Progressive Content Delivery for Mobile E-Services

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Abstract. In this paper we present a framework for the progressive delivery of Web documents in mobile Internet services. Progressive delivery enables users to get fast access to the most relevant parts of a document. The central part of the delivery consists of concepts to determine the most relevant document parts for successive delivery maintaining the documents' readability. To make this selection as flexible and effective as possible we consider the user's notion of relevance together with semantic author annotations and structural document characteristics. Using XML technology documents are automatically adapted to fit both personal user profiles and device constraints. A prototypical mobile news service exemplifies our approach to content selection, but our framework promises to be applicable to a broad range of future Internet services.

1 Introduction

The further improvement of efficient web-enabled multimedia database and middleware systems is a major topic in today's database research. Apart from basic data management the delivery of multimedia content is of essential importance: today value-added Internet applications like portal services, multimedia libraries or e-shops already have to provide a flexible delivery of multimedia data and complex digital content to support different kinds of Internet users and devices. With the potential convergence of Internet technologies and mobile communication the existing demand for personalization of e-services will even increase.

Within the scope of the HERON project [10] and the research initiative Preference World [4] we have developed a middleware framework called Multimedia Delivery for the efficient and effective adaptation and delivery of multimedia content to different users and mobile terminals with varying user profiles and specific device capabilities. Multimedia Delivery is to strengthen the infrastructure of future Internet applications and to facilitate the implementation of multi-channel e-services for different kinds of users and different types of mobile devices. Figure 1 illustrates the conceptual layers of Multimedia Delivery and shows how the delivery framework can be deployed in practice. The building blocks of Multimedia Delivery are as follows (cf. figure 1):

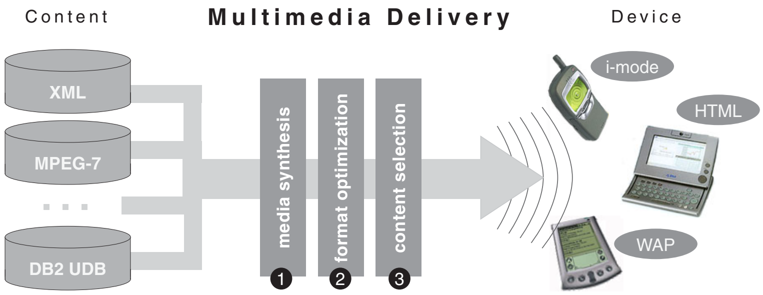


Fig. 1. The conceptual layers of Multimedia Delivery.

❶ **Media synthesis:** Multi-channel Internet applications have to deal with media objects in varying formats. The synthesis layer of Multimedia Delivery improves access to objects through conversion and allows for the efficient computation of media objects.

❷ **Format optimization:** Multimedia database systems such as IBM DB2 Universal Database or Oracle 9*i* are frequently deployed within e-services for the storage of multimedia content. The format optimization layer is targeted at the optimal format-centered configuration of database servers.

❸ **Content selection:** For delivery to an individual user a multimedia document can be adapted to the user's preferences and the technical constraints of mobile terminals. To optimize the personalized delivery parts of a document are preselected and progressively delivered with increased priority.

Details on the implementation and evaluation of the media synthesis and format optimization layer of our delivery framework are published elsewhere [11, 9]. In this paper we focus on the third framework layer aiming at the progressive delivery of complex multimedia documents.

The main goal of content selection is to provide an optimal delivery order for progressive delivery. Due to the possibly limited capacity in mobile environments (e.g. low bandwidths) the selection of content is twofold: with respect to a user's interests the most relevant parts of the documents should be delivered first. To identify content-bearing document parts relevance weightings are assigned to different parts of the structured document. Subsequently the document structure is altered such that highly weighted parts will be delivered first. However, to maintain the readibility and semantic links within a document it is necessary to avoid a high grade of fragmentation.

2 A mobile Internet news service

We will apply our concept of content selection in the framework of a personalized Internet news service targeting mobile clients. Our e-service will process and deliver newspaper articles that are taken from various online newspapers. All

Fig. 2. Sample news article as displayed on the Web.

articles are stored using a generic and device independent XML format. Figure 2 shows a sample article from USA Today's sports archive [8] (September 26, 2001) to be delivered to a mobile user.

2.1 Level of detail

For delivery the news article has to be broken down to single blocks with a certain level of detail (*lod*). These blocks form the smallest units of information and must be delivered without further division. Figure 3 depicts the tree-like document structure corresponding to our sample article. This figure also illustrates how a document is split into a hierarchy of *lod*s, which includes a hierarchy of the XML nodes used to store information: For our sample document n_1 the highest *lod* is 2 including just the root node n_1 itself. On a lower detail level the document is partitioned into several sub-documents with each partial document being evaluated and ranked for progressive delivery, e.g. at *lod* 1 relevance weights will be assigned to the sub-documents n_2, n_6, n_{12}, n_{16}.

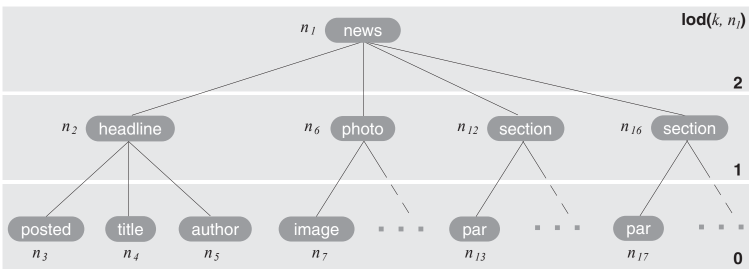


Fig. 3. Tree-like document structure of our sample article.

2.2 Relevance weighting

Prior to the progressive delivery of a document based on a relevance weighting we determine its natural reading sequence. The reading sequence of a document is defined as the list of nodes at the chosen level of detail as they appear in the author intended sequential reading of the document. In the following let R denote this natural reading sequence of a document. For our sample document at *lod* 1 we have $R = [n_2, n_6, n_{12}, n_{16}]$. The elements of R then have to be reordered for a relevance-based progressive delivery. Thus all document nodes are weighted according to their relevance to the user and subsequently sorted in descending order yielding in the delivery sequence of the document. Finally this sequence is used to deliver the document progressively, i.e. node by node, to the mobile user. We use a standard method based on the well-known vector space model [2] to measure the semantic relevance of textual document parts:

#	Name	911–WAT	FINANCIAL	WIZARDS
1	Cathy	0.5	0.5	0
2	Bill	0.9	0	0.1
3	Michael	0.1	0	0.9

Interest profiles are coded in the form of vectors bearing the the relative interest of a user in a certain topic, e.g. user Bill is mainly interested in news on the events following Sept. 11 and the "war against terrorism" (90%); while he shows a minor interest in basketball ("Wizards") (10%), financial news are of no interest for him (0%). Based on the vector space model and keyword lists associated with specific news topics we assign a relevance weighting to each textual leave of the document expressing how close it is related to the specific interests of a user.

2.3 Sample progressive delivery

We will now consider the progressive delivery of our sample article to user Bill based on the relevance weights. We choose 1 as the *lod* for this example delivery. This implies that the sub-documents starting with headline, photo, section are considered as the smallest units of the document which cannot be split any further. Here and throughout the paper we are exploring the mobile delivery of content to the Palmpilot PDA [5] using the AvantGo Web browser for mobile devices [1].

Figure 4 depicts the delivery to Bill's mobile terminal. As reflected by his interest profile p_2 user Bill is primarily interested in news from the category 911–WAT. While the article is mainly on Basketball and Jordan's comeback to the NBA, it also includes a passage reflecting some public opinion on professional sport in the light of the events of Sept. 11. It is this very passage (sub-document n_{16}) that will be delivered first to user Bill. However, the delivery solely based on relevance weightings reveals some deficiencies: In the progressive delivery of our sample article to user Bill the relevance weighting of a textual section dominates the delivery sequence of the article, i.e. sub-document n_{16} – the endmost textual section – even outweighs the headline of the article (screen 2, fig. 4).

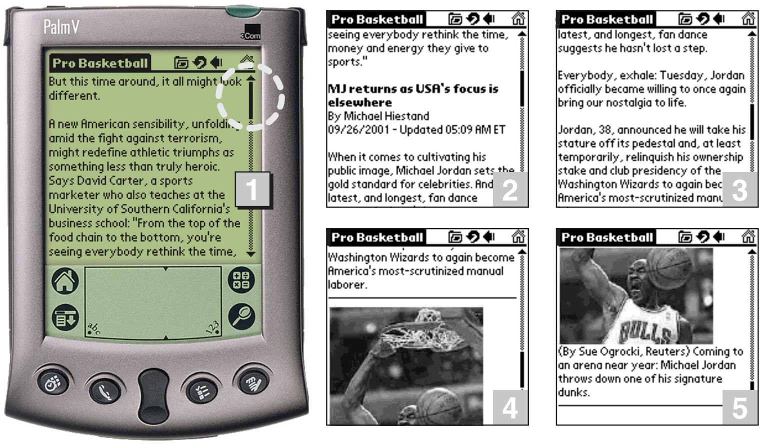


Fig. 4. Progressive delivery for sample user Bill (911–WAT).

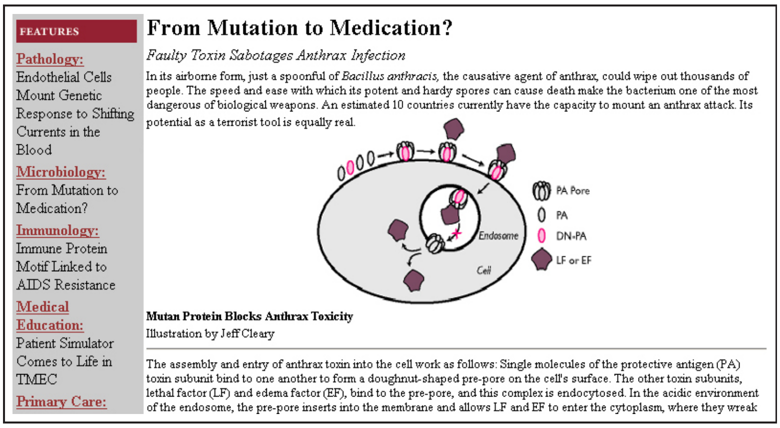
2.4 Author annotations

To overcome the problem of outweighing important structural parts we introduce author annotations as meta-markup tags associated with the document type definitions to suspend an unwanted dominance of certain sub-documents in the delivery process and to allow the creator of a document to assign default weighting factors to certain tags. In the spirit of transcoding hints used in the MPEG-7 format [6] these annotations express that some parts of a document should be ranked over other parts within the delivery. Author annotations state basic structural properties and will be used in a second delivery step to get a secondary weighting for each block. The two weightings will then be combined to form the total weighting for each block suppressing unwanted dominance of sub-documents in the delivery process.

Figure 5 shows the XML schema used to define articles in our mobile news service. Our schema is enriched by author annotations on the headline and the subtitle tag (line 5 and 11) which assign default weighting factors to these markup

```
1   <xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema">
2    <xsd:element name="news" type="News"/>
3    <xsd:complexType name="News">
4     <xsd:sequence>
5      <xsd:element name="headline" type="Headline" weight="5"/>
6      <xsd:element name="photo" type="Photo" minOccurs="0" maxOccurs="unbounded"/>
7      <xsd:element name="section" type="Section" maxOccurs="unbounded"/></xsd:sequence></xsd:complexType>
8    <xsd:complexType name="Headline">
9     <xsd:sequence>
10     <xsd:element name="title" type="xsd:string">
11     <xsd:element name="subtitle" type="xsd:string" minOccurs="0" maxOccurs="1" weight="10">
12     ...
```

Fig. 5. Author annotated XML schema for Internet news articles.



FEATURES

Pathology:
Endothelial Cells Mount Genetic Response to Shifting Currents in the Blood

Microbiology:
From Mutation to Medication?

Immunology:
Immune Protein Motif Linked to AIDS Resistance

Medical Education:
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Primary Care:

From Mutation to Medication?

Faulty Toxin Sabotages Anthrax Infection

In its airborne form, just a spoonful of *Bacillus anthracis*, the causative agent of anthrax, could wipe out thousands of people. The speed and ease with which its potent and hardy spores can cause death make the bacterium one of the most dangerous of biological weapons. An estimated 10 countries currently have the capacity to mount an anthrax attack. Its potential as a terrorist tool is equally real.

Mutan Protein Blocks Anthrax Toxicity
Illustration by Jeff Cleary

The assembly and entry of anthrax toxin into the cell work as follows: Single molecules of the protective antigen (PA) toxin subunit bind to one another to form a doughnut-shaped pre-pore on the cell's surface. The other toxin subunits, lethal factor (LF) and edema factor (EF), bind to the pre-pore, and this complex is endocytosed. In the acidic environment of the endosome, the pre-pore inserts into the membrane and allows LF and EF to enter the cytoplasm, where they wreak

Fig. 6. Web-based presentation of a scientific news article.

tags. These annotations express that by default the headline should always be ranked five times higher as other document parts on the same level of detail, e.g. photo or section. Furthermore, if a headline contains a subtitle, it should be weighted even higher (magnitude of 10). A newly initiated delivery process for user Bill based on these annotations will now remedy the delivery deficiencies depicted in figure 4: the headline of the article will be delivered first followed by the most relevant nodes starting with n_{16}.

3 Dealing with document fragmentation

Having determined the modified delivery order of a document there are certain cases where the generated delivery sequence is not entirely satisfactory. Especially if a low level of detail is chosen, the partitioning and reordering of the document may cause severe fragmentation, thereby affecting the document's readability. In particular in combination with a poor semantic ranking model which is incapable of capturing the semantic linkage of a textual node to its document context the negative effect of fragmentation can be multiplied.

Let us consider an example which illustrates this behavior: figure 6 depicts a scientific news article from Havard Medical School featuring a strong semantic linkage between the included pictorial illustration ("Mutan Protein Blocks...") and the adjacent text paragraph ("The assembly and entry.."), i.e. the text paragraph mainly provides an explanation of the picture. However, this semantic linkage will neither be expressed by author annotations nor by our textual ranking model: figure 7 shows the medical article's delivery sequence for Bill at lod 1 given the author annotations from above. Based on his profile the document parts related to 911–WAT are delivered first resulting in the separation of the pictorial content (end of delivery: screen 3, fig. 6) and the previously adjacent text paragraph (middle of delivery: screen 2, fig. 6). However, since the

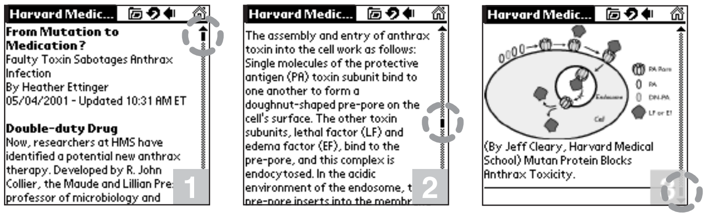


Fig. 7. Heavily fragmented delivery for sample user Bill.

paragraph mainly consists of a description of the helpful illustration and neither one can be understood without the other, the resulting document's readability is severely affected.

Even though author annotations are useful to express general structural and basic semantic aspects of a document, semantic links between single adjacent parts cannot be modeled adequately to avoid document fragmentation. Thus, we introduce a formal measurement for the degree of fragmentation. In the case of heavy fragmentation we will use heuristic defragmentation strategies to improve the document's readability prior to its final delivery (for proofs cf. [9]).

3.1 Measuring fragmentation

In the following let k be the length of the reading sequence and $\pi : \{1, \ldots, k\} \longrightarrow \{1, \ldots, k\}$ denote the permutation of documents nodes at the chosen level of detail. For instance, with $R = [n_2, n_6, n_{12}, n_{16}]$ and $D = [n_{12}, n_{16}, n_2, n_6]$ as the natural reading and the delivery sequence we have $\pi(1) = 3$ since node n_2 was shifted from the 1st position in R to the 3rd in D.

Fragmentation: The basic ratio of absolute fragmentation F_{abs} is defined as the sum of distances of all document parts in D from their original position in R. This value is normalized to $[0, 1]$ by $\frac{(k-1)^2}{2}$, the upper bound of F_{abs}, to abstract from the document's size:

$$F_{abs} = \sum_{i=1}^{k} |\pi(i) - i| \quad \text{and} \quad F_{rel} = \tfrac{2}{(k-1)^2} \cdot F_{abs} \ .$$

Incoherence: In addition to measuring how far the absolute positions of nodes are altered by the delivery we define C_{abs} as the ratio of incoherence. C_{abs} accounts for distances between nodes in the delivery sequence which were originally adjacent. Again we normalize this value to abstract from the documents size:

$$C_{abs} = \sum_{i=1}^{k-1} |\pi(i+1) - \pi(i)| \quad \text{and} \quad C_{rel} = \tfrac{2}{k \cdot (k-1)} \cdot (C_{abs} - (k-1)) \ .$$

Readability: Finally we completely abtract from absolute node positions and distances between document nodes. The sequential readability R_{abs} expresses how many nodes of the target document are still readable in their original sequential order. This is determined by iterating over the delivery sequence testing if the original order has been changed. Again we normalize to the relative ratio:

$$R_{abs} = \sum_{i=1}^{k-1} \begin{cases} 1\ , & \text{if}\ \ \pi(i+1) - \pi(i) = 1 \\ 0\ , & \text{otherwise.} \end{cases} \qquad , \qquad R_{rel} = \frac{1}{k-1} \cdot R_{abs}$$

3.2 A distance-based strategy for defragmentation

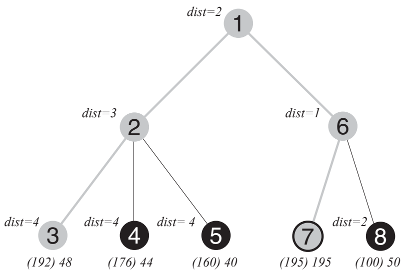
Several defragmentation strategies have been introduced in [9] aiming at the reduction of document fragmentation thereby regarding overall structural characteristics of the target and the source document. These strategies are typically applied directly after the document has been reordered with respect to the relevance weightings.

Especially for the delivery in mobile environments defragmentation has proven to be of essential importance: due to the restricted capabilities and bandwidth of mobile terminals the *lod* is often chosen low. However, the lower the *lod* is chosen, the higher is the risk of heavy fragmentation. In the following we will exemplify the idea of defragmentation by a sample strategy from [9].

S-DISTANCE: The strategy S-DISTANCE uses the distance between nodes adjacent in R with the distance (*dist*) between two nodes being defined as the length of the shortest path between the nodes in the document tree.

```
1  strategy S−DISTANCE (D : List(Node))
2  begin
3    first := head(D); rest := tail(D);
4    foreach (n ∈ rest) do
5      w(n) := w(n)/dist(c, first);
6    S−DISTANCE (sort(≤, v, rest));
7  end;
```

How S-DISTANCE works is best explained by a short example: consider the document structure depicted in figure 8 (left) ready for progressive delivery. At the lowest *lod* we have $R = [3, 4, 5, 7, 8]$ as the natural reading sequence. With relevance weights assigned as indicated in the figure (labels of tree leaves) the ad-hoc delivery sequence of the document is $D = [7, 3, 4, 5, 8]$. Note that in D node 7 and 8 (originally adjacent) are separated as far as possible. The left side of figure 8 also shows the first step in the execution of S-DISTANCE and illustrates the distances between node 7 (first node in D) and all other nodes in the tree, e.g. $dist(7, 3) = 4$ (*dist* between 7 and 3). Our strategy then iteratively adjusts the weights in D: the *first* node from D is removed (S-DISTANCE line 3). In turn the weights w of all remaining nodes n in the *rest* of D are scaled down by



D	3	4	5	7	8	D'
[7,3,4,5,8]	192	176	160	**195**	100	[ ]
[8,3,4,5]	48	44	40	**195**	**50**	[7]
[3,4,5]	**12**	11	10	**195**	**50**	[7,8]
[4,5]	**12**	**5.5**	5	**195**	**50**	[7,8,3]
[5]	**12**	**5.5**	**2.5**	**195**	**50**	[7,8,3,4]
[ ]	**12**	**5.5**	**2.5**	**195**	**50**	[7, 8,3,4,5]

Fig. 8. Defragmentation using strategy S-DISTANCE.

factor $1/\mathit{dist}(n, \mathit{first})$ (line 4-5). S-DISTANCE is then applied recursively on the *rest* of D which is reordered according to the modified node weights (line 6).

In addition figure 8 depicts the complete run of S-DISTANCE for our example displaying the modified weights of the nodes $3, 4, \ldots, 8$ in D together with the modified delivery sequence D' as the strategy's result. Starting with $D = [7, 3, 4, 5, 8]$ the delivery sequence D is recursively processed bringing some nodes together that where originally adjacent, e.g. 7 and 8, and separating some that were originally also separated, e.g. 5 and 8. S-DISTANCE terminates with the modified delivery sequence $D' = [7, 8, 3, 4, 5]$ in which parts 7 and 8 – adjacent in the original sequence – again get adjacent.

3.3 Experiments

In addition to small test scenarios as presented above we have evaluated our delivery framework in a larger context to prove the effective integration of content selection and defragmentation for real-world applications. We have set up a virtual Internet newspaper containing 15 different news articles. Each article is of roughly the same length and structure as our sports example (cf. figure 2). Using these documents at varying levels of detail 250 different delivery processes for randomly chosen user profiles have been evaluated. The following table shows the average impact of our defragmentation strategies on the fragmentation ratios F_{rel}, C_{rel}, R_{rel} and thus on the readability of the delivered newspaper document:

STRATEGIES	Ad-hoc	S-DISTANCE	All
F_{abs}	0.68	0.55	0.39
C_{abs}	0.54	0.09	0.07
R_{abs}	0.02	0.10	0.17

We can observe that the readability is significantly improved on the average, e.g. the document's incoherence measure C_{abs} is reduced by 83% from 0.54 for ad-hoc delivery (no strategy applied) to 0.09 by the single application of strategy S-DISTANCE; if other defragmentation strategies from [9] are applied C_{abs} is further reduced to 0.07. Considerable improvements can also be noted for F_{abs}

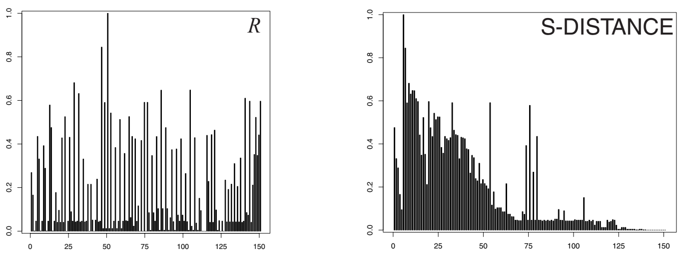


Fig. 9. Relevance distribution for original document and optimized delivery.

and R_{abs} (for R_{abs} higher values indicate an improved sequential readability). We have already seen that the readability of a document can be significantly improved by defragmentation strategies. But of course we do not want our defragmentation to entirely undo the reordering of our content selection. Thus we will have a look at the relevance weightings assigned by content selection and study the effect of our defragmentation strategies. We therefore examine the distribution of relevance weightings in the document to be delivered at different stages of content selection.

Figure 9 shows the relevance distribution for the newspaper document and a randomly chosen user profile: on the left-hand side the reading sequence R is displayed with relevance weightings somehow distributed over the document parts. Reordering the documents' nodes will yield in a delivery sequence with monotonically decreasing relevance weights. On the right hand side we see the new delivery path after defragmentation: some document parts have been reordered to improve the degree of fragmentation, but we can see that the overall distribution of relevance weightings is still as intended, i.e. after improving the document's readability through defragmentation the document parts with high relevance weightings will still be preferred for delivery.

4 Summary and outlook

We presented the progressive delivery of digital content in mobile applications, where the content-bearing document parts have to be determined for preferred delivery. Thus users are enabled to get fast access to most relevant information within a document and can decide if the entire document is useful, or the delivery could already be terminated at an early stage. The readability of documents is preserved through the application of defragmentation strategies based on a formal notion of readability. For details on the consideration of technical constraints see [9]. Related work on the personalized adaptation of digital content includes [10] where a prototypical system for mobile online auctions is presented featuring the synthesis of multimedia documents with suitable file formats for a wide variety of mobile client devices. Other related approaches focus on managing document parts in various file formats with optimized conversions for delivery of entire compound documents. In [7] conversion algorithms for pervasive computing are given based on simple profiles to evaluate different presentations and qualities of the content. In contrast [12] presents a semantic evaluation of structured documents for a later reordering of document parts with respect to a certain level of detail. However, the evaluation is not performed with respect to individual user profiles, but relies on word distributions within the document to find its most relevant parts.

In forthcoming work on progressive delivery key components of our system can be enhanced towards a more flexible and intuitive use of preference modelling, including an advanced user profiling, the determination of personalized document delivery paths and the concept of author annotations. For instance within the research initiative Preference World at the University of Augsburg ways towards intuitive personalization on the formal basis of strict partial orders are investigated [3].

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