Design Activity Framework: Investigating the Data Visualization Design Process

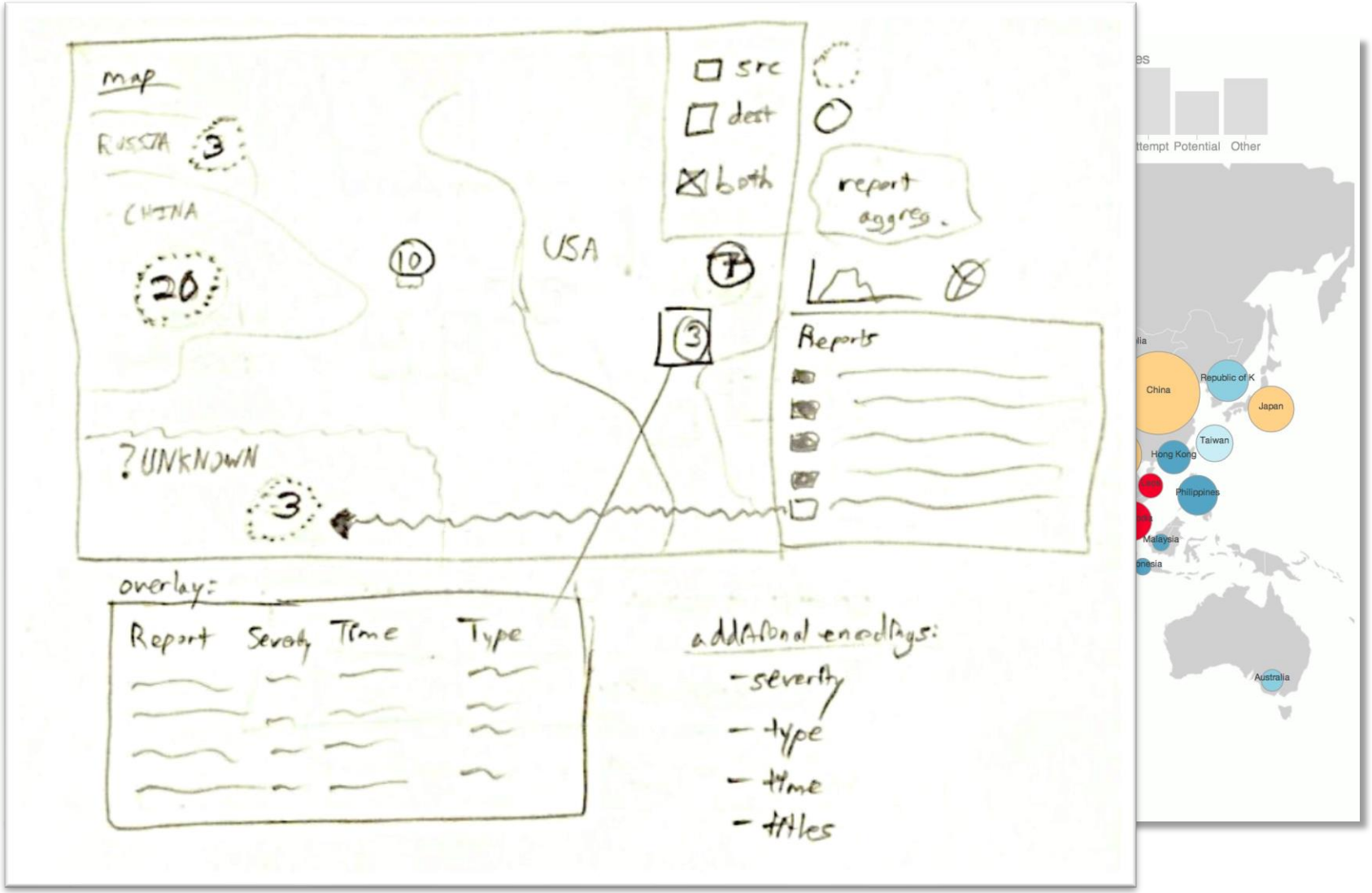
by Sean P. McKenna

June 1st, 2017

Dissertation Defense

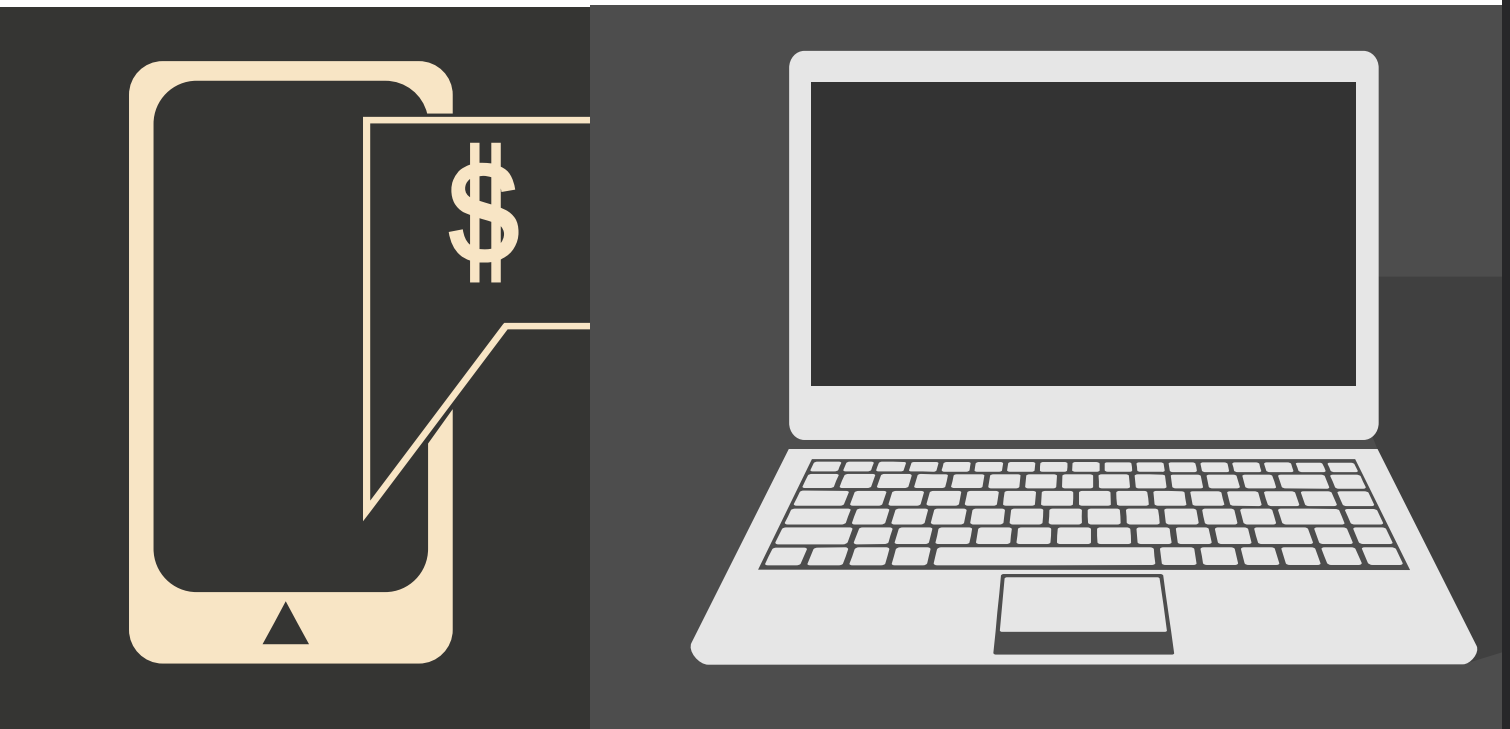
What is Visualization Design?

- process to create data visualizations
- work with users to identify their problems and needs
- ideas evolve and systems are built



Motivating Example

- more devices
- more data
- greater risk

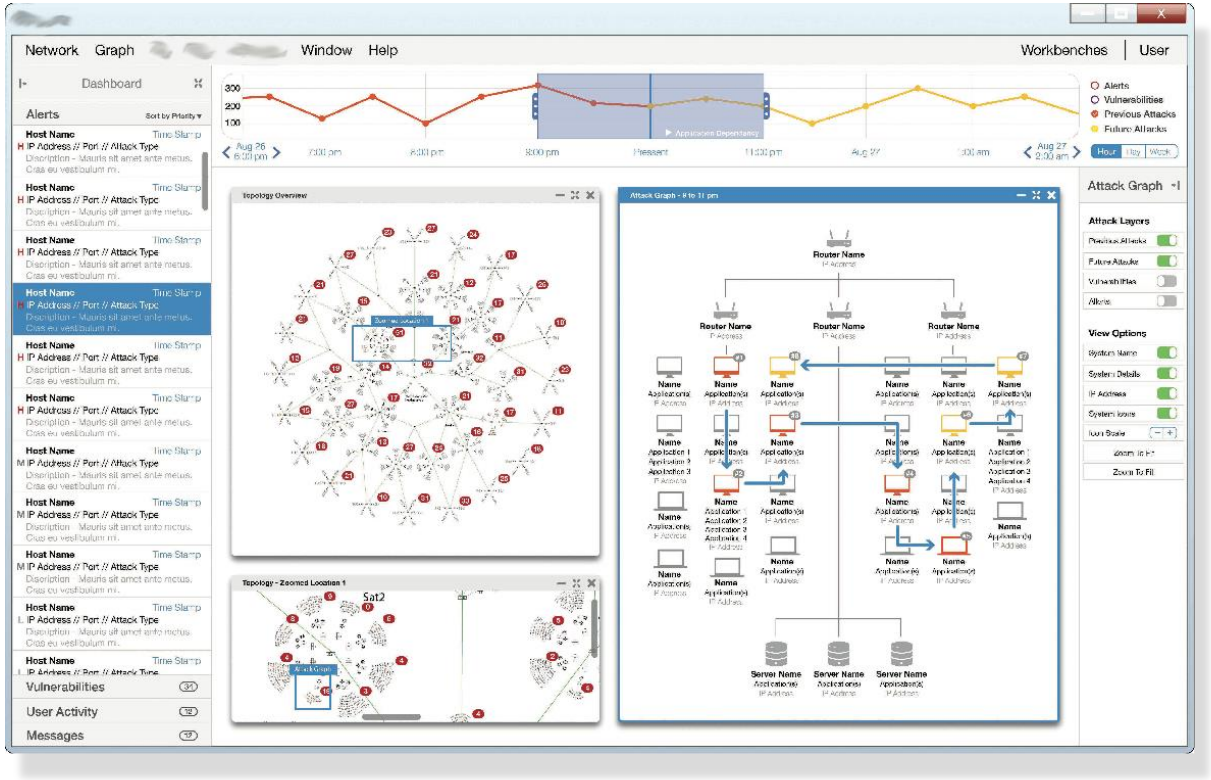


Cyber Security

- analysts work to protect our data

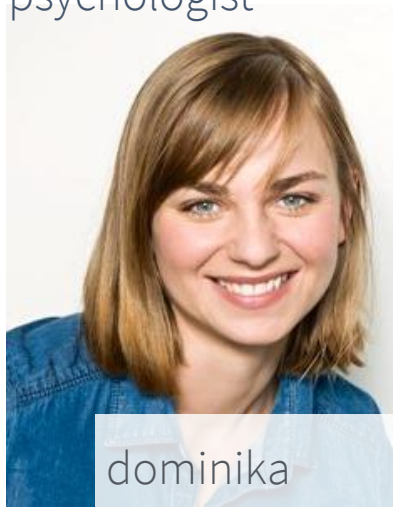
- many challenges exist:
  - adapting attacks
  - growing amounts of data
  - devil is in the details
  - missing information
  - limited access for designers

Redesign Project

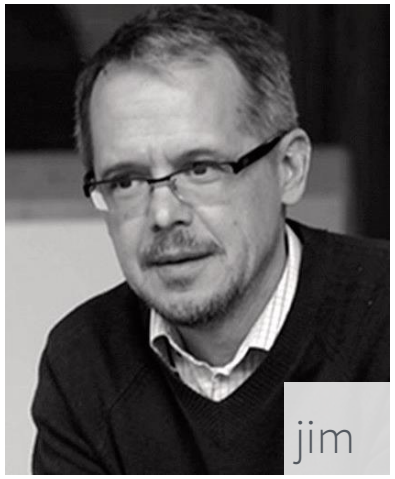


visualization experts

psychologist



designer



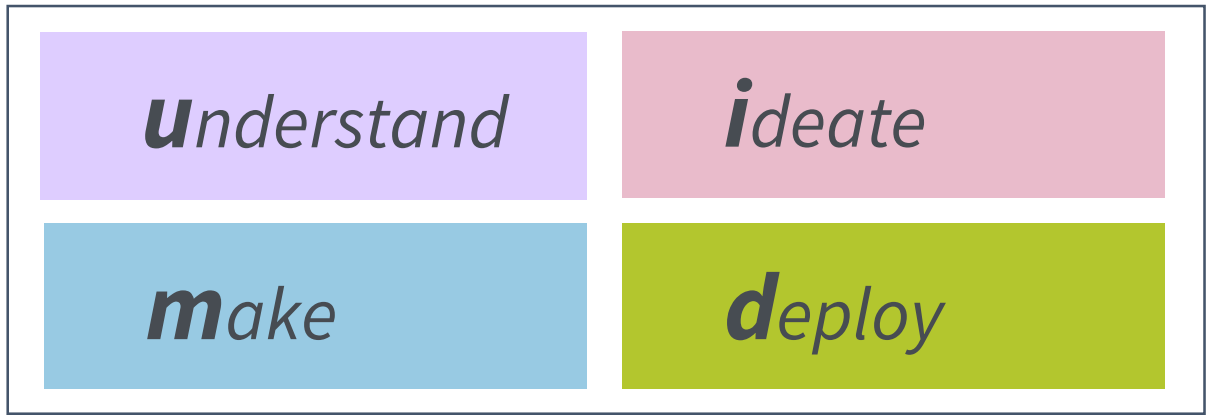
Design Activity Framework for Visualization Design
S. McKenna, D. Mazur, J. Agutter, and M. Meyer, IEEE TVCG, 2014

Visualization Design: Questions & Goals

• what am I trying to create?	→ achievable
• how do I compare and select these outcomes?	→ justifiable
• what actions can I perform?	→ discoverable
• where should I go to next?	→ flexible
• what are the steps I should perform?	→ actionable

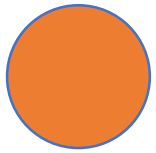
Design Activity Framework

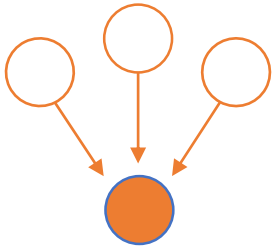
- data visualization design process model
- guide and support creation of visualization systems
- describe and capture design flexibility

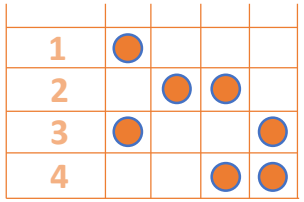


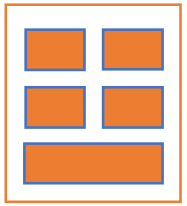
Design Activity Framework: Components

- visualization artifacts
- maps to design decisions
- table of design methods
- design timelines
- activity worksheets



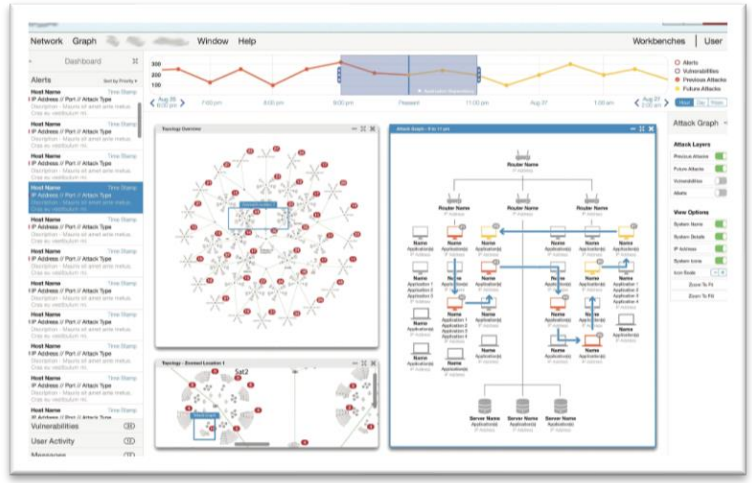






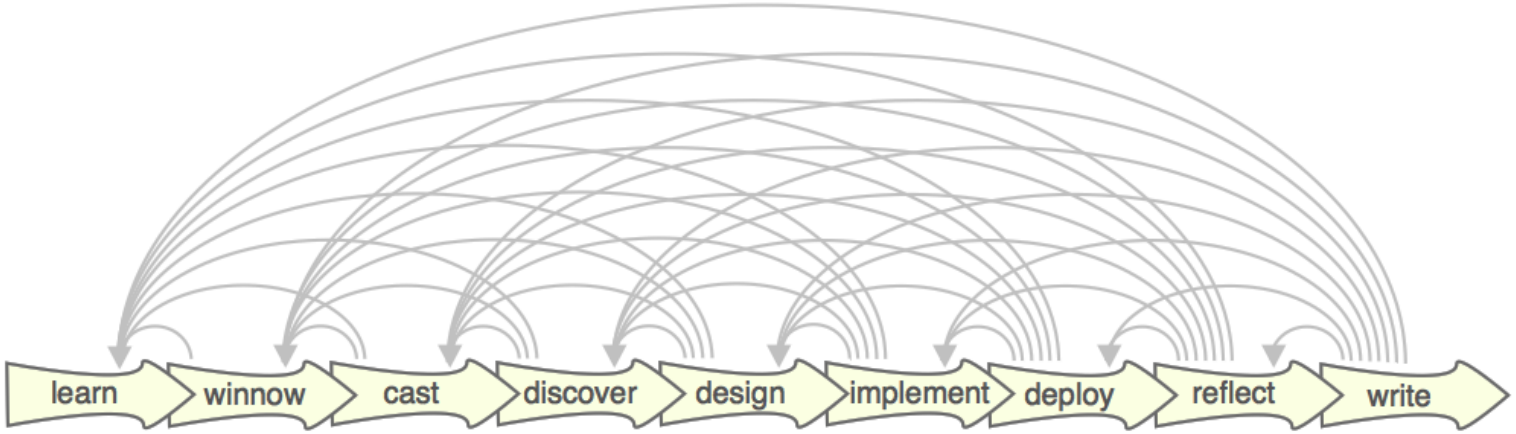
Design Activity Framework: Projects

- formative and summative projects
- validated the framework:
  - internally, via a design study
  - externally, with students
- reflected on other research projects:
  - technique-driven
  - evaluation



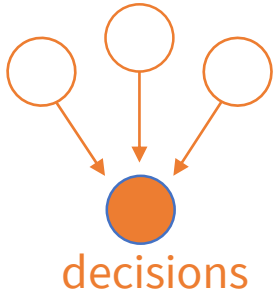
Related Work: Nine Stage Framework

- process for design studies
- planning to reflection phases
- missing aspects for visualization design

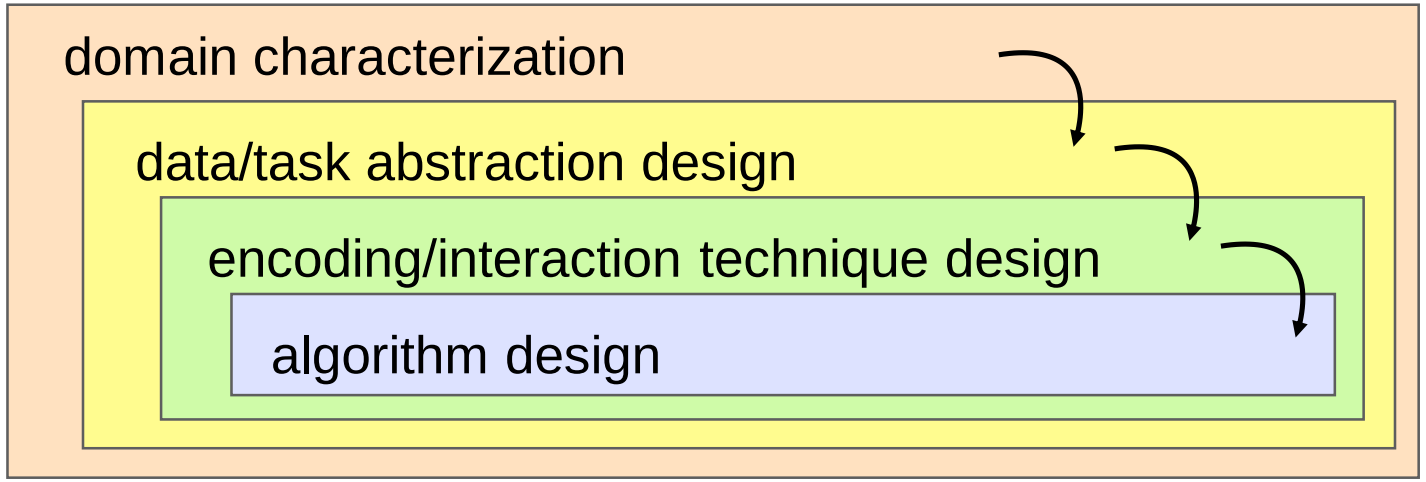


[Sedlmair, Meyer, Munzner 2012]

Related Work: Nested Model



- four levels for design decisions
- decisions cascade internally
- rationale & decision making
- supports knowledge transference

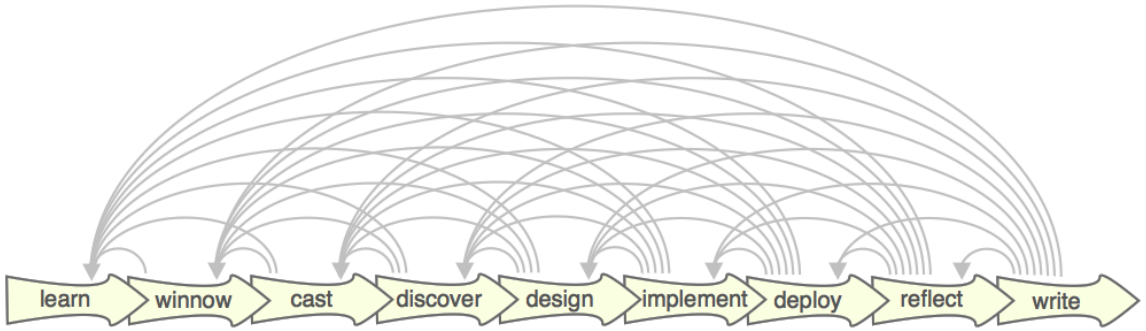


[Munzner 2010]

Related Work: Visualization Models

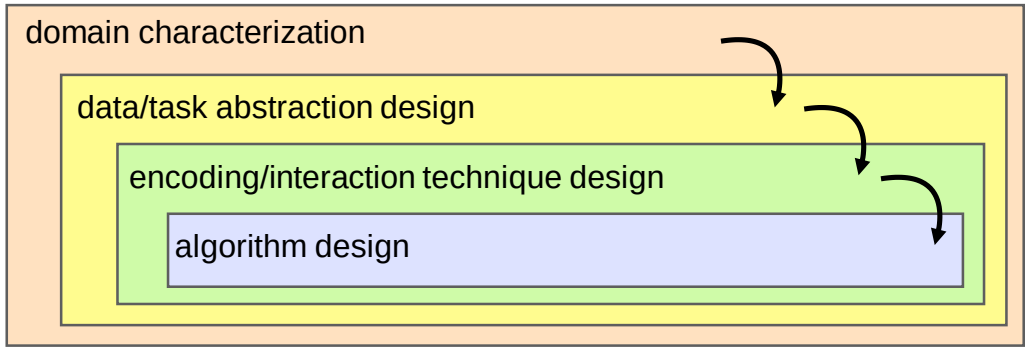
- connect **actions we take** with **decisions we make**: justifiable

process models



[Sedlmair, Meyer, Munzner 2012]

decision models

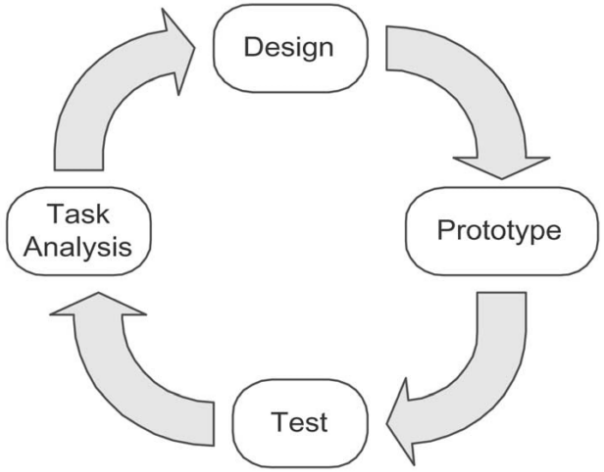


[Munzner 2010]

Related Work: Process Models

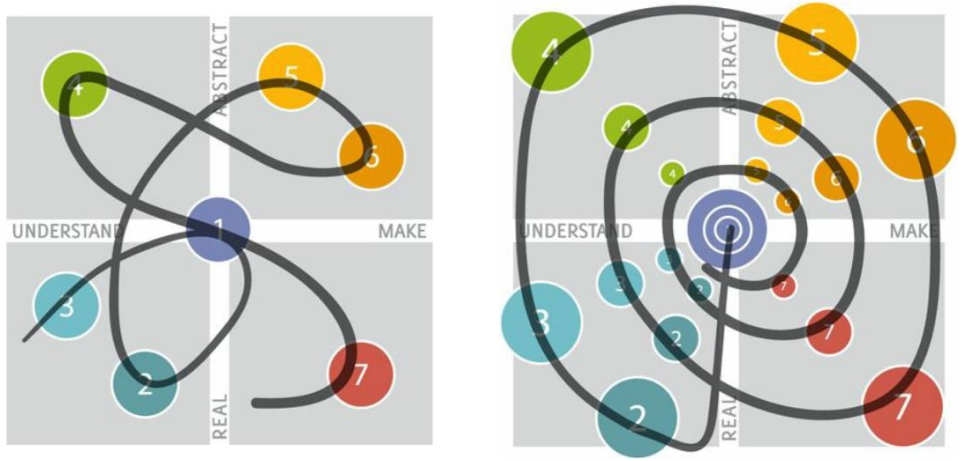
- support a **flexible** and **achievable** design process

engineering process



[Tory, Möller 2004]

creative process



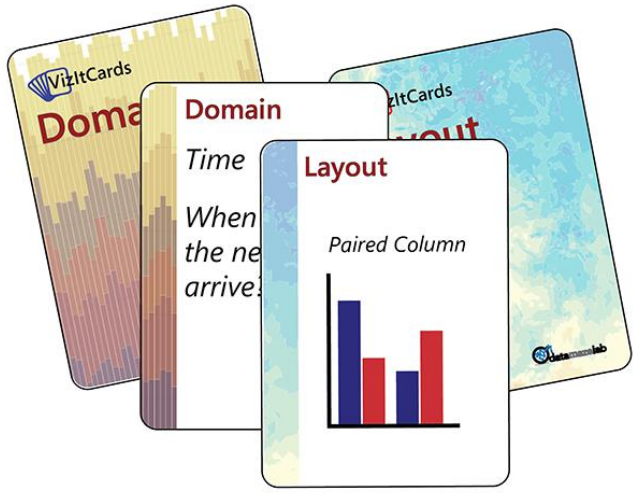
[Kumar 2012]

Related Work: Design Pedagogy

worksheets

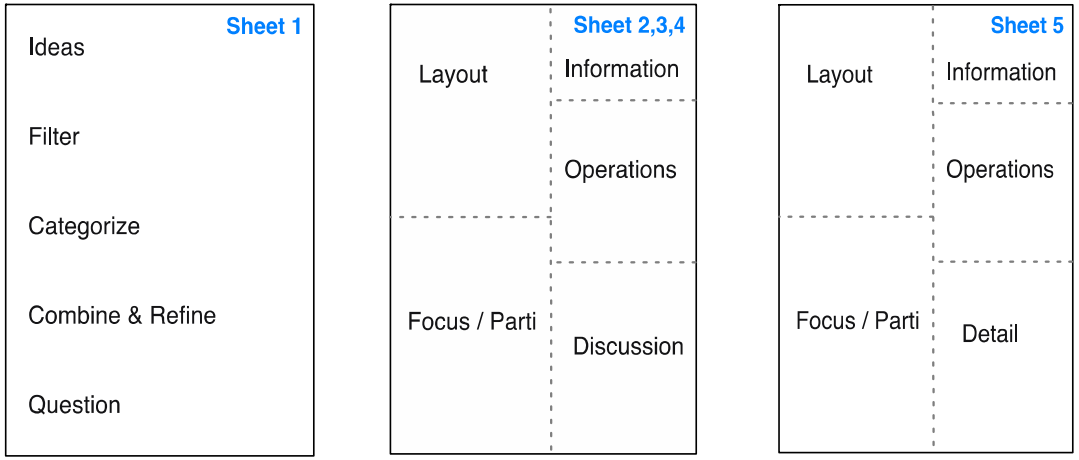
- teach design process: both **discoverable** and **actionable**

prescriptive choices



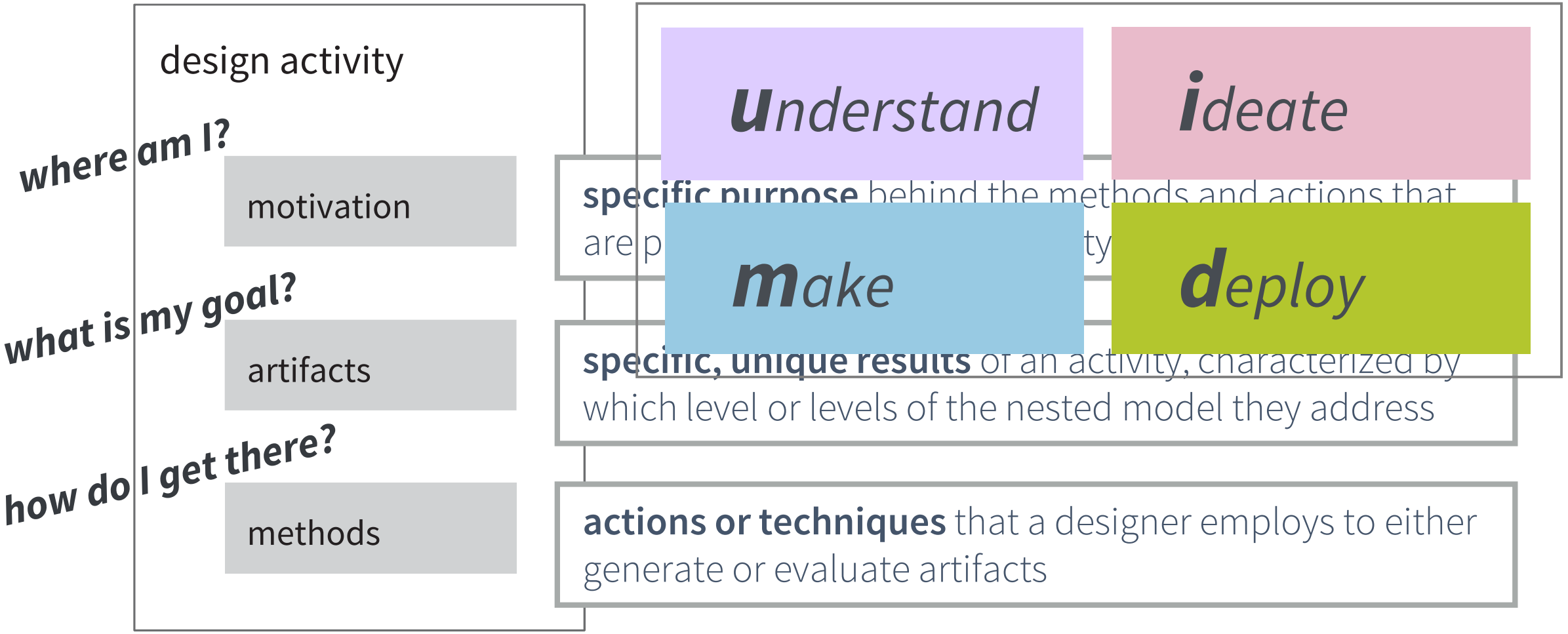
[He, Adar 2017]

guided steps



[Roberts, Headleand, Ritsos 2016]

A Design Activity



Four Activities

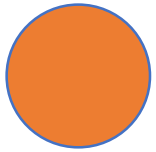
***u**nderstand*

***i**deate*

***m**ake*

***d**eploy*

Four Design Activities



u*nderstand*

motivation: finding the needs of the user
artifacts: sets of design requirements

i*deate*

generate good ideas to support needs
sets of ideas

m*ake*

concretize ideas, make them tangible
sets of prototypes

d*eploy*

bring a prototype into effective action
visualization system

Example of a Deploy Activity

artifacts

- software analysis of a visualization system

Example of a Understand Activity

artifacts

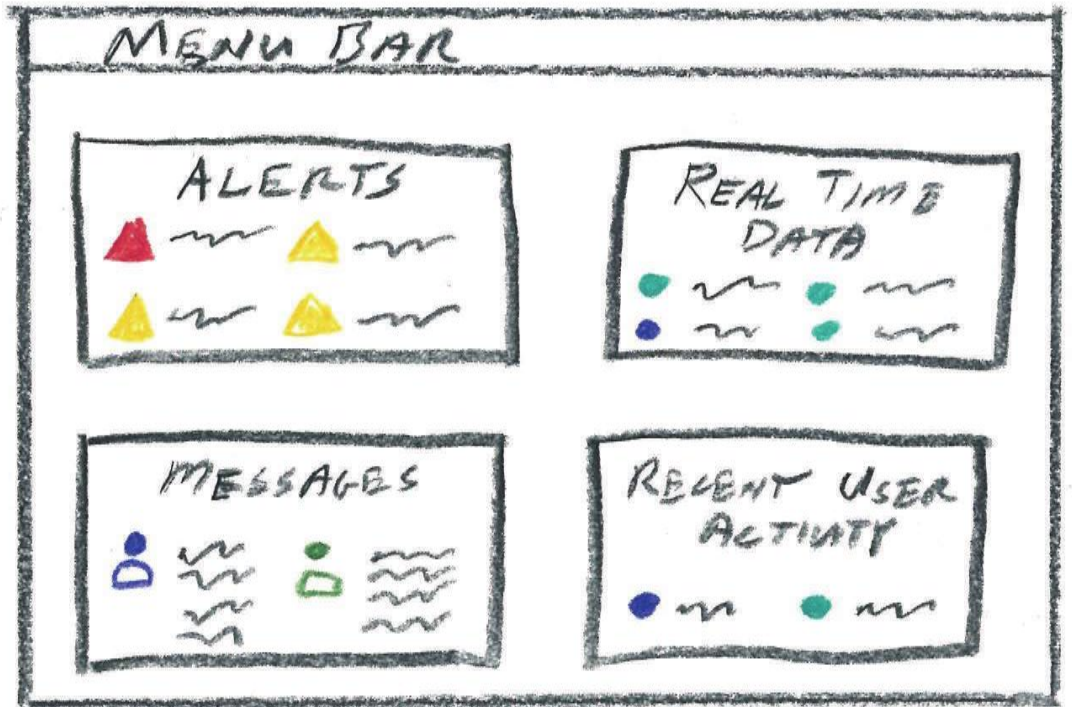
- qualitative coding of cognitive task analysis papers

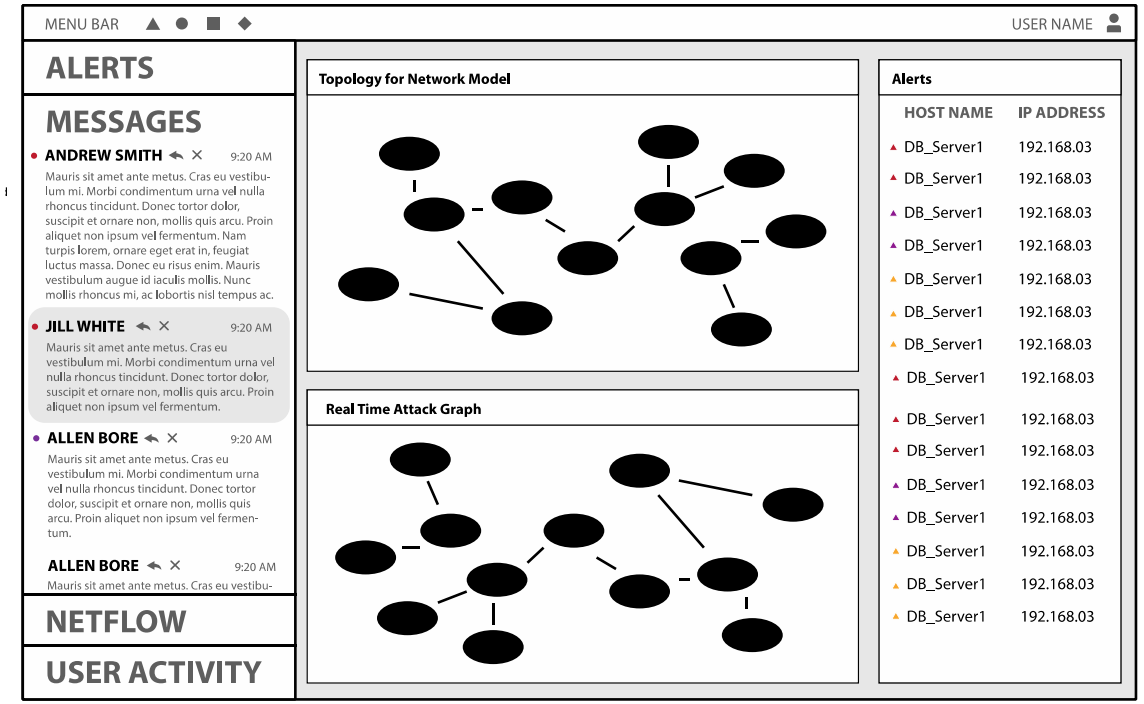
category	sub-category	sub-sub-category	evidence	author	pages	notes
communities	attackers		"... increasingly sophisticated technical and social attacks from organized criminal operations"	D'Amico	19	
data	external	website	"information published on hacker websites"	D'Amico	29	
data	processed	report	"incident report, intrusion set, problem set from other organizations, information about the source and or sponsor of attack" & "incident reports are [often] textual documents"	D'Amico	35	eg. power point, word doc, video, podcast, ...
data	raw	packets (data, netflow)	"network packet traffic, netflow data or host-based log data"	D'Amico	25	
design guidelines	tutorial		"tutorial on how to get started; not just the user's manual .... certification process so people can become certified"	Erbacher	212	
design guidelines	uncertainty visualization		"visualization should have a weight based on the accuracy of info" & "force-directed graphs where trust is the primary spring force"	Erbacher	210,212	
other	metaphor		"Cyber security is essentially a human-on-human adversarial game played out by automated avatars."	Fink	46	
phases	situational awareness	perception	"During the first stage, a CND analyst acquires data about the monitored environment, which is typical of the perceptual stage of situation awareness."	D'Amico	32	
responsibilities	communication		"importance of analyst communication in the data transformation"	D'Amico	30	
roles	managers		"most were active analysts; a few were managers"	D'Amico	23	
roles	network analyst		"computer network defense (CND) analysts"	D'Amico	19	
workflows	investigate		"If a vulnerability scan returned a suspect IP address, he would then have to go through several different tools in different windows to get information about the IP, such as the host name, its location in the network or building, its OS version and update status, its owner, and the owner's phone number."	Fink	49	

Example of a Ideate Activity

artifacts

- concept sketches & wireframes

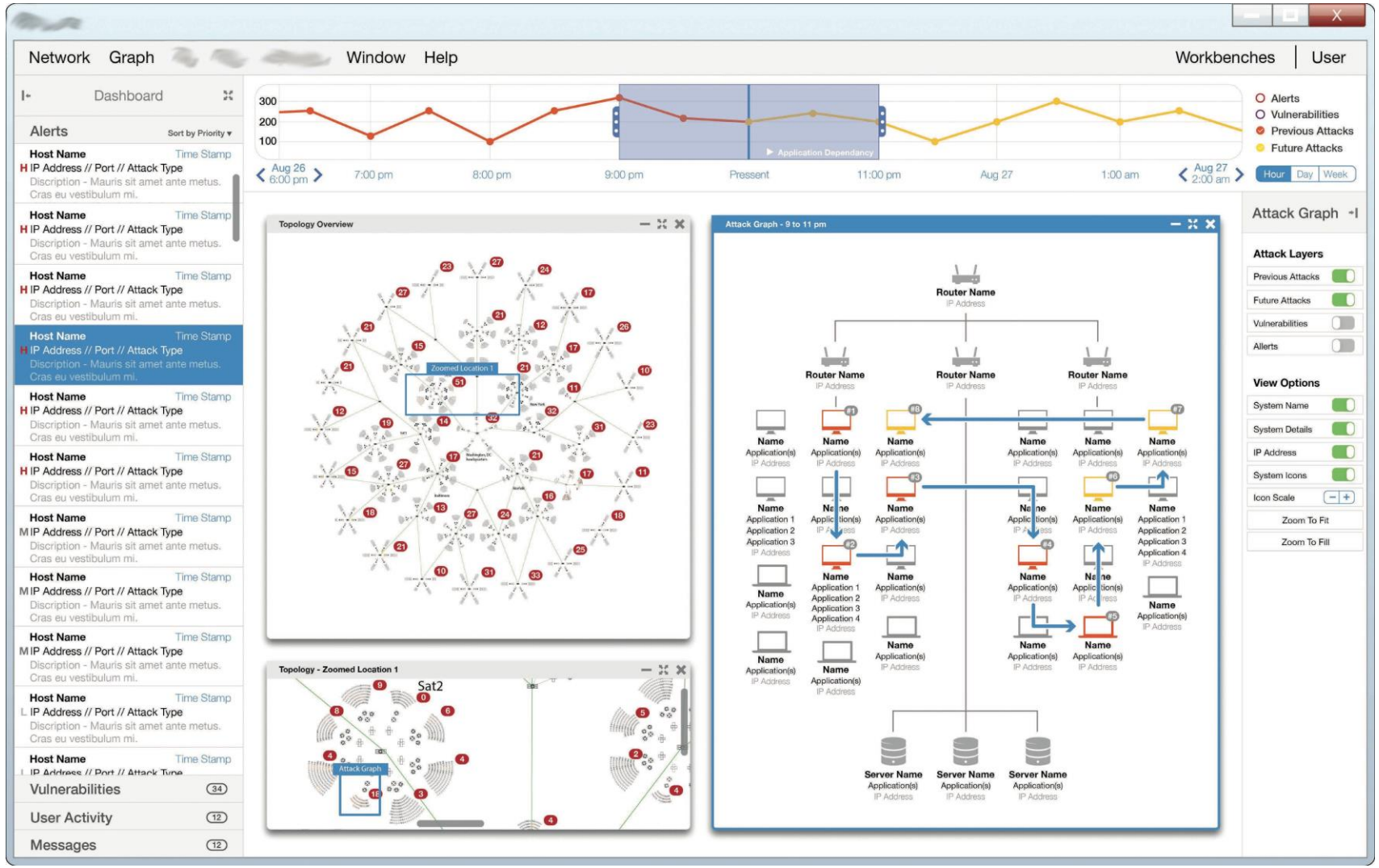




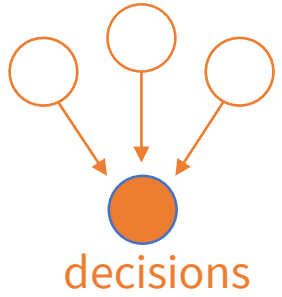
Example of a Make Activity

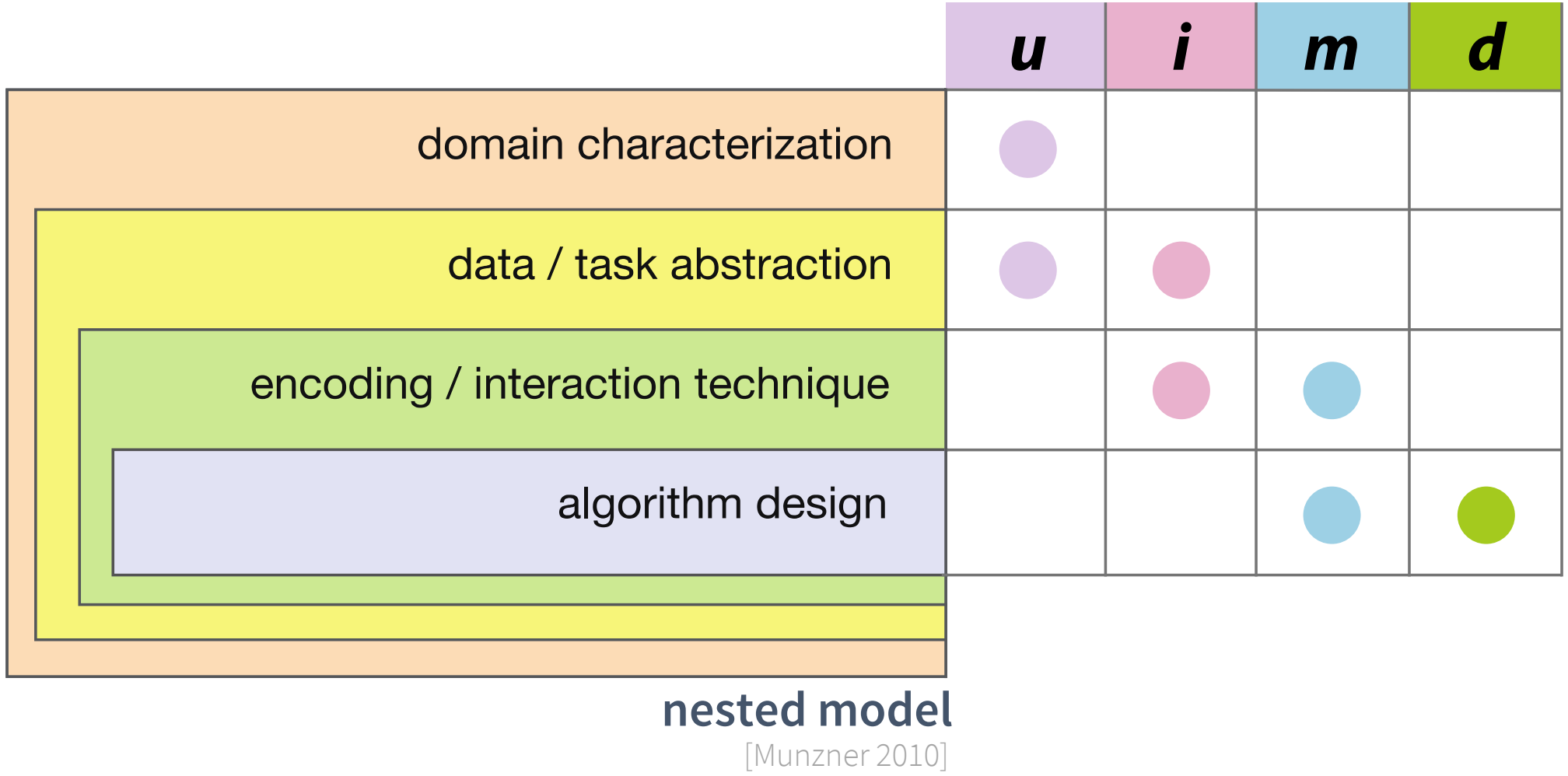
artifacts

- digital mockups



Mapping Design Decisions

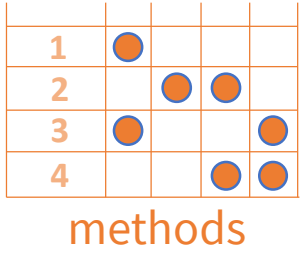




nested model

[Munzner 2010]

Discovering Design Methods



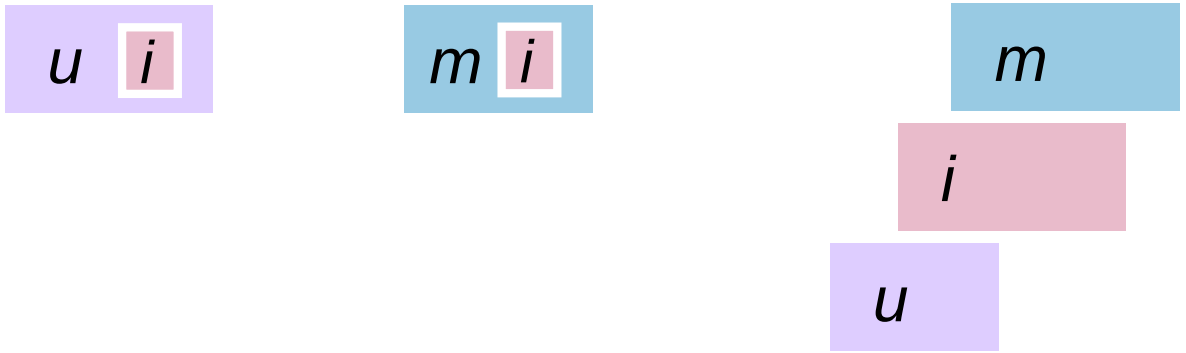
#	method	u g	u e	i g	i e	m g	m e	d g	d e	v	definition
1	A/B testing						●		●	●	"compare two versions of the same design to see which one pe statistically better against a predetermined goal" [25]
2	activity map	●	●								"structuring activities of stakeholders and showing how they to one another.... take a list of activities gathered during re and see how they are grouped based on their relationships" [
3	AEIOU framework	●	●								"organizational framework reminding the researcher to atte document, and code information under a guiding taxonc Activities, Environments, Interactions, Objects, and Users" [
4	affinity diagramming		●		●		●				"process used to externalize and meaningfully cluster observ and insights from research, keeping design teams grounded as they design" [25]
5	algorithmic performance	●	●				●		●	●	"quantitatively study the performance or quality of visual algorithms.... common examples include measureme rendering speed or memory performance" [30]
6	analogical reasoning	●		●						●	"cognitive strategy in which previous knowledge is accesse transferred to fit the current requirements of a novel situation"
7	appearance modeling			●		●		●			"refined model of a new idea that emphasizes visual styling" [
8	artifact analysis	●	●							●	"systematic examination of the material, aesthetic, and inte qualities of objects contributes to an understanding of their pl social, and cultural contexts" [25]

Design Process Timelines

- built to capture design flow
- **flexible**; support messiness

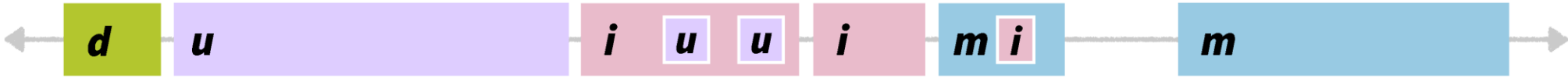
- two basic **movement principles**
  1. **forward** movement is **ordered**

  2. activities can be **nested** or conducted in **parallel**

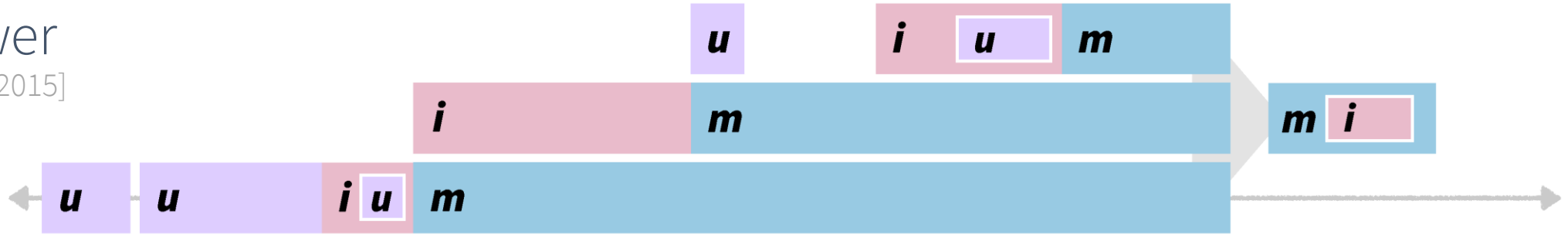


Design Process Timelines

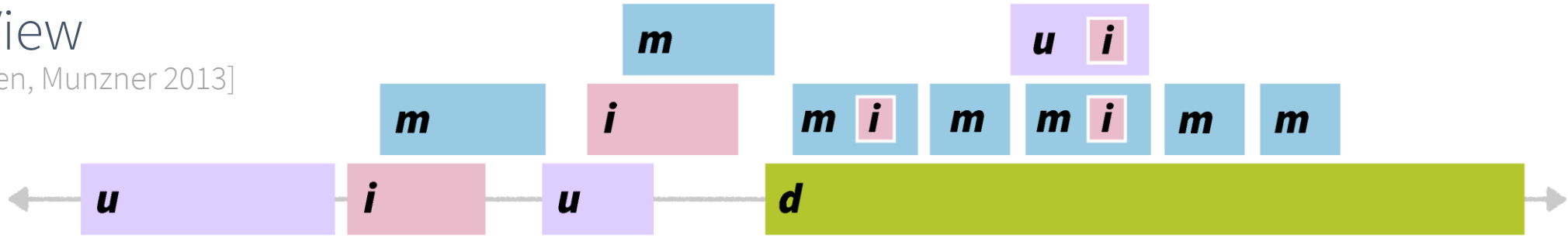
- redesign project



- Shotviewer
  [Kerzner et al. 2015]

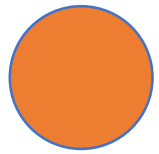


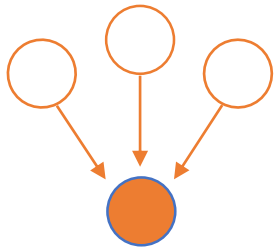
- Variant View
  [Ferstay, Nielsen, Munzner 2013]

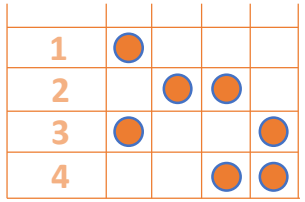


Design Activity Framework Summary

- design activities with visualization artifacts
- map to nested model decisions
- design methods for each activity
- plan and communicate with timelines

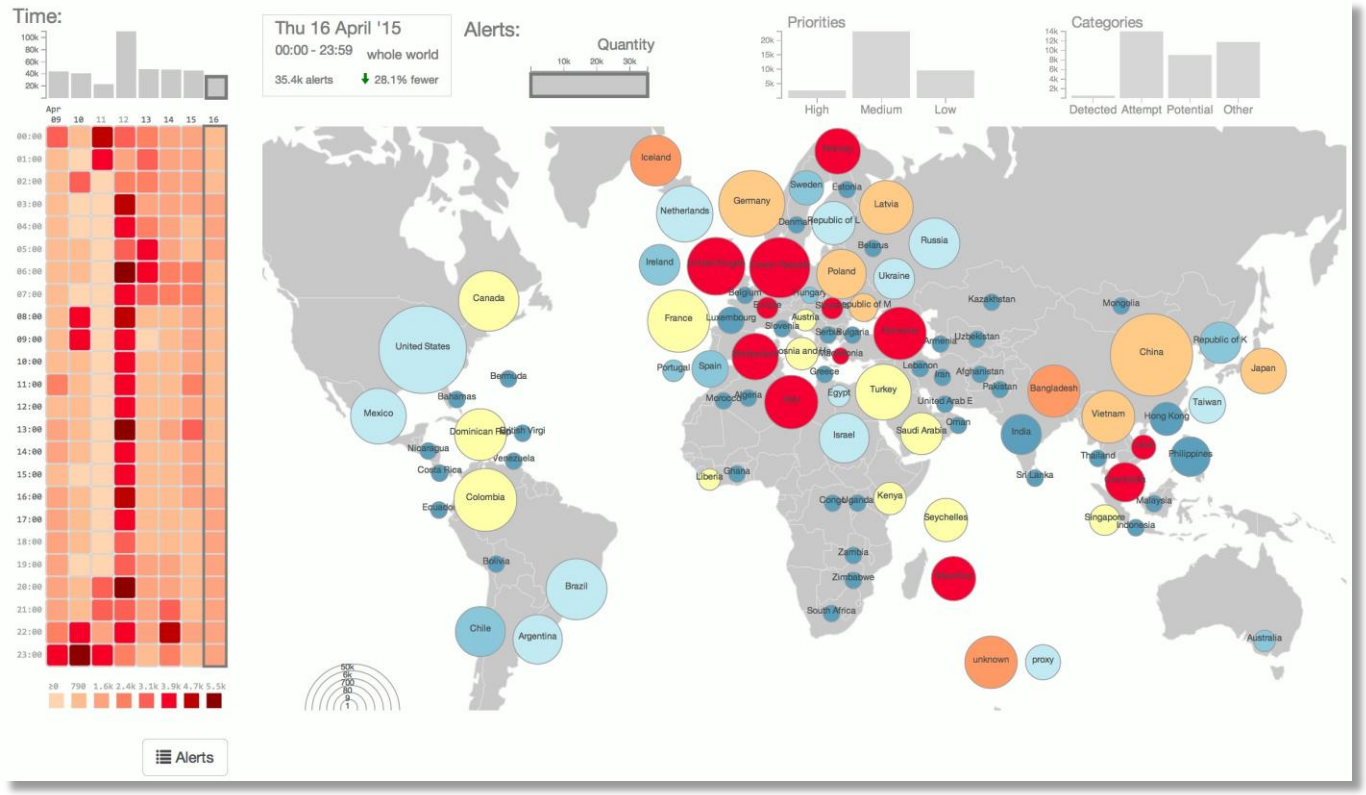






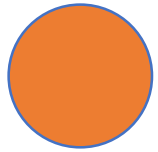
Conducting a Design Study

- validate the framework
- track visualization artifacts
- employ new design methods
- can this lead to success?



BubbleNet: A Cyber Security Dashboard for Visualizing Patterns
S. McKenna, D. Staheli, C. Fulcher, and M. Meyer, CGF, 2016

Data and Task Abstraction

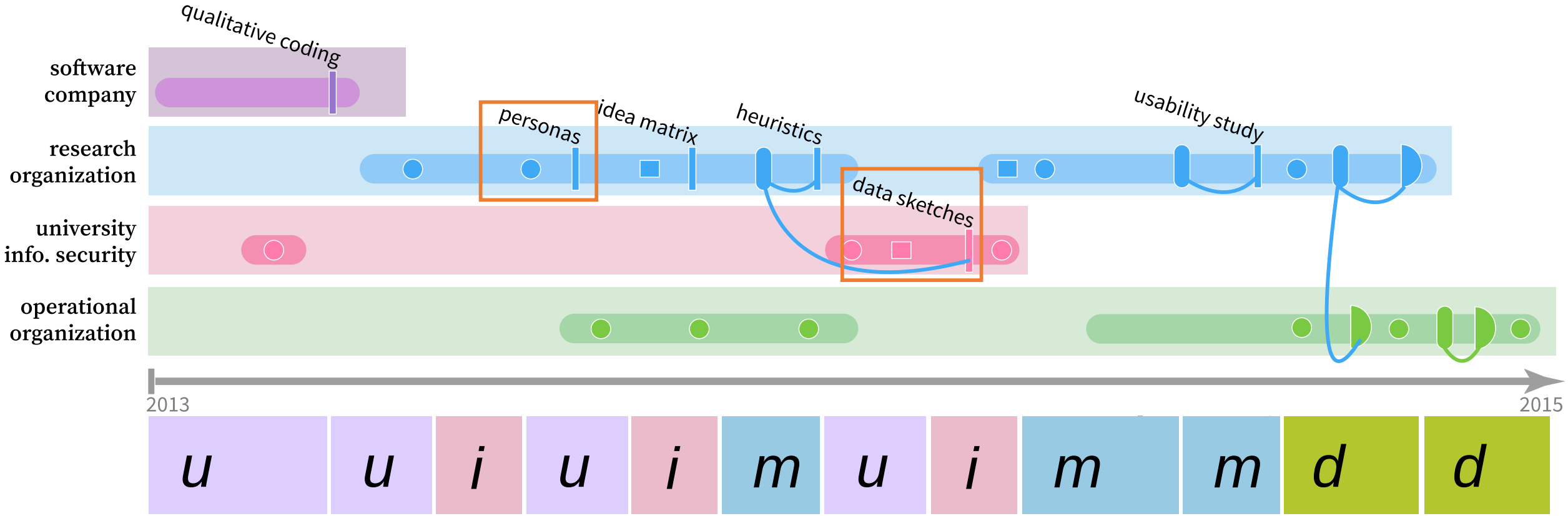


- **network record**:
  - metadata associated with the communication between two computers
- **pattern**:
  - collection of *network records* that represent recurring or abnormal behavior
- tasks: **discover** & **present**
  - dashboards show overview
  - aggregation & deviation

timelines

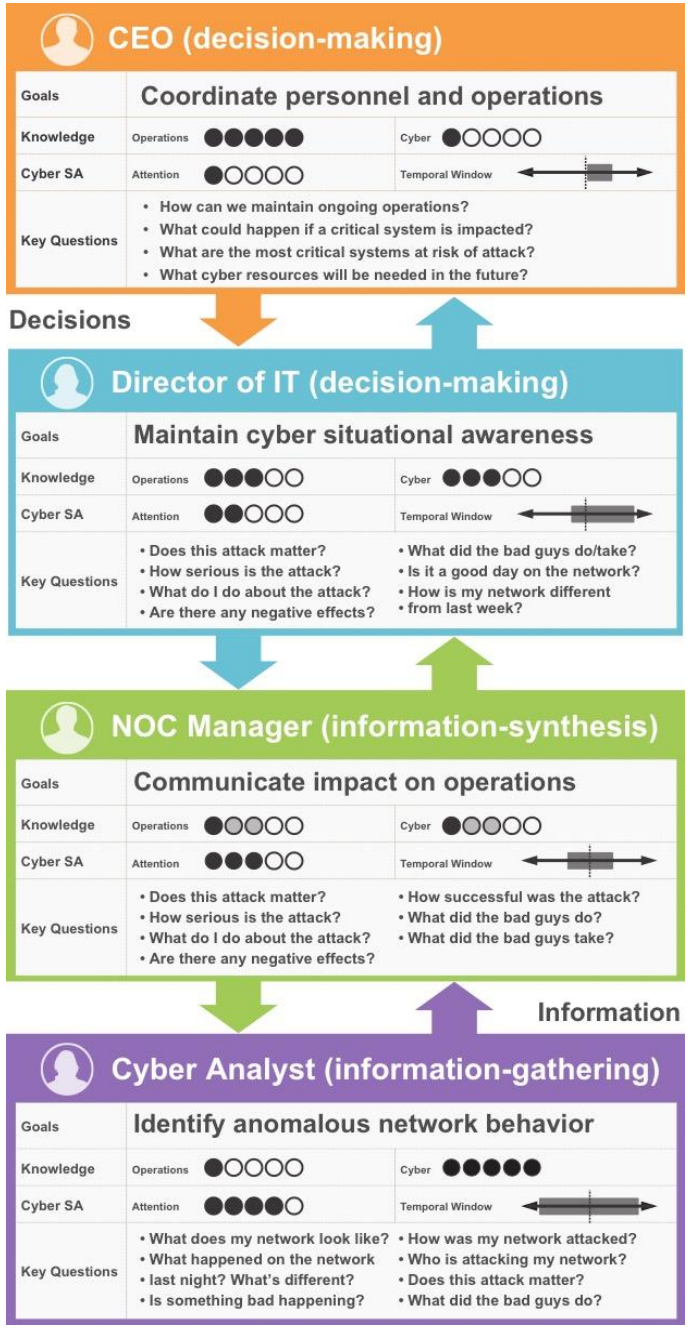
Dashboard Design Process

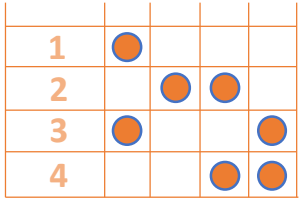
- framework guided us across multiple discourse channels [Wood, Beecham, Dykes 2014]



Personas Method

- identified potential users
- flow of information & decisions
- focused the final design:
  - analysts and managers

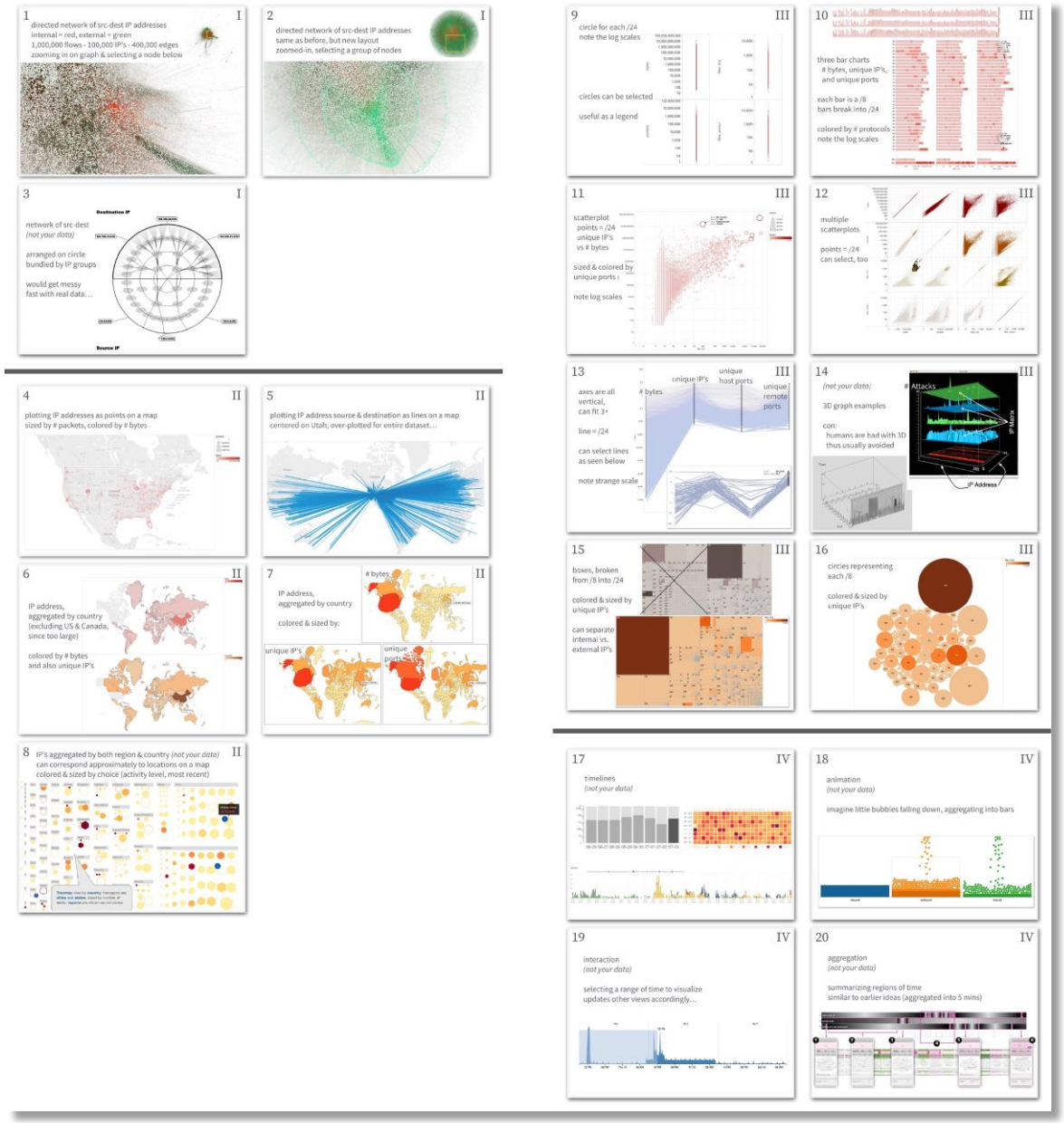


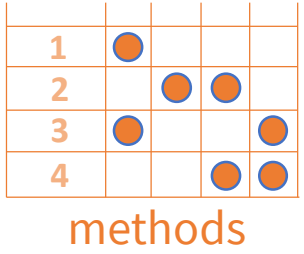


Unlocking User-Centered Design Methods for Building Cyber Security Visualizations
S. McKenna, D. Staheli, and M. Meyer, VizSec, 2015

Data Sketches

- data-driven sketches, test our abstractions
  [Lloyd & Dykes 2011]
- feedback from analyst
- location-based map encoding

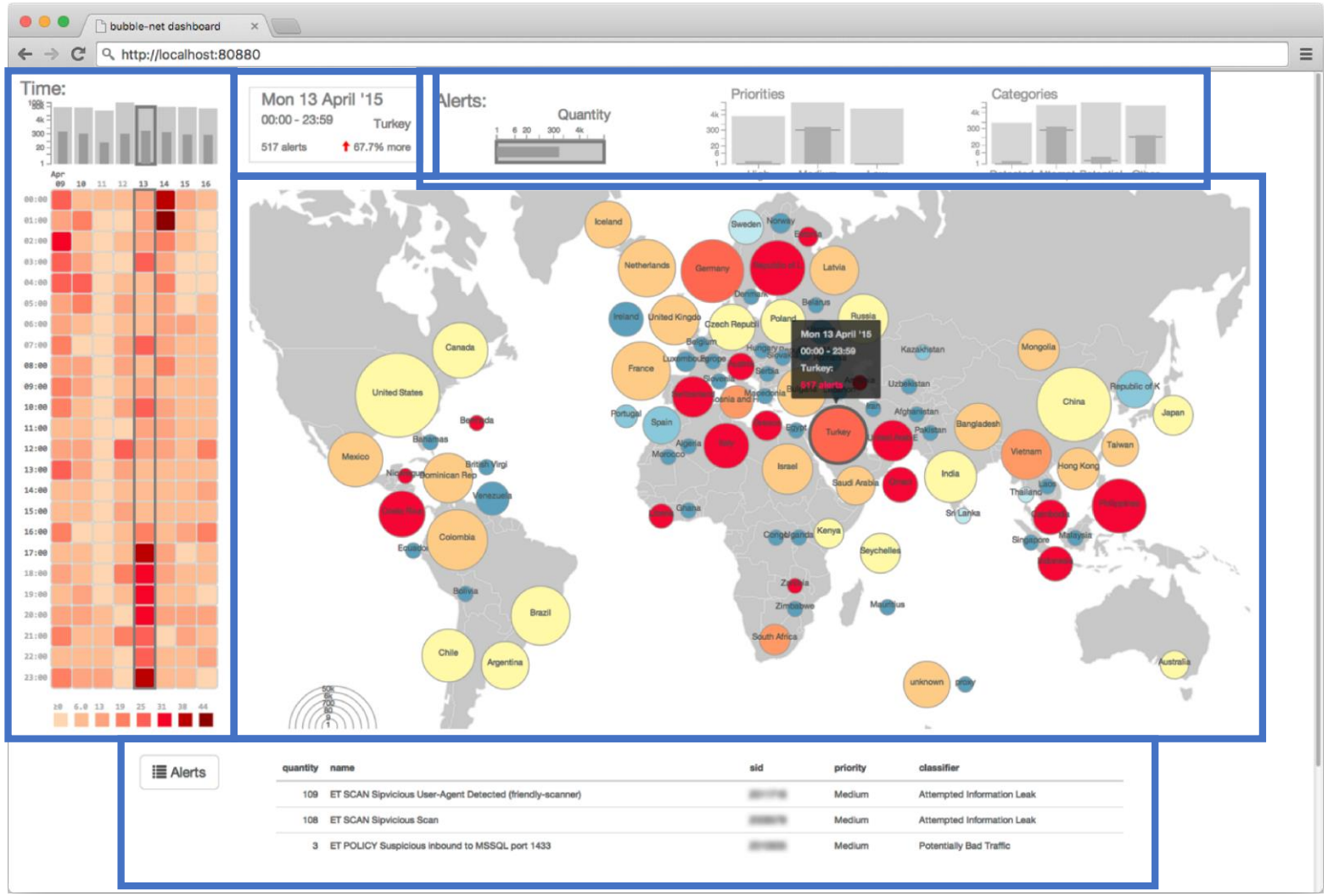




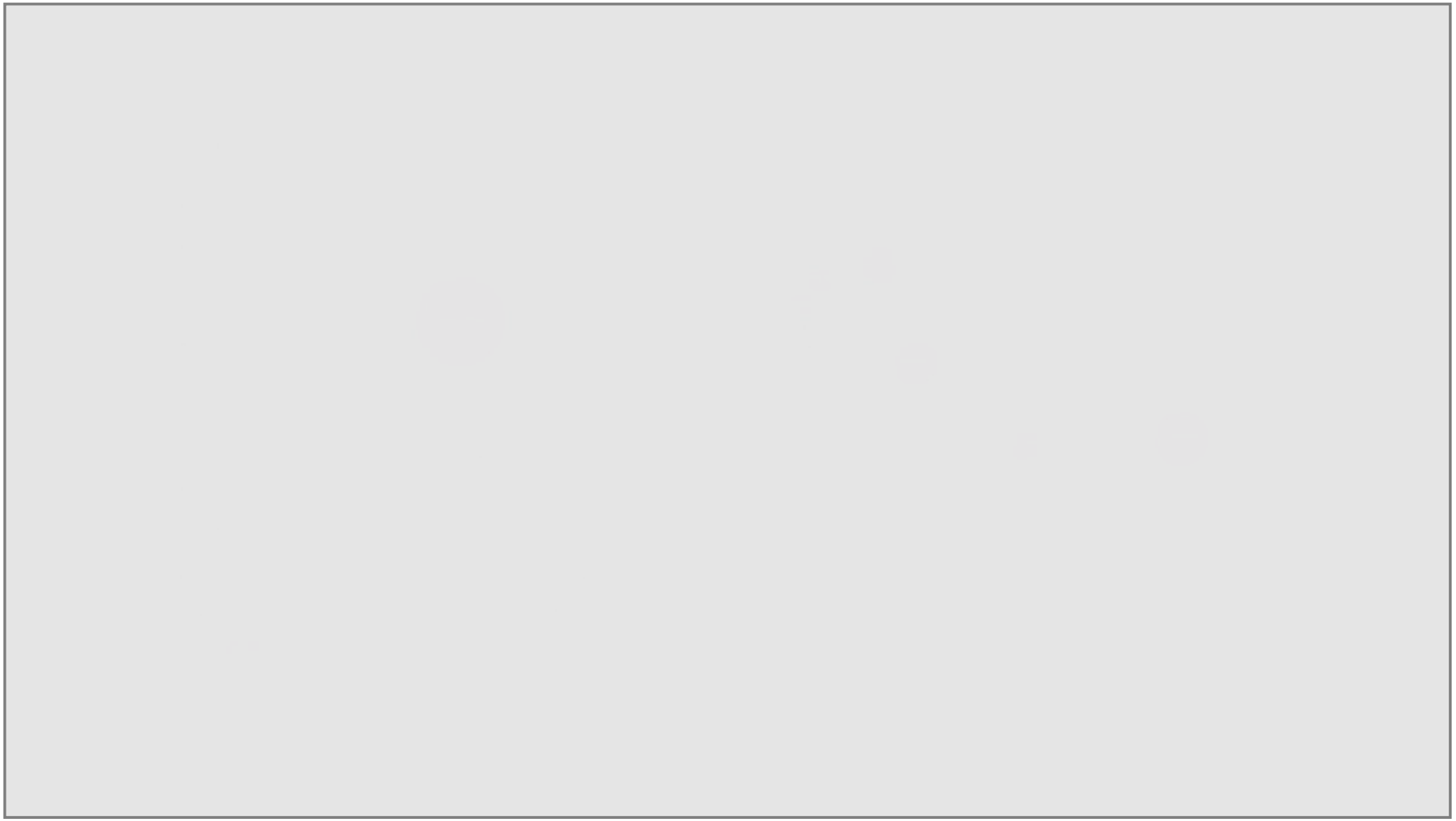
BubbleNet Dashboard

artifacts

- location view
- temporal views
- attribute bullet charts
- record details
- selection overview

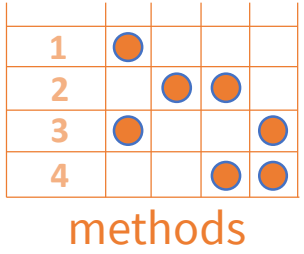


BubbleNet Dashboard Interactions

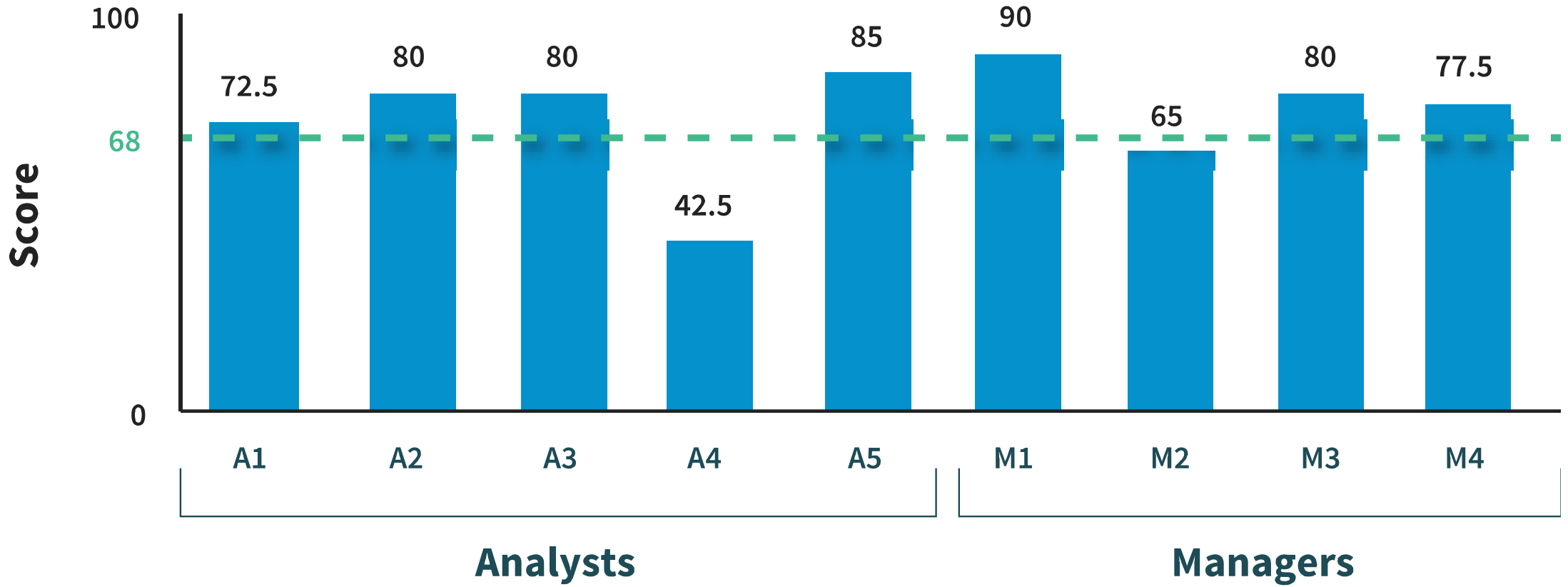


artifacts

Dashboard Evaluation

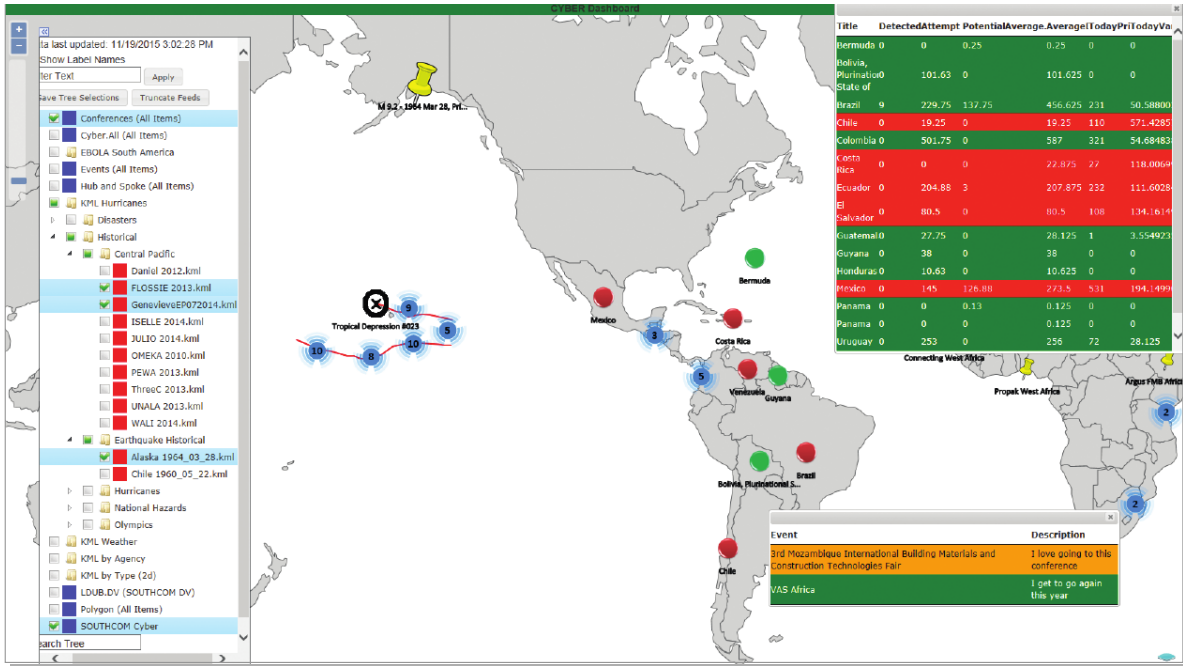


- usability scores with five analysts, four managers [Sauro 2011]
  - *"I could write a splunk query to do this, but **this is easier**"*



Design Study Summary

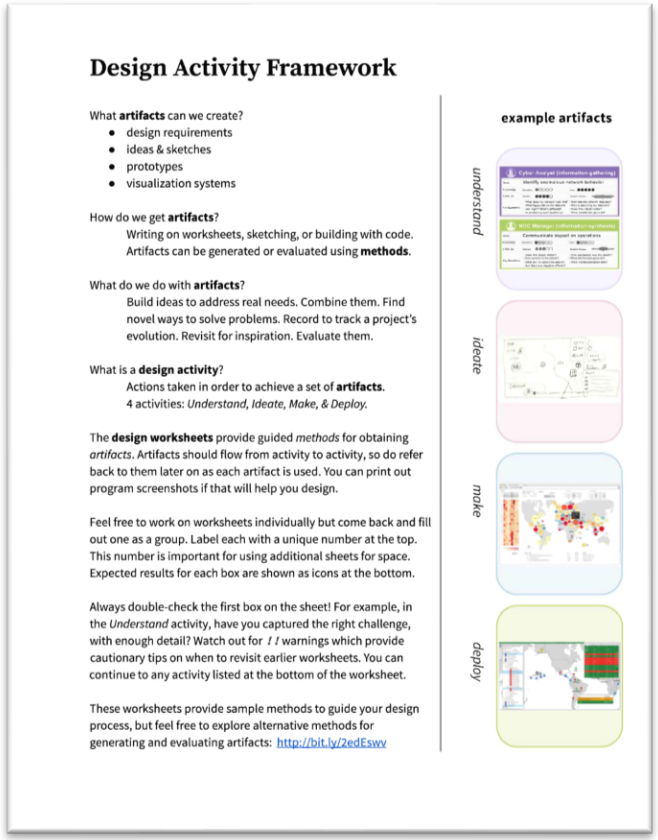
- successful design study
  - evaluation with users
  - tool deployments
- guided by the framework
- captured a rich description of the design process



Evaluating with Worksheets

worksheets

- external validation of the framework
- increase actionability with concrete steps
- worked with students on class projects
- can novices follow the framework?



Design Activity Framework

What **artifacts** can we create?
- design requirements
- ideas & sketches
- prototypes
- visualization systems

How do we get **artifacts**?
Writing on worksheets, sketching, or building with code. Artifacts can be generated or evaluated using **methods**.

What do we do with **artifacts**?
Build ideas to address real needs. Combine them. Find novel ways to solve problems. Record to track a project's evolution. Revisit for inspiration. Evaluate them.

What is a **design activity**?
Actions taken in order to achieve a set of **artifacts**.
4 activities: *Understand, Ideate, Make, & Deploy.*

The **design worksheets** provide guided *methods* for obtaining *artifacts*. Artifacts should flow from activity to activity, so do refer back to them later on as each artifact is used. You can print out program screenshots if that will help you design.

Feel free to work on worksheets individually but come back and fill out one as a group. Label each with a unique number at the top. This number is important for using additional sheets for space. Expected results for each box are shown as icons at the bottom.

Always double-check the first box on the sheet! For example, in the *Understand* activity, have you captured the right challenge, with enough detail? Watch out for *!!* warnings which provide cautionary tips on when to revisit earlier worksheets. You can continue to any activity listed at the bottom of the worksheet.

These worksheets provide sample methods to guide your design process, but feel free to explore alternative methods for generating and evaluating artifacts: http://bit.ly/2edEswv

example artifacts

understand

ideate

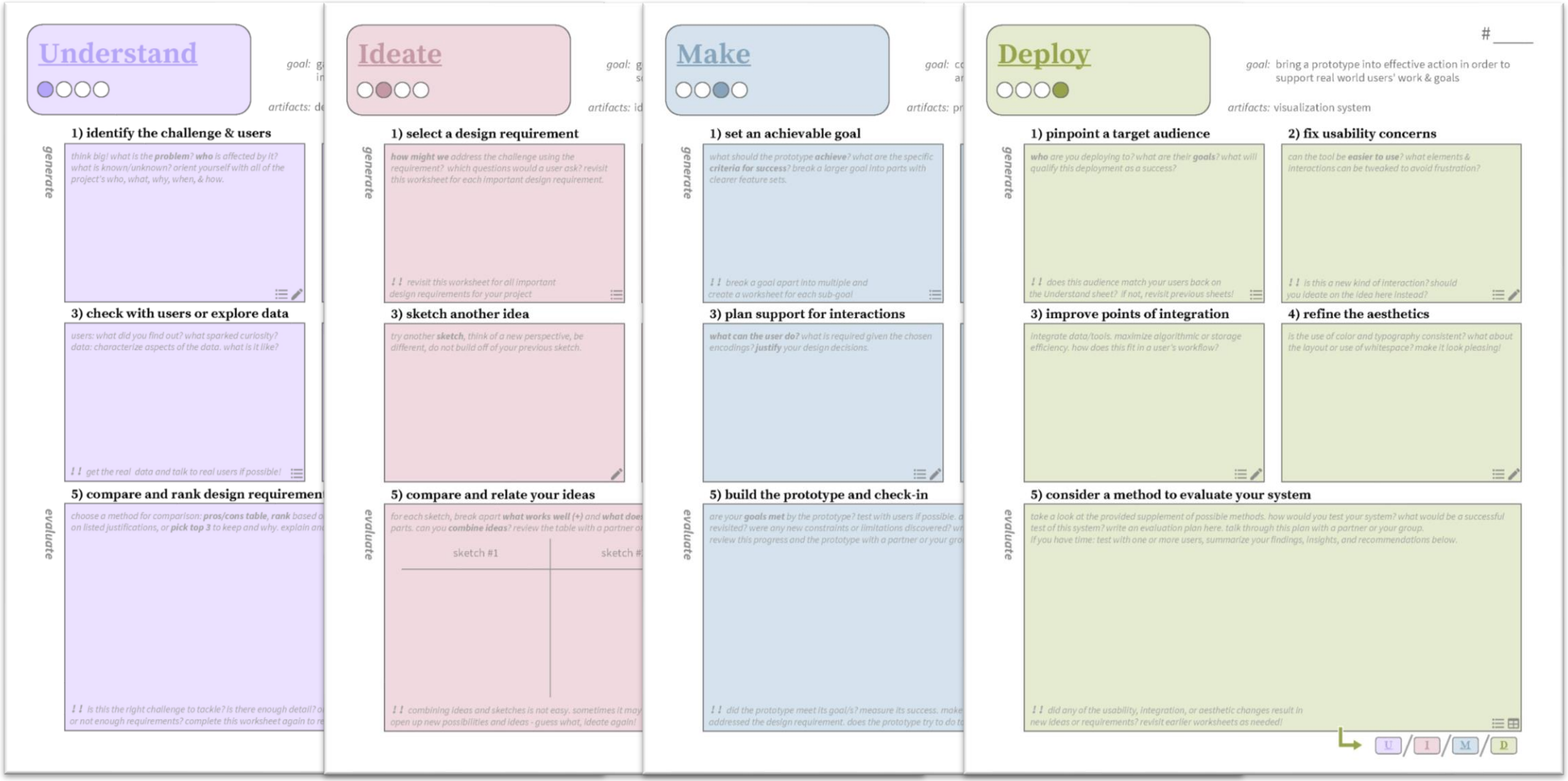
make

deploy

Worksheets for Guiding Novices Through the Visualization Design Process
S. McKenna, A. Lex, and M. Meyer, (to be submitted to Pedagogy of Data Vis. Workshop), 2017

Design Activity Worksheets

worksheets

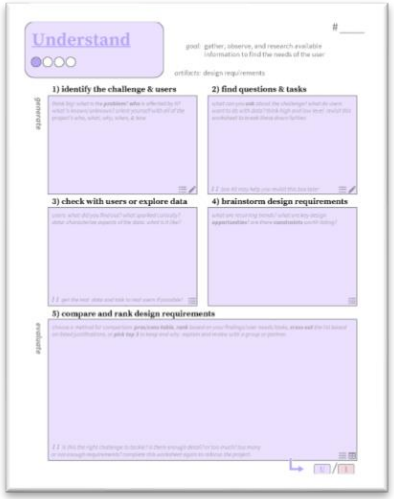


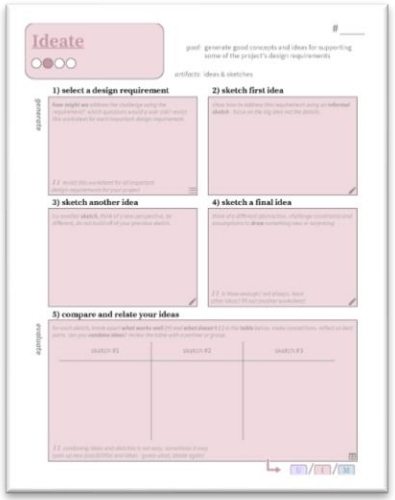
Worksheet Evaluation

worksheets

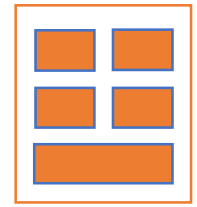
- lecture on visualization design

- mentored group projects with 13 students
  - weekly progress meetings
  - answered questions





Evaluation Results



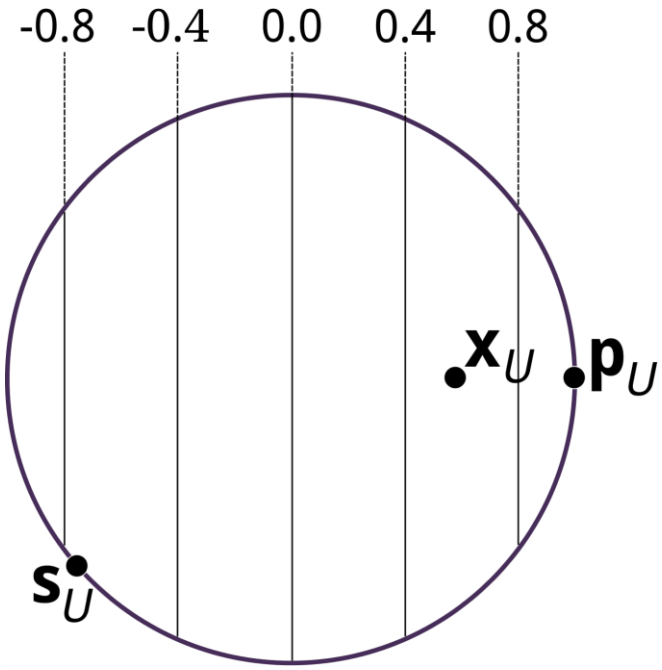
- design worksheets helped students learn
- most helpful: *understand* and *ideate*
  - both “helped to get the project off the ground”
  - “critique of one’s own design was most helpful”
- focused student projects & provided a “snapshot in time”
- steps: “it’s like a checklist to make sure everything is covered”

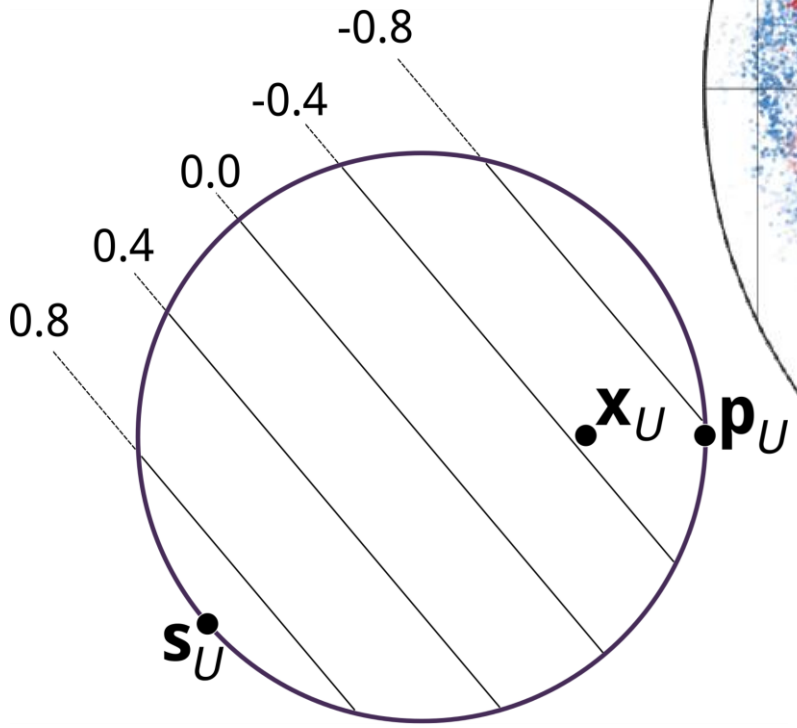
Application to Other Research

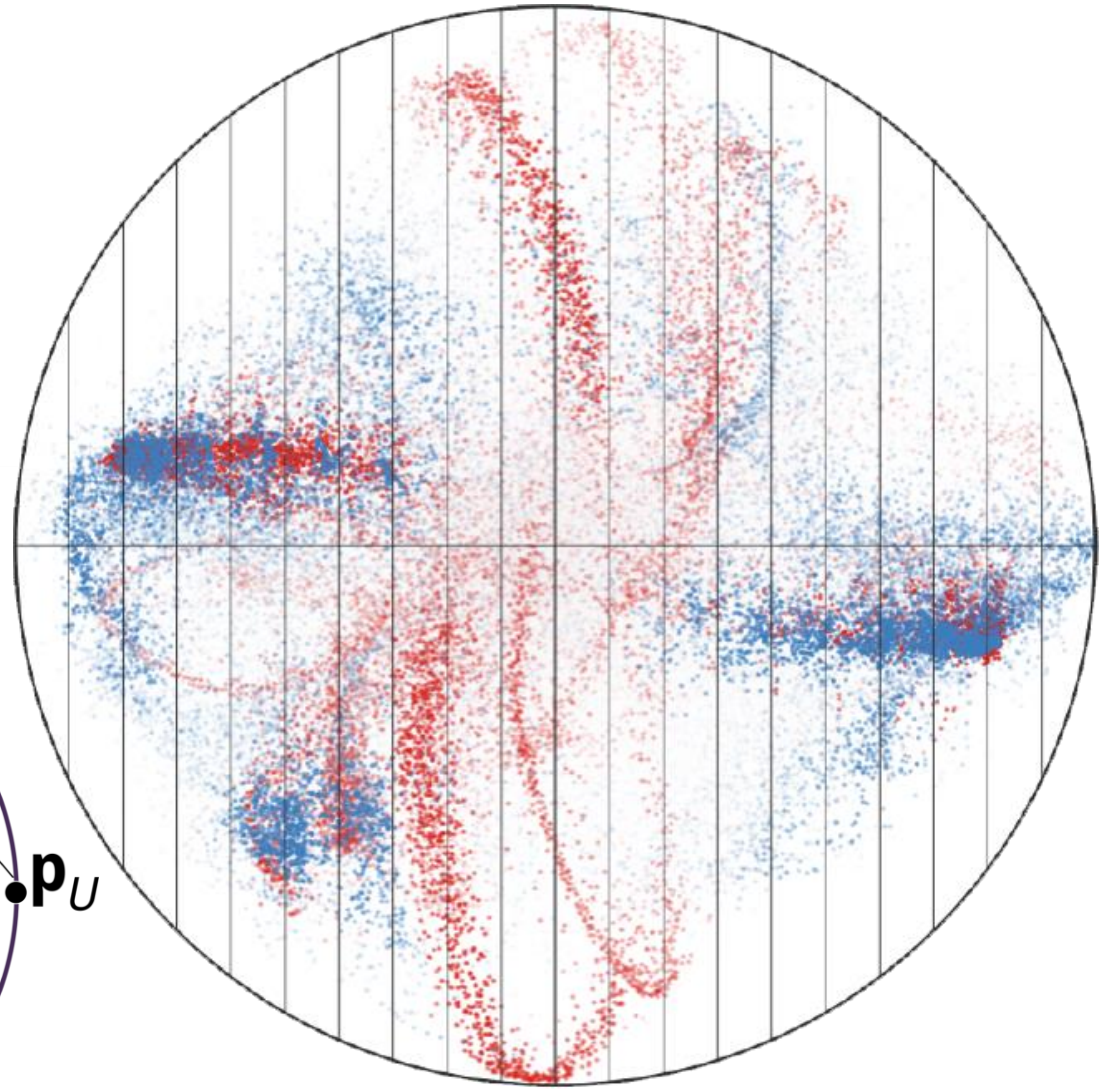
- beyond problem-driven work, research in:
  - technique development
  - evaluation methods
- what role does design play?
- does the framework lead to ruminations?

s-CorrPlot Technique

- encoding correlation in a scatterplot

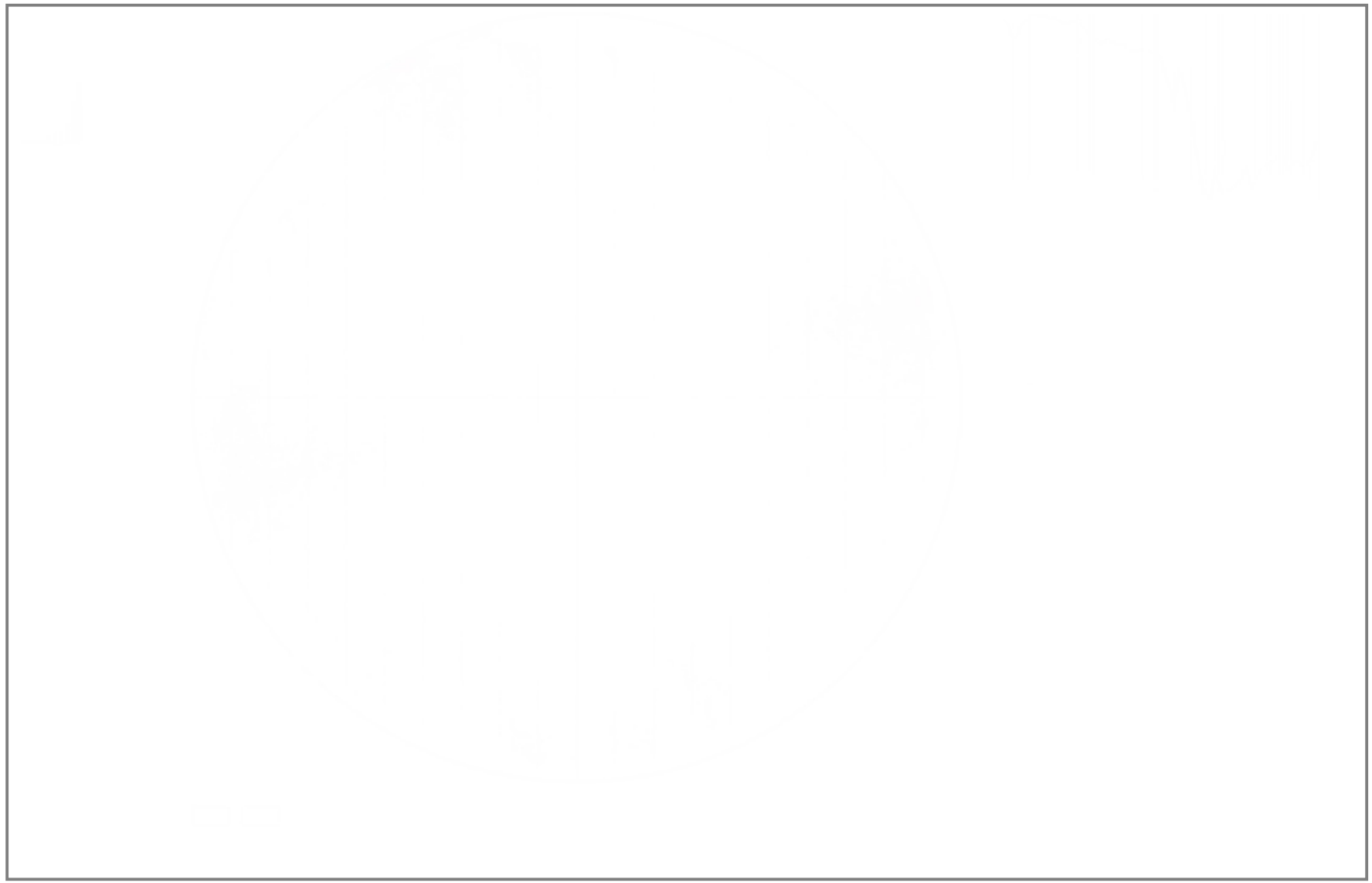






s-CorrPlot: An Interactive Scatterplot for Exploring Correlation
S. McKenna, M. Meyer, C. Gregg, and S. Gerber, JCGS, 2016

s-CorrPlot Interactions

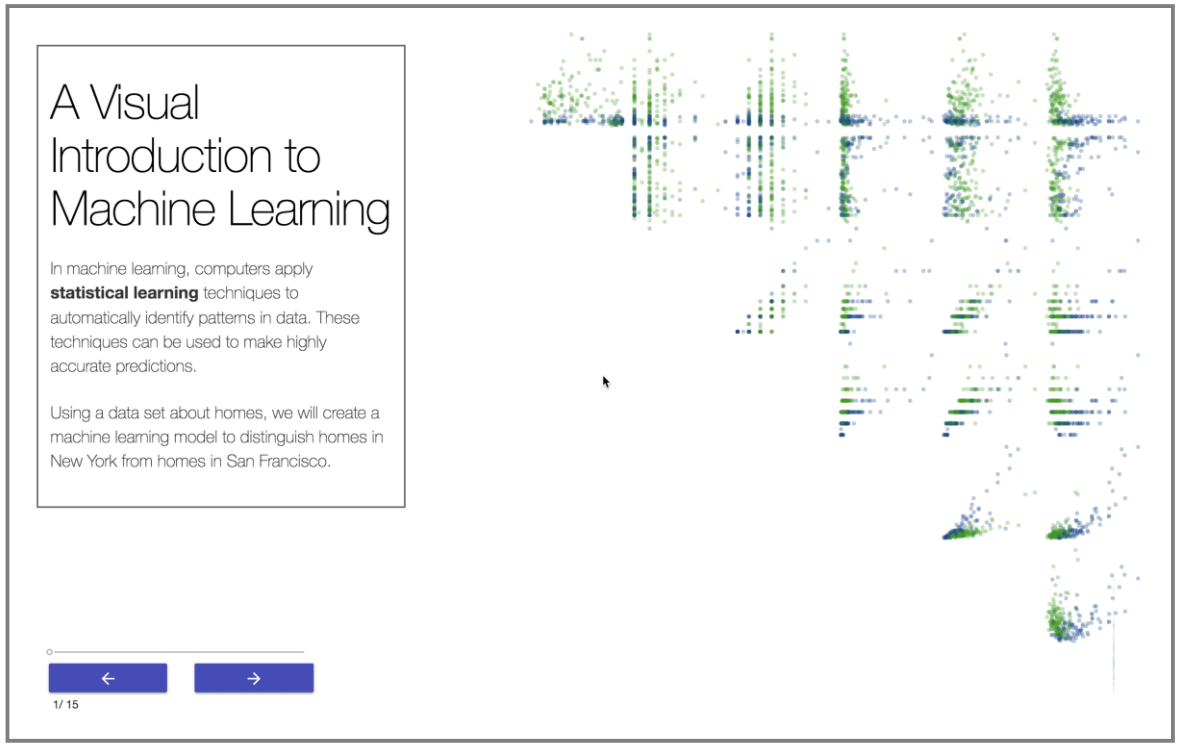


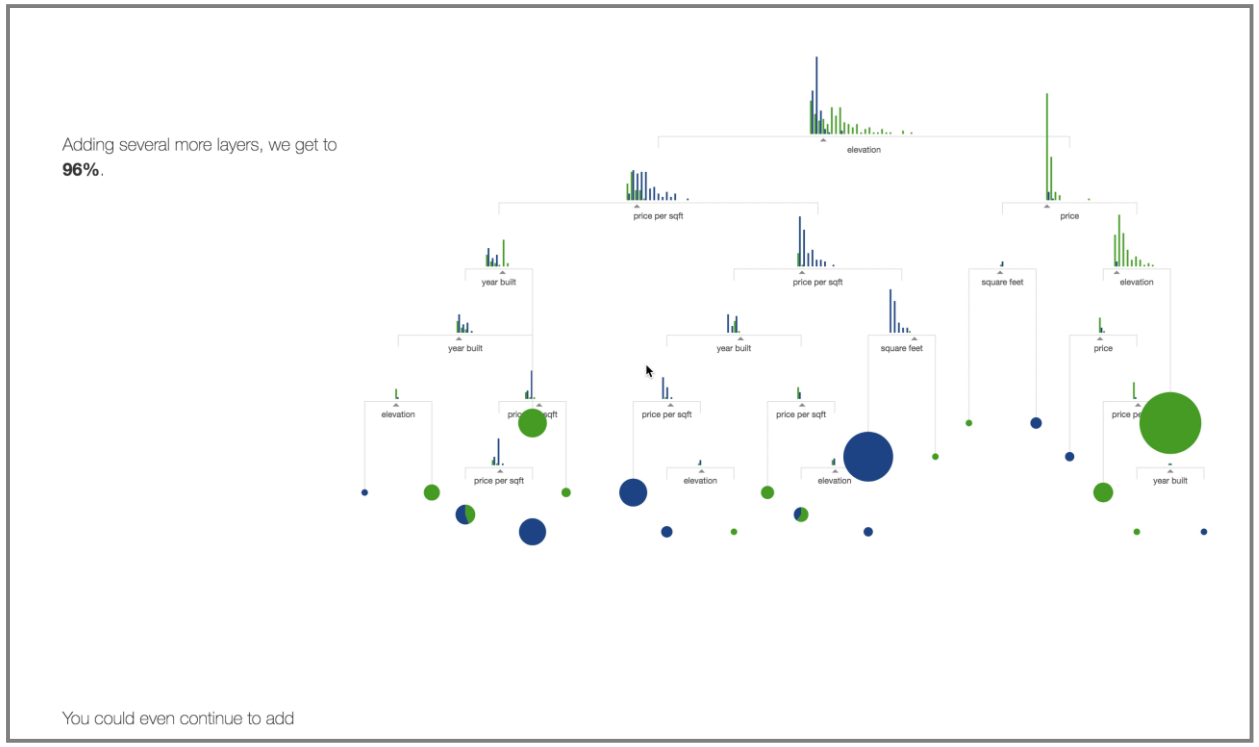
Designing for Techniques

- “incomplete problem”: tool needed more data
- identified new pitfalls for design studies
  - team miscommunication
  - prioritized novel idea
  - deployed too early
- similar process, except algorithmic decisions

Visual Data-Driven Stories

stepper **scroller**

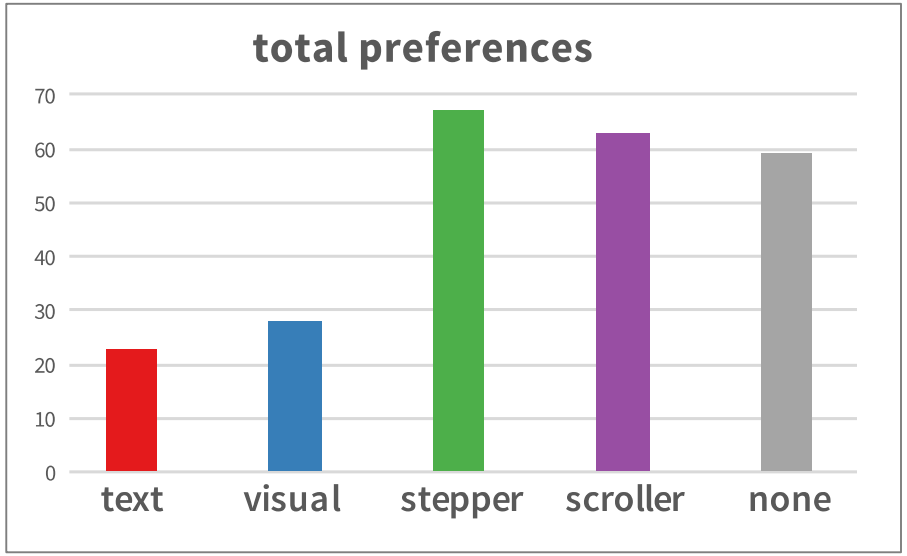


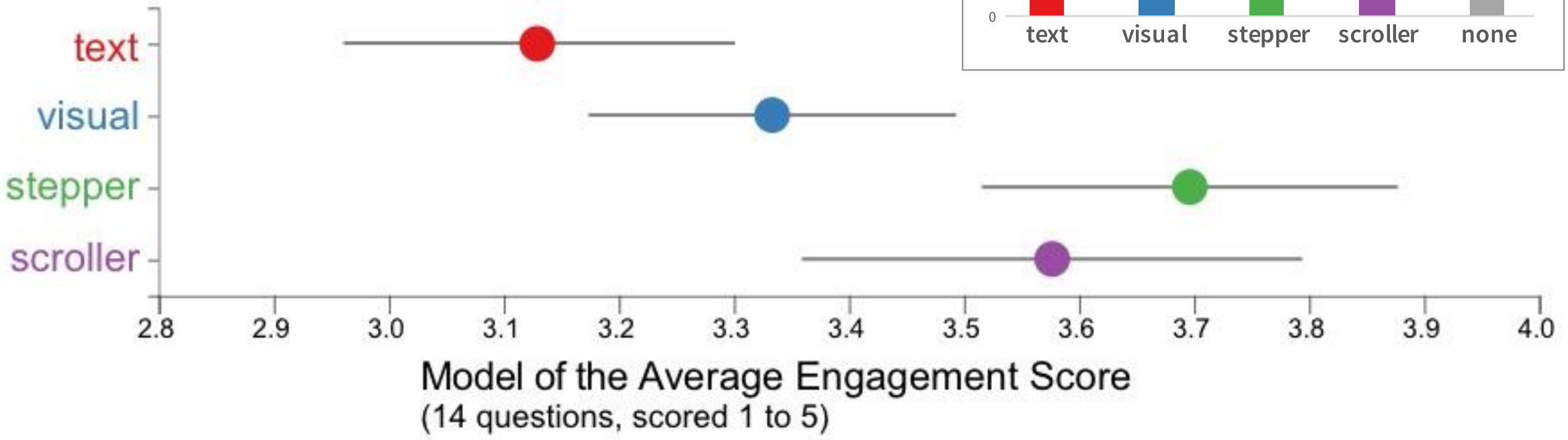


Visual Narrative Flow: Exploring Factors Shaping Data Visualization Story Reading Experiences
S. McKenna, N. Henry Riche, B. Lee, J. Boyd, and M. Meyer, CGF, 2017

Results of Crowdsourced Evaluation

- 240 participants, Amazon MTurk
  - compared two conditions each
  - survey on engagement





Designing for Evaluation

- hypotheses & story “prototypes” as artifacts
- pilots and exploratory studies employed
- vital to record details of experimental design
- guidelines established lack generalizability

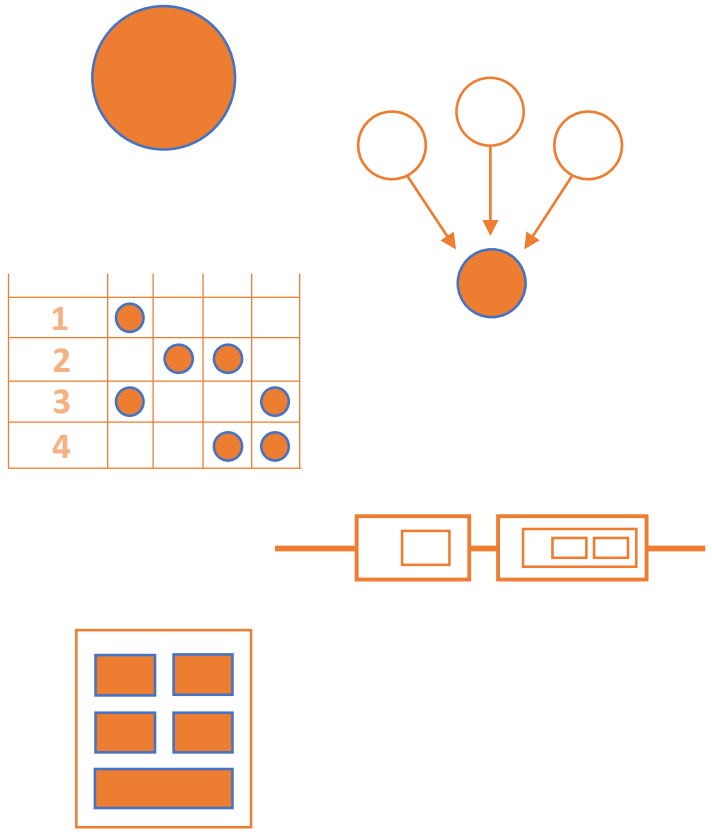
Discussion

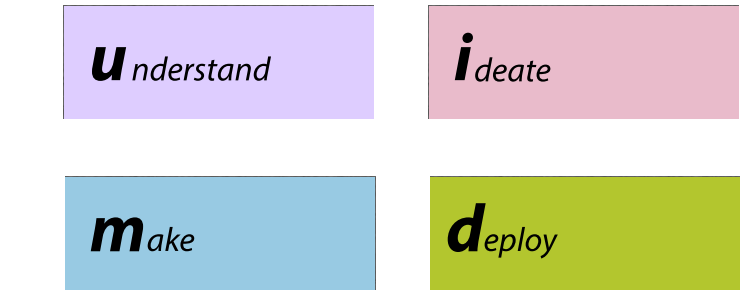
- design models may change and grow with new:
  - activities
  - methods
  - artifacts
  - decisions
- continue to evaluate the worksheets in the classroom and beyond
- apply model to other types of research
- consider the role of software engineering, e.g., agile

Conclusion

- design activity framework provides:
  - visualization artifacts
  - mapping to decisions
  - table of methods
  - timelines
  - worksheets

- validated with a design study
- evaluated worksheets with students
- reflected on other types of research





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- committee:
  - Miriah Meyer, Alex Lex, Tammy Denning, Jim Agutter, Nathalie Henry Riche
- family, friends, & mentors
- SCI & SoC staff
- colleagues & co-authors

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Related Publications

[1] Design activity framework for visualization design. S. McKenna, D. Mazur, J. Agutter, and M. Meyer, IEEE Trans. Vis. Comput. Graphics, vol. 20, no. 12, pp. 2191–2200, 2014.

[2] Unlocking user-centered design methods for building cyber security visualizations. S. McKenna, D. Staheli, and M. Meyer, Proc. Int. Symp. on Vis. for Cyber Security (VizSec), 2015, pp. 1–8.

[3] s-CorrPlot: An interactive scatterplot for exploring correlation. S. McKenna, M. Meyer, C. Gregg, and S. Gerber, J. Computational Graphical Statist., vol. 25, no. 2, pp. 445–463, 2016.

[4] BubbleNet: A cyber security dashboard for visualizing patterns S. McKenna, D. Staheli, C. Fulcher, and M. Meyer, Comput. Graph. Forum (EuroVis), vol. 35, no.3, pp. 281–290, 2016.

[5] Visual narrative flow: Exploring factors shaping data visualization story reading experiences. S. McKenna, N. Henry Riche, B. Lee, J. Boyd, and M. Meyer, Comput. Graph. Forum (EuroVis), vol. (to appear), 2017.

[6] Worksheets for guiding novices through the visualization design process. S. McKenna, A. Lex, and M. Meyer, (to be submitted to Pedagogy Data Vis., IEEE VIS Workshop), 2017.

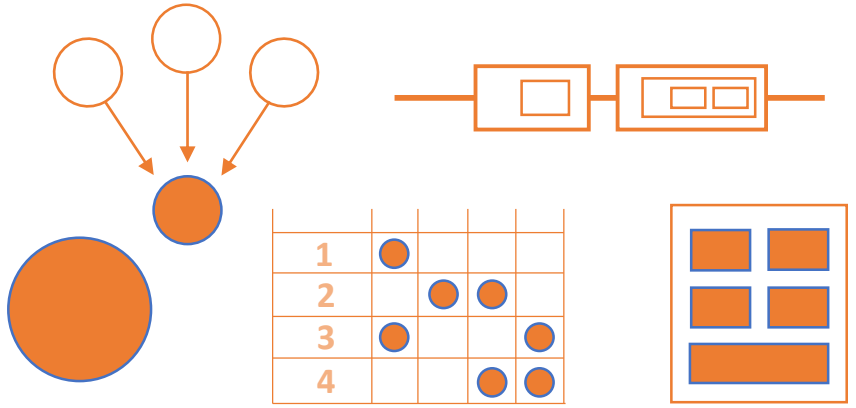
Thank You!

u nderstand

i deate

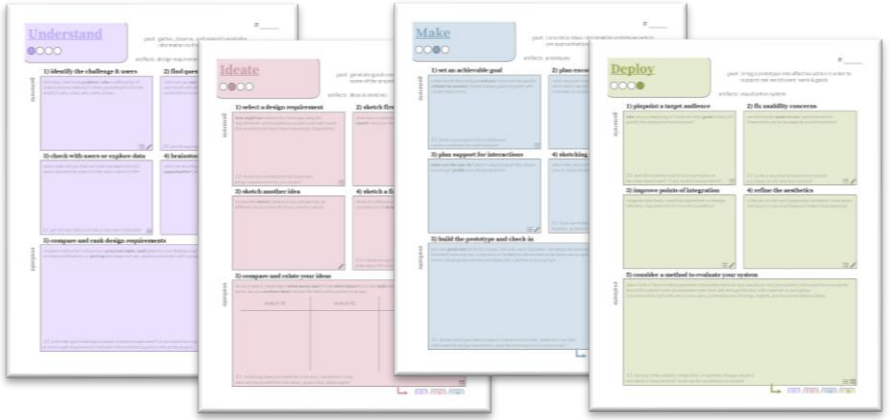
m ake

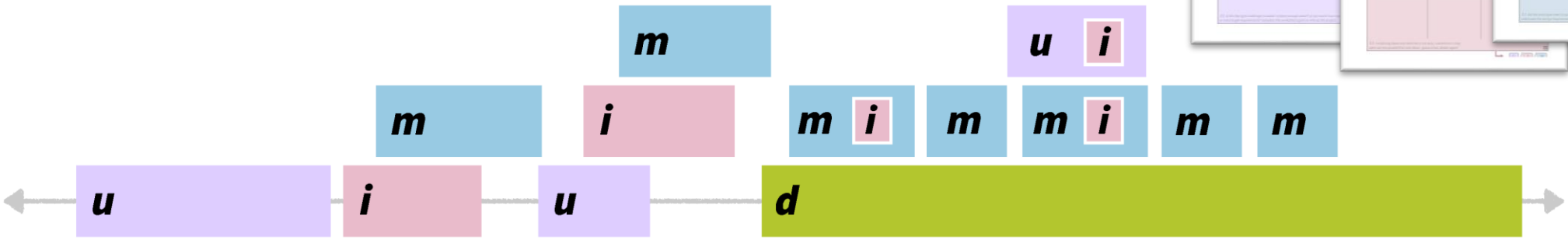
d eploy



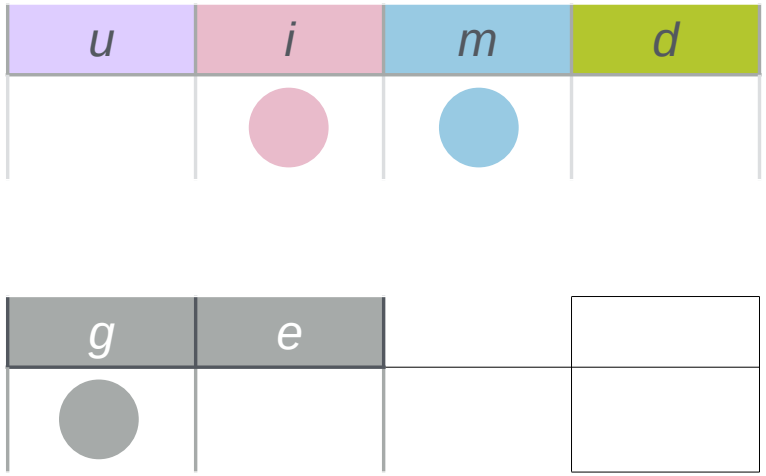
http://mckennapsean.com/projects/design-activity-framework/

http://design-worksheets.github.io/





Design Method: Paper Prototyping

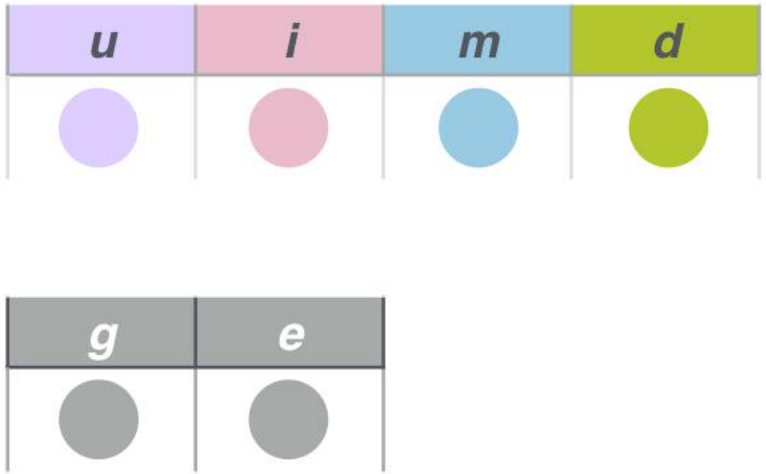


"create a **paper-based simulation of an interface** to test interaction with a user"

Maguire, "Methods to support human-centred design" 2001

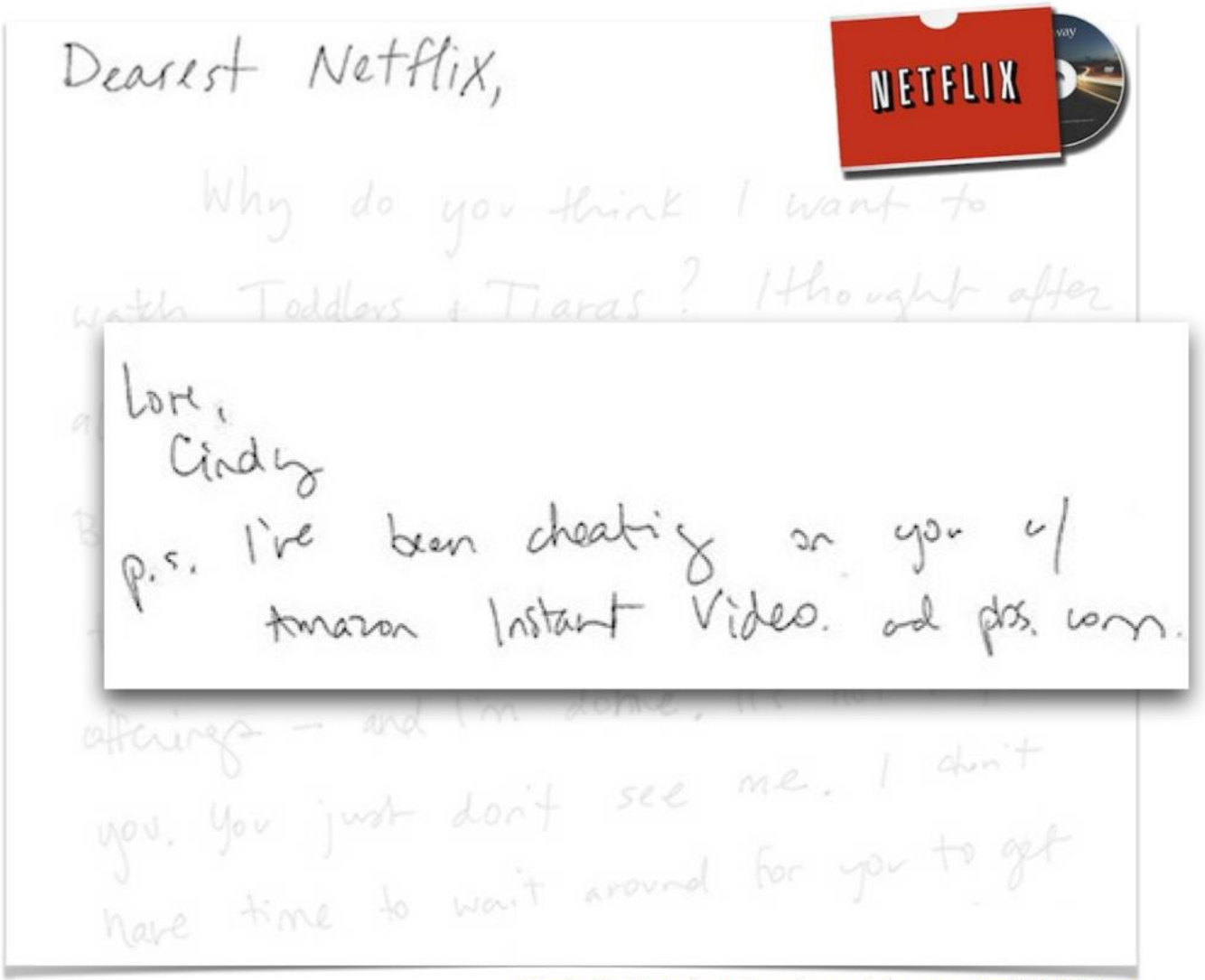
Lloyd & J. Dykes, "Human-centered approaches in geovisualization design" 2011

Design Method: Love Letter



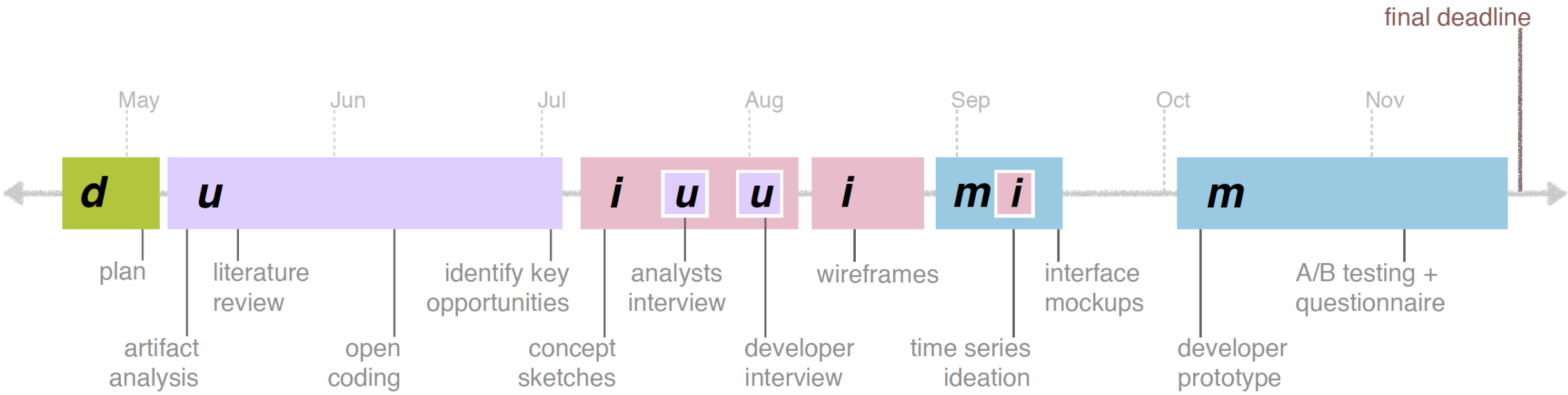
"**personal letter written to a product**… [to reveal] profound insights about what people value and expect"

Martin & Hanington, Universal Methods of Design: 100 Ways to Research, 2012

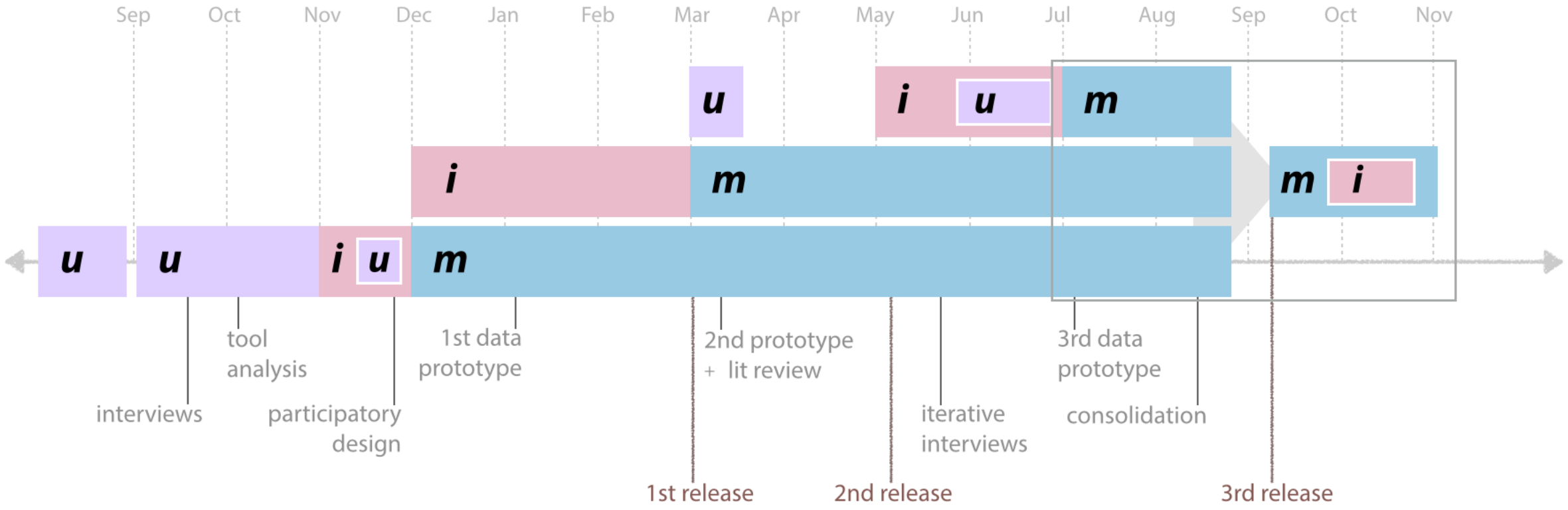


http://editorial.designtaxi.com/news-designerbreakup280114/1.jpg

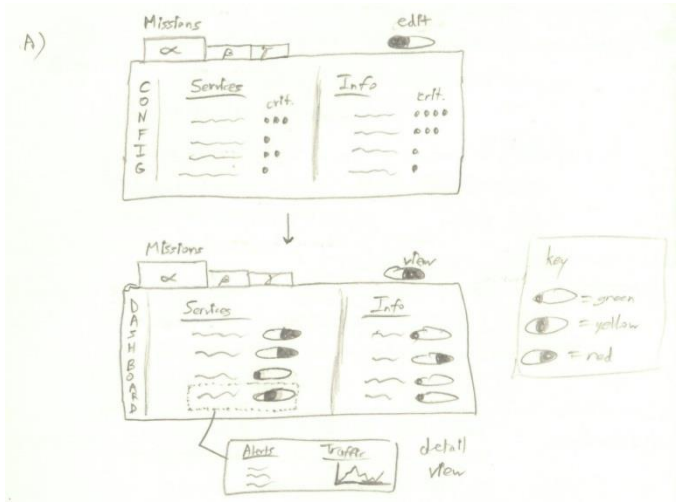
Design Timeline

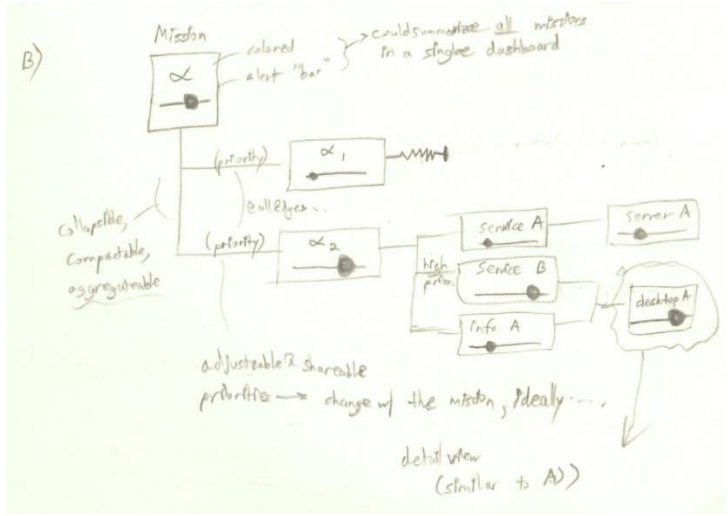


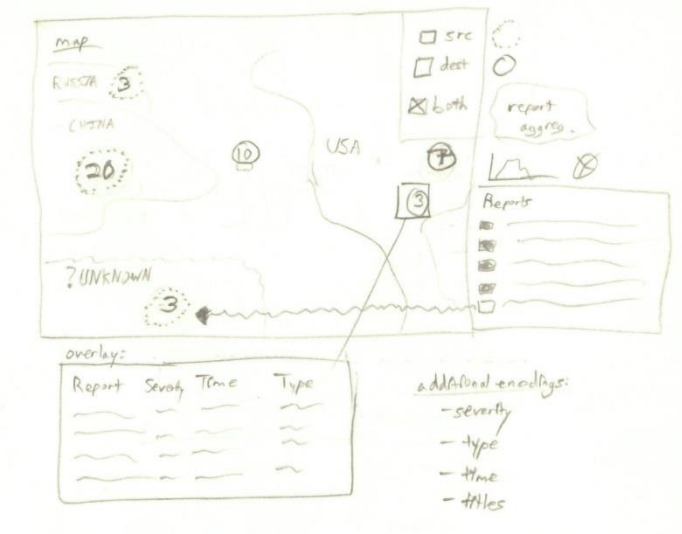
Design Timeline #2

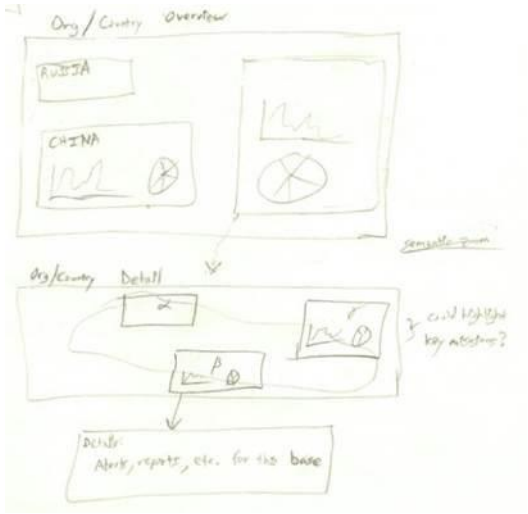


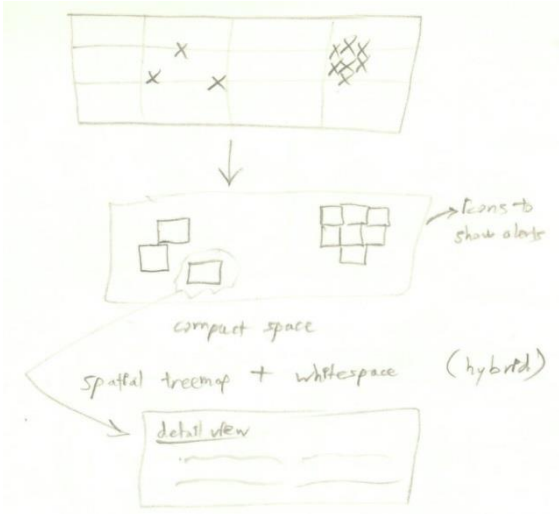
BubbleNet Sketches

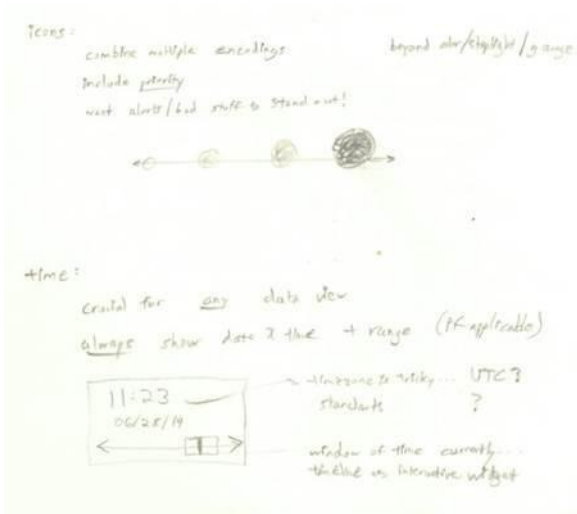








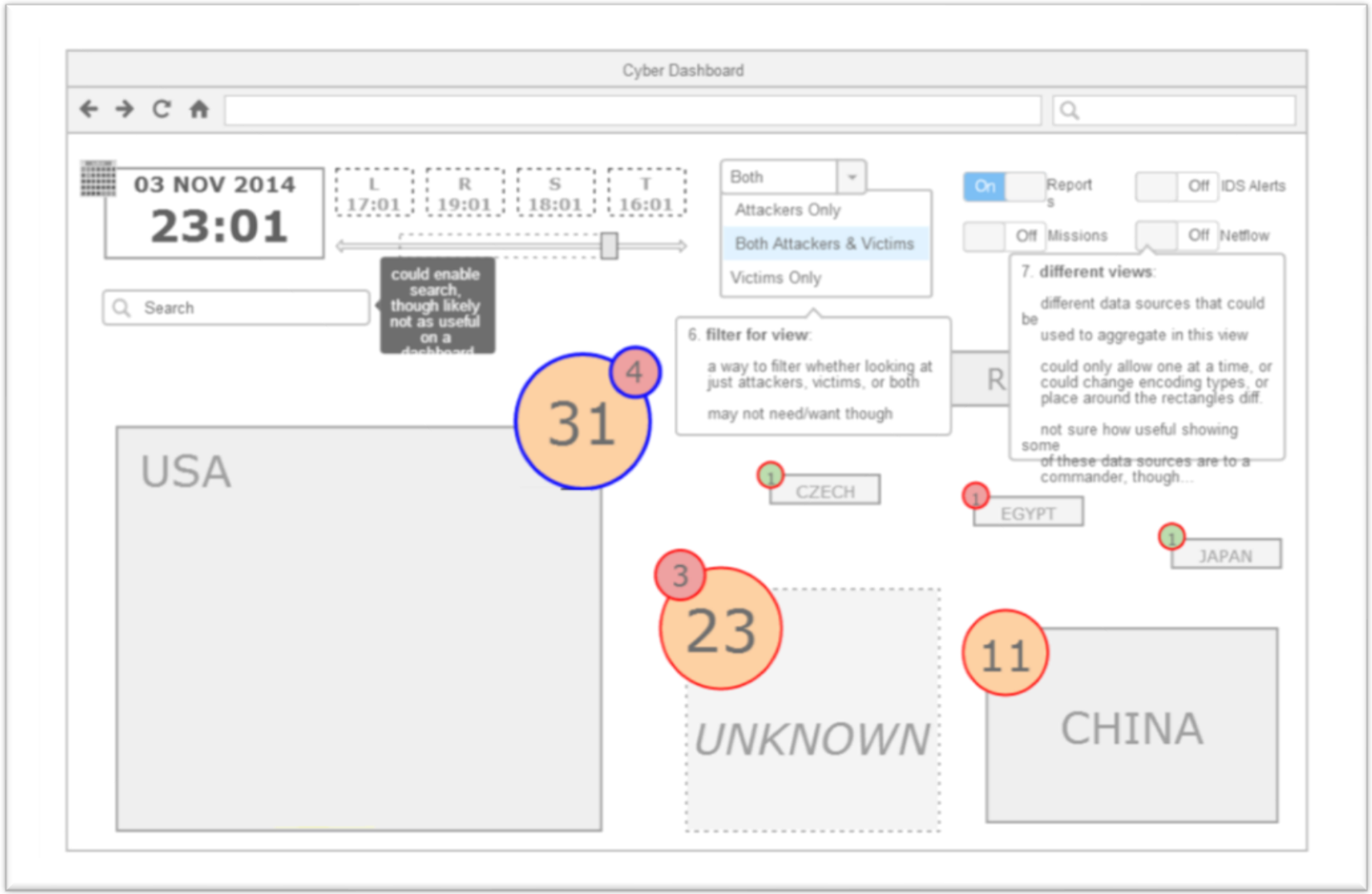




BubbleNet Weighted Matrix

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1	idea	automate	vis-pract	comm.	intuitive	novelty	user	mission	^ data	aggreg.	respons.	updates	collab.	details	proven.	d-classes		score					
2	priority	3	3	5	5	0	3	5	1	1	5	1	0	3	0	3							
3	mission-A	0	1	2	1	1	0	2	0	0	1	2	0	1	1	1		41	26	--> mission: include or combine A & B			
4	mission-B	0	1	2	1	1	1	2	0	1	0	2	0	1	1	1		40	26				
5	mission-C	1	1	1	1	2	0	2	0	1	1	1	1	1	0	1		39	25				
6	report-A (spec)	0	2	0	1	0	0	1	2	1	2	0	0	2	0	1		38	25				
7	report-B	2	1	1	2	1	0	1	1	2	1	2	1	1	1	1		45	30	--> report-B			
8	report-C	2	1	1	2	0	0	0	0	1	1	2	0	1	0	1		38	25				
9	report-D	1	1	0	0	2	1	1	1	0	0	0	0	1	1	1		21	14				
10	map-A	2	1	1	2	0	0	1	0	1	1	2	1	1	0	1		43	28	--> map: combine together A & B			
11	map-B	1	1	1	2	1	0	1	1	2	1	2	1	2	0	1		45	30				
12	mg-A	2	0	1	1	0	0	2	0	1	1	2	1	1	0	1		40	26	--> mg-A			
13	mg-B	1	1	1	1	1	0	2	1	0	0	0	1	1	0	1		33	21				
14	mg-C	2	1	1	1	2	0	2	0	1	0	1	1	1	0	1		37	24				
15	st-A	2	1	1	0	1	0	1	1	1	1	0	0	1	0	1		32	21				
16	st-B	2	1	2	1	2	0	1	1	1	1	0	1	1	0	1		42	27	--> st-B			
17	rm-A	1	1	1	1	2	0	2	1	1	1	0	1	1	0	1		39	25				
18	f-i	1	2	2	2	1	0	1	0	1	2	2	0	0	0	0		47	30	--> prioritize f-i & f-iii			
19	f-ii	0	1	1	1	2	0	2	1	1	1	0	1	0	1	1		33	21				
20	f-iii	1	2	2	2	0	0	1	2	2	1	1	0	0	1	1		47	31				
21	f-iv	0	1	0	1	1	0	2	1	1	1	1	1	0	0	1		29	19				
22																							

BubbleNet Mockup



BubbleNet Dataset

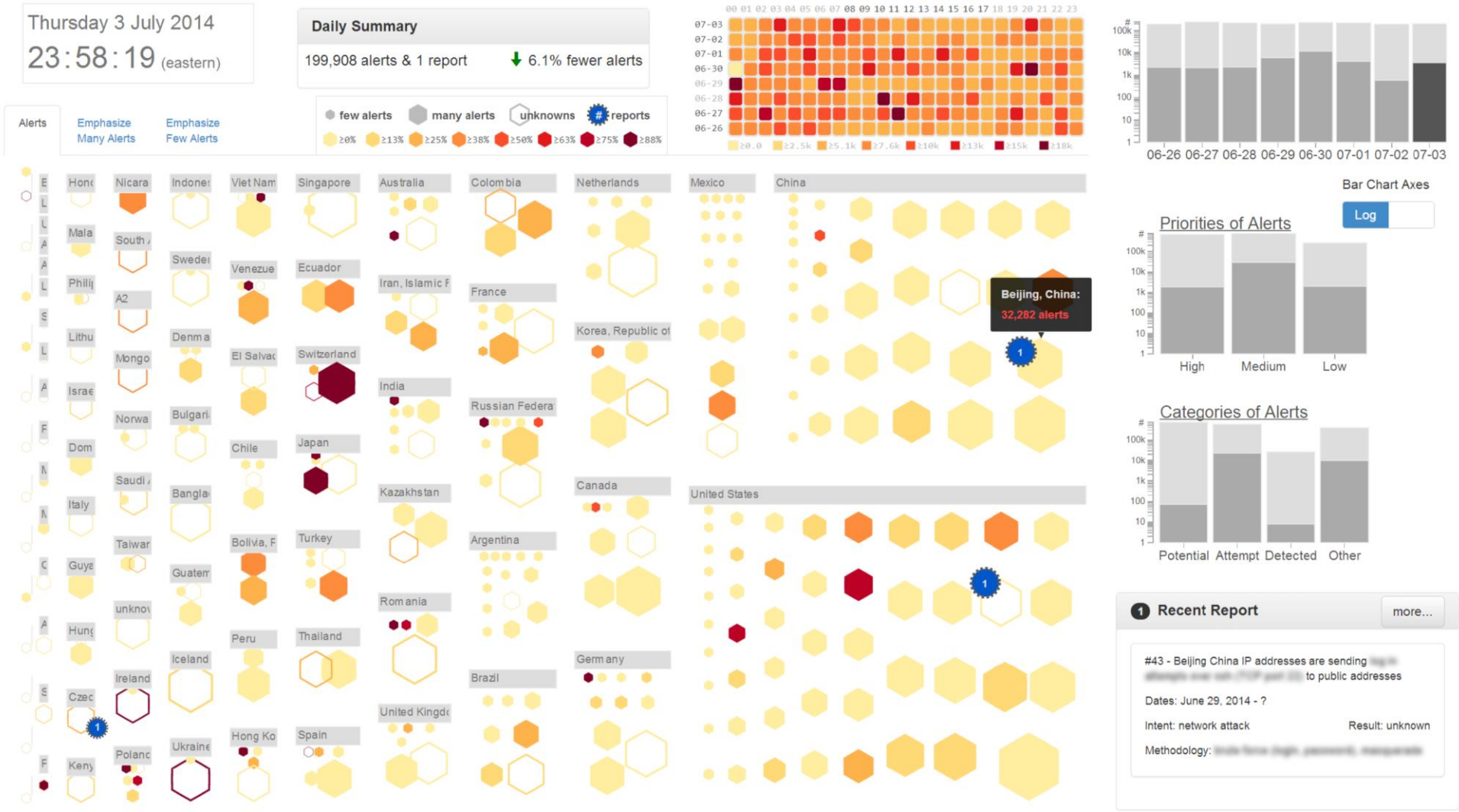
DATA	*SOURCE*
Geolocation	MaxMind database (IPs)
Reports	IT security analyst
Alerts	external network – IDS system

external traffic from **around the globe**

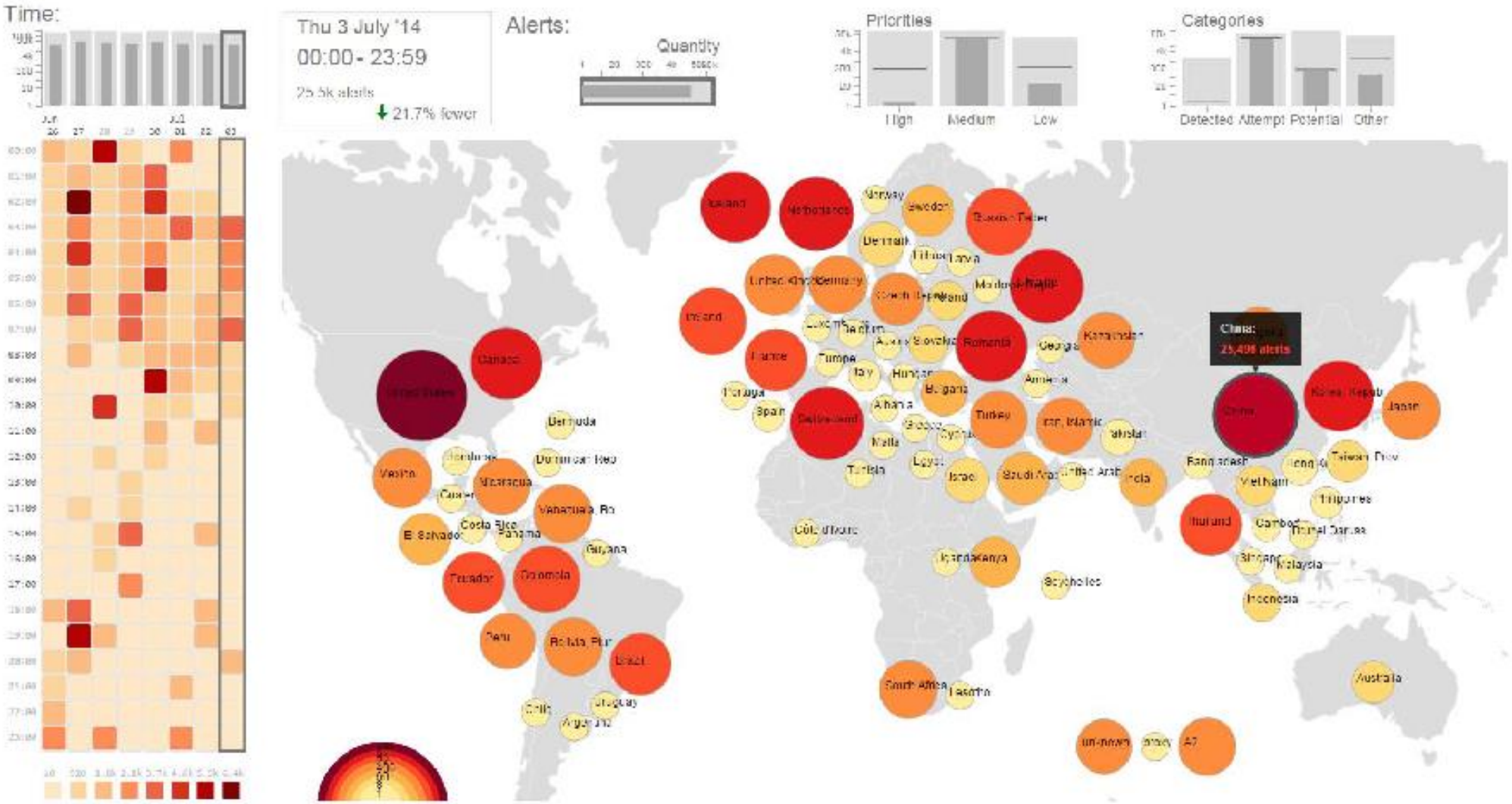
detailed information on **two recent incidents**

millions of alerts

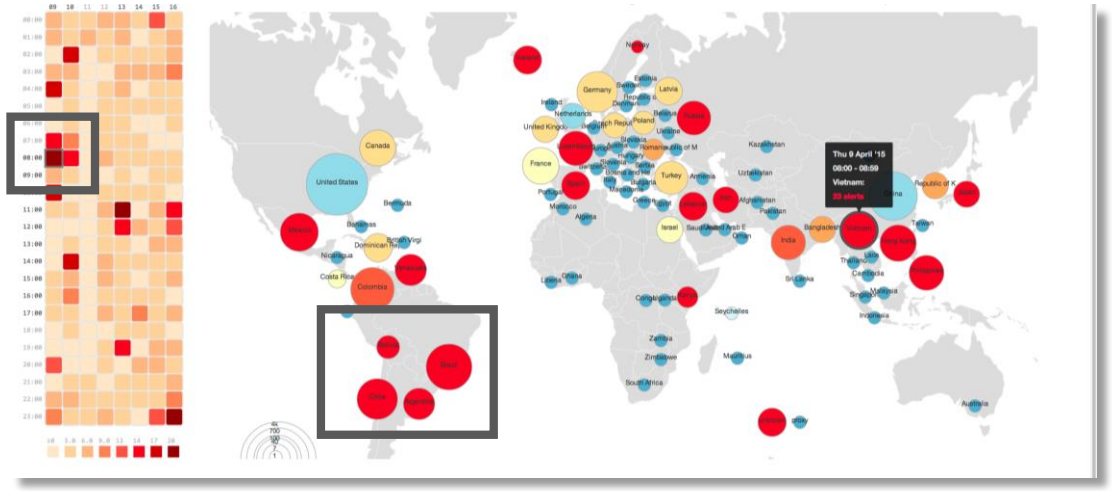
BubbleNet Prototype

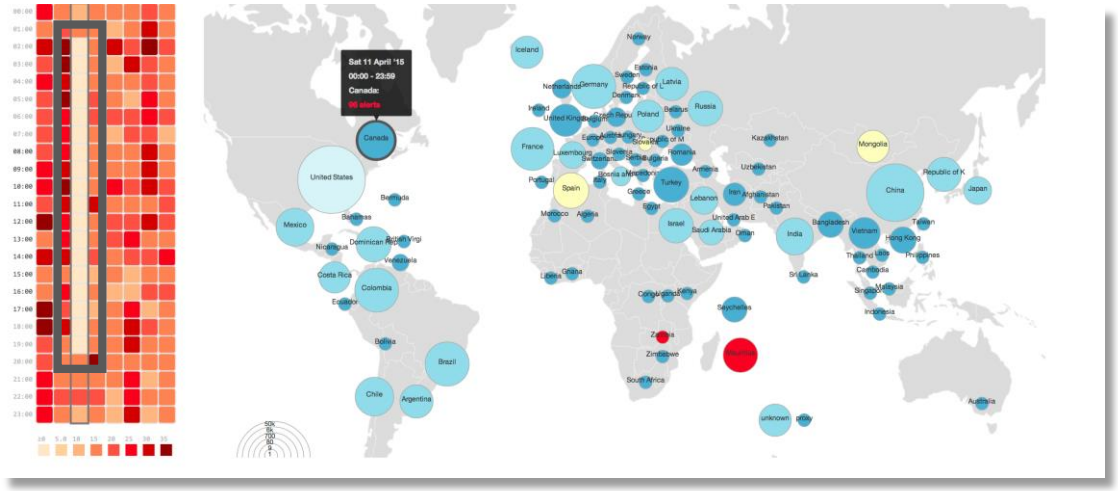


BubbleNet Prototype #2



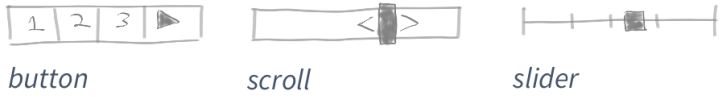
BubbleNet Patterns





Visual Narrative Flow: Design Space

navigation input

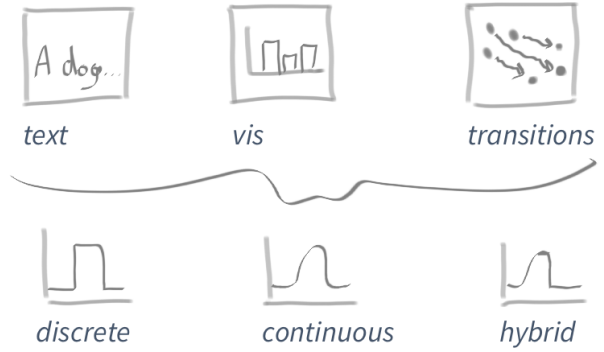


navigation progress

story layout

story progression

level of control



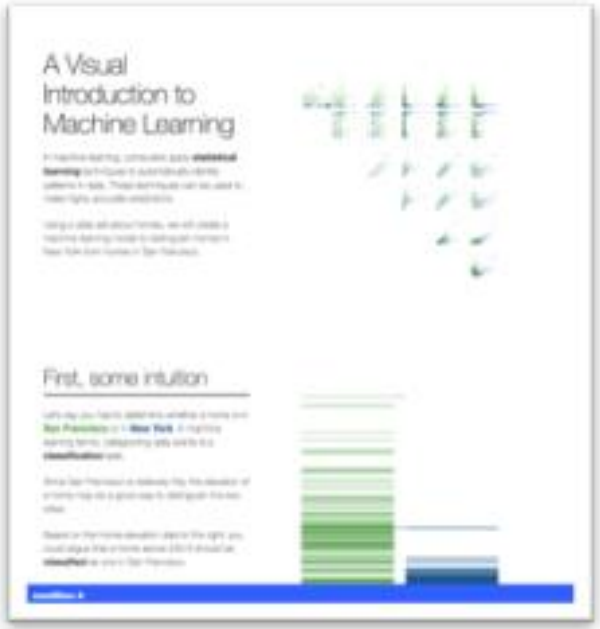
role of visualization

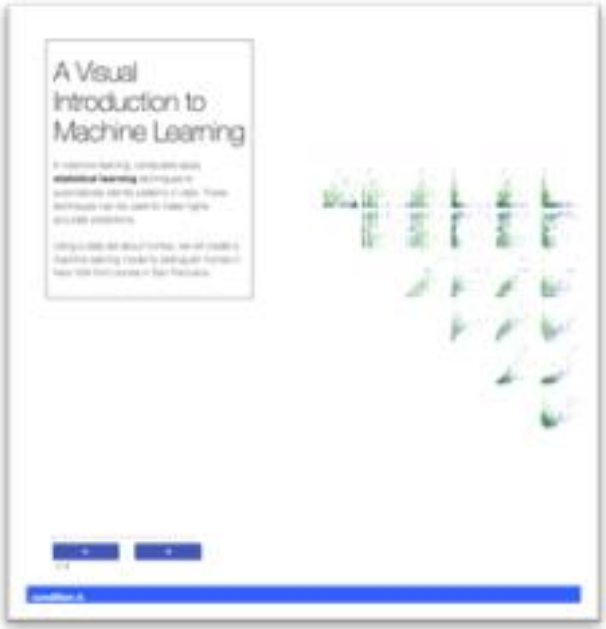
navigation feedback

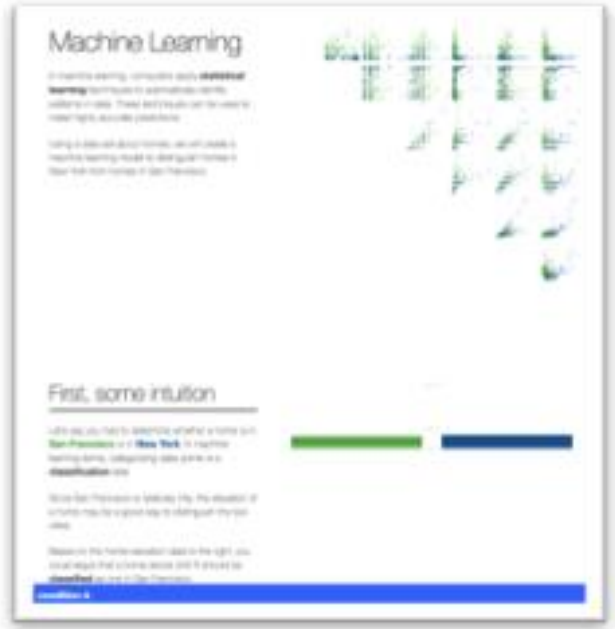
Visual Narrative Flow: Corpus

#	title	navigation input			level of control			navigation progress				story layout			role of visualization			story progression			navigation feedback			
		scroll	button	slider	text	vis	anim	text	dots	vis	other	doc	slide	cols	equal	figure	annot.	linear	skip	other	text	vis	widget	order
1	A Visual Introduction to Machine Learning	▯			C	C	C			▯		▯		2	▯			▯			▯			sync
2	Scientific Proof that Americans are Completely	▯			C	C	D					▯		2	▯			▯			▯			sync
3	Fewer Helmets, More Deaths	▯	▯		C	C	D		▯			▯	▯	2	▯			▯			▯		▯	vis
4	A 3-D View of a Chart That Predicts The Econ		▯		D	D	D		▯				▯	1			▯		▯				▯	sync
5	A Visual Analysis of Battle at the Berrics	▯			C	C	D					▯		1		▯		▯			▯			sync
6	Budget Forecasts, Compared With Reality		▯	▯	D	D	D	▯		▯			▯	1			▯		▯				▯	sync
7	Human Development Trends, 2005		▯		D	D	D	▯					▯	1			▯		▯				▯	hyb
8	Diary of a Food Tracker	▯	▯		H	H	H			▯		▯	▯	1					▯		▯	▯		vis
9	How Americans Die		▯		D	D	D		▯				▯	1			▯		▯				▯	text
10	Visualizing MBTA Data: An Interactive Explora	▯			C	C	C					▯		1		▯		▯			▯			vis
11	The World According to China	▯			C	C	D					▯		1	▯			▯			▯			swap
12	How the U.S. and OPEC Drive Oil Prices	▯			C	H	D		▯			▯	▯	1	▯				▯		▯		▯	sync
13	Scaling Mt. Everest: A Scroll Up the Icy Path	▯		▯	C	C	C			▯		▯		3	▯				▯		▯		▯	sync
14	Snow Fall: The Descent Begins	▯			C	C	D			▯		▯		2	▯			▯			▯			sync
15	The Story of Jess & Russ	▯			C	C	C					▯		1	▯			▯			▯			sync
16	2014 Was the Hottest Year on Record	▯			C	C	D			▯		▯		1			▯	▯				▯		sync
17	The World's Ball	▯	▯		C	C	D					▯		1		▯		▯			▯			swap
18	The Russia Left Behind	▯	▯		C	C	C			▯		▯		2		▯			▯		▯	▯		sync
19	The Water We Eat	▯			C	H	C			▯		▯	▯	1-2	▯	▯	▯	▯			▯	▯		sync
20	Ski Jumping	▯	▯		C	H	C		▯			▯	▯	1			▯		▯		▯		▯	swap
21	The Dawn Wall: El Capitan's Most Unwelcomi	▯			C	C	C			▯		▯		2	▯		▯	▯			▯	▯		sync
22	Russia's Endgame in Ukraine	▯			C	C	-					▯		1		▯	▯	▯			▯	▯		swap
23	At Top Colleges, an Admissions Gap for Mino		▯		D	D	D	▯					▯	1			▯		▯			▯		text
24	Greenland Is Melting Away	▯			C	C	C			▯		▯		2			▯	▯			▯	▯		sync
25	How Different Groups Spend Their Day		▯		D	D	D	▯					▯	1			▯			graph		▯		sync
26	Deconstructing the Past: A New Look at Histo	▯	▯		D	D	D				block		▯	1			▯		▯		▯		▯	sync
27	Dollar-a-Day Schools	▯	▯		D	D	D				image		▯	1			▯		▯		▯		▯	sync
28	ChopTainer	▯			H	C	-					▯	▯	1		▯	▯	▯			▯	▯		sync

Visual Narrative Flow: Conditions







Visual Narrative Flow: Preferences

order of conditions

text	visual	stepper	scroller
1		*2*	
2		*1*	
1			*2*
2			*1*
	1	*2*	
	2	*1*	
	1		*2*
	2		*1*
		1	*2*
		2	*1*
1	*2*		
2	*1*		

preferences by condition pairs