Data Visualization in Genomics and In-Car Network Engineering

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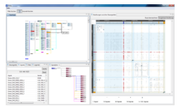
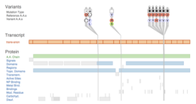
1 July 2014, London UK

http://www.cs.ubc.ca/~tmm/talks.html#london14

Outline

- Design Study Methodology
  - meta-paper: how to do design studies
- RelEx
  - overlay network optimization for in-car networks
- Variant View
  - sequence variant analysis in gene context





Defining Visualization

Computer-based visualization systems provide visual representations of datasets designed to help people carry out tasks more effectively.

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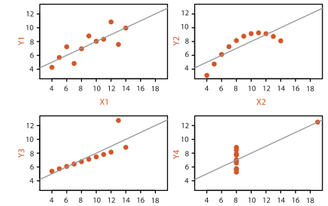
  - doesn't know exactly what questions to ask in advance

Identical statistics	
x mean	9.0
x variance	10.0
y mean	7.50
y variance	3.75
x/y correlation	0.816



http://upload.wikimedia.org/wikipedia/commons/b/b0/Anscombe.svg

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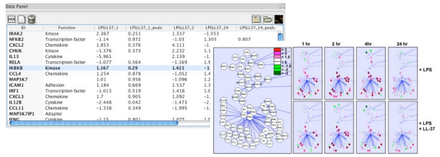
- external representation: replace cognition with perception



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- external representation: perception vs cognition
- intended task

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Defining Visualization

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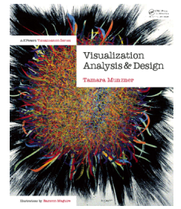
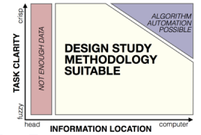
- human in the loop needs the details
  - doesn't know exactly what questions to ask in advance
- external representation: perception vs cognition
- intended task
- measureable definitions of effectiveness

more at:
Visualization Analysis and Design, Chapter 1.
Munzner. AK Peters, 2014, to appear.





Design Study Methodology

Reflections from the Trenches and from the Stacks

joint work with:
Michael Sedlmair, Miriah Meyer

http://www.cs.ubc.ca/labs/imager/tr/2012/dsm/

Design Study Methodology: Reflections from the Trenches and from the Stacks.
Sedlmair, Meyer, Munzner. IEEE TVCG 18(12): 2431-2440, 2012 (Proc. InfoVis 2012).

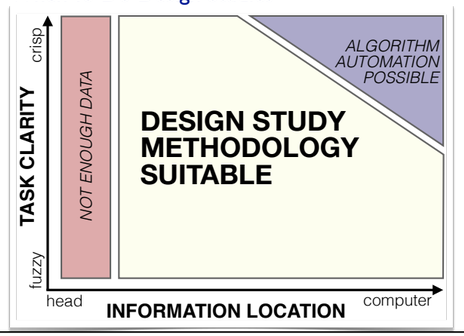
Defining Design Study

- a specific real-world problem
  - real users and real data,
  - collaboration is (often) fundamental
- design a visualization system
  - implications: requirements, multiple ideas
- validate the design
  - at appropriate levels
- reflect about lessons learned
  - transferable research: improve design guidelines for vis in general
    - confirm, refine, reject, propose

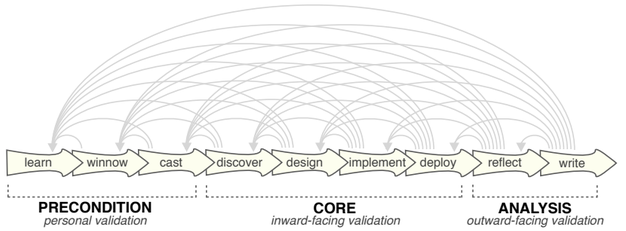
more at:
A Nested Model of Visualization Design and Validation.
Munzner. IEEE TVCG 15(6):921-928, 2009 (Proc. InfoVis 2009).

more at:
The Nested Blocks and Guidelines Model.
Meyer, Sedlmair, Quinan, Munzner. Information Visualization Journal, 2014, to appear.

When To Do Design Studies

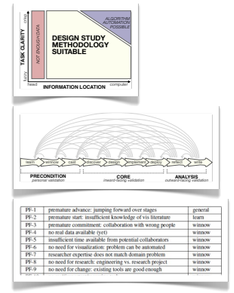


Nine-Stage Framework



How To Do Design Studies

- definitions
- 9-stage framework
- 32 pitfalls and how to avoid them



Pitfall Example: Premature Publishing

algorithm innovation

design studies

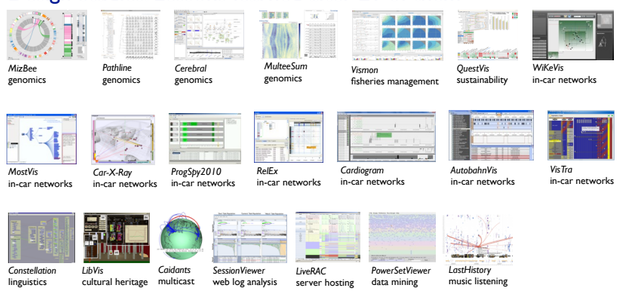
Must be first!

Am I ready?

http://www.pnlog.org/104803/34-wolverhampton-horse-racing-live-streaming-wolverhampton-handicap-8-jan-2010.html

http://www.alaineknipes.com/interests/violin_concert.jpg

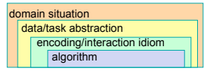
Design Studies: Lessons learned after 21 of them



- commonality of representations cross-cuts domains!

Abstractions and Idioms

- abstractions
  - translate from specifics of domain to vocabulary of vis
    - task abstraction: **why** they're looking at it
    - data abstraction: **what** to draw
  - transform data into form useful for task at hand
    - don't just draw what you're given; decide what is the right thing!
- idioms
  - visual encoding idiom: **how** to draw
  - interaction idiom: **how** to manipulate
- focus today: two mappings
  - from domain to abstraction
  - from abstraction to idiom



A Nested Model of Visualization Design and Validation.
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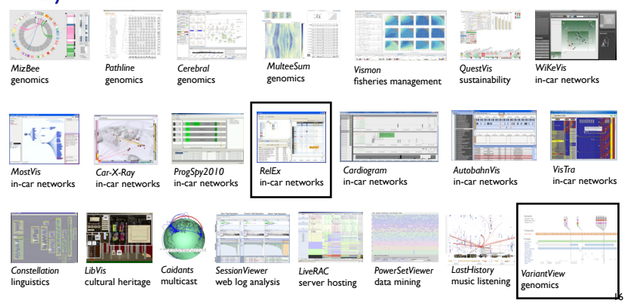
Today's Focus



Design Studies: giCentre Context

- methodology

  Human-centered approaches in geovisualization design: investigating multiple methods through a long-term case study. *Lloyd and Dykes. IEEE Transactions on Visualization and Computer Graphics, 17(12):2498–2507, 2011.*

- energy analysis

  Creative user-centered visualization design for energy analysts and modelers. *Goodwin, Dykes, Jones, Dillingham, Dove, Duffy, Kachkaev, Slingsby, Wood. IEEE Transactions on Visualization and Computer Graphics, 19(12), pp. 2516-2525, 2013.*

- BallotMaps

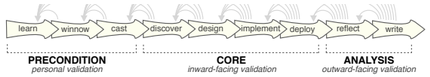
  BallotMaps: Detecting name bias in alphabetically ordered ballot papers. *Wood, Badawood, Dykes, Slingsby. IEEE Transactions on Visualization and Computer Graphics, 17(12), pp. 2384-2391, 2011*

- ODMaps

  Visualisation of origins, destinations and flows with OD maps. *Wood, Dykes, Slingsby. The Cartographic Journal, 47(2), pp. 117-129, 2010.*

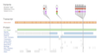
Themes

- task and data abstraction
  - both cases: complex and tricky
  - clear description in final talk/paper is end of a long, long road
    - writing as research: refine during reflection even after vis tool is finalized...

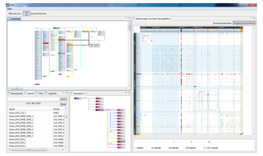


- visual encoding and interaction idioms
  - RelEx: reduce memory load with interaction
  - VariantView: reduce interaction load with better visual encoding

RelEx
in-car networks



VariantView
genomics



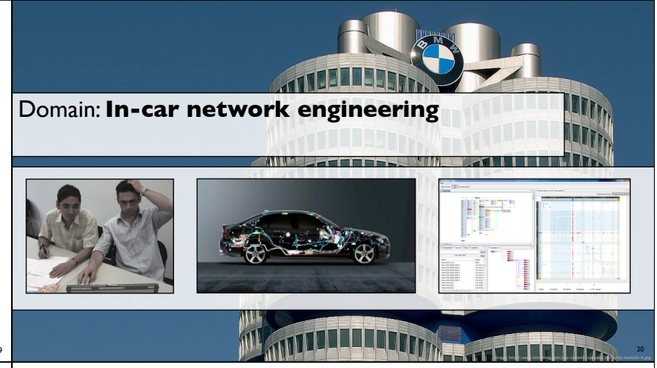
RelEx

Visualization for Actively Changing Overlay Network Specifications

joint work with:
Michael Sedlmair, Annika Frank, Andreas Butz

http://www.cs.ubc.ca/labs/imager/tr/2012/relex/

RelEx: Visualization for Actively Changing Overlay Network Specifications. *Sedlmair, Frank, Butz, Munzner. IEEE TVCG 18(12): 2729-2738, 2012 (Proc. InfoVis 2012).*

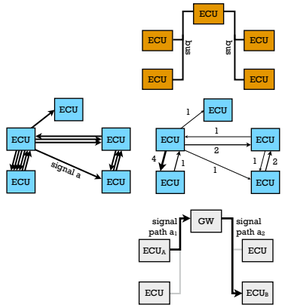


Abstractions

DATA
In-car Electronics

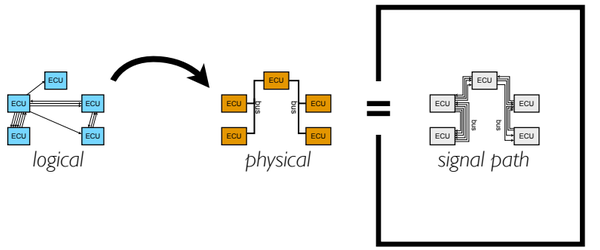
Data Abstraction: 3 Networks

- **physical** network
  - 100 nodes: *Electronic Control Units*
  - 10-15 hyperedges: *bus systems*
  - hardware engineers
- **logical** network
  - same nodes
  - 10,000 multigraph edges: *signals*
  - 1,000 weighted edges: *signal counts*
  - software engineers
- **overlay** network
  - maps logical onto physical
  - 30,000 edges: *signal paths*
  - target engineers



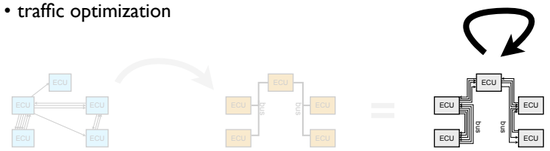
Task Abstraction: Mapping

- specify overlay network that maps logical onto physical



Task Abstraction: Optimizing

- traffic optimization

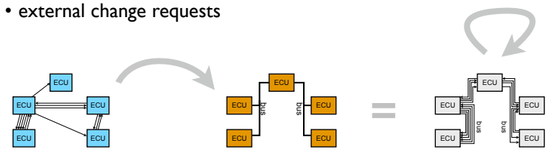


Many constraints
bandwidth ... delay/real time ...
path length ... load balance ...
reliability ... money ...

-- engineer, BMW --

Task Abstraction: Changing

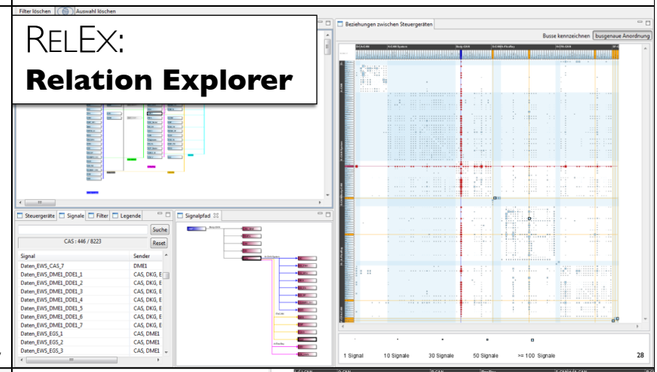
- external change requests



Change
(trivial requests might lead to complex changes)

Idioms

RELEX:
Relation Explorer

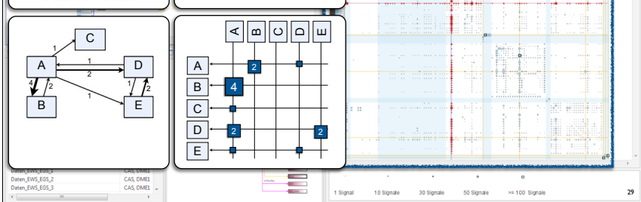


Vis Guideline [Ghoniem 2005]
Matrix for dense network data

SIGNAL COUNT NETWORK

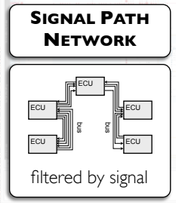
visual encoding:
size-coded matrix

Logical Network View: Overview



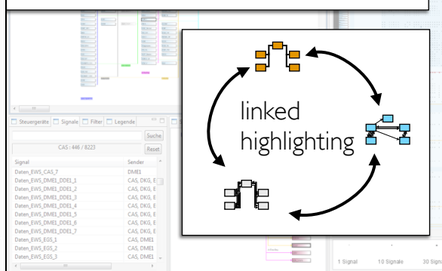
Vis Guideline [Ghoniem 2005]
Node-link for path following tasks

SIGNAL PATH NETWORK



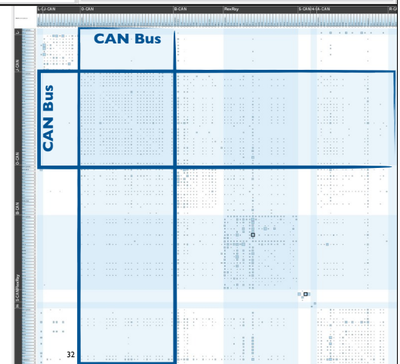
Signal Path View: Selected Signal

INTERACTION IDIOM:
Cross-Network Relations

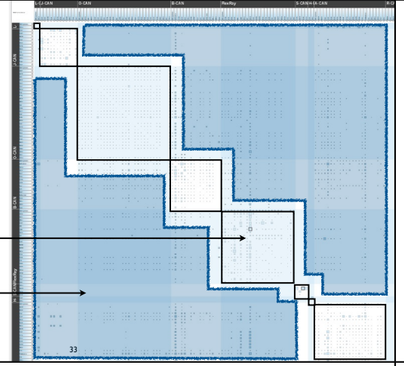


VIDEO

INTERESTS
Bus communication patterns

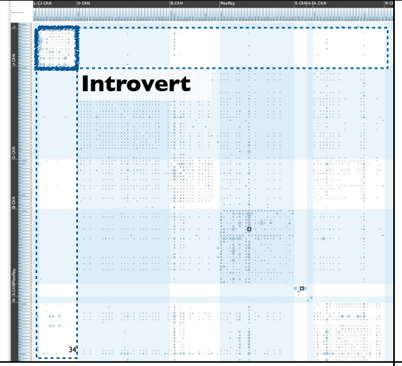


Interests
Bus communication patterns



Interests
Bus communication patterns

introvert
vs.
extrovert



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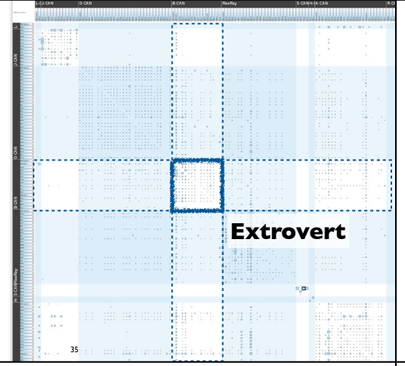


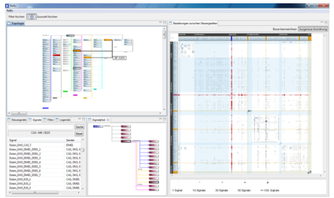
Methods

Phase 1: Discover
3 months learn → winnow → cast → **discover** → design → implement → deploy → reflect → write

- embedded within BMW
  - phases 1, 2, 3
- contextual inquiry
- abstracting
- deriving design requirements

Phase 2: Design, implement, deploy
4 months learn → winnow → cast → discover → **design** → **implement** → **deploy** → reflect → write

- iterative paper prototyping
- agile software development
  - 3 lead users (engineers)
  - 6 deployed releases
- usability engineering
  - domain experts
  - HCI students

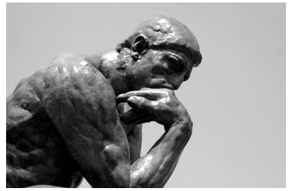


Phase 3: Summative evaluation
2 months learn → winnow → cast → discover → design → implement → **deploy** → reflect → write

- field study
  - 7 engineers
  - 5 weeks
- think aloud study
  - 10 engineers
  - ~1 hour each session
- adoption
  - 15+ users, 3 months post-study

Phase 4: Reflect and write
3 months learn → winnow → cast → discover → design → implement → deploy → **reflect** → **write**

- revisit abstractions
- relate to other design studies
- write up



Abstraction Innovation

Previous Work

Focus on social network analysis

- radically different task and data abstractions

Task Abstraction

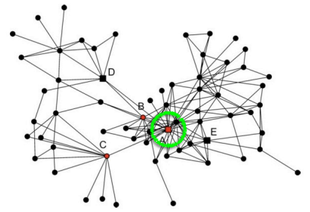
Social Network Analysis Domain

- find clusters

Task Abstraction

Social Network Analysis Domain

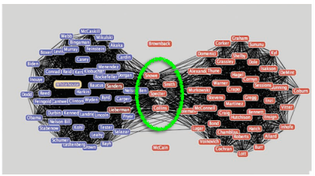
- find clusters
- find high-degree nodes



Task Abstraction

Social Network Analysis Domain

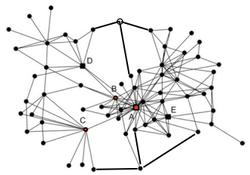
- find clusters
- find high-degree nodes
- find bridge nodes



Task Abstraction

Social Network Analysis Domain

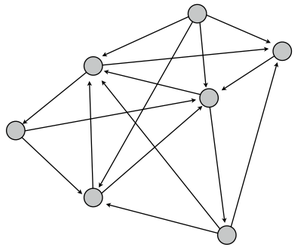
- find clusters
- find high-degree nodes
- find bridge nodes
- understand temporal dynamics
  - passively notice changes



Data Abstraction

Social Network Analysis Domain

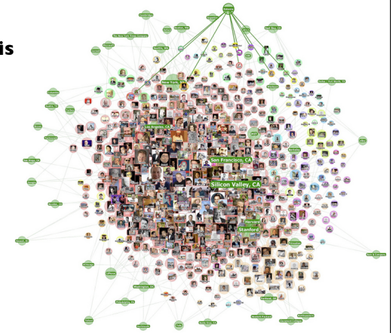
- single graph



Data Abstraction

Social Network Analysis

- single graph
- scalability challenge: nodes

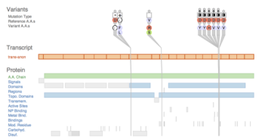


Abstraction Differences

Social Network Analysis vs Overlay Network Optimization

- data
  - single network
  - node scalability
    - sparse edges
- task
  - find clusters, high-degree nodes, bridge nodes
  - passive changes

- data
  - three related networks
    - physical, logical, overlay
  - path scalability
    - dense edges, few nodes
- task
  - traffic optimization
  - active changes



Variant View

Visualizing Sequence Variants in their Gene Context

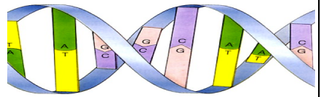
joint work with:
Joel Ferstay, Cydney Nielsen

http://www.cs.ubc.ca/labs/imager/tr/2012/VariantView/

Variant View: Visualizing Sequence Variants in their Gene Context.
Ferstay, Nielsen, Munzner. IEEE TVCG 19(12): 2546-2555, 2013 (Proc. InfoVis 2013).

Sequence Variant Definition

- Sequence variants
  - Difference between reference and given genome



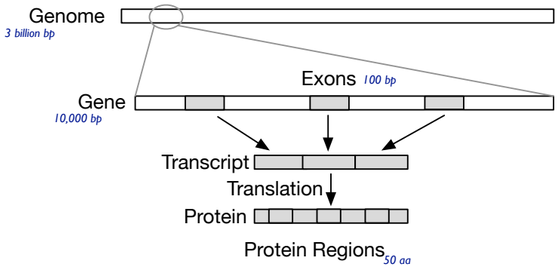
Reference Genome DNA:	ATA TGA TCA ACA CTT	
Sample 1 Genome DNA:	ATA TGG TCA ATA CTT	Harmful?
Sample 2 Genome DNA:	ATA TGA TGA ACA CCT	Harmless?

Cancer Research

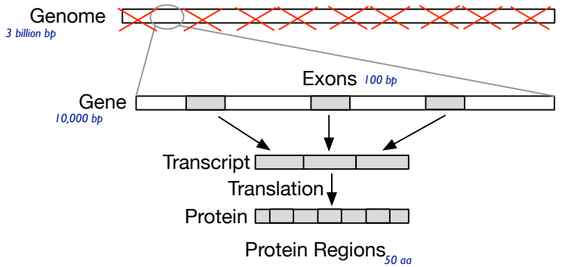
- collaboration with analysts at BC Genome Sciences Center
  - studying genetic basis of leukemia
- driving task
  - discover new candidate genes with harmful variants
- two big questions
  - what to show
    - data abstraction
    - challenge: enormous range of scales in the data
  - how to show it
    - visual encoding idiom

Abstractions

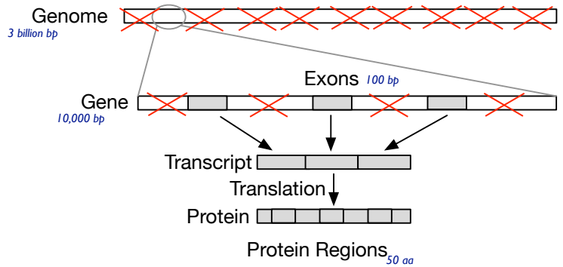
Data: Filtering to relevant biological levels and scales



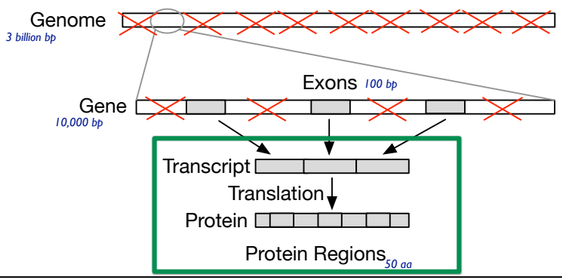
Filter out whole genome; keep genes



Filter out non-exon regions

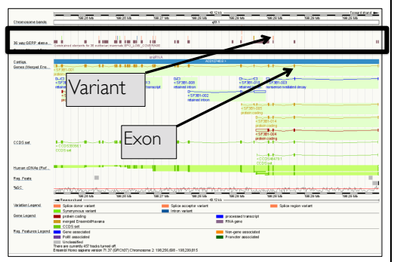


Data abstraction: highly filtered scope of *transcript coordinates*



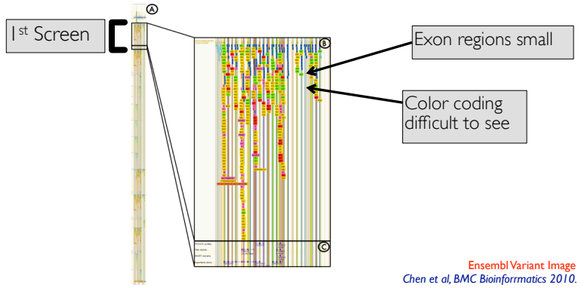
Dominant paradigm: genome browsers

- strengths: flexible and powerful
  - horizontal tracks: user data
  - shared coordinate system: *genome coordinates* (bp)
- problems
  - tiny features of interest spread out across large extent
    - must zoom far in to inspect known feature, then zoom out and pan to locate next
    - high cognitive load for interaction
    - must already know where to look



representative example: Ensembl
Chen et al, BMC Bioinformatics 2010.

Features of interest small even in variant-specific view

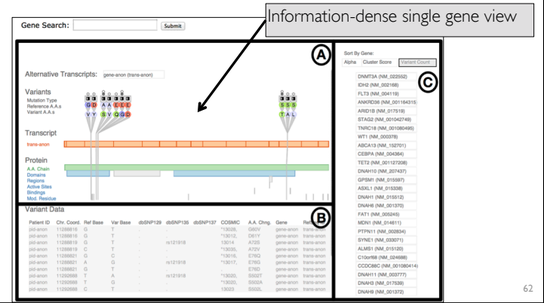


Ensembl Variant Image
Chen et al, BMC Bioinformatics 2010.

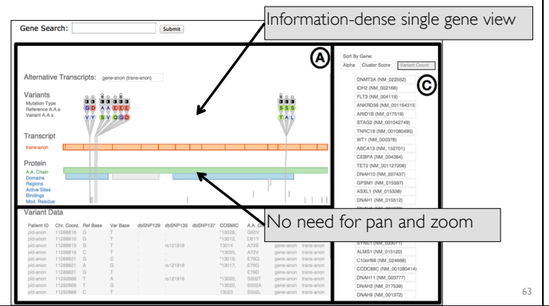
Idioms

Variant View

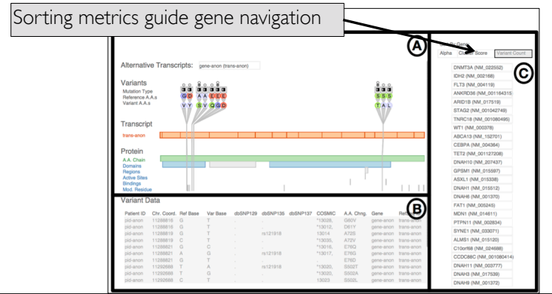
Variant View



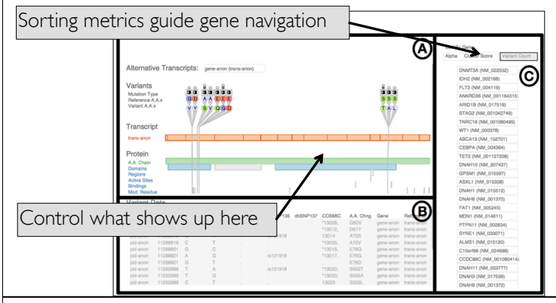
Variant View



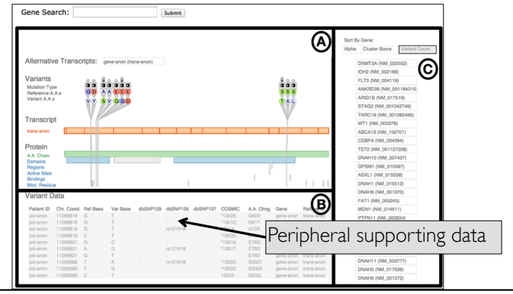
Variant View



Variant View

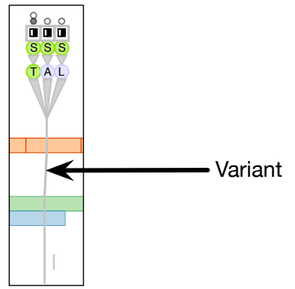


Variant View

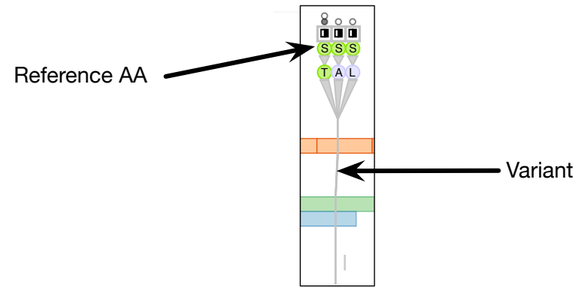


Design information-dense visual encoding

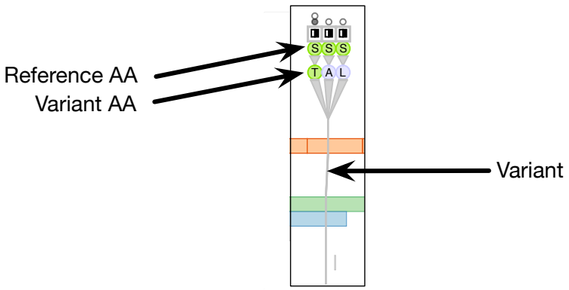
- show all attributes necessary for variant analysis
  - match salience with importance for analysis task
- variant not just a thin line!
- emphasize with high salience
  - collocated variants fan out at top
  - grey variant vertical stroke intersects horizontal colored protein regions



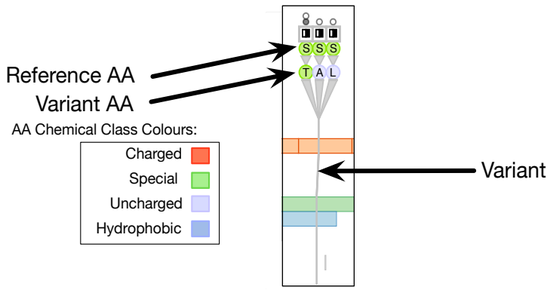
Design information-dense visual encoding



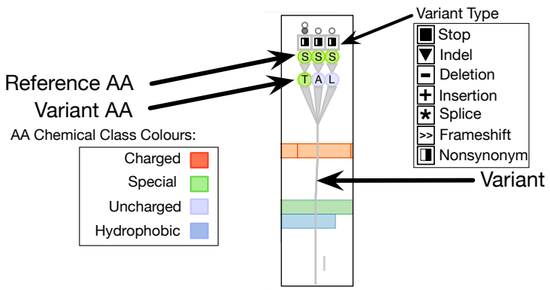
Design information-dense visual encoding



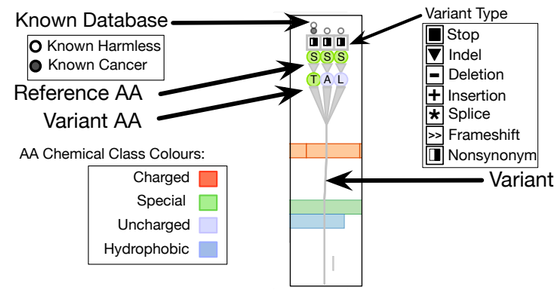
Design information-dense visual encoding



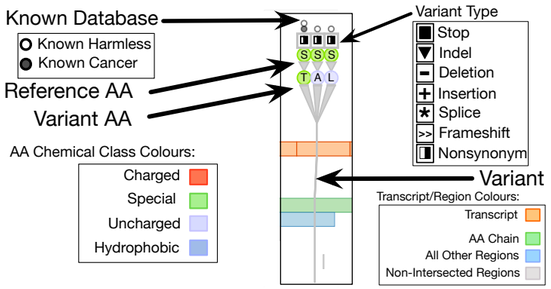
Design information-dense visual encoding



Design information-dense visual encoding

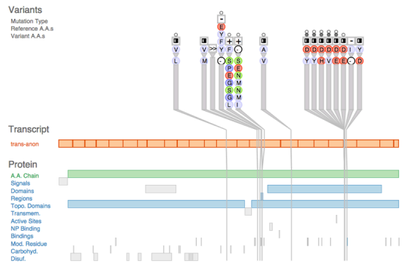


Design information-dense visual encoding

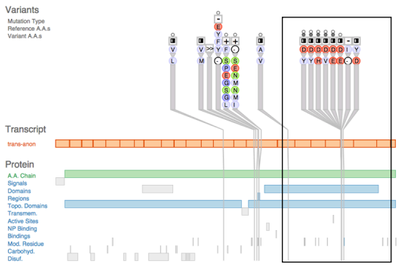


Results

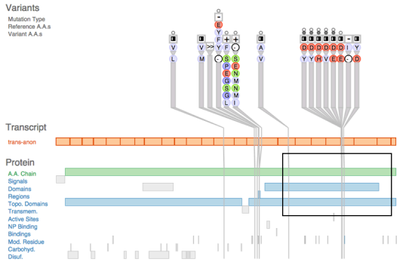
Highly scored gene by sorting metric: known leukemia gene



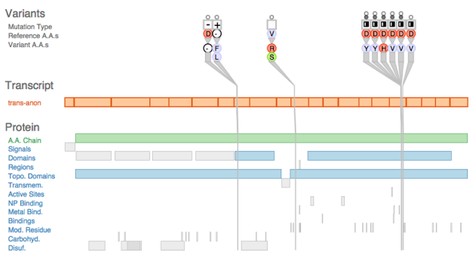
Visual inspection reveals collocation of variants



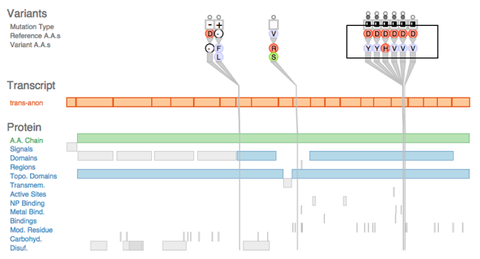
Several functional protein regions affected



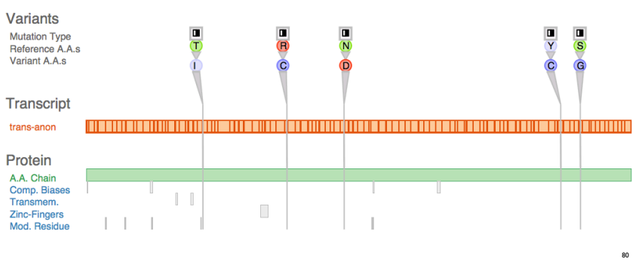
Highly scored by metric: not previously known, good candidate



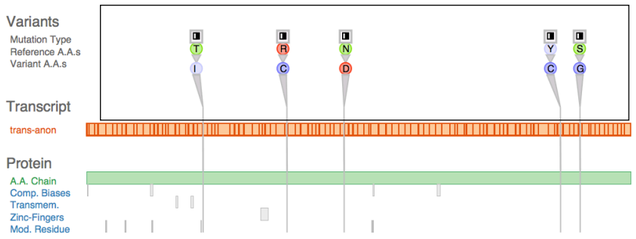
Protein chemical class change evident



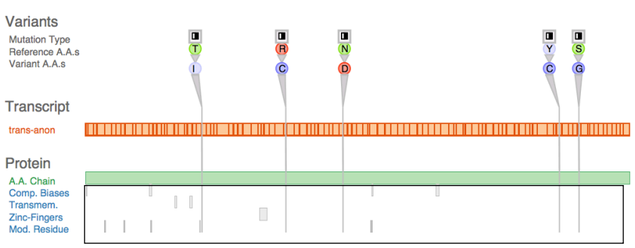
In contrast, low scoring gene



No collocation of variants



Mostly unaffected protein regions



Methods

Phase 1: Winnow and Cast

5 months

learn → winnow → cast → discover → design → implement → deploy → reflect → write

- embedded within GSC for all stages
- winnow stage
  - considered and ruled out many potential collaborators
- cast stage
  - gatekeeper (PI)
  - two front-line analysts (postdocs)

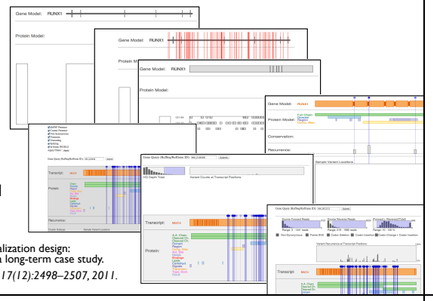
more at:
Design Study Methodology: Reflections from the Trenches and from the Stacks.
Sedlmair, Meyer, Munzner. IEEE TVCG 18(12): 2431-2440, 2012 (Proc. InfoVis 2012).

Phase 2: Core Design

5 months

learn → winnow → cast → discover → design → implement → deploy → reflect → write

- main task abstraction
  - discover gene
- semi-structured interviews
  - every week for 1 hr
- iterative refinement
  - 8 data sketches deployed



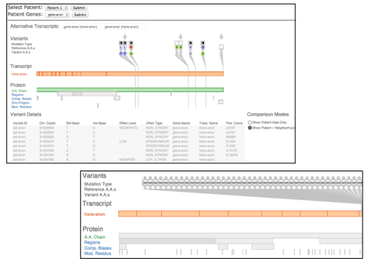
Human-centered approaches in geovisualization design:
investigating multiple methods through a long-term case study.
Lloyd and Dykes. IEEE TVCG (Proc. InfoVis), 17(12):2498–2507, 2011.

Phase 3: Two More Tasks

1 month

learn → winnow → cast → discover → design → implement → deploy → reflect → write

- two new analysts
  - connected by enthusiastic gatekeeper
- new task abstractions
  - compare patients
  - debug pipeline
- transferrable with minimal changes



Phase 4: Reflect and write

3 months

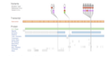
learn → winnow → cast → discover → design → implement → deploy → reflect → write

- abstraction innovation
  - data abstraction: highly filtered *transcript coordinates* (vs genome coordinates)
- guidelines
  - specialize first, generalize later
    - good for domains with complex data
  - high-level considerations
    - identifying scales of interest
    - what to visually encode directly vs what to support through interaction
    - when (and how) to eliminate navigation

Themes, Revisited

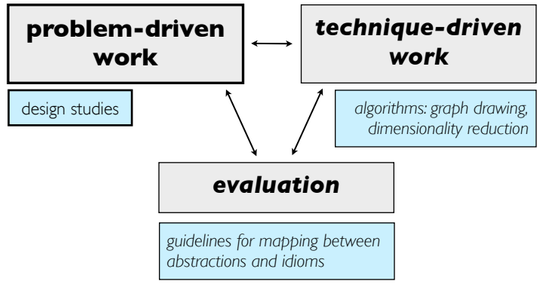
- what and why to show: task and data abstraction
  - task and data commonalities cross-cut domains
- how to show: visual encoding and interaction idioms
  - RelEx: reduce memory load with interaction
  - VariantView: reduce interaction load with better visual encoding
- transferability from design studies
  - DSM: reflection to confirm/refute/refine/propose guidelines

RelEx
in-car networks

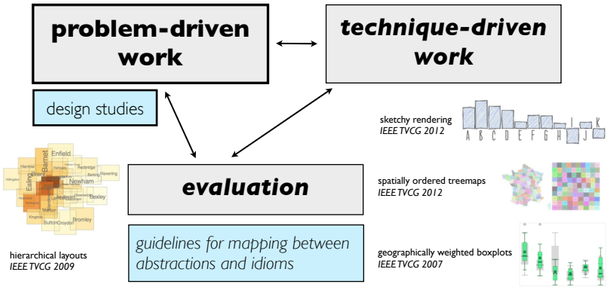


VariantView
genomics

Research Interests



Research Interests: giCentre Context



Further Information

- further info
  - http://www.cs.ubc.ca/~tmm/talks.html#london14 (this talk, and many others)
  - http://www.cs.ubc.ca/group/infovis (papers, software, videos)
  - http://www.cs.ubc.ca/~tmm/courses/infovis/book (book: to appear)
    - Visualization Analysis and Design. Munzner. AK Peters 2014
- open source software downloads
  - http://www.cs.ubc.ca/labs/imager/tr/2013/VariantView/VariantViewSoftware/
- acknowledgements
  - funding: NSERC, NSF
  - joint work: all co-authors
    - Andreas Butz, Annika Frank, Joel Ferstay, Miriah Meyer, Cydney Nielsen, Michael Sedlmair
  - feedback on this talk
    - Matthew Brehmer, Stephen Ingram