9. Text & Documents
Visualizing and Searching Documents

Vorlesung „Informationsvisualisierung”

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Konzept und Basis für Folien: Thorsten Büring

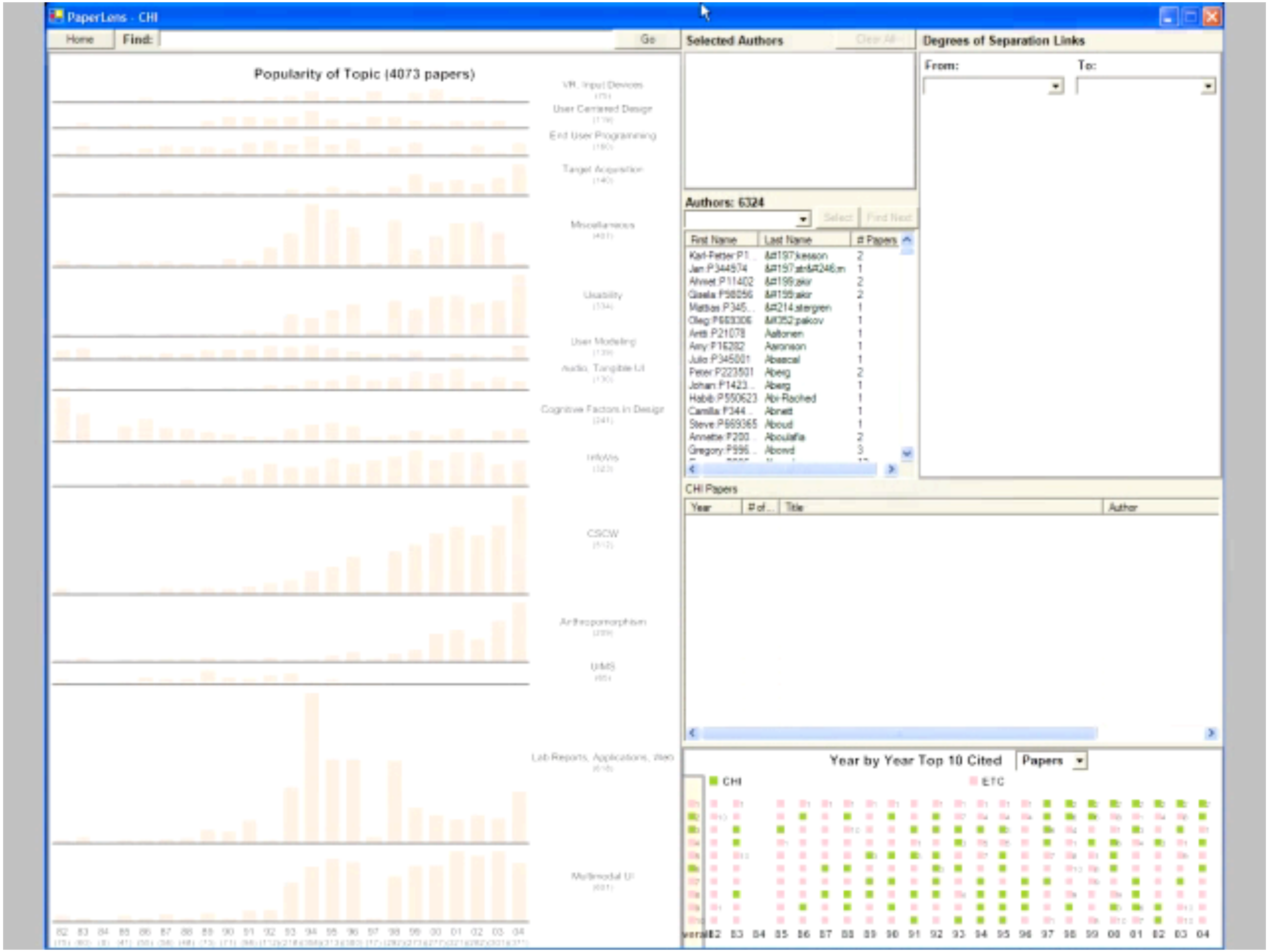
Outline

- Characteristics of text data
- Detecting patterns
  – SeeSoft
  – Arc diagrams
  – Visualizing Plagiarism
- Keyword search
  – TextArc
  – Enhanced scrollbar
  – TileBars
- Cluster Maps
  – Visualization for the document space
  – WEBSOM
  – ThemeScapes
- Cluster map vs keyword search

Text & Documents

- The main vehicle for humans to store information
- Huge existing resources: libraries, WWW
- What to visualize?
- Text is a nominal data type, but with many additional and interesting properties
- Text structure
- Meta data
  - Author
  - Dates
  - Descriptions
- Relations between documents (e.g. citation, similarity)
- Relevance of documents to a query
- Text statistics (e.g., frequency of different words)
- Content / Semantics

PaperLens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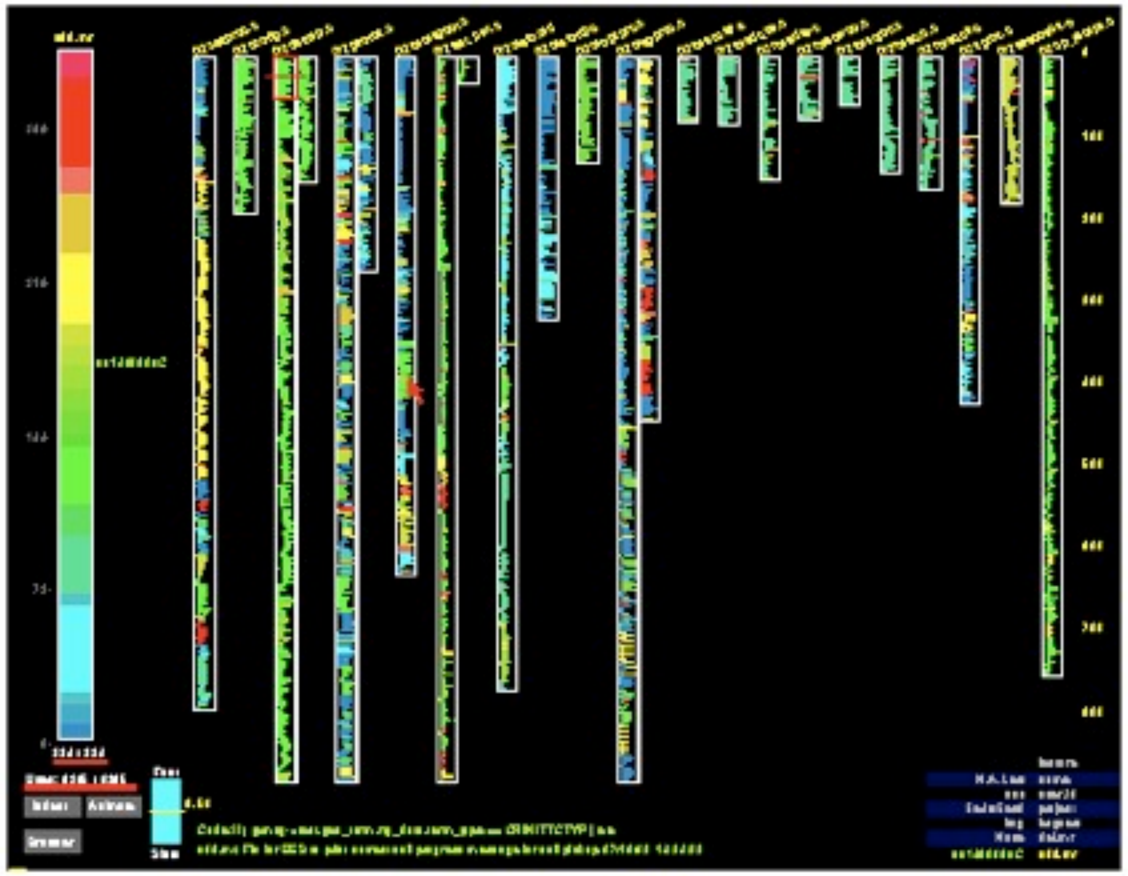
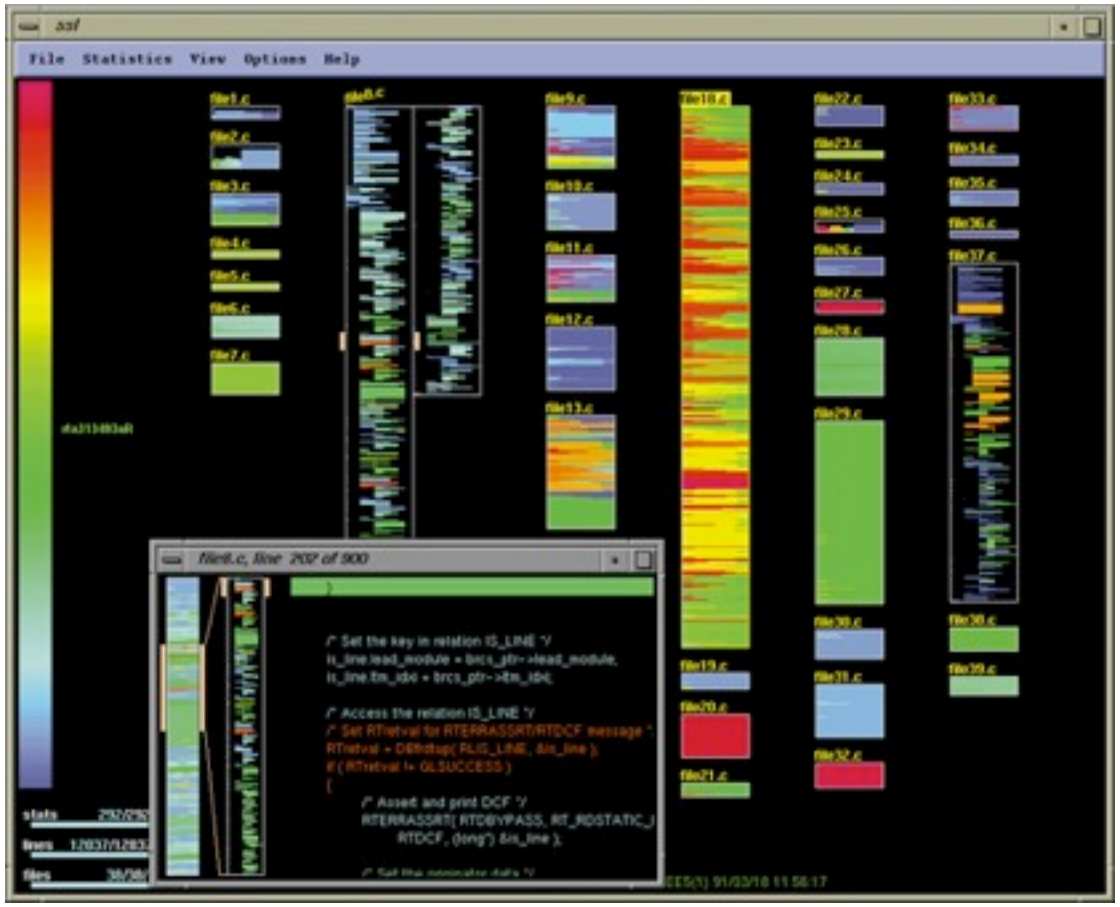
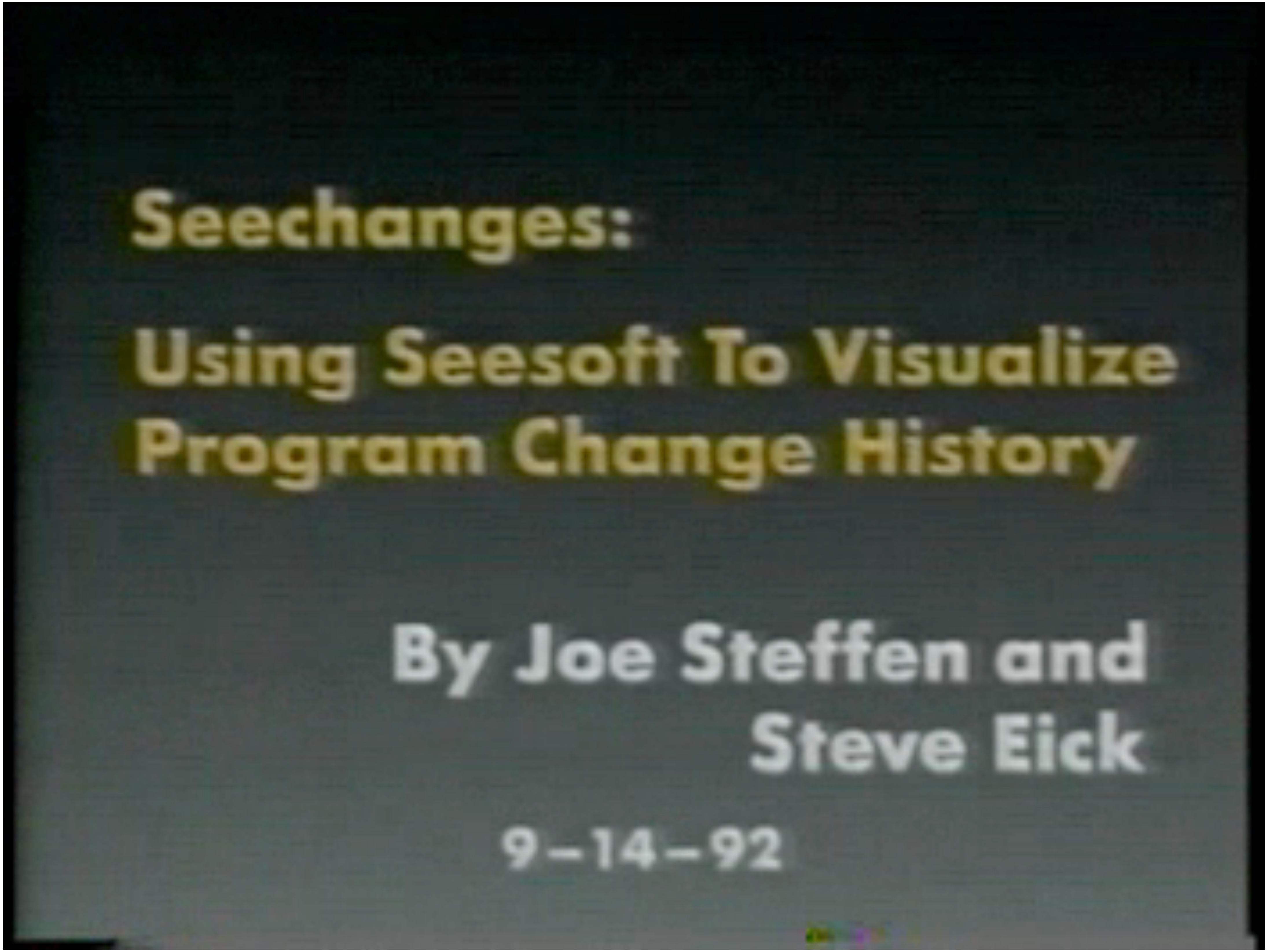
SeeSoft

- Eick et al. 1993
- Software visualization tool to display code line statistics (e.g., age, programmer, number of executions in recent test, etc.)
- Encoding
  - Each column represents a file
  - Height of column: length of the document
  - Files exceeding the height of the screen are continued over to the next columns
  - Each row represents a line of code
  - Width of row: length of line
  - Color: age of the line (red: newest; blue: oldest)
- Scales up to 50,000 lines on a single screen
- Example: 20 files with 9,365 lines of code
- Reading windows controlled by virtual magnifying boxes





SeeSoft


Seechanges:
Using Seesoft To Visualize
Program Change History
By Joe Steffen and
Steve Eick
9-14-92

Arc Diagrams

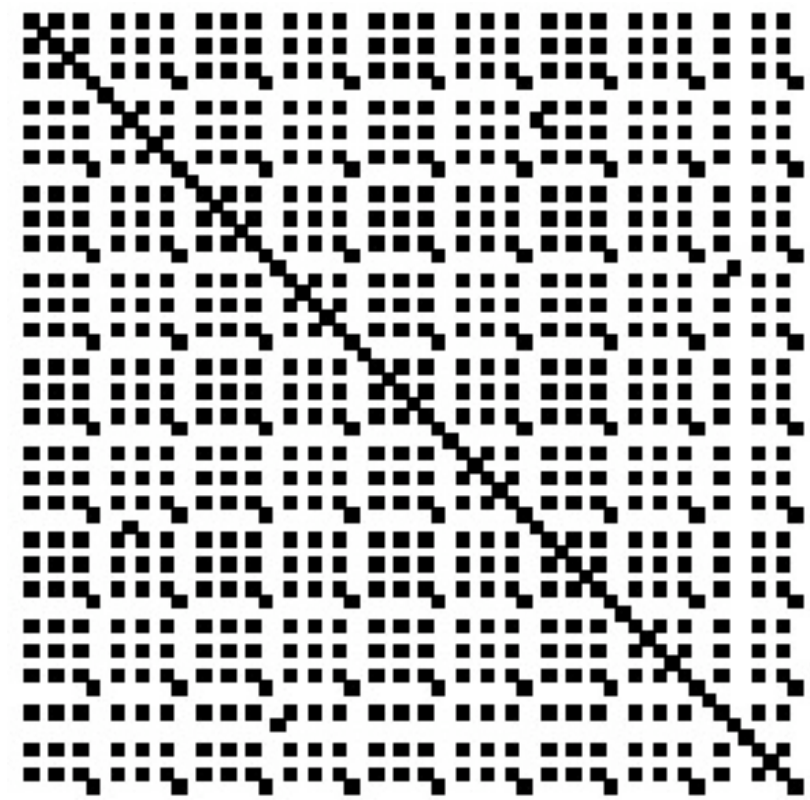
- Wattenberg 2002
- Visualizes repetition in string data
- Application domains: text, DNA sequences, music
- Approach: to avoid clutter, only visualize an essential subset of all possible pairs of matching substrings
- Display string on a single line
- Connect the consecutive intervals by a semi-circular arc
  - Thickness of the arc: length of the matching substring
  - Height of the arc: proportional to the distance of substrings

Arc Diagrams

- Apply translucency to not obscure matches
- Still: for strings with a high frequency of small repeated substrings the visualization may cause clutter
- Provide users with the ability to filter by minimum substring length to consider

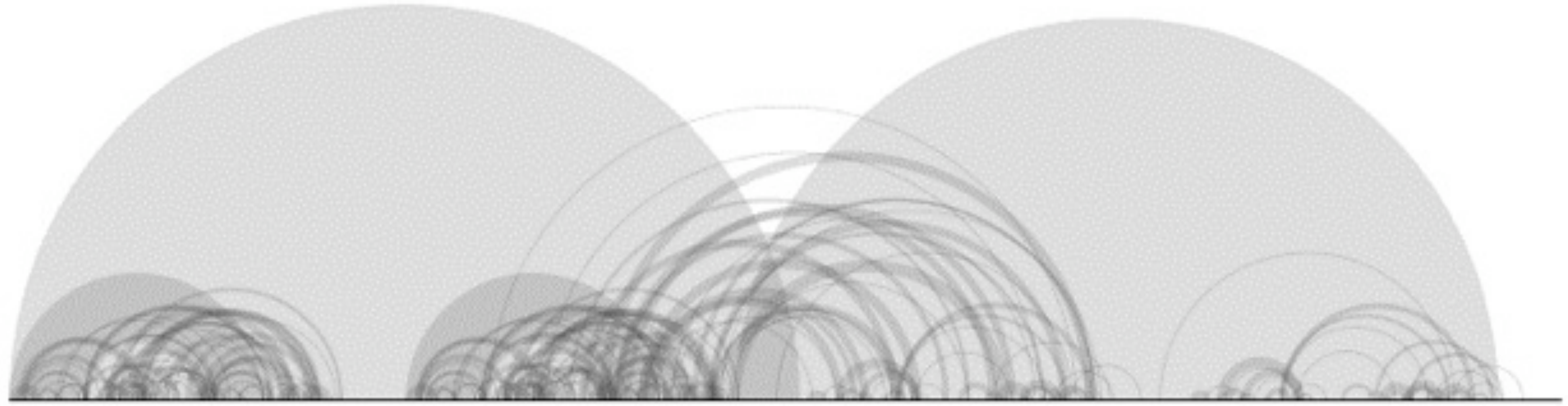
Arc Diagrams

- Comparison to a dotplot diagram
- Recap Matrix diagram
  - Correlation matrix
  - String of n symbols a_1, a_2, an is represented by an n*n matrix
  - Pixel at coordinate (i, j) is black if $a_i = a_j$
  - Can handle very large datasets
  - Shows both small and large-scale structures
- Heavy clutter caused by small substrings with high frequency: n repetitions of a substring lead to n^2 visual marks
- Arc Diagrams mark only similar sub-strings, which are subsequent



Arc Diagrams

- Applied to music, Minuet in G Major, Bach
- Shows classic pattern of a minuet: two main parts, each consisting of a long passage played twice
- Parts are loosely related: bundle of thin arcs connecting the two main parts
- Overlap of the two main arcs shows that the end of the first passage is the same as the beginning of the second passage



Visualizing Plagiarism

- Ribler & Abrams 2000
- Problem: programming assignment in a class with large number of students
- High probability of plagiarism
- Need to compare every document (code file) with every other document
- Visualization must support two steps
  - Highlight suspicious documents
  - Allow for detailed examination of the similar passages - high level of similarity between documents may not be due to cheating (e.g., headers)

Visualizing Plagiarism

- Categorical Patterngram
- Visualize frequencies of sequences of characters present in more than one document
- Remove all non-printable characters in the document collection
- Define length of character sequence to analyse (in the example: 4)
- Histogram-like approach
  - X-axis: start character of sequence
  - Y-axis: number of documents containing the sequence
  - Doc at Y = 1: base document to compare against all other documents

Toy0: This is a test.

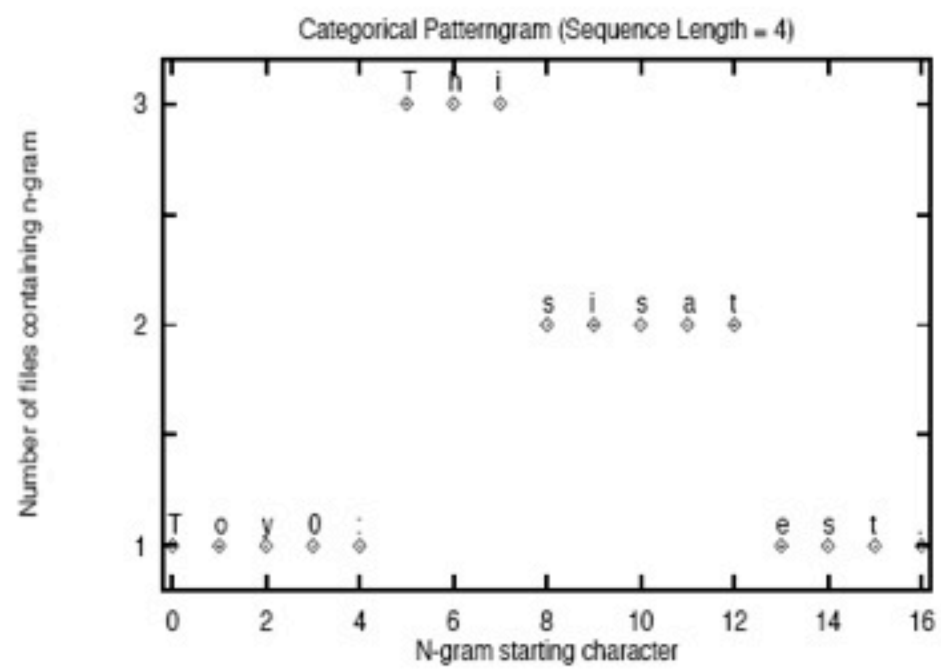
Figure 1. Toy File 0

Toy1: Oh yes. This is a test too.

Figure 2. Toy File 1

Toy2: Toy2 has little in common with the other two. This is common.

Figure 3. Toy File 2



Visualizing Plagiarism

- Composite Categorical Patterngram
- Visualizes which particular documents are similar
- Y-axis: each value corresponds to an individual document

Toy0: This is a test.

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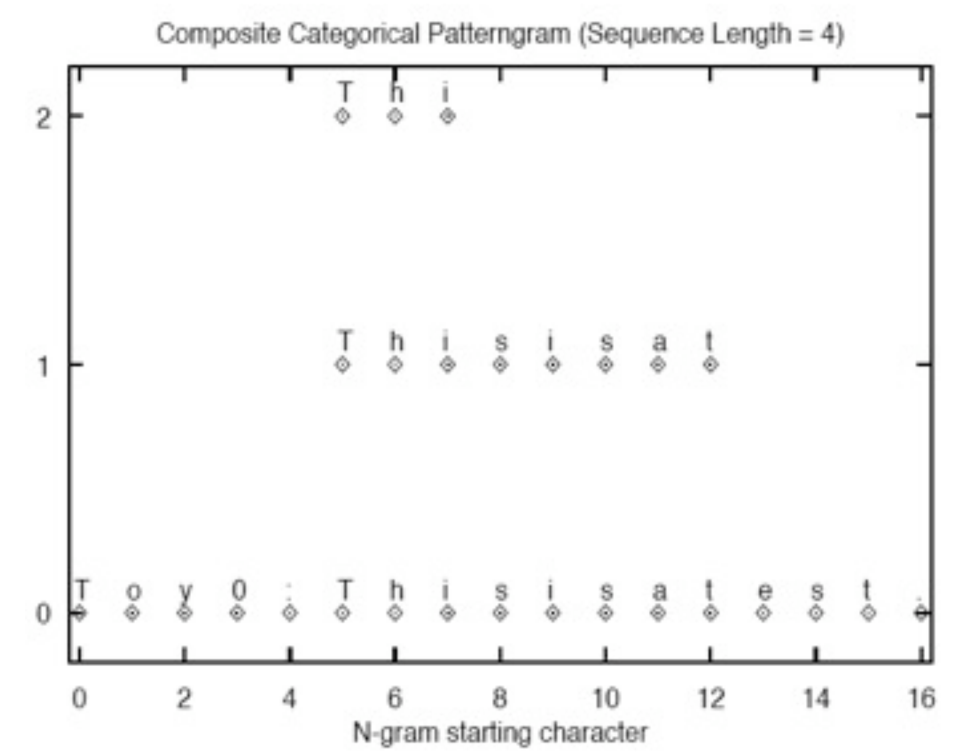
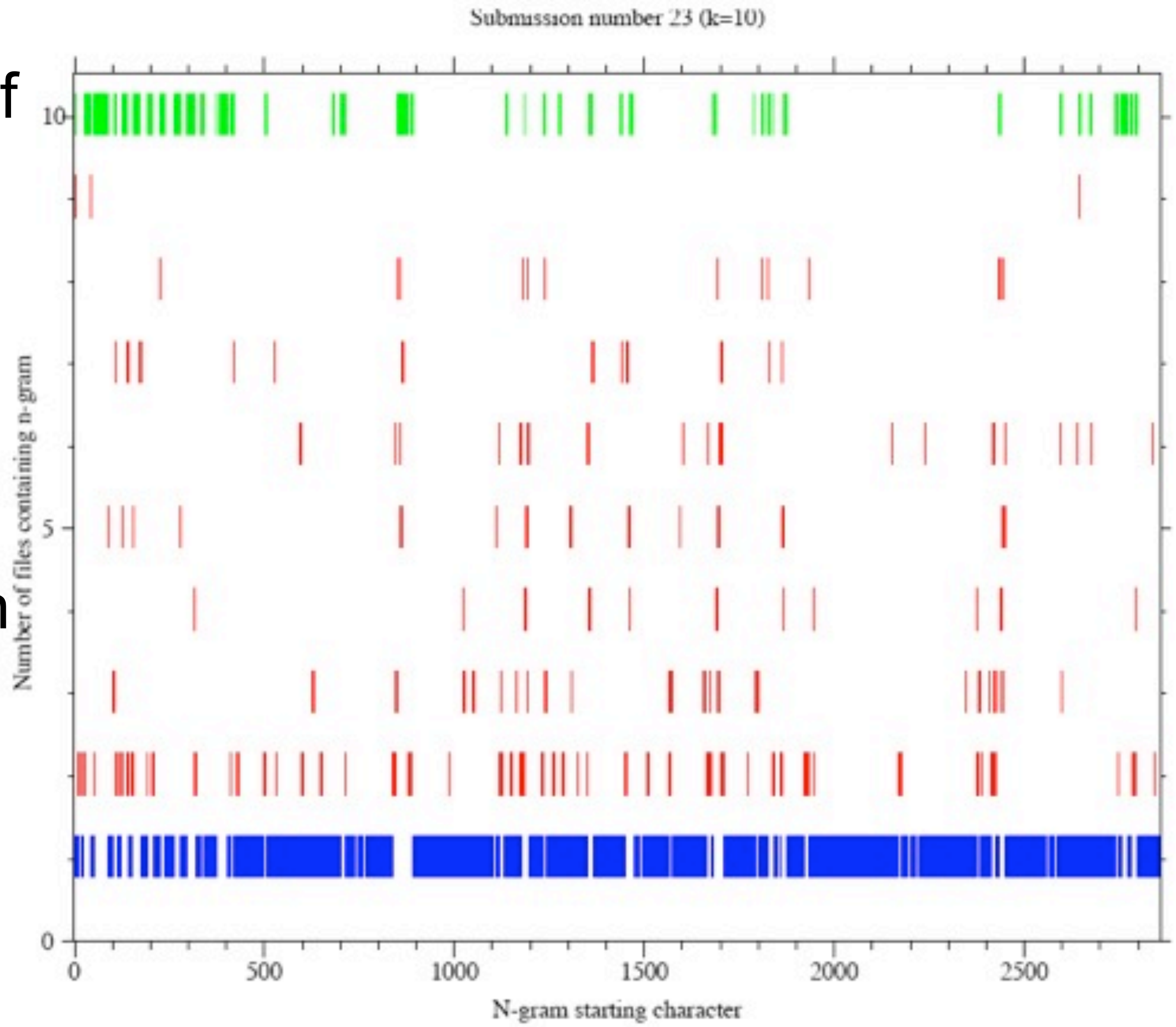


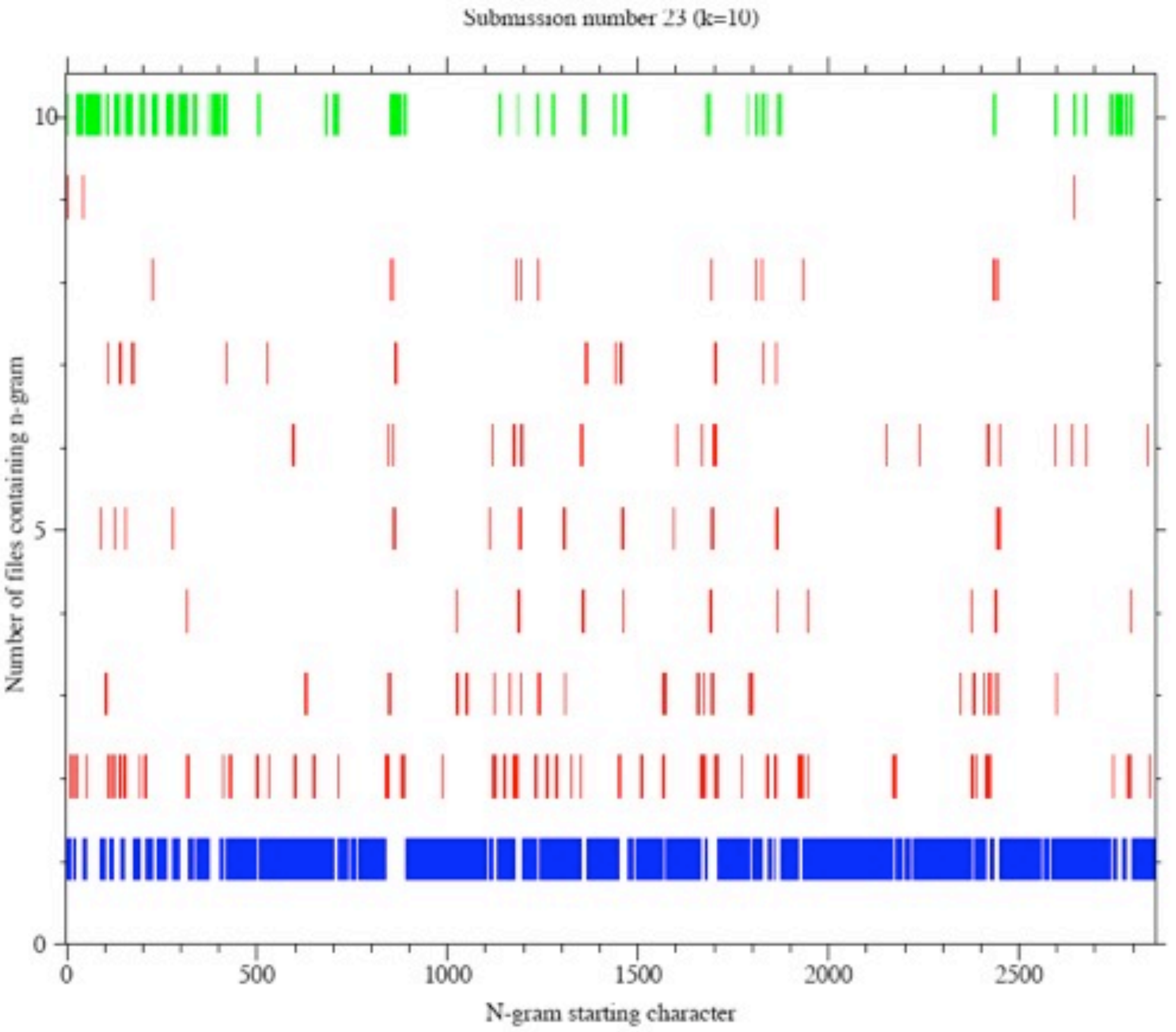
Visualizing Plagiarism

- Case study
- Students were asked to extend a sample program of about 30 lines of code
- Average completed program was about 150 lines
- Submission via email
- Graphic shows categorical patterngram for a single submission
  - Sequence length = 10
  - Lines not text due to high density
  - Rather confusing color coding
- Color coding (not very reasonable)
  - Green: frequency >= 10
  - Red: frequency < 10
  - Blue: base document
- Plagiarism or not?



Visualizing Plagiarism

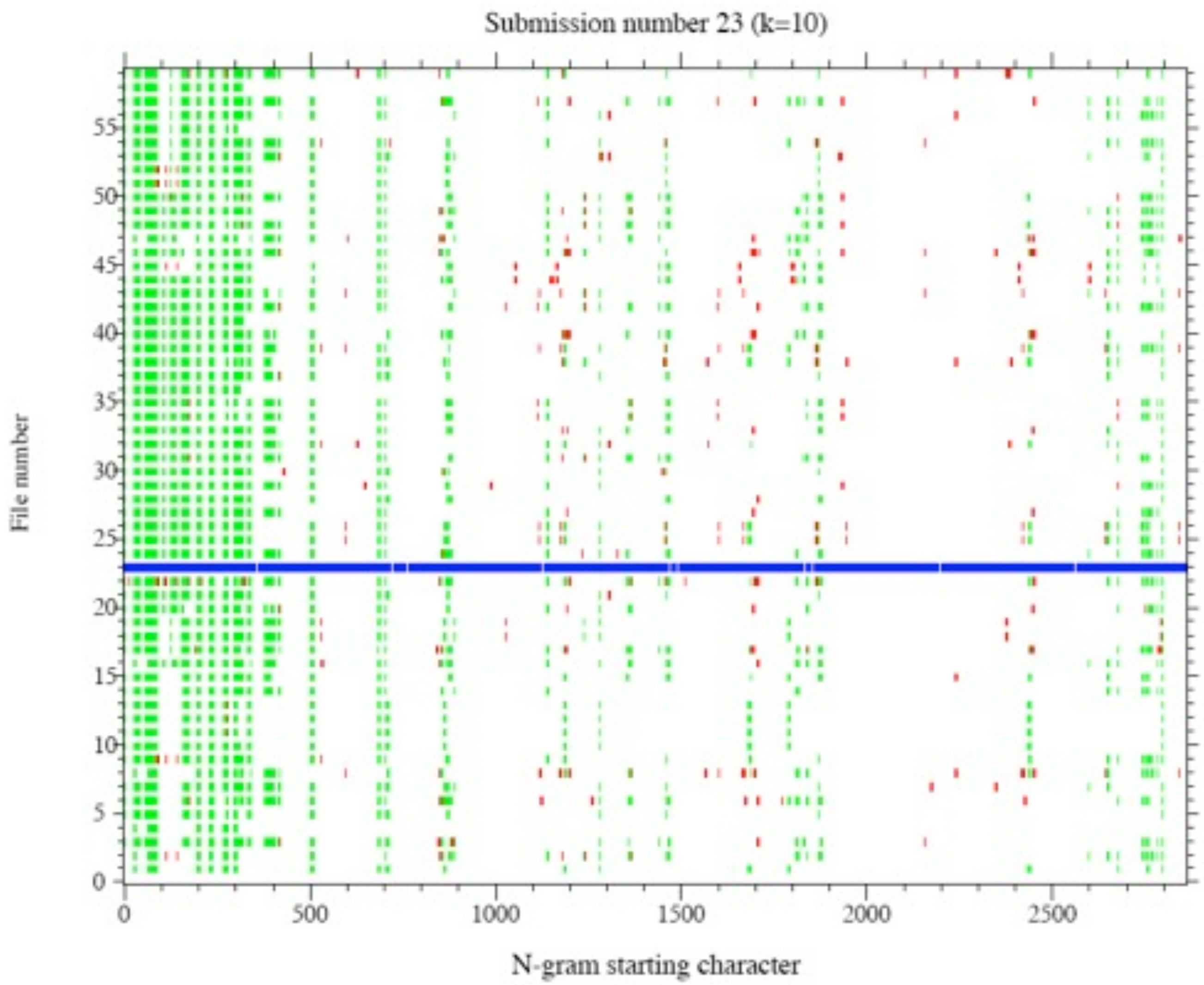
- What to look out for?
  - Sequences that occur frequently are not of interest - all points with y >= 10 are plotted as y = 10
  - Suspicious: accumulation of points with low frequencies



- Analysis
- Majority of points are plotted at Y = 1
- Hence most 10-char sequences are unique to the base document
- Number of points plotted at Y = 2, but evenly distributed

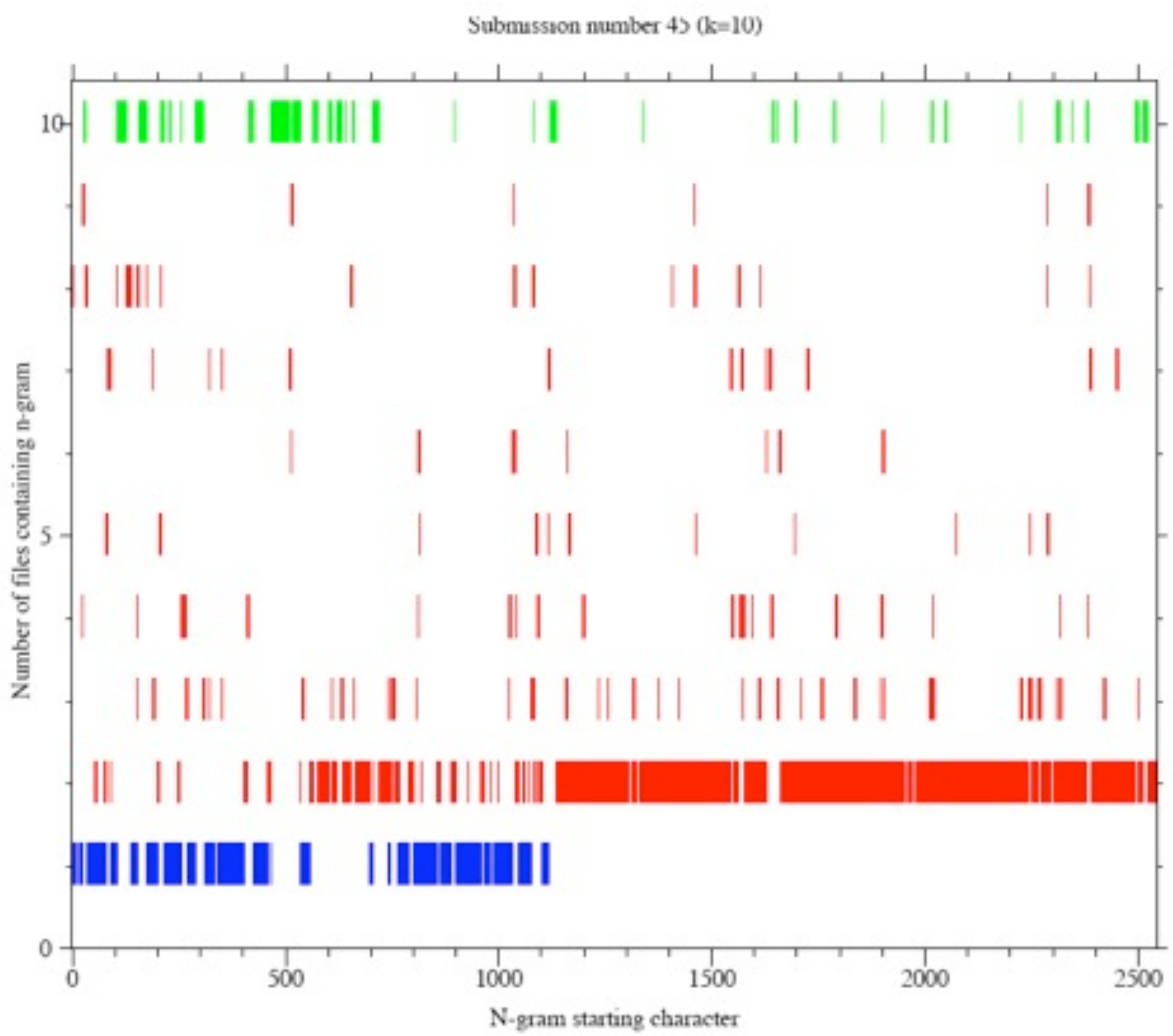
Visualizing Plagiarism

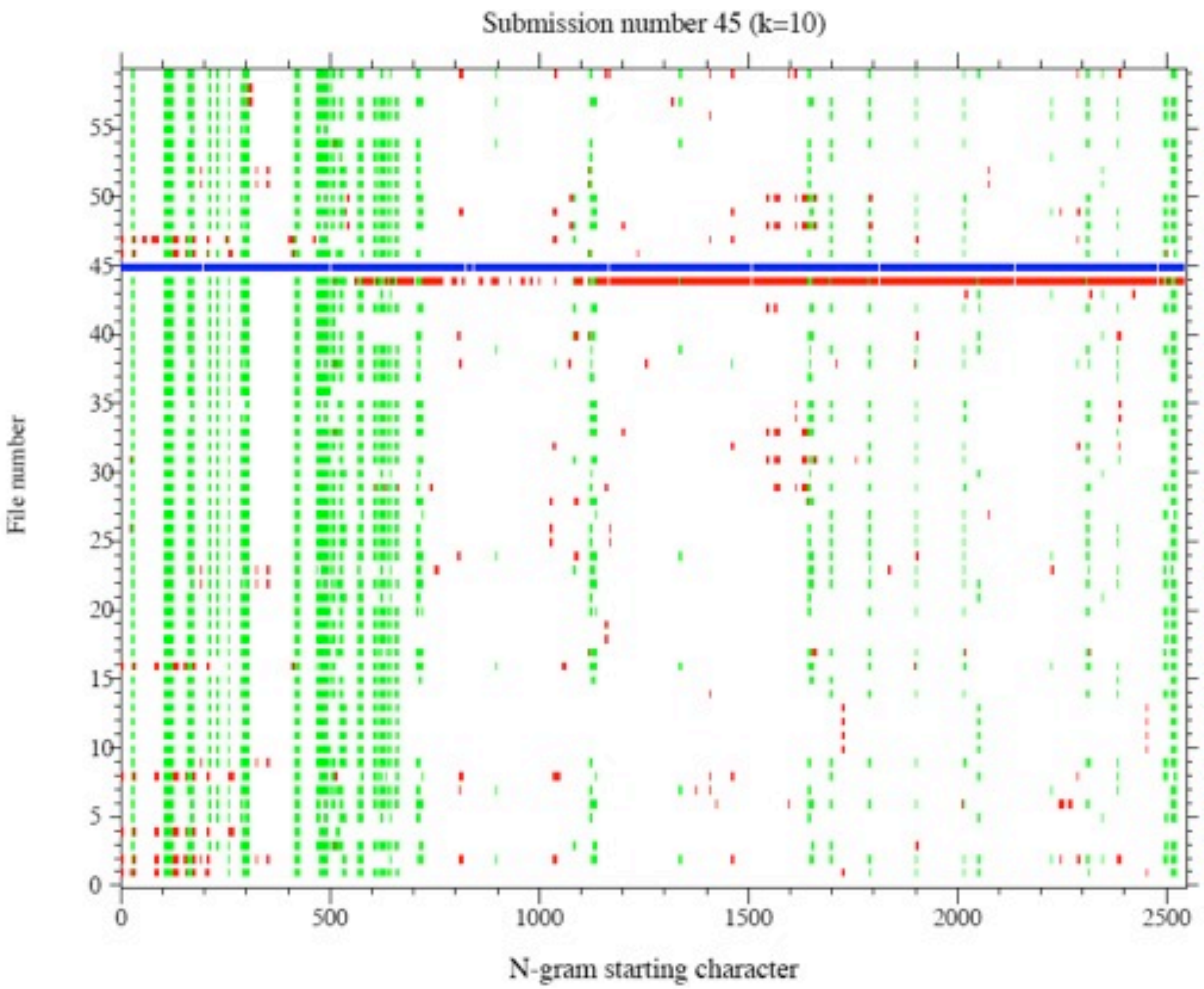
- Composite Categorical Patterngram for the submission
- Solid line represents the base document (submission number 23)
- Large number of points plotted in the range of x = [0; 500]: email message header
- Other frequent sequences due to the sample program
- Pattern typical for independent work



Visualizing Plagiarism

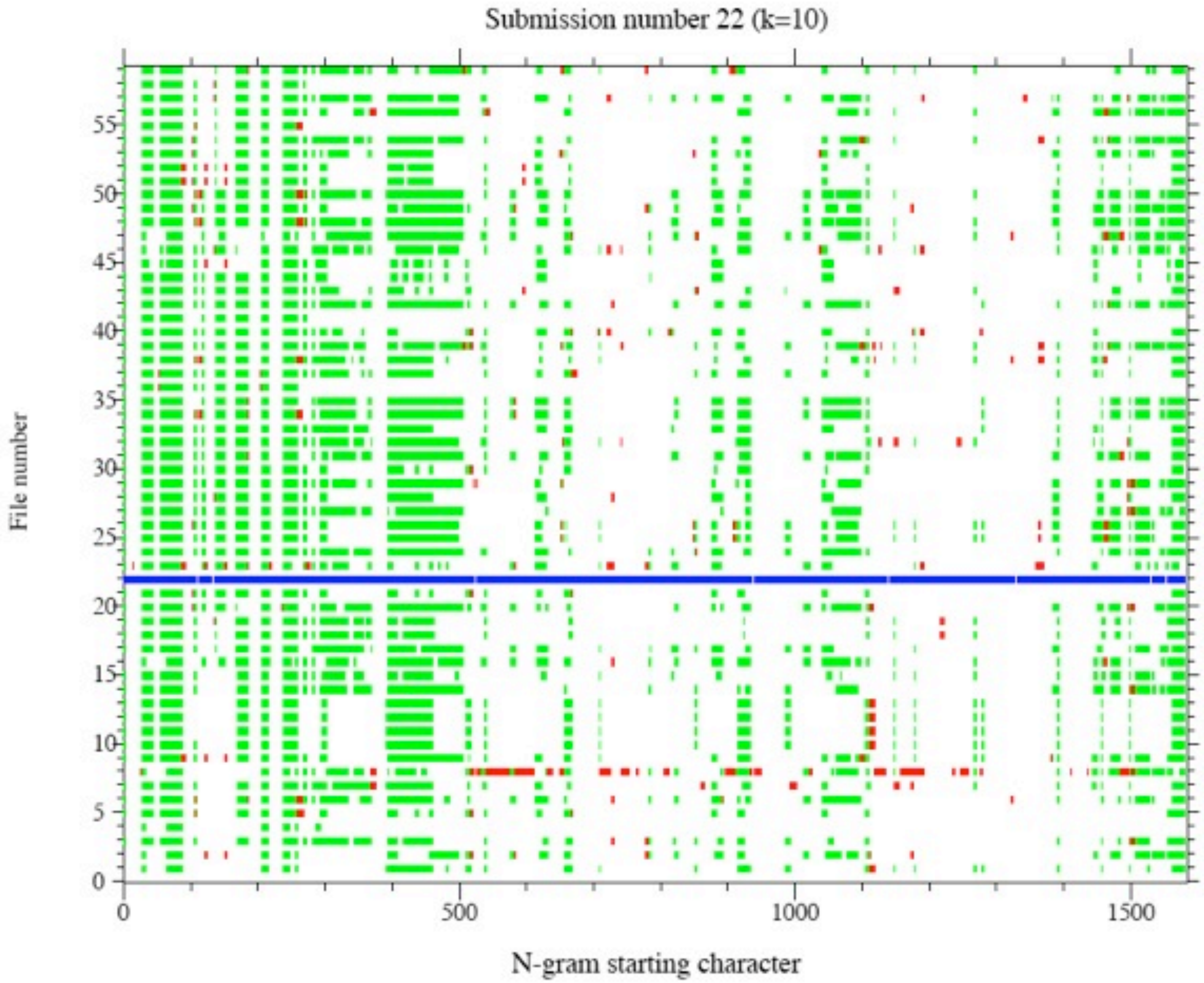
- Example of patterngrams indicating extensive plagiarism





Visualizing Plagiarism

- Patterngram of more subtle plagiarism

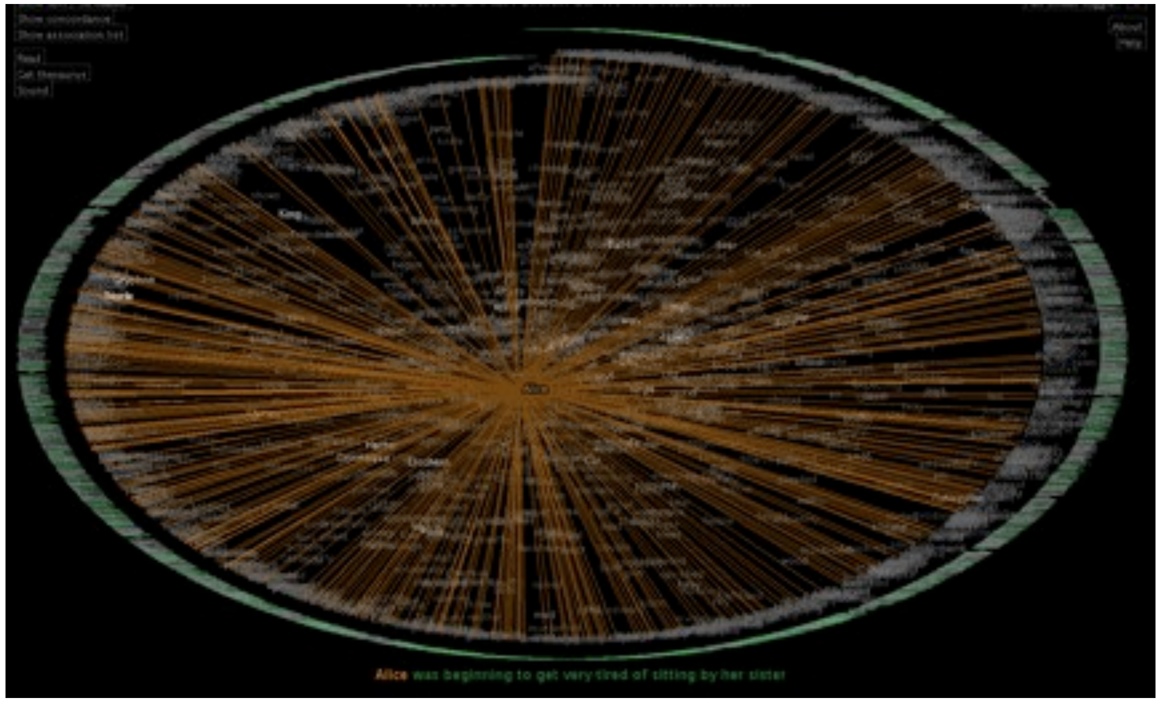


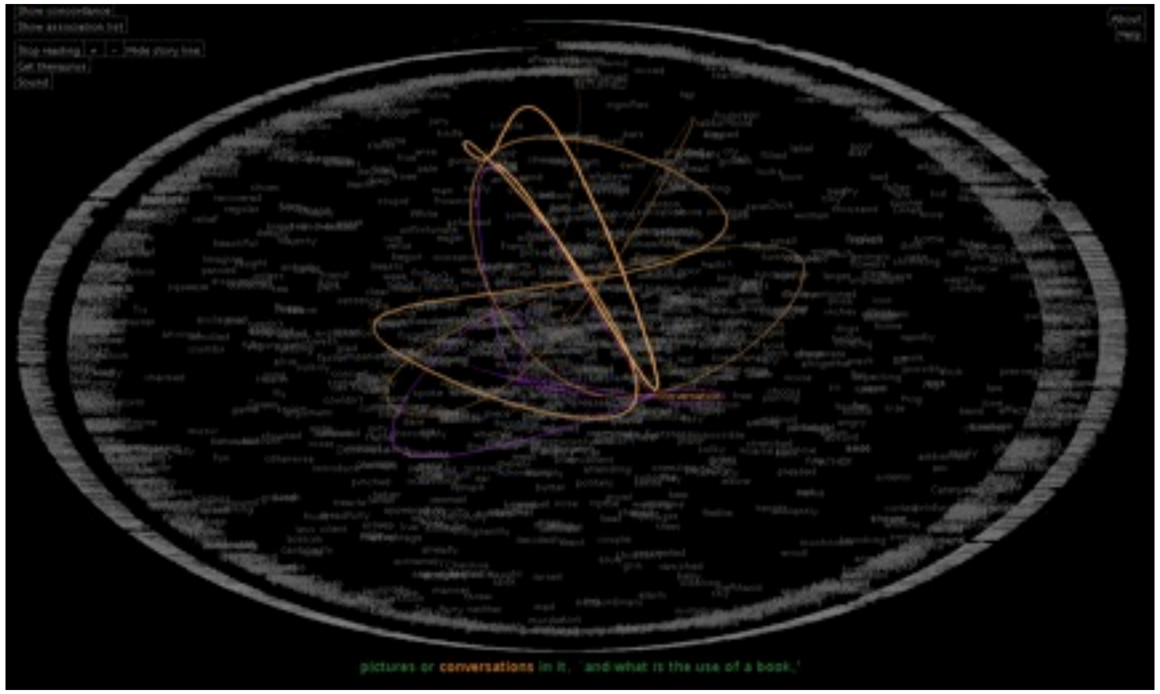
Visualizing Plagiarism

- What may a student do to mask plagiarized code
- Change variable names
- Minimize masking effect by replacing all alphanumeric strings in all documents into single characters
- Two documents with the same code but different variable names will produce identical patterngrams

TextArc

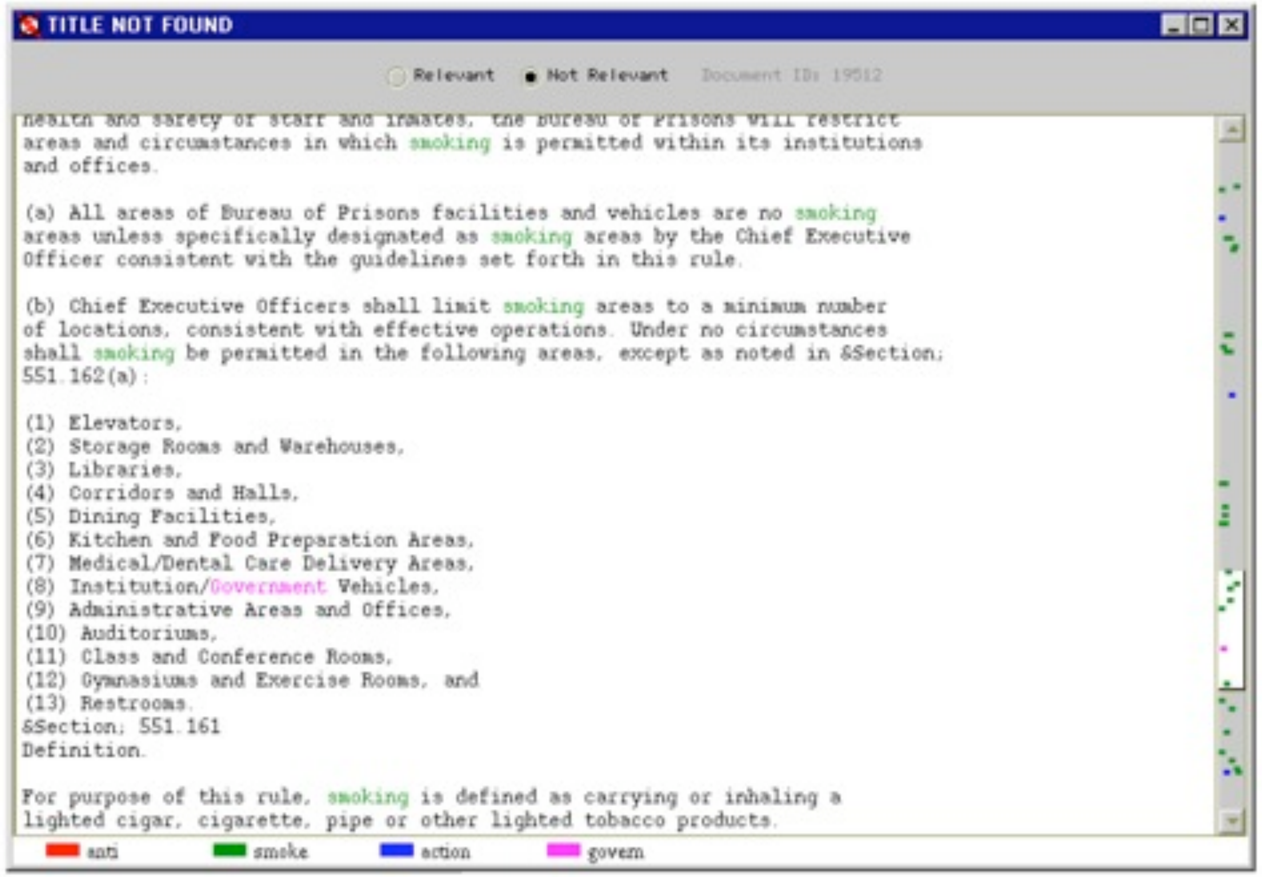
- http://www.textarc.org/ - demo
- Represents the entire text as 1 pixel lines in an outer circle
- Text is revealed via mouse-over
- Words are repeated in inner circle at a readable size
- Position of the words depend on where the word appears in the document
- Words that appear throughout the novel will be drawn to the center
- Frequent words stand out
- Example visualizes the novel “Alice in Wonderland”
- Various visualization features





Search Terms on a Scrollbar

- Byrd 1999
- Searching of keywords in a single document
- Color coding to map each occurrence of a keyword in the document as a small colored icon in the scrollbar
- Provides an overview of the entire document, not only of the portion currently visible
- Users can directly jump to keyword occurences by moving the slider thumb

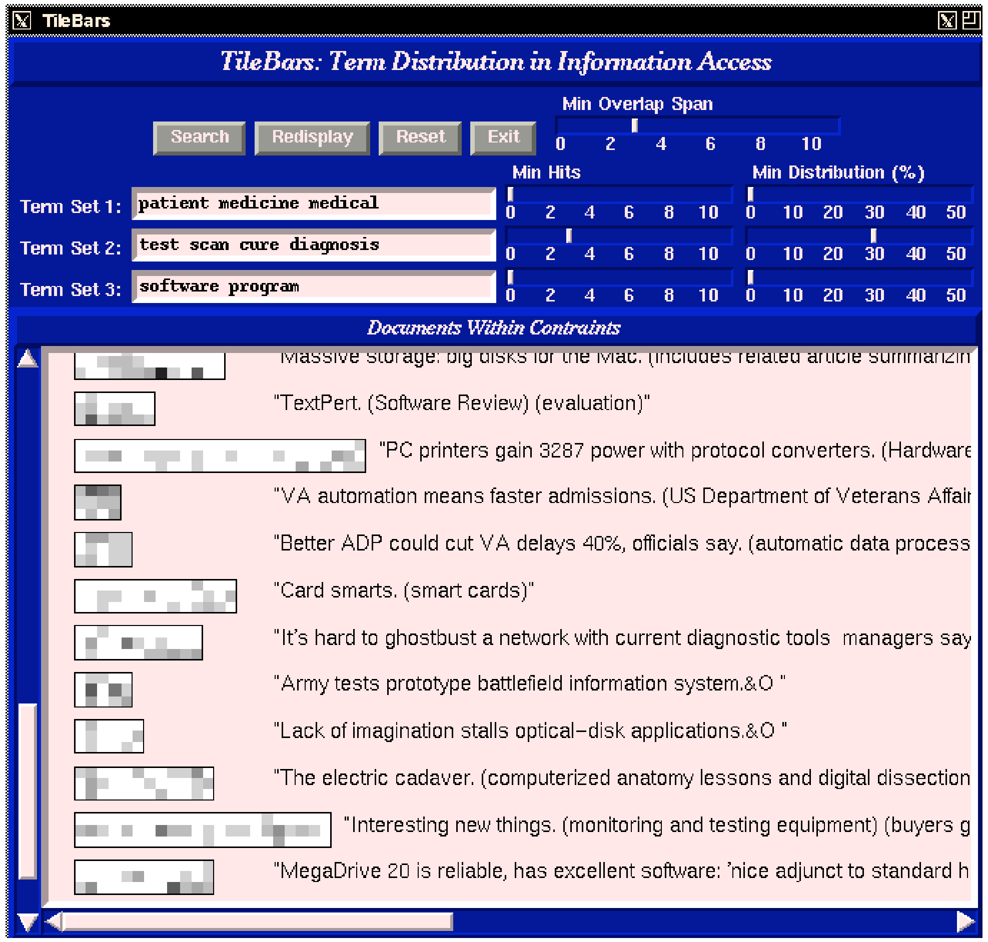


TileBars

- Hearst 1995
- Problem with document ranking of common search engines?
- Ranking approach is opaque:
  - What role did the query terms play in the ranking process
  - What is the relationship between the query terms in the document
- TileBars attempts to let the users make informed decisions about which documents and passages to view

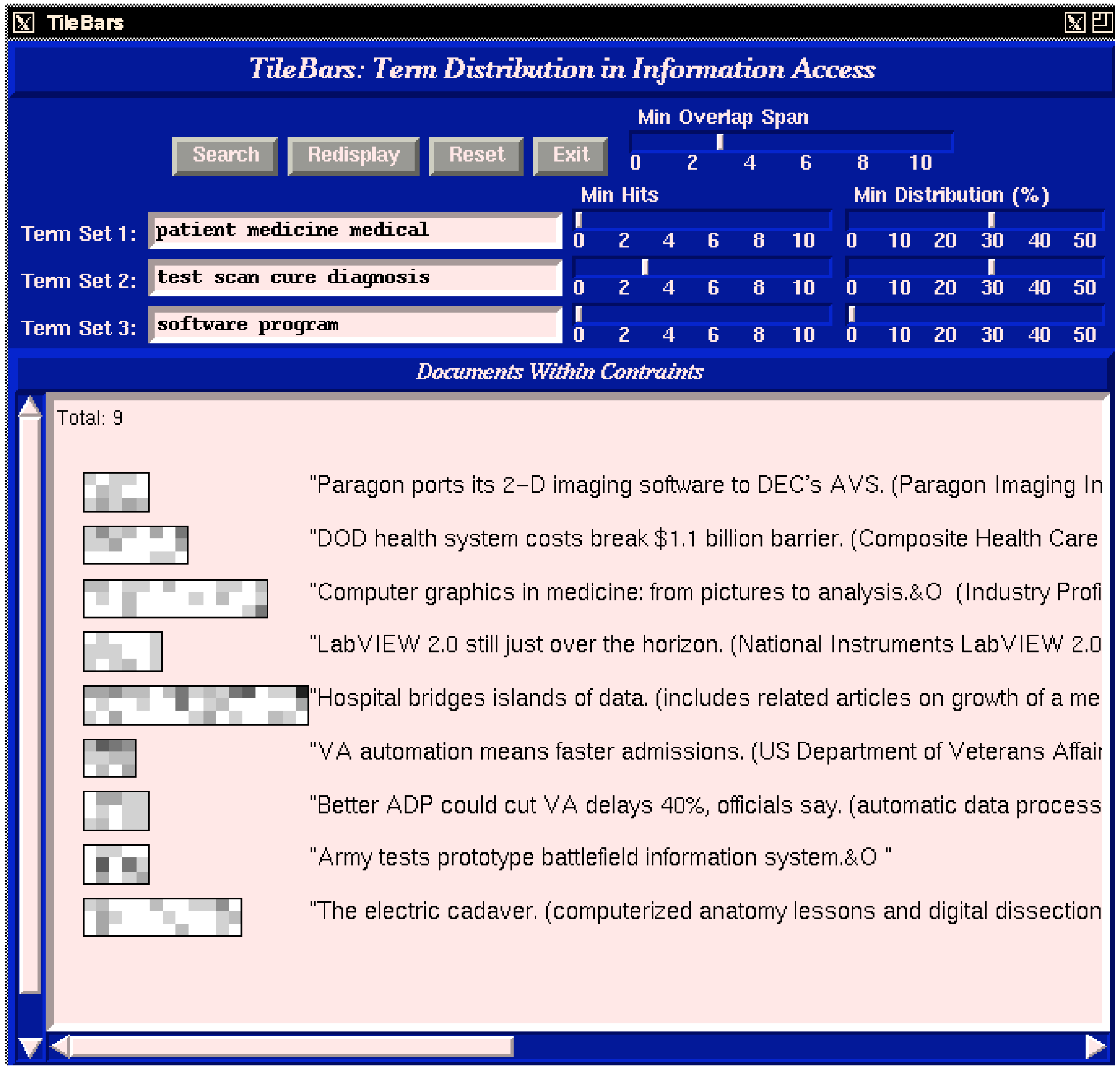
TileBars

- Users provide sets of query terms
  - OR within a set
  - AND between sets
- Documents are partitioned into adjacent, non-overlapping multi-paragraph segments
- Each document of the result set is represented by a rectangle - width indicates relative length of the document
- Stacked squares correspond to text segments
- Each row of the stack corresponds to a set of query terms
- Darkness of the square indicates the frequency of terms from the corresponding term set - (Why is this a reasonable color mapping?)
- Title + initial words appear next to each document
- Users can click on segments to retrieve the corresponding text



TileBars

- Analysis hints
  - Overall darkness indicates that all term sets are discussed in detail throughout the document
  - When terms are discussed simultaneously the tiles blend together causing an easy to spot block
  - Scattered term set occurrence show large areas of white space
  - Helps to distinguish between passing remarks and prominent topic terms
- Users may also set distribution constraints to refine the query
  - Minimum number of hits per term set
  - Minimum distribution (percentage of tiles containing at least one hit)
  - Minimum adjacent overlap span



Cluster Maps

- Downscaling of n-dimensional document space to 2D
- Map of a document collection
- Similar documents are placed close to each other
- Dissimilar documents are placed farer apart from each other
- Provide thematic overview for exploration (same concept as product arrangements in a store)
- How to - Vector space model and map construction
  – Create inverted index of document collection
  – Exclude stop words and the most frequent words (“and” may not be a good discriminator of content)
  – Matrix of indexing words versus documents gives you document vectors
  – A document vector reflects the frequency of index words occurring in the document

Cluster Maps

- How to - Vector space model and map construction (continued)
  - Compute similarity between pairs of documents (e.g. dot product of vectors)
  - Layout documents in 1D/2D/3D
- Common approaches
  - Spring model of graph layout
  - Multi-dimensional scaling
  - Clustering (e.g. hierarchical)
  - Self-organizing maps (SOM aka Kohonen map)

Document vectors

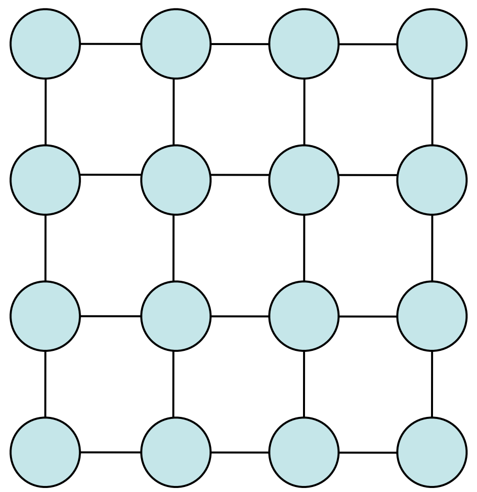
	Doc 1	Doc 2	Doc 3
"Artificial"	1	2	0
"Creativity"	2	1	0
"Java"	0	0	3

Similarity Matrix

	Doc 1	Doc 2	Doc 3
Doc 1	1	0.66	0
Doc 2	0.66	1	0
Doc 3	0	0	1

SOM

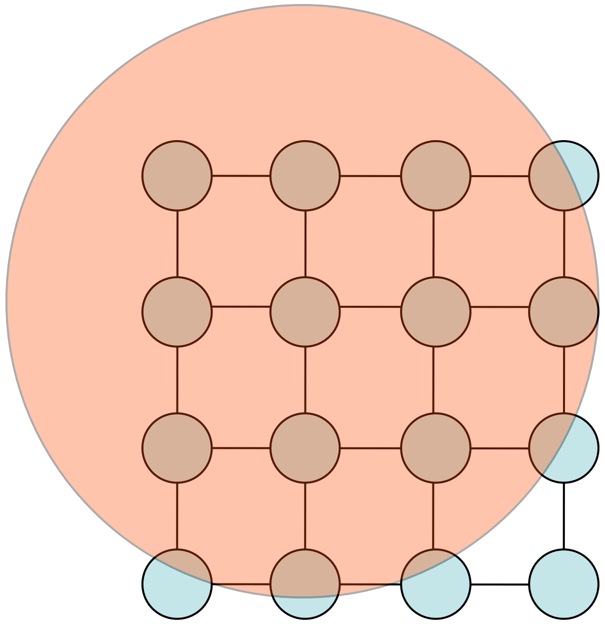
- Unsupervised learning algorithm
- SOM map is formed from a regular grid of neurons (nodes)
- Each node has
  - An x y coordinate in the grid
  - A weight vector of the same dimensionality as the input vectors
- Input vectors
  - Used to train the map
  - Represent collection of objects
- In case of visualizing text, input vectors are usually equal to document vectors

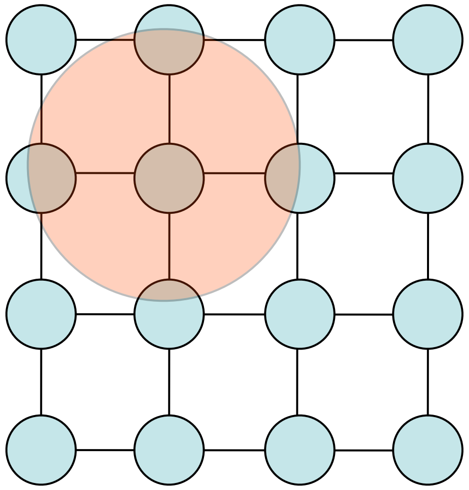


Network of 4x4 nodes

SOM - Algorithm

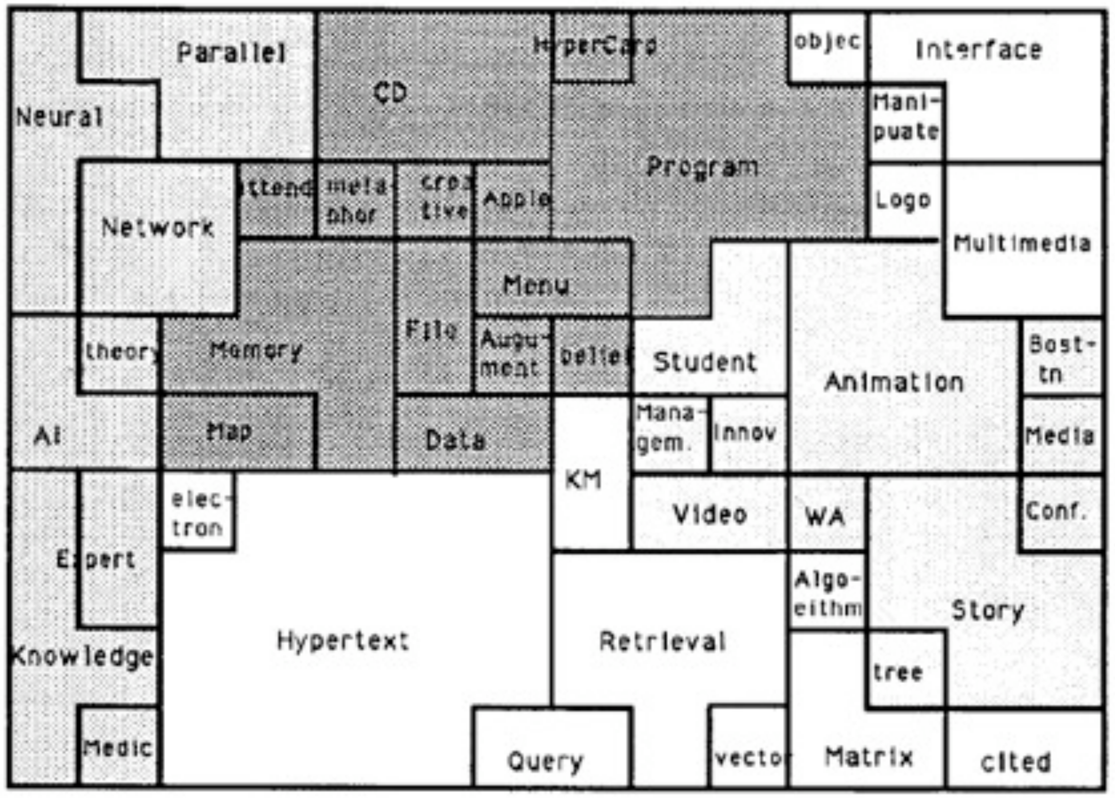
- 1. Start with assigning small random weights to the nodes of the grid
- 2. Chose a vector at random from the set of input vectors and present it to the grid
- 3. For each node: calculate the Euclidean distance between each node's weight vector and the current input vector - the closest node is called the Best Matching Unit (BMU)
- 4. Calculate the radius of the BMU (radius diminishes with each time-step)
- 5. For each node within the radius of the BMU: adjust the weights to make them more similar to the input vector - the closer a node is to the BMU, the more its weights get altered
- 6. Repeat step 2 for N iterations
- When training is completed each document is assigned to its BMU





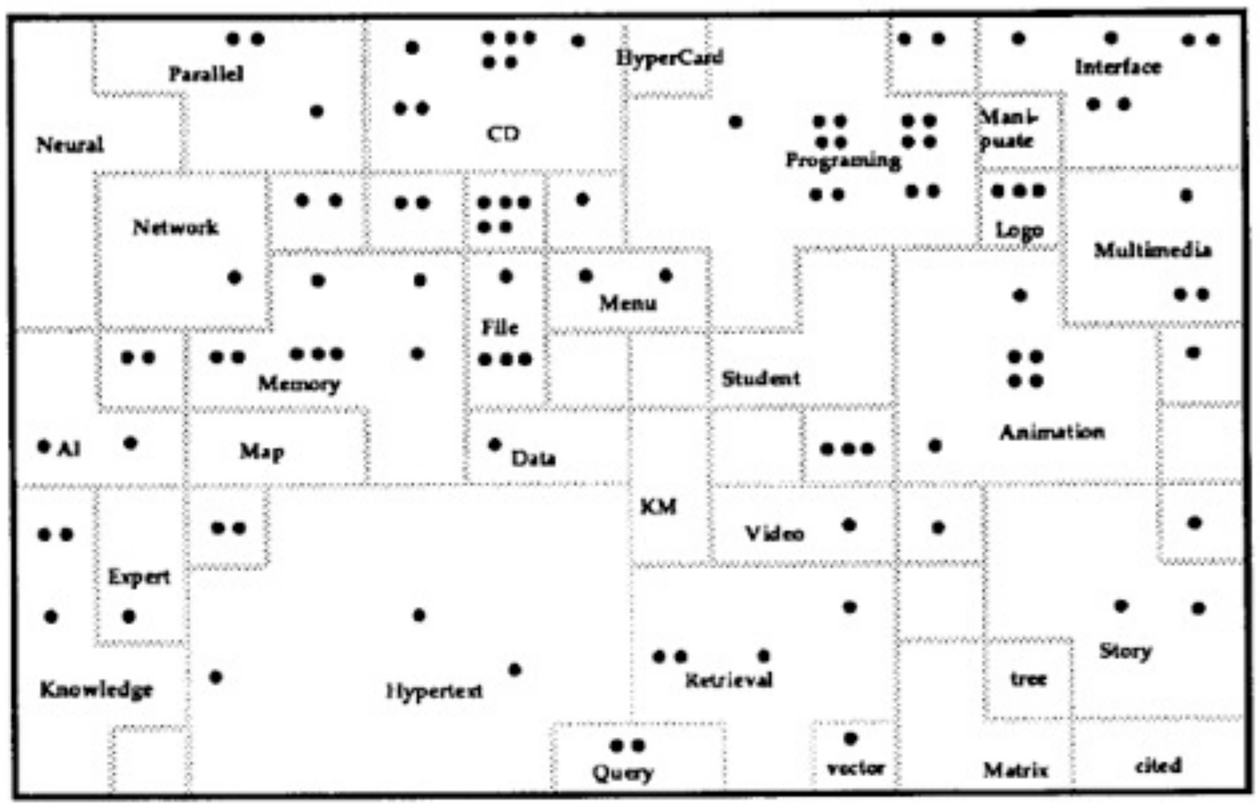
Cluster Maps

- Lin 1992
- Personal collection of 660 research documents
- 2500 learning iterations
- Labeled word show most frequent title words
- Size maps to frequencies of occurrence of the words
- Neighboring relationships of areas indicate frequencies of the co-occurrence of words

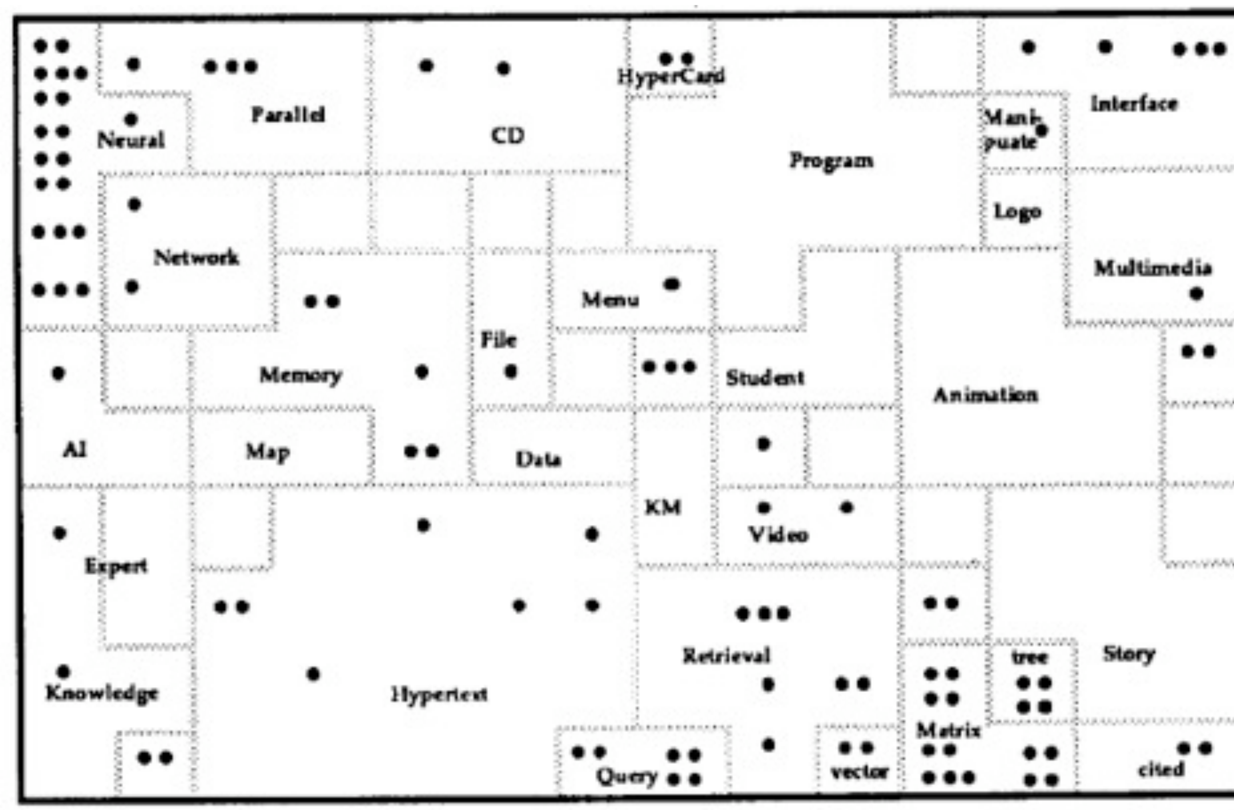


Cluster Maps

- Research interest changing over time



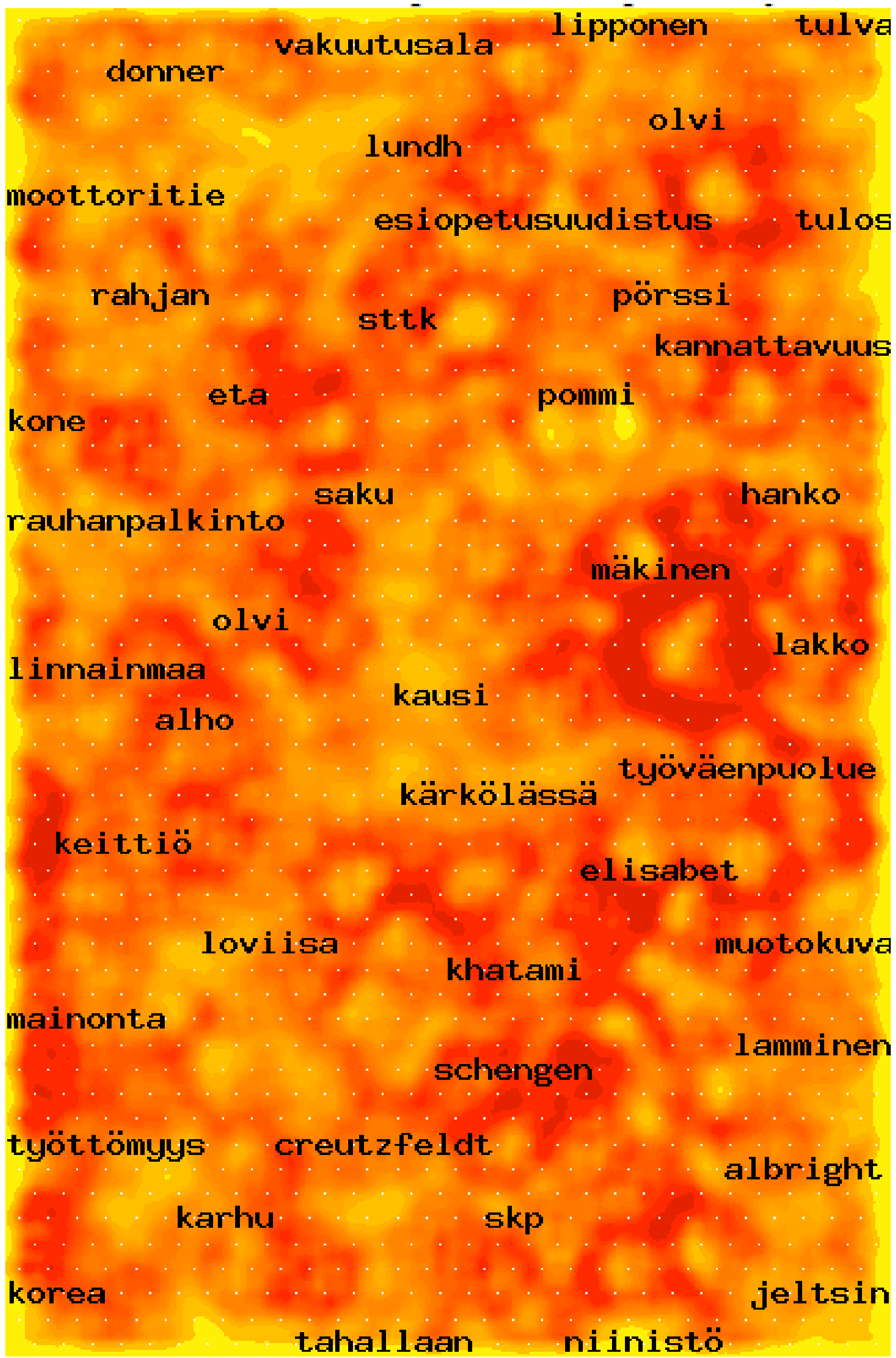
(a) Distribution of the first 100 documents in the personal collection



(b) Distribution of the latest 100 documents in the personal collection

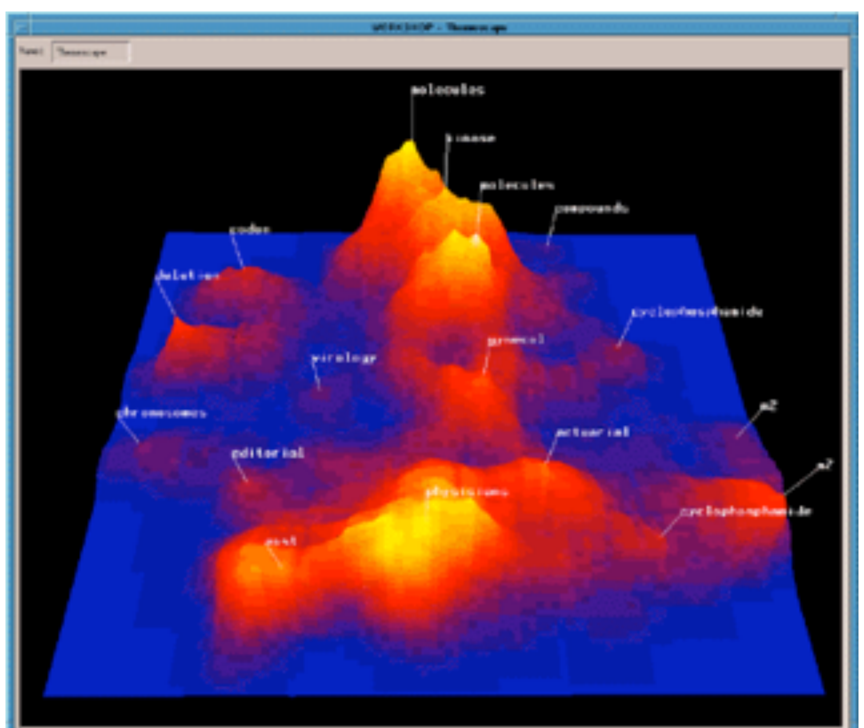
WEBSOM

- http://websom.hut.fi/websom/
- SOM of Finnish news bulletins for exploring and retrieving documents
- Labels show the topics of areas in the SOM
- Coloring encodes density - light areas contain more documents
- Navigation via zooming and panning
- Documents can be retrieved on the lowest level of the visualization

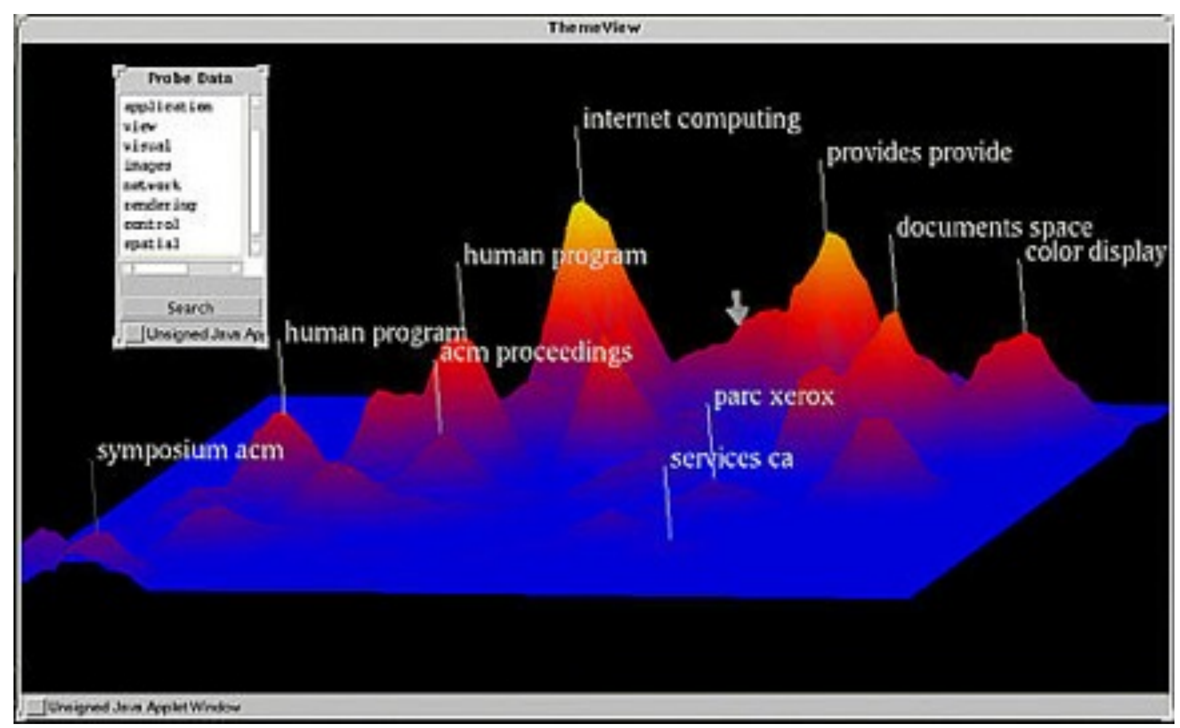


ThemeScapes

- Wise et al. 1995
- Map document density to third dimension
- News article visualized as an abstract 3D landscape
- Mountains represent frequent themes in the document corpus (height proportional to number of documents relating to the theme)
- Spatial characteristics of the map should map to interconnections of themes



http://nd.loopback.org/hyperd/zb/spire/spire.html



http://infoviz.pnl.gov/technologies.stm

Cluster Map vs Keyword Search

- Chris North
- Cluster Map pros
  - Facilitates non-targeted exploration and browsing by spatially organizing documents
  - Provides overview of document set: major themes, sizes of clusters, relationships between themes
  - Scales up
- Cluster Map cons
  - How to label groups?
  - What does the space mean? How to label space?
  - Where to locate documents with multiple themes: both mountains, between mountains, …?
  - Relationships within documents?
  - Algorithm (SOM) is time-consuming

Cluster Map vs Keyword Search

- Chris North
- Keyword search pros
  - Reduces the browsing space according to user’s interests
- Keyword search cons
  - What keywords do I use?
  - What about other related documents that don’t use these keywords?
  - No initial overview
  - Mega-hit, zero-hit problem

TagClouds

- Show the frequency of words in a text
- Frequency is mapped to size and/or color
- Often found as navigation aid on web pages
- example below generated by wordle.net

Additional Sources

- Jonn Stasko, lecture material, CS 7450
- Chris North, lecture material, CS 5764