Universität
Konstanz

MAGNOSTICS

Finding Interesting Matrix Views for Guided Network Exploration

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Jean-Daniel Fekete and Tobias Schreck

Michael Behrisch
Data Analysis and Visualization Group
Universität Konstanz

Baltimore, October 2016

TU Graz
Graz University of Technology

Microsoft Research - Inria
JOINT CENTRE

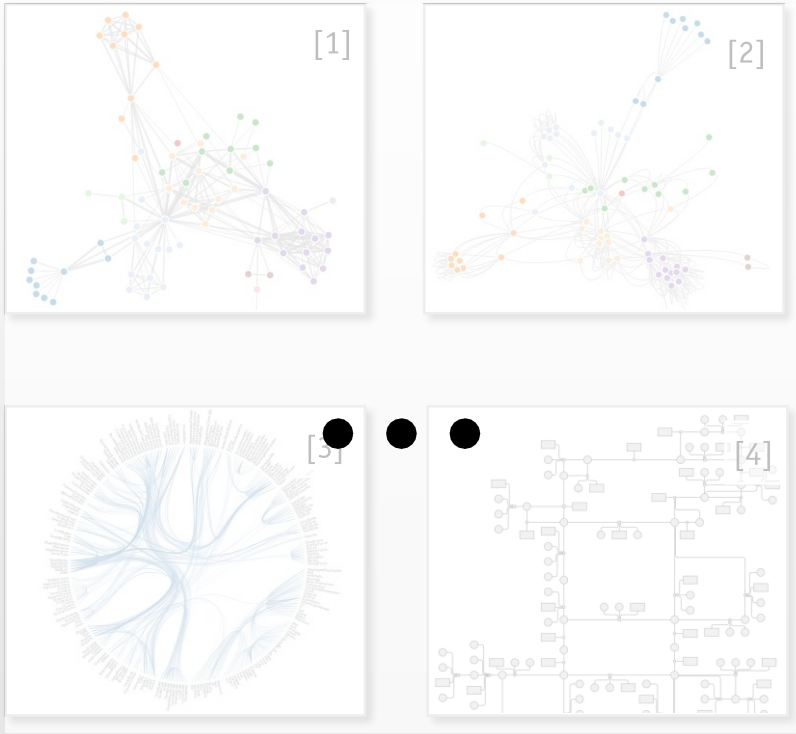
Aviz

Magnostics.
Motivation.

Standard Network Analysis Approach.

Network Related Data
Raw Data

Visual Mapping
Node-Link Diagram



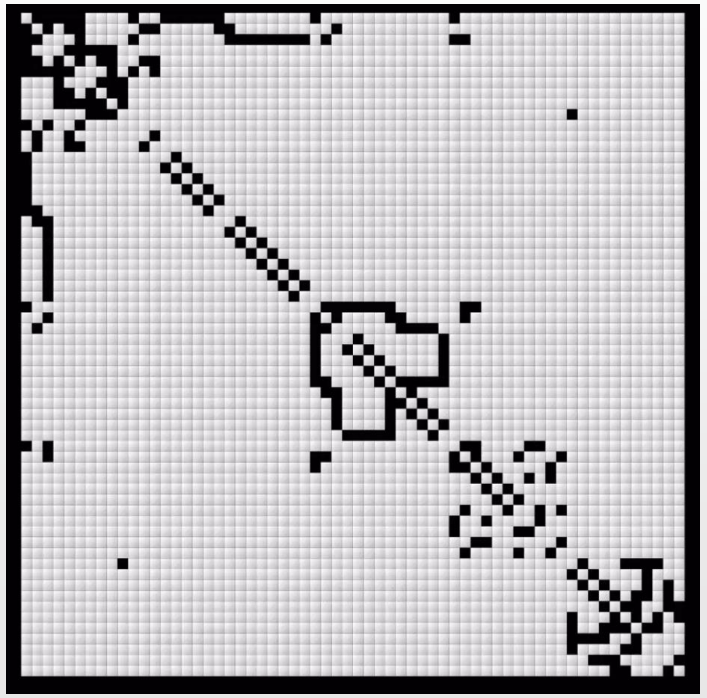
Pictures courtesy: [1] http://bl.ocks.org/mbostock/4062045, [2] http://bl.ocks.org/mbostock/4600693. [3] http://bl.ocks.org/mbostock/1044242
[4] Kieffer, Steve, et al. "Hola: Human-like orthogonal network layout." IEEE transactions on visualization and computer graphics 22.1 (2016): 349-358.

Magnostics.
Motivation.

Standard Network Analysis Approach.

Network Related Data
Raw Data

Visual Mapping
(Adjacency) Matrix



Magnostics.
Motivation.

Motivation and Use-Cases.

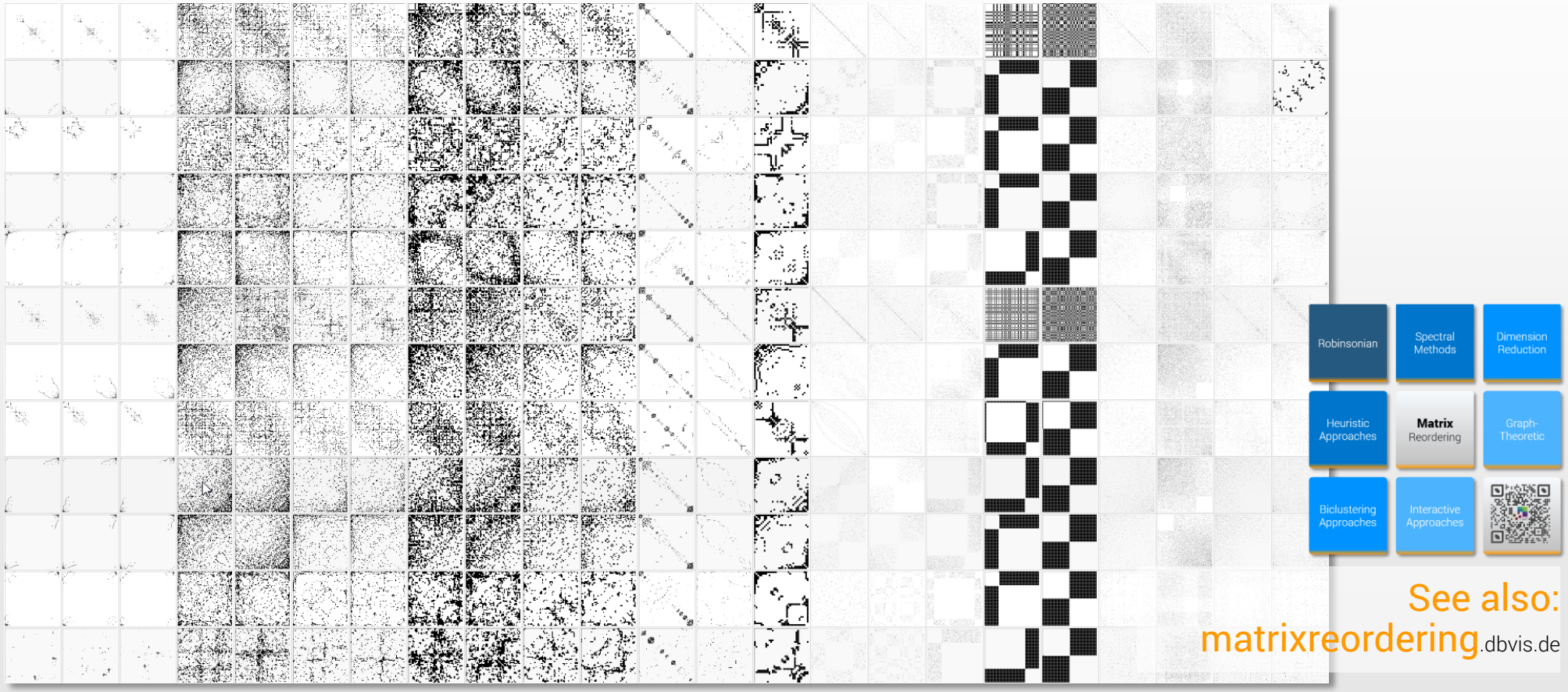
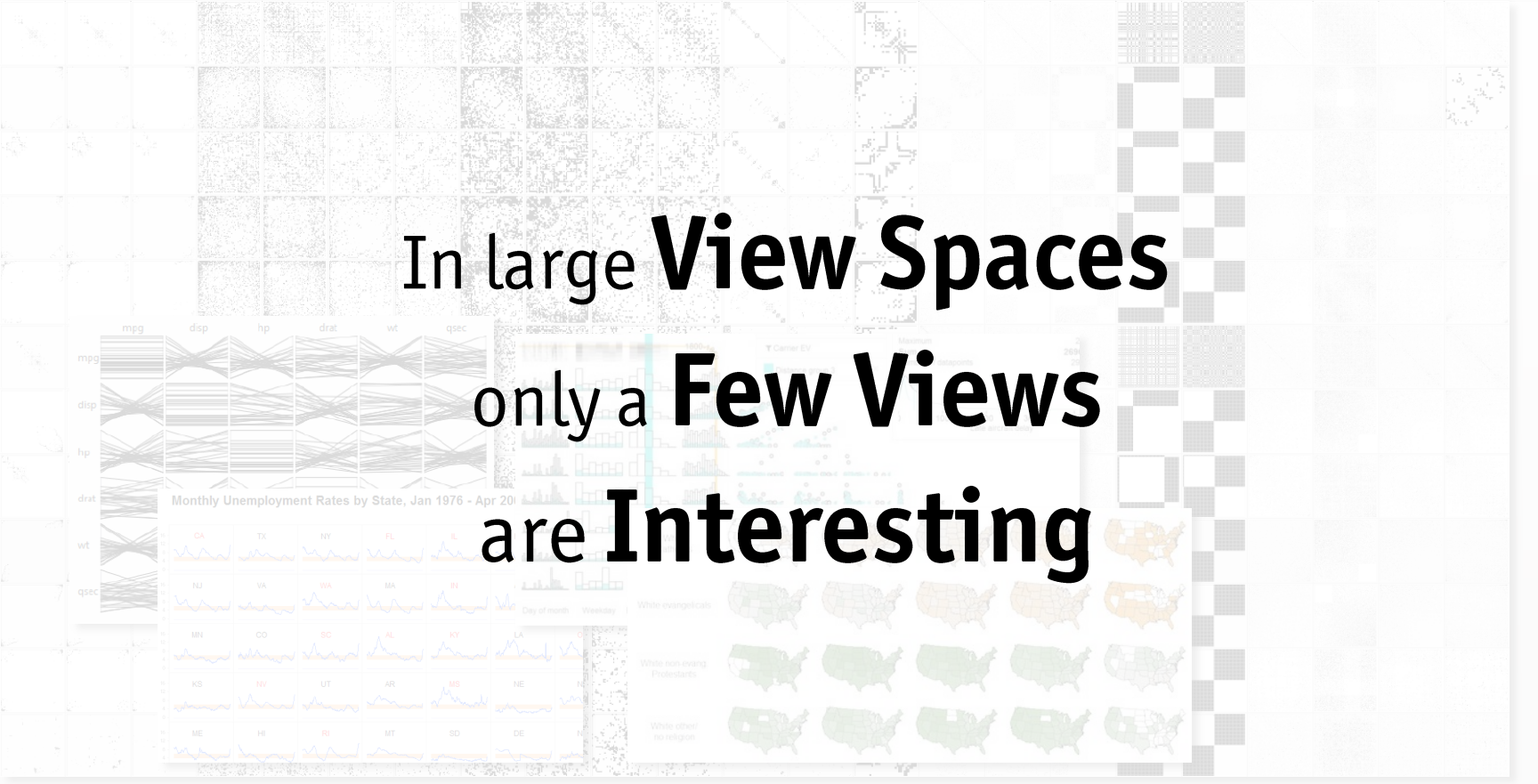


Image taken from matrixreordering.dbvis.de;
Behrisch, Michael, et al. "Matrix Reordering Methods for Table and Network Visualization." Computer Graphics Forum. Vol. 35. 2016.

Magnostics.
Motivation.

Problem Statement.

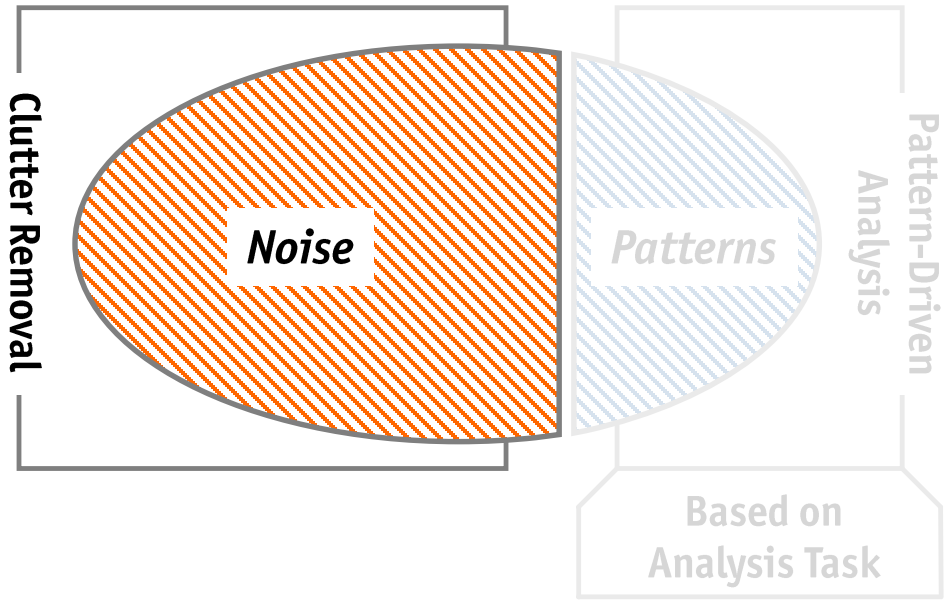


Images courtesy: [1] http://www.jara.org/?id=43&L=0

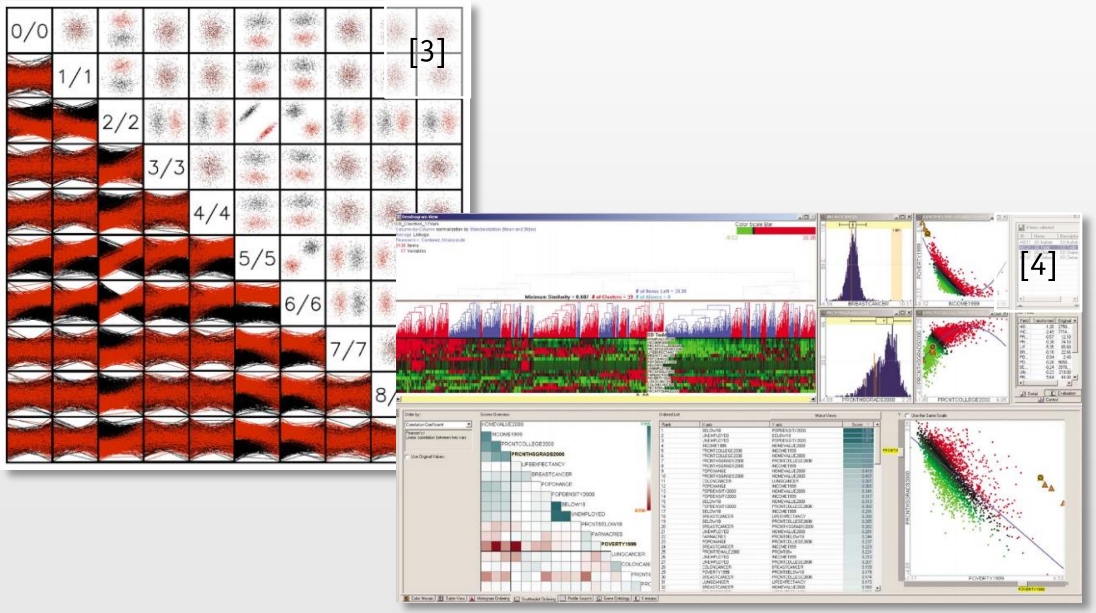
Magnostics.
Motivation.

Related Approaches.

Noise Removal versus Pattern Retrieval



Quality Metrics

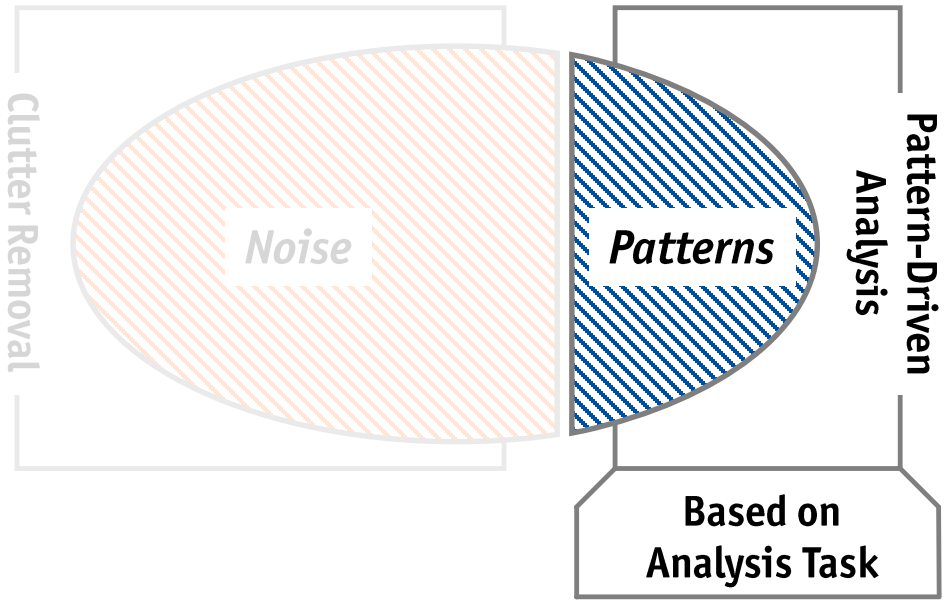


[3] Tatu, Andrada, et al. "Automated Visual Analysis Methods for an Effective Exploration of High-Dimensional Data.." TVCG 17.5 (2011):584-597.
[4] Seo, Jinwook, and Ben Shneiderman. "A rank-by-feature framework for interactive exploration of multidimensional data." Information visualization 4.2 (2005): 96-113.

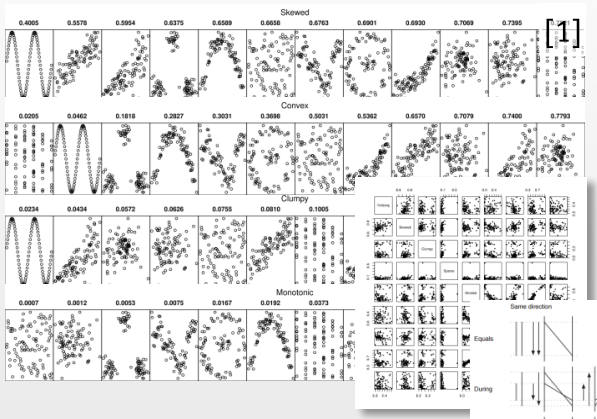
Magnostics.
Motivation.

Related Approaches.

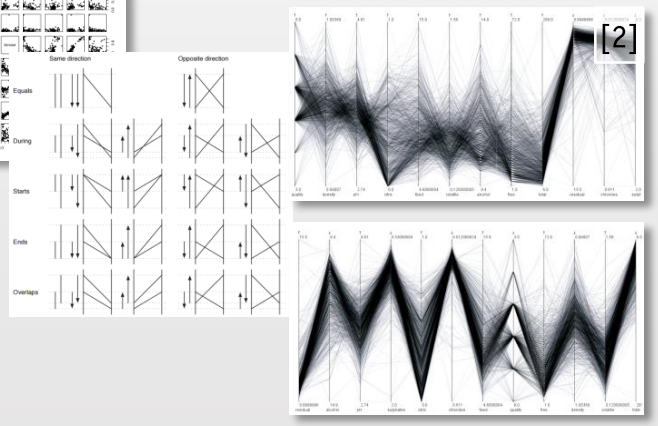
Noise Removal versus Pattern Retrieval



Scagnostics



Pargnostics

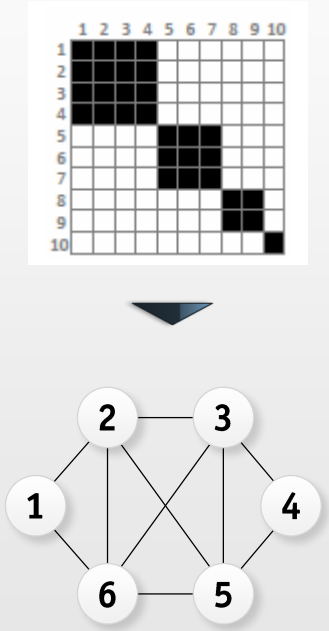


[1] Wilkinson, Leland, Anushka Anand, and Robert L. Grossman. "Graph-Theoretic Scagnostics." INFOVIS. Vol. 5. 2005.
[2] Dasgupta, Aritra, and Robert Kosara. "Pargnostics: Screen-space metrics for parallel coordinates." IEEE TVCG 16.6 (2010): 1017-1026.

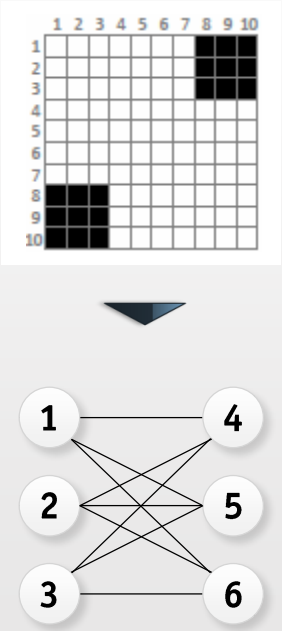
Background.
Patterns in Matrices.

Block Related Patterns

Block-Diagonal

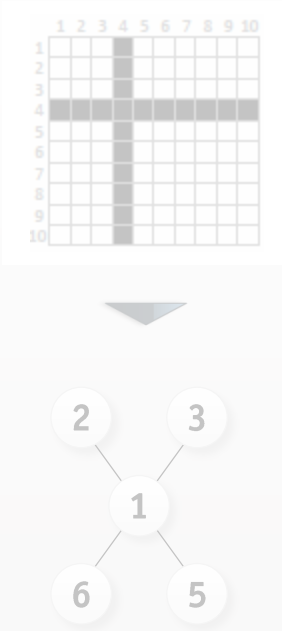


Off-Diagonal

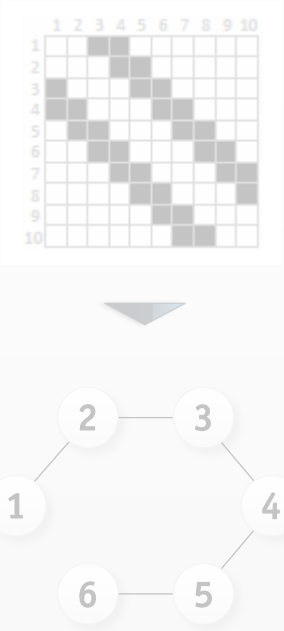


Line Related Patterns

Star/Line

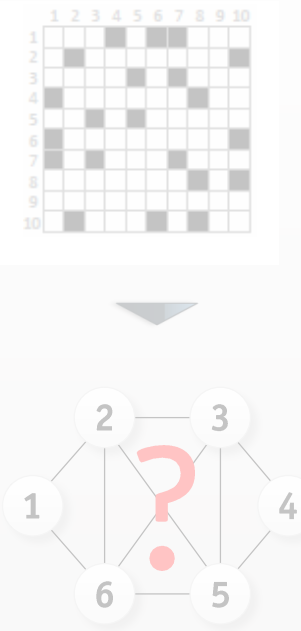


Bands

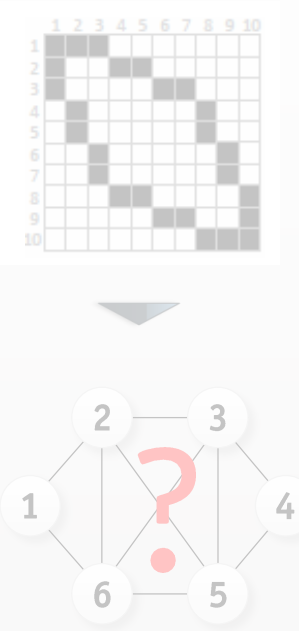


Anti-Patterns

Noise



Bandwidth



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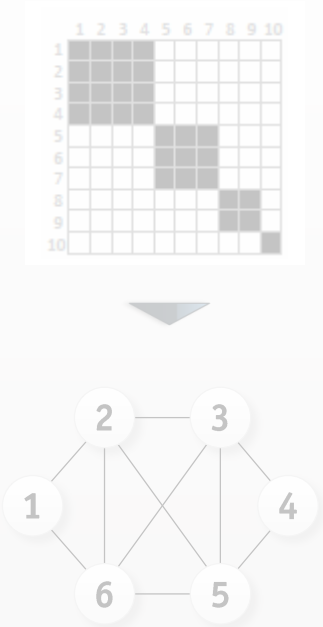
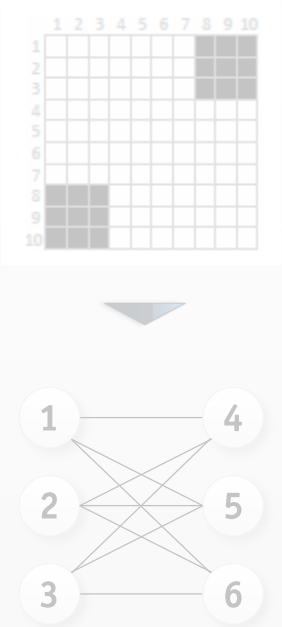
Background.
Patterns in Matrices.

Block Related Patterns

Block-Diagonal

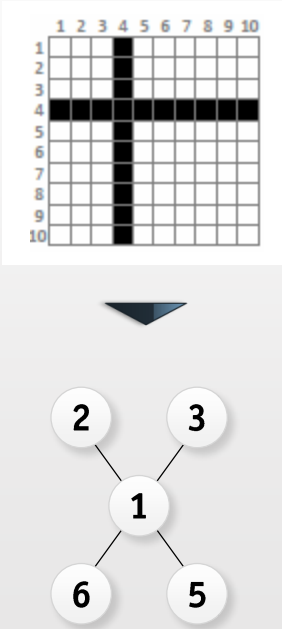


Off-Diagonal

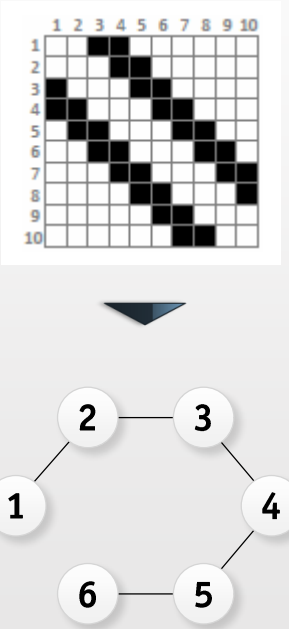


Line Related Patterns

Star/Line

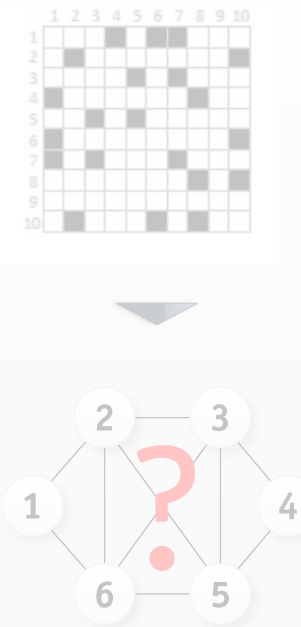


Bands

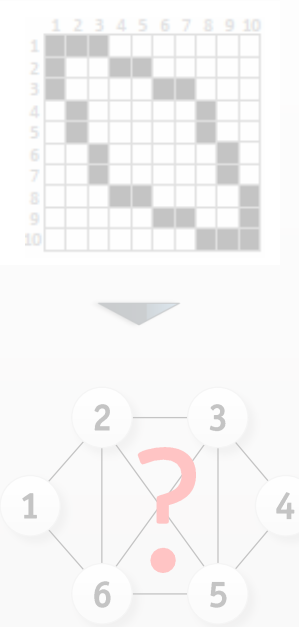


Anti-Patterns

Noise



Bandwidth



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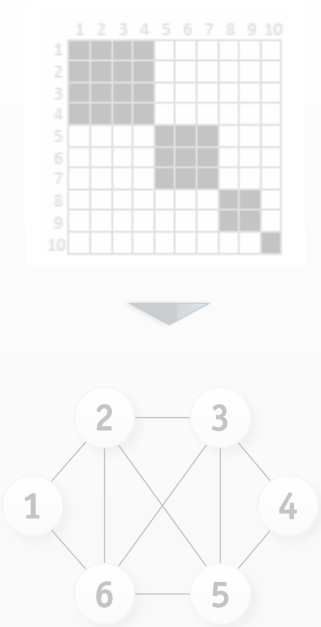
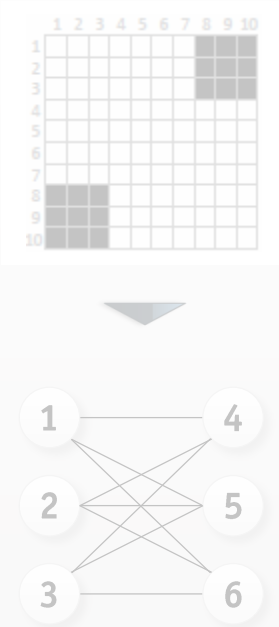
Patterns in Matrices.

Block Related Patterns

Block-Diagonal

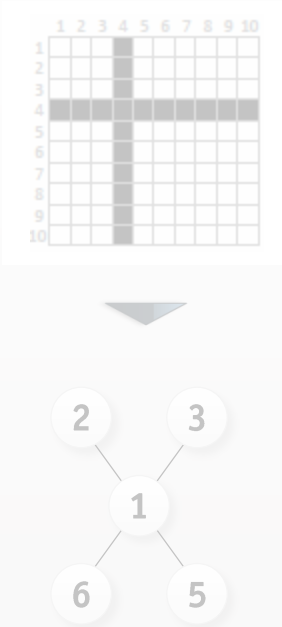


Off-Diagonal

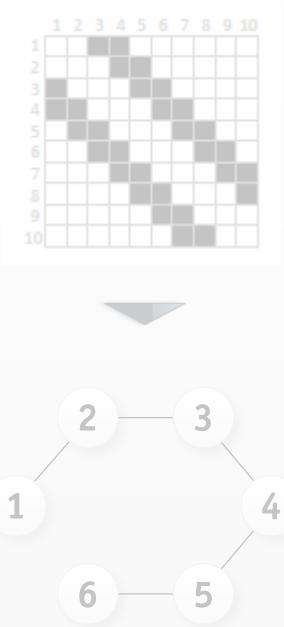


Line Related Patterns

Star/Line

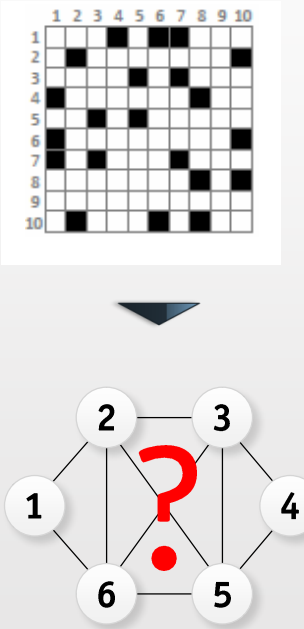


Bands

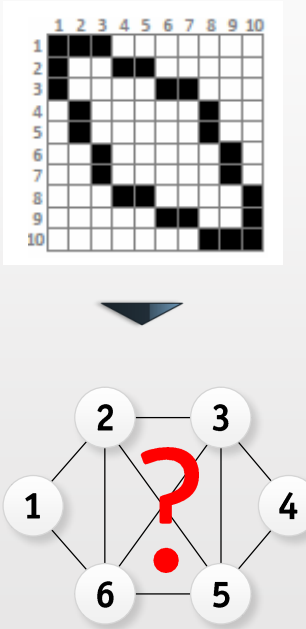


Anti-Patterns

Noise



Bandwidth



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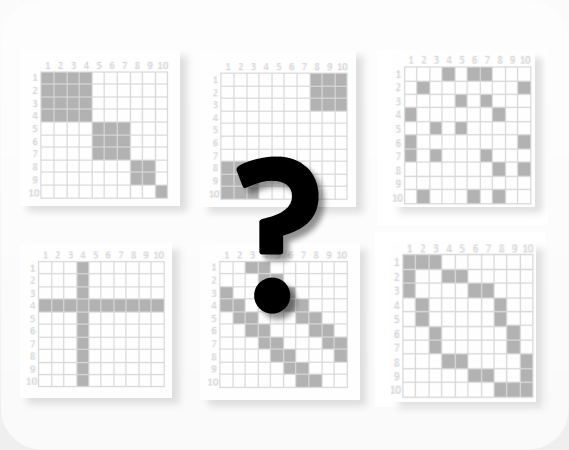
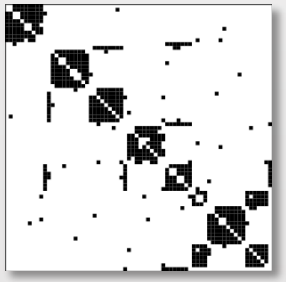
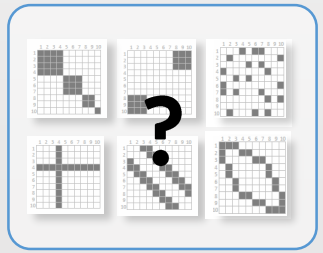
Magnostics.
Research Objectives and Contributions.

Research Goals and Questions.

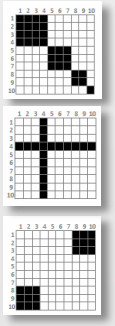


Imaginary Example 1





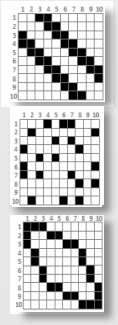
MAGNOSTICS



≈ 89%

≈ 6%

≈ 3%



≈ 1%

≈ 1%

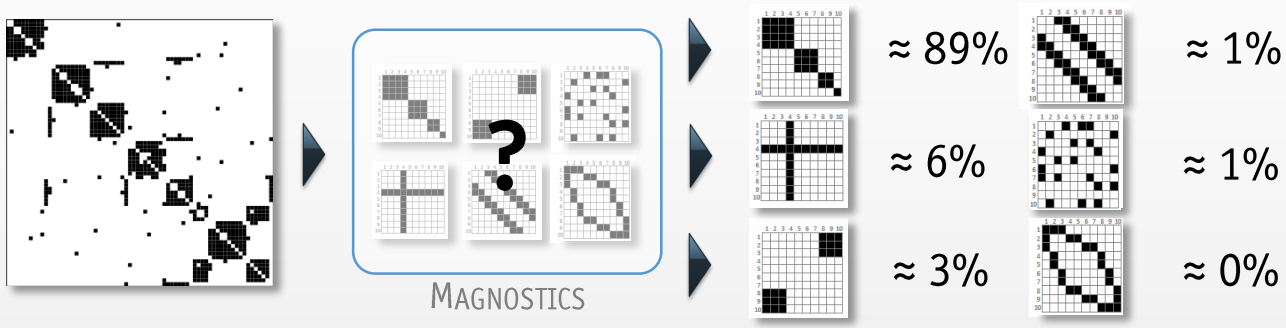
≈ 0%

Can we **quantify** the **existence** of **visual patterns** in matrices?

- **C1** Pattern Response
- **C2** Pattern Variability
- **C3** Pattern Sensitivity
- **C4** Pattern Discrimination

Magnostics.
What is it (not)?

Contributions.



- **Frontend:** Best Performing Image-based Feature Descriptors (FDs).
- **Backend:** Evaluation Framework and Matrix Pattern Benchmark Dataset.

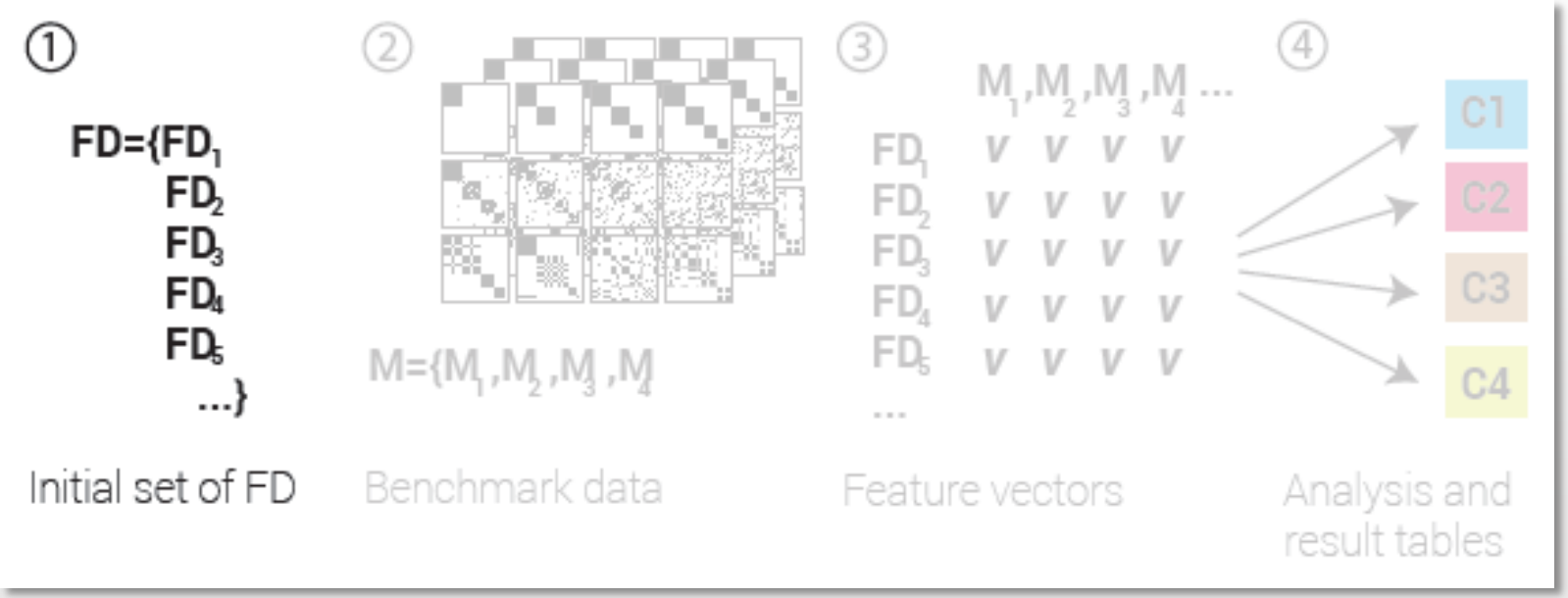
Magnostics.

Pattern-Driven Analysis of Matrices.

Pattern Analysis

2.0

Automatic Analysis of Matrix Patterns.



Magnostics.

Pattern-Driven Analysis of Matrices.

Automatic Analysis of Matrix Patterns.

Feature Descriptor	Group	Reference
GLOBAL_COLOR_HISTOGRAM	Color	[30]
AUTO_COLOR_CORRELOGRAM		[18]
FUZZY_HISTOGRAM		[13]
FUZZY_OPPONENT_HISTOGRAM		[41]
COLOR_OPPONENT_HISTOGRAM		
THUMBNAIL		
MPEG7_COLOR_LAYOUT	Color Layout	
LUMINANCE_LAYOUT		
CEDD		
FCTH		
JCD		
EDGEHIST	Edge	
MPEG7_EDGE_HISTOGRAM		
HOUGH		

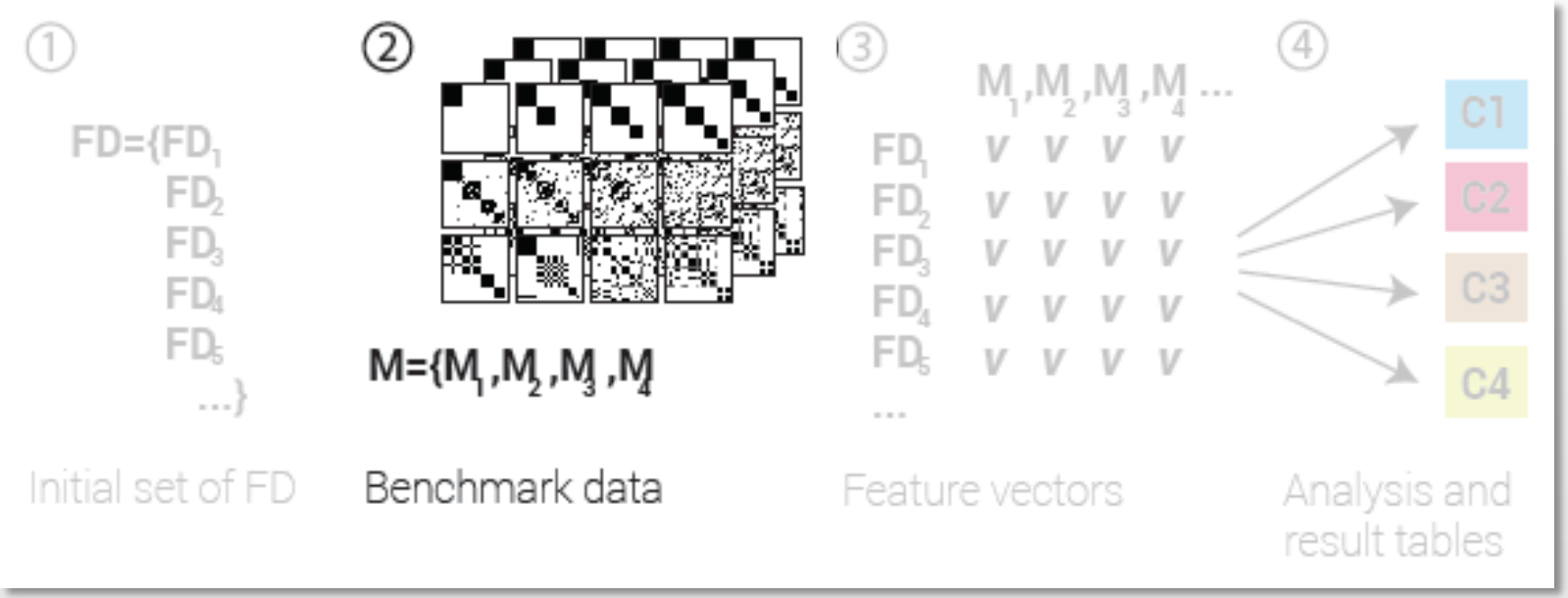
Feature Descriptor	Group	Reference
SURF	Point of Interest	[3]
FAST		[29]
BLOCKS	Shape	Java
COMPACTNESS		[25]
ECCENTRICITY		[47]
ADAPTIVE_GRID_RESOLUTION		
JPEG_COEFFICIENT_HISTOGRAM	Structure	
PROFILES		
FRACTAL_BOX_COUNTER		
PHOG		

Feature Descriptor	Group	Reference
HARALICK	Texture	[14]
GABOR		[23]
TAMURA		[38]
LOCAL_BINARY_PATTERN		[15]
NOISE_STATISTICAL_SLIDINGWINDOW		Java
NOISE_DISSIMILARITY		[1]
GRADIENT		[42]

Magnostics.

Pattern-Driven Analysis of Matrices.

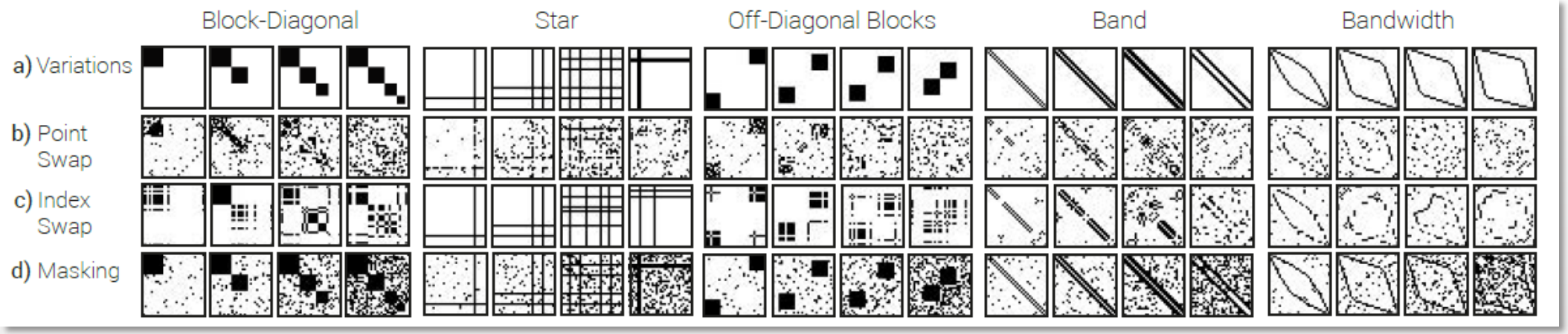
Automatic Analysis of Matrix Patterns.



Magnostics.

Pattern-Driven Analysis of Matrices.

Automatic Analysis of Matrix Patterns.



5570 Artificially Generated Benchmark Matrix Plots

- Five base patterns + one noise antipattern
- Three “degeneration methods”
- Up to ten base pattern variations

Magnostics.

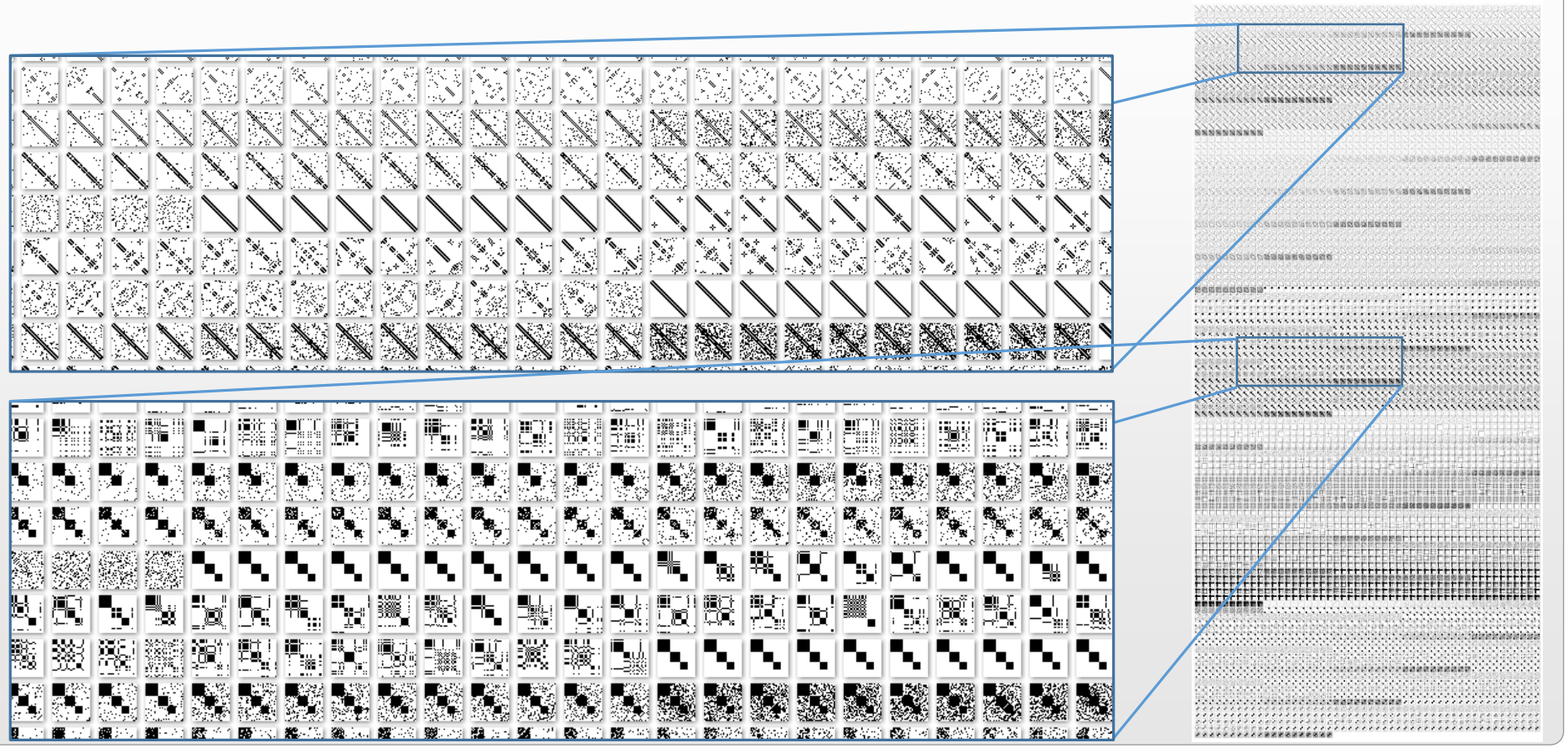
Pattern-Driven Analysis of Matrices.

Pattern Analysis

2.2

Matrix Pattern Benchmark Dataset.

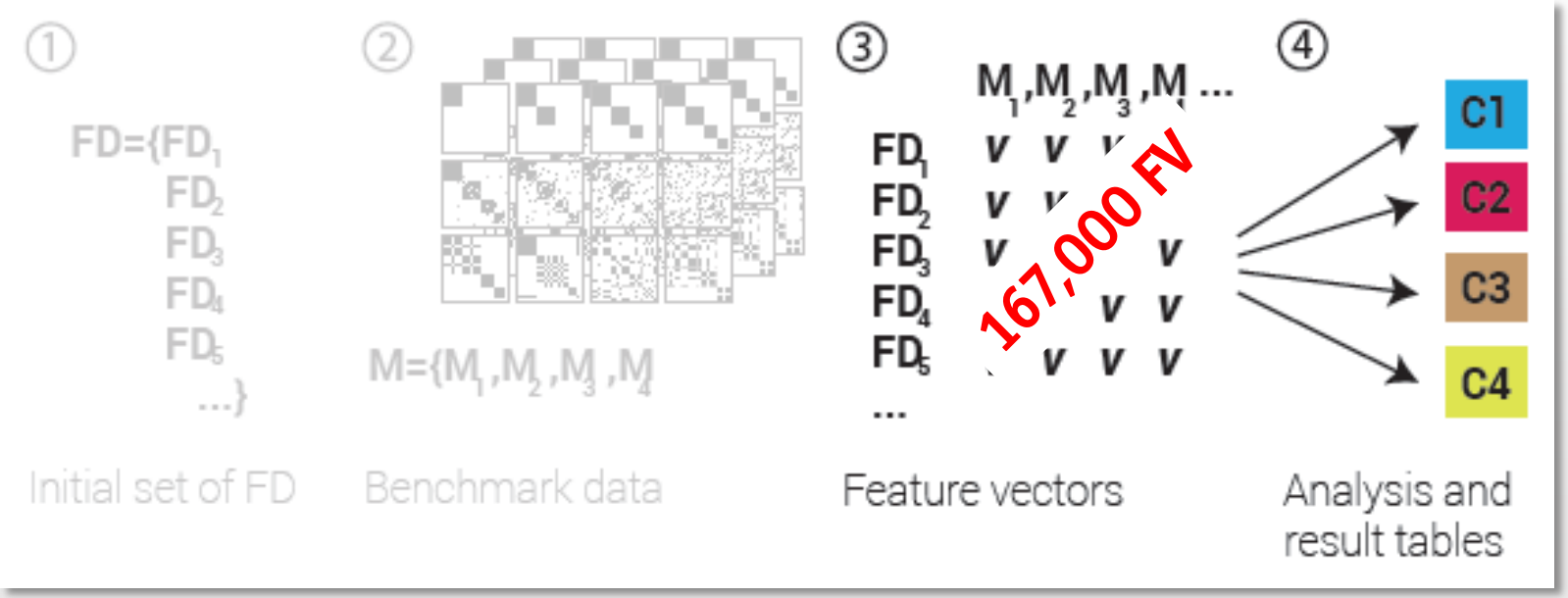
Base Pattern Variation



Magnostics.

Pattern-Driven Analysis of Matrices.

Automatic Analysis of Matrix Patterns.

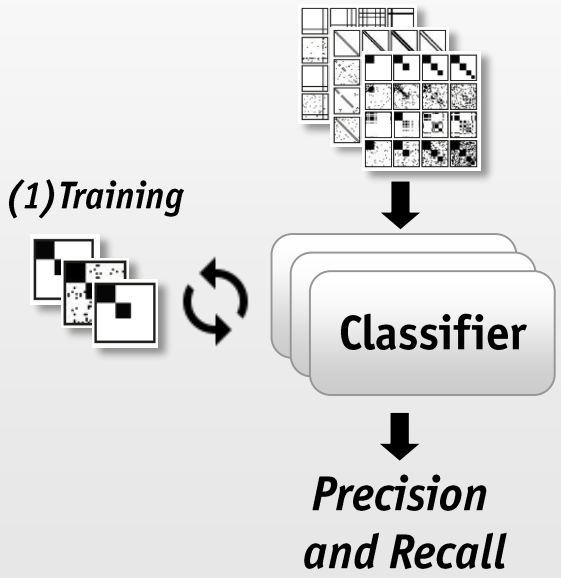


Magnostics.
Pattern-Driven Analysis of Matrices.

Evaluation Criteria

C1 **Pattern Response** *To which specific matrix pattern(s) does the FD respond?*

Experiment Setup



Metric Target/Goal

Favoring High Recall over **High Precision**
retrieve a large fraction of all correct answers.

Quality Metric

$$F_\beta = (1+\beta^2)\cdot\frac{\text{precision}\cdot\text{recall}}{(\beta^2\cdot\text{precision})+\text{recall}}$$

Magnostics.

Pattern-Driven Analysis of Matrices.

Evaluation Criteria

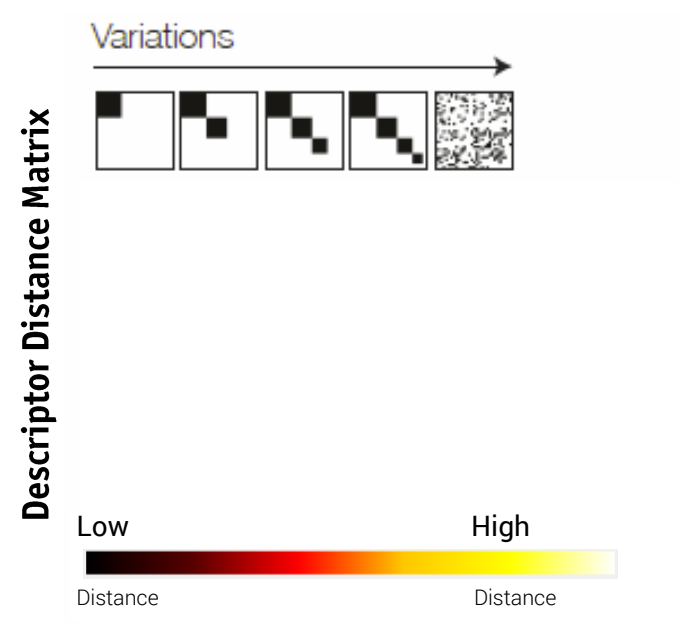
C2	**Pattern Variability**	*How much variation in the pattern can the FD detect?*

Magnostics.
Pattern-Driven Analysis of Matrices.

Evaluation Criteria

C2 **Pattern Variability** *How much variation in the pattern can the FD detect?*

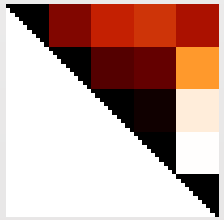
Experiment Setup



Metric Target/Goal

High Standard Deviation represents FDs ability to discriminate the base patterns.

Negative Example



FUZZY_
OPPONENT_
HISTOGRAM

Quality Metric

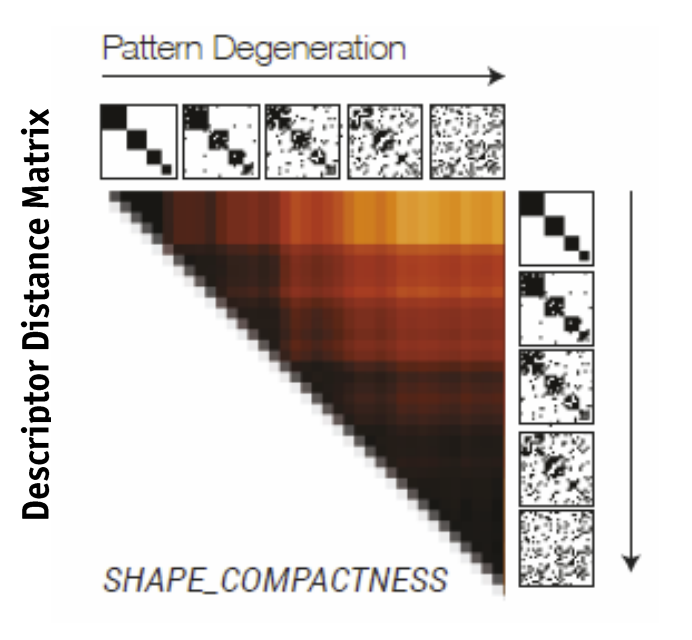
$$\sigma_{FD_i}(PV) = \sqrt{\frac{1}{|PV|} \sum_{1 \le i,j \le |PV|} \left(ndist(PV_i, PV_j) - \bar{x}\right)^2}$$

Magnostics.
Pattern-Driven Analysis of Matrices.

Evaluation Criteria

C3 **Pattern Sensitivity** *How sensitive is the FD to pattern degeneration (noise)?*

Experiment Setup

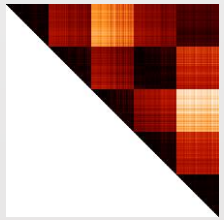


Metric Target/Goal

(1) Monotony degeneration degree reflected by the FD distances

(2) Sensitivity highly sensitive (fast increase of distances) versus tolerant (slow increase of distances).

Negative Example



TEXTURE
GABOR

Quality Metric

(1)
$$monotony(FD_i, P_j) = \begin{cases} 1, & (mean_{l+1} - mean_l + 0.05) > 0; \\ & \forall l \in noise_levels. \\ 0, & otherwise \end{cases}$$

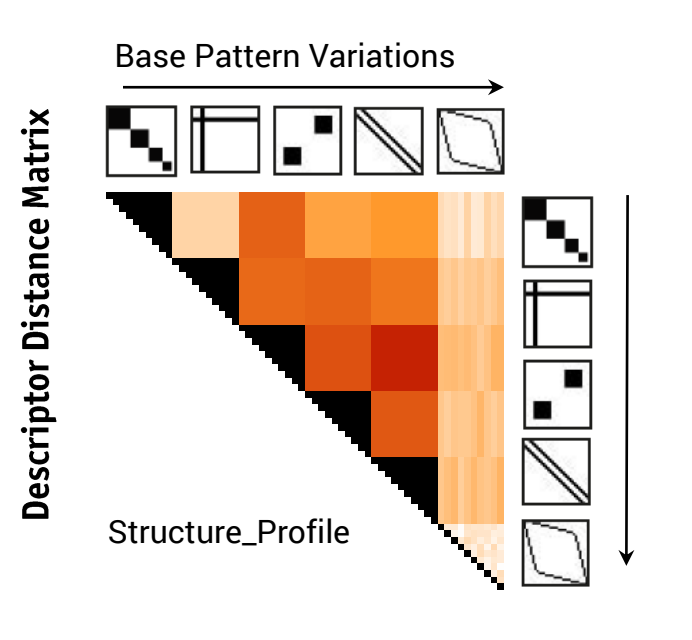
(2)
$$sensitivity(FD_i, P_j) = \sum_{l=0}^{|noise_levels|-1} \left((mean_k - (\frac{l}{|noise_levels|})) \right)$$

Magnostics.
Pattern-Driven Analysis of Matrices.

Evaluation Criteria

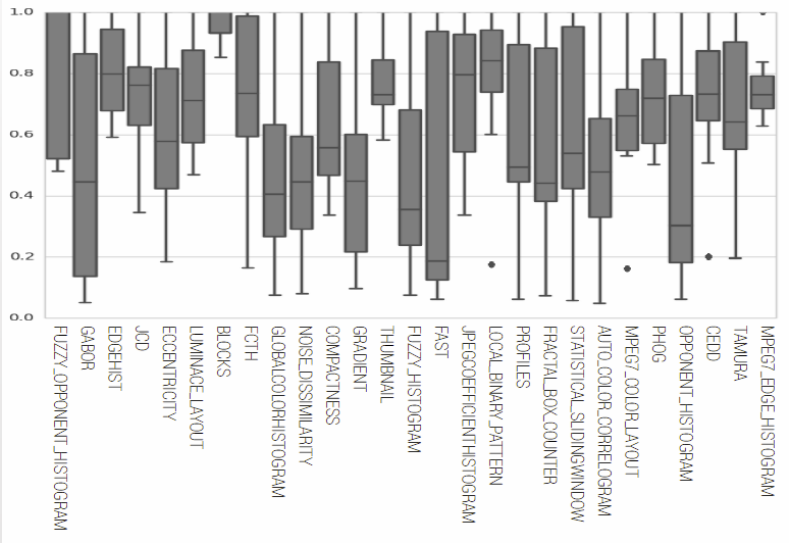
C4 **Pattern Discrimination** *How different does the FD respond to different patterns?*

Experiment Setup



Metric Target/Goal

High Median and **Low Variance** reflects strong discrimination



Negative Example

COLOR
FuzzyOpponent
Histogram

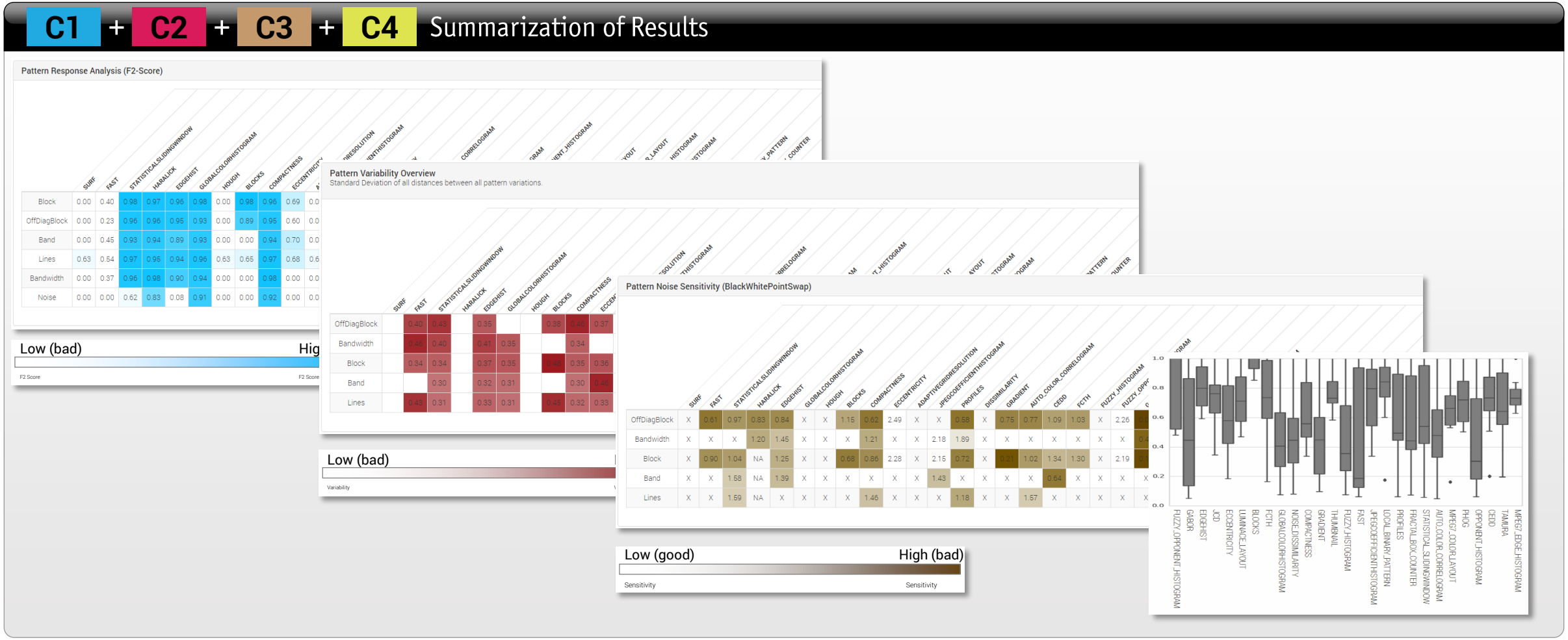
Magnostics.

Pattern-Driven Analysis of Matrices.

Pattern Analysis

2.4

C1 + C2 + C3 + C4 Summarization of Results



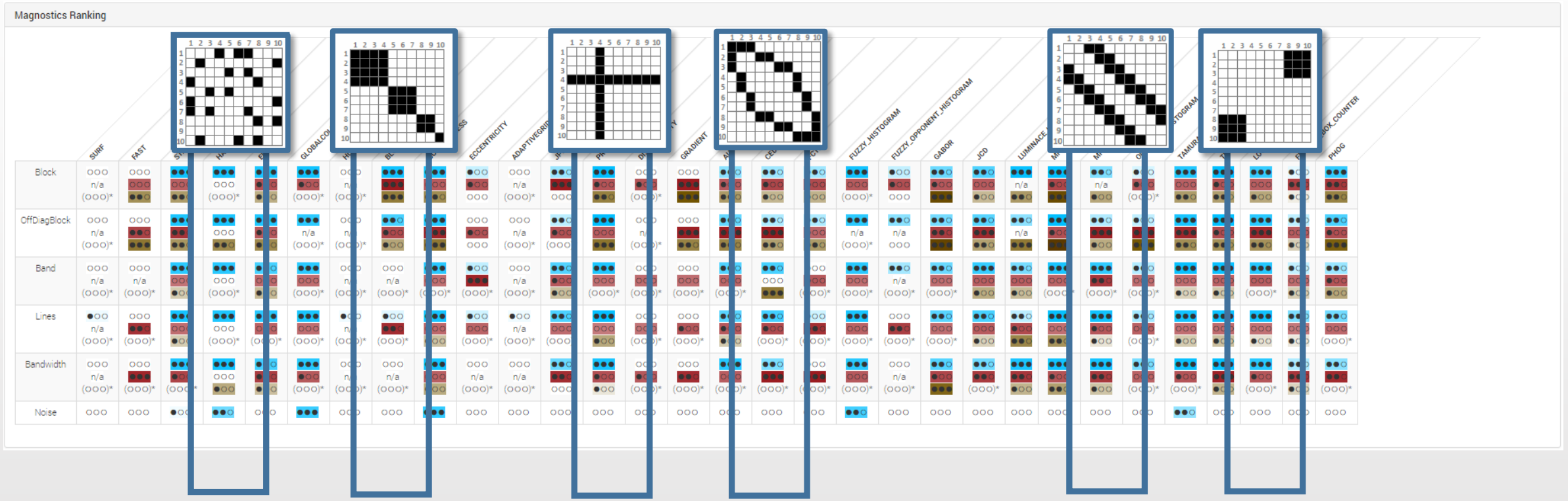
Magnostics.

Pattern-Driven Analysis of Matrices.

Pattern Analysis

2.4

C1 + **C2** + **C3** + **C4** Summarization of Results



Haralick

Blocks

Profiles

CEDD

MPEG7 Edge Histogram

Local Binary Patterns

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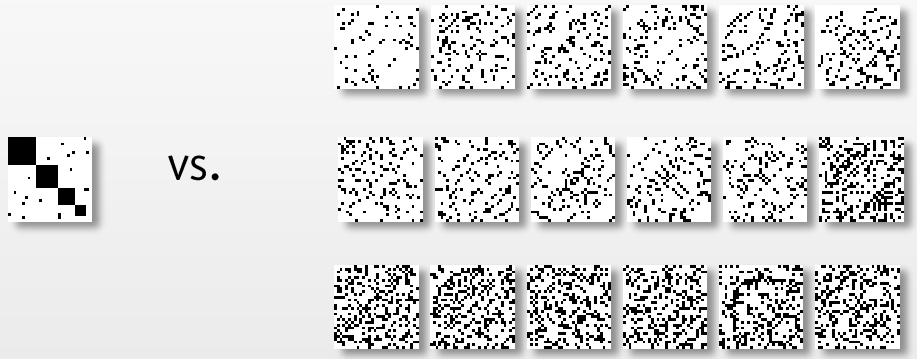
Pattern-Driven Analysis of Matrices.

C1 + C2 + C3 + C4 Visual Inspection of Results

Distance to Noise
Independent from benchmark



Noise more and more visible

Pattern more and more visible

Distance to Base Pattern
More natural understanding, but benchmark dependent

Pattern more and more visible

Noise more and more visible

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Pattern-Driven Analysis of Matrices.

C1 + **C2** + **C3** + **C4** Visual Inspection of Results Discrimination

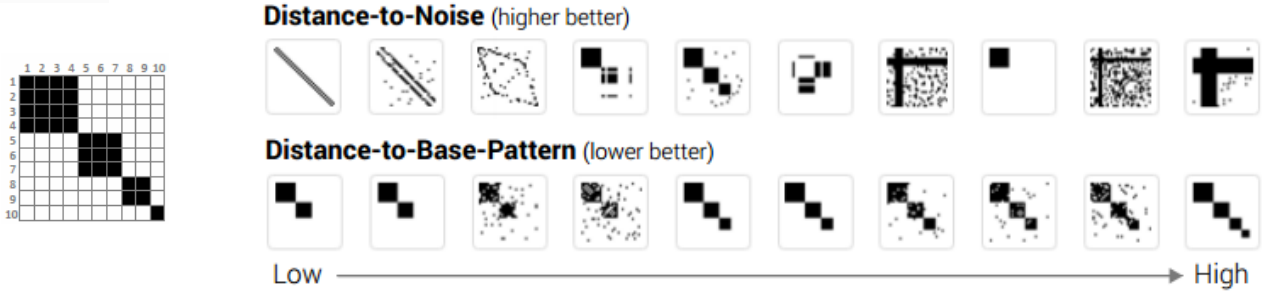

Figure 1.10 Examples for our Block Descriptor, specifically engineered to retrieve blocks around the matrix diagonal.

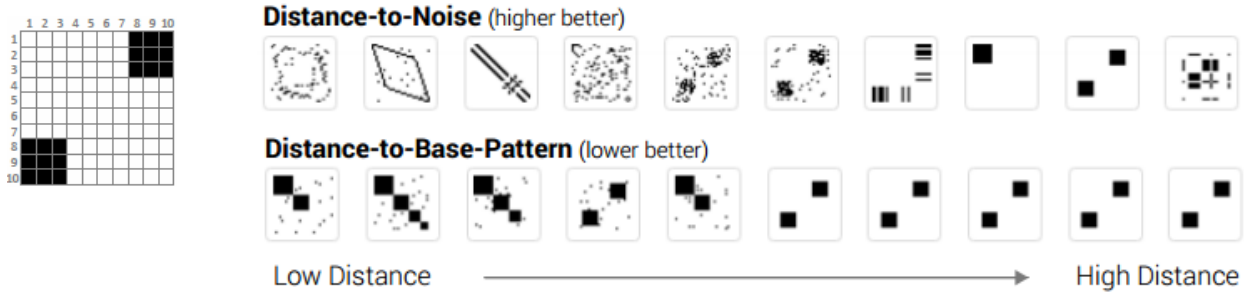

Figure 1.11 Examples for the Local Binary Pattern Descriptor.

Magnostics.
Pattern-Driven Analysis of Matrices.

C1 + **C2** + **C3** + **C4** Visual Inspection of Results Discrimination

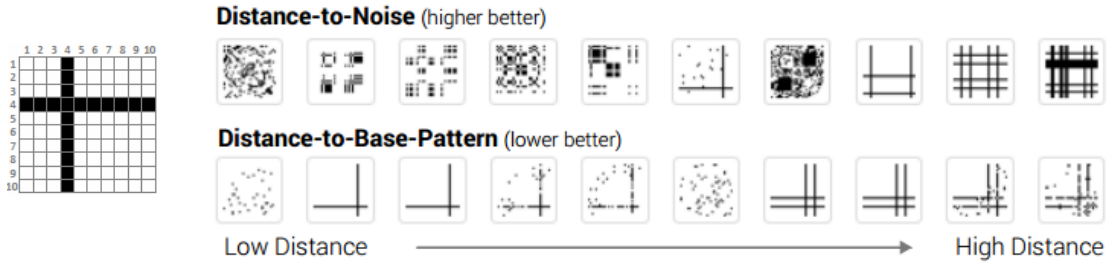

Figure 1.12 Examples for our Profile Descriptor.

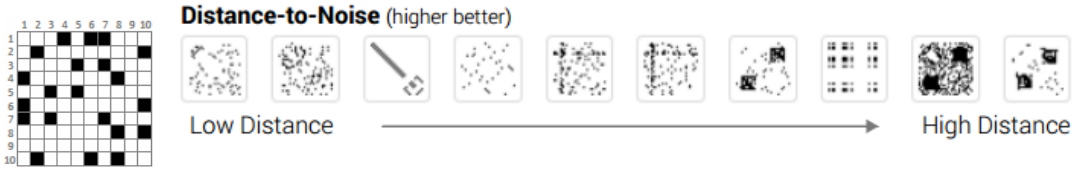

Figure 1.15 Examples for our STATISTICAL SLIDING WINDOW Descriptor.

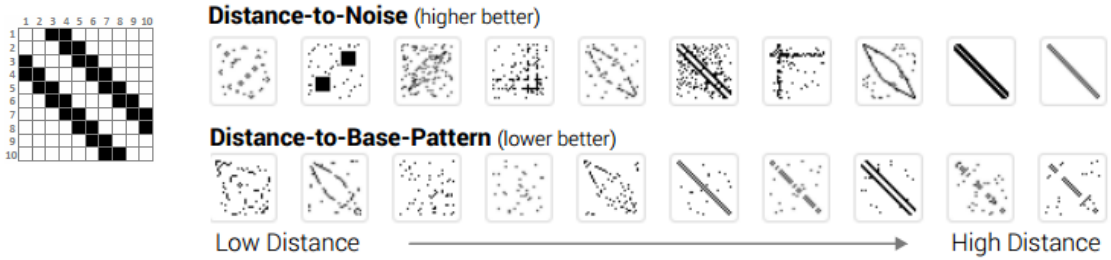

Figure 1.13 Examples for the MPEG7 Edge Histogram Descriptor.

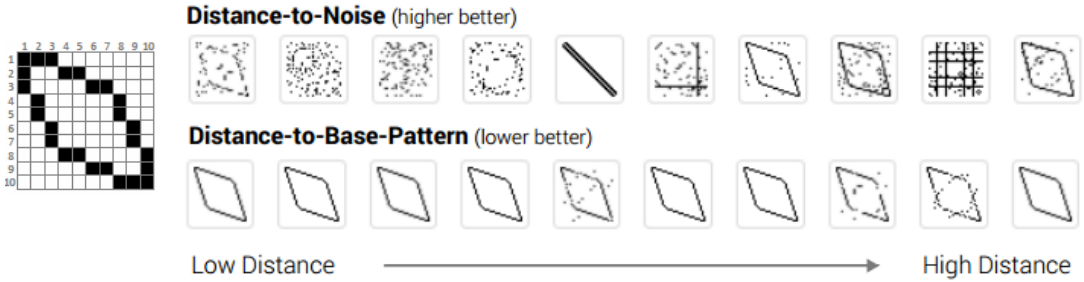

Figure 1.14 Examples for the CEDD Descriptor.

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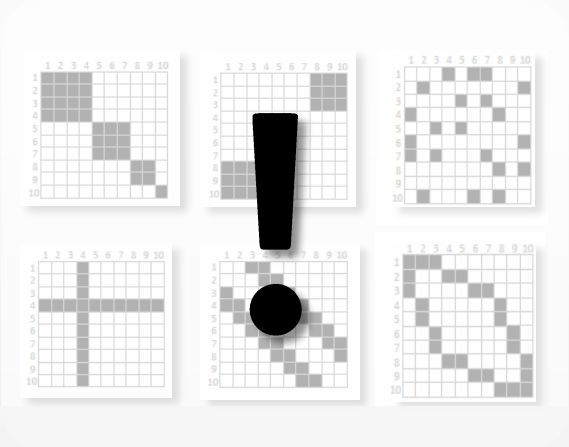
Research Directions.

Opportunities and Future Research Directions.



Magnostics

helps **quantify** the existence of **visual patterns** in matrices

Imaginary Example 1

MAGNOSTICS

≈ 89% ≈ 1%

≈ 6% ≈ 1%

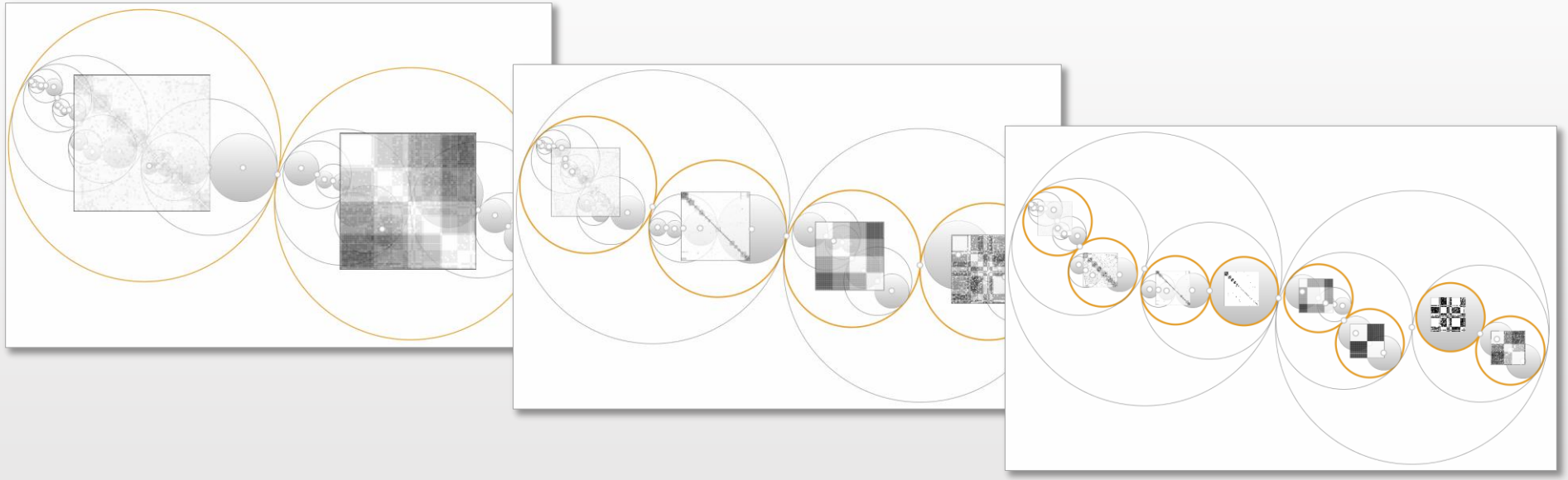
≈ 3% ≈ 0%

C1	Pattern Response
C2	Pattern Variability
C3	Pattern Sensitivity
C4	Pattern Discrimination

Magnostics.
Research Directions.

Opportunities and Future Research Directions.

Interface Design for Retrieval.

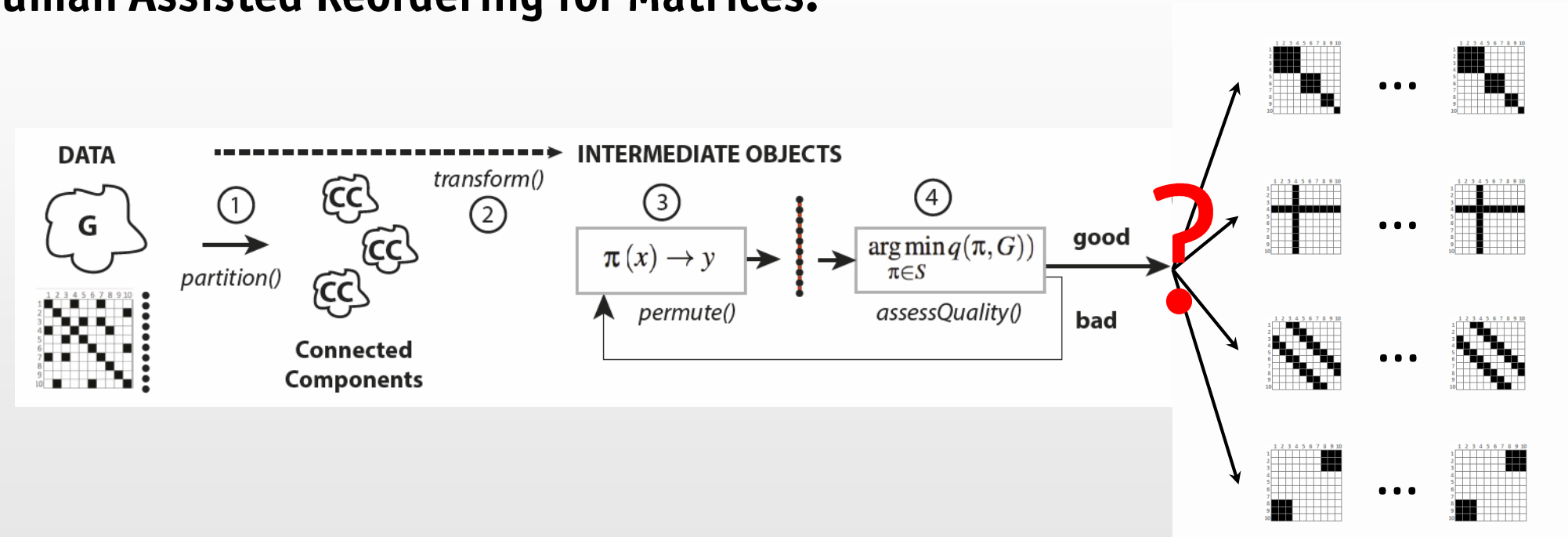


Visual Support and Visual Analytics is needed.

Magnostics.
Research Directions.

Opportunities and Future Research Directions.

Human Assisted Reordering for Matrices.



Steering at Critical Points and Interactive Reordering.

Images courtesy: Laura von Rüden Masterthesis „Visual Analytics of Parallel-Performance Data - Automatic Identification of Relevant and Similar Data Subsets“ RWTH Aachen 2015

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Conclusion.

Take Home Messages.

- Visual **Matrix Pattern Analysis** is possible.
- Allows for a totally **New Approach** to **Matrix Analysis.**
- **Visual Analytics** allows to relate **Pattern** to **User Tasks.**

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Magnostics.
Conclusion.

Take Home Messages.

!!!

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Postdoc Position

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Magnostics.
Conclusion.

Thank you.

!!!

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THANK YOU FOR YOUR ATTENTION!!