Designing Visualizations

http://unearthedcomics.com/comics/the-new-guy/

Designing Visualizations

- Intro to Design
- Real World Example
- Nested Model
- Design Activity Framework
- Design Methods
- Final Projects

Intro to Design

https://negliadesign.com/general/design-matters/

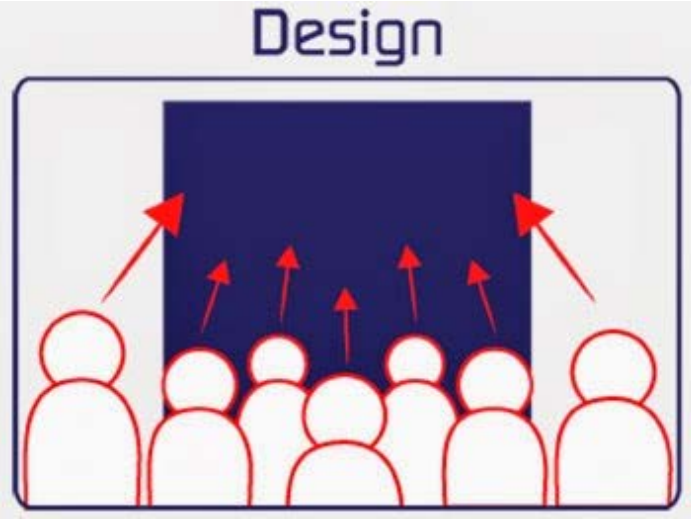
What is Design?

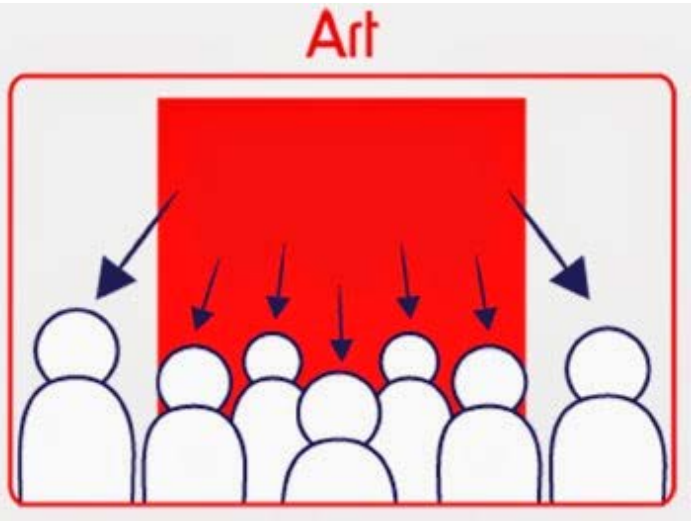
- creating something new to solve a problem
- can be used to make buildings, chairs, user interfaces, etc.
- design is used in many fields
- many possible users or tasks

https://www.youtube.com/watch?v=hUhisi2FBuw

What is Design Not?

- just making things pretty
- art – appreciation of beauty or emotions invoked
- something without a clear purpose
- building without justification or evidence





http://woodyart211.blogspot.com/2015/01/art-vs-design-comments.html

Form & Function

- commonly: “form follows function”

http://img.weburbanist.com/wp-content/uploads/2015/05/sculptural-furniture-main-960x481.jpg

- function can constrain possible forms
  - form depends on tasks that must be achieved

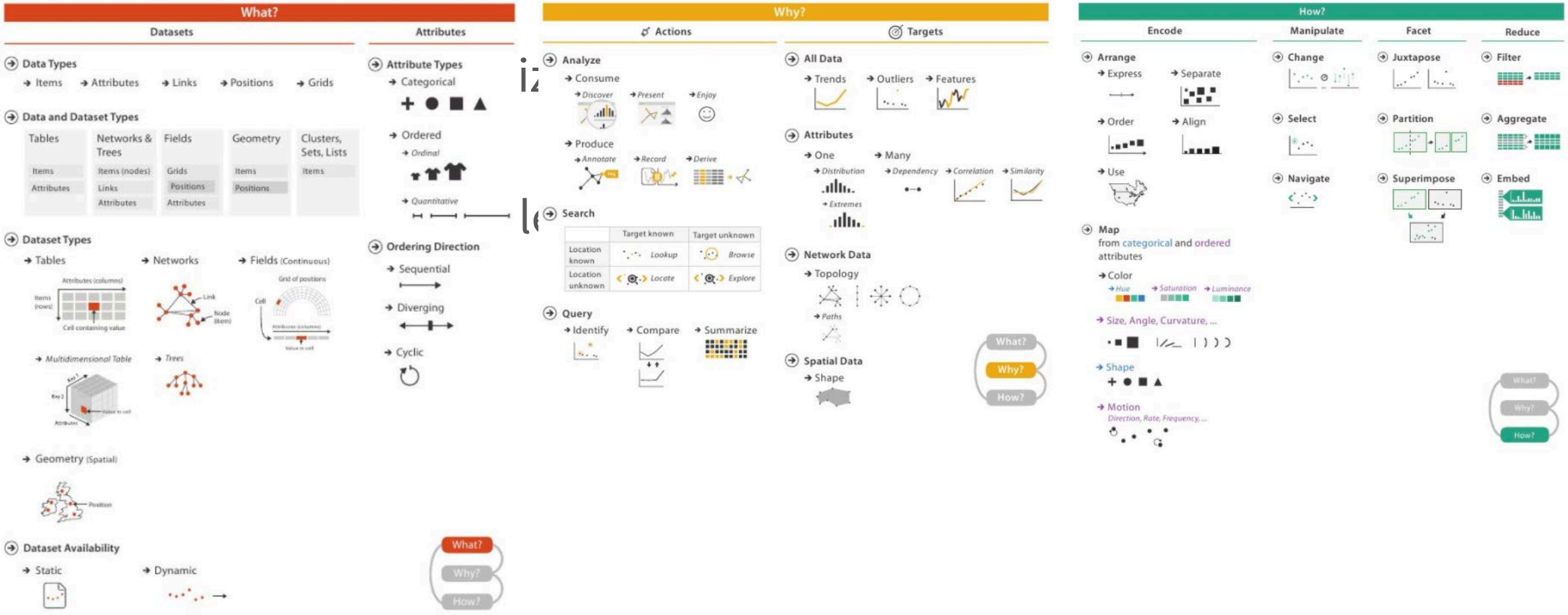
- “the better defined the goals of an artifact, the narrower the variety of forms it can adopt” –Alberto Cairo

The Functional Art: An introduction to information graphics and visualization. New Riders, 2012.

Why does Design Matter for Vis?

- many ineffective visualization combinations
- users with unique problems & data
- variations of tasks
- large design space

Why does Design Matter for Vis?



When do we Design?

- wicked problems
  - no clear problem definition
  - solutions are either good or bad (not true/false)
  - no clear point to stop with a solution

  Dilemmas in a general theory of planning. Rittel, H.W. and Webber, M.M., Policy Sciences, 1973.

- examples of non-wicked (“tame”) problems
  - mathematics, chess, puzzles

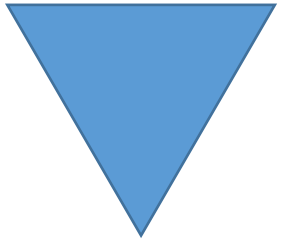
- many different examples of wicked problems

Relation to Other Fields

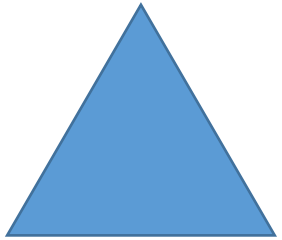
- user-centered design (UCD) or human-centered design (HCD)
- engineering / architecture
- human-computer interaction (HCI)
- human-machine/human-robot interaction (HMI/HRI)

Problem-Driven vs Technique-Driven

- problem-driven
  - top-down approach
  - identify a problem encountered by users
  - design a solution to help users work more effectively
  - sometimes called a design study



- technique-driven
  - bottom-up approach
  - invent new idioms or algorithms
  - classify or compare against other idioms and algorithms



Real World Example

what is cyber security?

http://www.digitaltrends.com/computing/uk-spy-agency-approves-new-cyber-degrees/

http://i.huffpost.com/gen/2338148/images/o-FBI-SONY-HACK-facebook.jpg http://www.wired.com/wp-content/uploads/2014/12/sony-gop-hack-screen.jpg

What is Cyber Security?

- analysts protect networks against:
  - information disclosure
  - theft
  - denial of service

- why is this hard?
  - LOTS of data
  - human interpretation of human attackers
  - attacks are robust

http://images.politico.com/global/2012/08/120801_cybersecurity_analyst_ap_328.jpg

Cyber Security Dataset

- intrusion detection system (IDS) data
  - captures alerts
  - rules triggered and may hint at potential incidents
  - requires a priori knowledge

time	id	name	origin	origin location	destination	destin. location	class
01/23/1998 16:56:12	345	WCA	192.168.1.30	Lexington, MA	68.38.97.25	Hope, IN	detected
01/23/1998 16:56:15	2335	MBP	68.230.80.60	Phoenix, AZ	192.168.1.30	Lexington, MA	potential
01/23/1998 16:56:17	43	KPO	192.168.0.40	Lexington, MA	176.151.22.45	Angouleme, France	other
01/23/1998 16:56:17	345	JOS	46.185.133.223	Al Jubayhah, Jordan	192.168.0.20	Lexington, MA	attempt
01/23/1998 16:56:19	44	KPO	192.168.0.40	Lexington, MA	175.29.141.60	Jessore, Bangladesh	other
01/23/1998 16:56:24	371	MBV	128.240.221.153	Newcastle, UK	192.168.0.20	Lexington, MA	detected

Cyber Security Dataset

- exercise: what are some types of encodings we could use? why?

time	id	name	origin	origin location	destination	destin. location	class
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01/23/1998 16:56:24	371	MBV	128.240.221.153	Newcastle, UK	192.168.0.20	Lexington, MA	detected

- what do users use?

What about the User?

- worked with an analyst on-campus
- worked with analysts at MIT LL and government sites
- conducted interviews, observations
  - analysts find anomalies in data streams to protect networks
  - for one user: “main bottleneck is the hard drive read times”
  - dashboards play an important role: “pictures are great when going up to management because you have 60 seconds to make your case”

Personas Design Method

- “documents to foster communication within a design team as archetypes of users, their behavior, and their knowledge”

  Universal methods of design. Hanington, B. and Martin, B., 2012.

- to build personas:
  - conducted interviews across stakeholders

- identified four types of personas:
  - analyst, manager, director of IT, and a CEO
  - specific to a cyber security dashboard

  Unlocking user-centered design methods for building cyber security visualizations. McKenna, S., Staheli, D. and Meyer, M., IEEE VizSec, 2015.

https://www.flickr.com/photos/nnova/2081056587/in/photostream/

Personas Design Method

Cyber Analyst (information-gathering)

Goals	Identify anomalous network behavior	
Knowledge	Operations ●○○○○	Cyber ●●●●●
Cyber SA	Attention ●●●●○	Temporal Window
Key Questions	• What does my network look like? • What happened on the network • last night? What's different? • Is something bad happening?	• How was my network attacked? • Who is attacking my network? • Does this attack matter? • What did the bad guys do?

NOC Manager (information-synthesis)

Goals	Communicate impact on operations	
Knowledge	Operations ●●●○○	Cyber ●●●○○
Cyber SA	Attention ●●●○○	Temporal Window
Key Questions	• Does this attack matter? • How serious is the attack? • What do I do about the attack? • Are there any negative effects?	• How successful was the attack? • What did the bad guys do? • What did the bad guys take?

Director of IT (decision-making)

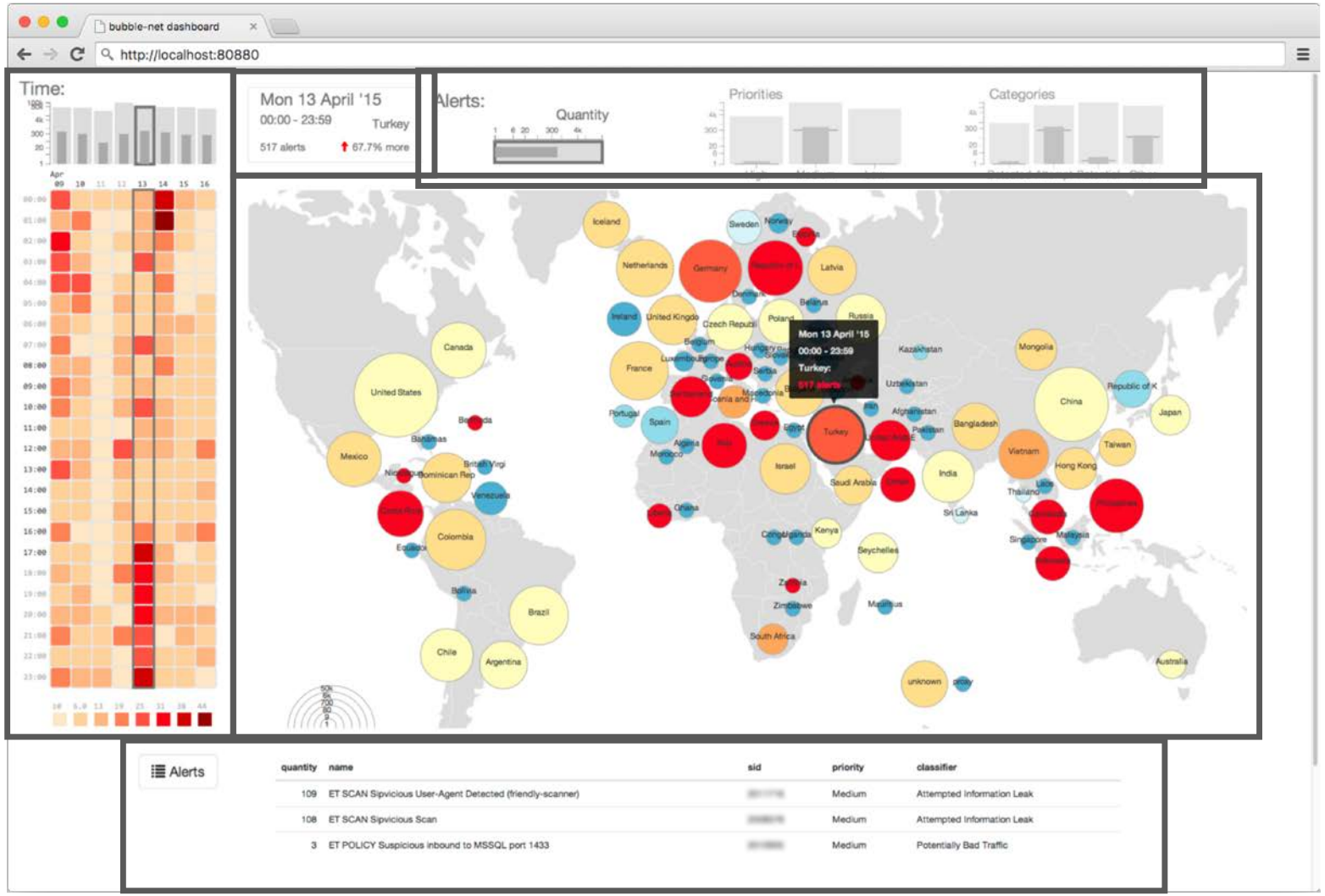
Goals	Maintain cyber situational awareness	
Knowledge	Operations ●●●○○	Cyber ●●●○○
Cyber SA	Attention ●●○○○	Temporal Window
Key Questions	• Does this attack matter? • How serious is the attack? • What do I do about the attack? • Are there any negative effects?	• What did the bad guys do/take? • Is it a good day on the network? • How is my network different • from last week?

CEO (decision-making)

Goals	Coordinate personnel and operations	
Knowledge	Operations ●●●●●	Cyber ●○○○○
Cyber SA	Attention ●○○○○	Temporal Window
Key Questions	• How can we maintain ongoing operations? • What could happen if a critical system is impacted? • What are the most critical systems at risk of attack? • What cyber resources will be needed in the future?	

Cyber Security Dashboard

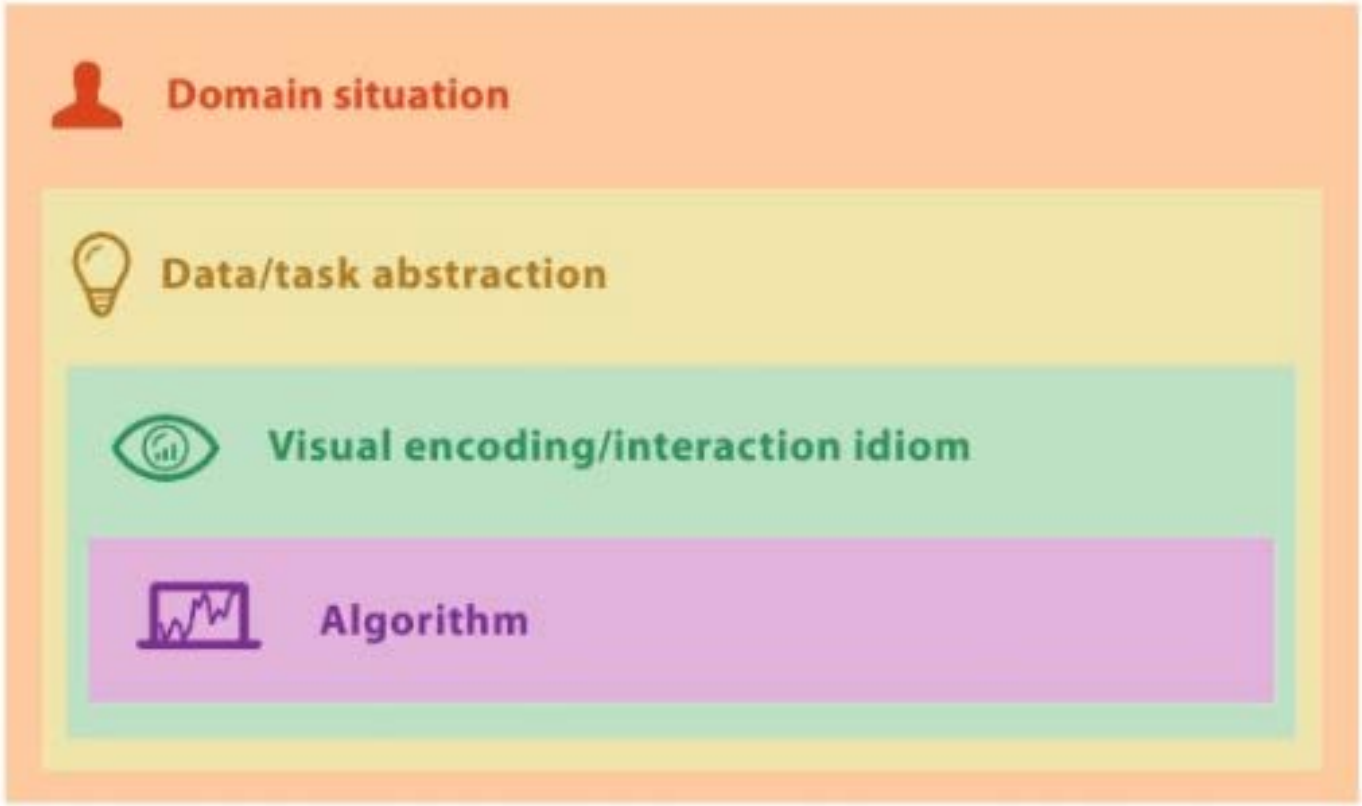
- location view
- temporal views
- attribute bullet charts
- record details
- selection overview



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

https://www.youtube.com/watch?v=8gKNJcIduN8

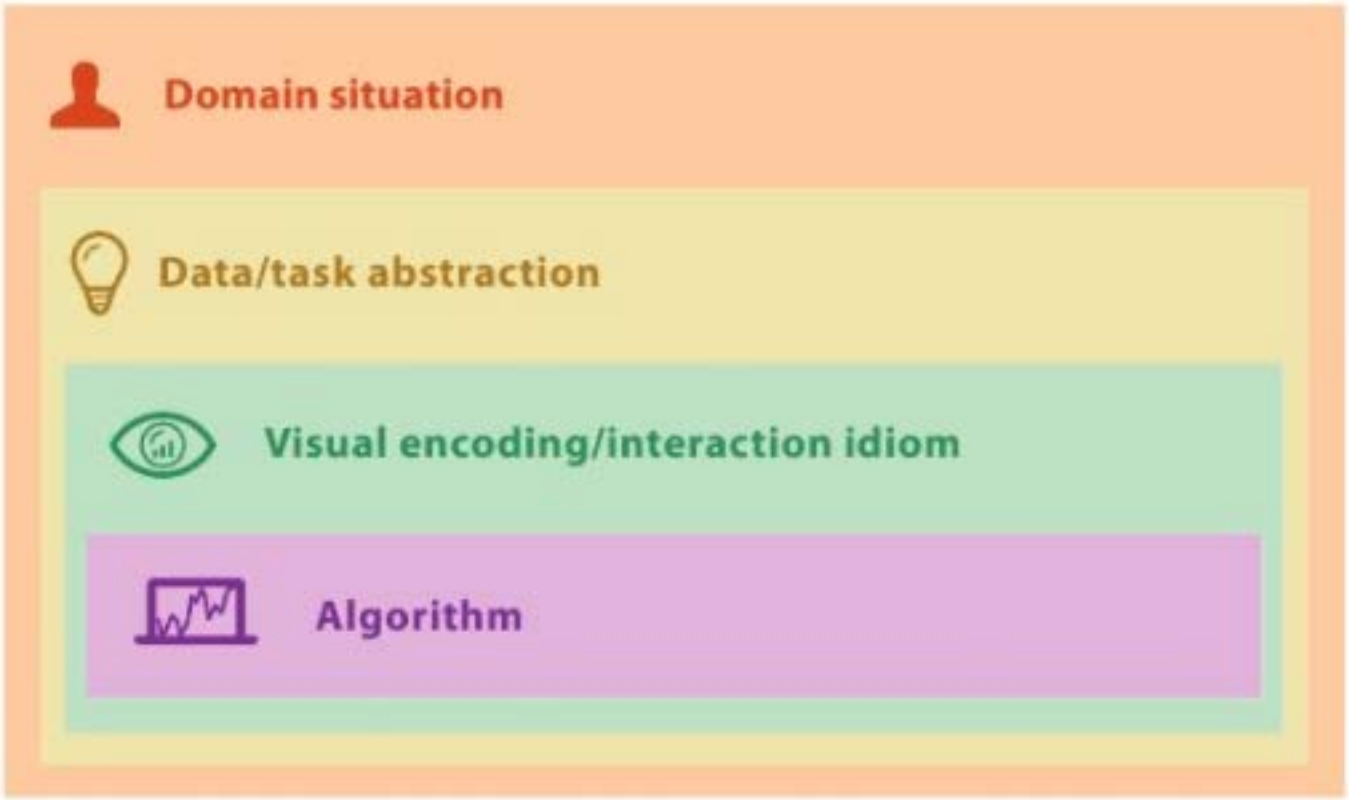
Nested Model



Purpose of the Nested Model

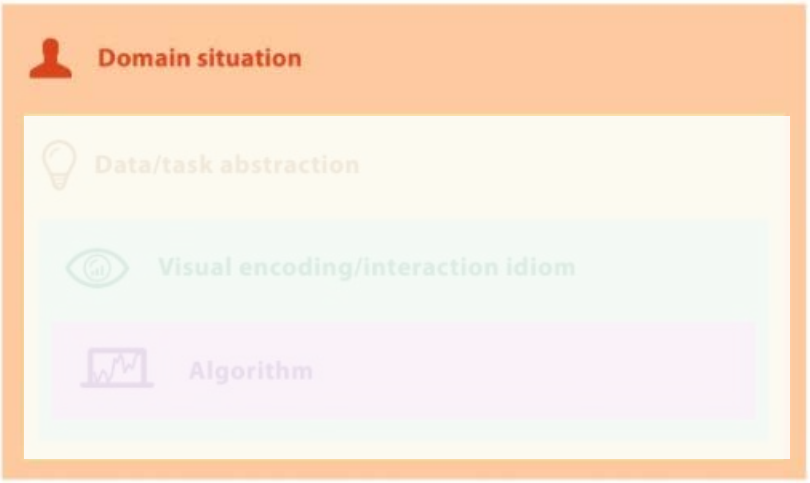
- capture design decisions
  - what is the justification behind your design?
- analyze aspects of the design process
  - broken apart into four different concerns
- validate early & often
  - avoid making ineffective solutions

Levels of the Nested Model



A nested model for visualization design and validation. Munzner, T., IEEE InfoVis, 2009.

Domain Characterization

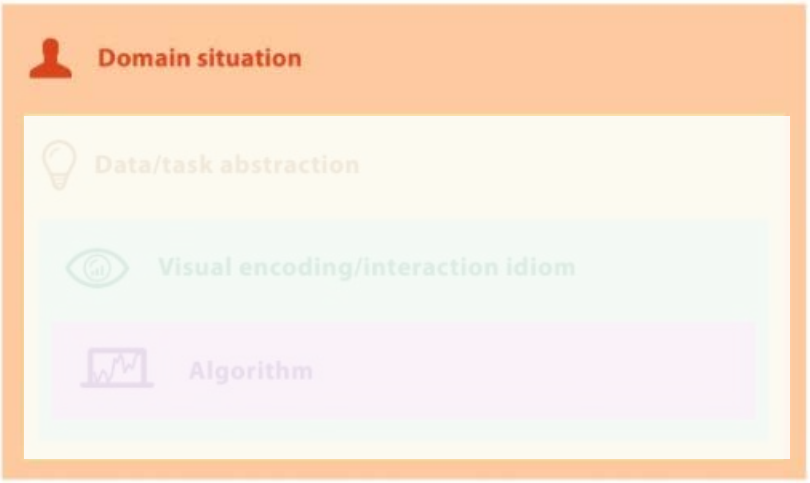


- details of an application domain

- group of users, target domain, their questions, & their data
  - varies wildly by domain
  - must be specific enough to continue with

- cannot just ask people what they do
  - introspection is hard!

Domain Characterization



- cyber security dashboard
  - read many papers to understand the field
    - need to communicate cyber information
  - interviewed & observed both researchers and users
  - created personas to identify target users

Cyber Analyst (information-gathering)

Goals	Identify anomalous network behavior	
Knowledge	Operations ●○○○○	Cyber ●●●●●
Cyber SA	Attention ●●●●○	Temporal Window ◄——►
Key Questions	• What does my network look like? • What happened on the network • last night? What's different? • Is something bad happening?	• How was my network attacked? • Who is attacking my network? • Does this attack matter? • What did the bad guys do?

NOC Manager (information-synthesis)

Goals	Communicate impact on operations	
Knowledge	Operations ●●○○○	Cyber ●●○○○
Cyber SA	Attention ●●●○○	Temporal Window ◄——►
Key Questions	• Does this attack matter? • How serious is the attack? • What do I do about the attack? • Are there any negative effects?	• How successful was the attack? • What did the bad guys do? • What did the bad guys take?

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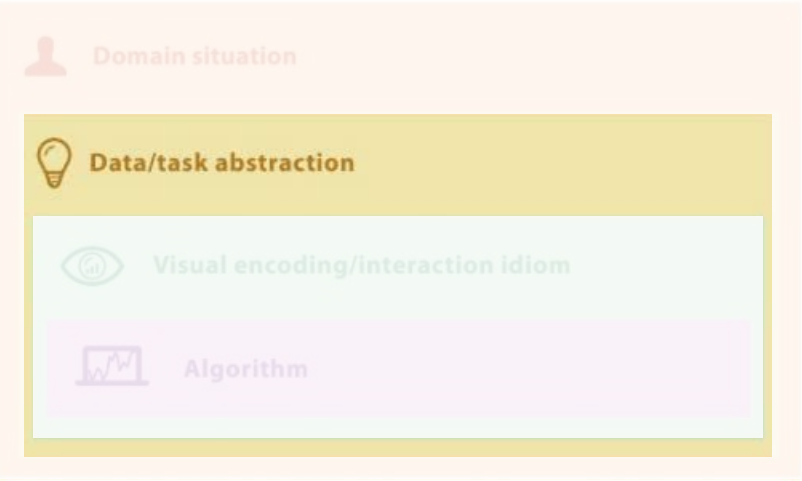
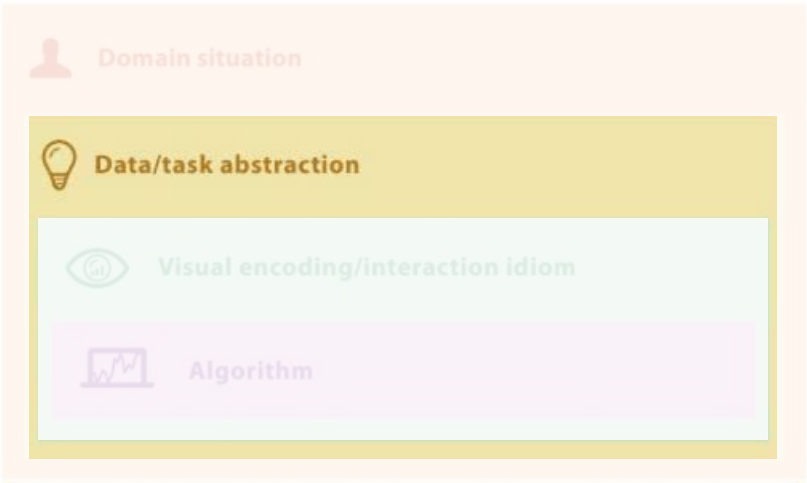
Data & Task Abstraction

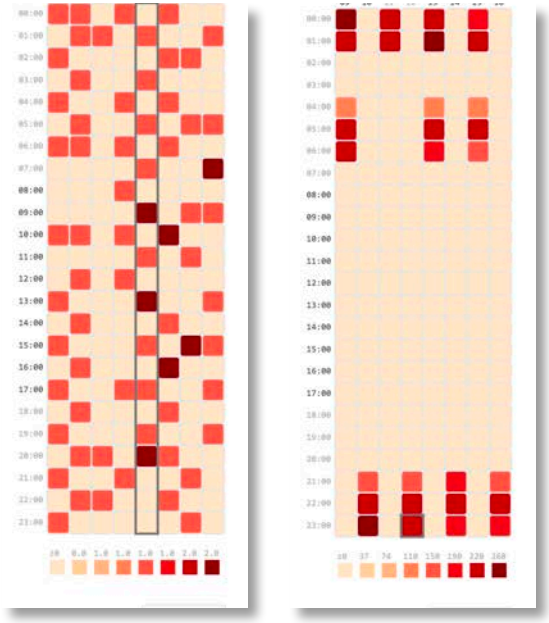


- the what-why, map into generalized terms
- identify tasks that users wish to perform or already do
- find data types and good model of the data
- sometimes must transform the data for a better solution
  - this can be varied and guided by the specific task

Data & Task Abstraction



- cyber security dashboard
  - for communication, analysts discover and present patterns
  - patterns are a collection of network alerts that represent some recurring or abnormal behavior
  - for patterns, must support identification and comparison
    - can be done through aggregation
    - e.g. collecting records by location on the internet
    - e.g. collecting records by day and hour



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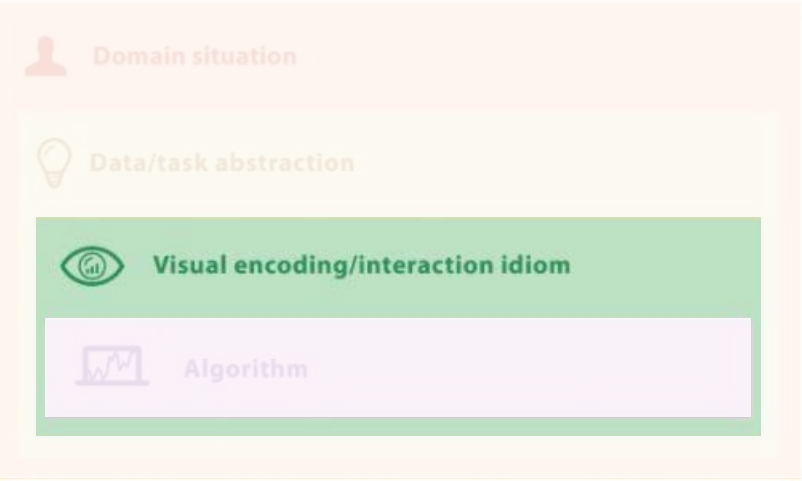
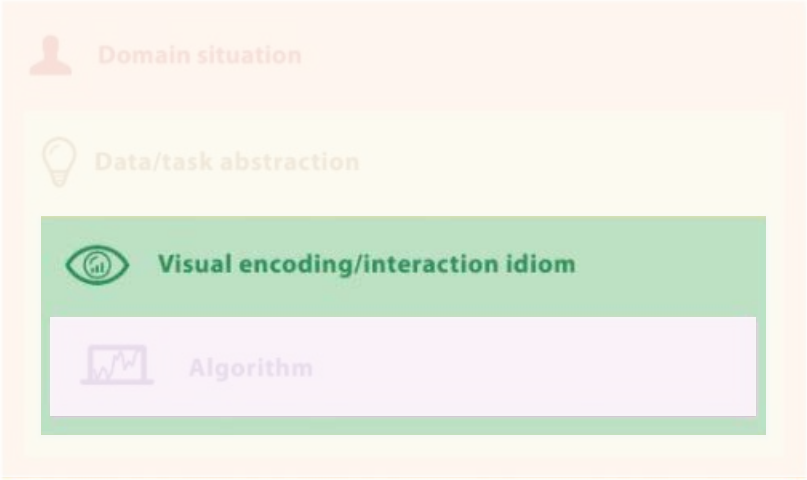
Encodings & Interactions

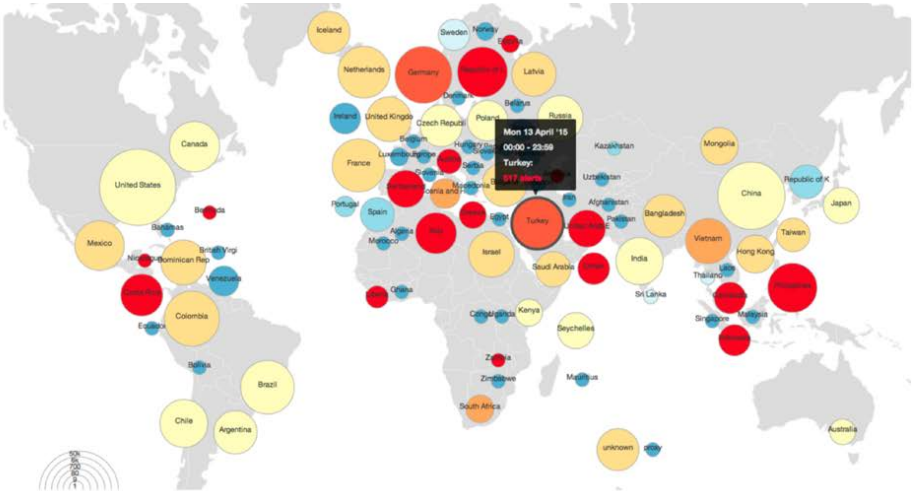


- the design of idioms that specify an approach
  - visual encodings
  - interactions
- ways to create and manipulate the visual representation of data
- decisions on these may be separate or intertwined
- principles of visual perception & memory can drive decisions here

Encodings & Interactions



- cyber security dashboard
  - location view – novel patterns can be seen
    - Dorling cartogram
    - alerts outside of network
  - encodes quantity with size
    - and deviation from average with color
  - interaction mitigates less-ideal encoding choices (i.e. size, color)
    - some users just wanted a map
    - entices users to dig into additional detail views



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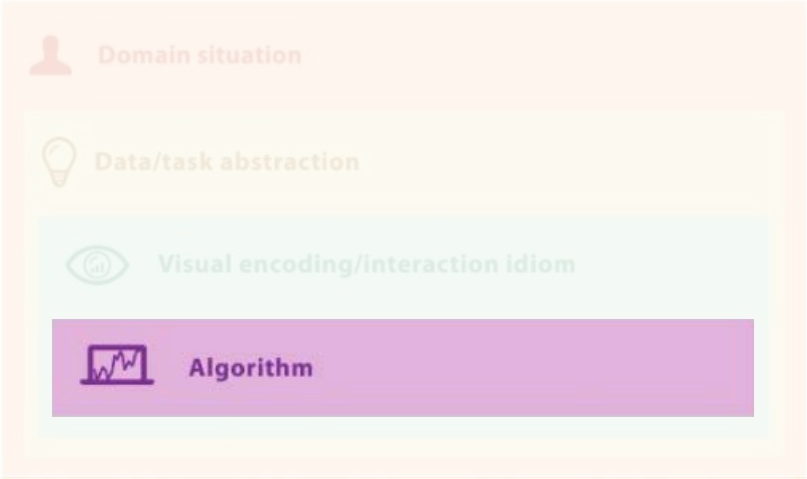
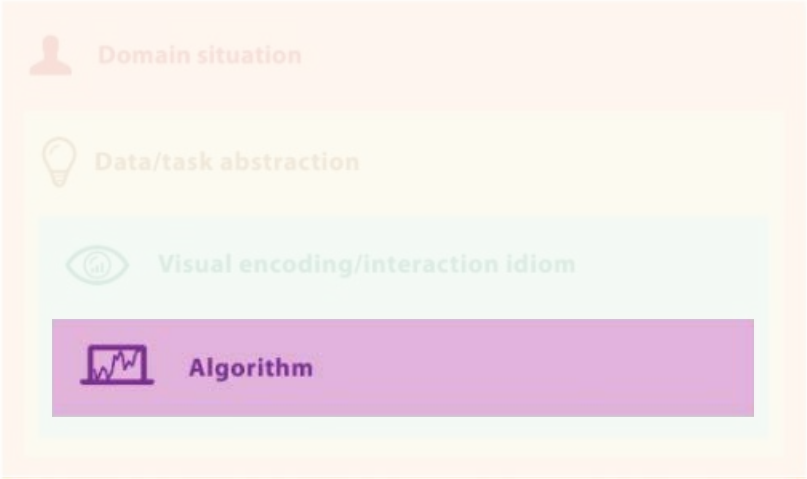
Algorithm

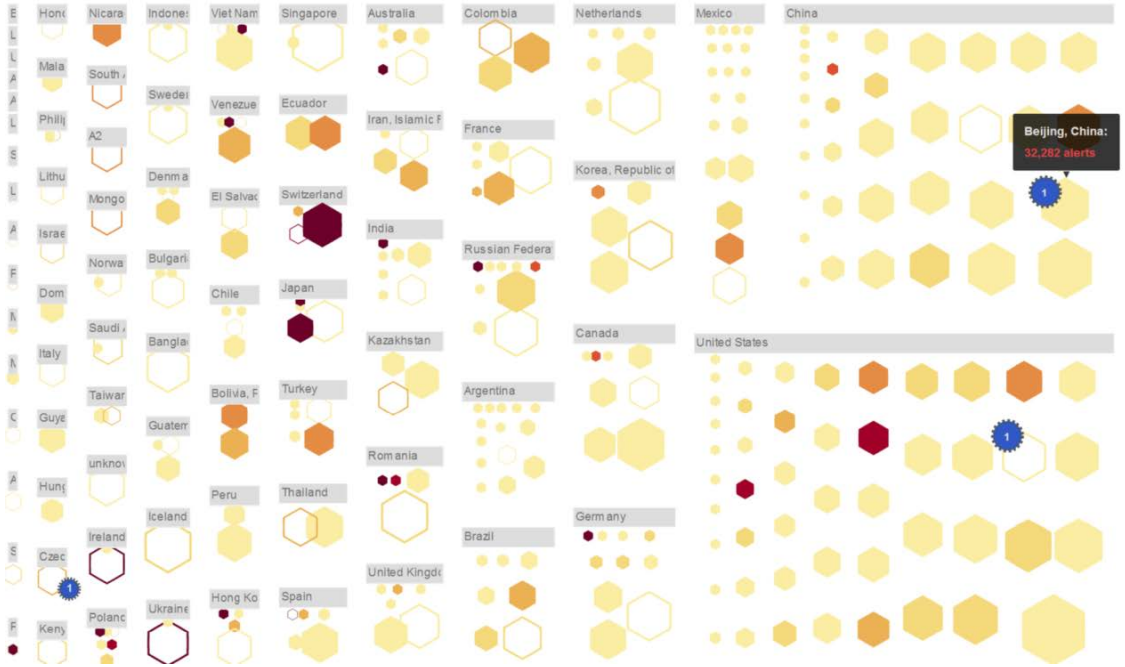


- instantiate an algorithm computationally
- inner-most level
- must efficiently handle all idioms
- factors such as computing time, memory, or exactness/uncertainty
- best to strive for a “fast enough” response / interactive frame rates

Algorithm



- cyber security dashboard
  - alternative encoding option: treemap instead of a map
    - space-filling, hierarchy (country, city)
  - algorithm to spatially lay this out
    - non-trivial and could have implemented
  - challenges:
    - size and small number of alerts
    - larger is not more important
    - less intuitive encoding to users

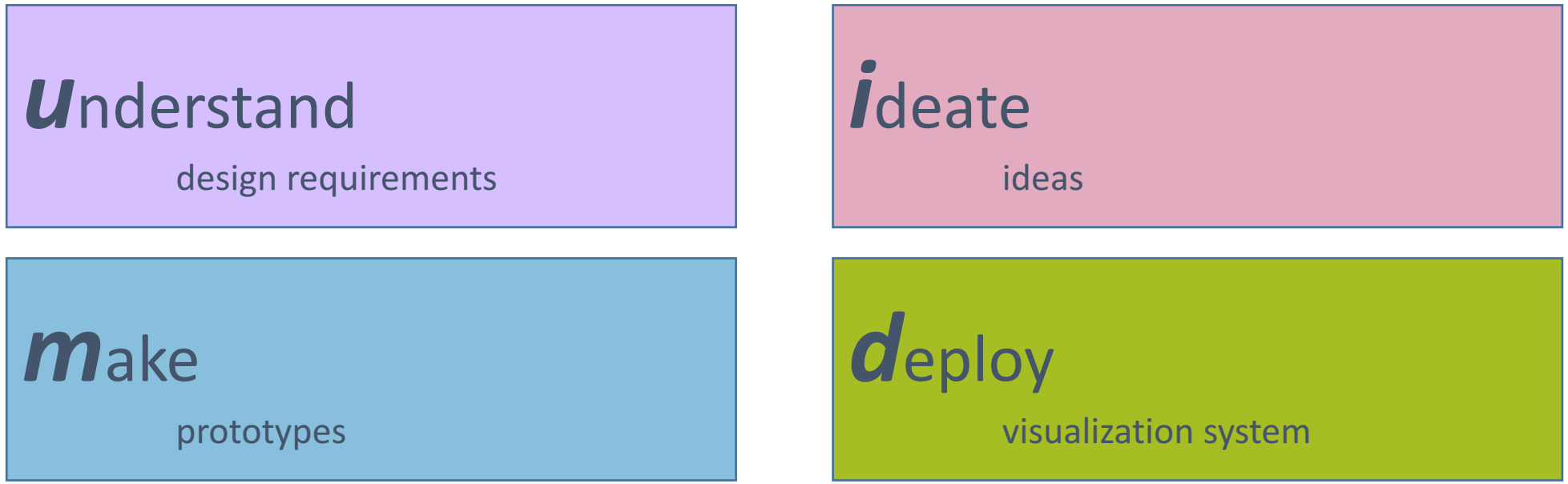


Unlocking user-centered design methods for building cyber security visualizations. McKenna, S., Staheli, D. and Meyer, M., IEEE VizSec, 2015.

Role of Evaluation

- also known as validation
- to avoid ineffective solutions, justify ones that work
- measure success, using:
  - user feedback
  - perceptual principles
  - user metrics/adoption rates
  - algorithmic runtime/complexity

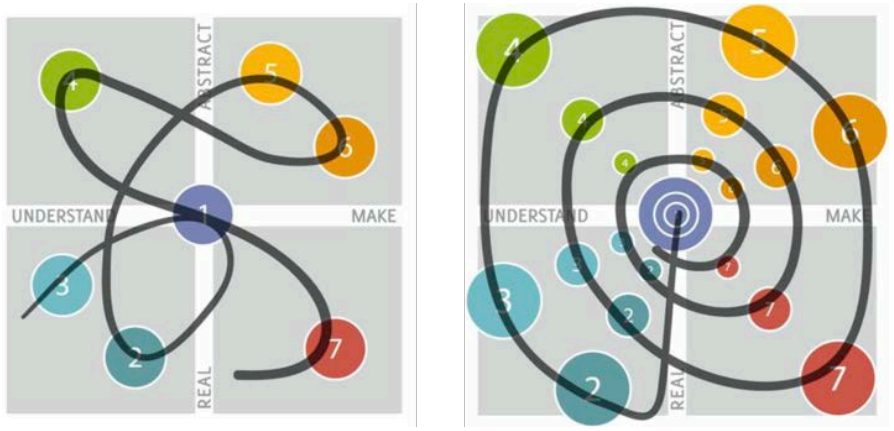
Design Activity Framework



Design activity framework for visualization design. McKenna, S., Mazur, D., Agutter, J. and Meyer, M., IEEE InfoVis, 2014.

Purpose of the Framework

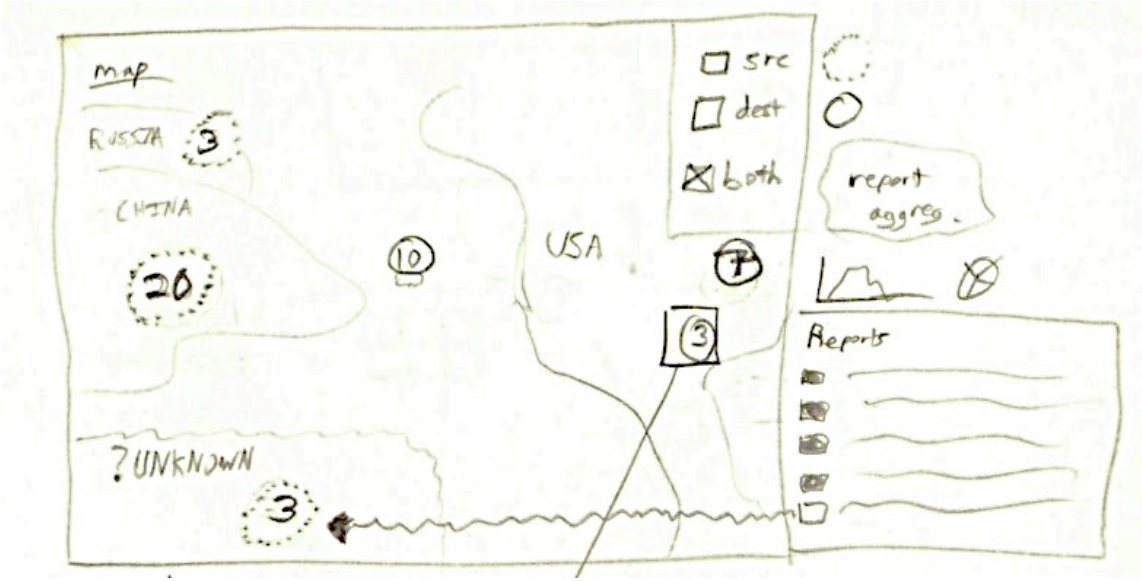
- guide the process of problem-driven work for visualization design
- connect actions we take with decisions we make
- support a more flexible design process
- influenced by models in HCI & design

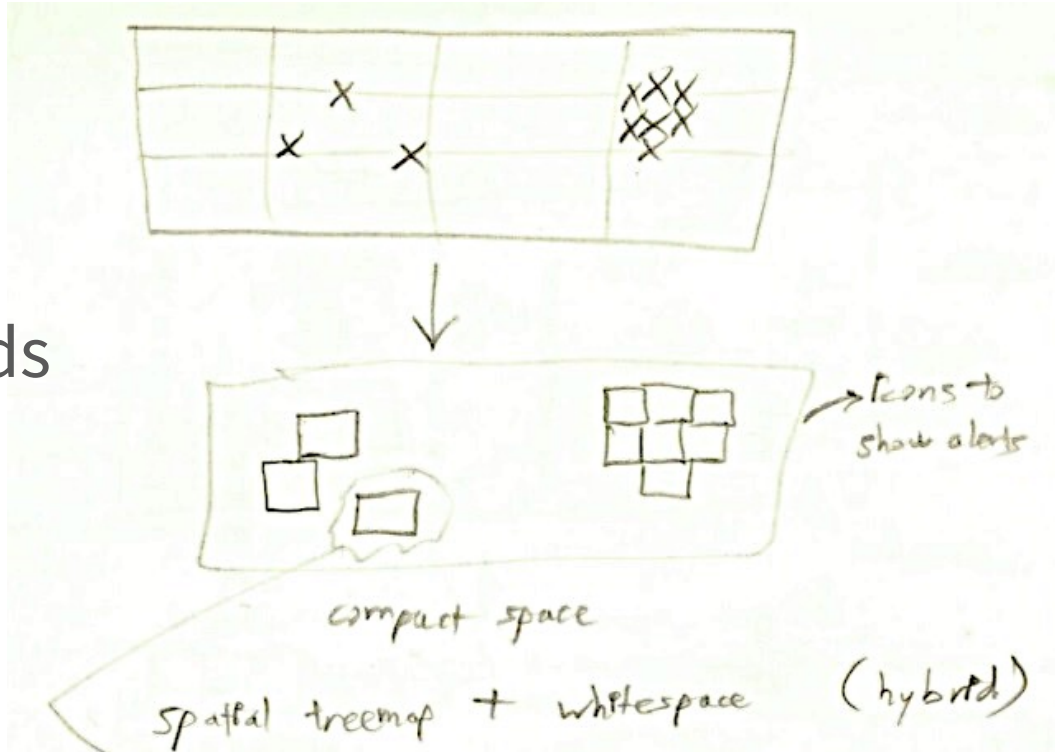


101 design methods: A structured approach for driving innovation in your organization. Kumar, V., 2012.

Design Artifacts

- these are what we create in design
  - each has a purpose and is unique
  - can motivate creation of more artifacts
- can be recorded, sketched, coded, etc.
- obtain artifacts through design methods
  - e.g. personas and sketches





Cyber Analyst (information-gathering)

Goals	Identify anomalous network behavior	
Knowledge	Operations ●○○○○	Cyber ●●●●●
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Key Questions	• What does my network look like? • What happened on the network • last night? What's different? • Is something bad happening?	• How was my network attacked? • Who is attacking my network? • Does this attack matter? • What did the bad guys do?

NOC Manager (information-synthesis)

Goals	Communicate impact on operations	
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Design Activities

- a design activity is collectively working towards specific artifacts

- framework has four main activities

understand

artifacts: design requirements

ideate

artifacts: ideas

make

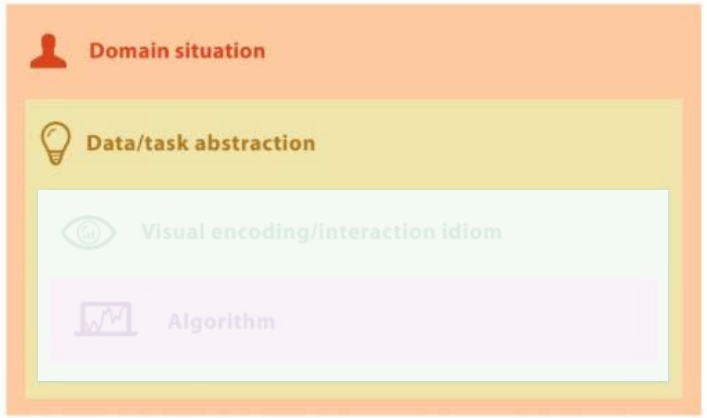
artifacts: prototypes

deploy

artifacts: visualization system

*U*nderstand

artifacts: design requirements



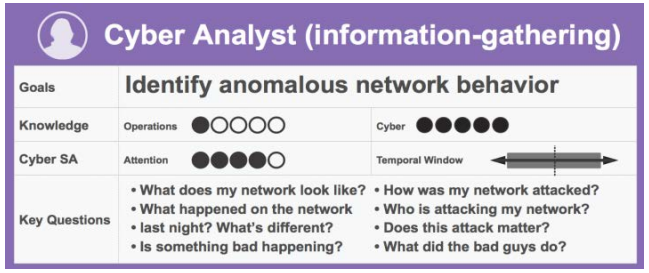
- motivation: gather, observe, and research available information to find the needs of the user

- design requirements can be broken into:
  - opportunities
  - constraints (limitations)
  - considerations (more flexible)

*U*nderstand

artifacts: design requirements

- cyber security dashboard



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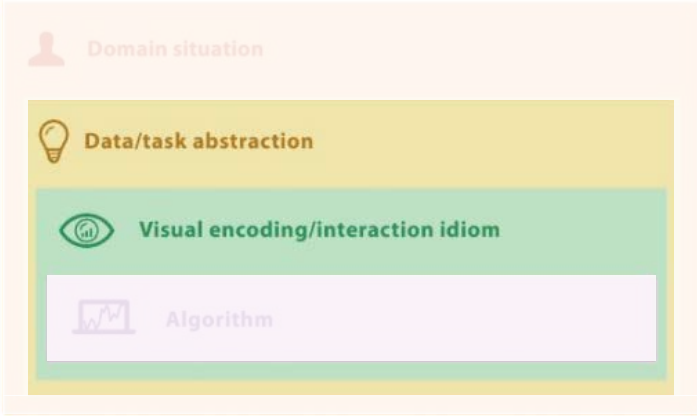
- read many research papers to understand the field and different users
- observed and interviewed many users
- created personas to filter to a subset of users
- identified high-level goal of communication of cyber information

*i*deate

artifacts: ideas

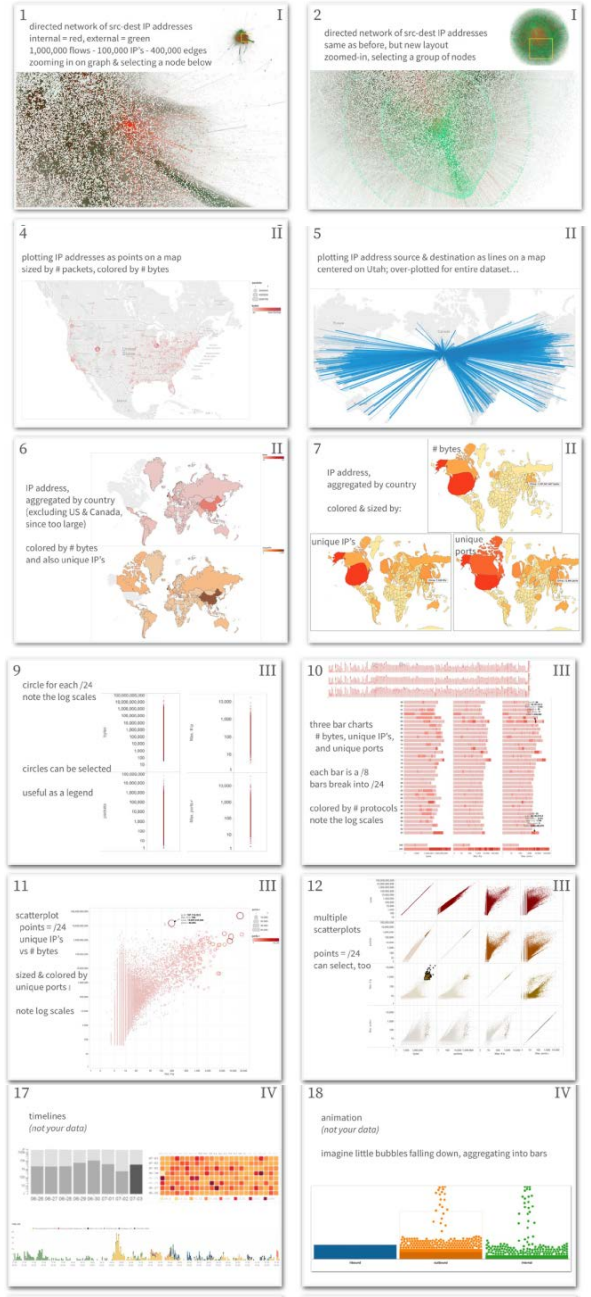


- motivation: to generate good ideas for supporting the understand artifacts
- sketches often get externalized in various forms, up to mock-ups and wireframes
- anyone can sketch! the goal is to capture an idea, not create a masterpiece or spend hours cleaning up the sketch

*i*deate

artifacts: ideas

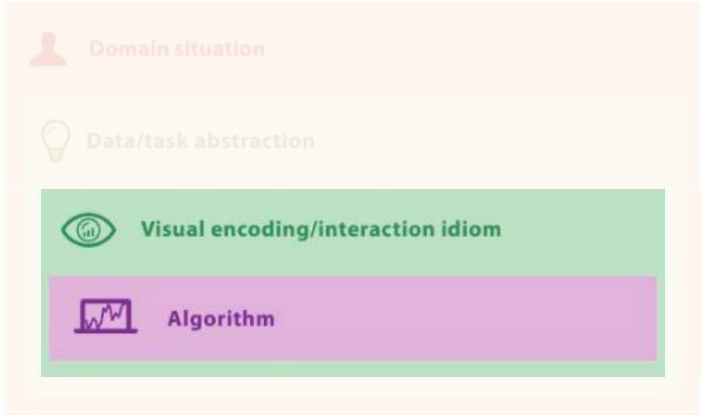
- cyber security dashboard
  - sketched out various forms of the data
  - created data sketches:
    - 20 different ways to visualize the data
  - evaluated these with an analyst
  - identified most clear encoding for all users



Unlocking user-centered design methods for building cyber security visualizations. McKenna, S., Staheli, D. and Meyer, M., IEEE VizSec, 2015.

*m*ake

artifacts: prototypes



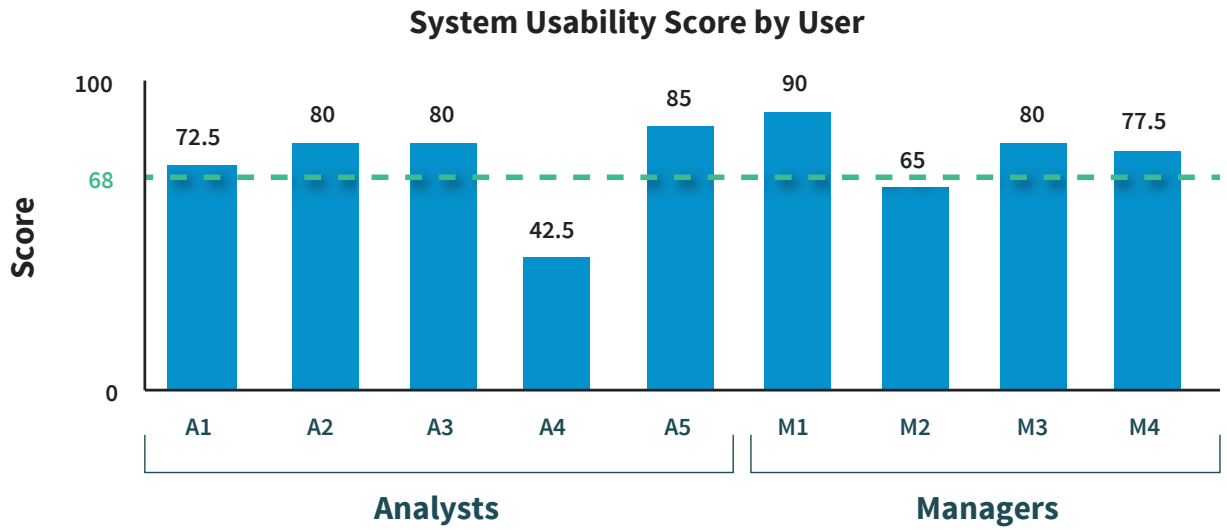
- motivation: to concretize ideas into tangible prototypes
- prototypes are “approximations of a product along some dimensions of interest”

  Reflective physical prototyping through integrated design, test, and analysis. Hartmann, B., Klemmer, S.R., Bernstein, M., Abdulla, L., Burr, B., Robinson-Mosher, A. and Gee, J., ACM UIST, 2006.
- can be lower or high-fidelity prototypes, usually over time
- for visualization, often built using code and higher-fidelity

*m*ake

artifacts: prototypes

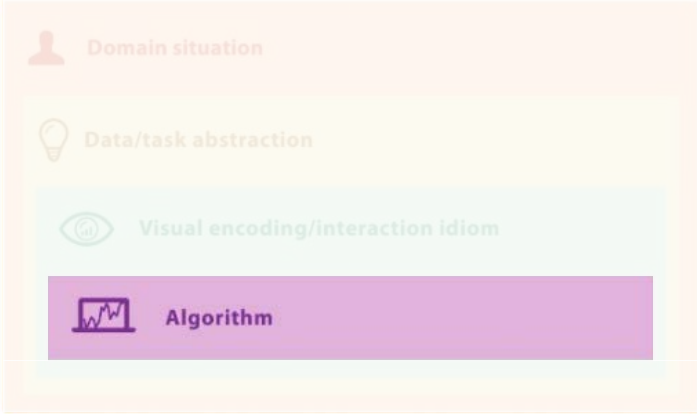
- cyber security dashboard
  - built first prototype using a treemap of alerts
  - evaluated this treemap as an idea, leading to map view
  - constructed map-based dashboard
  - evaluated with users, anecdotally and in a usability study



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

*d*eploy

artifacts: visualization system

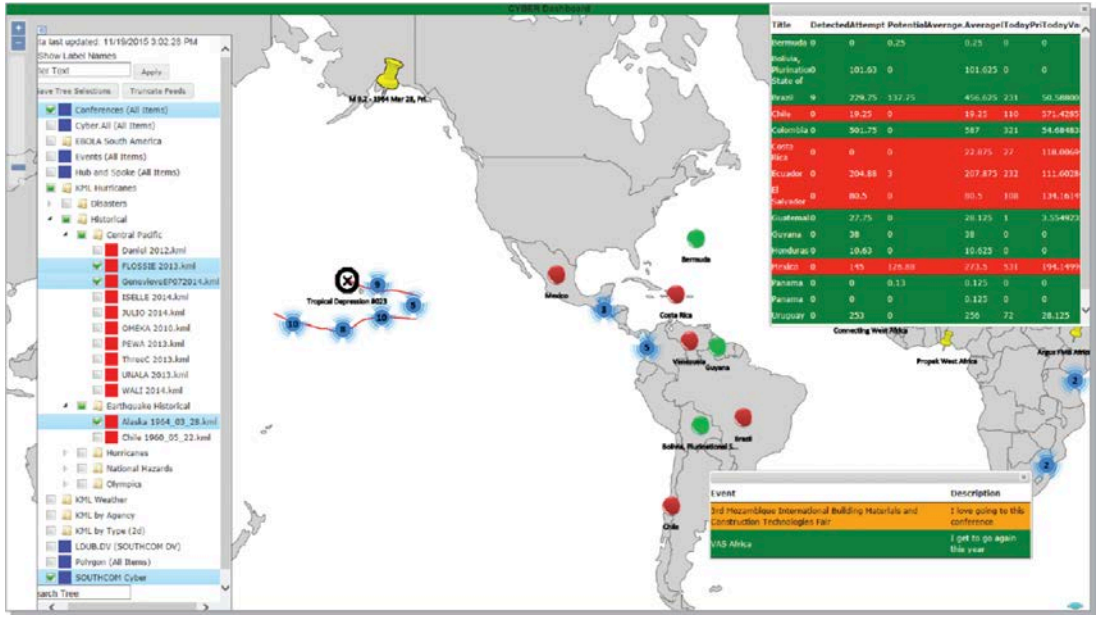


- motivation: to bring a prototype into effective action in a real-world setting in order to support the target users' work and goals
- more software engineering-related decisions
- tool must be usable and fit into a user's workflow
- may have to optimize algorithms to increase interactivity and speed

*d*eploy

artifacts: visualization system

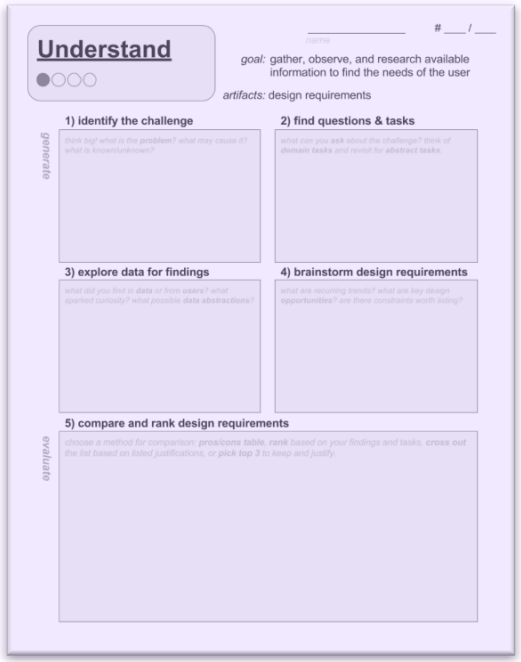
- cyber security dashboard
  - showcased prototype to find its benefits
  - implemented some benefits in an existing toolkit
  - adoption of the simpler map-based view
  - utilization of multi-view, instant interactions

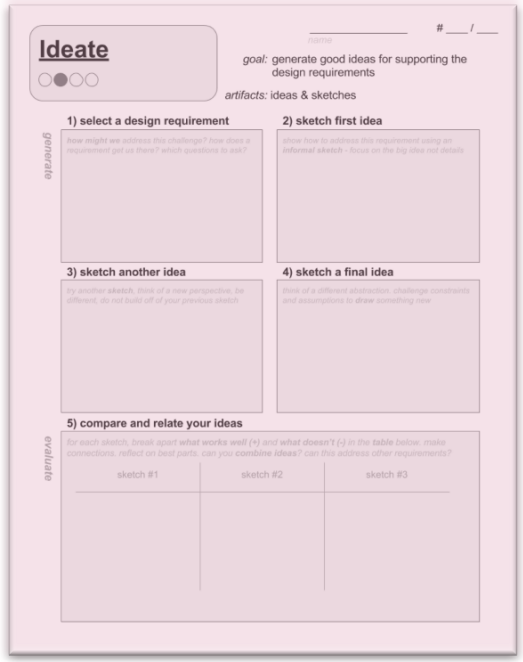


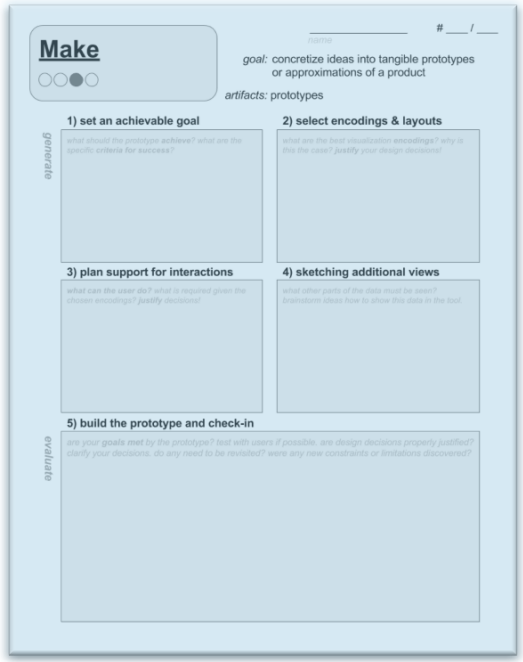
Cloudbreak: Answering the Challenges of Cyber Command and Control. Staheli, D., Mancuso, V.F., Leahy, M.J. and Kalke, M.M., Lincoln Laboratory Journal, 2016.

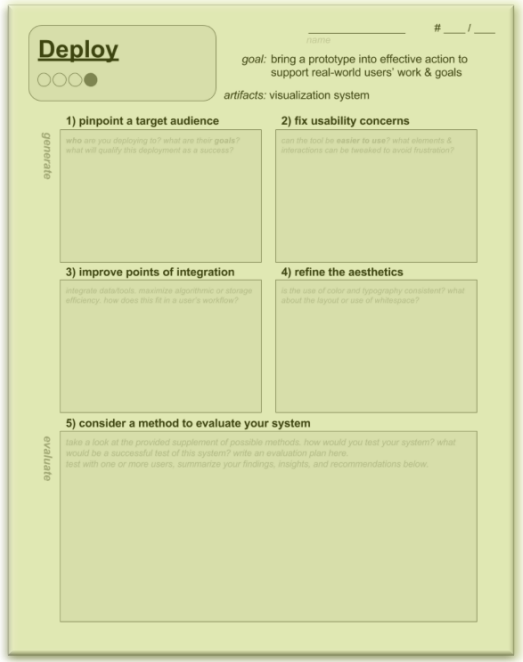
Design Worksheets

- structure the design process









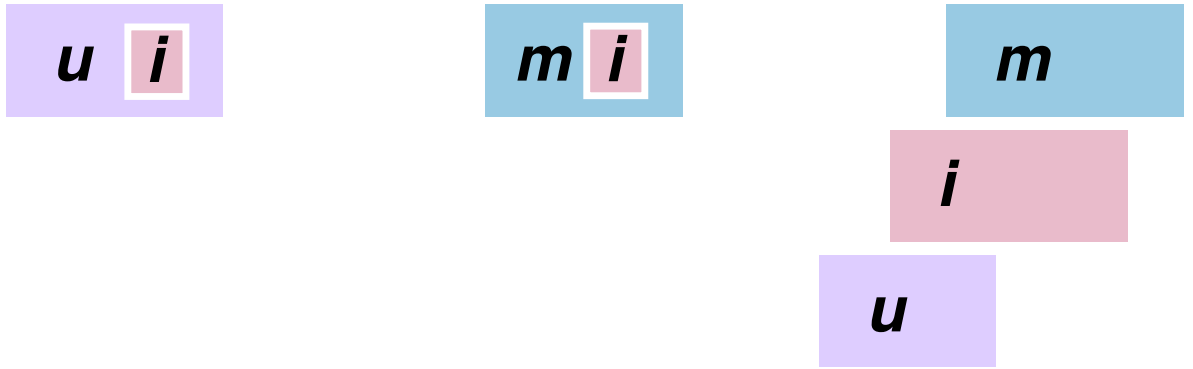
- capture design artifacts and goals on paper

Capturing Design Flow

- flexible; supports messiness

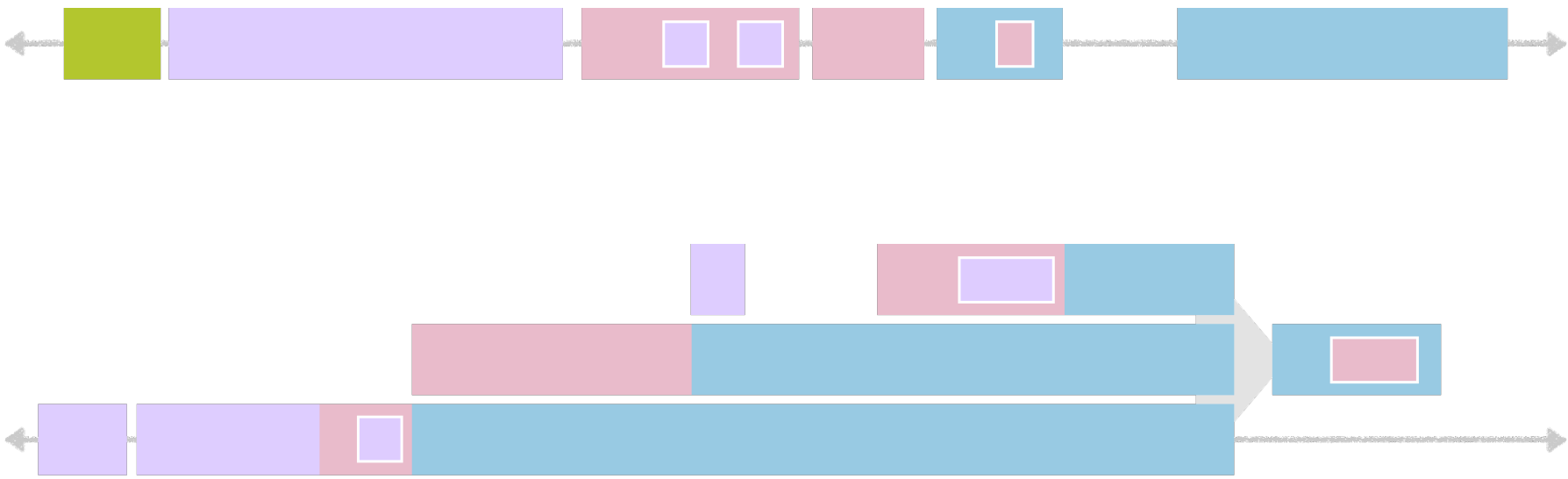
- two basic movement principles:
  1. forward movement is ordered

  2. activities can be nested or conducted in parallel



Iterative Process

- these four levels of the nested model rarely occur in order
- real design processes are “messy” – iterative



Generative & Evaluative Methods

- generative methods create artifacts
  - interview & observe
  - field study
  - sketching

- evaluative methods compare and winnow artifacts
  - justify design idioms
  - lab study
  - benchmarks / complexity analysis

- methods can be used for both purposes and across activities!

Design Methods

What Methods have we seen so far?

generative

- interviews/observations
- qualitative analysis
- personas
- data sketches
- coding

evaluative

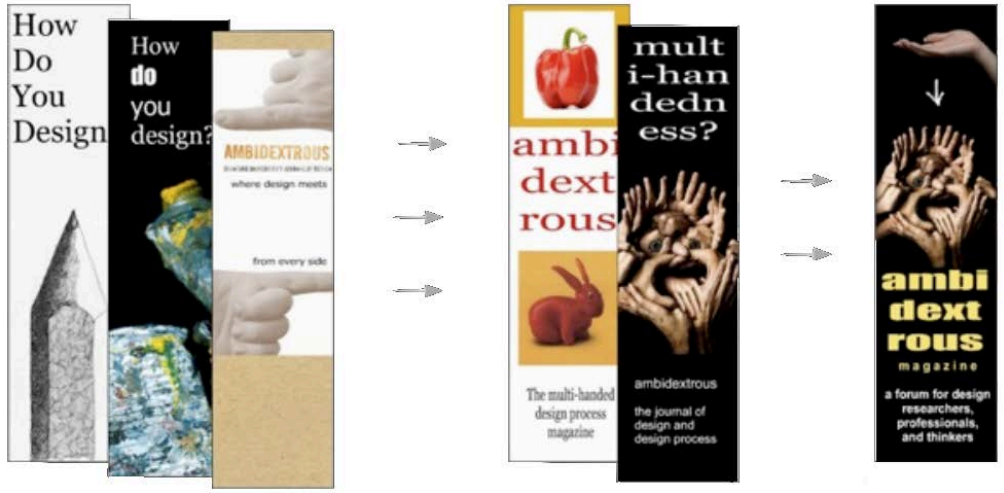
- personas
- data sketches
- justify design idioms
- usability study
- anecdotal evidence

Parallel Prototyping

- user study in HCI
  - graphic web design
  - serial vs parallel design: create & critique
- functional fixation
- benefits of designing in parallel
  - more clicks, more time on site
  - better ratings, more exploration
  - increased design confidence

serial

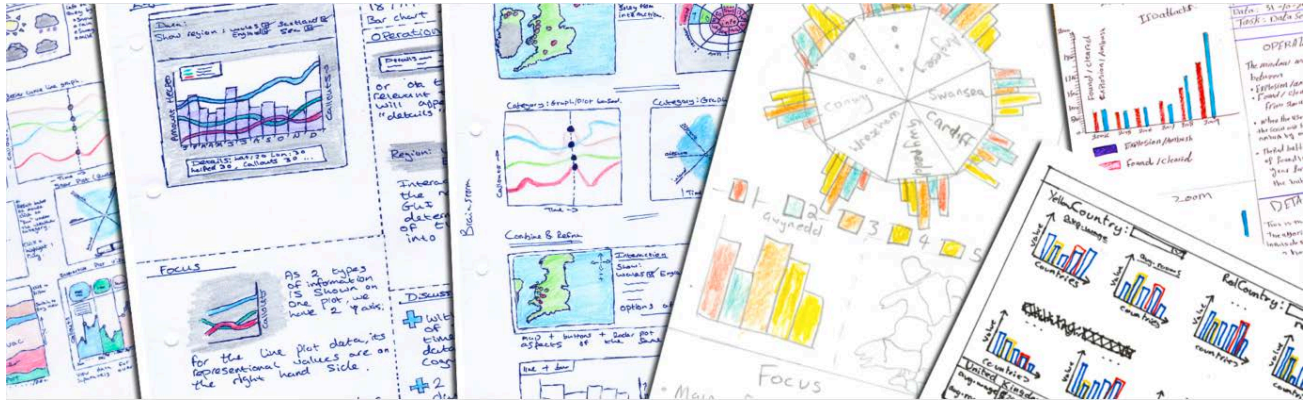
parallel



Parallel prototyping leads to better design results, more divergence, and increased self-efficacy. Dow, S.P., Glassco, A., Kass, J., Schwarz, M., Schwartz, D.L. and Klemmer, S.R., Design Thinking Research, 2012.

Five-Design Sheets

- tailored to visualization design
  - in industry and classroom use
  - sketching as a way to plan

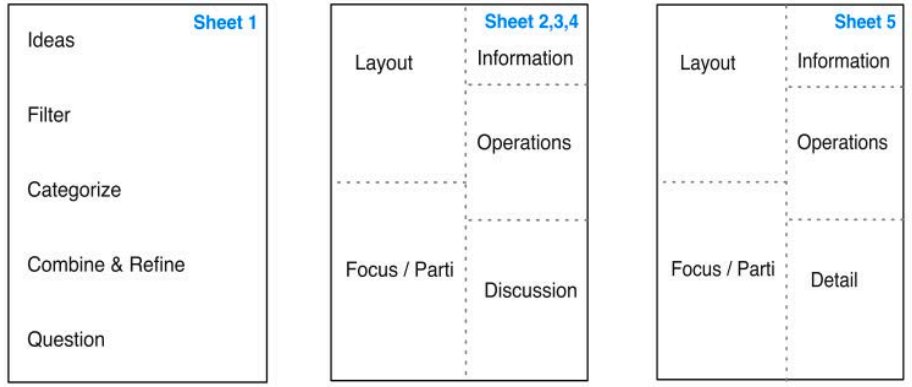


- the design sheets:

  #1 brainstorm solutions to a task

  #2-4 different principle designs

  #5 converge on design to implement



Sketching designs using the Five Design-Sheet methodology.
Roberts, J.C., Headleand, C. and Ritsos, P.D., IEEE InfoVis, 2015.

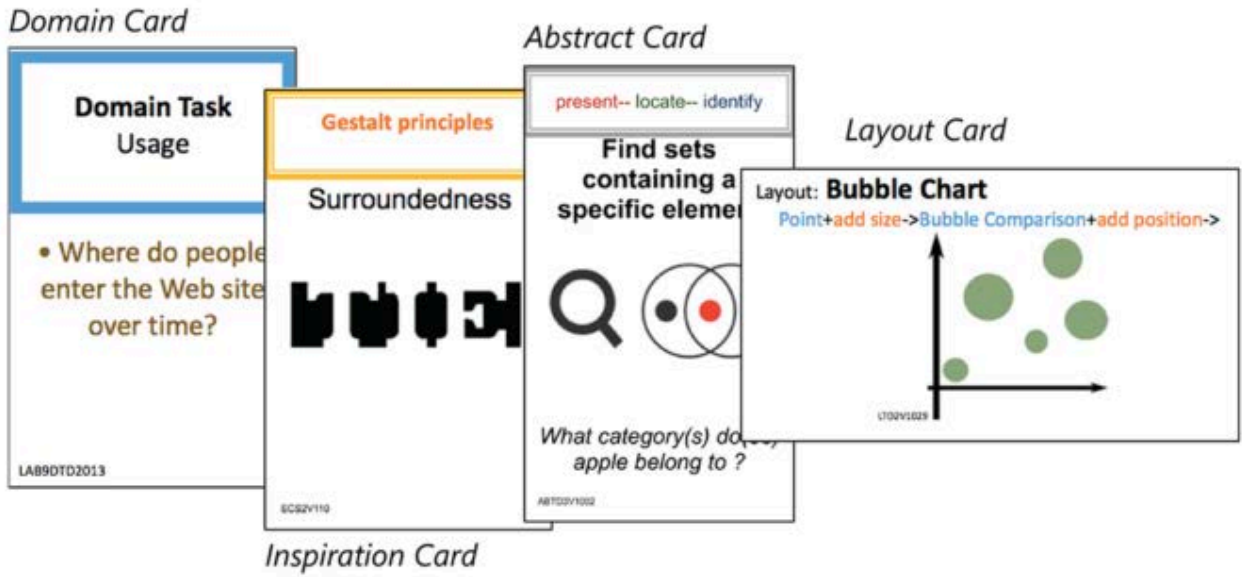
- http://fds.design/

VizIt Cards

VizIt Cards: A card-based toolkit for infovis design education. He, S. and Adar, E., IEEE InfoVis, 2016.

- different cards to assist with visualization design

- types of cards
  - domain
  - inspiration
  - abstract
  - layout



- aim to help students design, compare, collaborate, apply, and synthesize
- http://vizitcards.org

Paper Prototyping

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

  Methods to support human-centred design. Maguire, M., International Journal of Human-Computer Studies, 2001.

- received more suggestions than digital
- users requested more features to add
- hypothesis that paper prototyping stimulates creativity and interaction

Human-centered approaches in geovisualization design: Investigating multiple methods through a long-term case study. Lloyd, D. and Dykes, J., IEEE InfoVis, 2011.

Creativity Workshops

- goals:
  - generate design requirements
  - promote creativity
- combined a variety of techniques:
  - wishful thinking
  - constraint removal
  - excursion
  - analogical reasoning
  - storyboarding

- measured prototypes for appropriateness, novelty, & surprise

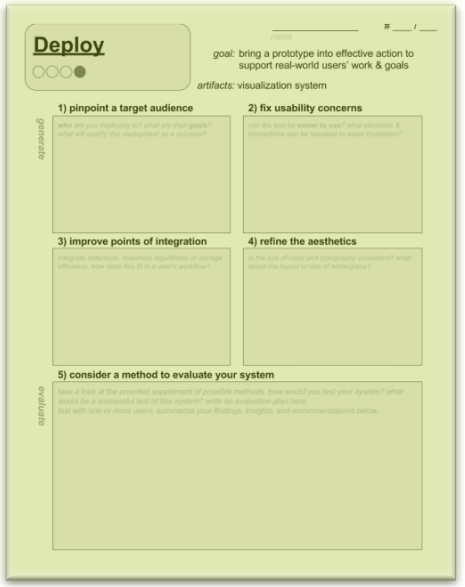
Creative user-centered visualization design for energy analysts and modelers. Goodwin, S., Dykes, J., Jones, S., Dillingham, I., Dove, G., Duffy, A., Kachkaev, A., Slingsby, A. and Wood, J., IEEE InfoVis, 2013.

https://www.flickr.com/photos/novecentino/2937239799/

Final Project

Role of Worksheets

- help you make great visualization projects!
  - make effective designs
  - capture your process and decisions
- encouraged for class use
  - contact me if you have questions or need any assistance
- will conduct a survey at the end of the class and optional interviews



More on the Worksheets

- more to come on these design worksheets
  - exercise in a future class
  - links to instructional sheet and the worksheets

- remember to contact me if you would like me to advise your group's project! first-come, first-serve basis