Glyph-Based Visualization
Metrics and Formalizations

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History of Visual Communications

- Glyph = Greek γλυφή, *glyphē*, “carving”
- Symbols: unit of knowledge representation
  - Paleolithic Age, 18000 BC
- Pre-writing:
  - Petroglyphs
    - Hard-wired in human brain ([EM91])
  - Pictograms
  - Ideograms
  - Logograms
Visual Communications Today...

- Pictograms and Ideograms today
Theory of Signs and Sign Systems

SIGN = STIMULUS PATTERN + MEANING

- Semiosis (*Peirce*, [PB55]): process by which a culture produces signs and attributes specific meanings.
- Semeiotic (*Eco* [Eco 79]): the science of signs, into the conditions which are necessary in order for representations of objects to function as signs.
Semeiotics: Theory of Signs and Sign Systems

- Semiosis (*Peirce, [PB55]*): process of cooperation between signs, their objects, and their “interpretants” (mental rep.)

\[ \text{SIGN} = \text{STIMULUS PATTERN} + \text{MEANING} \]

- Peirce’s Model [PB55]:
  - Triad: Representamen, Vehicle, Interpretant

- Saussure’s Model [SBSR83]:
  - Dyad: Signifier, Signified

Signifying Element or Sense or Representamen
Object or Sign Vehicle
Interpretant or Refrent

Chandler [Cha02]
Sign Classification (Peirce [Pei55]):

- **Icons**: resembles the quality of the object it stands for
  - Functional Domain: items all share topological similarity with the object they are related.
  - Examples: images, metaphors and diagrams.
- **Indices**: demonstrates the influence of its object (sensory feature)
  - Functional Domain: abstractions that rely on a physical cause/effect relation with the object to which they relate to.
  - Examples: clock, thermometer, fuel gauge.
- **Symbols**: is interpreted a reference to its object
  - Functional Domain: abstractions which rely on a code conventionally used in order to determine meaning.
  - Examples: mathematical symbols, alphanumerical characters.
Sign Systems - Codes

• Code: framework within which signs assume a meaning.
• Coding:
  – one of the fundamental concepts in semiotics and
  – represents a deterministic functional relation between a signifier and a signified.
• Codes (Chandler [Cha02]):
  – Social: verbal languages, body language, commodity and behavioural codes.
  – Textual: scientific, aesthetic, rhetorical, media.
  – Interpretative: ideological and perceptual codes (visual perception).
Sign and Glyphs

• Are Glyphs signs?

Sign → Code (learned rule) → Meaning
A Formal System: Semiotic Algebra and Grammar

- Algebra: signs are always part of a formal system (Saussure [SBSR83], Goguen [Gog03]):
  - Sorts (subparts of a sign):
    - colour, location, size;
    - hierarchical relationships: inheritance, partial ordering etc.;
  - constructor rules:
    - whole/part relationships
    - generate complex signs = sorts + additional features;
    - importance rank = partial ordering between constructors.

- Grammar: syntax of visual signs by Bertin [Ber83]
  - First attempt using formal rules.
  - Six visual primitives (fundamental visual variables).
  - Each primitive rated in function of the signified datasets.
Design Pipeline and Metrics

- **Design Space:** Pettersson [Pet10] “the main goal in information design is clarity of communication; in order to fulfil this goal, all messages must be accurately designed, produced and distributed, and later correctly interpreted and understood by members of the intended audience.”

- **Design Metrics:** Eco [Eco79] “a general semiotic theory should include not only a theory of how codes may establish rules for systems of signification but a theory of how signs may be produced and interpreted to clarify aspects of communications.”

\[
\text{Design Space} \quad + \quad \text{Design Metrics} \quad => \quad \text{Design Process}
\]
Design Space – Perceptual Codes

• Perceptual Codes:
  – Gestalt Principles
    • Proximity (> colour similarity)
    • Similarity
    • Continuity (> colour similarity)
    • Closure
    • Symmetry
    • Figure/Ground:
      – Area (or surroundedness), symmetry, parallelism, extremal edges.
    • Prägnanz (simplest always favoured)
Design Space – Visual Channels

- **Visual Channels:**
  - Primitive visual representations to convey variable values: colour, size, shape, orientation.
  - Retinal Variables (*Bertin* [Ber83])
  - Visual Encoding Variables (*Ware* [War04])
  - Taxonomy by Chen and Floridi [CF12]:
    - Geometric
    - Optical
    - Topological/Relational
    - Semantic

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**Visual Channels Taxonomy [CF12]**

<table>
<thead>
<tr>
<th>Geometric Channels</th>
<th>Optical Channels</th>
<th>Topological and Relational Channels</th>
<th>Semantic Channels</th>
</tr>
</thead>
<tbody>
<tr>
<td>size / length / width / depth / area / volume</td>
<td>intensity / brightness</td>
<td>spatial location</td>
<td>number</td>
</tr>
<tr>
<td>orientation / slope</td>
<td>colour / hue / saturation</td>
<td>connection</td>
<td>text</td>
</tr>
<tr>
<td>angle</td>
<td>opacity / transparency</td>
<td>node / internal node / terminator</td>
<td>symbol / ideogram</td>
</tr>
<tr>
<td>shape</td>
<td>texture (partly geometric)</td>
<td>intersection / overlap</td>
<td>sign / icon / logo / glyph / pictogram</td>
</tr>
<tr>
<td>curvature</td>
<td>line styles (partly geometric)</td>
<td>depth ordering / partial occlusion</td>
<td>isotype</td>
</tr>
<tr>
<td>smoothness</td>
<td>focus / blur / fading</td>
<td>closure / containment</td>
<td></td>
</tr>
</tbody>
</table>
Design Criteria – Metaphoric Associations

• Maguire et al. [MRSS*12]:
  – Semantic Relevance:
    • Semantic criteria: associative, selective, ordered and quantitative (Bertin, [Ber83]).
    • Familiarity can support selectivity with almost any shape.
  – Channel Composition:
    • Glyphs likely to feature a number of visual channels.
    • Constructive composition may affect how individual channels are perceived.
    • Measurable Euclidean Distances.
  – Pop-out Effects:
    • Identification of a target within a few nanoseconds of initial exposure to the visual search space.
  – Visual Hierarchy:
    • visual system strategies (top-down, bottom-up) vs.
    • saliency of features
Design Criteria – Visual Orderability

- Chung et al. [CLP*13]:
  - Typedness
  - Visual Orderability
  - Channel Capacity
  - Separability
  - Searchability
  - Learnability
  - Attention Balance
  - Focus and Context
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[Charts and diagrams related to the design criteria are presented in the slide.]
Measurements and Norms (*McDougal* [MdBC00])

- **Criteria:**
  - Concreteness
  - Visual Complexity
  - Meaningfulness
  - Familiarity
  - Semantic Distance

- **Quantifiable Metrics:**
  - Subjective Rating
  - Icon-based metrics: sum of the components of an icon such as letters, lines, arrows etc.
  - Automatic visual measure: image analysis of icon features such as edge detection, perimeter determination etc.

- **Relationship between:**
  - Concreteness vs. *visual complexity*
  - Concreteness vs. *meaningfulness*
  - Meaningfulness vs. *familiarity* vs. *semantic distance*
Are Glyphs just Signs?

• Glyphs ⊆ Signs
• Signs: well established theory
  – Semeiotics: Formal System
• Glyph: well established practice
  – Design Space
  – Design Metrics
• Is that all folks?
  – Before: Ad-hoc methods based on intuitions
  – Now: metrics meets challenges (field mature enough)