VizSEC 2007
Workshop on Visualization for Computer Security

Georgia State University
Department of Computer Science

Measuring the Complexity of Visualization for Computer Security

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Motivation

- We propose a method to analyze the complexity of a information visualization design
- The method evaluates a set of factors that influence the efficient comprehension of visual information
- The method is useful during the visualization design stage before any user study can take place

Case Studies

- Two open source security visualization software are used as case studies
  - TNV: http://tnv.sourceforge.net/
  - Rumint: http://www.rumint.org/
- The sample dataset is obtained from http://wiki.ethereal.com/CIGI

Outline

- Complexity Analysis
- Case Studies (Rumint)
- Conclusion and future work

Complexity analysis steps

- Analyze the design space
- Separable dimensions of visual units
- Analyze the visual integration complexity
- Analyze the visual mapping complexity
- Analyze the visual search complexity

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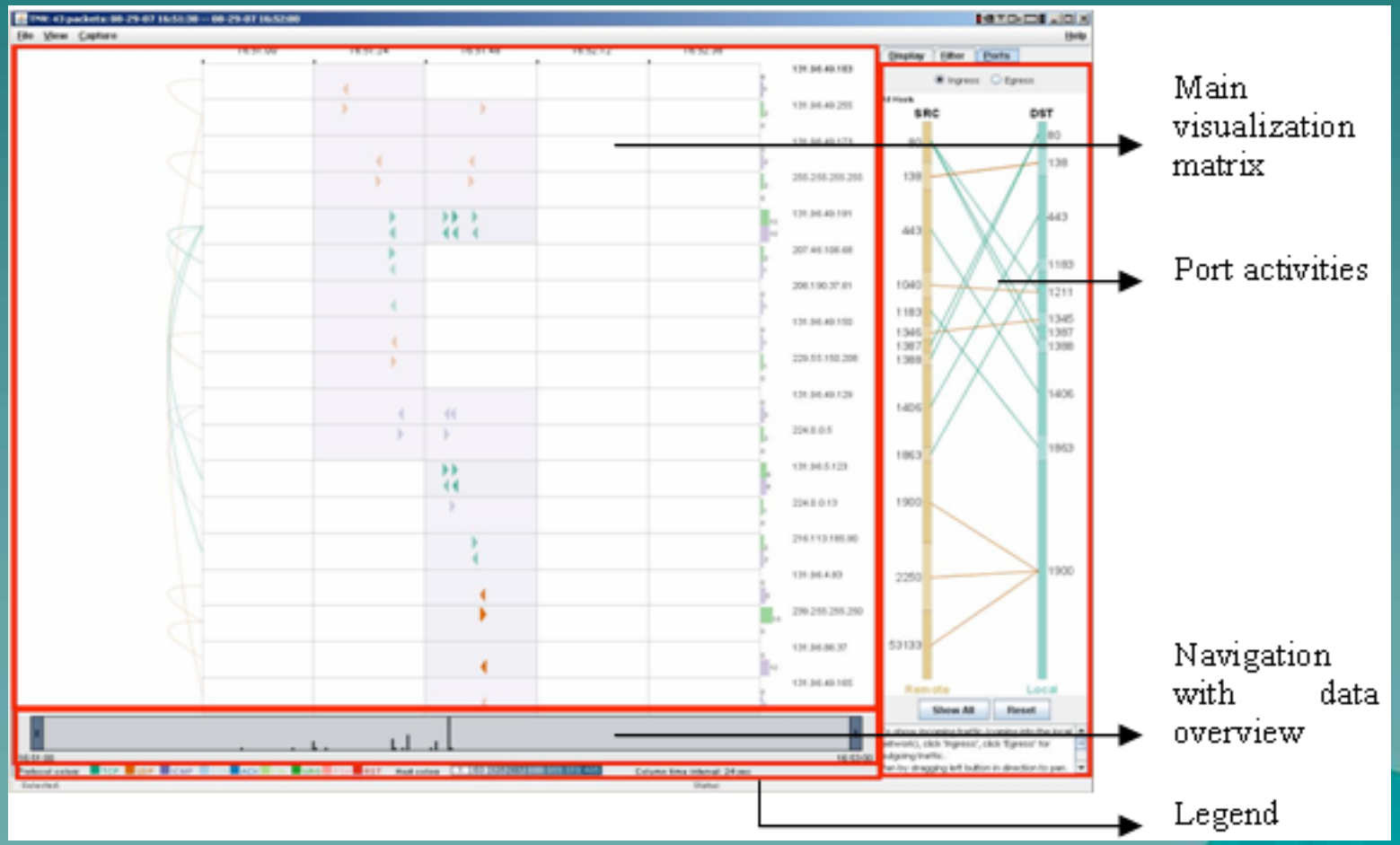
Hierarchical analysis of data visualization

- Workspace
  - One or more visual frames that are designed for a specific purpose.
- Visual frame
  - A visual frame is a window within a workspace and contains multiple visual patterns.
- Visual patterns
  - A visual pattern is a set of visual units that are readily perceived as a group
- Visual units
  - Some examples of visual units such as: point, line, 2D shape (glyph), 3D object, text, and image.
- Visual attributes
  - Each visual unit is defined by seven visual attributes [10]: position, size, shape, value, color, orientation, and texture.

TNV Interface



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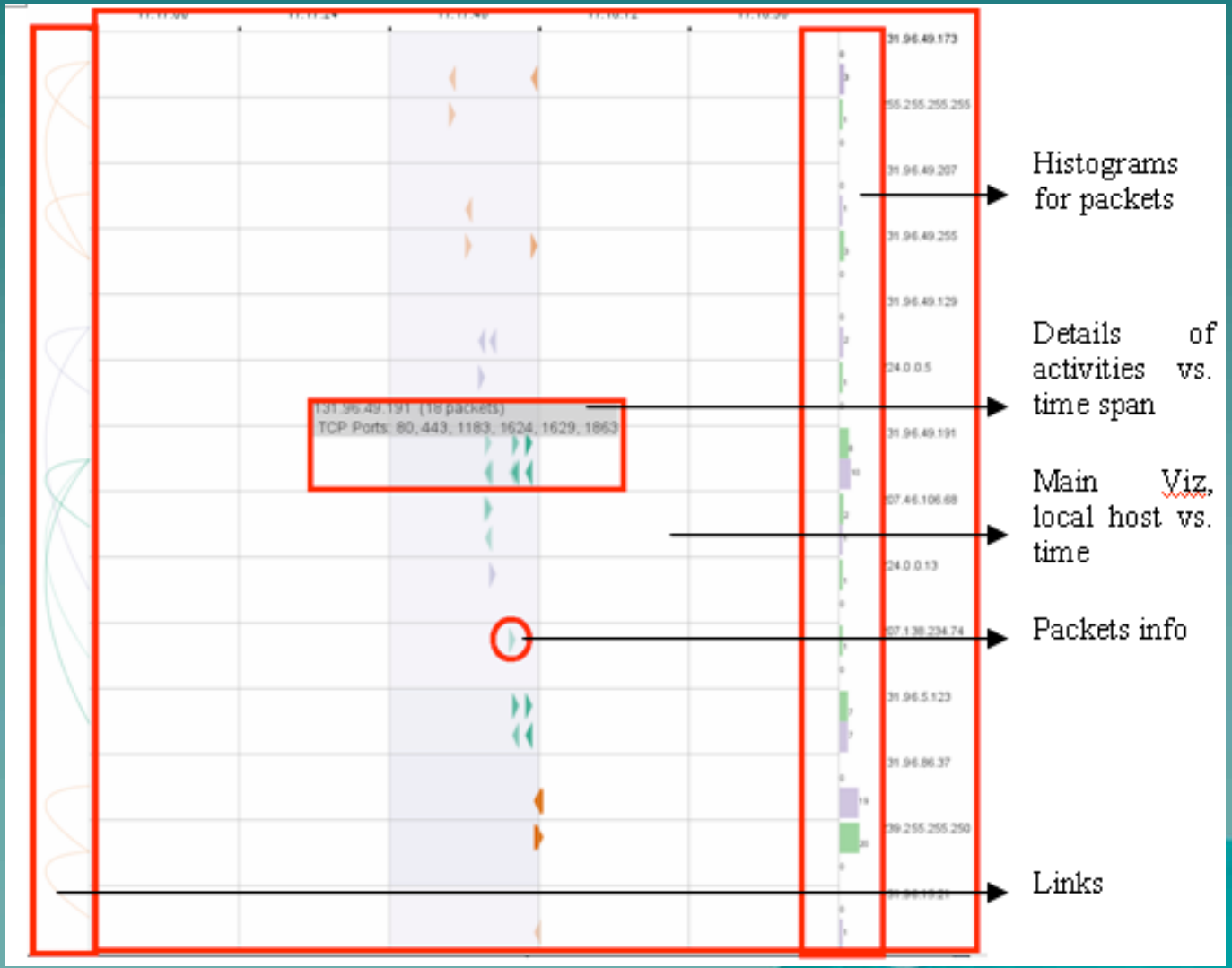
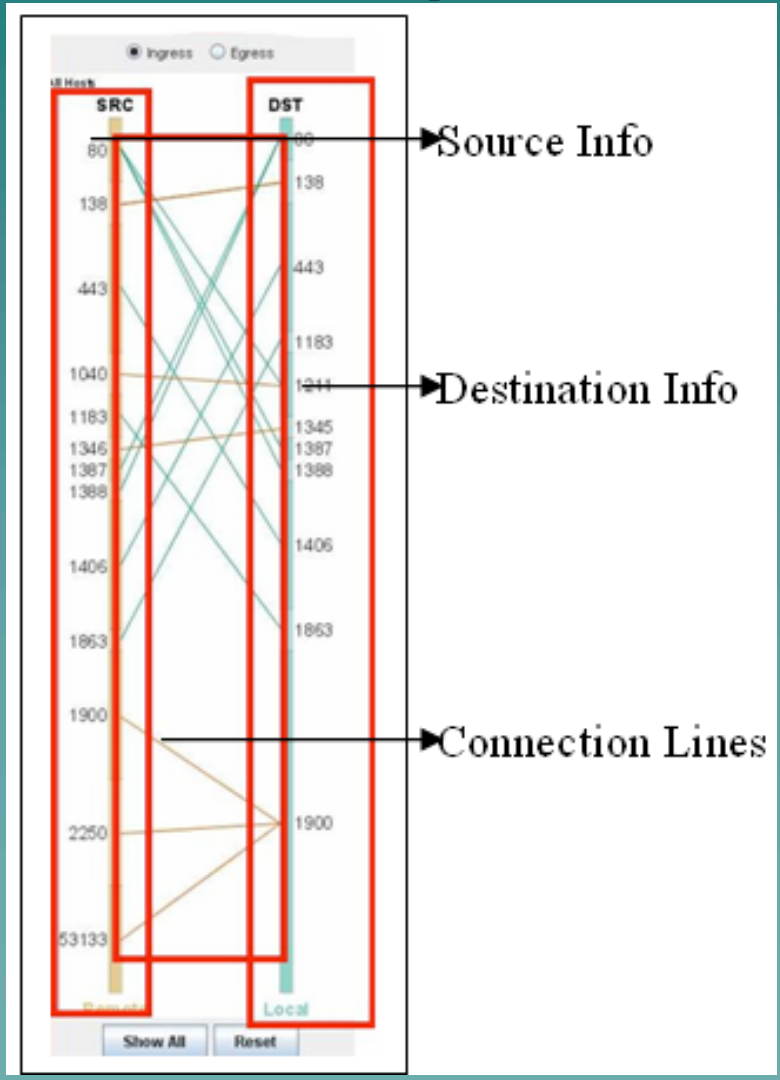
Criterion of separable dimensions

- X and Y coordinates (position)
- Shape, Size, Color,
- Value (gray scale),
- Orientation

Five different dimensions in TNV main visualization matrix.



Three different dimensions in port visualization



- (a) Source and destination information is categorized based on the coordinate (vertical axis).
- (b) Connection lines between the two axes are categorized based on shape/color

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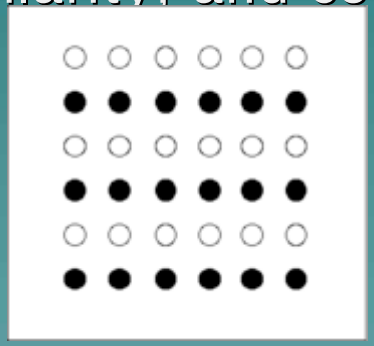
Complexity of visual integration

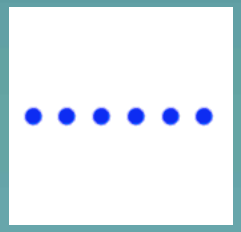
- For each visual frame, we identify the visual patterns in that frame based on four Gestalt laws: proximity, good continuation, similarity, and common fate.

Law of Proximity



Law of Similarity

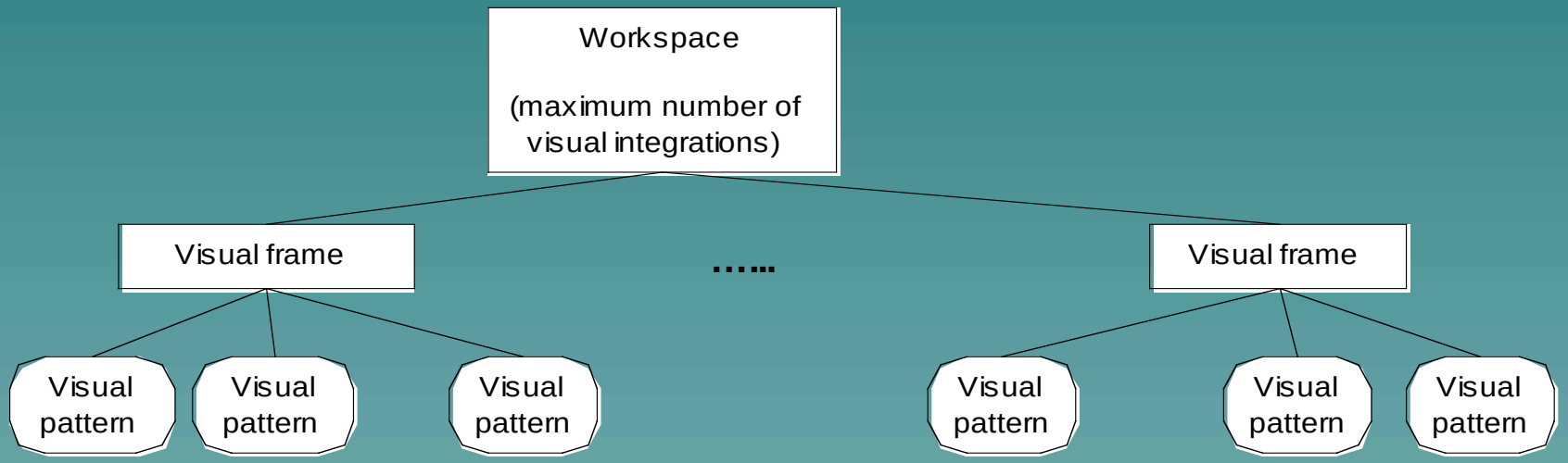
Law of Continuation



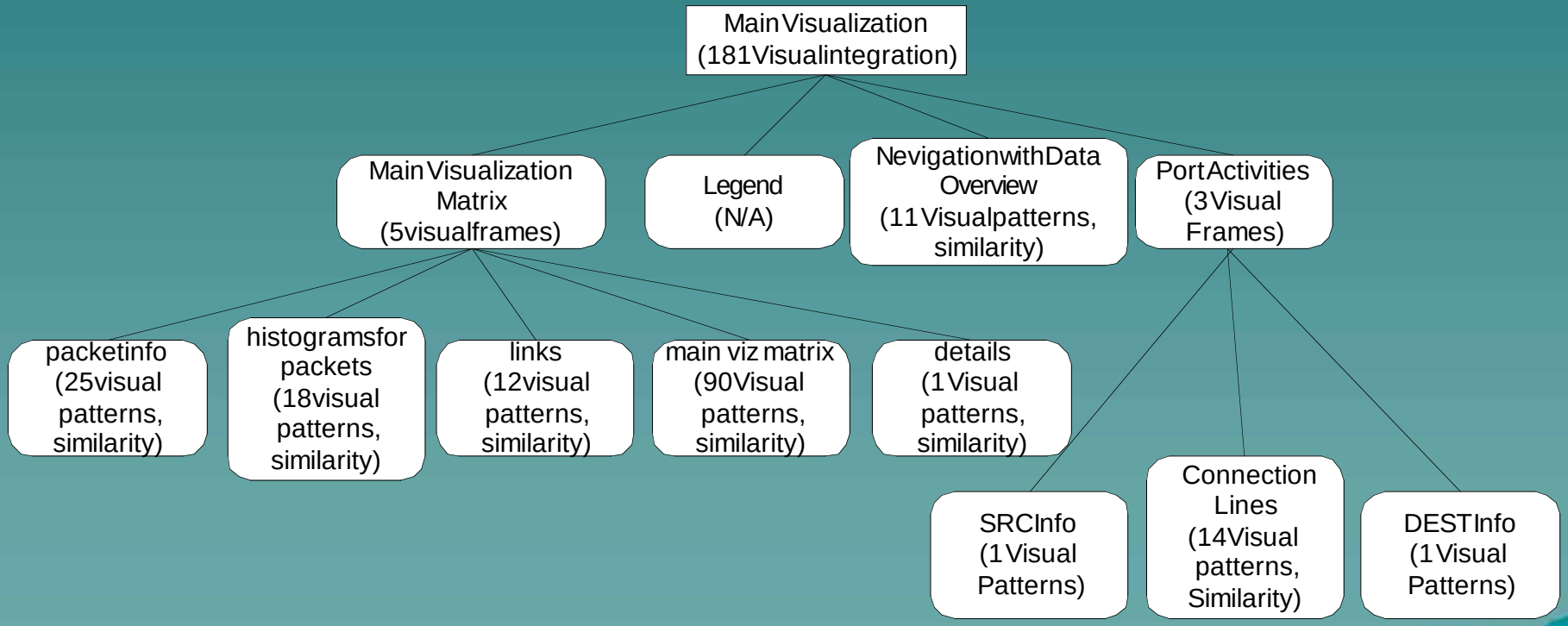
Law of Common Fate

- The number of nodes on the visual integration complexity represents the upper bound of visual integration a reader might perform.

Visual integration tree



Visual integration tree for TNV



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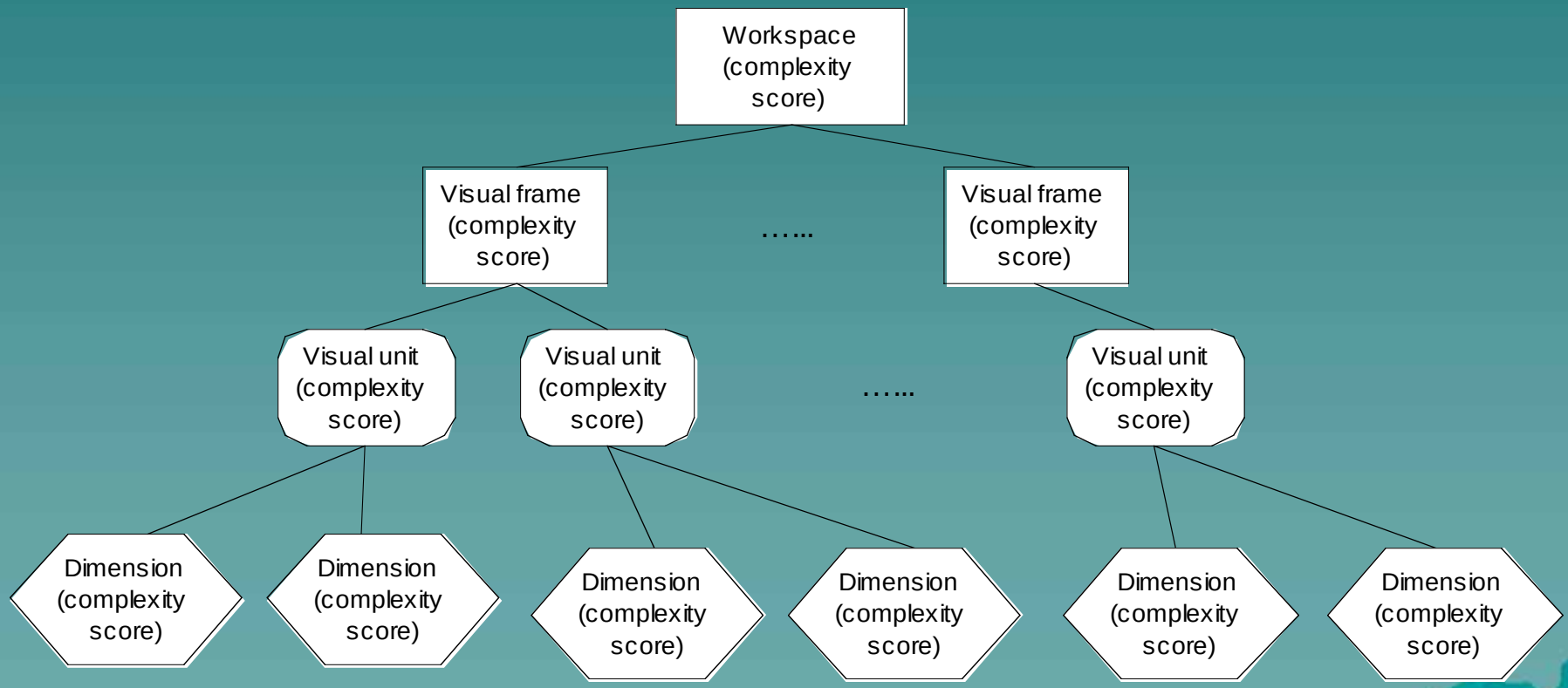
Complexity of visual mapping

- Readers not only need to remember the mapping between data parameters and visual attributes, they also need to interpret the value of these visual attributes.
- The mental effort for such interpretation is another source of extraneous cognitive load.
- For each separable dimension, we assign a score for the complexity of interpreting the values of the visual attribute based on the following criteria

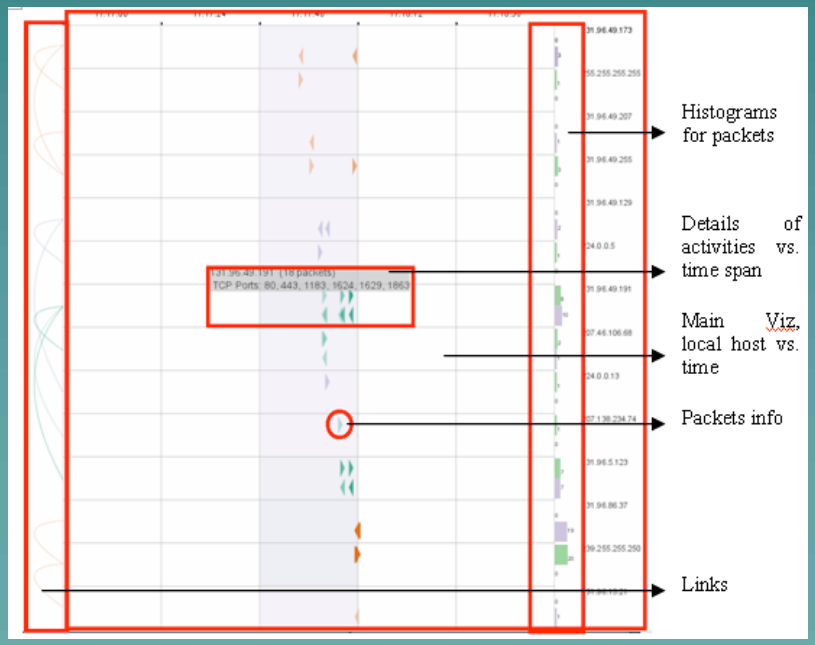
Complexity scores for interpreting visual units

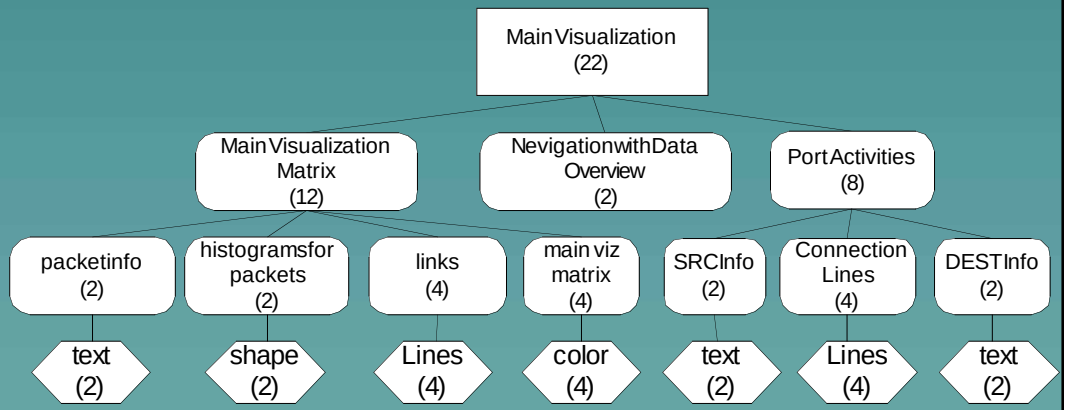
Complexity score	*Criteria*
5	Very difficult to interpret. There is no legend. A typical reader has to memorize the mapping between the value of the visual attribute and the value of the corresponding data parameter
4	More difficult to interpret. A typical reader needs to frequently refer to a legend to interpret the value of the visual attributes
3	Somewhat difficult to interpret. A typical reader needs to refer to a legend from time to time.
2	Relatively easy to interpret. A typical reader only needs to refer to a legend occasionally.
1	Easy to interpret. This is based on common knowledge. There is no need to memorize or refer to a legend.

Visual mapping complexity tree



Visual mapping complexity tree for TNV





Complexity analysis steps

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Complexity of visual search

- Target-distracter difference is the key to efficient visual search
- Four major factors affect the target-distracter differences

Color

$$c = \left(\left|\frac{\sum_{i=1}^{n} T_r}{N} - D_r\right| + \left|\frac{\sum_{i=1}^{n} T_g}{N} - D_g\right| + \left|\frac{\sum_{i=1}^{n} T_b}{N} - D_b\right|\right) / 765$$

motion

$$M = \frac{\left|\frac{\sum_{i=1}^{n} Tf}{N} - Df\right|}{F}$$

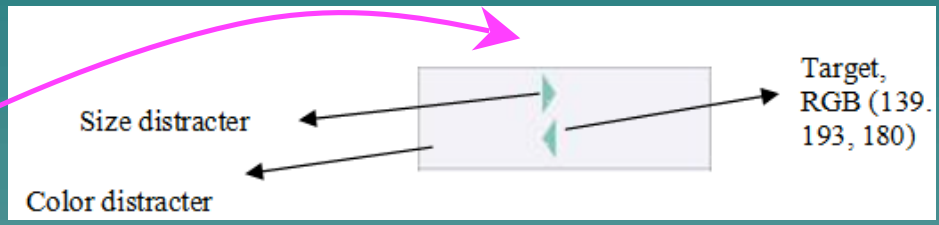
Size

$$s = \frac{\sum_{i=1}^{n} \frac{|Ts - Ds|}{s}}{N}$$

orientation

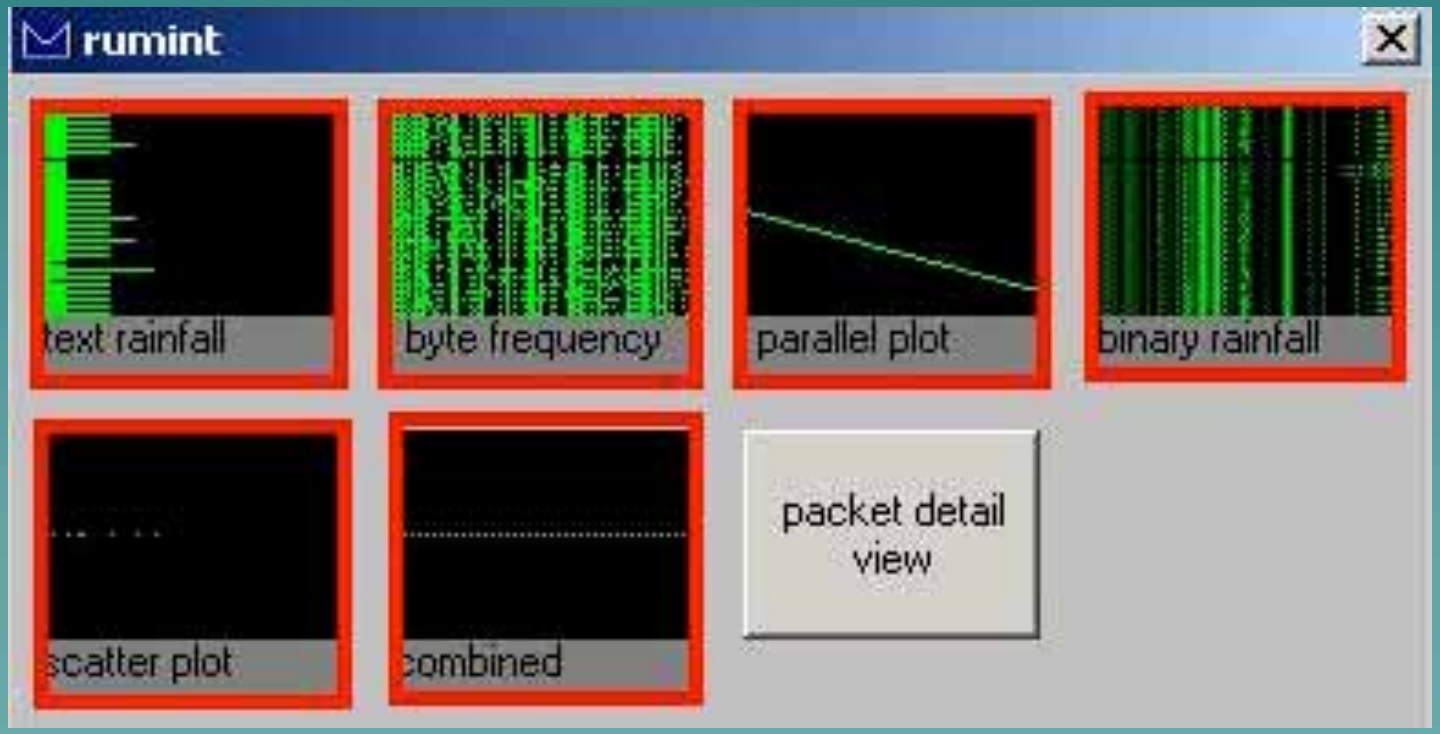
$$o = \frac{\sum_{i=1}^{n} \frac{|To - Do|}{N}}{180}$$

Target-distracter difference scores for TNV

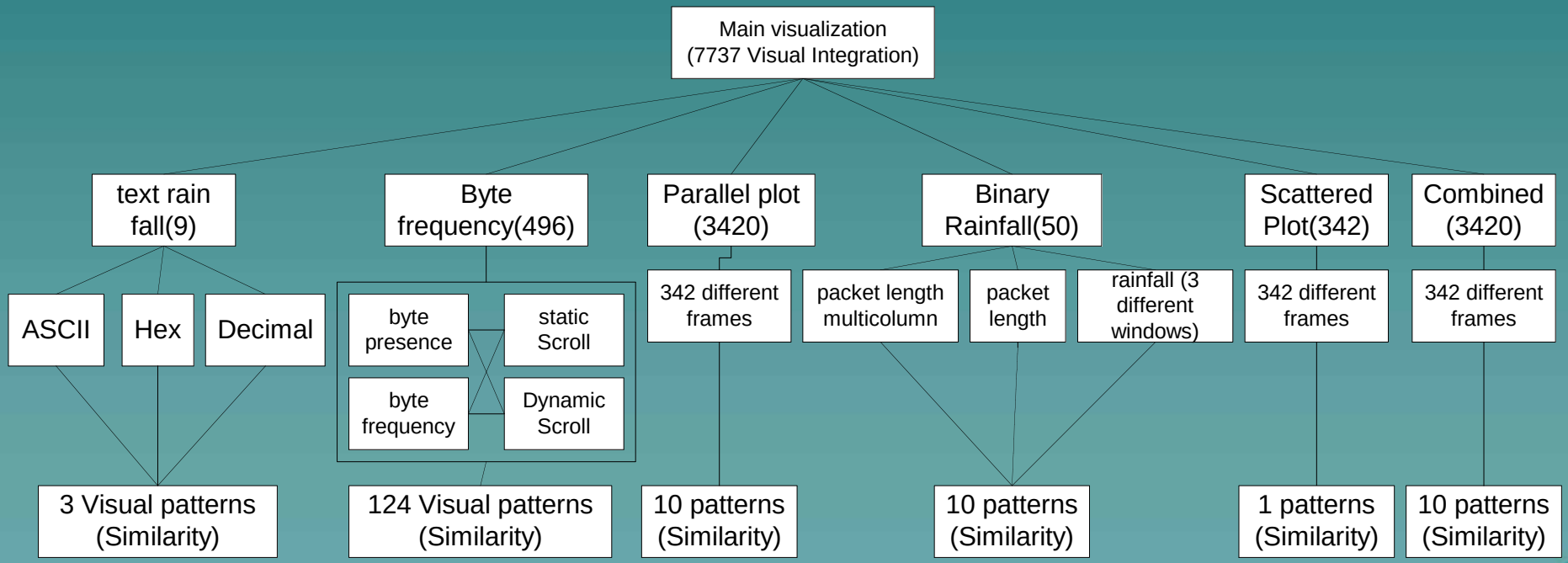


	Color	Motion	Size	Orientation
Target-distracter Difference scores	0.2850	N/A	0	1

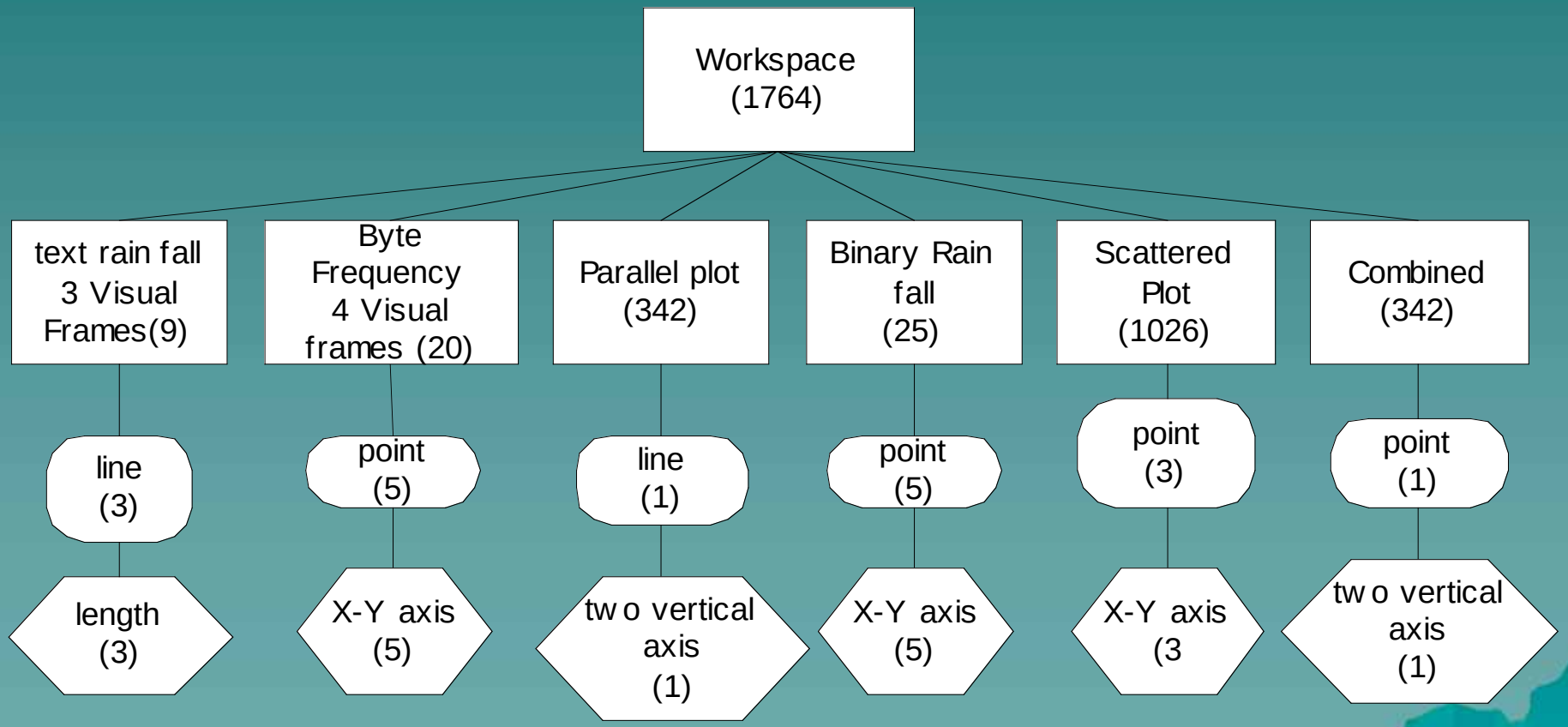
Rumint thumbnail overview



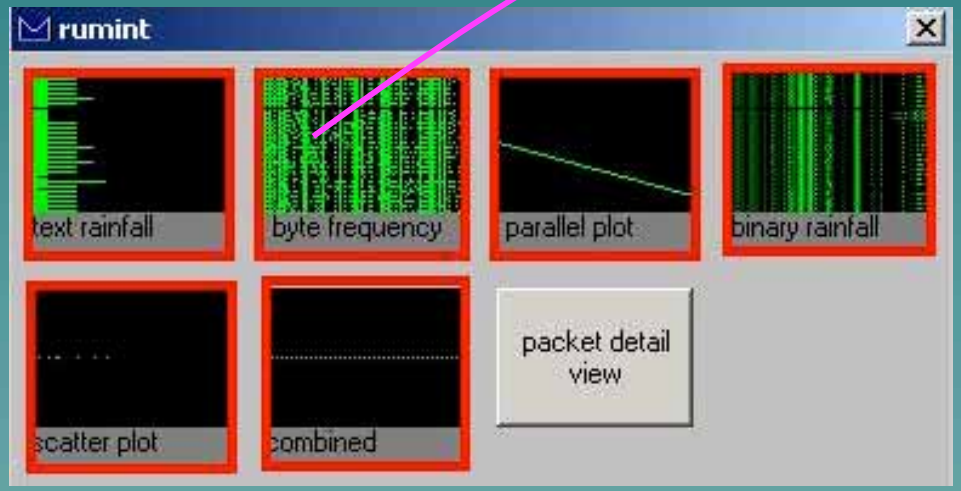
Visual integration tree for Rumint

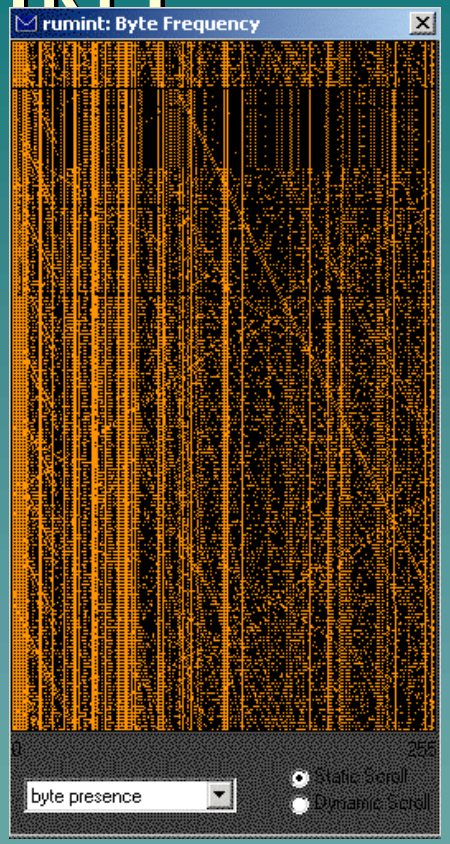


Visual mapping tree for Rumint



Visual search complexity metrics for RUMINT





	Color	Motion	Size (pix^2)	Orientation
Target-distracter difference scores	0.33333	n/a	0.32169	0

Comparison

- Rumint has a higher visual integration complexity score than TNV
- Rumint also has a higher visual mapping complexity score than TNV
- In general, Rumint is more complex than TNV, but it also presents more information than TNV

Conclusion and future work

- We have presented a method to analyze the complexity of information visualization design
- The complexity is measured in terms of
  - Analyze the design space
  - Analyze the visual integration complexity
  - Analyze the visual mapping complexity
  - Analyze the visual search complexity
- They indicate the amount of cognitive load involved in comprehending a particular visualization design

Conclusion and future work

- The complexity analysis is a quick way to review the visualization design before any user study can be conducted.
- We are currently applying and refining this complexity analysis method in the fields of computer security and bioinformatics.