Page Segmentation by Web Content Clustering

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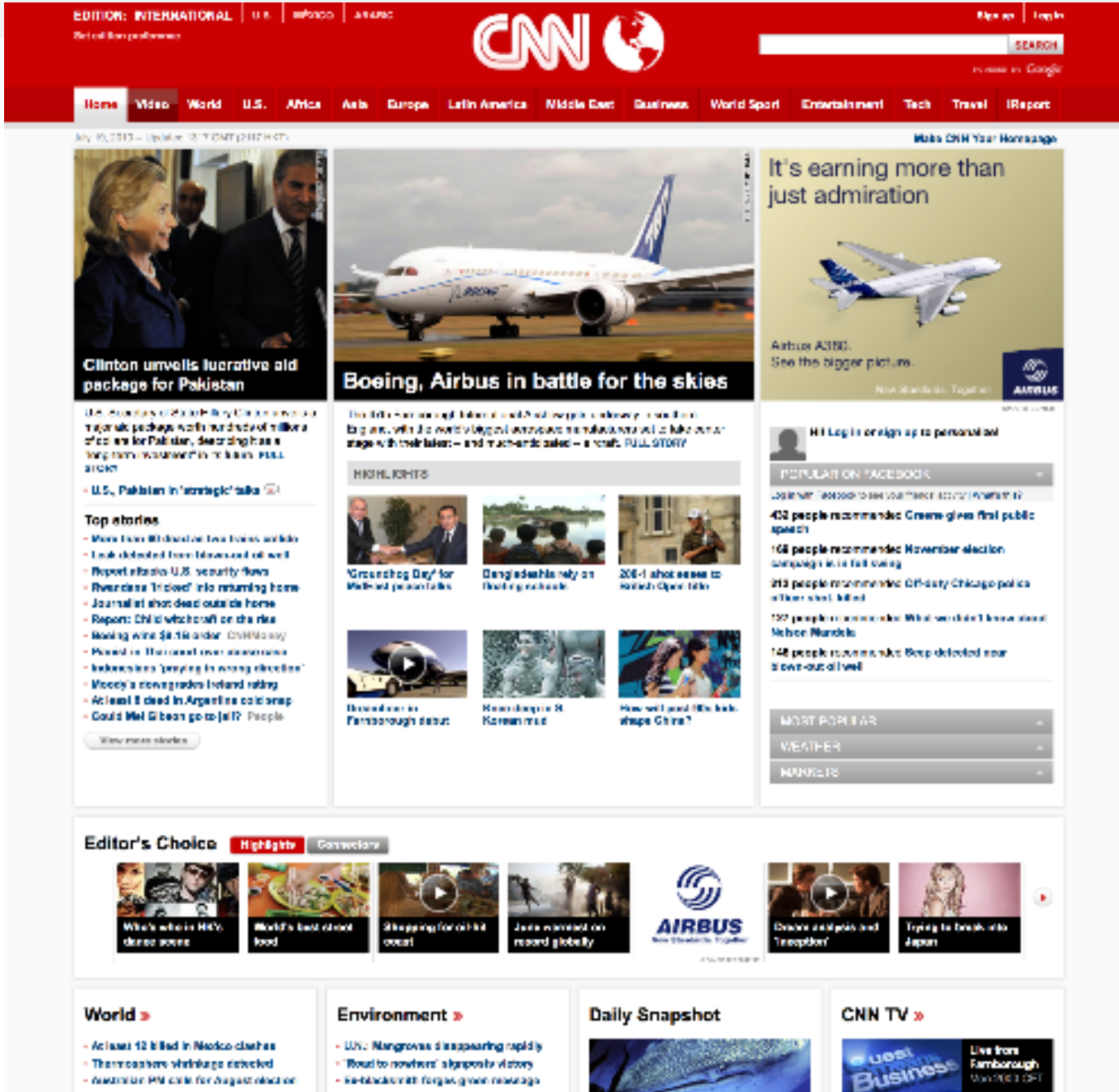
May 26, 2011

Outline

Motivation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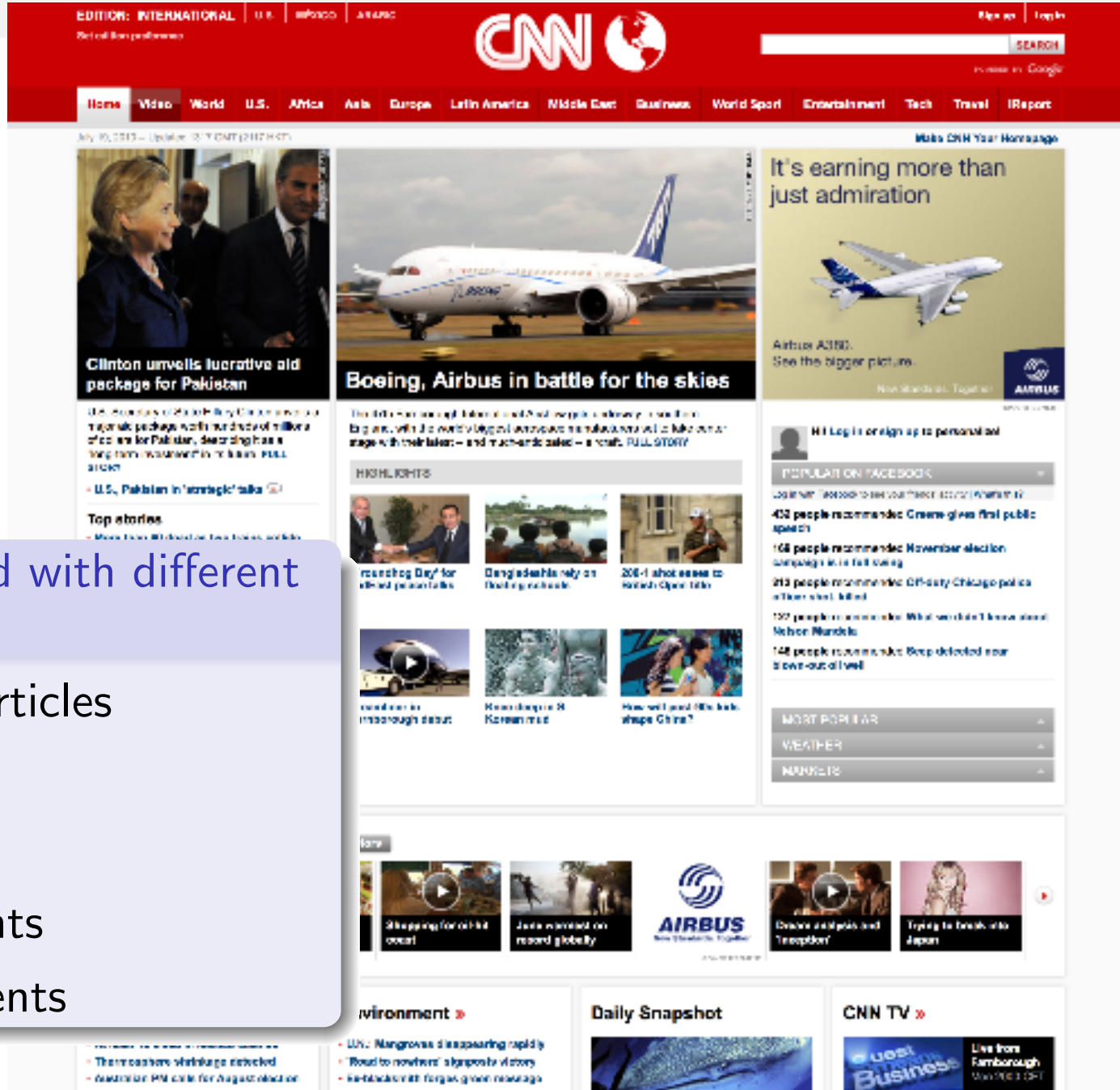
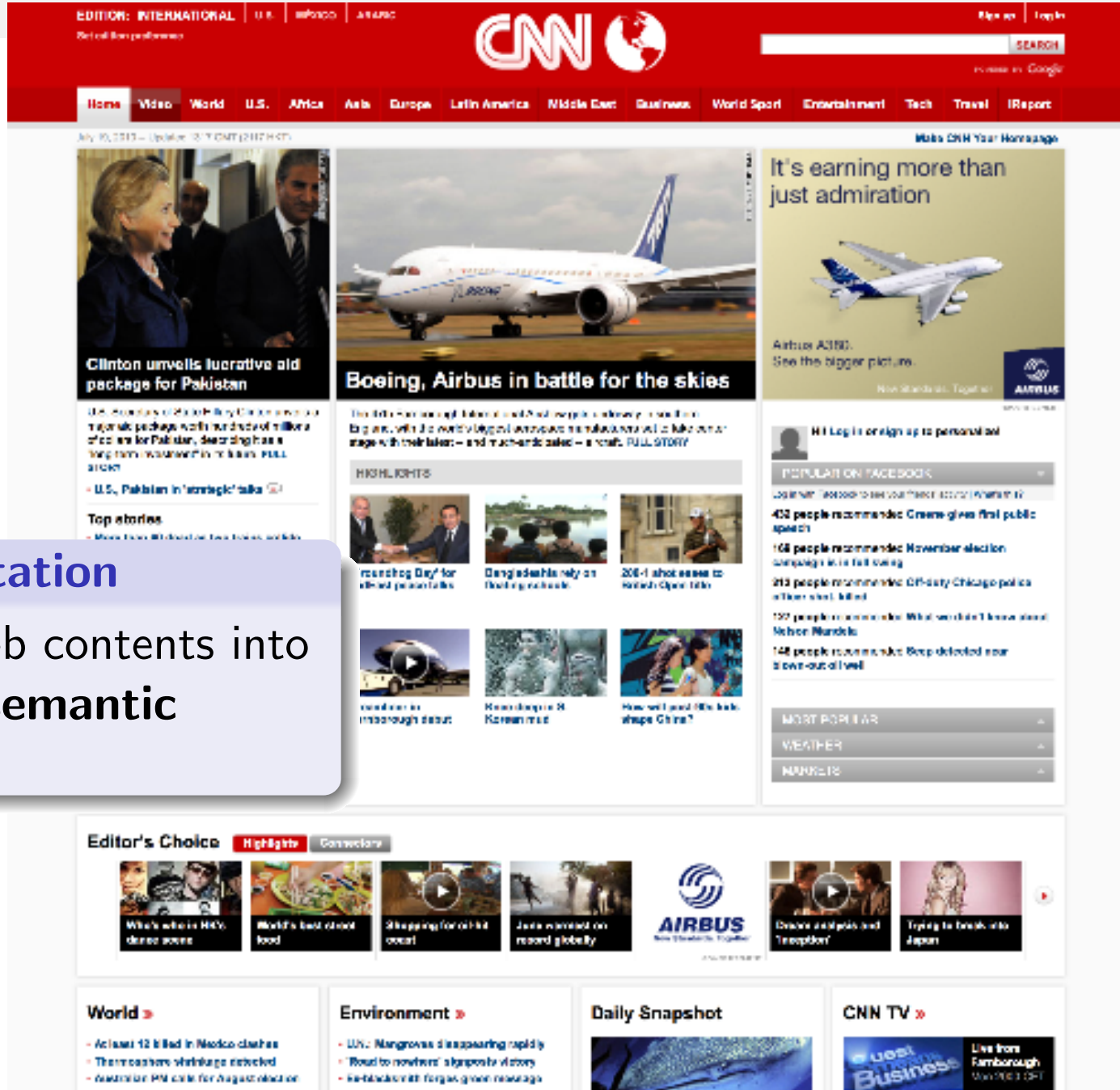


Web Page is cluttered with different contents

- Different news articles
- Link lists
- Commercials
- Template elements
- Functional elements

Motivation



Web Page Segmentation

- Separation of web contents into **structural** and **semantic** cohesive blocks

Motivation

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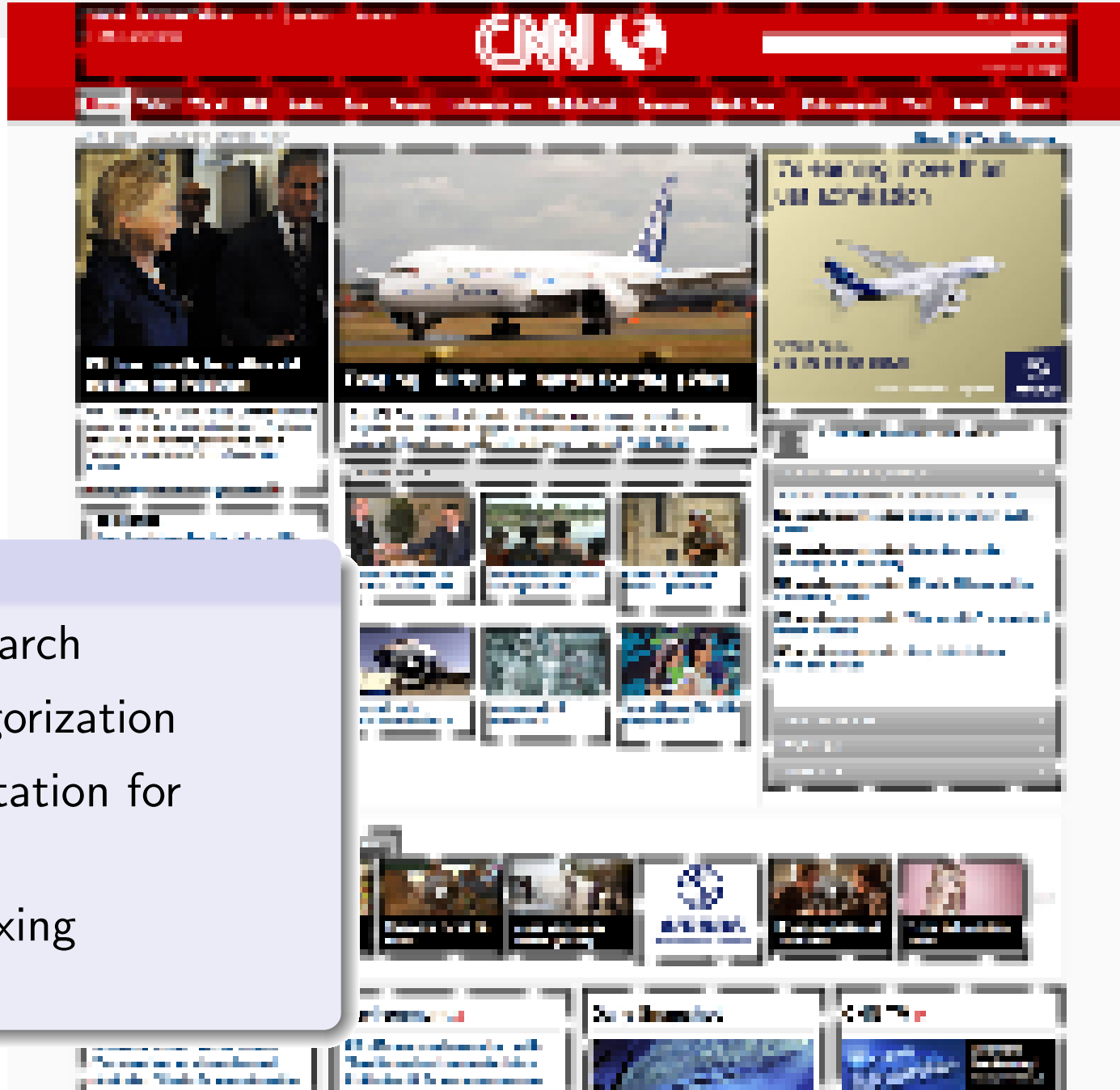

Applications

- Web Content Search
- Web Page Categorization
- Web Page Adaptation for Mobile Devices
- Web Image Indexing
- ...

Overview of Related Work to Web Page Segmentation

- **TOP-DOWN page segmentation:**
  - KDD'02: Lin and Ho. *Discovering Informative Content Blocks from Web Documents* (Table properties)
  - APWeb'03: Cai et al. *Extracting content structure for web pages based on visual representation* (Heuristic rules on visual and DOM properties)
  - TKDE'05: Kao et al. *Web Intrapage Informative Structure Mining Based on DOM* (Term entropy based on heuristics)
- **BOTTOM-UP page segmentation:**
  - CIKM'02: Li et al. *Using Micro Information Units for Internet Search* (Heuristic rules)
  - WWW'08: Chakrabarti et al. *A graph-theoretic approach to webpage segmentation* (Graph partitioning)
  - CIKM'08: Kohlschuetter and Nejdl. *A densitometric approach to web page segmentation* (Partitioning of a histogram of text density)

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Basic Idea

- Start with complete Page as initial block
- Decide for each block:
  - should the block be separated?
  - if yes, where to separate?

! Based on heuristics

Overview of Related Work to Web Page Segmentation

Basic Idea

- Start with smallest content units (e.g., DOM leafs)
- group them to blocks of coherent content
- How?

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Overview of Related Work to Web Page Segmentation

Our Approach

- belongs to BOTTOM-UP methods
- DOM leafs are used as basic web objects
- Idea!: group web objects to blocks by **clustering**

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Web Page Segmentation by Clustering

Page Segmentation by Clustering

General Definition: Clustering

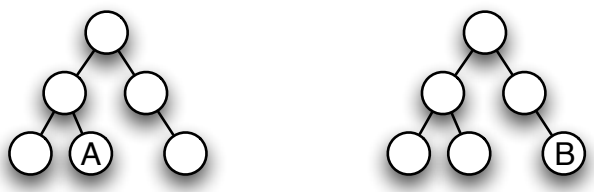
- Clustering is *the process of organizing objects into groups whose members are similar in some way*
- A cluster is therefore a collection of objects which are **similar** between them and are **dissimilar** to the objects belonging to other clusters

Open questions addressed in this work

- How can the similarity (or dissimilarity) of web objects be estimated?
- Which representation is best suitable to represent web objects?
- Which clustering method should be applied for clustering?

Different Representations of Web objects

- Geometric Representation
  - web browser puts every object of a web page in a 2-dim plane
  - extract the **bounding rectangle** for each object
- Semantic Representation
  - elements in DOM contain some textual contents
  - extract **keywords** from the corresponding text
- DOM-based Representation
  - each object is a node in the DOM tree of the page
  - use the **position of the object in DOM tree** to characterize it



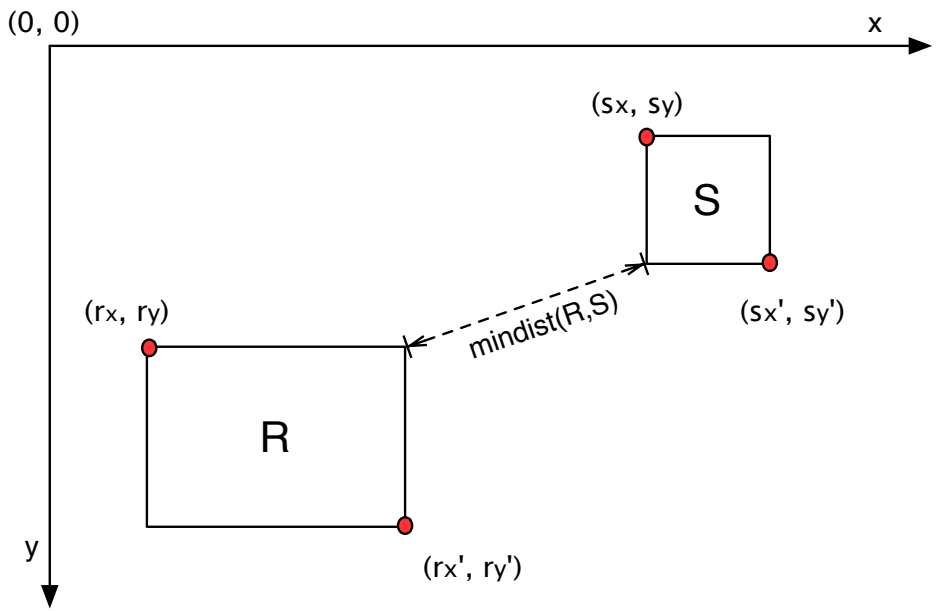
$\Rightarrow$ **Different distance measures are possible**

Geometric Distance

- Let $R = [(r_x, r_y), (r_x', r_y')]$ and $S = [(s_x, s_y), (s_x', r_y')]$ be two bounding rectangles
- The geometric distance of R to S is given by

$$dist(R,S) = \left(\sum_{i \in x,y} {t_i}^2\right)^{\frac{1}{2}}, \text{ with } t_i = \begin{cases} r_i - s_i' & \text{if} \quad r_i > s_i' \\ s_i - r_i' & \text{if} \quad r_i' < s_i \\ 0 & \text{if} \quad \text{otherwise.} \end{cases}$$

- Visually:

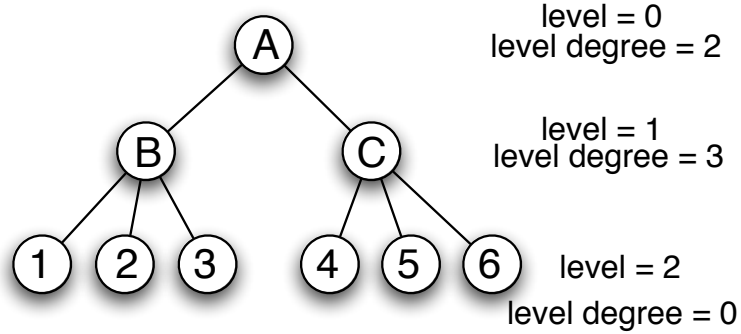


Semantic Distance

- Given $T_1 = (\text{dog, run, street})$, $T_2 = (\text{puppy, walk, road})$
- Cosine Similarity Measure (Information Retrieval)
  - Lexical word-to-word matching $\rightarrow sim(T_1, T_2) = 0$
- to strict: e.g. synonym and hyponym relationships are not considered
- Instead: text similarity measure based on WordNet [Corley 05]
  - Words are mapped to concepts in WordNet (concept-to-concept matching)

$$sim(T_1, T_2) = \frac{\sum_{w_i \in T_1} maxSim(w_i, T_2) \cdot idf(w_i)}{\sum_{w_i \in T_1} idf(w_i)}$$

DOM-based Distance



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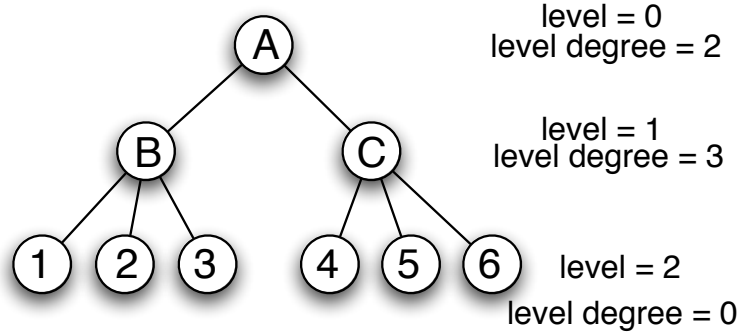

Requirements

- Nodes under same parent are closer than nodes under different parent
- Nodes on higher tree level are closer that nodes on lower level

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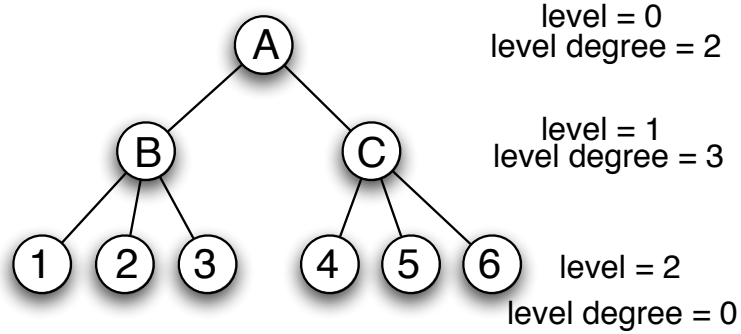
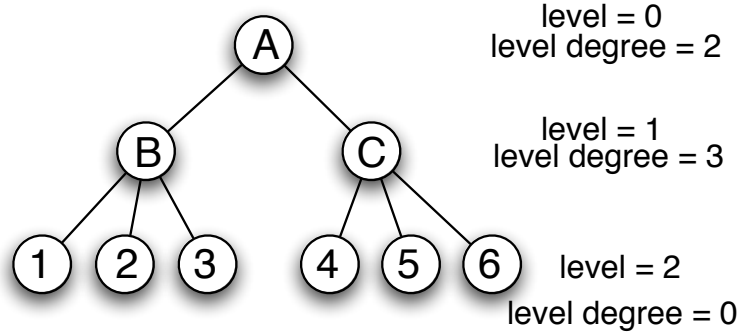


- Traverse DOM-tree in preorder traversing:

$$P = (\text{Ⓐ}, \text{Ⓑ}, ①, ②, ③, \text{Ⓒ}, ④, ⑤, ⑥)$$

DOM-based Distance



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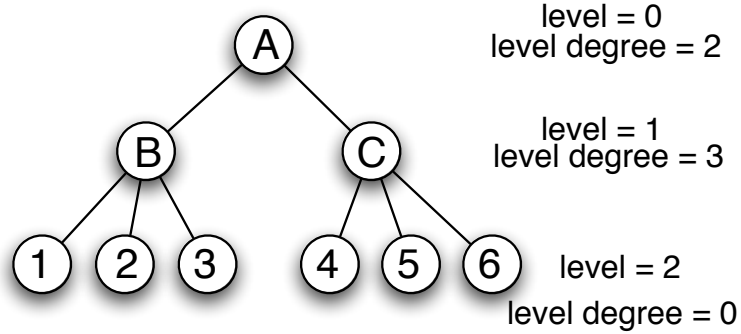
$$P = (\text{Ⓐ}, \text{Ⓑ}, ①, ②, ③, \text{Ⓒ}, ④, ⑤, ⑥)$$

- For each element in P define a weight w_{p_i} that expresses the costs needed to reach p_i from its predecessor in P

DOM-based Distance

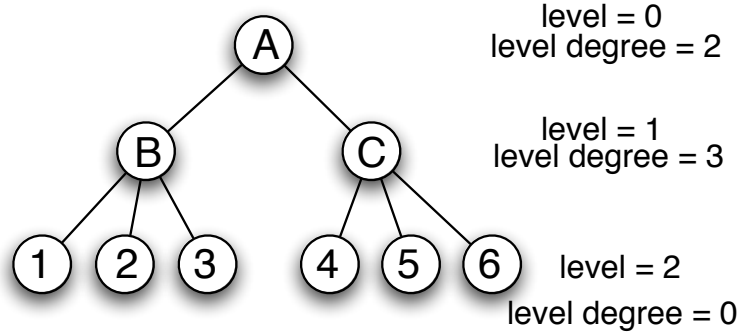


- The distance between $p_a, p_b \in P$, (wlog. $a < b$) is defined as:

$$d(p_a, p_b) = \sum_{i=a+1}^{b} w_{p_i}$$

Example: $d(②, ④) = w_3 + w_C + w_4$

DOM-based Distance



- The weight w_i of a node $p_i \in P$ depends on the level l and the level degree d_l of p_i:

$$w(l) = \begin{cases} c & : \quad d_l = 0 \\ d_l \cdot w(l+1) & : \quad d_l > 0, \end{cases} \tag{1}$$

e.g., $w(2) = c$, $w(1) = 3 * w(2) = 3c$, $w(0) = 2 * w(1) = 6c$,

Clustering Methods

- Partitioning Clustering
  - **k-medoid** (similar as k-means, but cluster representatives are real objects)
- Agglomerative Hierarchical Clustering
  - **single link** method applied to compute distance between sets of objects
- Density-based Clustering
  - **DBSCAN** variant (able to find clusters of different density levels)

Evaluation Studies

Distance-Matrix Visualization

- A distance matrix contains all pairwise distances of the objects to be clustered, e.g.

	a	b	c
a	0	1.9	1.1
b	1.9	0	2.3
c	1.1	2.3	0

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29-43

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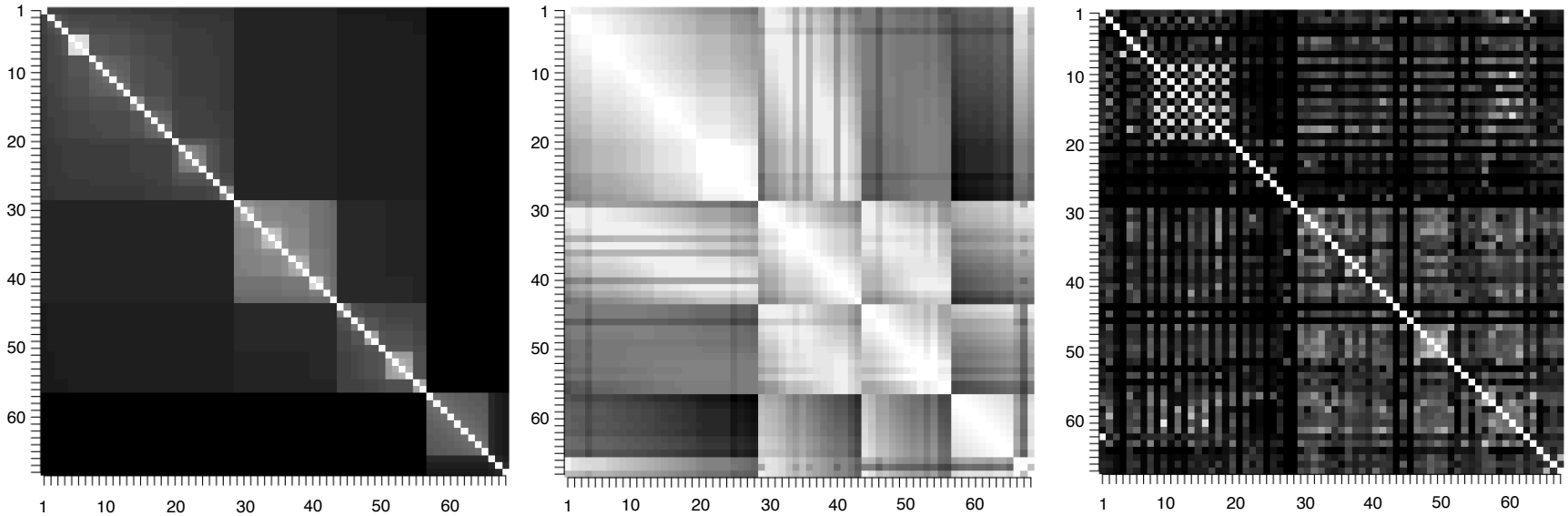
Numbers

- indicate the position of particular web objects in the source code

Distance-Matrix Visualization



- left and bottom axe represent the web objects ordered by their appearance on the web page
- each pixel represents a distance value
- white means lowest distance, black means highest distance
- bright squares in the diagonal indicate possible page blocks

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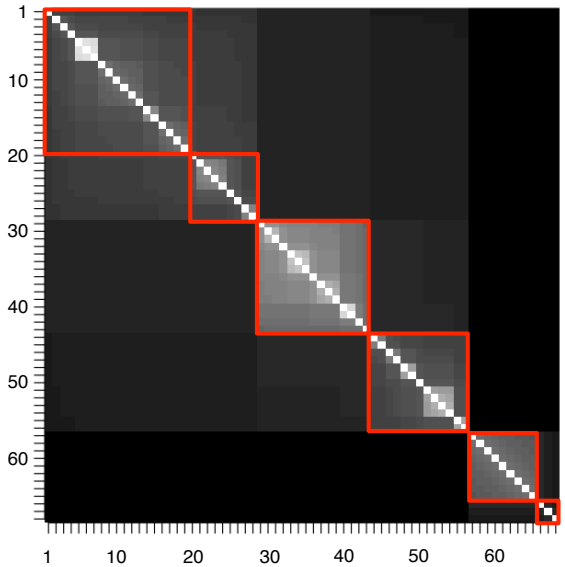
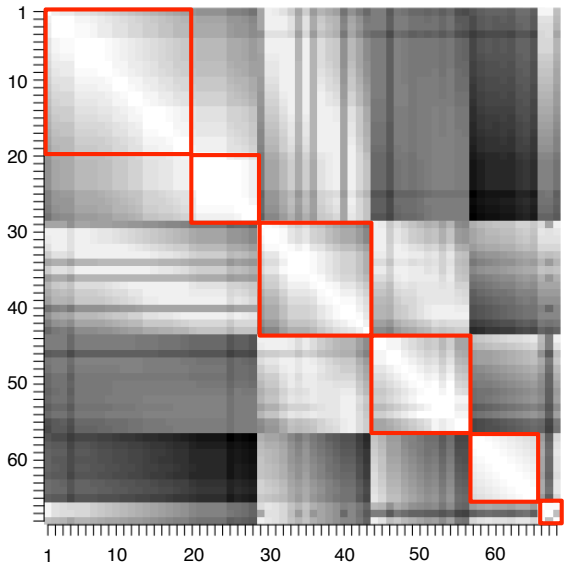
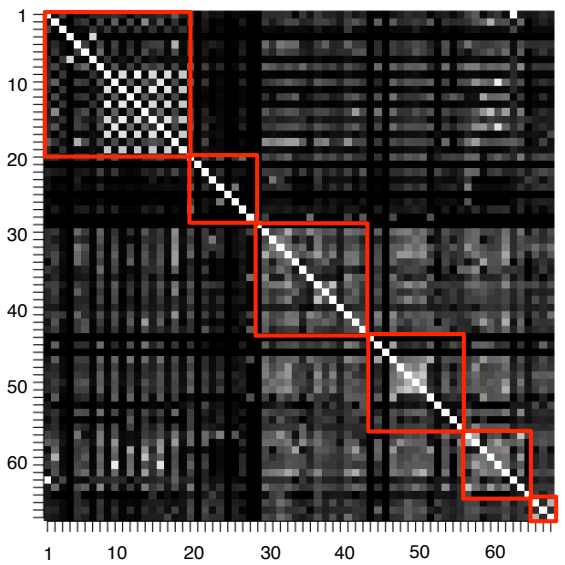


a) DOM-Distance

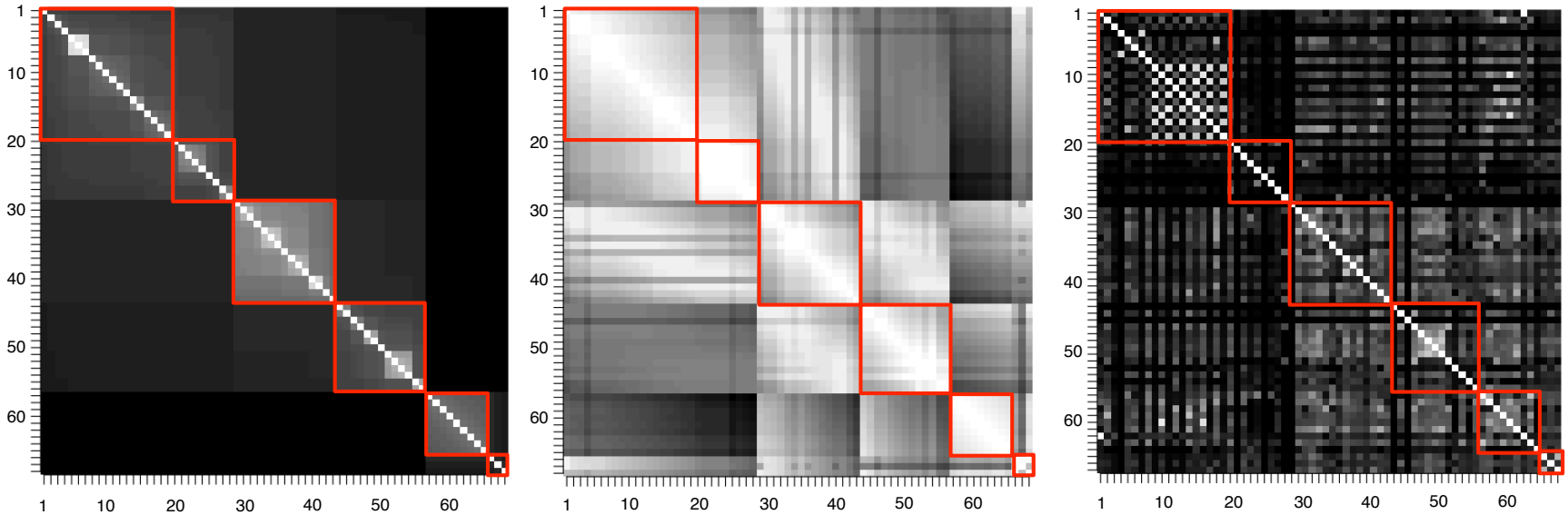


b) Geometric-Distance



c) Semantic-Distance

Distance-Matrix Visualization



a) DOM-Distance b) Geometric-Distance c) Semantic-Distance

Results:

- DOM-distance has good correspondence

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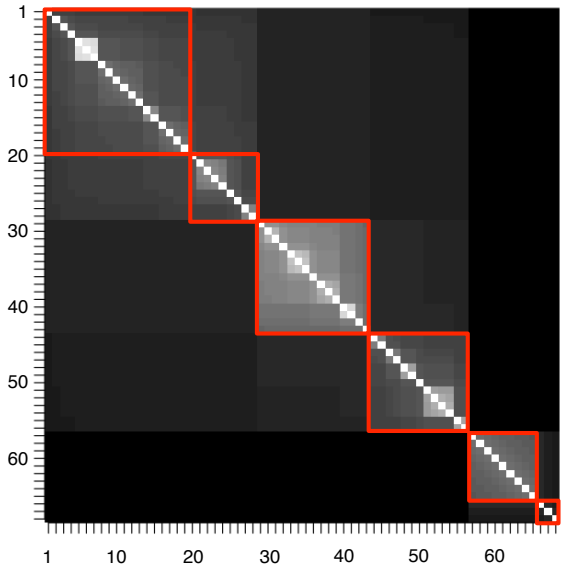

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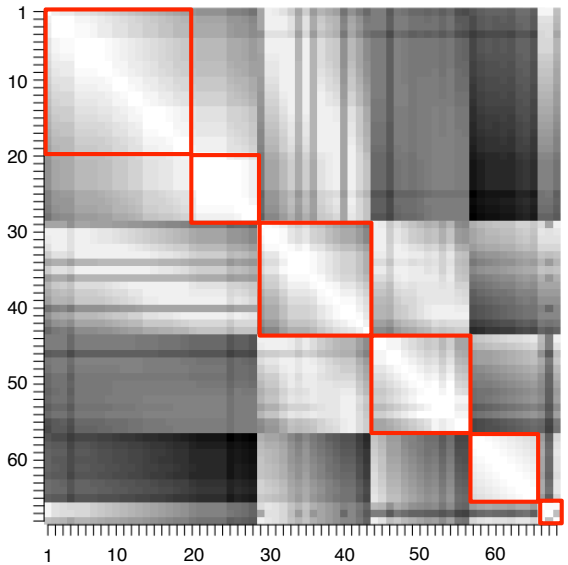

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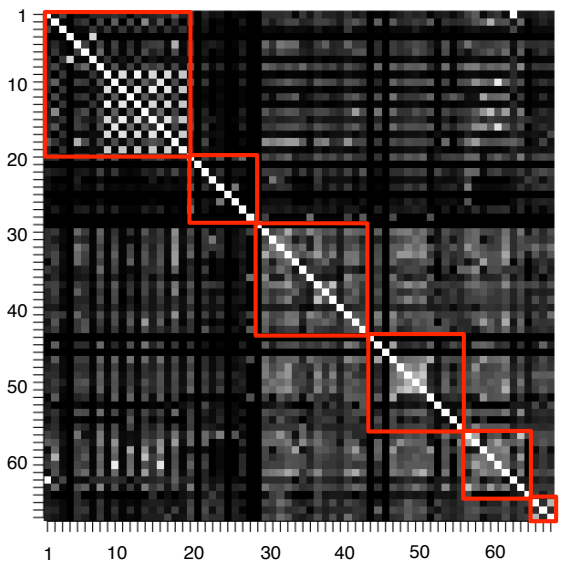

c) Semantic-Distance

Results:

- DOM-distance has good correspondence
- Geometric distance has some correspondence, but there are other bright rectangles

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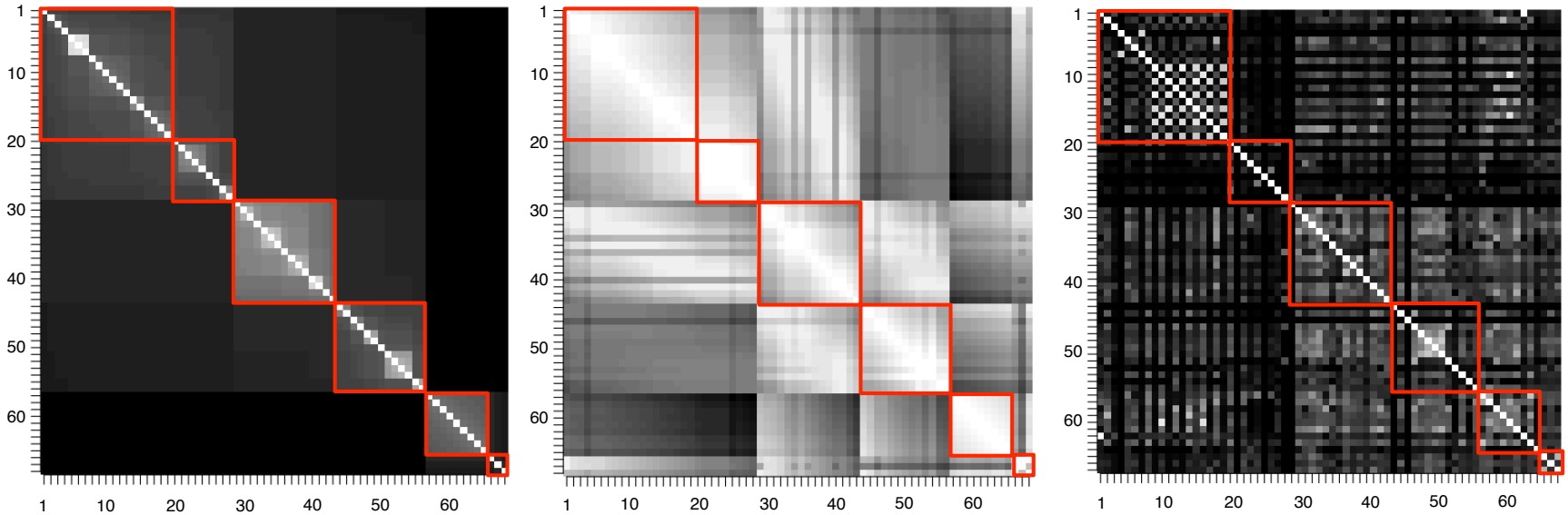
Distance-Matrix Visualization



a) DOM-Distance b) Geometric-Distance c) Semantic-Distance

Results:

- DOM-distance has good correspondence
- Geometric distance has some correspondence, but there are other bright rectangles
- Semantic distance has almost no correspondence

Evaluation - Clustering Performance

Dataset

- 78 web documents from 8 different categories from Yahoo! directory
- 23,819 web contents (in average 305 per web page)
- Web contents clustered manually by 3 volunteers
- Ground truth is combination of all three proposals

Method

- For each combination of clustering method & distance function
  - compute clustering of the web contents into page blocks
- Ground Truth Clustering (GT), Computed Clustering (C)

Evaluation - Performance Measure

Based on Contingency Table for pairs of objects:

	Same cluster in C	Different cluster in C
Same cluster in GT	f_{11}	f_{10}
Different cluster in GT	f_{01}	f_{00}

Performance Measure

$$Rand\ statistic = \frac{f_{00} + f_{11}}{f_{00} + f_{01} + f_{10} + f_{11}}$$

Average Rand Statistic Results

	DOM-based	geometric	semantic
partitioning	0.45	**0.47**	0.25
hierarchical	**0.52**	0.41	0.24
density-based	**0.61**	0.43	0.27

Results:

- Rand statistic values are similar to the results of Distance Matrix Visualization
- DOM distance reaches highest values with DB clustering
  - the distances between together belonging objects are varying in the metrical space derived by DOM distance
  - DB clustering is able to find clusters of different densities

Conclusion and Future Work

Conclusion

- Web Page Segmentation by Clustering was presented
- three different distance function for web objects based on geometric, semantic and DOM properties
- three clustering methods from different categories: partitioning, hierarchical and density-based clustering
- best clustering accordance to ground truth with DOM-Distance and DB clustering

Future Work

- combination of distance measure (linear, multiplicative, ?)
- comparison to other Web Page Segmentation methods from literature
- application of Web Page Segmentation to Web Image Context Extraction (paper accepted, to be published)

Thank You!