Page Segmentation by Web Content Clustering

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Outline

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   • Motivation
   • Related Work

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   • General Idea
   • Distance functions for web contents
   • Clustering methods

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   • Distance functions
   • Clustering

4 Conclusion and Future work
Web Page is cluttered with different contents

- Different news articles
- Link lists
- Commercials
- Template elements
- Functional elements
Web Page Segmentation

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

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 leaves)
- 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
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

⇒ Different distance measures are possible
Geometric Distance

- Let \( R = [(r_x, r_y), (r'_x, r'_y)] \) and \( S = [(s_x, s_y), (s'_x, s'_y)] \) be two bounding rectangles.

- The geometric distance of \( R \) to \( S \) is given by

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

- Visually:

![Diagram showing geometric distance between two bounding rectangles R and S.]
Semantic Distance

- Given $T_1 = (\text{dog}, \text{run}, \text{street})$, $T_2 = (\text{puppy}, \text{walk}, \text{road})$
- 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

![DOM-based Distance Diagram](image)

- **level = 0**
- **level degree = 2**
- **level = 1**
- **level degree = 3**
- **level = 2**
- **level degree = 0**
DOM-based Distance

Requirements

- Nodes under same parent are closer than nodes under different parent
- Nodes on higher tree level are closer than nodes on lower level
DOM-based Distance

▶ Traverse DOM-tree in preorder traversing:

\[ P = (A, B, 1, 2, 3, C, 4, 5, 6) \]
DOM-based Distance

▶ Traverse DOM-tree in preorder traversing:

\[ P = (A, B, 1, 2, 3, C, 4, 5, 6) \]

▶ For each element in \( P \) define a weight \( w_{pi} \) 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: $d(\overline{2}, \overline{4}) = w_3 + w_C + w_4$
**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 $p_i$:

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

(1)

- e.g., $w(2) = c$, $w(1) = 3 \cdot w(2) = 3c$, $w(0) = 2 \cdot w(1) = 6c$, 

![DOM-based Distance Diagram](image)
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.

<table>
<thead>
<tr>
<th></th>
<th>a</th>
<th>b</th>
<th>c</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>0</td>
<td>1.9</td>
<td>1.1</td>
</tr>
<tr>
<td>b</td>
<td>1.9</td>
<td>0</td>
<td>2.3</td>
</tr>
<tr>
<td>c</td>
<td>1.1</td>
<td>2.3</td>
<td>0</td>
</tr>
</tbody>
</table>
Welcome

The International Conference on Web Intelligence, Mining and Semantics (WIMS'11) will be organised under the auspices of Western Norway Research Institute.

This is the first in a new series of conferences concerned with intelligent approaches to transform the World Wide Web into a global reasoning and semantics-driven computing machine. Next conferences in this series, WIMS'12 and WIMS'13, will take place in Craiova (Romania) and Madrid (Spain) respectively.

The conference will provide an excellent international forum for sharing knowledge and results in theory, methodology and applications of Web intelligence, Web mining and Web semantics. The program will feature several keynote and invited talks, from academia and the industry.

The purpose of the WIMS'11 is:

- To provide a forum for established researchers and practitioners to present past and current research contributing to the state of the art of Web technology research and applications.
- To give doctoral students an opportunity to present their research to a friendly and knowledgeable audience and receive valuable feedback.
- To provide an informal social event where Web technology researchers and practitioners can meet.

Scientific American article by Tim Berners-Lee, Ora Lassila and James Hendler was published in May 2001. The WIMS'11 conference is an annual event to reflect on the 10 years - successes and misses.

Call for Breaking News Abstracts
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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Distance-Matrix Visualization

a) DOM-Distance
b) Geometric-Distance
c) Semantic-Distance
**Distance-Matrix Visualization**

Results:
- DOM-distance has good correspondence
- Geometric distance has some correspondence, but there are other bright rectangles
- Semantic distance has almost no correspondence
Distance-Matrix Visualization

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Distance-Matrix Visualization

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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:

<table>
<thead>
<tr>
<th></th>
<th>Same cluster in C</th>
<th>Different cluster in C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same cluster in GT</td>
<td>$f_{11}$</td>
<td>$f_{10}$</td>
</tr>
<tr>
<td>Different cluster in GT</td>
<td>$f_{01}$</td>
<td>$f_{00}$</td>
</tr>
</tbody>
</table>

Performance Measure

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

<table>
<thead>
<tr>
<th></th>
<th>DOM-based</th>
<th>geometric</th>
<th>semantic</th>
</tr>
</thead>
<tbody>
<tr>
<td>partitioning</td>
<td>0.45</td>
<td>0.47</td>
<td>0.25</td>
</tr>
<tr>
<td>hierarchical</td>
<td>0.52</td>
<td>0.41</td>
<td>0.24</td>
</tr>
<tr>
<td>density-based</td>
<td>0.61</td>
<td>0.43</td>
<td>0.27</td>
</tr>
</tbody>
</table>

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!