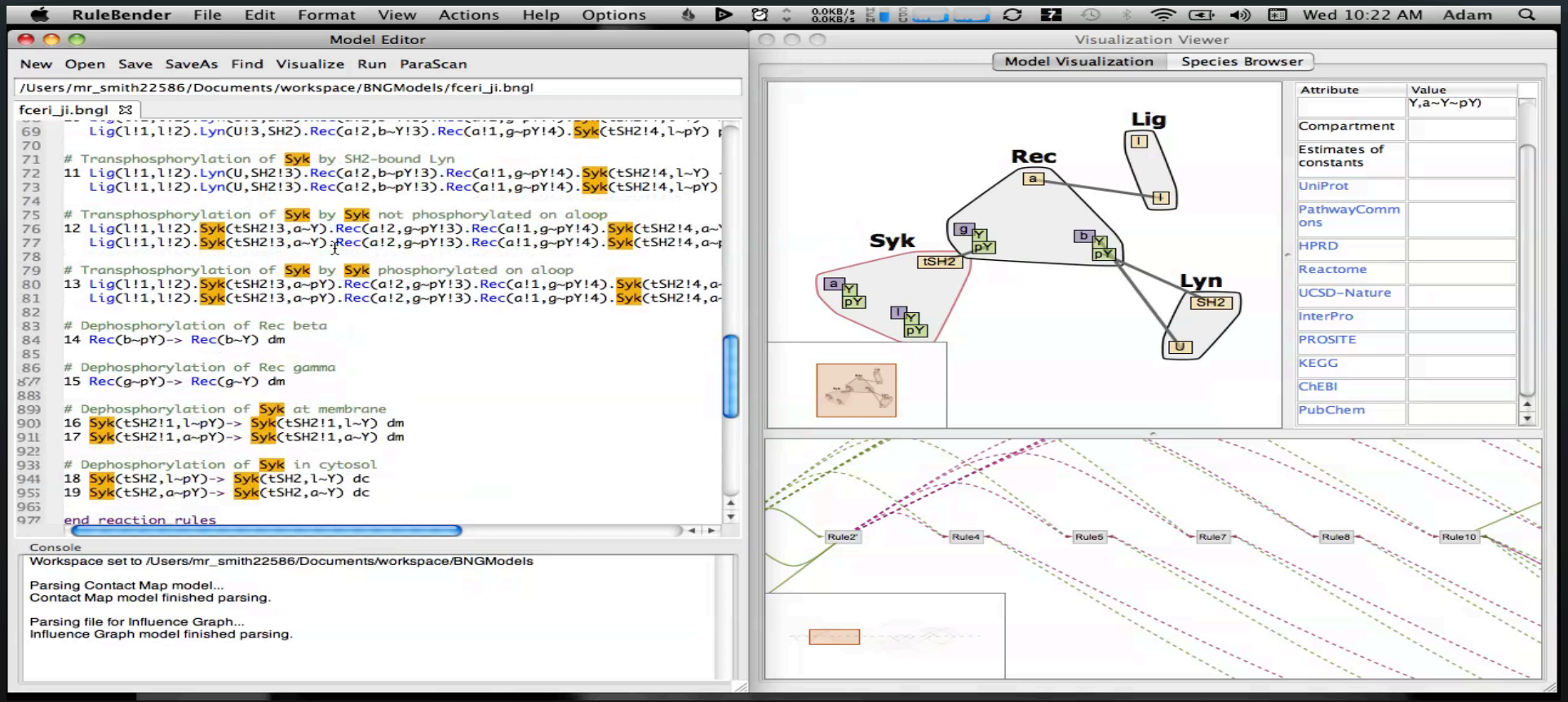
[Vis BioVis 2011] Best Paper Award
[BMC J Bioinformatics 2012]
[J Bioinformatics 2011]
w/ J.Faeder, A.Smith, W.Xu



RuleBender: scientific software with thousands of users

[Vis BioVis 2011] Best Paper Award
[BMC J Bioinformatics 2012]
[J Bioinformatics 2011] w/ J.Faeder, A.Smith, W.Xu

UIC UNIVERSITY OF ILLINOIS AT CHICAGO



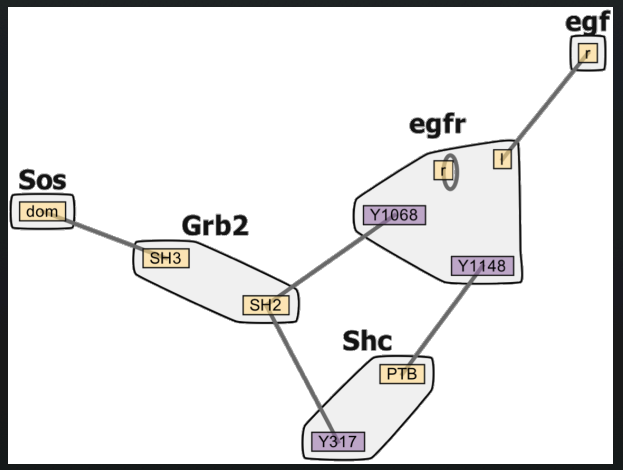
Contact map

UIC UNIVERSITY OF ILLINOIS AT CHICAGO

- Concise, scalable, graph representation
  - Example: 6 molecules, 37 interactions
  - (generated 365 molecules, more than 3000 interactions)

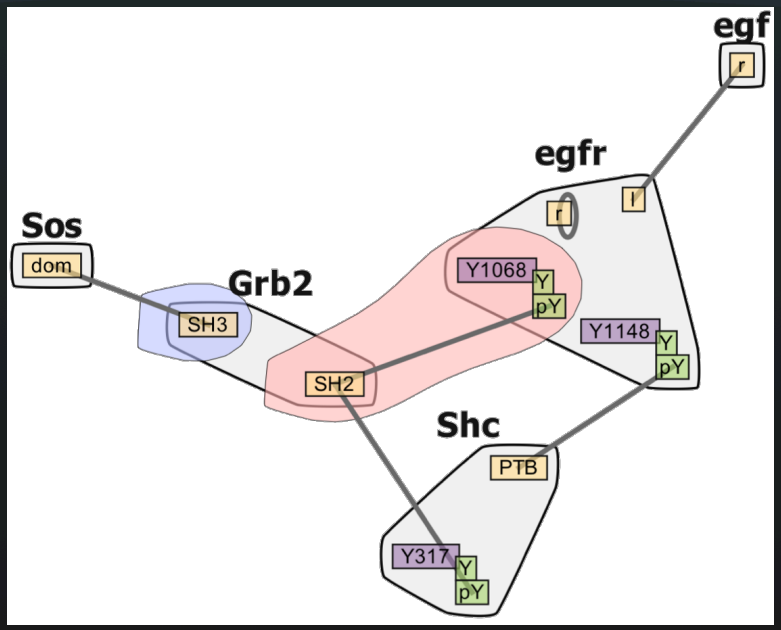
- Provides global view of a model

- Molecules, internal domains, and states
- Rules:
  - Bond creation/destruction
  - State change



Bubble Sets, Filtering and Data on Demand

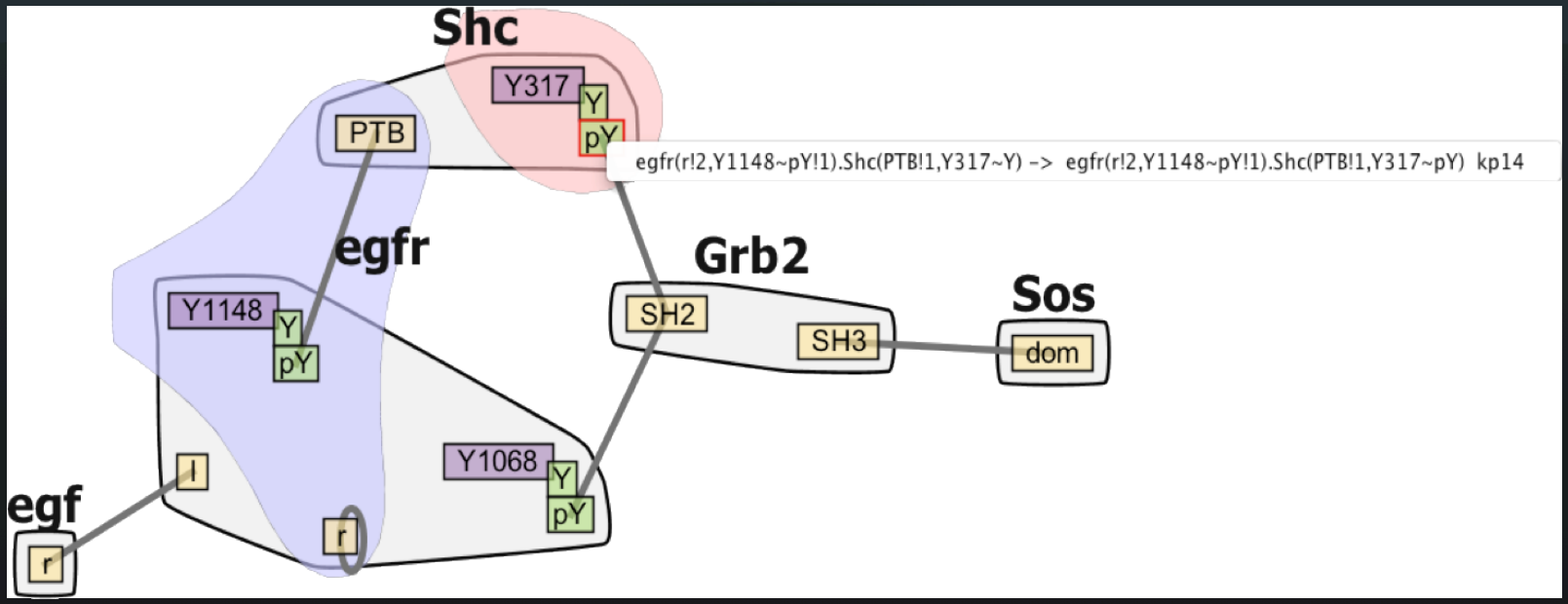
UIC UNIVERSITY OF ILLINOIS AT CHICAGO



egfr(Y1068~pY) + Grb2(SH2, SH3) **<->** egfr(Y1068~pY!1).Grb2(SH2!1, SH3)

Case Study:
EGFR: 6 molecules and 37 rules

UIC UNIVERSITY OF ILLINOIS AT CHICAGO

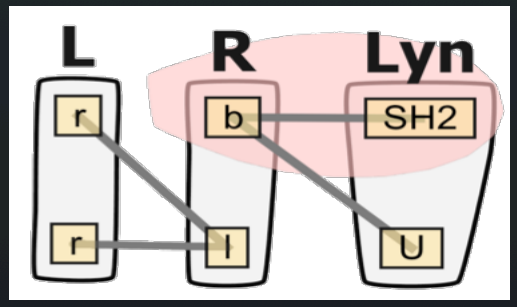


- Contact Map shows two paths for Sos binding
- Bubble Sets shows that egfr dimerization is a necessary condition for the recruitment to take place.

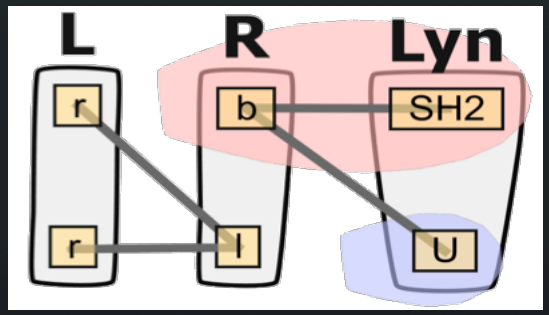
Case Study: Lyn Binding

UIC UNIVERSITY OF ILLINOIS AT CHICAGO

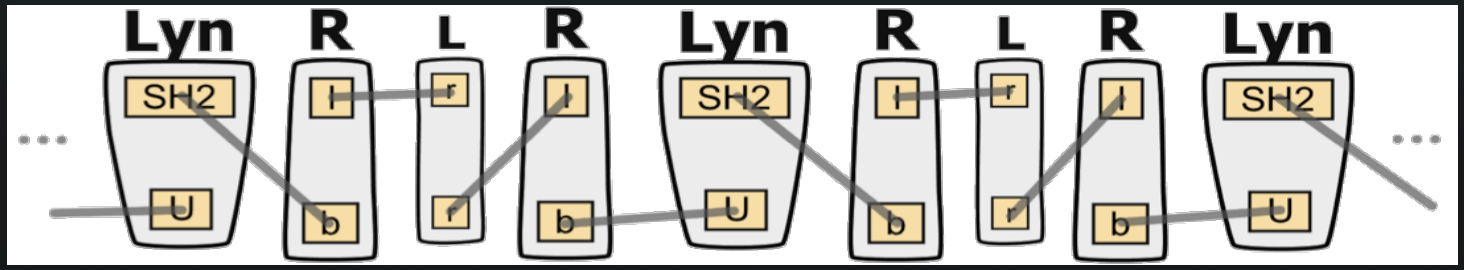
Contact Map:



Incorrect



Correct



Infinite Species

BioVis: 700 *E. Coli* genomes in comparative genomics

UIC UNIVERSITY OF ILLINOIS AT CHICAGO

w/ J. Aurisano et al, ”BactoGeNie”, BMC Bioinformatics 2015

Images courtesy of the UIC Electronic Visualization Laboratory (Photos: Lance Long, UIC).

Roadmap

UIC UNIVERSITY OF ILLINOIS AT CHICAGO

- EVL and Visual Computing
- Beyond ParaView
- Precision Medicine
- Bioinformatics

Visual computing can impact significantly scientific research

UIC UNIVERSITY OF ILLINOIS AT CHICAGO

- Visual Computing: both applications and theory, algos, encodings
- In engineering: facilitate analysis of complex datasets and make insights possible
- In precision medicine: enable novel calculations over images and 3D models
- In bioinformatics: bridge wet-lab with in silico experimentation; enable analysis of large, heterogeneous datasets

- Create shared cognitive spaces; Facilitate communication of results

Acknowledgments

UIC UNIVERSITY OF ILLINOIS AT CHICAGO

- NIH R01 CA214825, R01 CA225190, NIH R01 LM012527
- NSF CAREER IIS-1541277, CBET-1250171, DMS-1557559 and CNS-1625941

- Collaborators and students
- Electronic Visualization Laboratory

Contact

UIC UNIVERSITY OF ILLINOIS AT CHICAGO

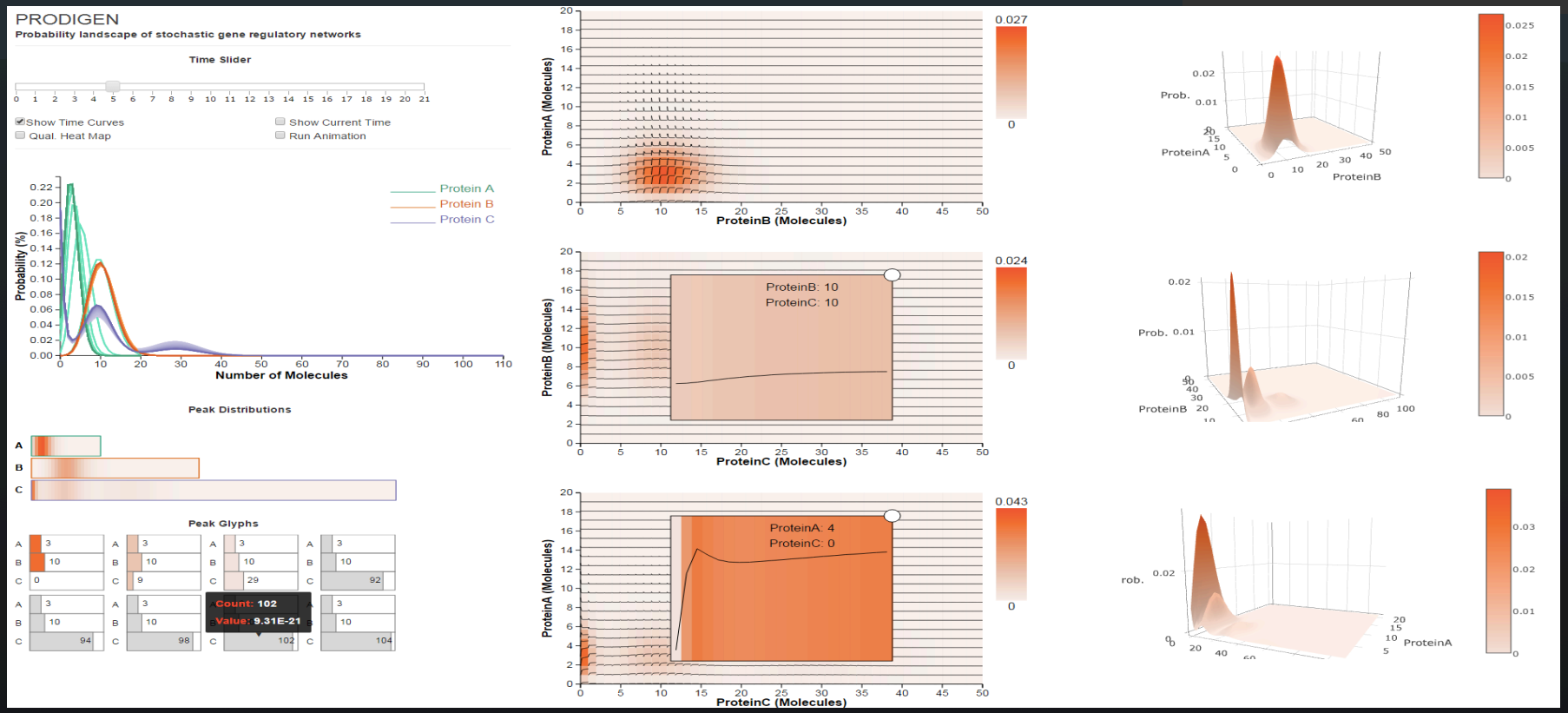
Liz Marai

Electronic Visualization Laboratory, Chicago IL, USA www.evl.uic.edu

UIC UNIVERSITY OF ILLINOIS AT CHICAGO

Prodigen: exploring stochastic cell signaling networks

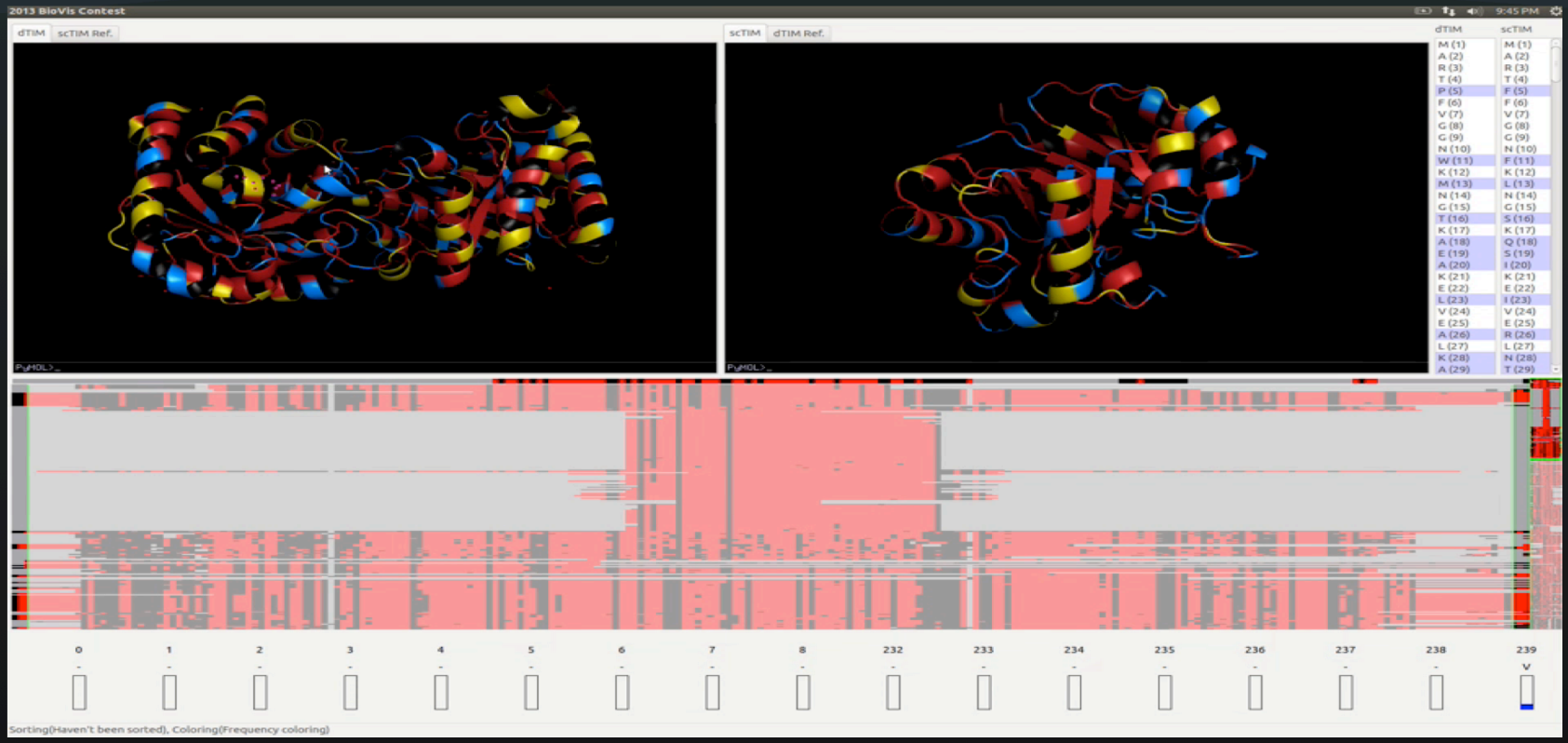
UIC UNIVERSITY OF ILLINOIS AT CHICAGO



[Ma et al, BMC Bioinformatics'17] w/ C. Ma, J. Linag, A. Terebus

FixingTIM: identify which mutations are responsible for loss of functionality

UIC UNIVERSITY OF ILLINOIS AT CHICAGO



[Luciani et al, BMC'13] BioVis Contest Award
w/ T. Luciani, J. Wenksovitch, K. Chen

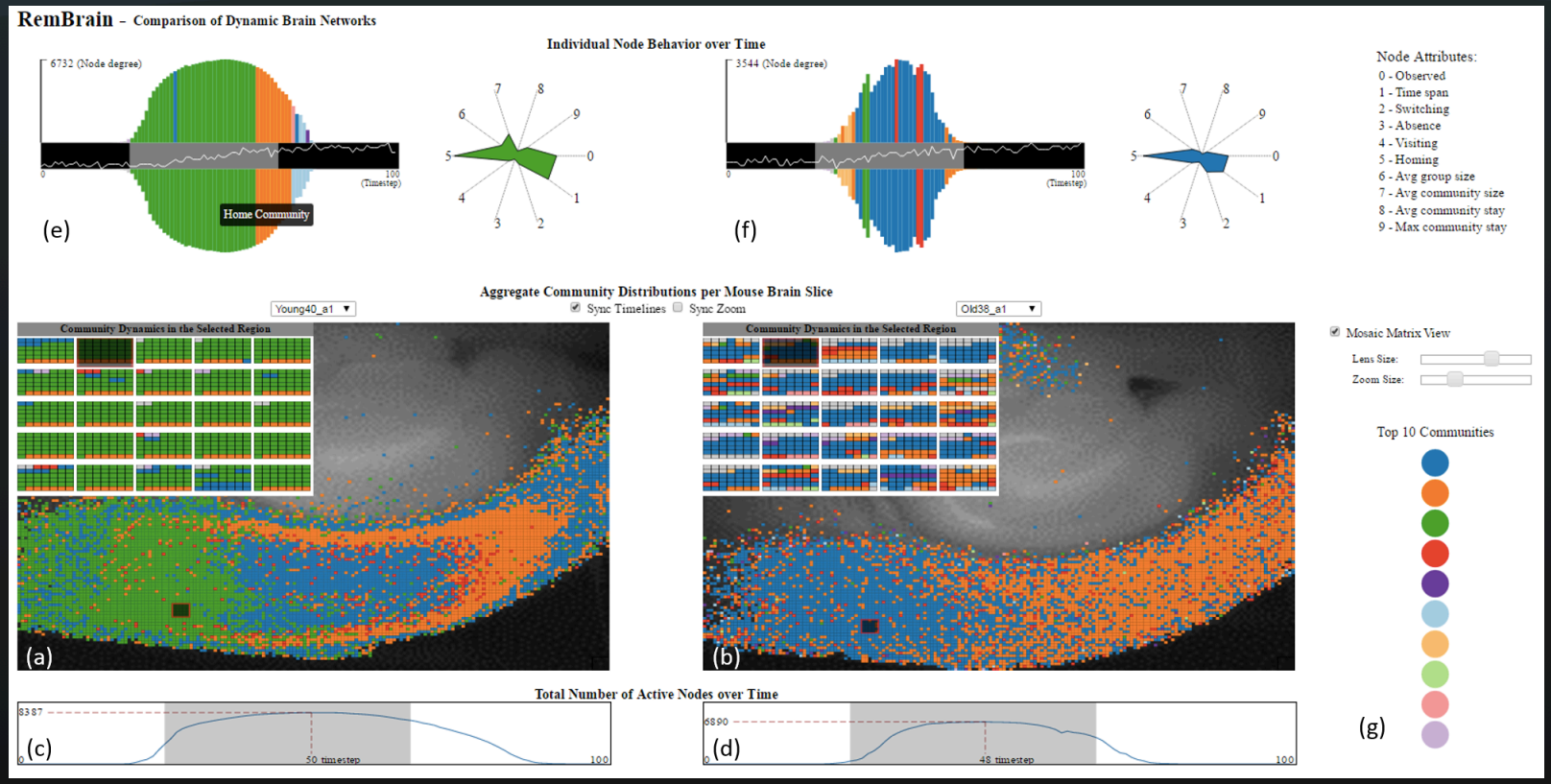
ECHO: effective care hand-offs in ICUs

UIC UNIVERSITY OF ILLINOIS AT CHICAGO

[VHAC'17] w/ M.Thomas, T.Kannampallil, J.Abraham

RemBrain: exploring dynamic networks in mouse brains

UIC UNIVERSITY OF ILLINOIS AT CHICAGO



w/ C. Ma, R. Kenyon, D. Llano, T. Berger-Wolf