Designing Large Scale Software Systems

Design space exploration

Mary Shaw

January 31, 2024

The Role of Design Spaces

Mary Shaw

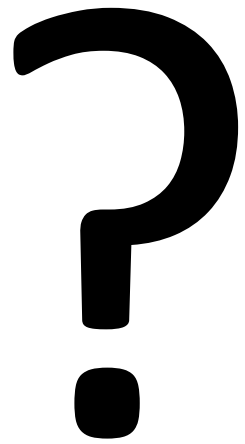
IEEE Software, Feb 2012

Design Spaces and How Software Designers Use Them

Mary Shaw and Marian Petre

Designing 2024 Workshop at ICSE, to appear

Are there any questions?



Designing involves considering multiple alternatives and choosing the one that best fits the client's needs.

Design spaces help to organize design alternatives and the dependencies among the choices so the designer can analyze, predict, make tradeoffs, understand dependencies.

The designer's principal responsibility is to understand the client's needs and find solutions that satisfy those needs. Design spaces, like other tools and techniques, are a means to that end, not an end in themselves.

The Plaid Corporation collects and analyzes very large amounts of data. In addition to its central headquarters, Plaid Corp has branches located around the country; the branches are named Red, Yellow, Blue, and Green.

At the end of each month, each branch does some normalization and analysis of the data it has collected during the month and sends the entire dataset to Plaid Corp Headquarters.

Plaid then weaves the Red, Yellow, Blue, and Green results together and publishes a monthly report.

How should the Red, Yellow, Blue, and Green branches move their data to Plaid Corp headquarters? What factors (start with data size, distance, bandwidth) affect the decision?

How else could you move big datasets?

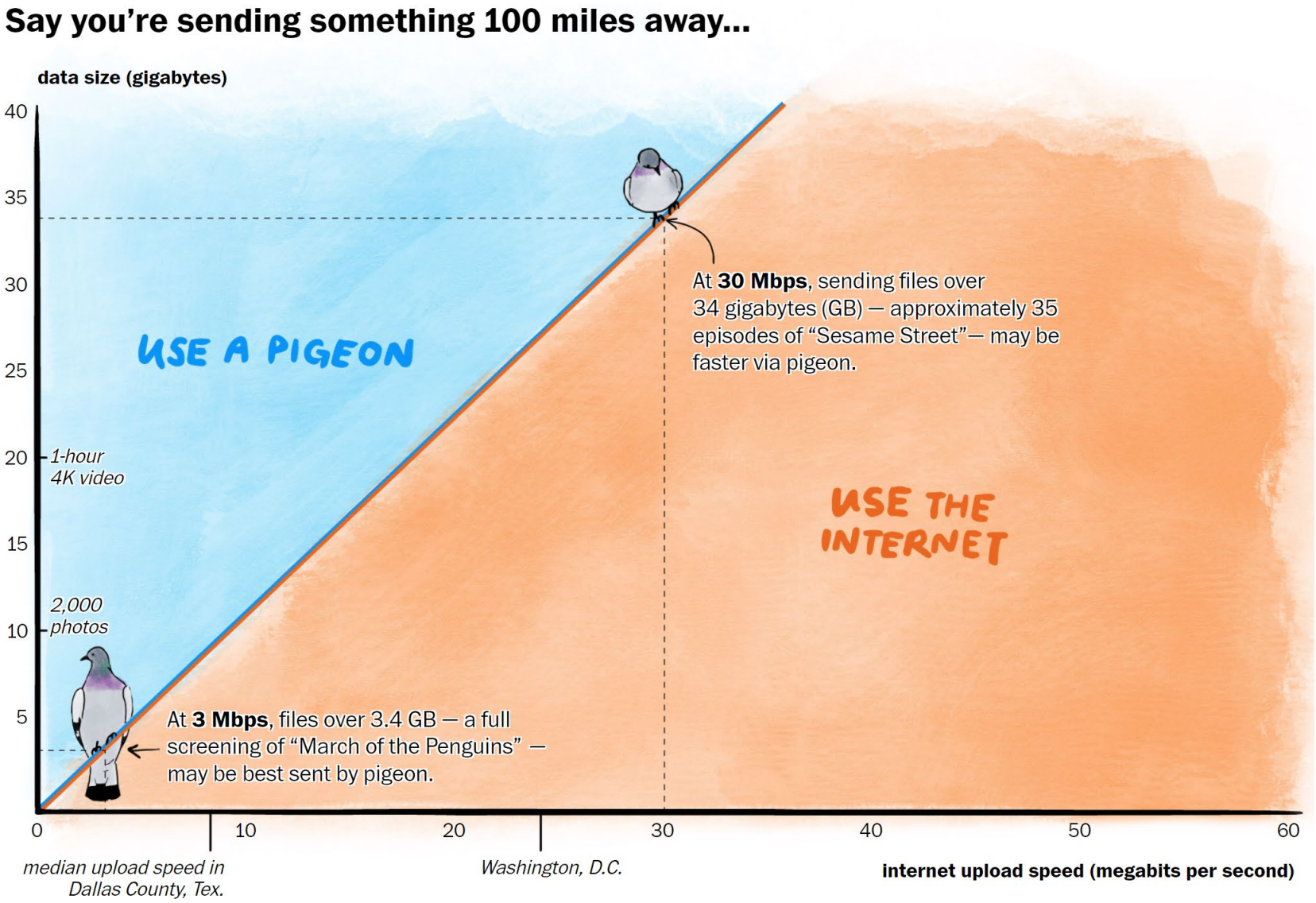
Pigeons

Sneakernet

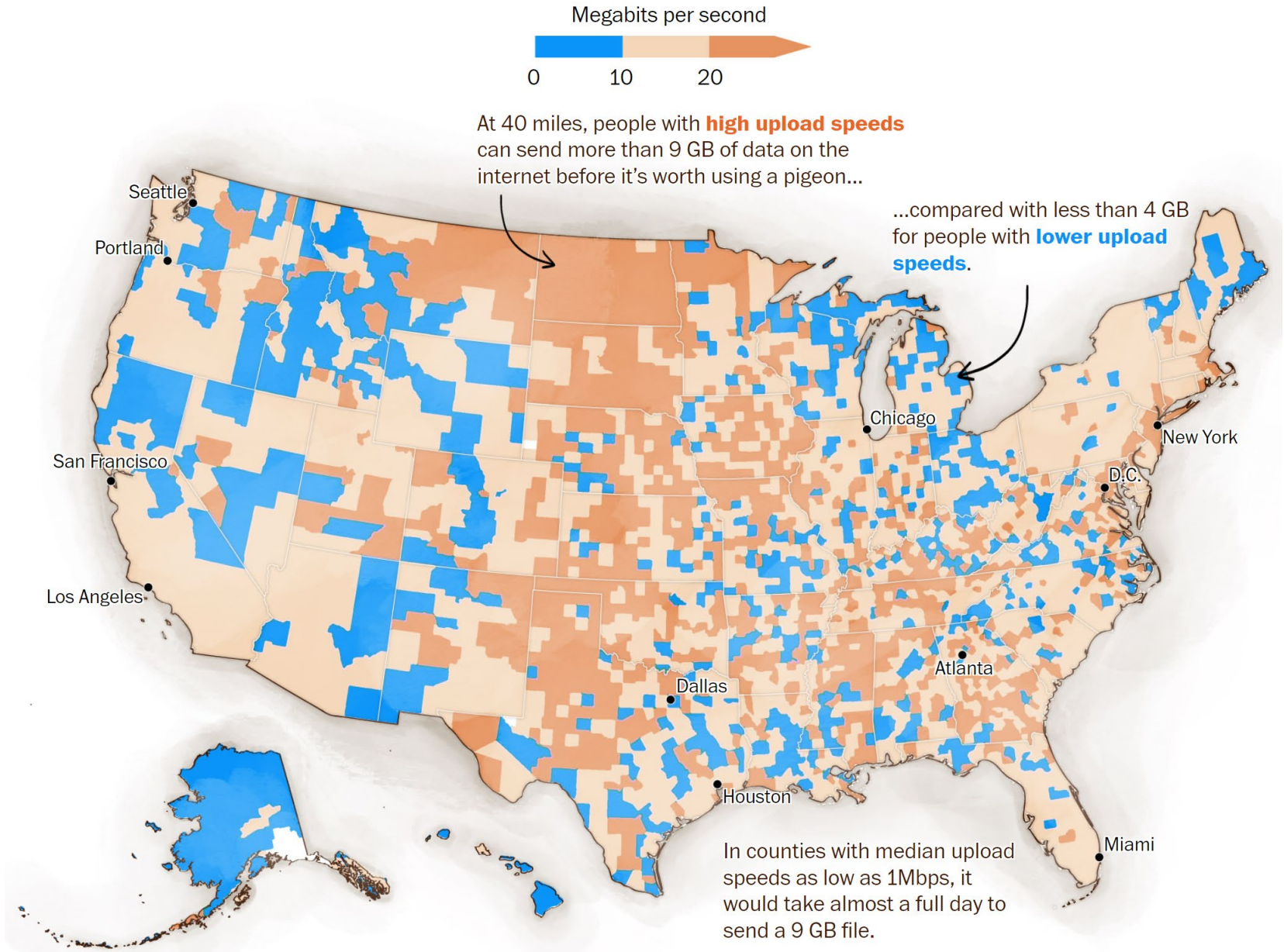
Trucks

Pigeons are still (sometimes) faster than your internet

https://www.washingtonpost.com/technology/2023/11/10/pigeons-are-faster-than-your-internet/



Lest you think everyone has gigabit connections …



Sneakernet

Alt text:
Every time you email a file to yourself so you can pull it up on your friend's laptop, Tim Berners-Lee sheds a single tear.

From September 2011

https://www.explainxkcd.com/wiki/index.php/949:_File_Transfer

Sneakernet

Never underestimate the bandwidth of a station wagon full of tapes hurtling down the highway.

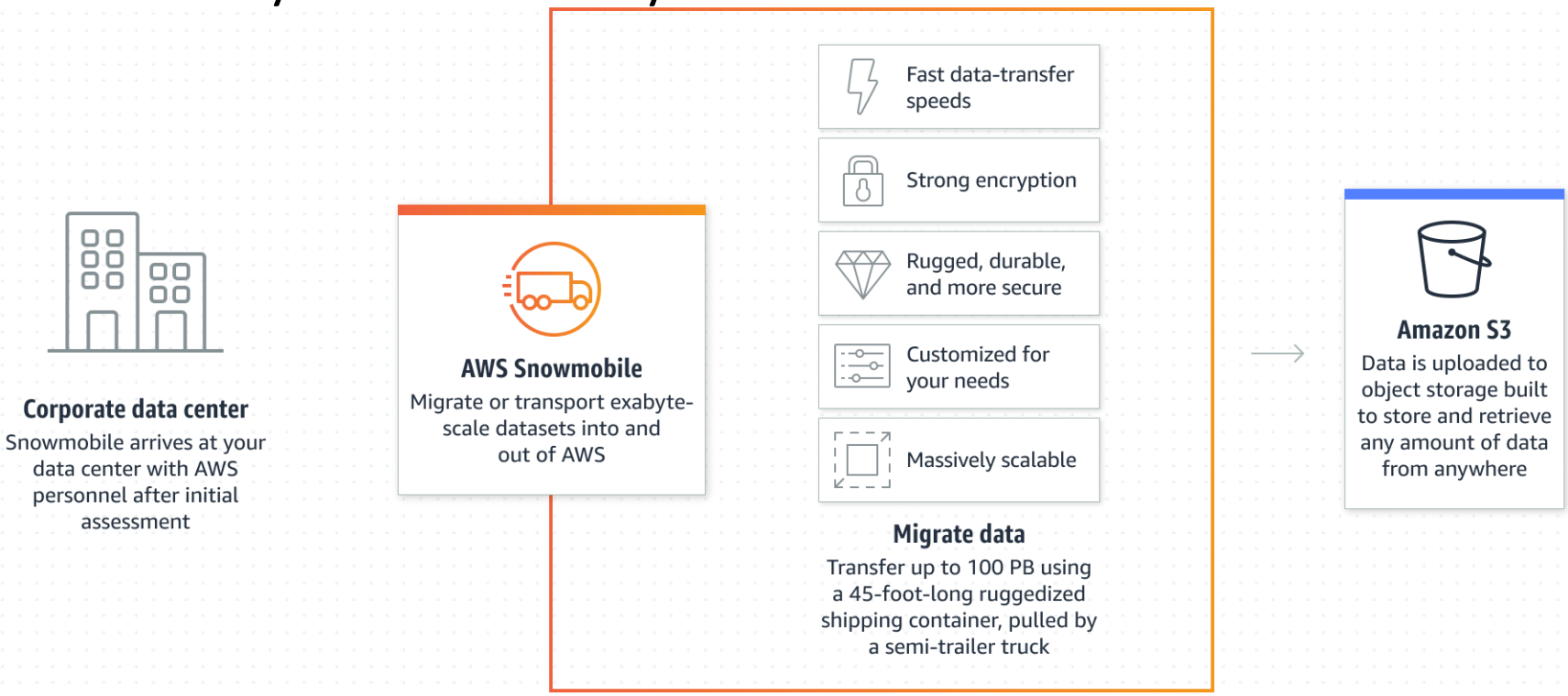
–Andrew Tanenbaum, 1981

The bandwith of the Internet will surpass FedEx in 2040

https://what-if.xkcd.com/31/

Trucks: AWS Snowmobile https://aws.amazon.com/snowmobile/

A shipping container that can hold up to 100 petabytes of data — that's 20 billion iPhone photos. Even with very fast internet speeds, 100 petabytes would take decades to upload to the internet. Trucking that data across the country would take only a matter of days.



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Any other ideas?

Using design spaces to compare designs

Road System

- High-level organization
  - ## Intersections — AD
  - ## Roads
  - ## **Network** — AD IN
- Intersections
  - ## **Collection of signals** — IN
  - ## Signals and sensors in approaches — MB
  - ## Have roads (with lights and cars) — AD
- Roads
  - Lanes
    - ## No lanes
    - ## Lanes, with signal per lane — AD IN
  - Throughput
  - Capacity — AD
  - Latency — IN MB
- Connection of roads to intersections
  - ## Intersections have queues (roads) — AD
  - ## Lights and sensors in approaches — MB
  - ## Unspecified or unclear — IN
  - ## Simulator handles interaction

Traffic Signals

- Place in hierarchy
  - ## Belong to roads — AD
  - ## Belong to intersections — IN
  - ## Belong to approaches, which connect roads to ints — MB
- **Safety**
  - ## Independent lights with safety checks
    - ##Controller checks dynamically — AD IN
    - ## UI checks at definition time — MB
  - ## One set per intersection, selected from safe set
- Relations among intersections
  - ## Independent — AD
  - ## **Synchronized** — IN MB
- Setting timing
  - ## System sets timing — AD IN MB
  - ## **Students set timing** — MB
- Sensors
  - ## Immediately advance on arrival — IN
  - ## **Wait to synchronize**

Mary Shaw. The role of design spaces. IEEE Software, vol. 29, no. 1, pp. 46- 50, Jan.-Feb. 2012, doi: 10.1109/MS.2011.121.

Using design spaces to capture domain knowledge

Style	Constituent parts		Control issues			Data issues				Control/data interaction		Type of reasoning
	Components	Connectors	Topo-logy	Synch-ronicity	Binding time	Topo-logy	Contin-uity	Mode	Binding time	Isomorphic shapes	Flow directions	
Data-centered repository styles: Styles dominated by a complex central data store, manipulated by independent computations												Data integrity
Transactional data-base [Be90, Sp87]	memory, computations	trans. streams (queries)	star	asynch, opp	w	star	spor lvol	shared, passed	w	possibly	if isomorph-ic, opposite	ACID[5] properties
•Client/server	managers, computations	transaction opns with history[3]	star	asynch.	w, c, r	star	spor lvol	passed	w, c, r	yes	opposite	
Blackboard [Ni86]	memory, computations	direct access	star	asynch, opp	w	star	spor lvol	shared, mcast	w	no	n/a	convergence
Modern compiler [SG96]	memory, computations	procedure call	star	seq	w	star	spor lvol	shared	w	no	n/a	invariants on parse tree

Key to column entries	
Topology	hier (hierarchical), arb (arbitrary), star, linear (one-way), fixed (determined by style)
Synchronicity	seq (sequential, one thread of control), ls/par (lockstep parallel), synch (synchronous), asynch (asynchronous), opp (opportunistic)
Binding time	w (write-time--that is, in source code), c (compile-time), i (invocation-time), r (run-time)
Continuity	spor (sporadic), cont (continuous), hvol (high-volume), lvol (low-volume)
Mode	shared, passed, bdcast (broadcast), mcast (multicast), ci/co (copy-in/copy-out)

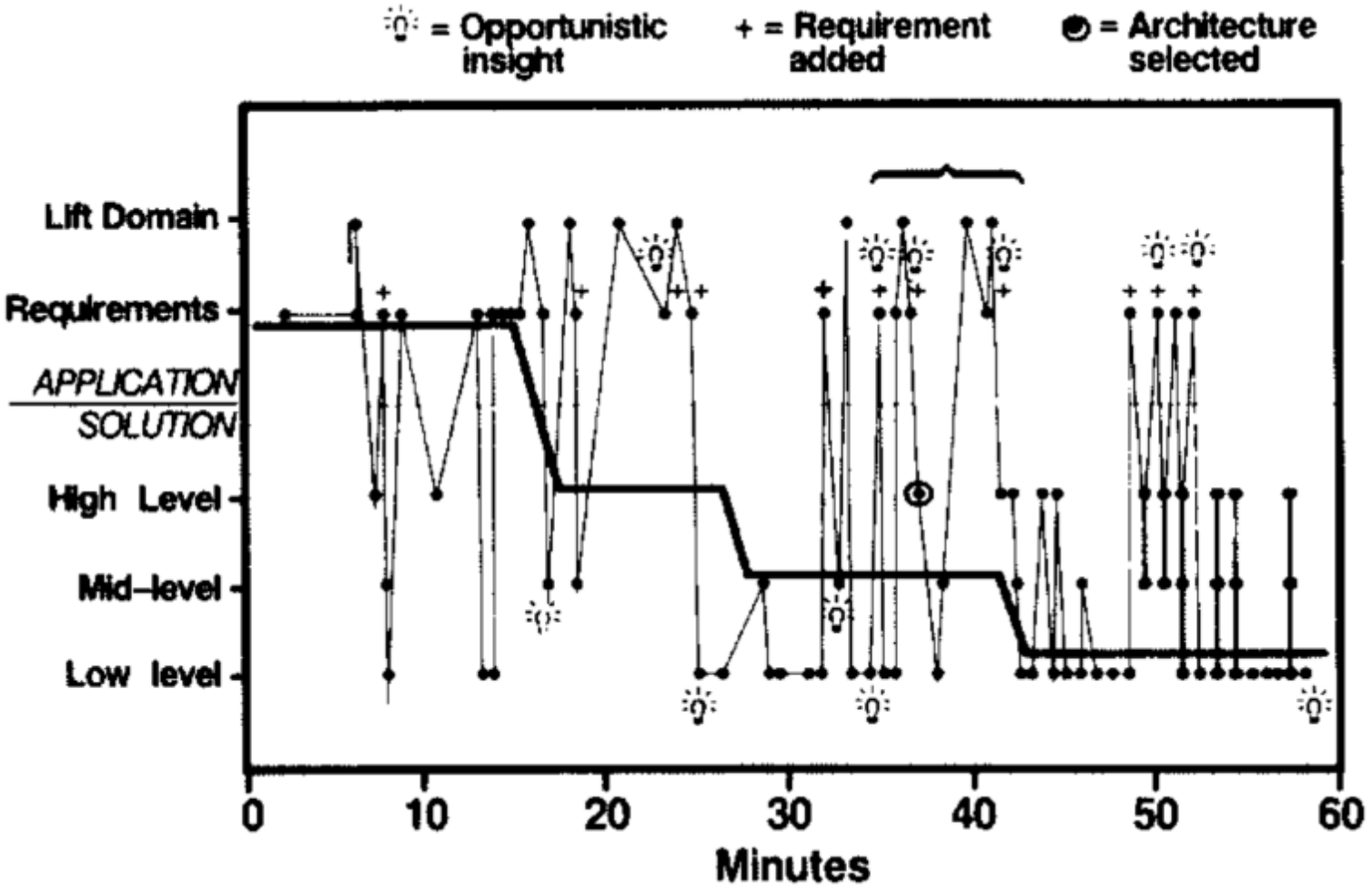
Mary Shaw and Paul Clements. A field guide to boxology: Preliminary classification of architectural styles for software systems. Proc. COMPSAC97, 21st Int'l Computer Software and Applications Conference, August 1997, pp.6–13. doi: 10.1109/CMPSAC.1997.624691

Using design spaces to recommend design choices

1. **Functional dimensions.** These represent the system requirements that are significant in choosing a structure.
   (a) **External requirements.** This group includes requirements of the particular applications, users, and I/O devices, as well as constraints imposed by the surrounding computer system.
   (b) **Basic interactive behavior.** This group includes the key decisions about user interface behavior that fundamentally influence internal structure.
   (c) **Practical considerations.** This group covers development cost considerations; primarily, the required degree of adaptability of the system.
2. **Structural dimensions.** These represent the design alternatives available to satisfy system requirements.
   (a) **Division of functions and knowledge between modules.** This group considers how system functions are divided into modules, the interfaces between modules, and the information contained within each module.
   (b) **Representation issues.** This group considers the representations used for user-interface-related data, including both actual application data (input and output values) and meta-data such as the definition of the user interface.
   (c) **Control flow, communication, and synchronization issues.** This group considers the dynamic behavior of the user interface code.

Thomas G. Lane. User Interface Software Structures. PhD thesis, Carnegie Mellon University, May 1990.

Using design spaces for evolving understanding of task



Guindon, R. Designing the Design Process: Exploiting Opportunistic Thoughts. Human-Computer Interaction, 5, 305-344. doi: 10.1207/s15327051hci0502&3_6

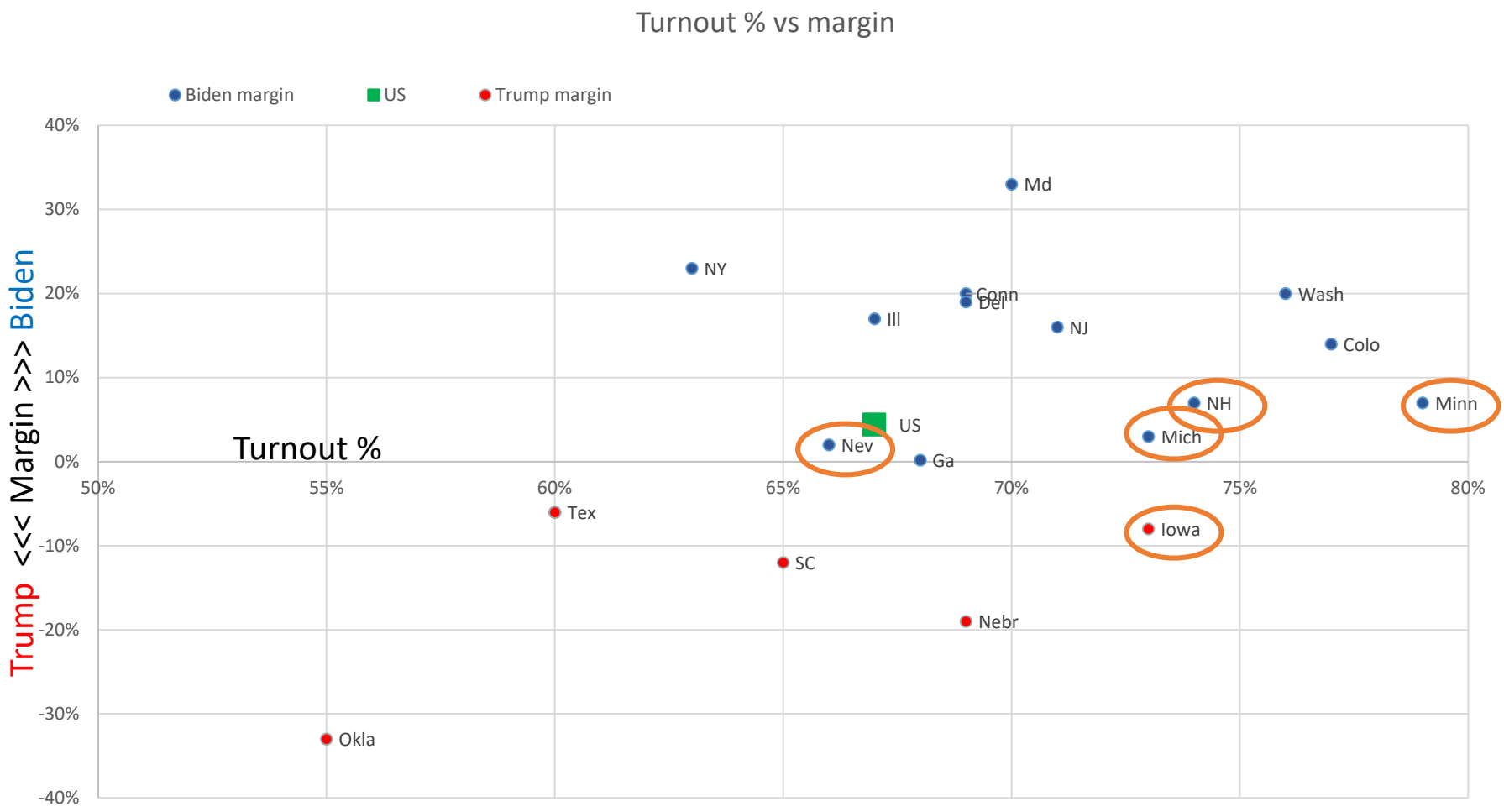
Bill Curtis. Insights from empirical studies of the software design process. Future Generation Computer Systems, Volume 7, Issues 2–3, 1992, pp 139-149, ISSN 0167-739X, doi: 10.1016/0167-739X(92)90002-S

Using design spaces for tightly coupled decisions

In US elections, which five states should have early primaries?

- 18 states applied to be early; there 8,568 sets of five.
- What factors should be considered?

https://www.washingtonpost.com/politics/interactive/2023/democratic-primary-calendar-builder-tool/


Turnout % vs margin
Biden margin
US
Trump margin
Trump <<< Margin >>> Biden
Turnout %
40%
30%
20%
10%
0%
-10%
-20%
-30%
-40%
50%
55%
60%
65%
70%
75%
80%
Md
NY
Conn
Del
Wash
Ill
NJ
Colo
NH
Minn
US
Mich
Nev
Ga
Tex
Iowa
SC
Nebr
Okla

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Exit ticket

Your grandparents have smartphones but no home computer. How would you send them each of the following? Why?

greetings on their 40th anniversary
(what if you just remembered it's today?)

a photo of you winning the CMU Mobot competition

the 824 photos you took on your trip home over the holiday