Quality Metrics for Information Visualization

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SFB-TRR 161
Quantitative Methods for Visual Computing

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TU Graz
ETH zürich
Universität Stuttgart

Effectiveness

Usefulness

Appropriateness

Efficiency

Usability

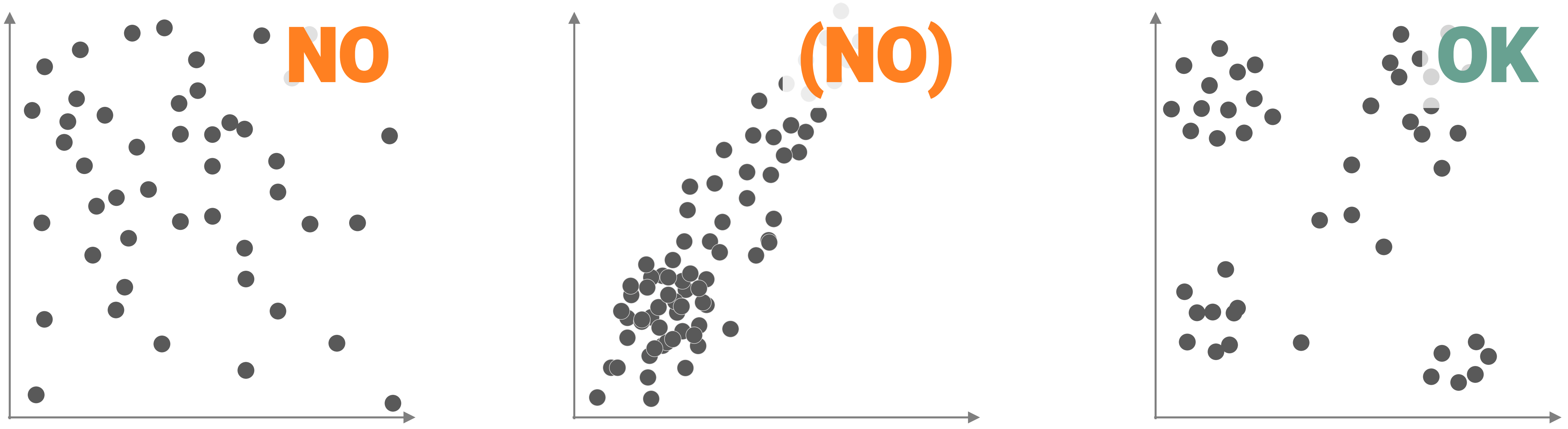
Expressiveness

Expressiveness

Interpretability

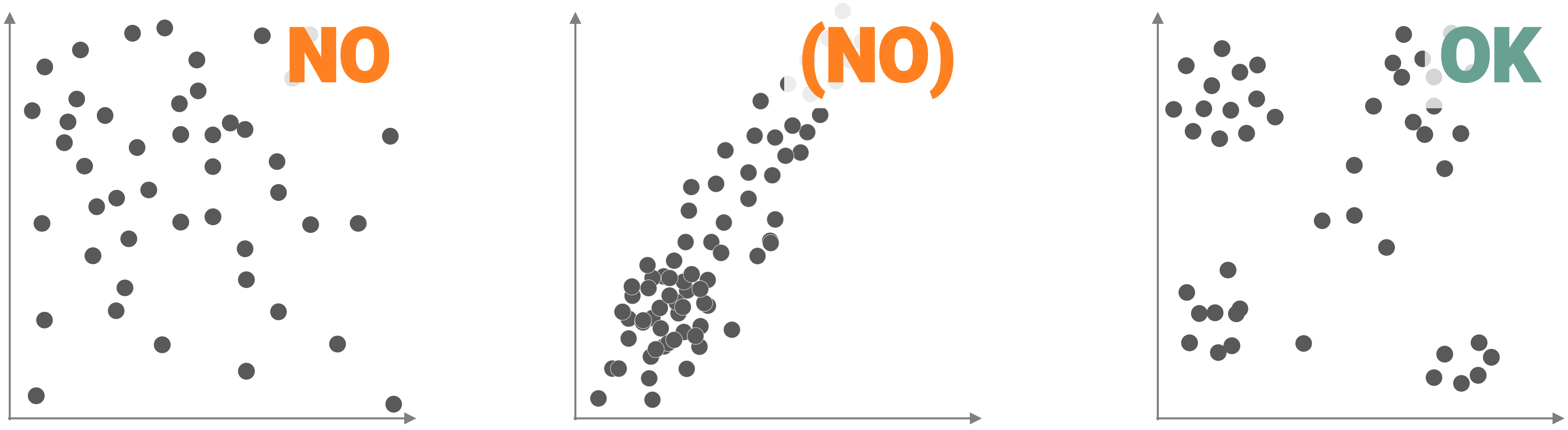
Quality **Metrics**

Patterns in Information Visualizations



Conceptual/
Pattern Space ⟷ **Task**

Patterns in Information Visualizations



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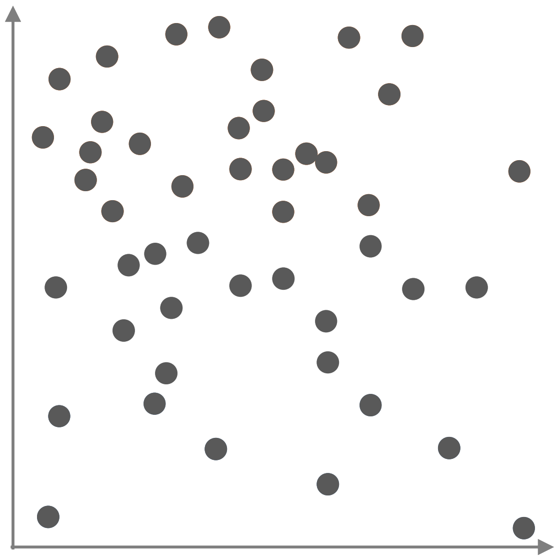
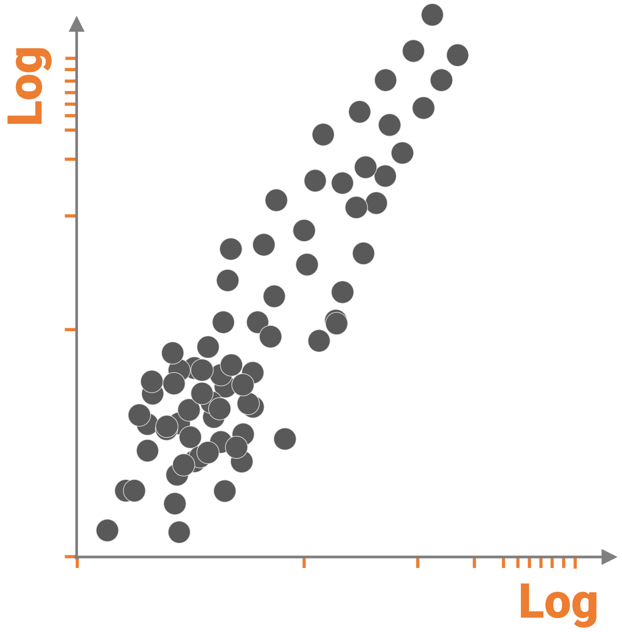
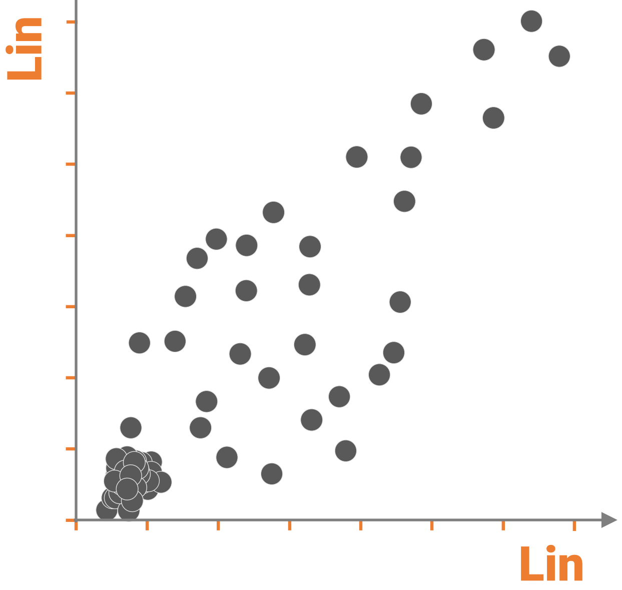
Patterns in Information Visualizations







Visualization Parameter ⟷ **Dataset** Characteristics

Visualization Parameter ⟷ **User** Understandability

Quality **Metric**

Visualization Parameters

Data

User

Task

$$q(\phi \mid D, U, T)$$

Optimization Algorithm

Quality **Criterion**

Structure and Goals of the Survey

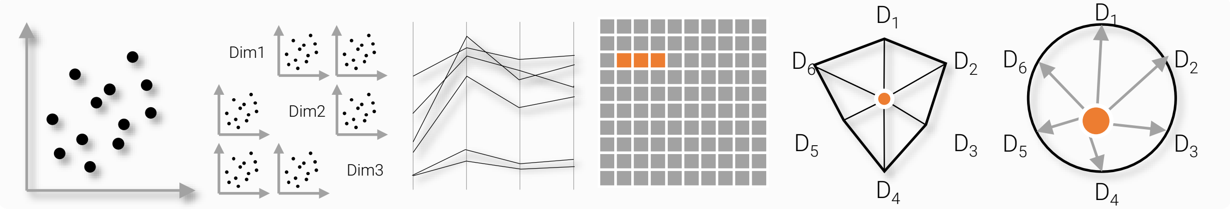
Research Goals

Reference Manual for QM

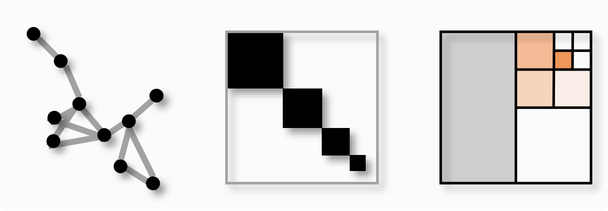
Establish Common **Vocabulary**

Open Challenges and **Future Research Directions**

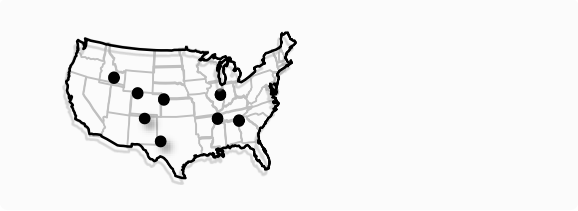
Multi- and **High-Dimensional**



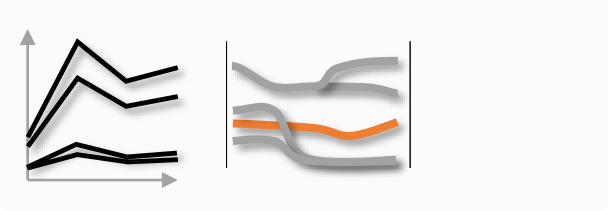
Relational Data



Geo-Spatial Data



Sequential/Temporal

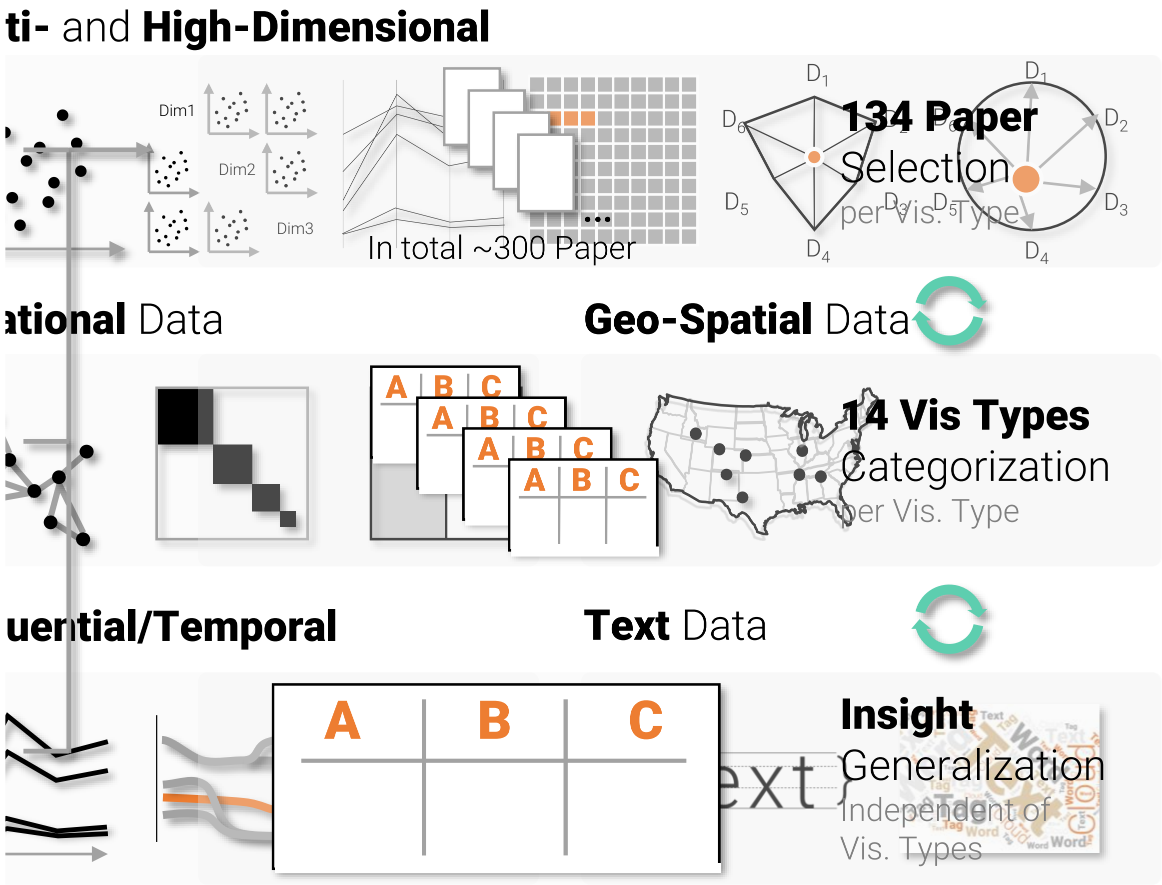


Text Data

Structure and Goals of the Survey

For each Vis Type

1. Visualization Description
2. Why do we need QMs?
3. **Typical Analysis Tasks**
4. Summary of Approaches
5. **Evaluations Methods**
6. Open Research Questions



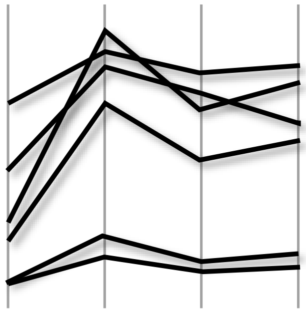
Quality **Metric**

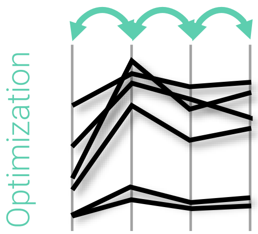
$$\arg \underset{\phi \in \Phi}{\substack{\min \\ \max}} \; q(\phi \mid D, U, T)$$

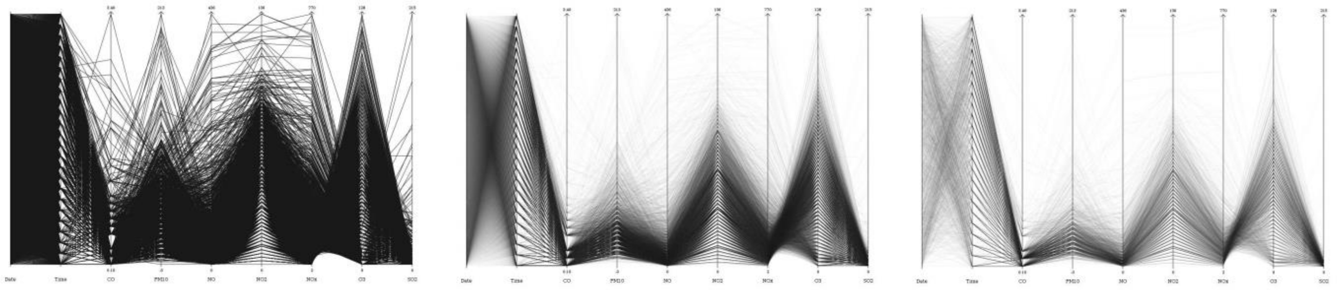
Clutter Removal vs **Pattern** Retrieval

Auto-Sampling – Clutter Removal

Parallel Coordinates





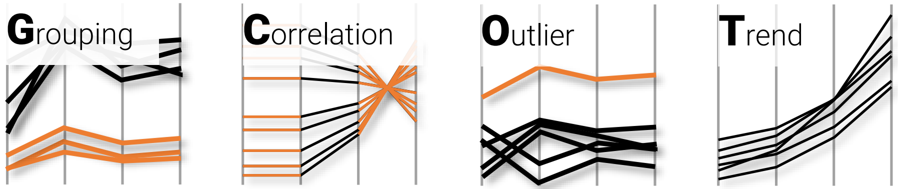


(a) Initial plot showing 8392datapoints.

(b) Opacity reduced to 4%.

(c) Opacity reduced to 4% and 75% of the data removed.

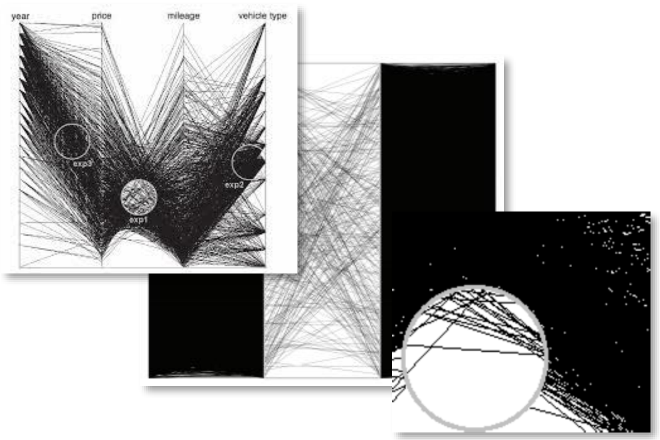
Patterns and Tasks



Overplotted%
Percentage of pixels containing more than one plotted point

Overcrowded%
Percentage of plotted points hidden behind a pixel

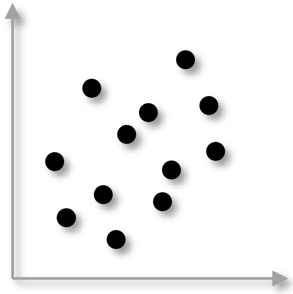
Hidden%
Percentage of plotted points that are hidden due to being overplotted

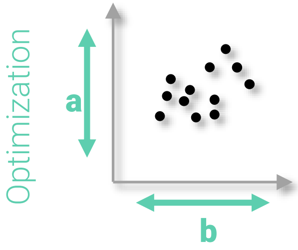


[Ellis2006]

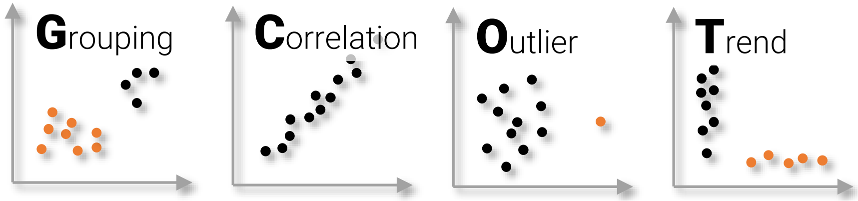
Scagnostics – Pattern Retrieval

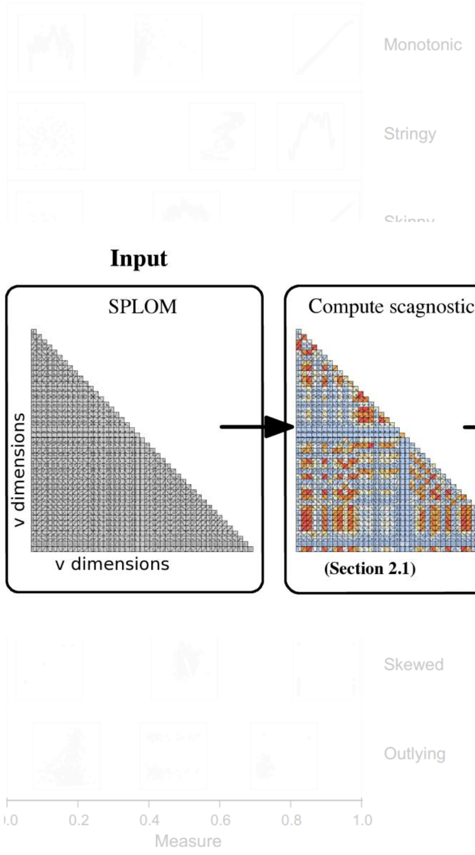
Scatter Plots



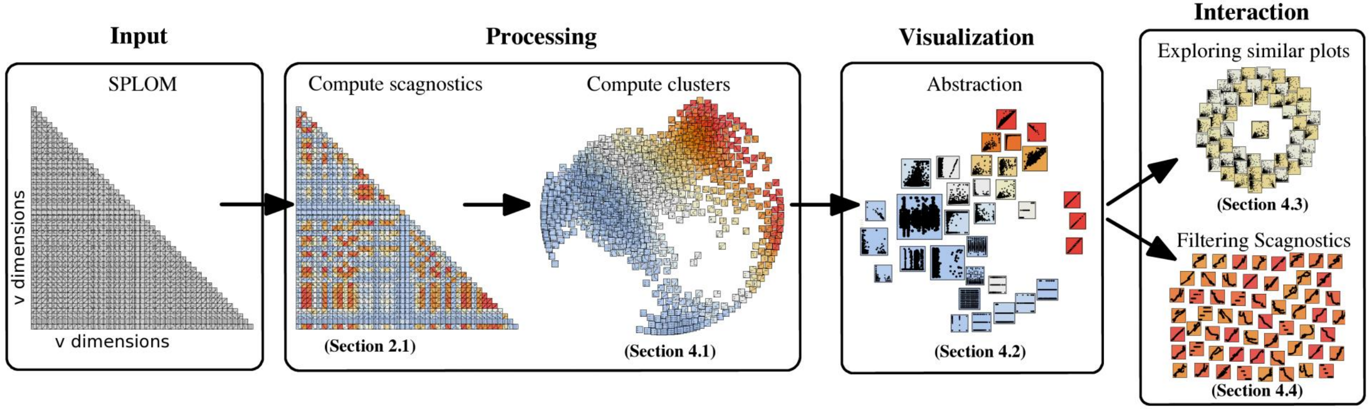


Patterns and Tasks





[Wilkinson2006]



[Dang2014]

Stringy:
Ratio of 2-degree V in MST to # of V > 1-degree

Quality **Metric**

$$\arg\min_{\phi \in \Phi}\max\; q(\phi \mid D, U, T)$$

Analysis Scenarios/Tasks for QM

Clutter Removal

Pattern-Driven Analysis

Reduces Cognitive **Overload**

Focuses on Analysis **Task**

Search for **Data Groups**

Search for **Outliers**

Search for **Dimension Relations**

Preservation Task

Data- and Visualization **Specific Tasks**

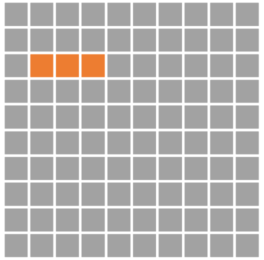
Quality **Metric**

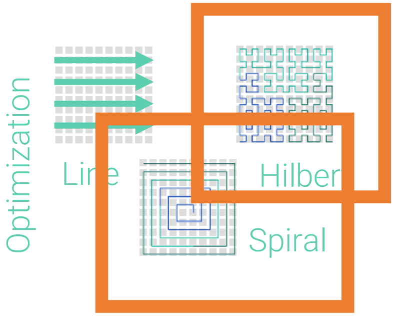
$$\underset{\phi \in \Phi}{\arg\,\substack{\min \\ \max}}\; q(\phi \mid D, U, T)$$

Explicit and **Implicit** QM

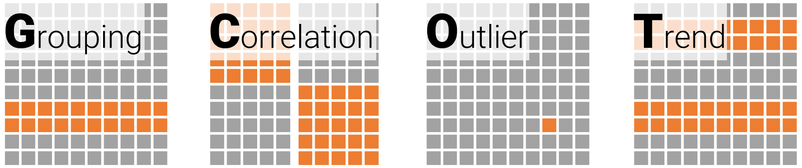
Noise Dissimilarity – Explicit QM

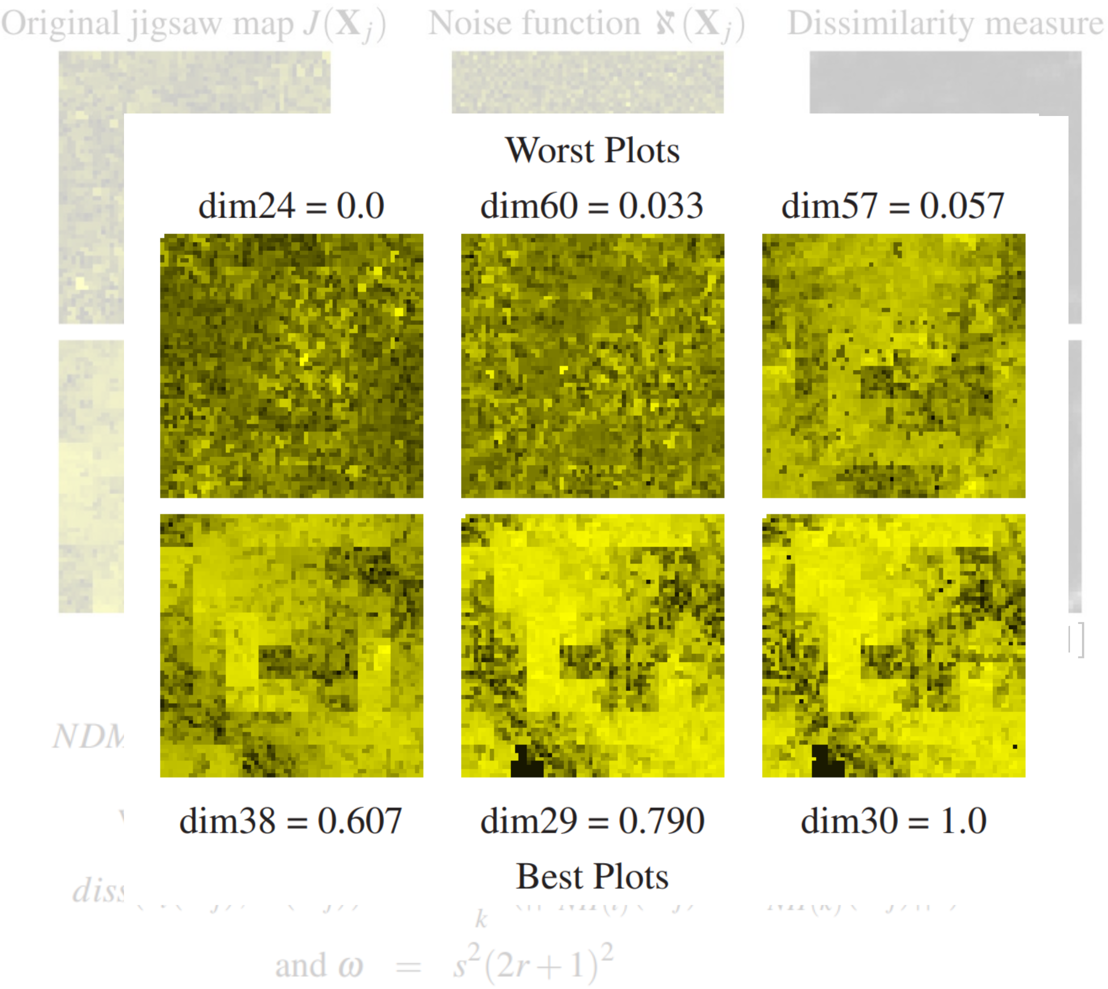
Pixel-based Techniques





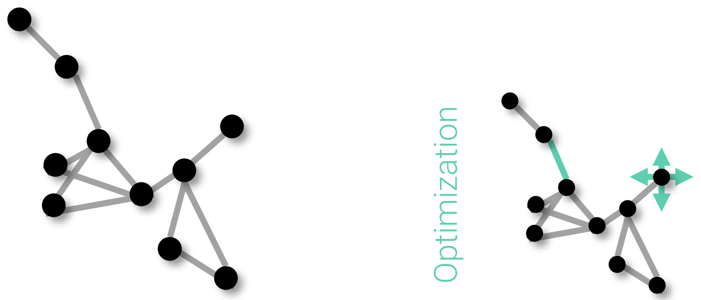
Patterns and Tasks



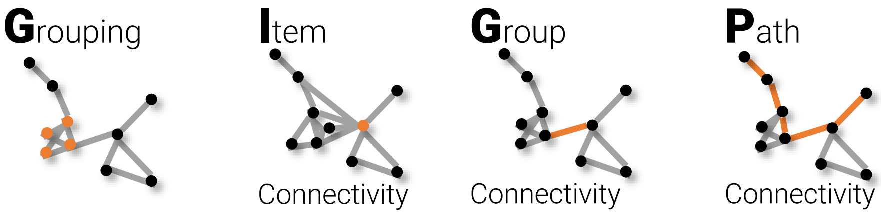


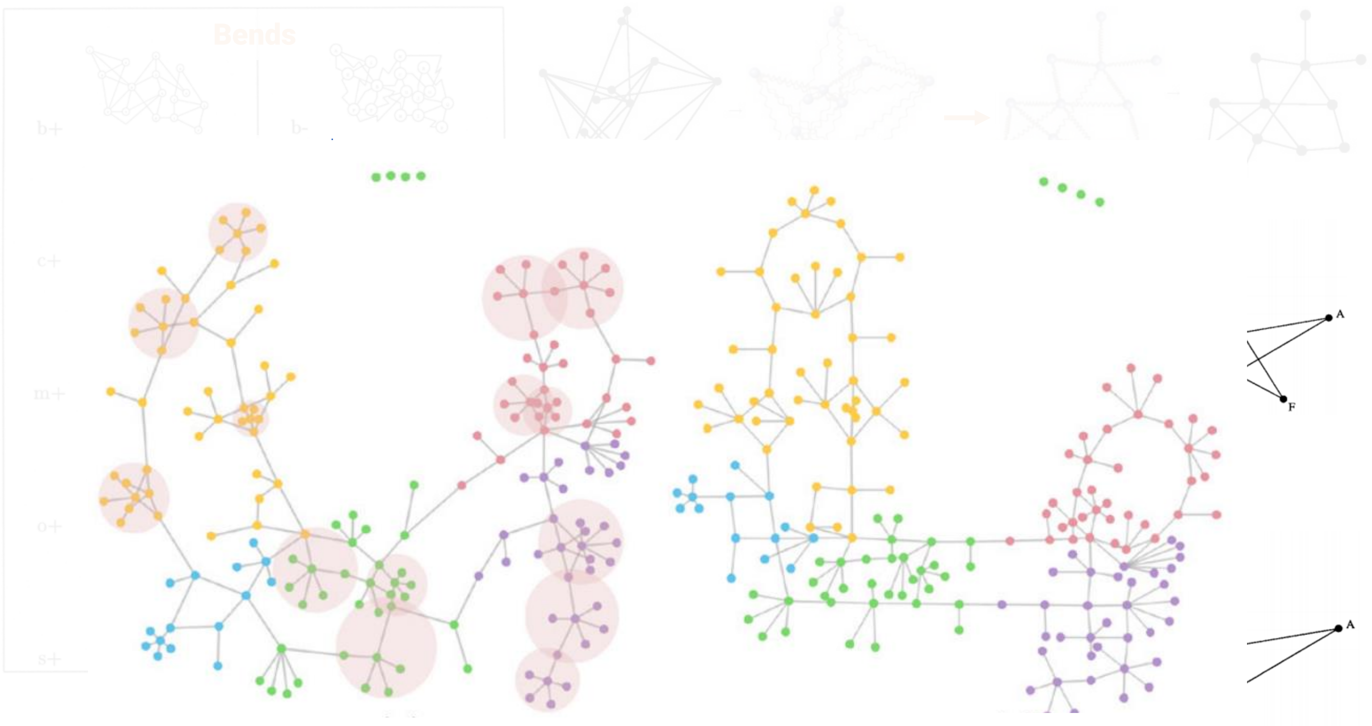
Force Directed Layout – Implicit QM

Node-Link Diagrams



Patterns and Tasks





Cluster Overlap + Star Constraint

Cluster Overlap + Circle + Star Constraint

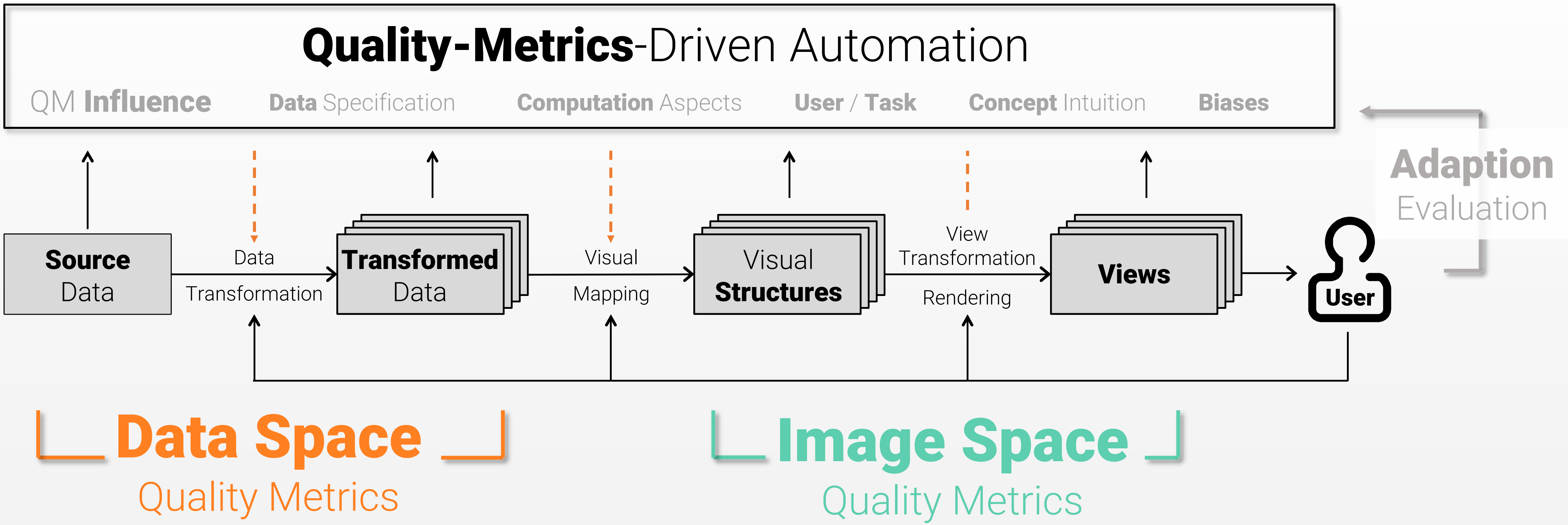
Quality **Metric**

$$\underset{\phi \in \Phi}{\arg\,\substack{\min \\ \max}}\; q(\phi \mid D, U, T)$$

Data Space vs **Image Space**

Quality **Metric**

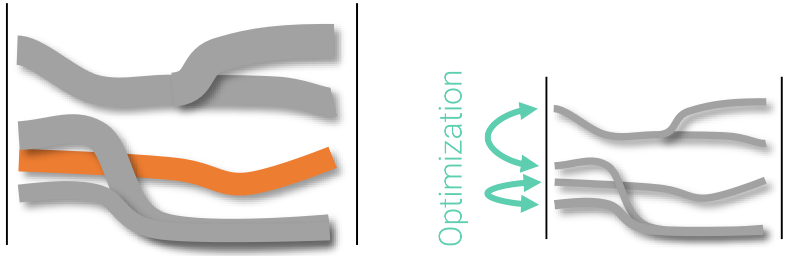
$$\underset{\phi \in \Phi}{\arg \begin{smallmatrix}\min\\ \max\end{smallmatrix}} \; q(\phi \mid D, U, T)$$

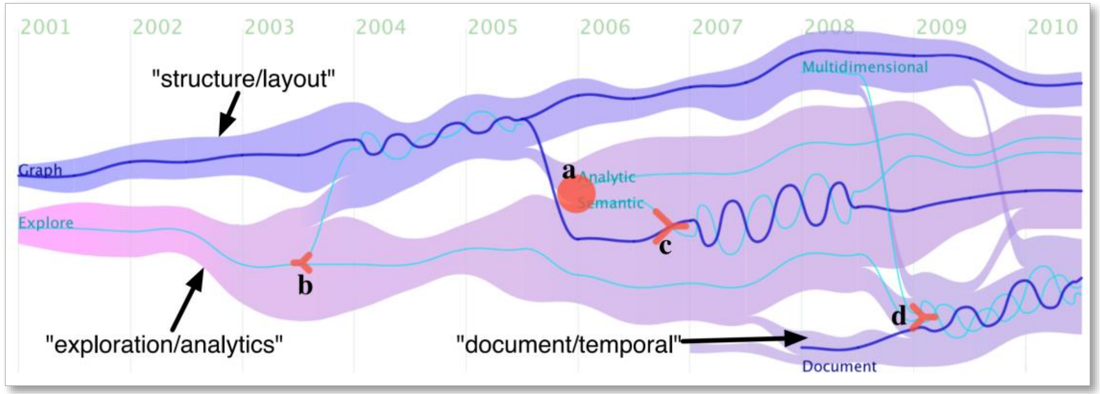


[adapted from Bertini2011]

TextFlow – Data Space QM

Stacked Charts

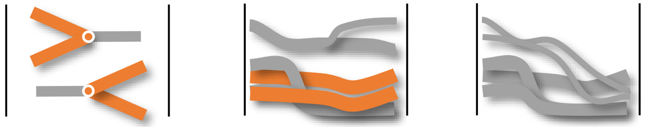


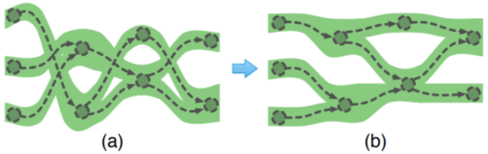


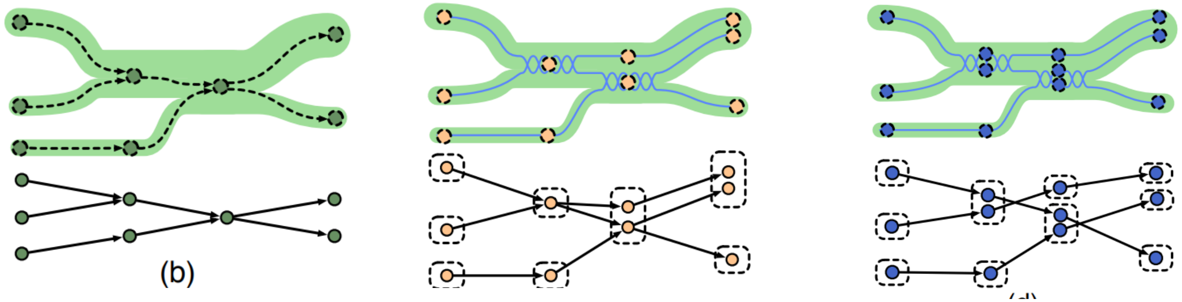
[Cui2011]

Patterns and Tasks

Split / **M**erge **P**arallel **T**rend



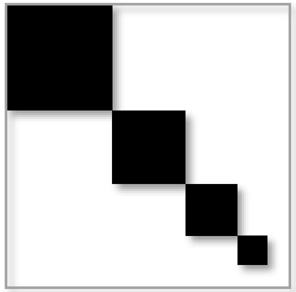


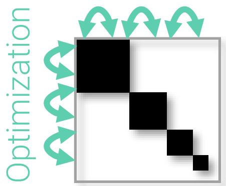


Topic Flow Topic Bundles Thread

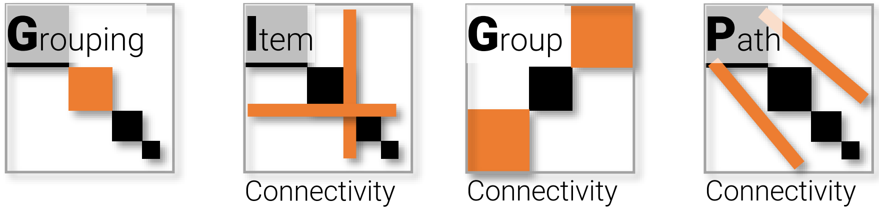
Magnostics – Image Space QM

Matrix





Patterns and Tasks



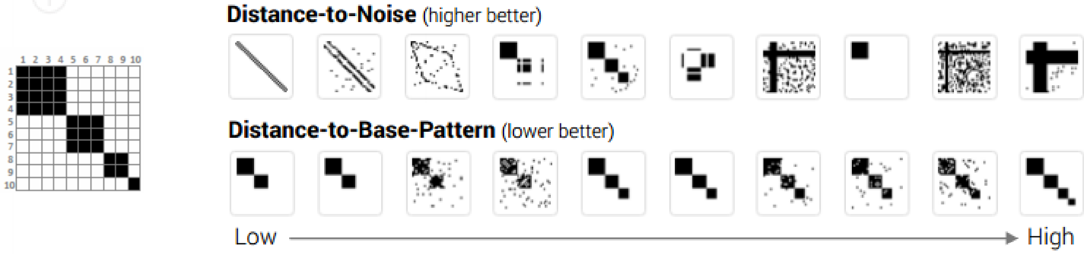


Figure 1.10 Examples for our Block Descriptor, specifically engineered to retrieve blocks around the matrix diagonal.

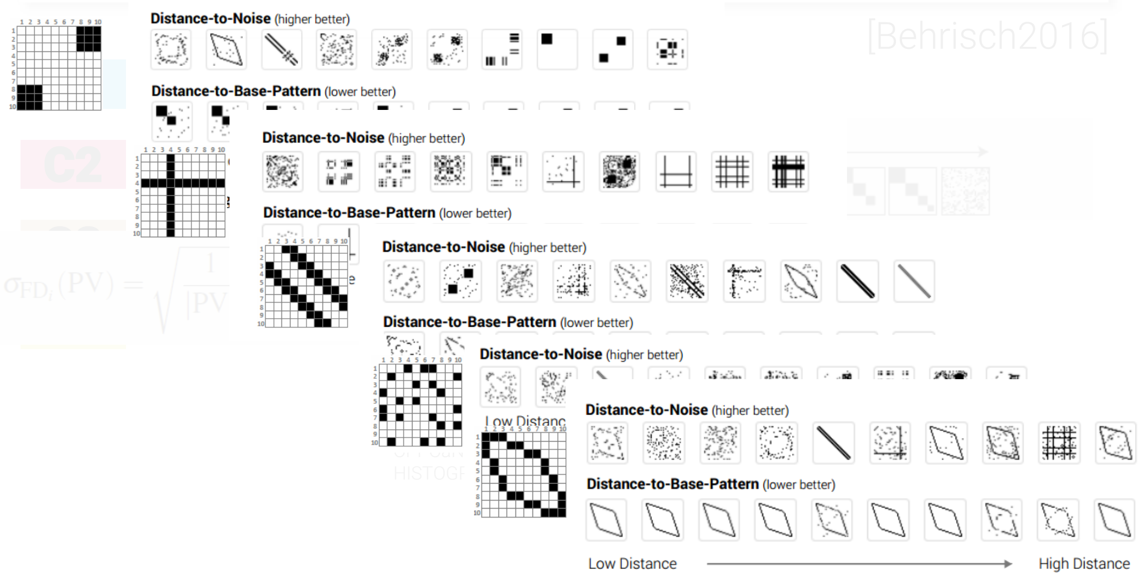


Figure 1.14 Examples for the CEDD Descriptor.

[Behrisch2016]

Quality Metrics Landscape

Cognitive Process / Complexity

High-Level Meta-Perception / User

Memorability, Understanding, Confidence, Faithfulness, Trustworthiness, Cognitive Biases, Engagement, User Level Convention, Aesthetics, Joyfulness

Clutter Removal vs **Pattern** Retrieval

Mid-Level Perception / Task

Patterns versus **Anti-Patterns**, Clutter-reduction, Task-effectiveness "Overview-First & Details-on-Demand" "Search, show context, expand on demand"

Explicit vs **Implicit** QM

Low-Level Perception

Preattentive Processing, Gestalt Laws, Visual Variables, Change Blindness, Just Noticeable Differences

Data Space vs **Image Space**

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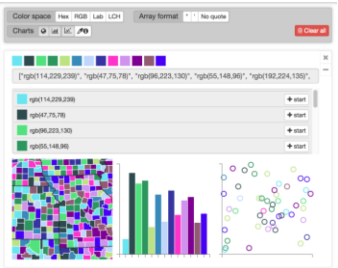
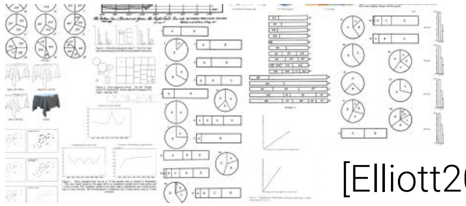
Color Research



[Gramazio2016]

[Mittelstädt2015]

39 studies about human perception in 30 minutes



[Elliott2016]

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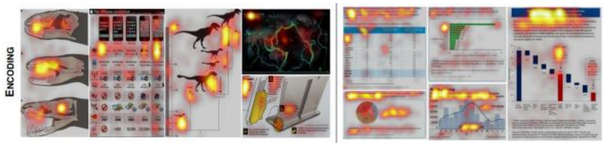
Memorability

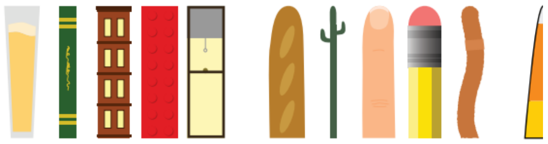


[Borkin2015]

DECISIVe 2017

Dealing with Cognitive Biases in Visualisations : a VIS 2017 workshop

Aesthetics
Joyfulness



(a) *Rectangular bars* (b) *Rounded-top bars*

[Skau2017]

Quality Metrics Landscape

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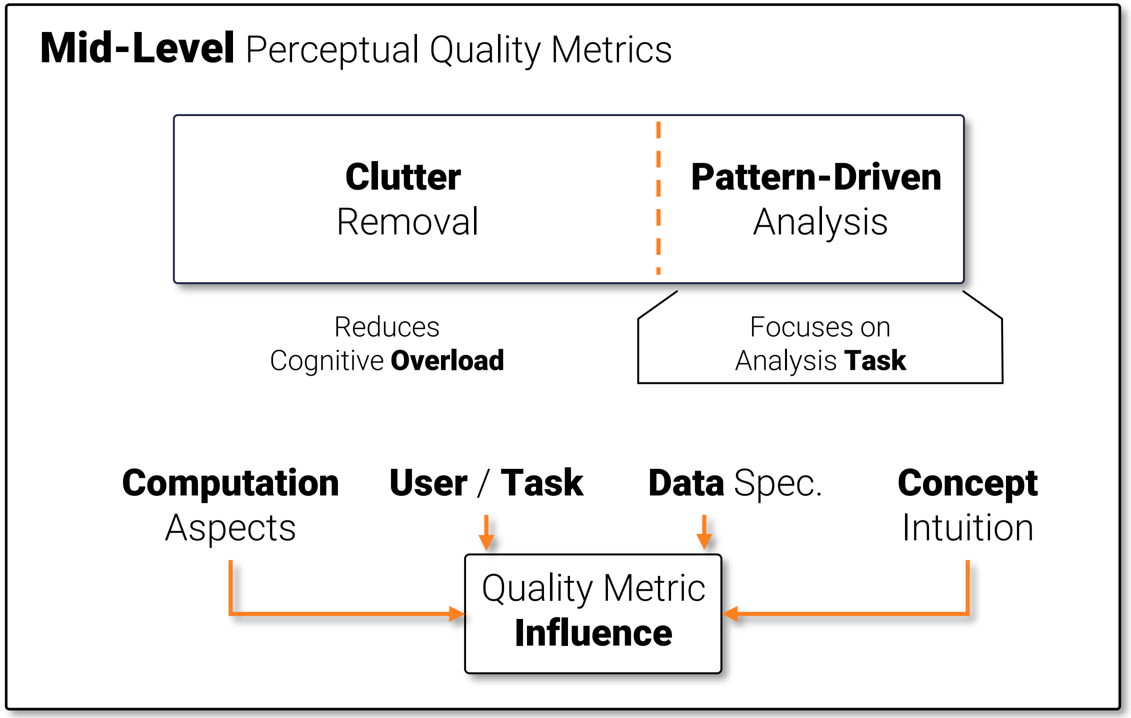
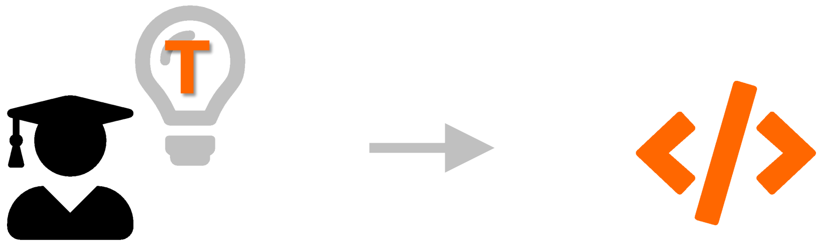


Discussion and Findings

Which **QM favors** which **visual pattern?**



$$\arg \begin{matrix} \min \\ \max \end{matrix}_{\phi \in \Phi} \overbrace{q(\phi \mid D, U, T)}^{\text{Quality } \textbf{Metric}}$$

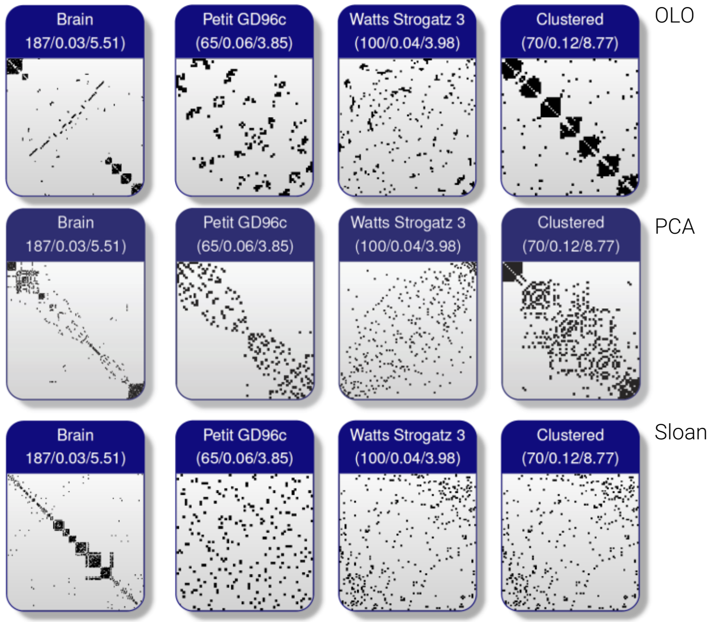
- Implicit, domain-inspired, pot. subjective expectation
- What if pattern is not known apriori? Which QM?
- Majority of QMs do not describe visual pattern

Discussion and Findings

What are **extreme cases** that a QM can deal with?

Quality **Metric**

$$\arg \min_{\phi \in \Phi} \max \; q(\phi \mid D, U, T)$$



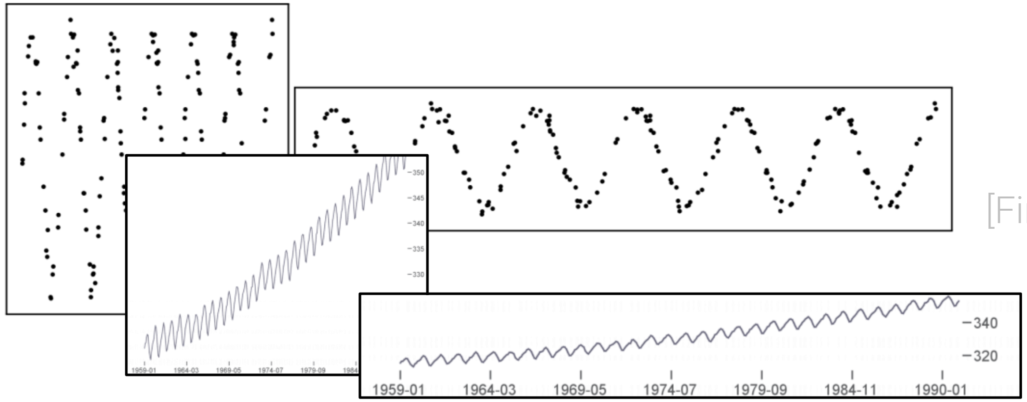
- Noise (in-)variances and robustness toward skewed distributions
- Bad QM must mean no pattern

Discussion and Findings

Is QM research **transferable** among visualization types?

Quality **Metric**

$$\underset{\phi \in \Phi}{\arg} \begin{matrix}\min \\ \max\end{matrix} \; q(\phi \mid D, U, T)$$



[Fink2013]

[Heer2006]

> Some vis subdomains share similar concepts

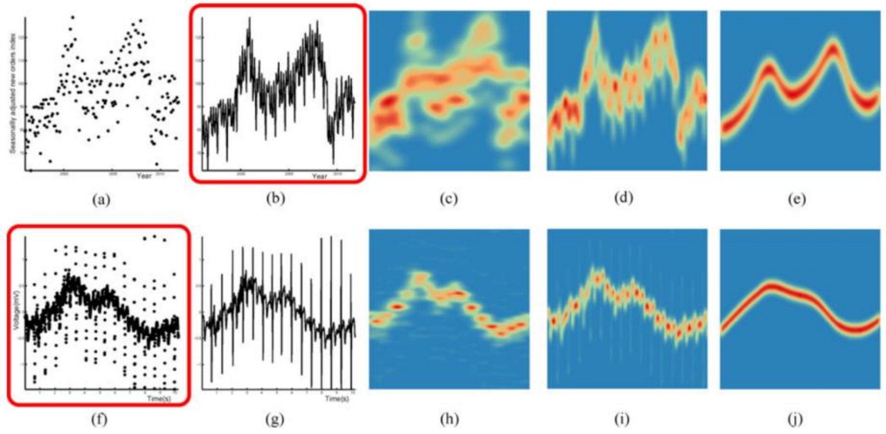
> Set of base patterns in both visualizations

Discussion and Findings

Are QMs equally **descriptive?**

Quality **Metric**

$$\underset{\phi \in \Phi}{\arg \min_{\max}} \; q(\phi \mid D, U, T)$$



[Wang2018]

> QM for recommendation of visualization technique

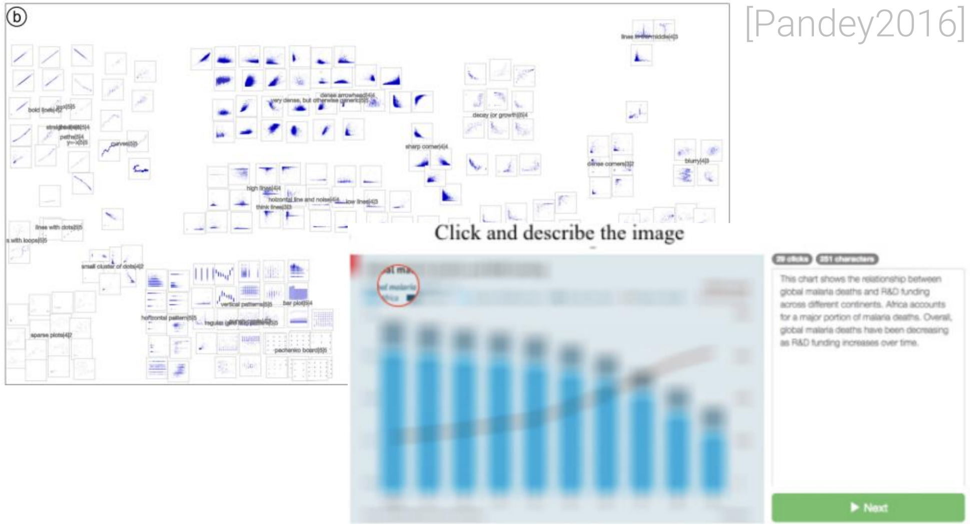
> But, only standard patterns (not domain dependent)

Discussion and Findings

Evaluation of Quality Metrics

Quality **Metric**

$$\underset{\phi \in \Phi}{\arg} \, {}^{\min}_{\max} \; q(\phi \mid D, U, T)$$



[Pandey2016]

[KimBylinskii 2018]

- Heuristic, quantitative, pattern-focused QM research not backed up (enough) by perception QM studies
- Design recommendations solely base their recommendations on studies

Research Directions

Multi-Criteria & Task-Adapted QM.

Mixture of patterns;
Tasks change in exploratory settings

- Intelligently navigate pattern space.

Machine Learning.

Deep learning possible, iff (1) suff. large training set;
(2) appropriate architecture

- Deep-Learning based QM.

Interactive & Human-Supported Quality Steering.

Algorithms can benefit from the user’s input
to produce high quality results.

- Visual Support and Visual Analytics is needed.

Closing the Gap to Higher-level Perceptual QM.

Central goal is still reduce cognitive overload.

- QM can help to build understanding and trust.

Take Home Messages

Task and Pattern-based Quality Metrics.
Choose the right QM! More evaluation is necessary.

Visual Exploration Interfaces.
Needed to make use of QMs in the wild.

Visual Analytics will change the field (once again).
Opening the Black-Box will lead to novel algorithms.

visualquality.dbvis.de

Thank YOU

SFB-TRR 161
Quantitative Methods for Visual Computing

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and Applied Sciences

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Universität
Stuttgart

ETH zürich

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Quality
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