Data visualization and financial stability

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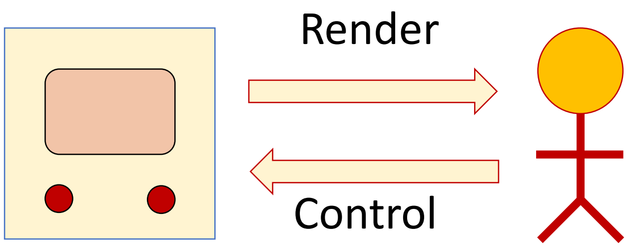
Course on Financial Stability

Mexico City, 18 September 2019

What is data visualization?

Visualization as a human-computer interface

- **Cognitive amplification to exploit the strengths of human perception**
  - **Humans as pattern recognizers**
  - **“A picture is worth 1,000 words”**



- **Core Functionality**
  - **Visual rendering of data – computer presents to the (human) user**
    - **Typically 2-dimensional**
    - **3-dimensional (even multimedia) data renderings are possible**
  - **User interaction – user controls the computer**
    - **Zoom**
    - **Filter**
    - **Details on demand**

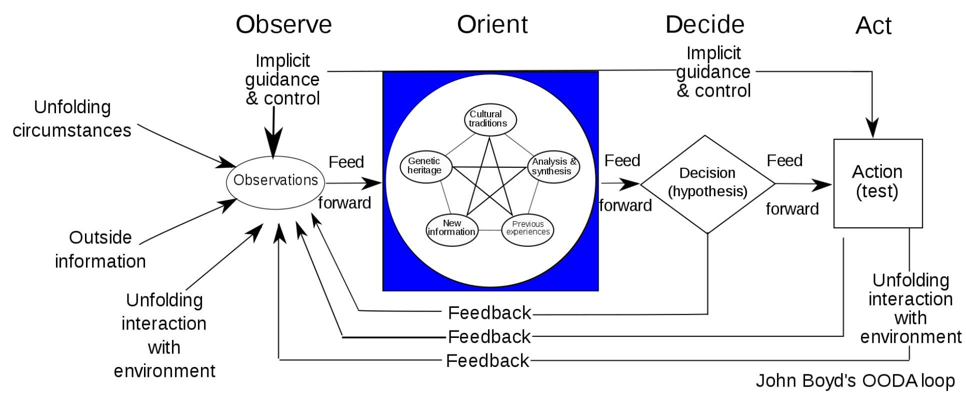
Classification of data visualization techniques

	Non-interactive	Interactive
Static	**No user input after initial rendering, and image does not change. “Fixed.”** *Example: Newspaper infographic*	**Ongoing user input, but rendering does not change between input events.** *Example: Spreadsheet chart*
Dynamic	**No user input after initial rendering, but image may change.** *Example: Animated GIF*	**Ongoing user input, and rendering may change between input events.** *Example: Video game*

Institutional context for visualization

Core functions of visualization

- **Sensemaking**
  - Data exploration
  - Trial-and-error analytics
  - Compressed decision iterations
- **Decision-making**
  - Formal authority
  - Common knowledge requirement
  - Agendas and minutes
- **Rulemaking**
  - Formal authority
  - Laws, regulations, interpretations
  - Notice and comment
- **Transparency**
  - Audience-specific renderings
  - Common knowledge requirement
  - Emphasize facts over interpretations

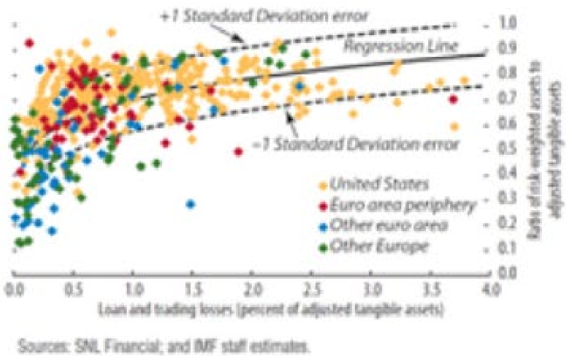


Sensemaking Paradigm

Observe–Orient–Decide–Act (OODA)

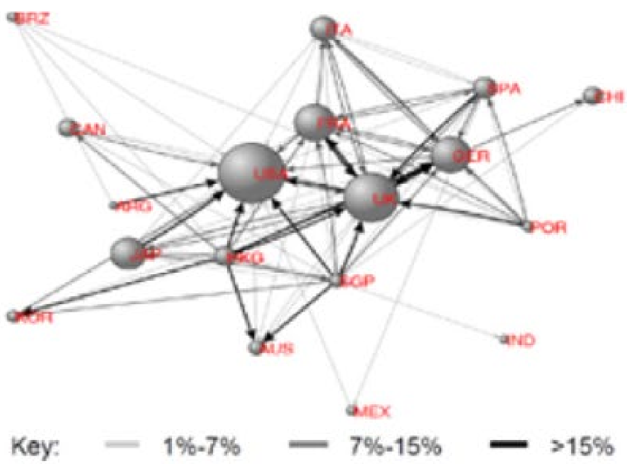
Image: Wikipedia

Common types of financial data

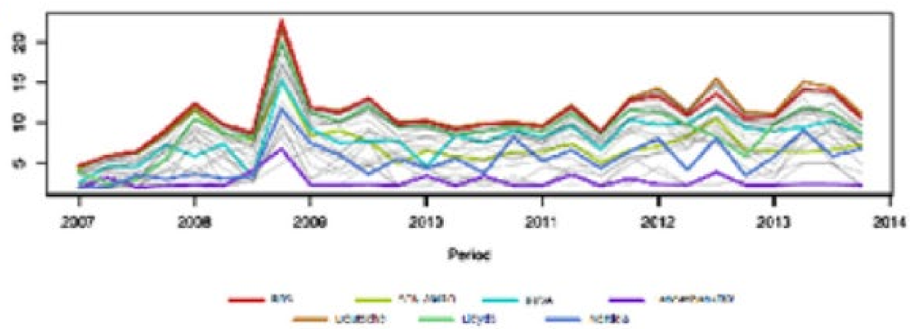


Numeric
IMF (2013)

Geographic
Federal Reserve (1932)



Network
Kubelec and Sá (2012)



Textual
Rönnqvist and Sarlin (2014)

Interactive visualization

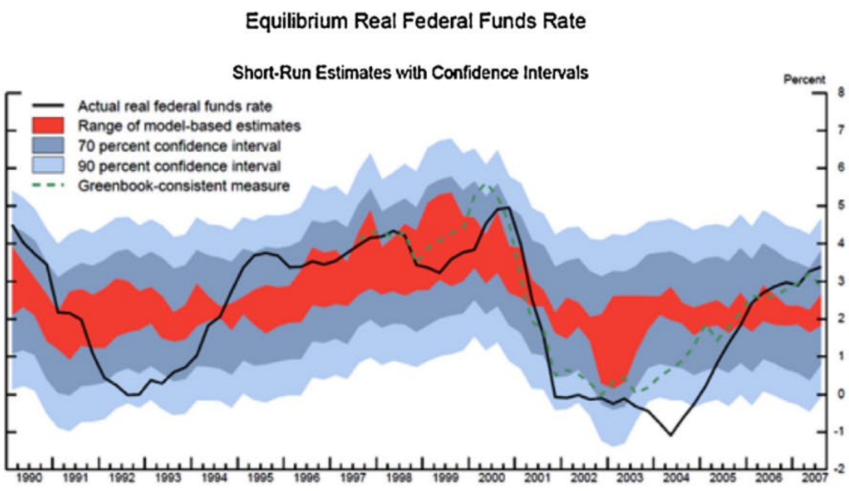
Putting the human "in the loop"

- Shneiderman's (1996) seven data types:

1. **One-dimensional**
   - "Linear" data – e.g., text documents, source code, alphabetical lists
2. **Two-dimensional**
   - Planar data – e.g., geographic maps, floor plans, document layout
3. **Three-dimensional**
   - Real-world objects – e.g., molecules, anatomy, buildings
4. **Temporal**
   - Specialization of one-dimensional data, with a time-series history
5. **Multidimensional**
   - Data as points in *n*-space – e.g., relational and statistical databases
6. **Tree**
   - Simple hierarchies, with one parent for each child node
7. **Network**
   - Graph structures with arbitrary connections between nodes

Visualization for decision-making

- **Federal Open Market Committee (FOMC)**
  - **Decisions on short-term monetary policy**
  - **Confidential briefing materials ("Bluebook"), September 2007**
  - **Absence of interpretation or narrative**
  - **Emphasis on uncertainty, both historical and forward-looking**



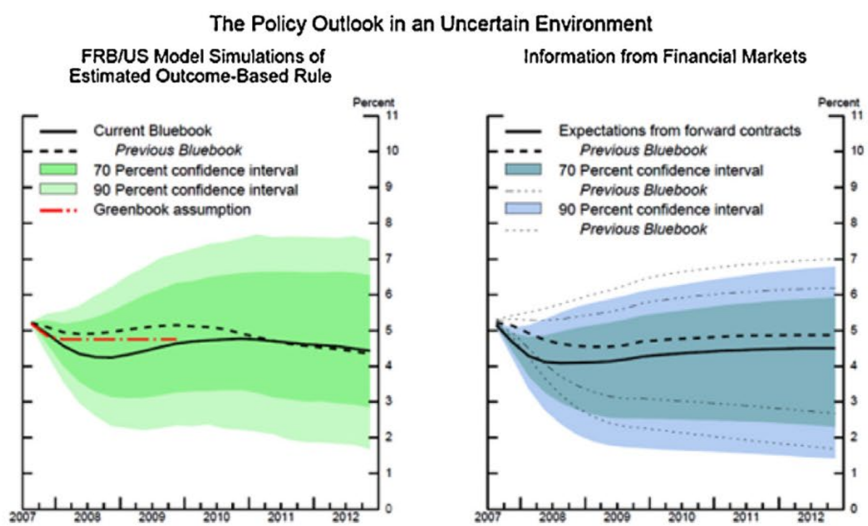
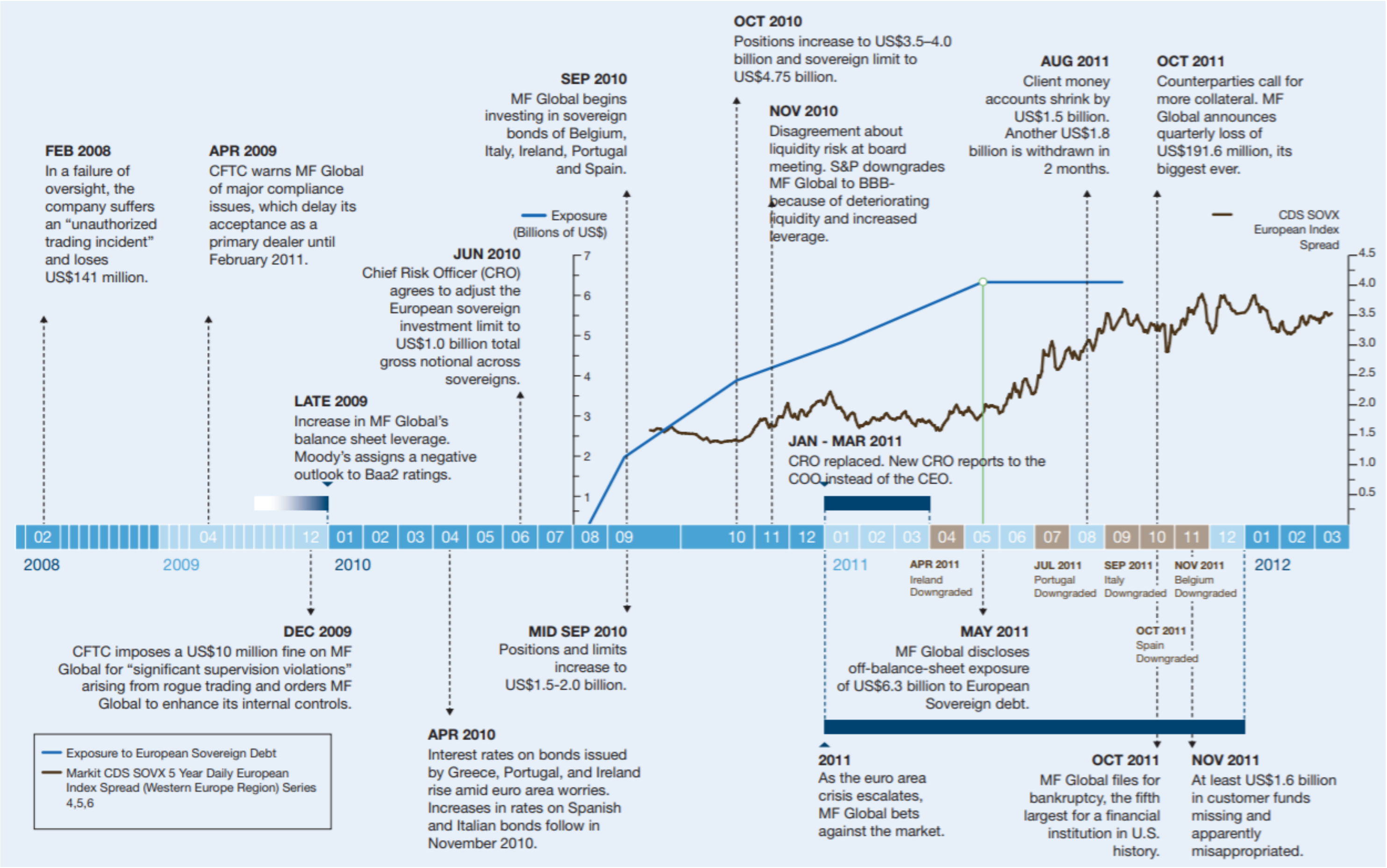


Image: Federal Reserve

Visualization for transparency

- **Narrative visualization**

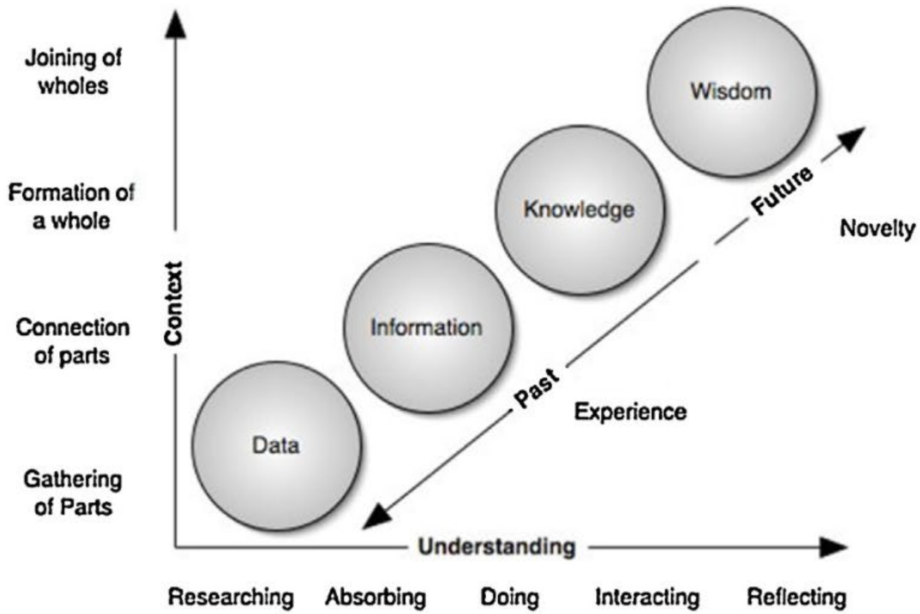


The Lead-Up to the Collapse of MF Global Holdings Ltd.

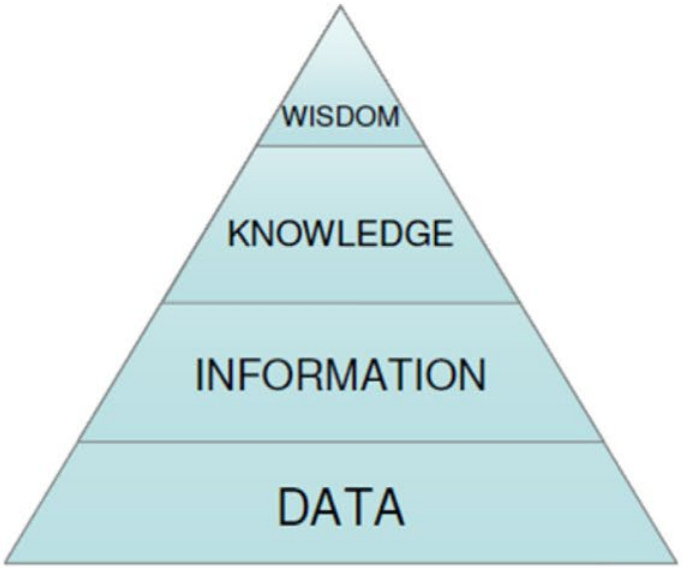
OFR Annual Report (2014)

Data – Information – Knowledge – Wisdom (DIKW)

- **Two views of the DIKW transformation**
  - **Data** – raw observations, typically factual
  - **Information** – data augmented with meaning and/or interpretation
  - **Knowledge** – information in context (cultural, historical, organizational)
  - **Wisdom** – abstracted, effective understanding of patterns in knowledge



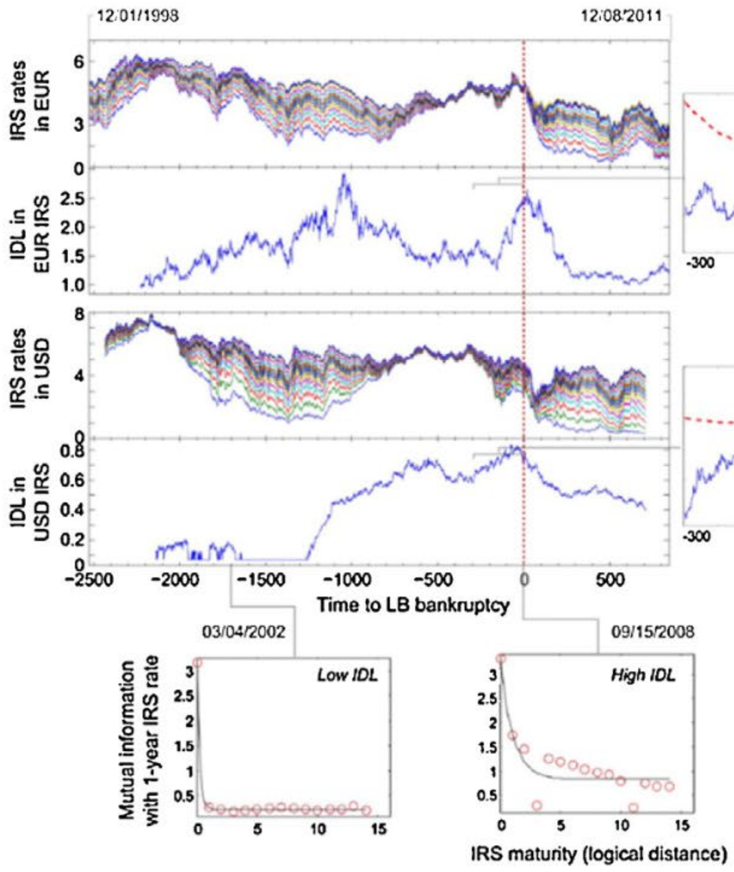
Progressing to Wisdom (Clark, 2010)



Winnowing to Wisdom (Hey, 2004)

Visualizations for diverse purposes – time series data

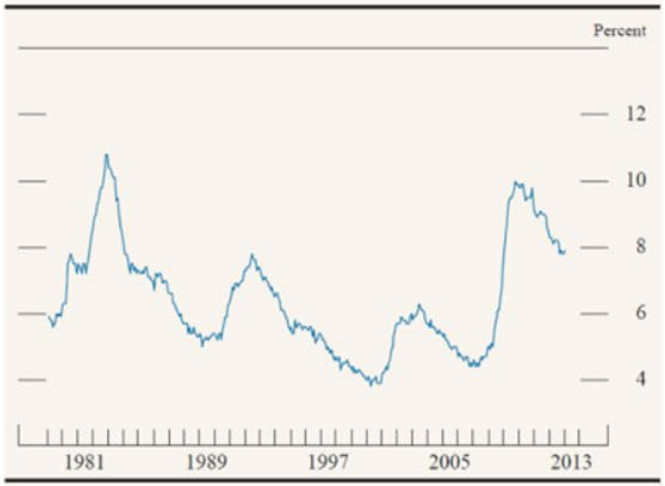
Sensemaking



Foreign exchange and interest rates

[Quax, et al., (2013)](#)

Transparency

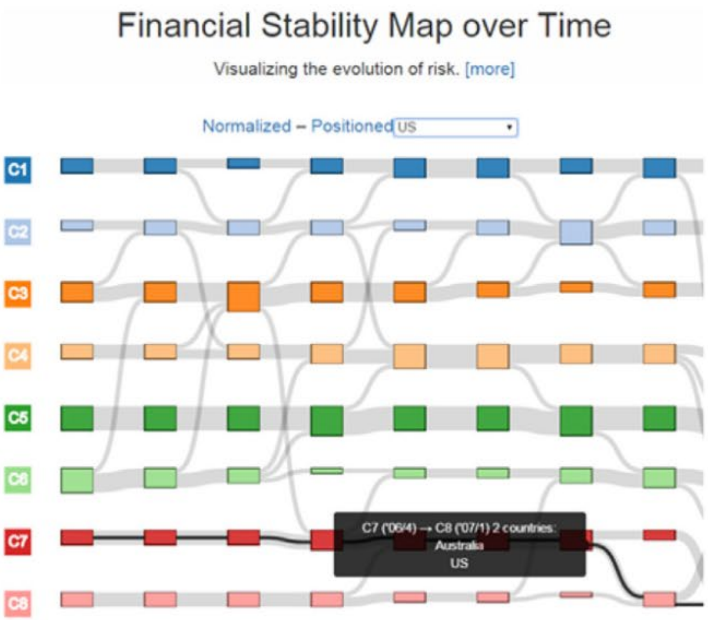


Civilian unemployment rate

[Federal Reserve (2013)](#)

Visualizations for diverse purposes – financial stability maps

Sensemaking



Self-organizing financial stability map
VisRisk (2015)

Transparency

Financial Stability Monitor
Office of Financial Research (2015)

Interactive visualization

Interactive types for the human "in the loop"

- Shneiderman's (1996) ***Mantra***

"Overview first, zoom and filter, then details-on-demand"

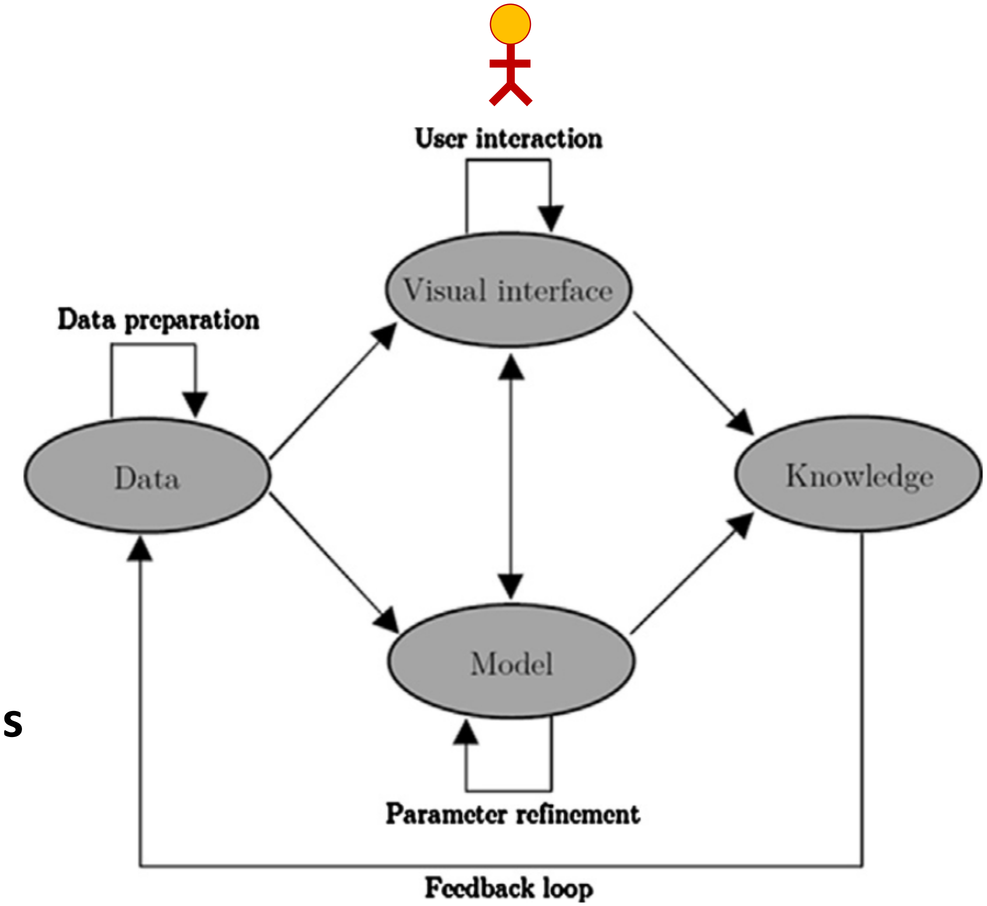
The seven tasks:

1. **Overview**
   - Gain an overview of the entire collection
2. **Zoom**
   - Zoom in on items of interest
3. **Filter**
   - Filter out uninteresting items
4. **Details-on-demand**
   - Select an item or group and get details when needed
5. **Relate**
   - View relationships among items
6. **History**
   - Keep a history of actions to support undo, replay, and progressive refinement
7. **Extract**
   - Allow extraction of sub-collections and of the query parameters

Visual analytics

Formalizing visual interaction

- Analytical reasoning – facilitated by interactive visual interfaces
- Combines:
  - Interactive visualization
  - Automated analysis
- Exploits:
  - Human visual perception
  - Expert judgment
- Rapid-feedback, iterative analysis
  - Software-assisted
  - Requires development of a software model

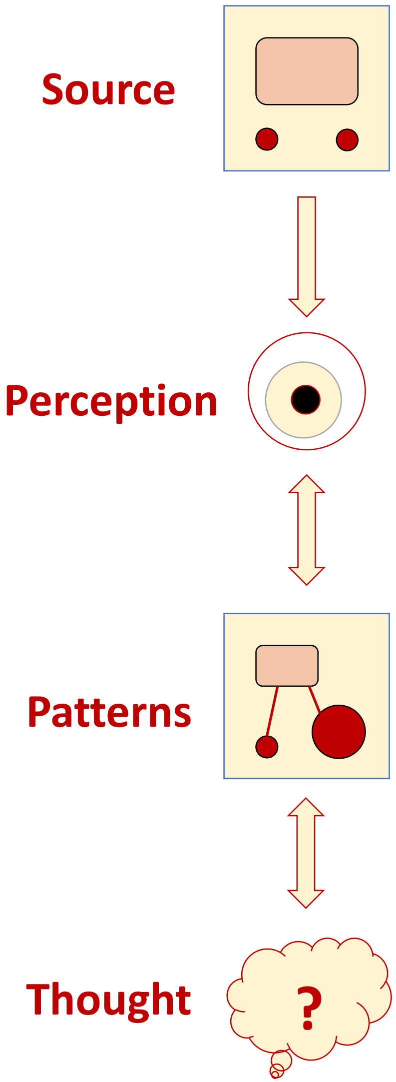


Human "in the loop" analysis
Sarlin (2016)

Perceptual Processing

Three levels of human perception

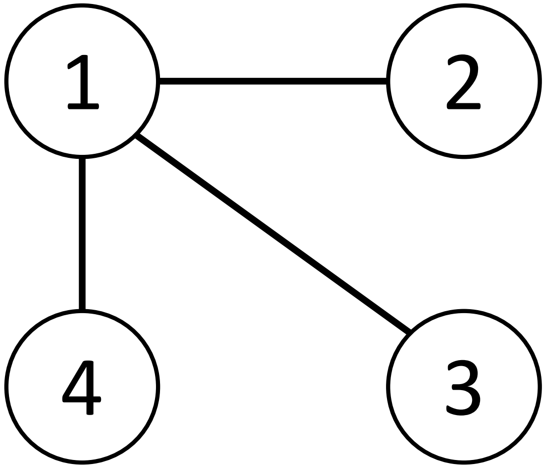
1. **Pre-attentive perception**
   - Rapid parallel processing
   - Basic feature extraction
     - Color, texture, orientation, movement, etc.
   - Transitory storage – very short term – of visual cues
   - Bottom-up, involuntary processing
2. **Pattern perception**
   - Attentive activity
   - Slower serial processing
   - Identified patterns are "bound" for a few seconds
   - Top-down, partially voluntary attention management
3. **Visual working memory**
   - Active attention management
   - Search strategies and visual queries



Exploiting human perception

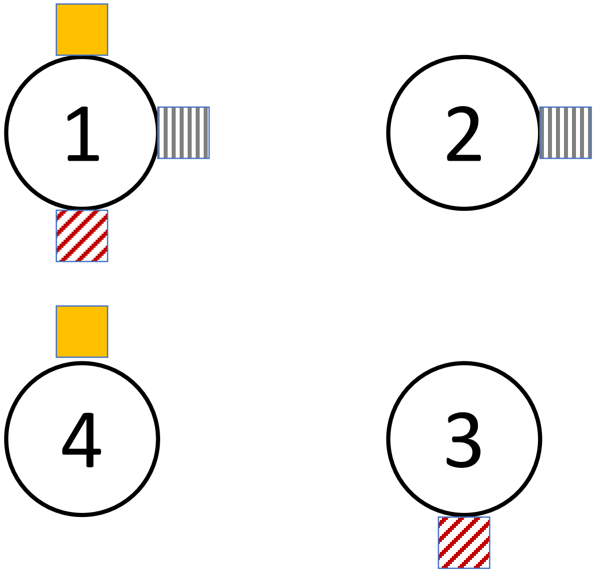
Example: Representing relationships

- **Connectedness is more powerful than:**
  - Proximity, matched color, matched size, matched shape



Continuous contours

Pre-attentive processing



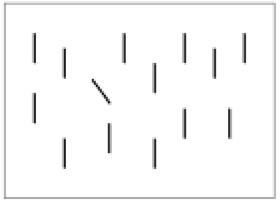
Symbolic indicators

Active interpretation needed

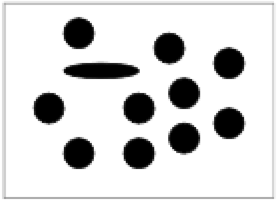
Pre-attentive features

Features with visual salience

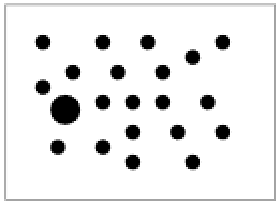
- Orientation



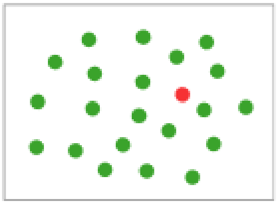
- Shape



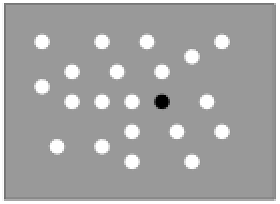
- Size



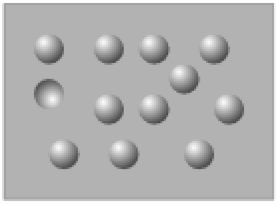
- Color



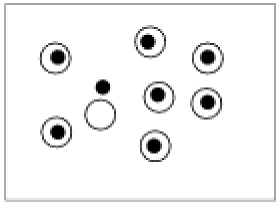
- Light/dark



- Convex/concave



- Enclosure



- Shape

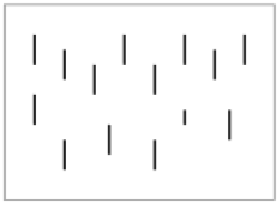
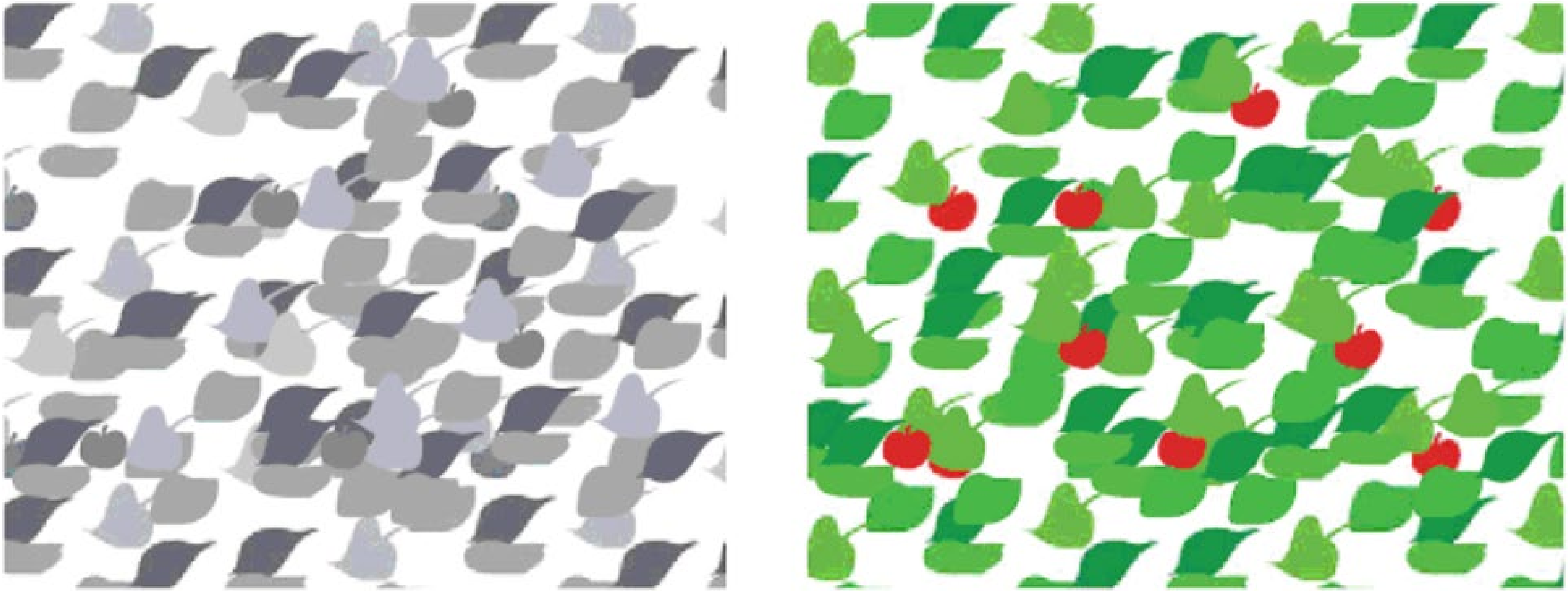


Image source: Ware (2013)

Exploiting human perception – Visual salience

Example: Color contrast "pops out"

- **Exploits pre-attentive channels for color**



Find the cherries in the tree

Image source: Ware (2013)

Visual salience failure

Find the orange square

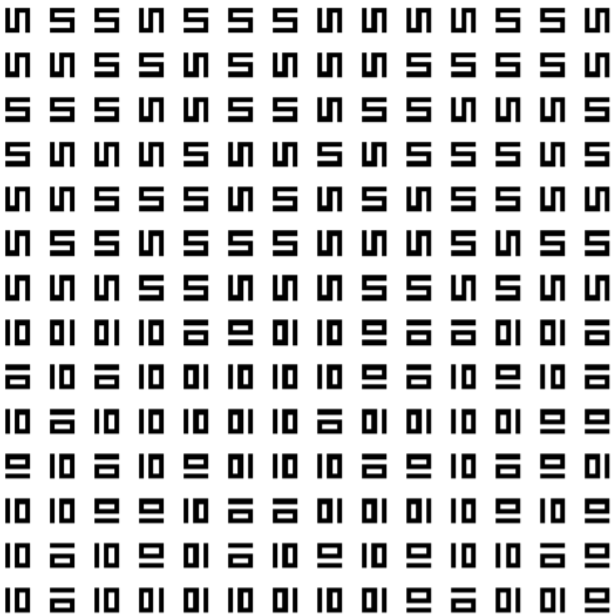
- **Competition for pre-attentive channels → sequential search**

Image source: Cross (2008)

Texture recognition

Some texture distinctions are available pre-attentively

- **Repetitive small-scale patterns in larger-scale regions**



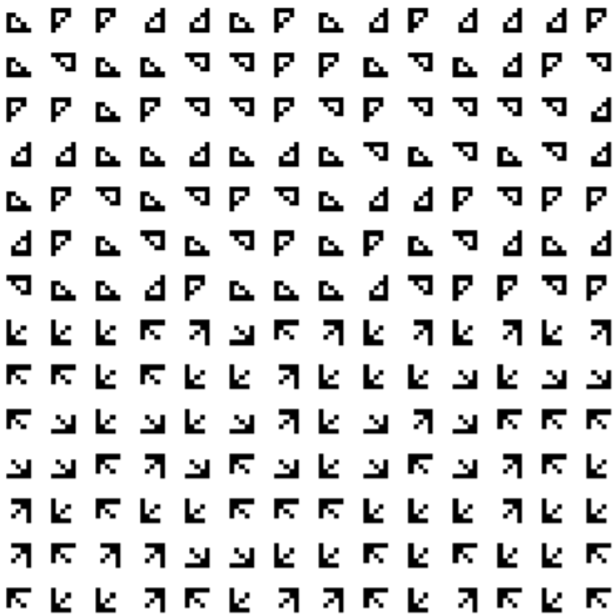
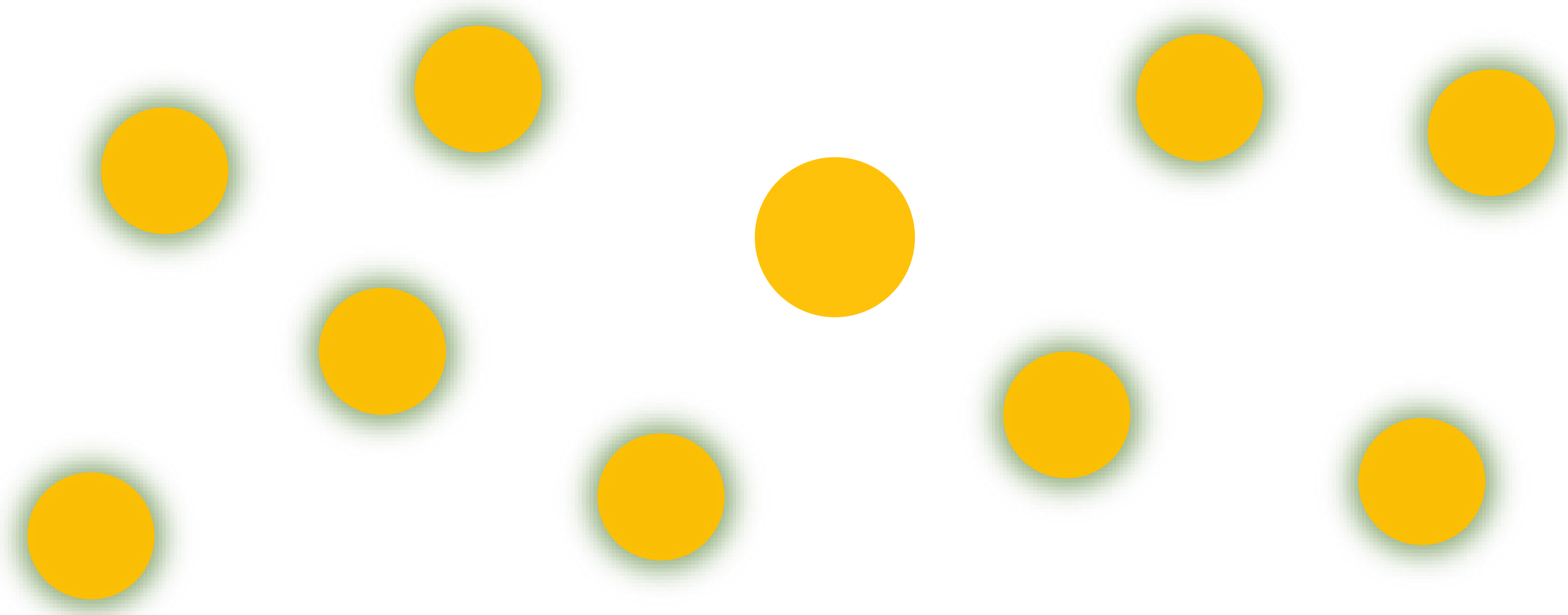


Image source: Tuceryan and Jain (1998)

Contour recognition

Distinction in edge sharpness focuses attention

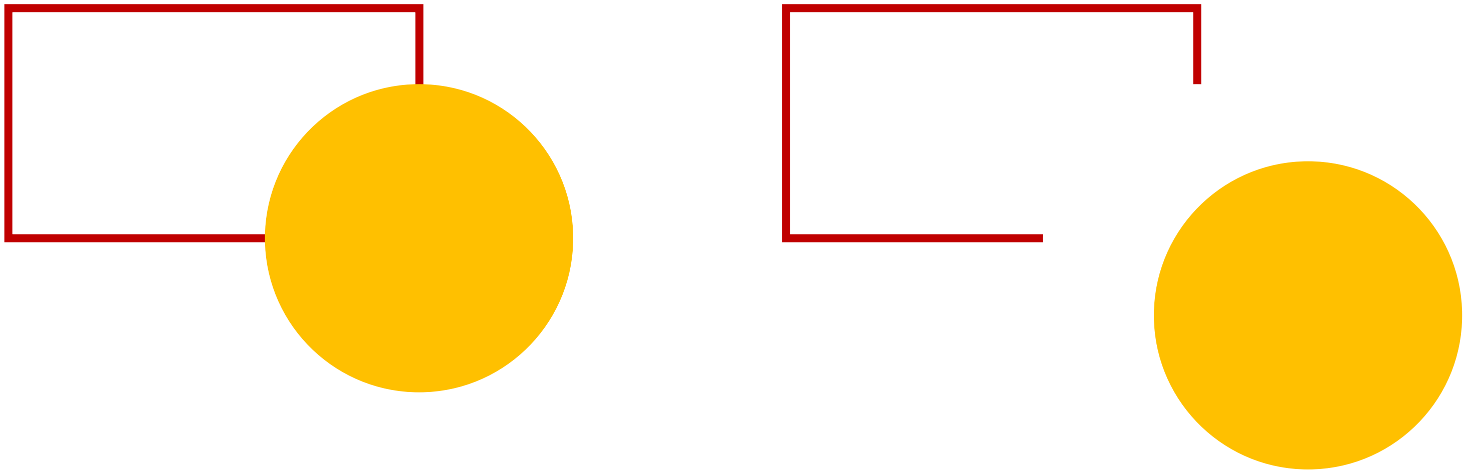
- **Sharpness is captured pre-attentively**



Gestalt perception

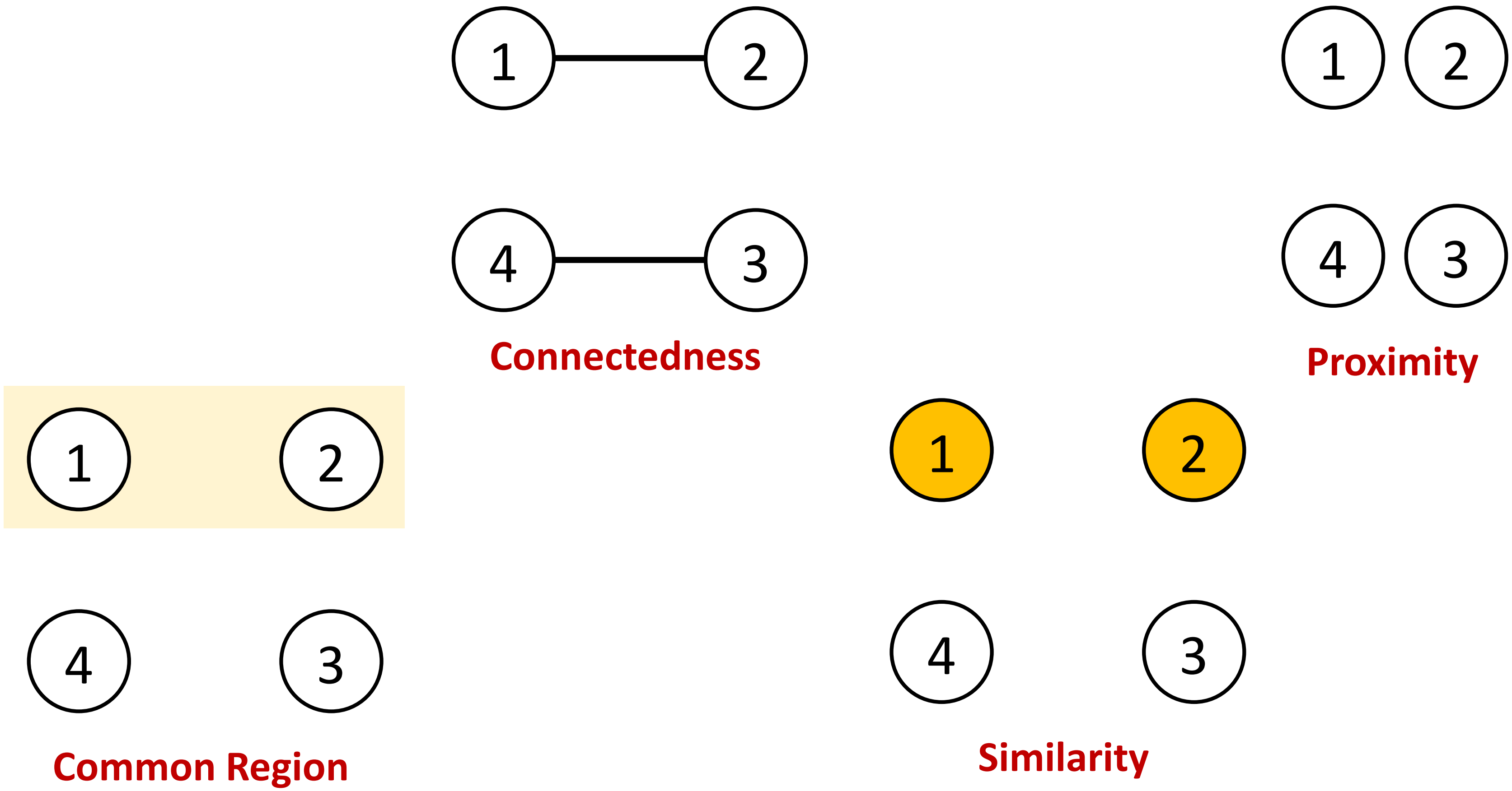
Does the yellow ball obscure a rectangle?

- **Closure: Inference of integral forms (even when absent)**



Gestalt mechanisms for pattern perception

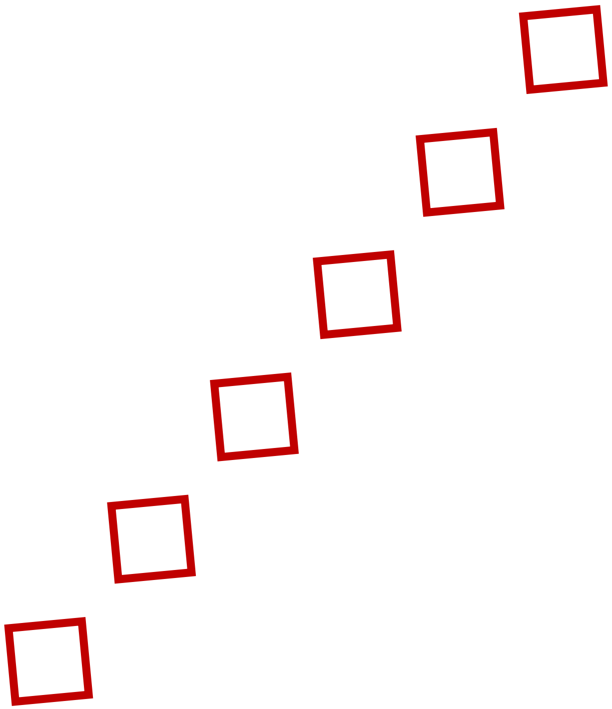
Connectedness dominates the other mechanisms



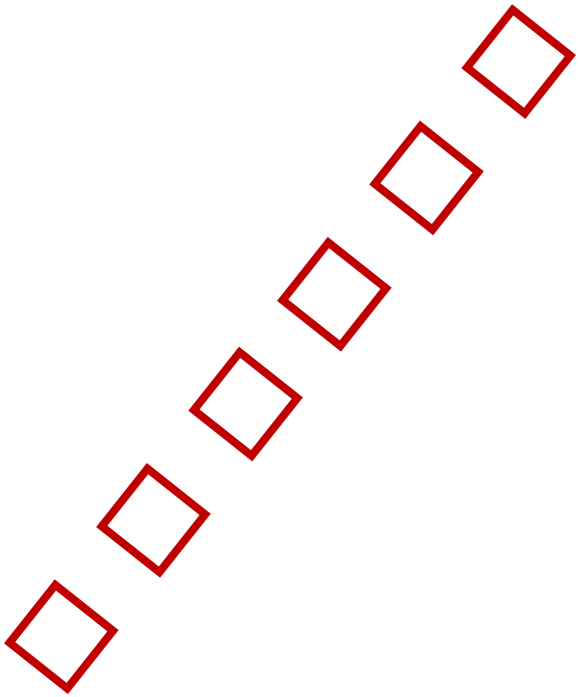
Gestalt symmetry and similarity

Similar shapes are grouped

- **Regular alignment creates an axis of symmetry**



Axis of Diamonds

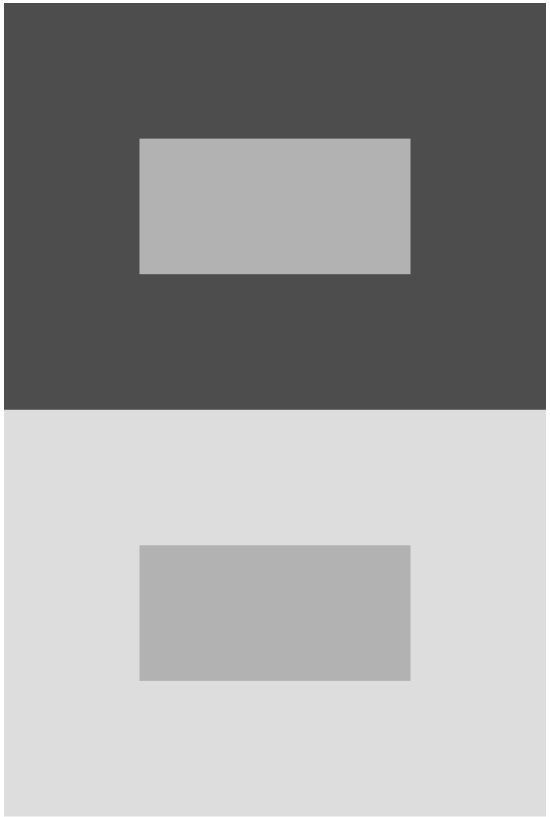


Axis of Squares

Lightness and Brightness

Measured versus perceived light

- **Luminance**
  - **Physically measured** amount of light
  - Emitted or reflected by a source
- **Brightness**
  - **Perceived** amount of light
  - Typically light **emitted** by a source
- **Lightness**
  - **Perceived** amount of light
  - Typically light **reflected** by a source

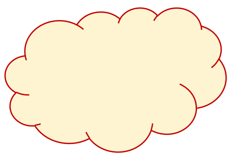


Simultaneous Brightness

Visual Semiotics

Study of symbols and their meaning

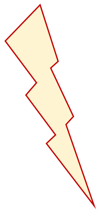
- How do "signs" create meaning?
  - Systems of signs are social constructs that impart meaning
- Signifier – physical representation that conveys meaning
  - Icon – signifier that resembles the signified
  - Symbol – signifier with no resemblance
  - Index – clue that only occurs in conjunction with the signified
- Signified – personal interpretation of a signifier
  - Paradigm – set of signifiers or signifieds with shared features or functionality
  - Syntagm – framework of relationships among the signifiers (for example, syntax of a language)
- Visual semiotics
  - Focus on visual signs
    - Color, texture, orientation, movement, etc.
    - Physical juxtaposition of signifiers on the page/screen



Icon

"CLOUD"

Symbol

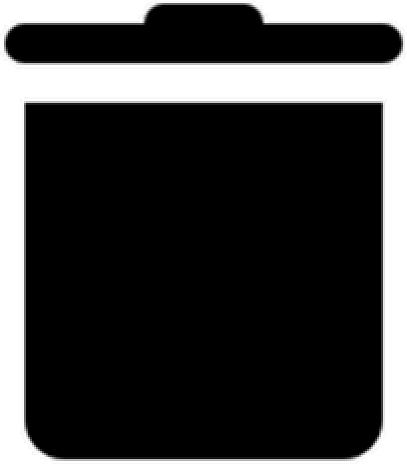


Index

Semiotics in practice

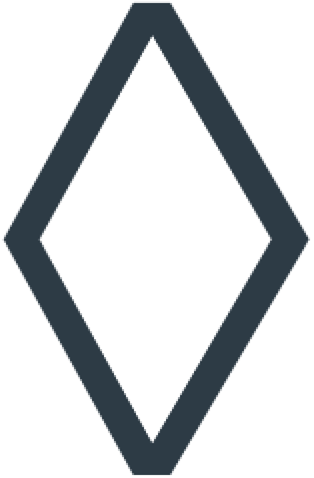
Mixing shape and meaning

- **Icons are representational – can carry socialized meaning**
    - Useful in pedagogical contexts, as a shorthand
- **Typographic glyphs are typically phonetic**
- **Abstract symbols are useful as neutral indicators of data**



“Delete” Icon

Typographic Glyph



Abstract Symbol

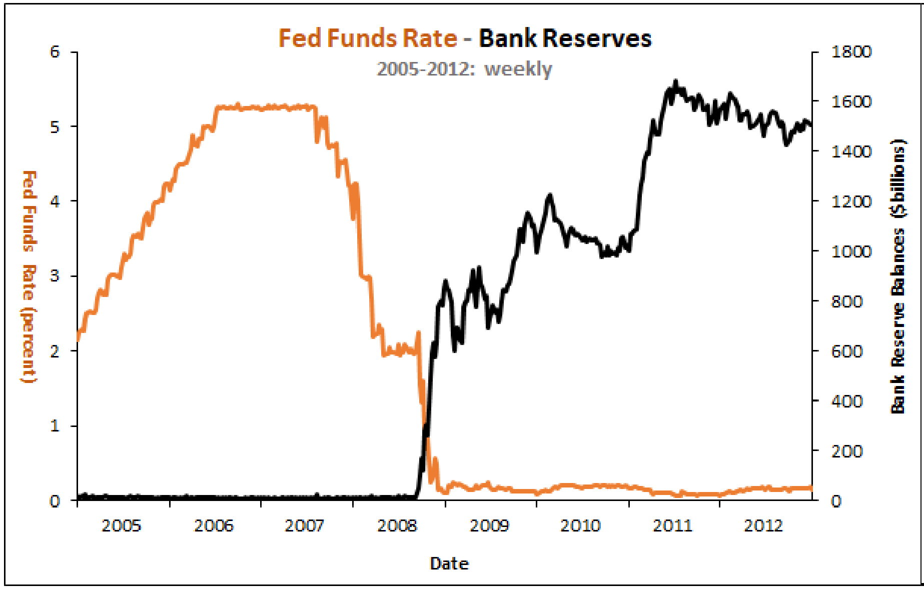
"Chart Junk"

Optimize the "signal-to-noise" ratio in your visualizations

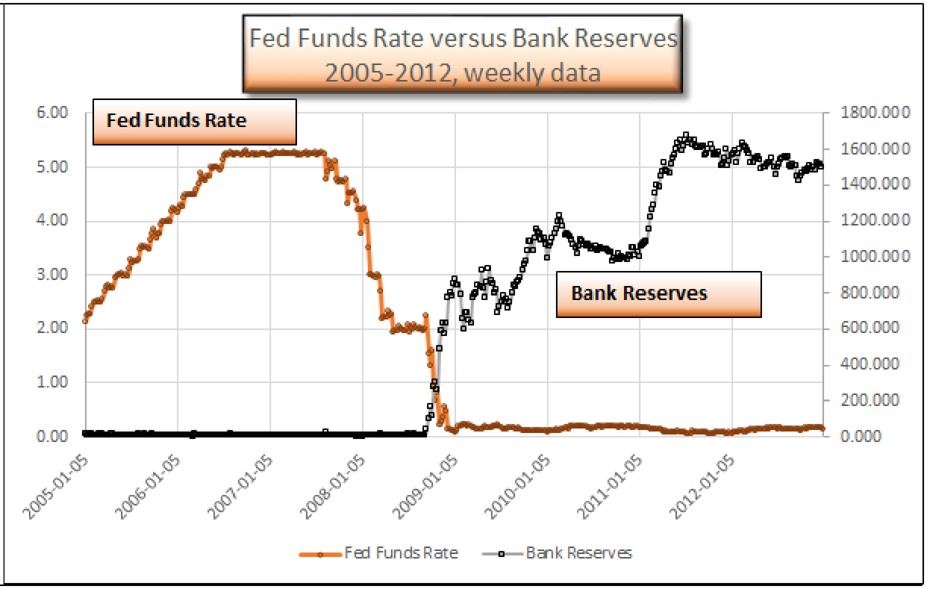
Every rendered element should convey a specific meaning

- **Data or metadata attributes**

- **When in doubt, omit it**
- **Volume of "ink" should be proportional to the importance of the element**
- **Fill the canvas – it is precious**
  - **Area is $O(x^2)$ for x = length**

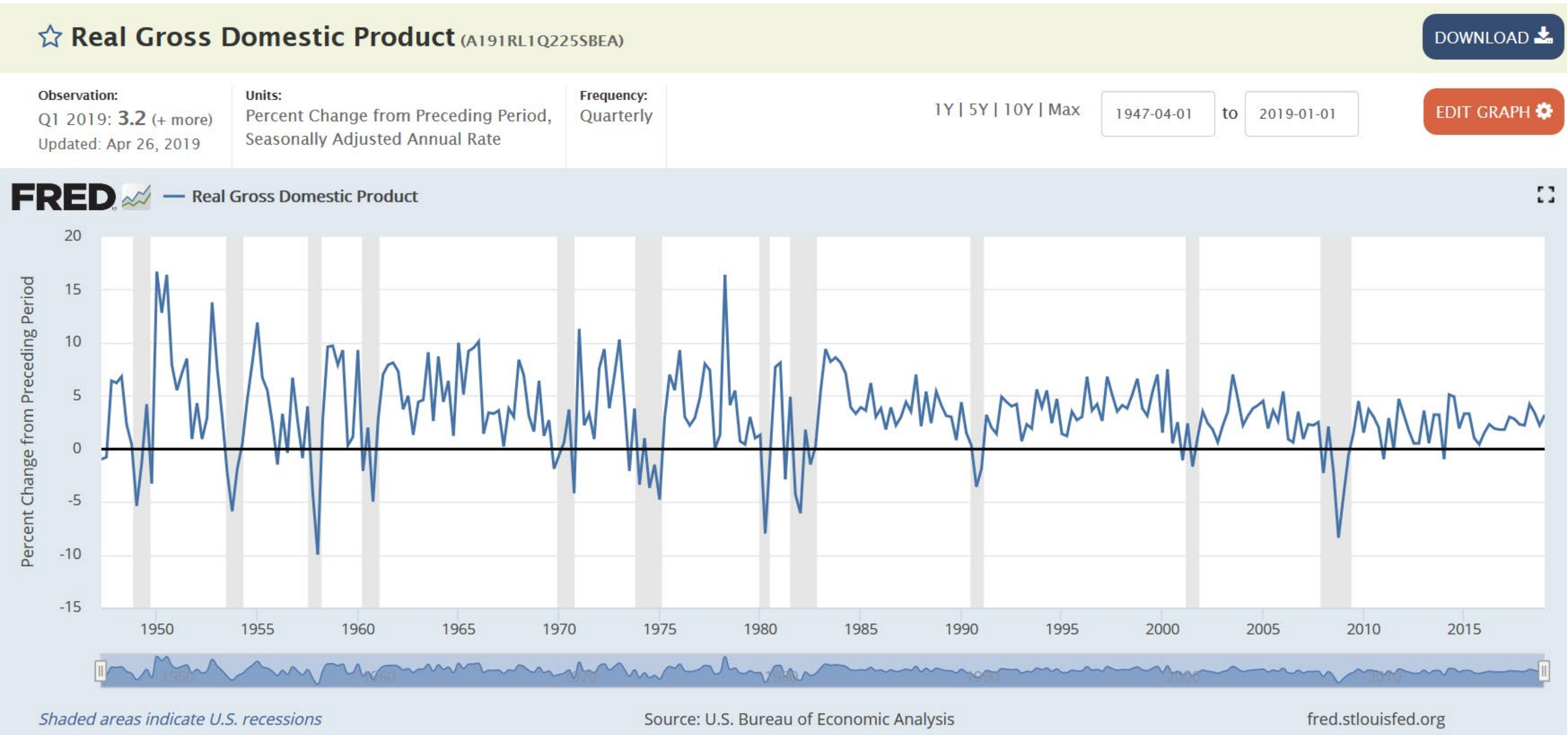


Maximizing data density



Maximizing decoration

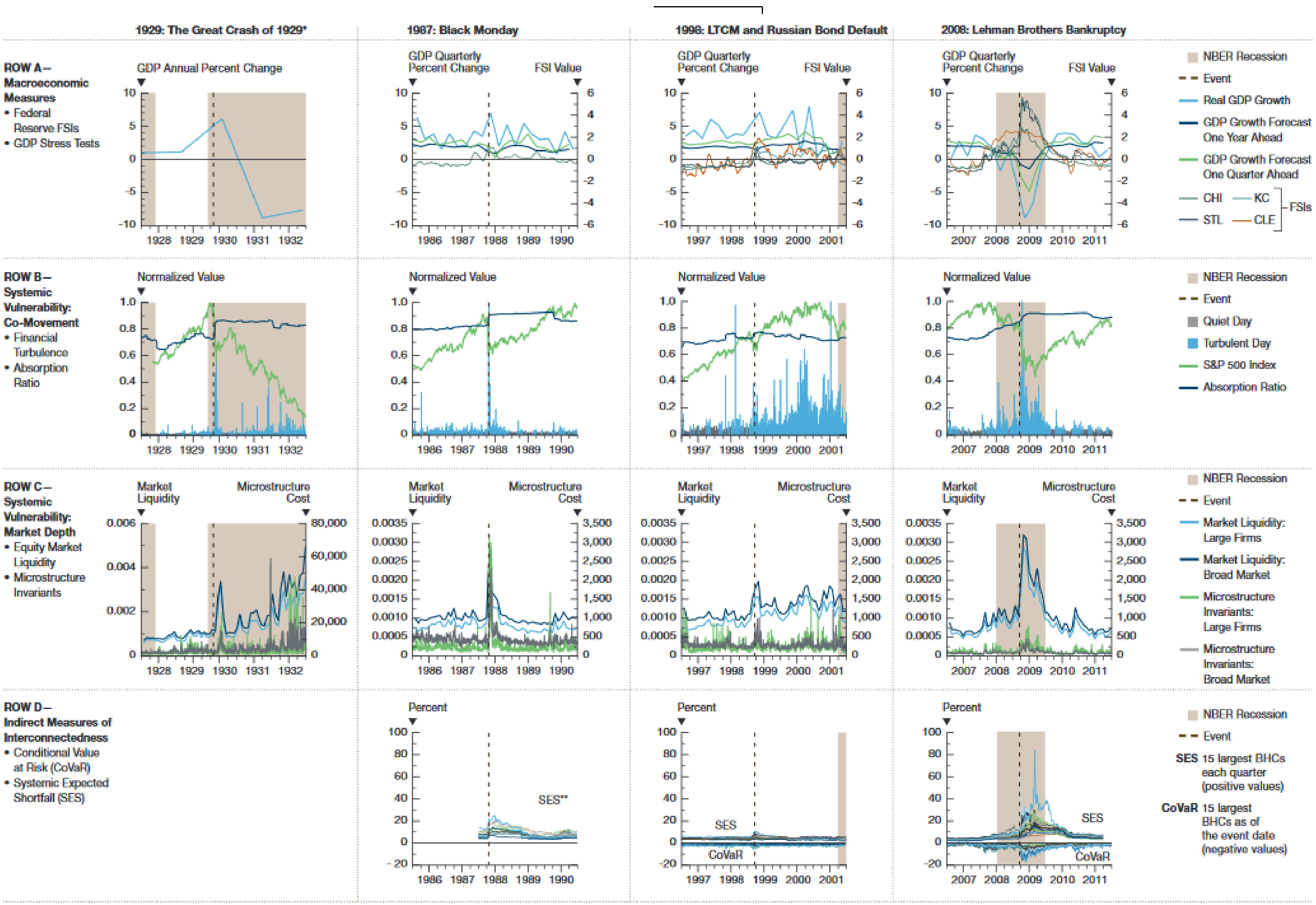
Juxtaposition as a source of meaning – Time-series plots



What would FRED do? (You probably should do that too)

https://fred.stlouisfed.org

Juxtaposition as a source of meaning – Small multiples



Reading suggestions

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