Ocupado: Visual Analytics for Occupancy Applications

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Cisco Toronto
26 Jun 2018

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@tamaramunzner

Ocupado project

- occupancy data for facilities management
  - estimate human occupancy of buildings using mobile device connections as common denominator
    - innovative uses for CMX data
  - create visual and predictive decision-support tools
    - visual analytics interface to make data actionable by people
  - investigate multiple stakeholder contexts of use
    - from energy management to space planning and beyond

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Ocupado collaboration: Partners

- visualization and data analysis: UBC Computer Science
  - led by Tamara Munzner
  - students: Michael Oppermann, Yann Dubois
- building management systems and data recording: Sensible Building Science
  - UBC Sustainability spinoff
  - led by Stefan Storey
- machine learning: UBC Statistics
  - led by Jeff Andrews
- networking infrastructure: Cisco
  - liaison: Rob Barton

Ocupado collaboration: Funding

- kickstarted by Cisco funding ($25K)
  - *Locational Service Analytics: Machine Learning and Data Visualization for CMX Data Applications*
- matched 3.5x
  - UBC Campus as a Living Lab ($41K)
  - NSERC Engage ($25K)
  - planned: MITACS ($25K)
- substantial increase in project scope & duration
  - 40% spent over 16 months from May 2017 - Sep 2018
    - we're now at month 13
  - 60% to spend in 24 months from Oct 2018 - Aug 2020

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Project threads: Completed to date

- visualization research
  - requirements analysis
  - visualization prototyping in *Sandbox* environment
    - experiment w/ static data
    - integrate with live data
- machine learning research
  - basic prediction: short & long-term forecasting
- SBS Bridge2 product
  - develop & deploy
  - integrate basic ML

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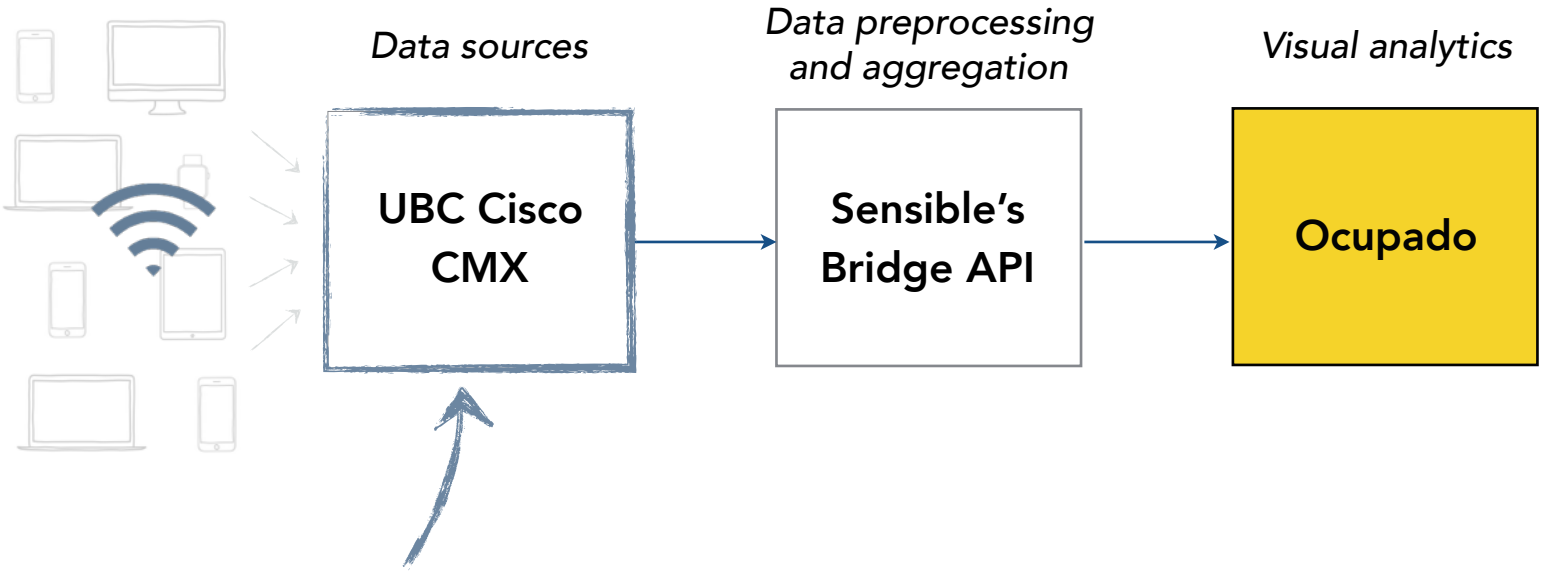
Data architecture



- Collects wireless network signals and infers locations of mobile devices via triangulation
- Already deployed, independently of our project

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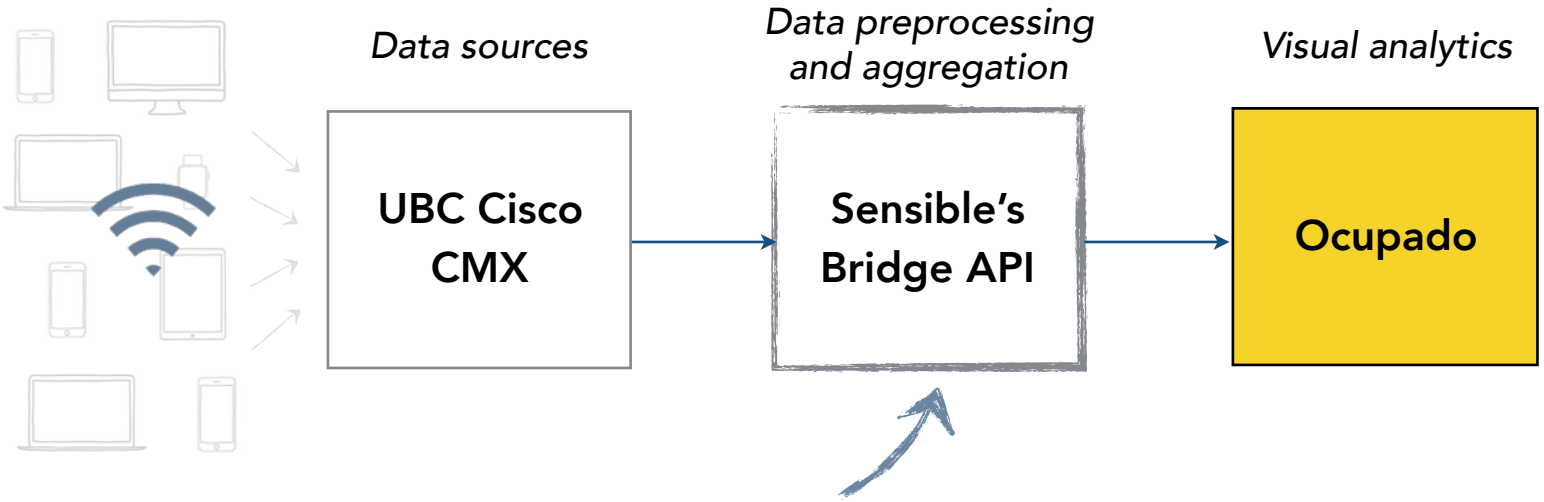
Data architecture



- Requests data from UBC Cisco CMX every 5 min
- Aggregates device coordinates by pre-defined zones (a zone can be a research lab, hallway, composite of multiple offices, …)
- Provides a REST API for external user interfaces

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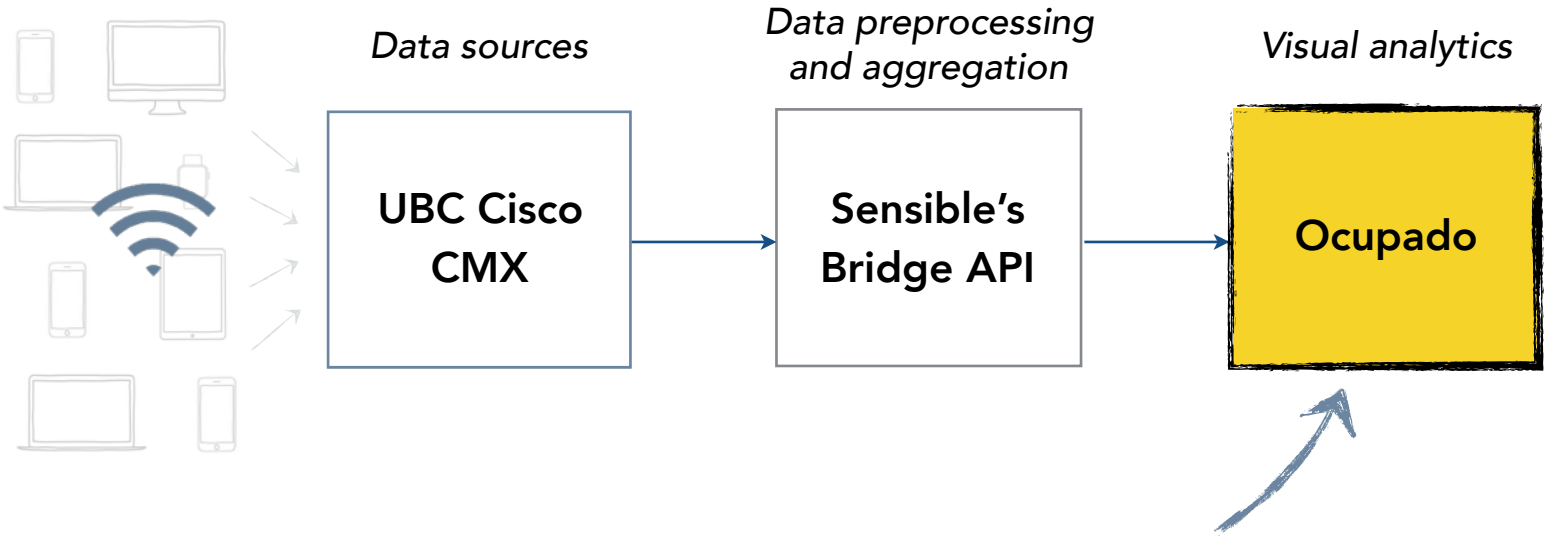
Data architecture



- Tool for visual exploration of W-Fi activity data (estimated occupancy)
- Support different stakeholders in decision-making process

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Data: Wifi as proxy for human occupancy

- wifi device activity strongly correlated with occupancy
  - rough proxy for headcounts in rooms
    - device counts every 5 minutes, per zone
  - good spatial precision if zone large enough
    - rooms with multiple people, not single-person offices
  - excellent temporal resolution
- privacy preserving architecture
  - keep only counts per zone per time slice
  - no tracking of individuals or trajectories
    - privacy built in to SBS Bridge infrastructure at fundamental level
    - MAC addresses thrown away, not stored
      - we'd love CMX protocol change so they're not sent out!
      - (3 month delay in data gathering due to UBC Legal concerns)

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Data abstraction

SPACE (regions of interest)

Campus

Building

Floor

Zone

Wi-Fi
Custodial
...

Room

Enrollment

TIME (periods of interest)

Continuous vs. discrete time series

- custodial shifts
- course sessions
- weekdays
- past/next *X* hours
- weekends and holidays
- term vs exams

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Task analysis: Facilities management stakeholders

- known in advance
  - energy systems
    - SBS first product: occupancy for HVAC control
- identified as high priority
  - space planning
    - informal learning spaces
    - classroom services
  - custodial services
  - building managers
- investigated and considered lower priority
  - risk management
  - security and parking
  - transportation

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Task analysis: Example stakeholder questions

- only basic query handled by previous SBS interface
  - ***What is the current activity level of a specific region?***
- many stakeholder questions require bigger picture
  - *Which regions are busy/quiet now?*
  - *Which regions were heavily used and are empty now?*
  - *What does the long-term activity profile of region X look like?*
  - *What is the typical usage pattern of a specific region?*
    - *weekdays vs weekends/evening/holidays, according to shift boundaries*
  - *How does the utilization differ between regions?*
    - *for subset based on size, space type or other attributes*
  - *What is the predicted activity for a region in the next X hours?*
  - *Which regions are normally heavy used but quiet now? (or vice versa)*
    - *detecting current anomalies vs. average patterns*

Ocupado Sandbox

alpha 0.1

- Dynamic filtering, slicing, and sorting of regions

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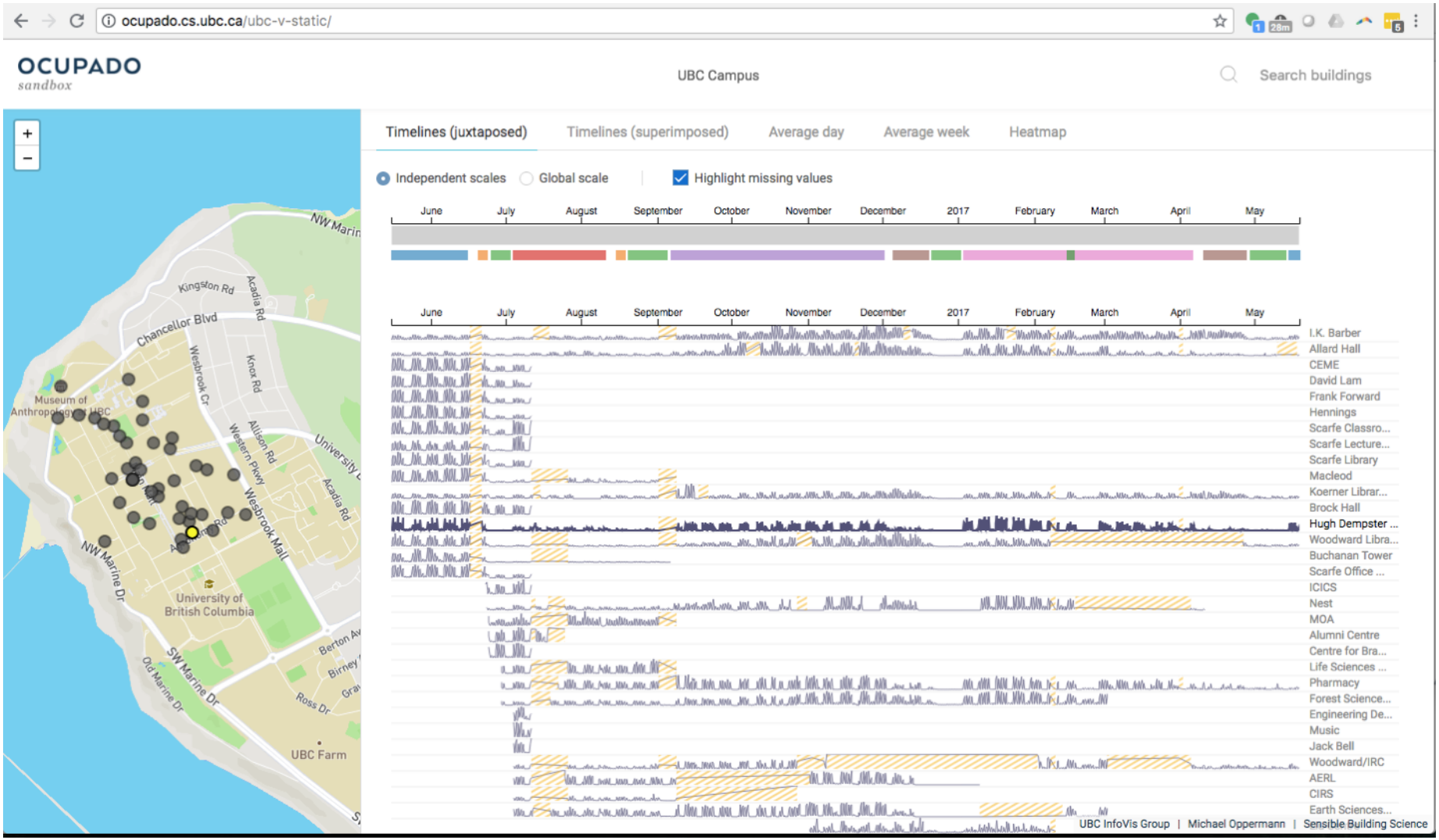
Static data: Test deployment, obvious gaps



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Ocupado Sandbox

alpha 0.2

- Integrate static data with other data sources:
  course schedules,
  predictions

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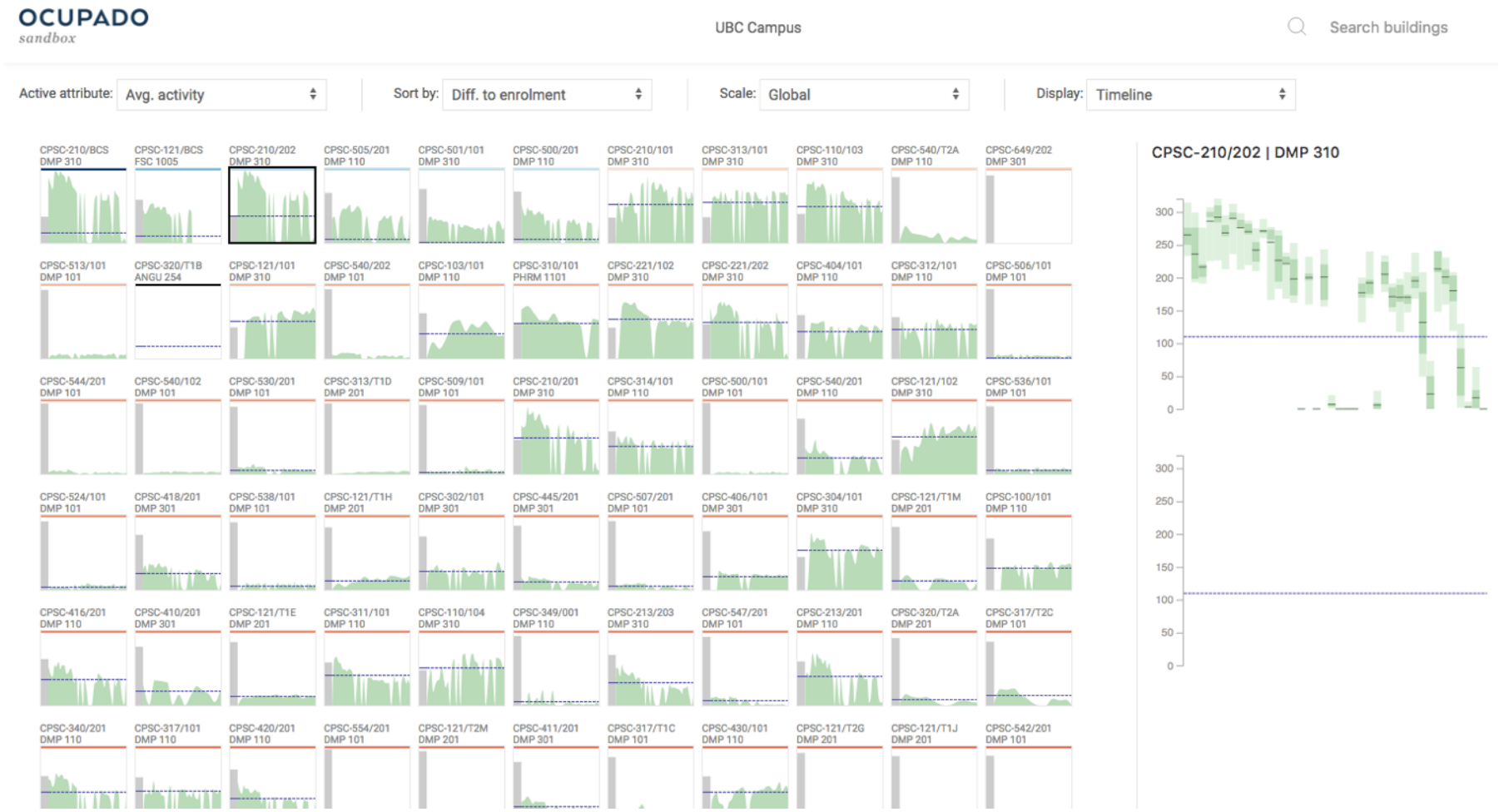
Scheduling data: Actual vs enrolled in courses



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Integrate with ML prediction data

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Ocupado Sandbox

alpha 0.3

- Flexible visual exploration interface between the user and the Bridge API
- Integration of live activity data
- Presets for quickly answering common domain questions
- URL bookmarks for replicating and sharing a certain application state

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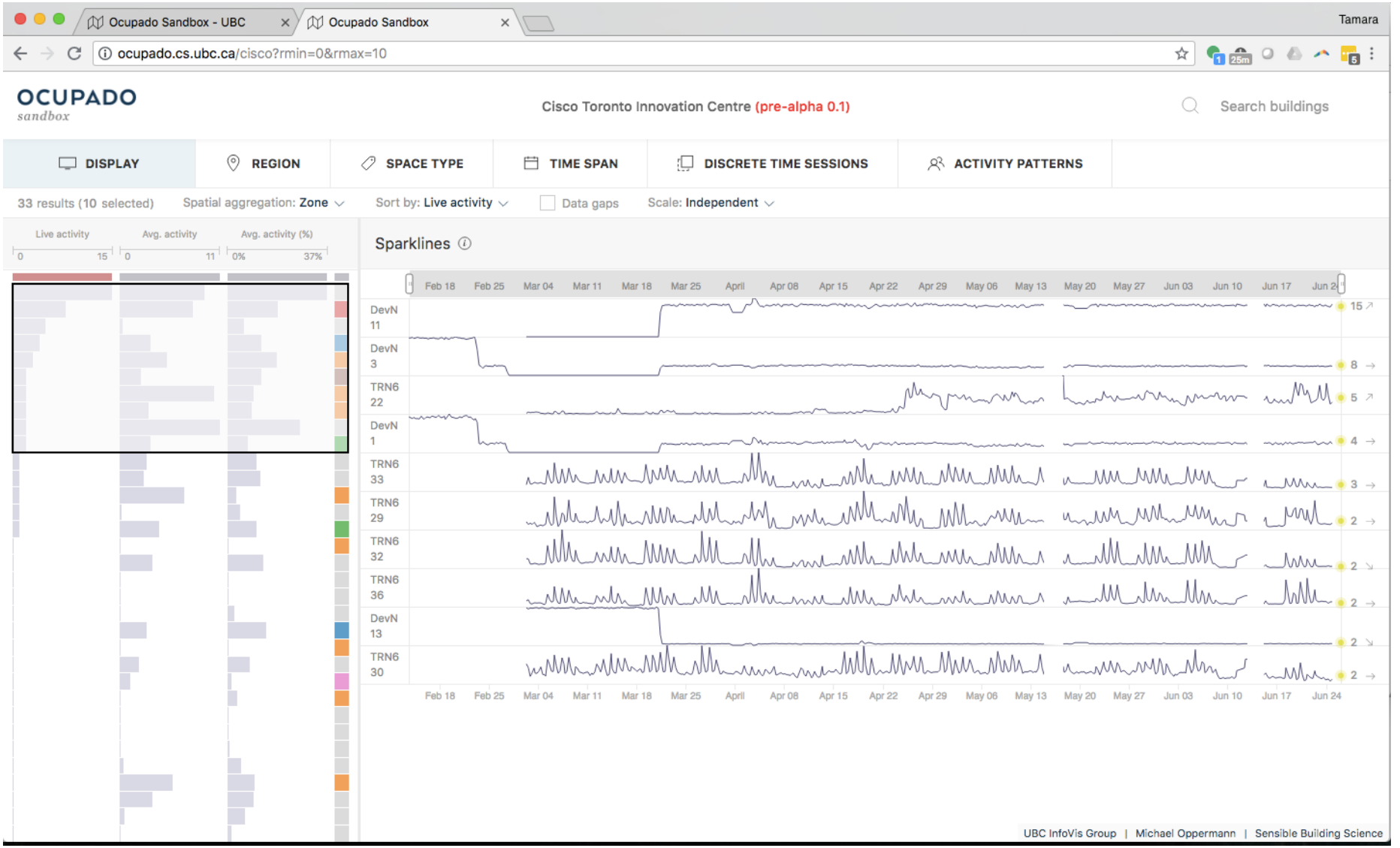
Cisco office: Live data testbed (real vs synthetic)



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Ocupado Sandbox

alpha 0.4

- Live data flowing from UBC
- Continued development of visual interface

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Demo

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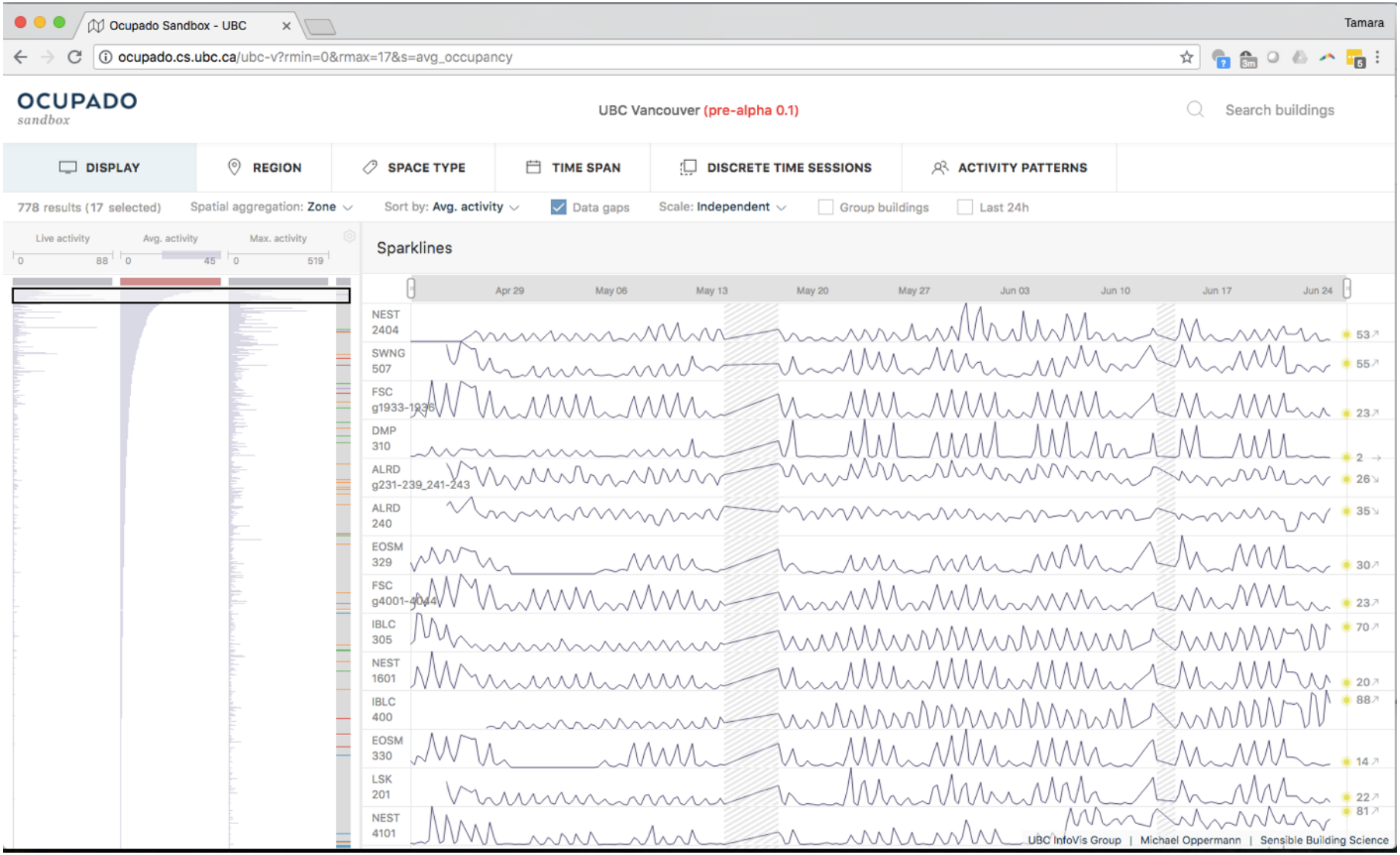
Overview: Busiest zones, on average



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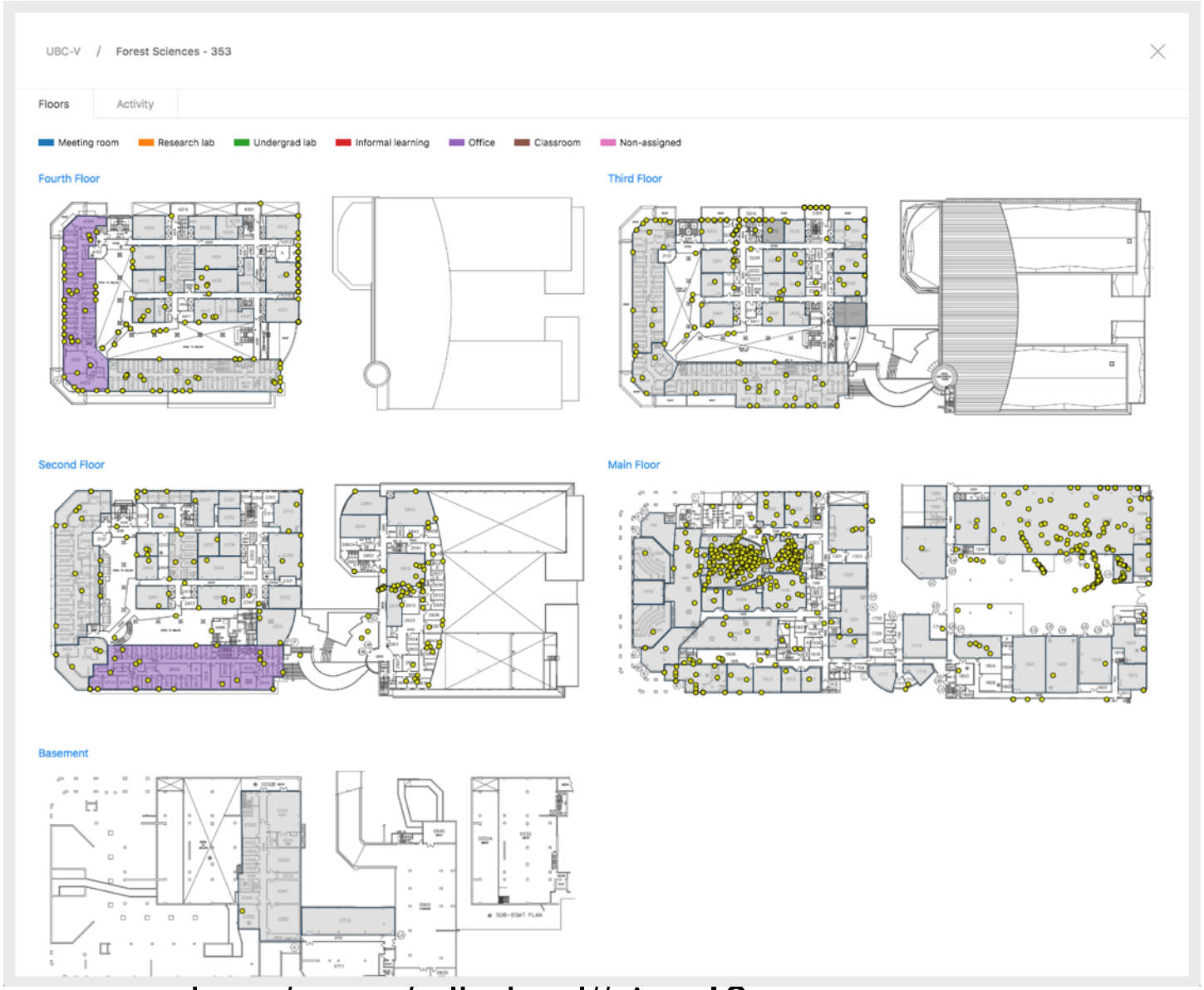
Building view



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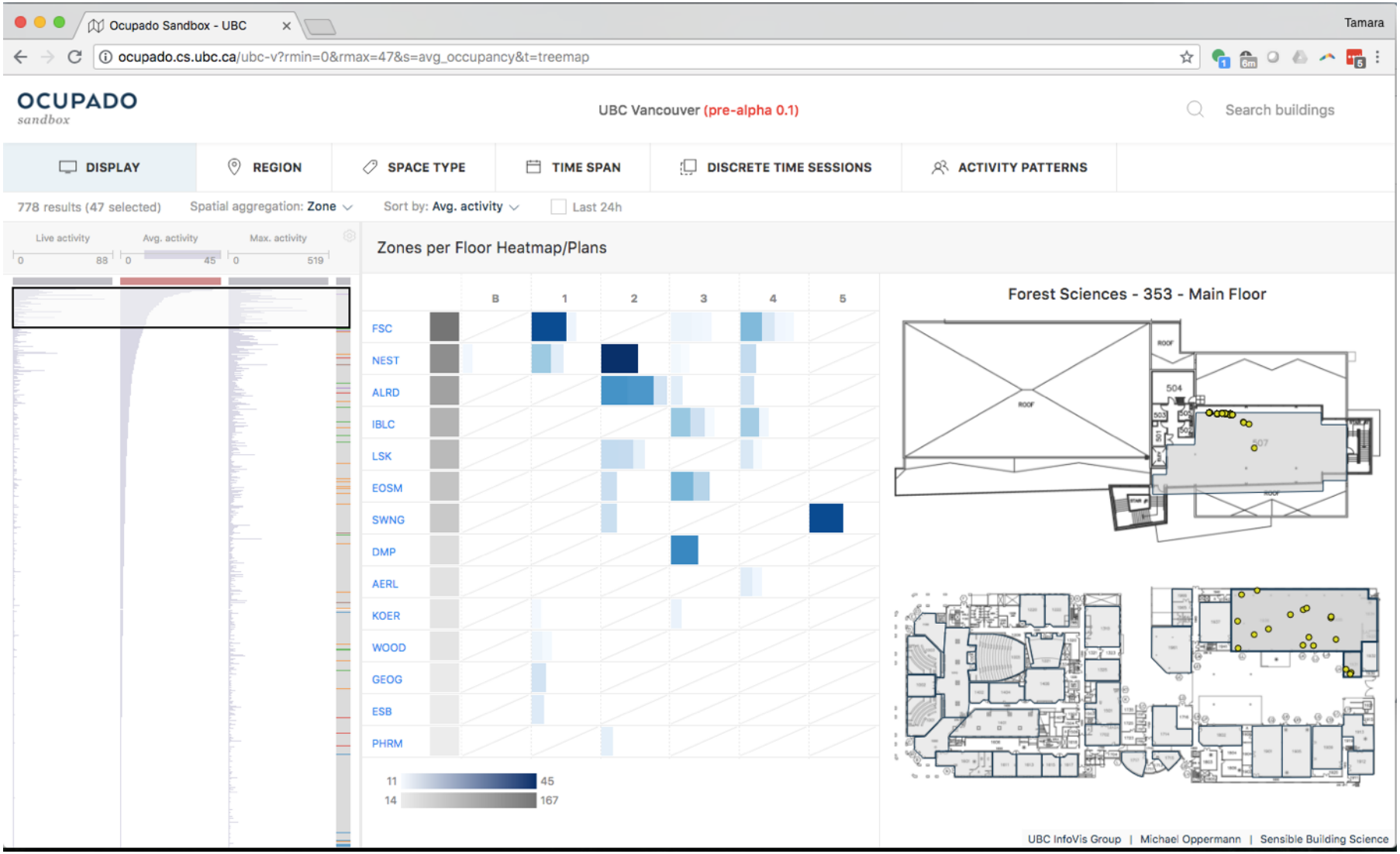
Busiest buildings, by floor, with floor plans



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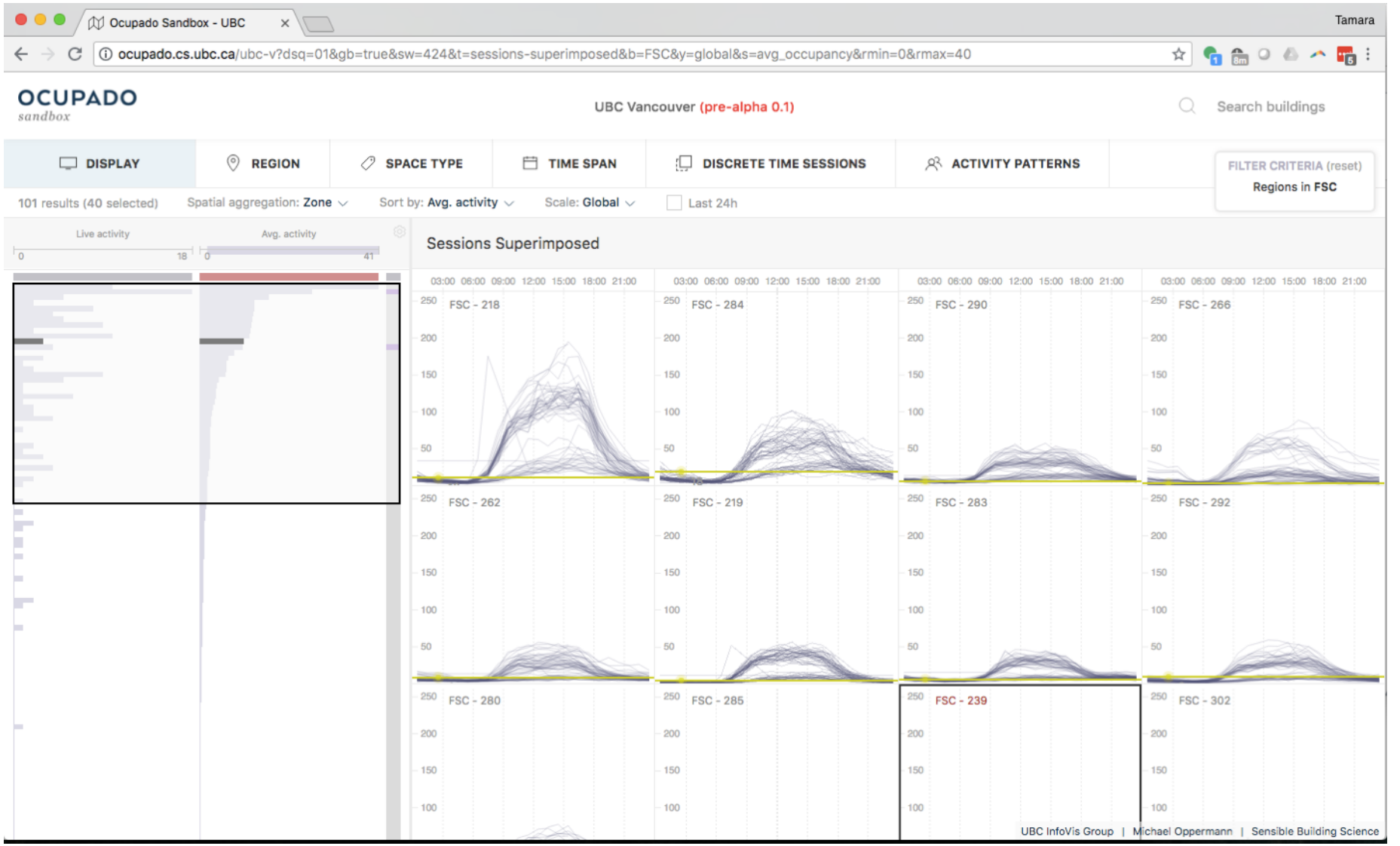
Browsing patterns within building: Room by room



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… Scrolling down

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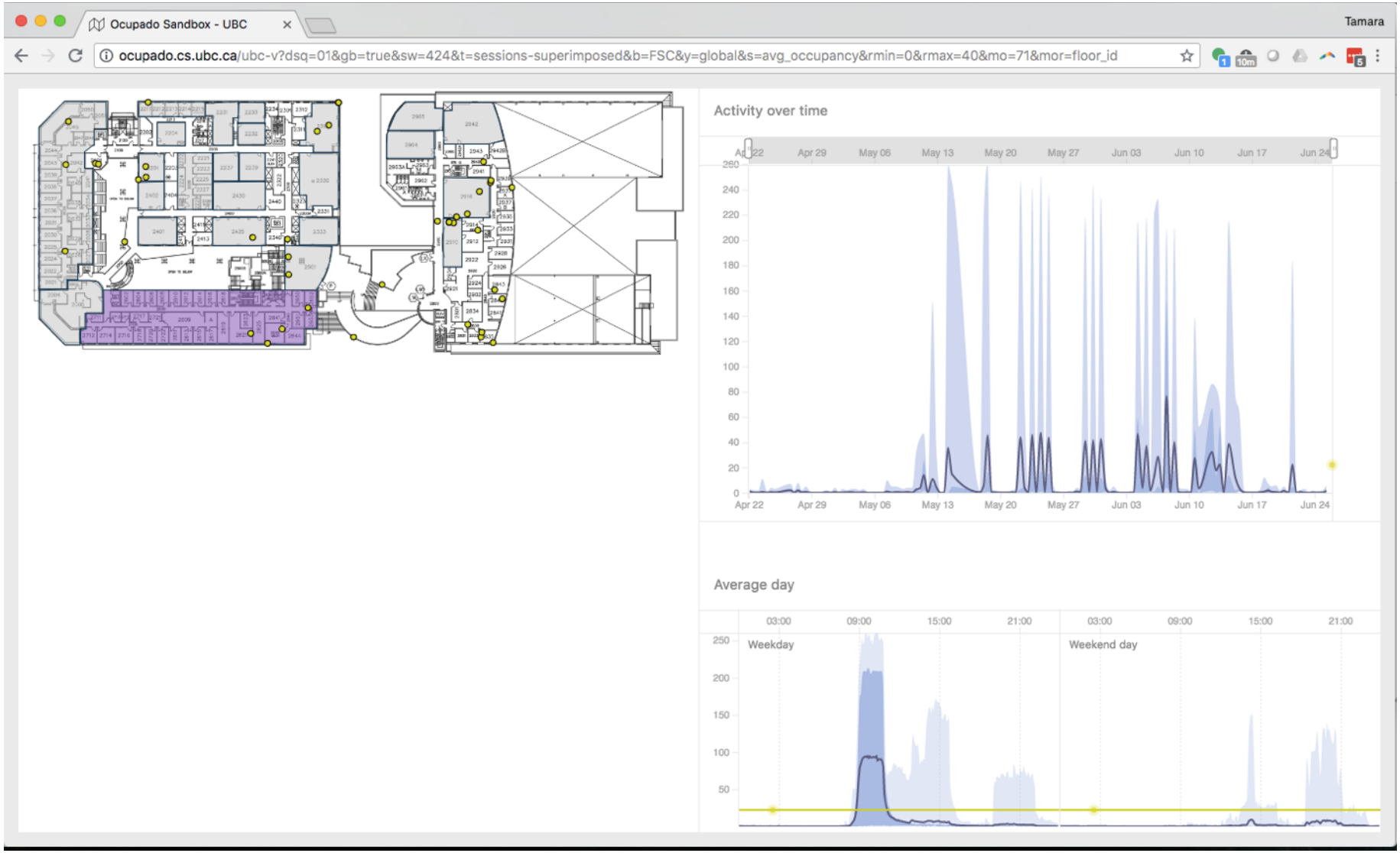
Investigating anomalous zone



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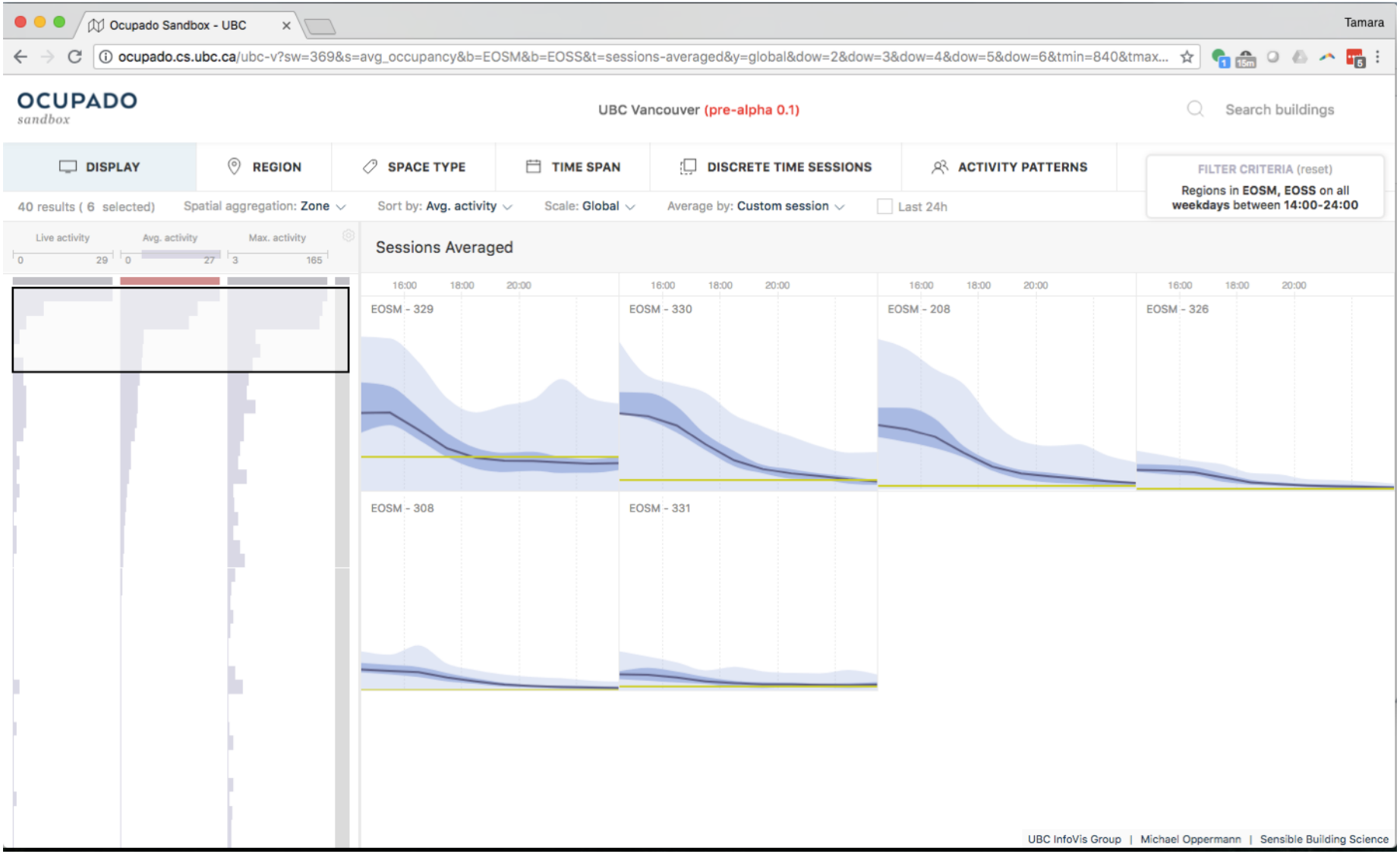
Zones in one building, evening custodial shift



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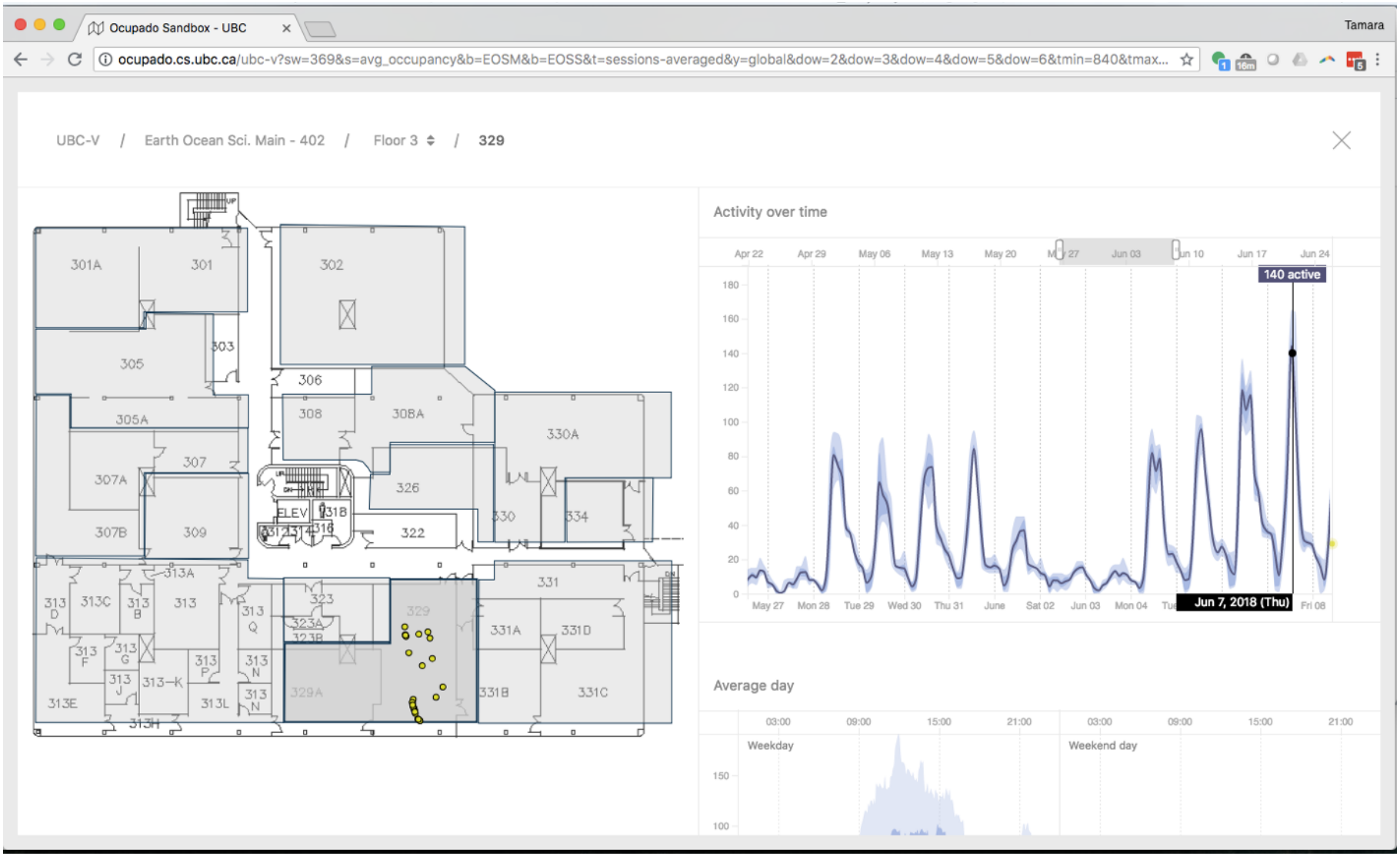
Details for one zone



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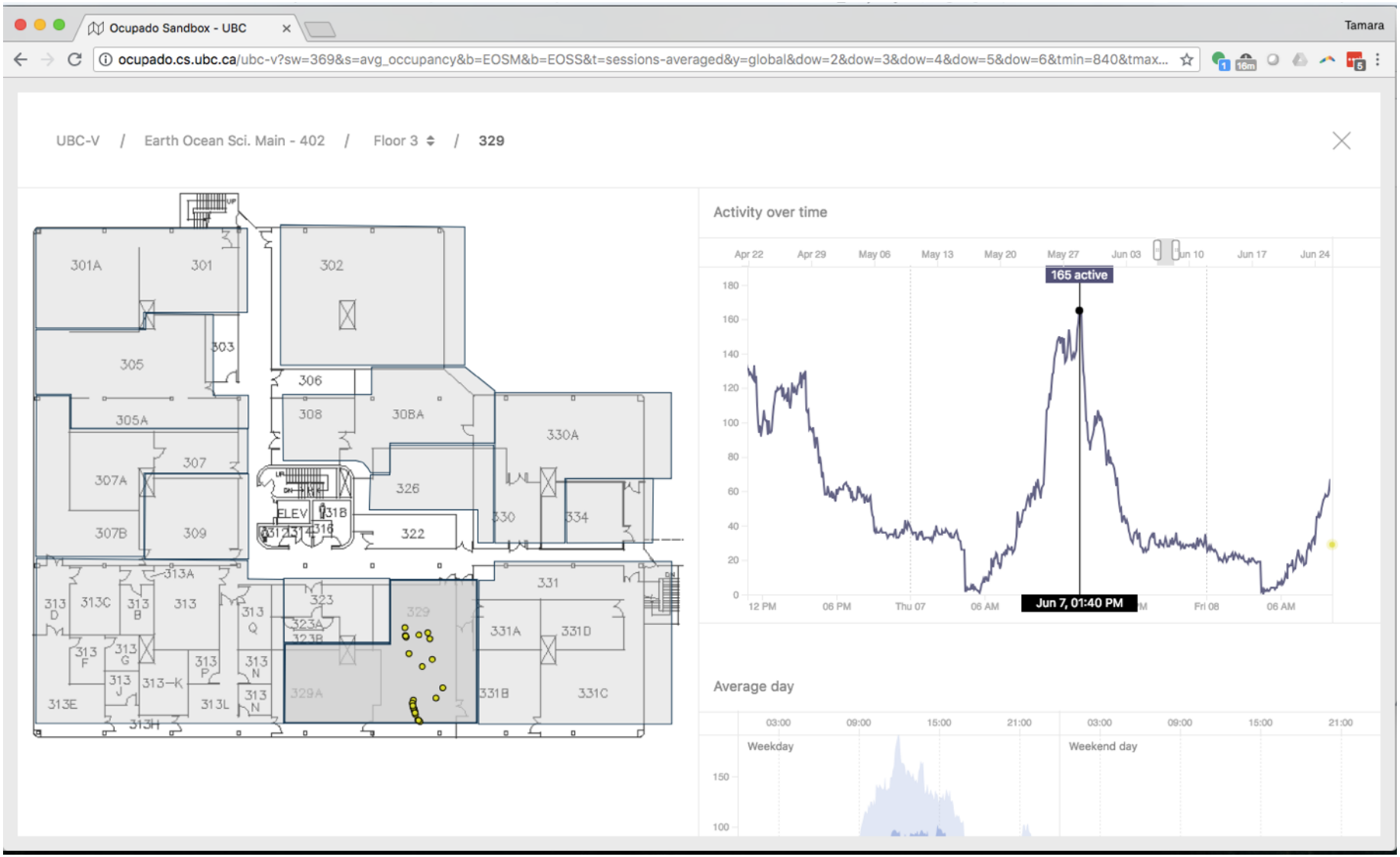
Zooming in



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Ocupado timeline: Milestones to Sep 2018

May 2017 - Sep 2018

UBC: Machine learning (prediction), Task/requirements analysis
Yann Dubois (BSc/Intern), Munzner, Andrews
May - Sep 2017

SBS: Bridge2 (data infrastructure), Machine learning (integration)
Felipe Deo, Nick Bradley (MSc/Intern)
May 2017 - Apr 2018

UBC: Visualization prototypes, Task/requirement analysis
Michael Oppermann (PhD), Munzner
Aug 2017 - Sep 2018

First 1.3 yrs: 40% funds used

May - Dec 2017
18K (Cisco/CLL)

(SBS)

Jan - Sep 2018
25K (NSERC Engage)

Final 2 yrs: 60% funds left

Sep 2018 - Aug 2020
48K (Cisco/CLL) +
25K *(planned MITACS)*

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Project threads

- visualization research
  - **requirements analysis**
  - **visualization prototyping in *Sandbox* environment**
    - **experiment w/ static data**
    - **integrate with live data**
  - customized visualization *Skins* for stakeholders
    - initial development (Jun 2018)
    - deployment & testing (Sep 2018)
  - exploit advanced ML in visualization (Sep 2019)
- machine learning research
  - **basic prediction: short & long-term forecasting**
  - semi-supervised asset tagging (Sep 2018)
  - advanced prediction: gaps & assets (Apr 2019)
- SBS Bridge2 product
  - **develop & deploy**
  - **integrate basic ML**
  - integrate advanced ML (Jan 2020)

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Intellectual property

- open-source everything created at UBC
  - after moderate delay, under commercializable license
- unified whole
  - each part builds on and depends on others
  - impossible to disentangle IP into multiple buckets based on chronology/source
- benefits to partner companies
  - open-source Ocupado specifically designed as front end that interoperates with proprietary Bridge infrastructure from SBS
  - Ocupado+Bridge combination showcases benefits of occupancy tracking via Cisco CMX product
  - intellectual contribution of task analysis of stakeholder needs for different verticals is crucial but not patentable

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UBC InfoVis Group: Research Approach

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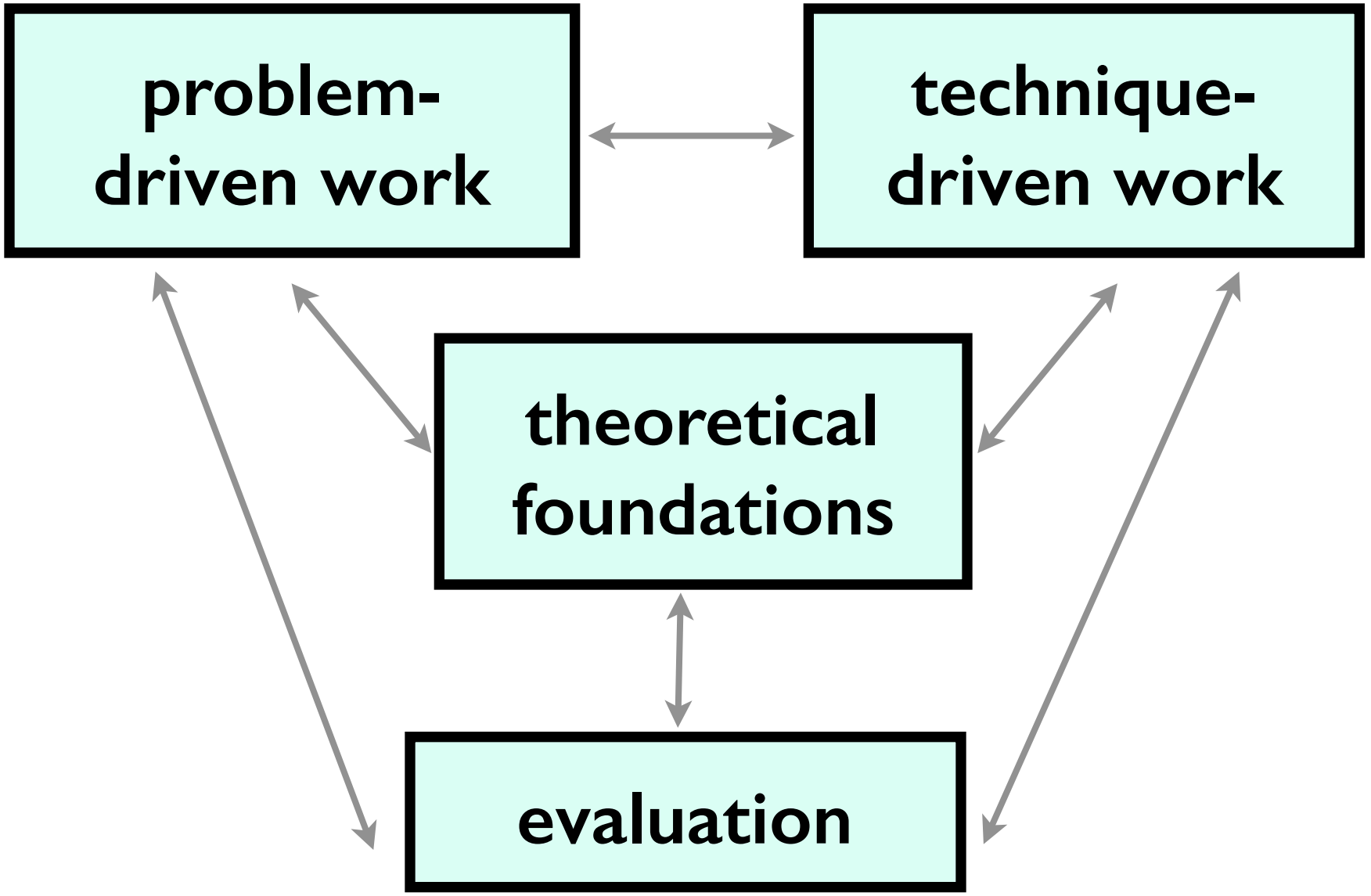
Research agenda: Interleaved angles of attack



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Problem-driven work

- design studies
  - in collaboration with target users
    - real data, real tasks
    - intensive requirements analysis
  - iterative refinement
    - deploy tools/systems
  - typical evaluation: field studies

- my strategy: opportunistic collaboration
  - many domains
  - both industrial and academic partners

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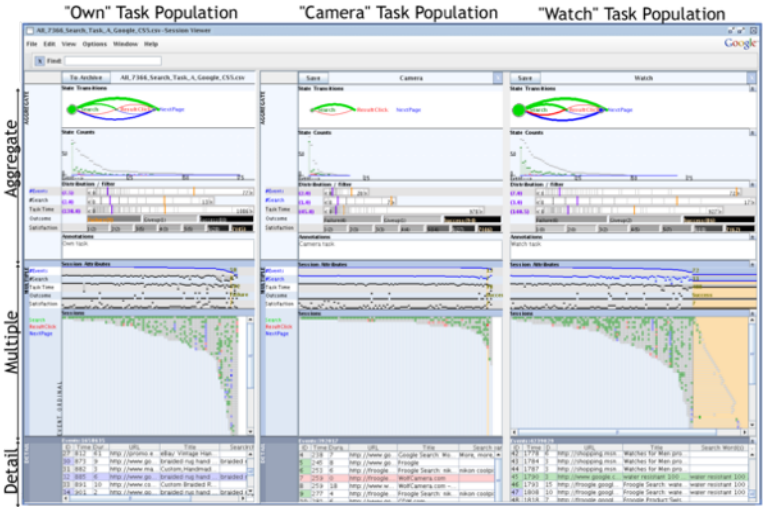
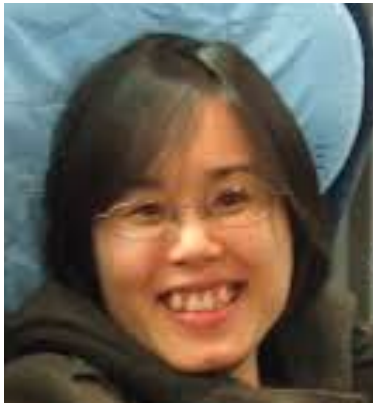
Problem-driven: Tech industry



SessionViewer: web log analysis
https://youtu.be/T4MaTZd56G4

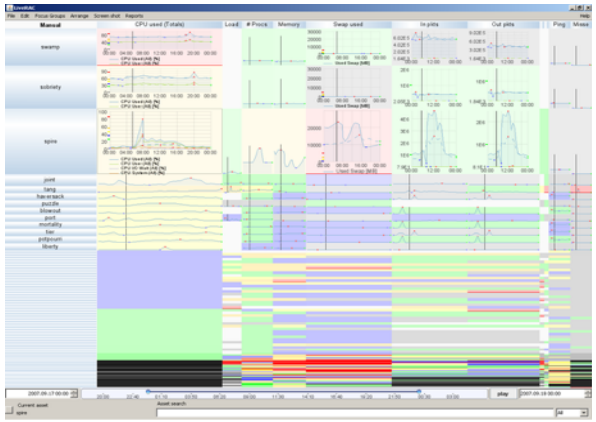
Heidi Lam



Diane Tang
(**Google**)

Peter McLachlan

Stephen North
(**AT&T Research**)



LiveRAC: systems time-series logs
https://youtu.be/ld0c3H0VSkw

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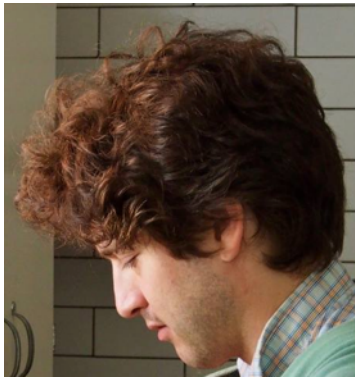
Problem-driven: Genomics

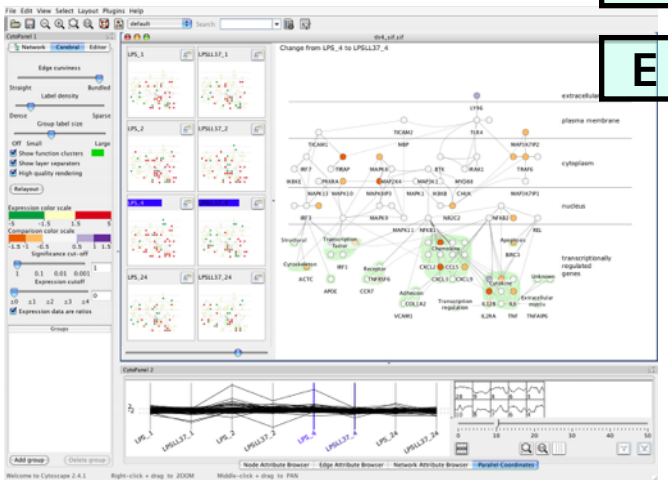
T F E P

Aaron Barsky



Jenn Gardy (UBC Micro)

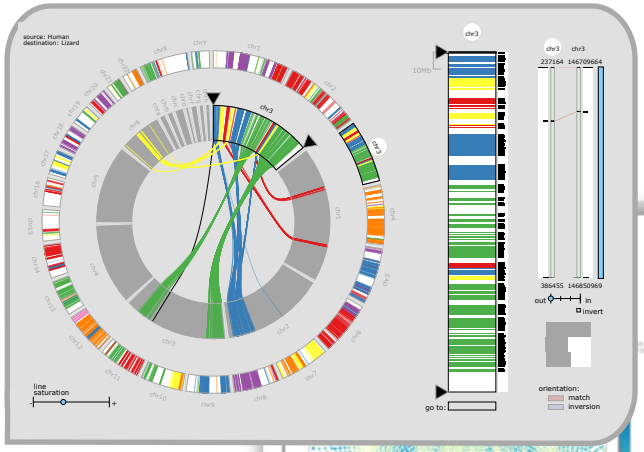
Robert Kincaid **(Agilent)**



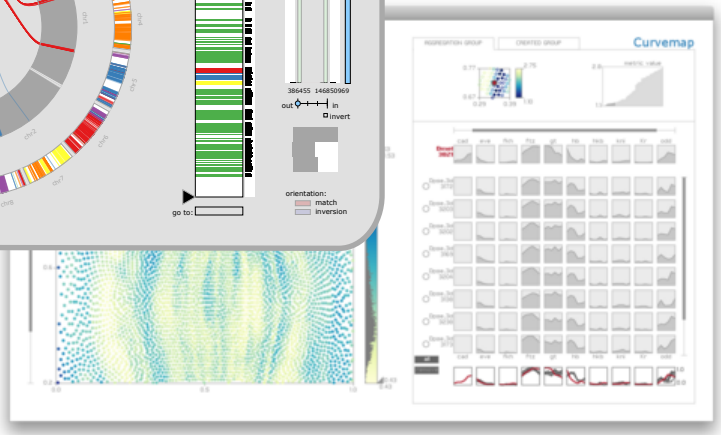
Cerebral
https://youtu.be/76HhG1FQngI

Miriah Meyer

Hanspeter Pfister (Harvard)



MizBee



MulteeSum, Pathline

https://youtu.be/86p7brwuz2g

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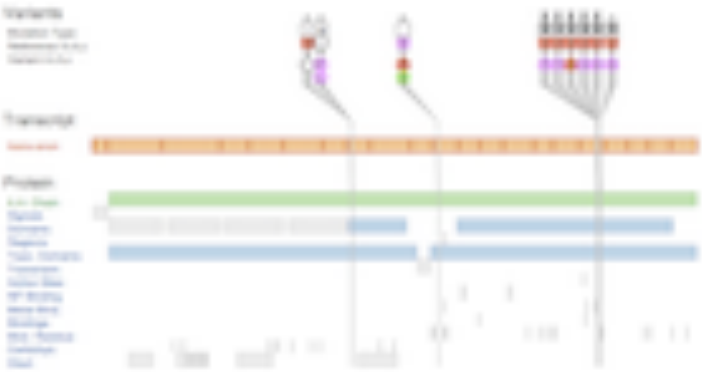
Problem-driven: Genomics

T F E P

Joel Ferstay

Cydney Nielsen
(BC Cancer)



Variant View

https://youtu.be/AHDnv_qMXxQ

Ana Crisan

Jenn Gardy
(UBC Public Health & BC CDC)

current work:
genomic epidemiology

Zipeng Liu

current work:
gene trees
(UBC Zoology)

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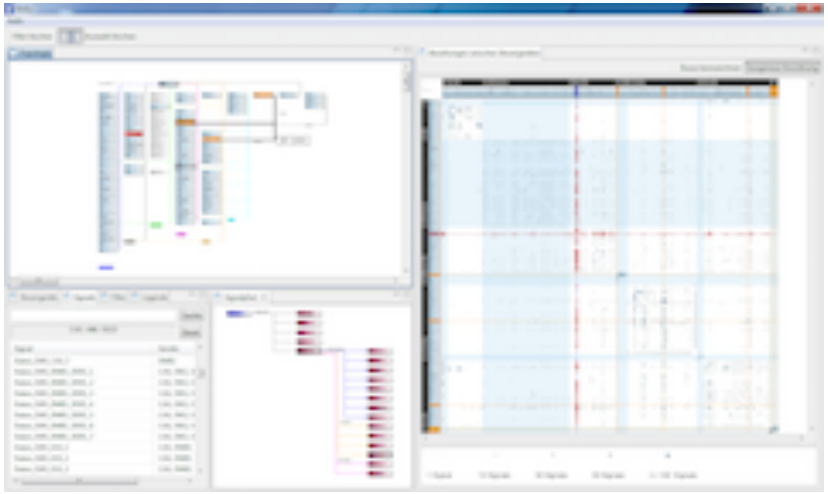
Problem-driven: Automotive, journalism

T F E P

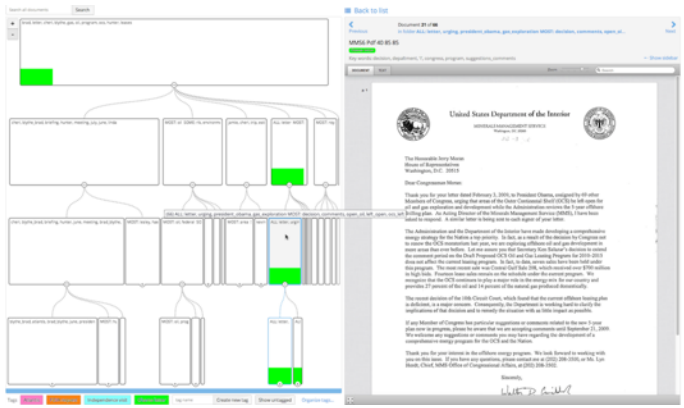


Michael Sedlmair

RelEx (BMW)

https://youtu.be/89lsQXc6Ao4

Jonathan Stray
(Assoc Press)



Overview

https://vimeo.com/71483614

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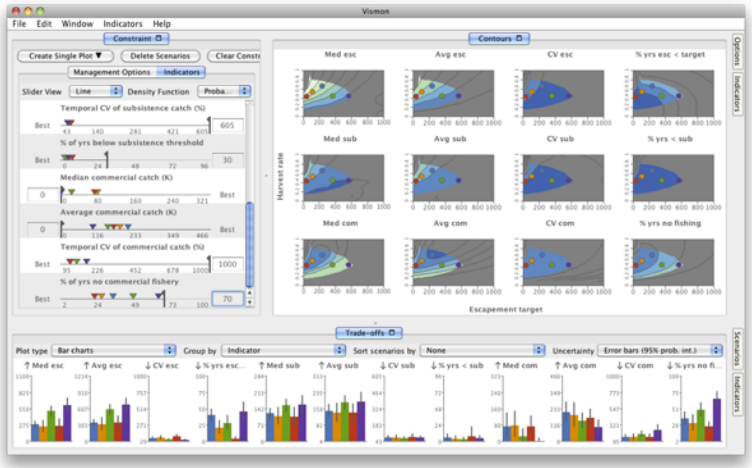
Problem-driven: Building mgmt, fisheries

T F E P

Energy Manager

Matt Brehmer

Kevin Tate
(Pulse/EnerNOC)



Vismon https://youtu.be/h0kHoS4VYmk

Maryam Booshehrian

Torsten Moeller (SFU)

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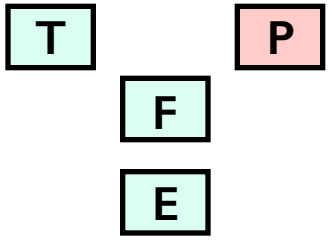
Problem-driven: Current data science



Kimberly Dextras-Romagnino

current work:
Segmentifier
(Mobify)

e-commerce clickstreams

build tools for human-in-the-loop visual data analysis

Michael Oppermann

current work:
Ocupado
(Sensible Building Science, Cisco)

wifi proxy for real-time building occupancy

integrate visual analytics and predictive ML for facilities management

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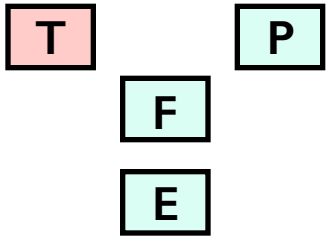
Technique-driven work

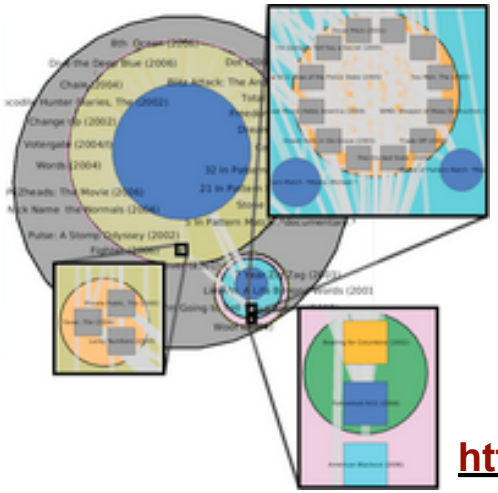
- scalable algorithms & systems
  - typical evaluation: computational benchmarks
- new layout & interaction techniques
  - typical evaluation: controlled experiments on human subjects

Technique-driven: Graph drawing



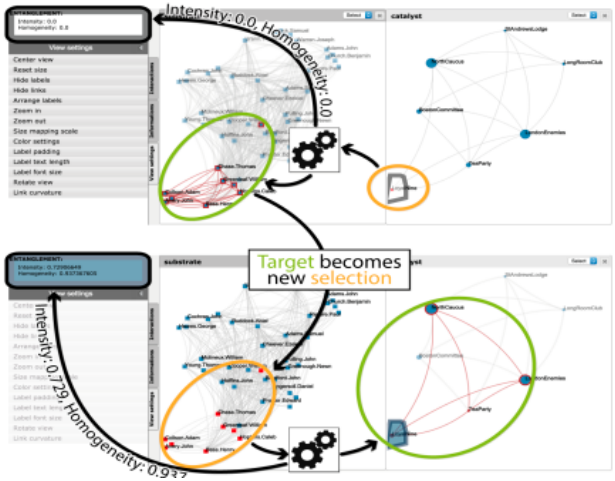
Daniel Archambault

David Auber (Bordeaux)

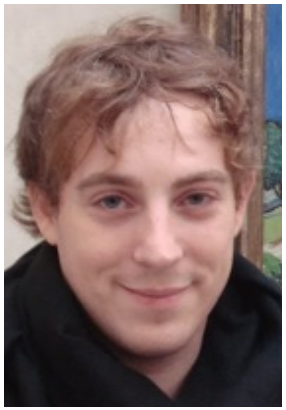


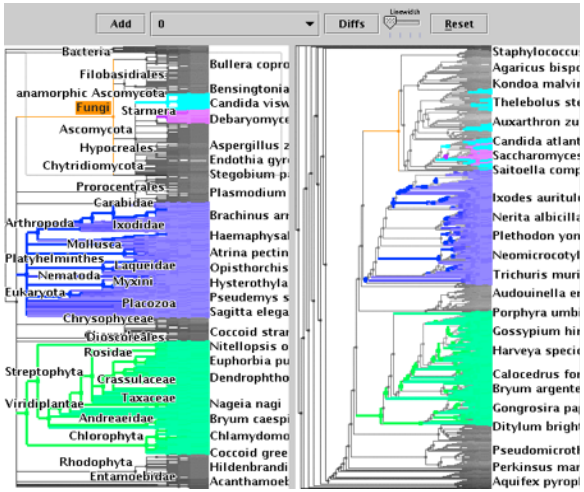
TopoLayout
SPF
Grouse
GrouseFlocks
TugGraph

https://youtu.be/AWXAe8zvkt8



Benjamin Renoust





Detangler https://youtu.be/QOtnHSsUV6k

Guy Melançon (Bordeaux)

TreeJuxtaposer

https://youtu.be/GdaPj8a9QEo

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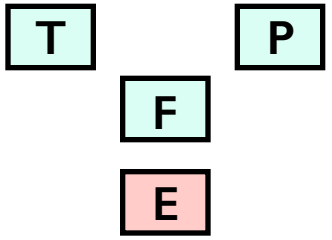
Evaluation experiments: Graph drawing



Dmitry Nekrasovski

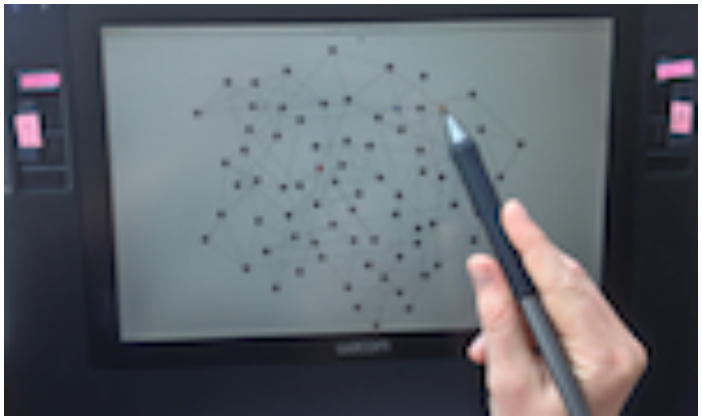
Adam Bodnar

Joanna McGrenere

Stretch and squish navigation

Jessica Dawson

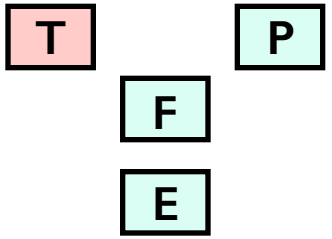
Joanna McGrenere



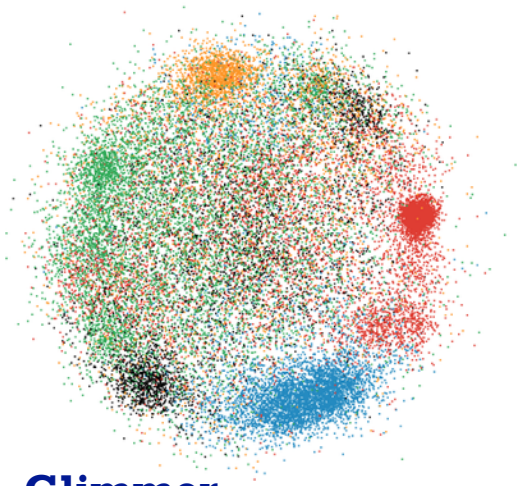
Search set model of path tracing

www.cs.ubc.ca/~tmm/talks.html#cisco18

Technique: Dimensionality reduction

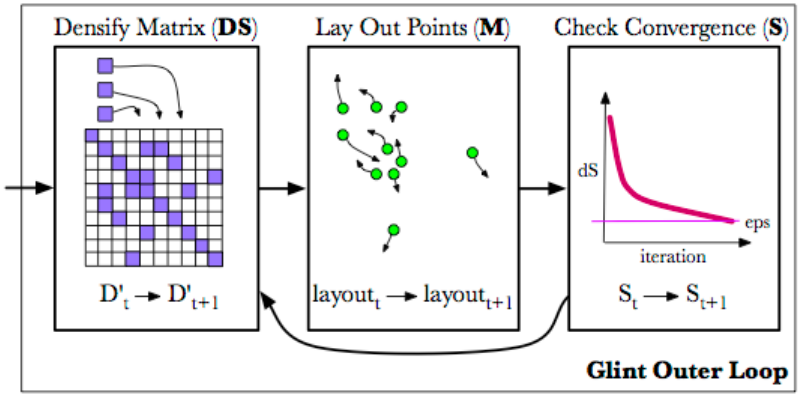


Stephen Ingram

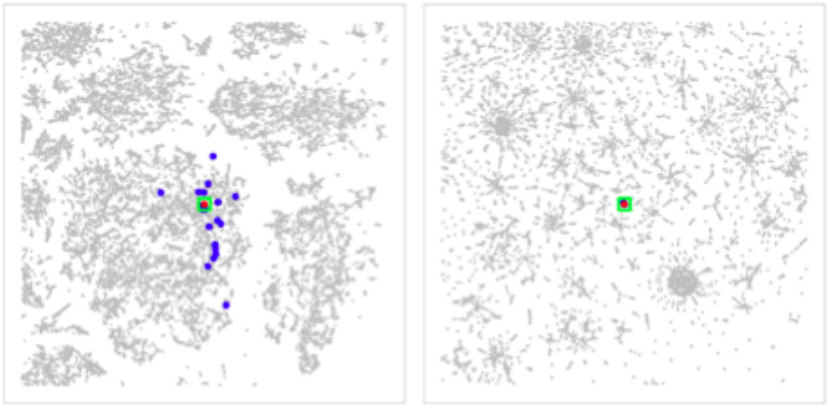


Glimmer

DimStiller



Glint



QSNE

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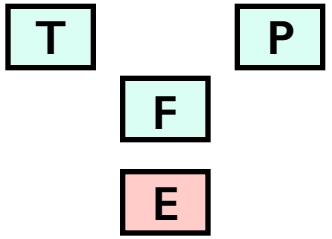
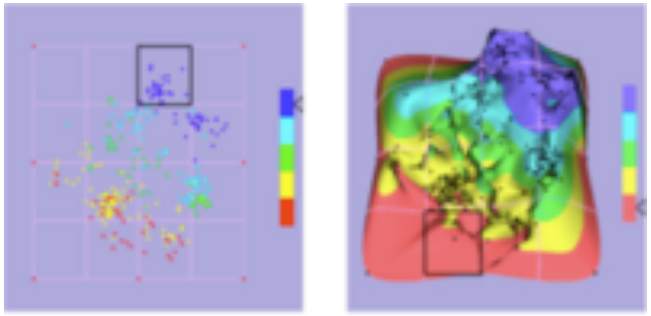
Evaluation experiments: Dim. reduction

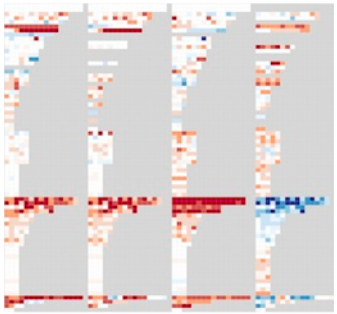


Melanie Tory

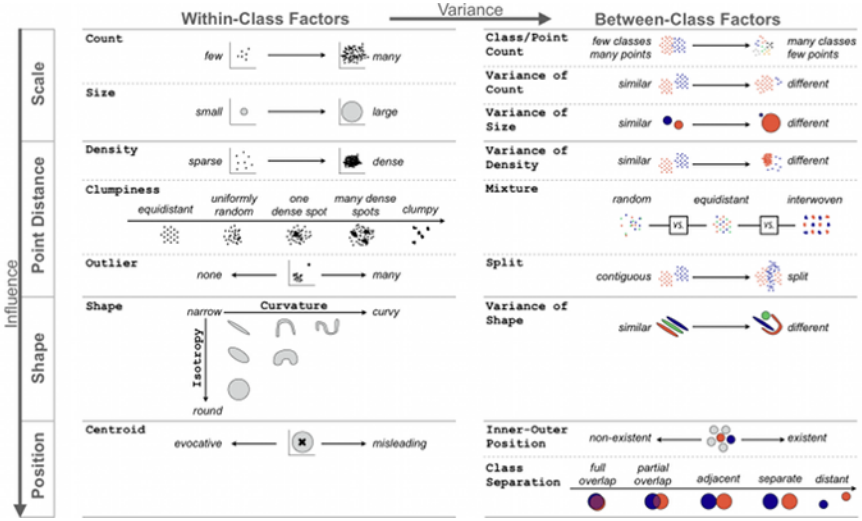


Points vs landscapes for dimensionally reduced data

Michael Sedlmair



Guidance on DR & scatterplot choices



Taxonomy of cluster separation factors

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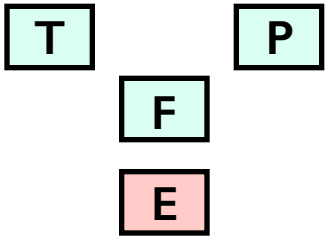
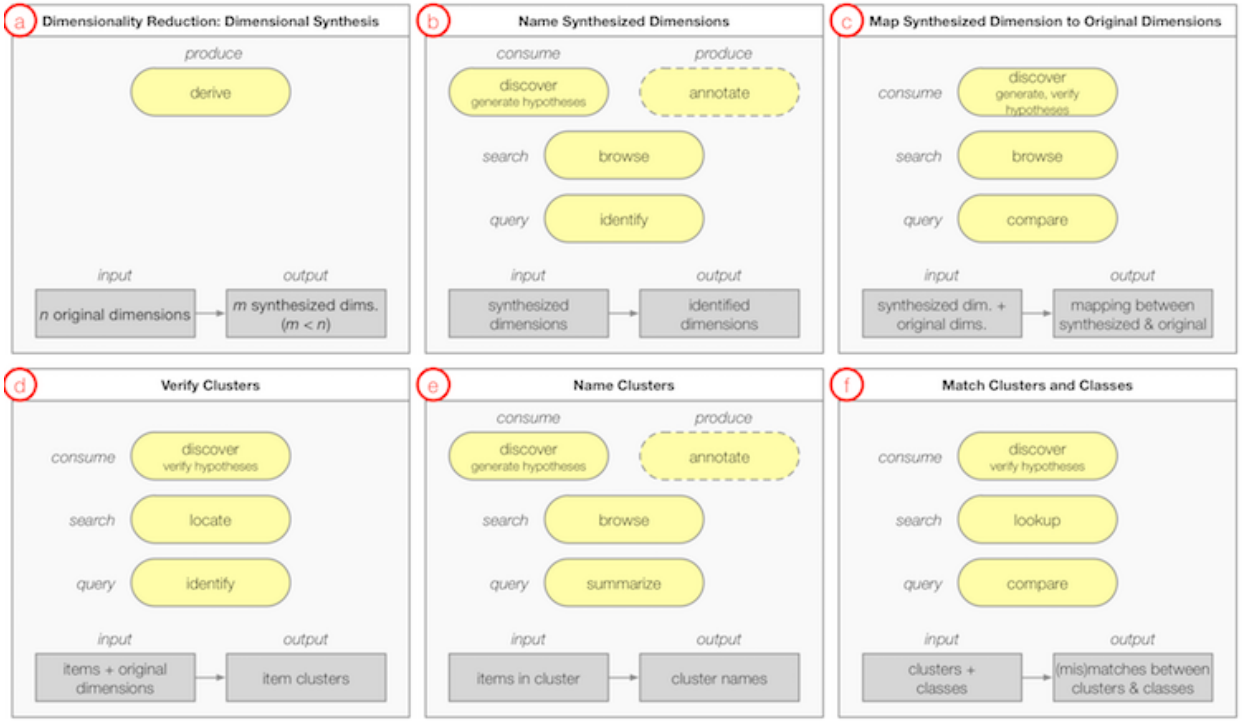
Evaluation in the field: Dim. reduction





DR in the Wild

Matt Brehmer

Michael Sedlmair

Melanie Tory

Stephen Ingram

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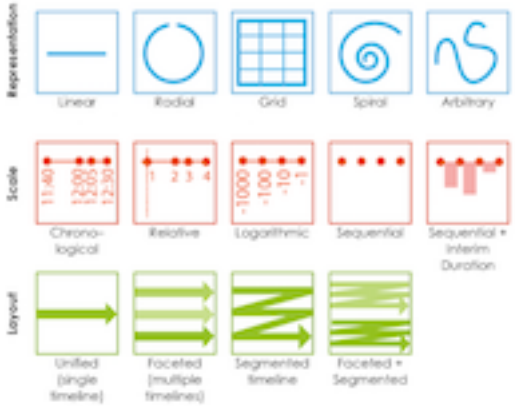
Curation & Presentation: Timelines

TimeLineCurator

https://vimeo.com/123246662

Matt Brehmer

Johanna Fulda
(Sud. Zeitung)



Timelines Revisited

timelinesrevisited.github.io/

Bongshin Lee
(Microsoft)

Benjamin Bach
(Microsoft)

Nathalie Henry-Riche
(Microsoft)

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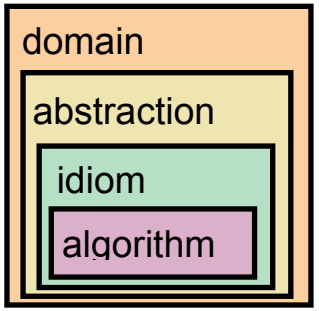
Theoretical foundations

Papers Process & Pitfalls

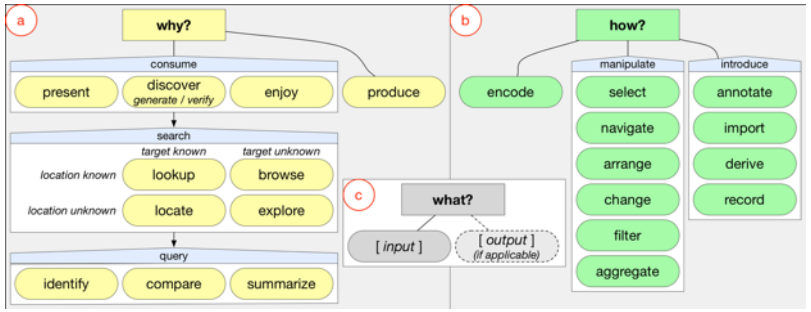
Design Study Methodology

Michael Sedlmair

Miriah Meyer



Nested Model



Abstract Tasks

Matt Brehmer

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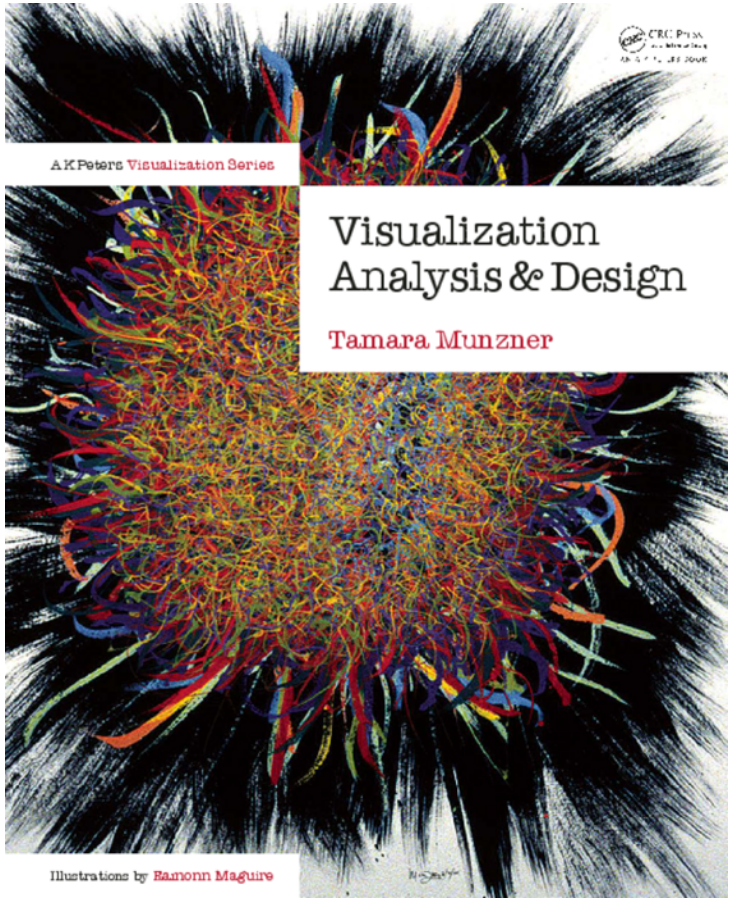
Theoretical foundations



Visualization Analysis & Design

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More information

- papers, videos, open source software, talks, courses

  http://www.cs.ubc.ca/group/infovis
  http://www.cs.ubc.ca/~tmm