An Intelligent Shopping List - Combining Digital Paper with Product Ontologies

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Abstract. This paper proposes a novel system which automatically extracts the intended items to buy from a handwritten shopping list. This intelligent shopping list relies on an ontology of the products which is provided by the shopping mall. In our scenario the shopping list is written on digital Anoto paper. After transmitting the handwritten strokes to the computer, the list items are recognized by a handwriting recognition system. Next, the recognized text is parsed in order to detect the amount and the desired item. This is then matched to the underlying ontology and the intended order is recognized. Our current prototype works on an ontology of 300 products. In our real-world experiments we asked 20 persons to write shopping lists without any constrains.

Keywords: Digital Paper, Ontology, Anoto, Information Extraction

1 Introduction

In order to remember the items to buy most people either rely on their memory or they write down a list of items [1, 8]. In the latter case one takes a common pen and a piece of paper and writes down every item that he or she needs. This list is then physically taken to the market. Nowadays, as mobile phones and smart phones become more and more attractive for such tasks, people can use a stylus or their fingers on a touch screen and create a shopping list.

However, such mobile devices are not always at hand and it is quite unnatural to note down a shoppling list, especially for elderly people which are used to do everything the way they practiced it for many years. So, the traditional way of writing shopping list is to use pen and paper.

This paper proposes an application that closes the gap between the traditional and the modern way: smartSL, the system that takes a written shopping list as an input and transforms the handwritten notes into digital data. The data obtained this way can be used, for example, in a shopping market that supports innovative shopping facilities. Our specific prototype has been designed for the Innovative Retail Laboratory (IRL) [7] located in St. Wendel. The IRL, a research laboratory of DFKI in cooperation with GLOBUS SB-Warenhaus Holding, illustrates how a shopping center in the future might look like.

The rest of this paper is organized as follows. First, Section 2 describes the background of our work. Second, the proposed system is described in Section 3. Next, an evaluation of several system components is described in Secion 4. Finally, Section 5 concludes the paper.

2 Background

2.1 Innovative Retail Lab

As mentioned above, the IRL is an application-oriented research laboratory of the German Research Center for Artificial Intelligence (DFKI) run in collaboration with the German retailer GLOBUS SB-Warenhaus Holding. In this lab, several demonstrators are installed which have been developed to support customers during their shopping processes. These domonstrators are related to intelligent shopping assistance, product information presentation, and indoor navigation in a supermarket. Figure 1 [left] shows a picture of a small part of the IRL. A key technology used in the IRL is RFID. In the IRL, the products are tagged with RFID labels, and the shelves and shopping carts are equipped with RFID antennas in order to identify each product instance and obtain product related information.

One core idea of the IRL is the holistic view on the shopping process, which does not only take place in the supermarket but starts and ends at the customer's home. In this context, we have developed an instrumented refrigerator which assists the customer in the pre-shopping and post-shopping phases. Due to its instrumentation that encompasses two RFID antennas placed inside the fridge and a touch screen fitted into its door, the user can get an overview of the products placed in the fridge without opening it. In addition to the recognition of products, the fridge offers a service for creating a digital shopping list. For this purpose, the retailer's weekly leaflet is visualized on the fridge's screen. The user can browse the different pages or she can filter the leaflet by product categories, such as "food" or "beverages". For this purpose, the leaflet is semantically annotated with product category tags. Whenever the user clicks on a tag in the visualized tag cloud, the system displays only those pages that contain at least one product of the corresponding category. In order to add products to her shopping list, the user can apply a drag and drop gesture.

The created shopping list is stored on a web server in the user's profile and thus can be transferred to a mobile device. Apart from the visualization on a mobile device, the digital shopping list can be loaded on the IRL SmartCart [5]. This shopping cart is instrumented with a touch screen integrated into its handle, which acts as input and output interface and is connected to a laptop mounted on the back of the shopping cart. In addition, two RFID antennas, a single button, a finger print sensor, and an NFC-reader are connected to this laptop. After the customer has logged in at the SmartCart, her personal electronic shopping

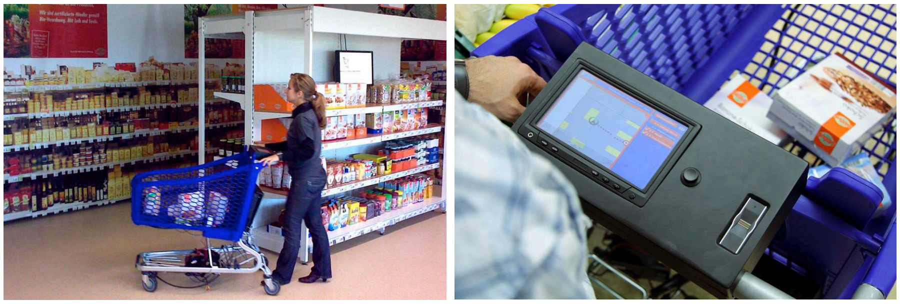

Fig. 1. Picture showing a part of the Innovative Retail Laboratory [left] and IRL SmartCart displaying a navigation route and the user's shopping list [right].

list is loaded from the web server and displayed at the cart's touch screen. Since the entries are semantically annotated, the shopping cart system can retrieve the corresponding product locations in the IRL. Using this information, the shopping list entries are sorted according to a predefined route through the IRL. When the customer puts a product into the cart that is specified on the electronic shopping list, the corresponding entry is (digitally) crossed out and moved to the end of the list. In order to facilitate the shopping procedure, the SmartCart additionally offers a navigation service. For this purpose, the current location of the SmartCart is obtained using RFID tags that are placed in a grid under the lab's flooring, and the shortest path to the searched product is calculated using an A* algorithm. Figure 1 [right] depicts the IRL SmartCart displaying the user's shopping list and a navigation route. The products placed in the basket are recognized, and the corresponding shopping list entries are crossed out.

In order to enable the navigation service, the shopping cart system must be able to interpret the shopping list entries. Currently, the user can compose her shopping list out of products which are included in the current leaflet, i.e. a very limited product range. Whenever a product is added, deleted, or modified, the changes are synchronized with the user profile stored at the web server. The application proposed in this paper aims at bridging the gap between the traditional way of creating and using shopping lists and the innovative ways of using shopping list information in the IRL.

2.2 Digital Paper

In order to retrieve written annotations from paper documents, our system builds on the Anoto technology.[4] The Anoto framework enables the capture of user actions on paper and the activation of corresponding digital services or access to digital resources. In order to become interactive, documents are Anoto-enabled at print time by augmenting the paper with a special Anoto dot pattern. The Anoto pattern represents an absolute positioning system based on (x,y) coordinates

[4] www.anoto.com

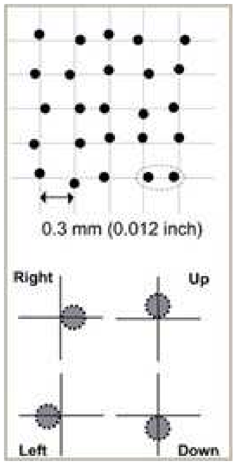

Fig. 2. Dot Pattern

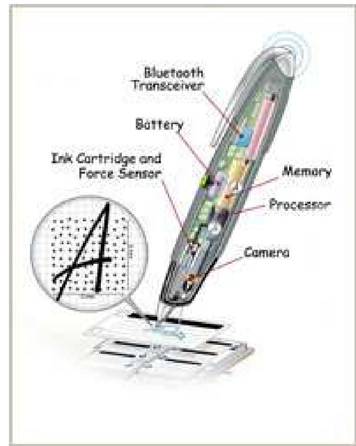

Fig. 3. Digital Pen

that can be read by special digital pens such as the Magicomm G303[5]. This pen is equipped with a camera that records (during writing) the Anoto dot pattern printed on the paper. The dot pattern and the digital pen could be seen in Figures 2 and 3. After decoding the pattern, the pen transmits the (x,y) positions to a computer either through a wireless Bluetooth connection or via USB.

2.3 Handwriting Recognition

Handwriting recognition (HWR) has been the topic of research for many decades. While the first recognizers have been developed for isolated characters or digits, later recognizers focused on complete words or even sentences [2, 6, 9]. Nowadays there exist solutions which have a quite good recognition performance (e.g., recognizers from Microsoft© and Vision Objects©).

Recent approaches go into the direction of directly recognizing the contents of the handwritten texts. A first system for English handwritten texts has been proposed in [3]. In this paper we try to follow this idea and try to identify handwritten words in a specific ontology or knowledge base.

3 Proposed System

The work flow of the proposed system is illustrated in Figure 4. First, the pen strokes are transmitted to the computer. Second, the handwritten list items are recognized by a handwriting recognition system. Subsequently, the handwritten result is matched to an underlying ontology and the desired item is detected.

5 http://www.magicomm.co.uk

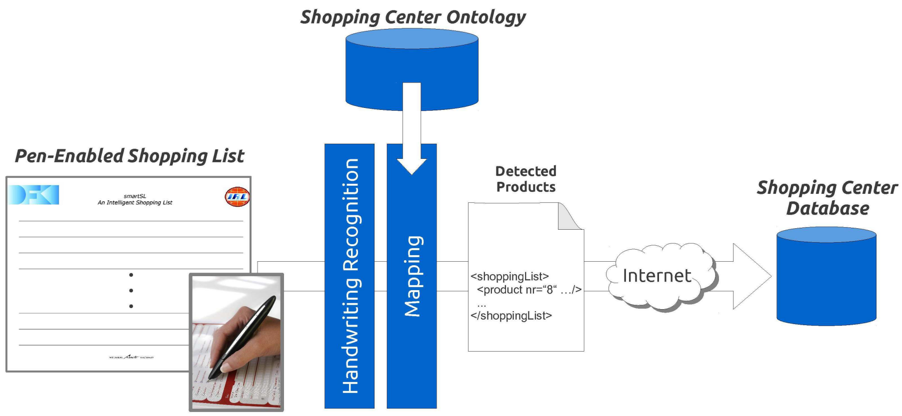

Fig. 4. Proposed System

This final detection result is directly send to the shopping database in order to make use of it during shopping.

In the following the process of detecting the desired item is further explained. In order to retrieve already good recognition results we use the terms of the ontology as dictionary entries, as proposed by [3]. Then we are using a string distance measure to determine how close the handwritten output is to one of the entries in the ontology. Two distance measures were taken into account.

First, the Levenshtein or Edit Distance, which is one of the most widely used distances metrics on strings, has been used. Given two strings a and b it counts the minimum number of insertions, deletions and substitutions of individual characters that are needed to transform a into b [4]. All these operations are applied to a only. Formally the distance can be obtained as follows [4]: Let S be the set of strings, $s, t \in S$, $m = |s|, n = |t|$ the lengths of s and t. Then the following algorithm computes the edit distance encoded in the matrix $D \in \mathbb{R}^{m \times n}$:

$$D_{0,0} = 0 \tag{1}$$

$$D_{i,0} = i, \quad 1 \leq i \leq m \tag{2}$$

$$D_{0,j} = j, \quad 1 \leq j \leq n \tag{3}$$

$$D_{i,j} = \min \begin{cases} D_{i-1,j-1} + 0 \text{ if } s_i = t_j \\ D_{i-1,j-1} + 1 \text{ substitution} \\ D_{i,j-1} + 1 \text{ insertion} \\ D_{i-1,j} + 1 \text{ deletion} \end{cases} \tag{4}$$

$$1 \leq i \leq m, 1 \leq j \leq n \tag{5}$$

The distance of s and t can then be found at $D_{m,n}$.

The second method is the largest common subsequence, which is defined as "a subset of the characters of s arranged in their original 'relative' order." This is not to be confused with substrings because substrings require that all characters between the start and the end of the substring is part of it. Hence, a substring is a special case of a subsequence. For example given *leopard*, then *leo* is a substring, *lord* is a subsequence.

A common subsequence for two strings s and t is "a subsequence that appears both in s and t" [4]. Finding the length of the longest common subsequence of s and t is task of the string distance metric induced by the longest common subsequence problem. For $leopard$ and $elefant$ the longest common subsequence is lea, thus the length is 3.

Formally the length of the largest common subsequence can be obtained as follows: Let S be the set of strings, $s, t \in S$, $m = |s|, n = |t|$ the lengths of s and t. Then the following algorithm computes the length encoded in the matrix $D \in \mathbb{R}^{m \times n}$:

$$D_{i,j} = \begin{cases} 0 \text{ if } i = 0, j = 0 \\ D_{i-1,j-1} + 1 \text{ if } s_i = t_j \\ \max\{D_{i-1,j}, D_{i,j-1}\} \end{cases} \tag{6}$$

$$0 \leq i \leq m, 0 \leq j \leq n \tag{7}$$

4 Evaluation

We have evaluated our system on the data of 30 persons who volunteered in writing example shopping lists. The individuals were randomly chosen from different social background. Altogether 22 male and 8 female persons contributed with their data. Each person wrote 5 shopping lists with around 10 items per list (Example lists are depicted in Fig. 5. Finally, we asked the persons to fill out a questionnaire where we asked the persons about their usual shopping behavior and if they often write shopping lists.

Table 1. Results of the recognition experiments performed on 363 items

Recognizer	Correctly recognized items in %
Simple HWR-Result	75
Levenshtein-Distance	80
Subsequence Matching	83

Table 1 shows the results of the item identification algorithm using three different approaches. The first approach simply applies the HWR and matches the result against the ontology. Methods 2 and 3 perform a string matching (either edit distance or subsequence matching). Using the subsequence method the best performance has been achieved. Note that we only took 363 items of the data because often people used terms which did not appear in the ontology, i.e.,

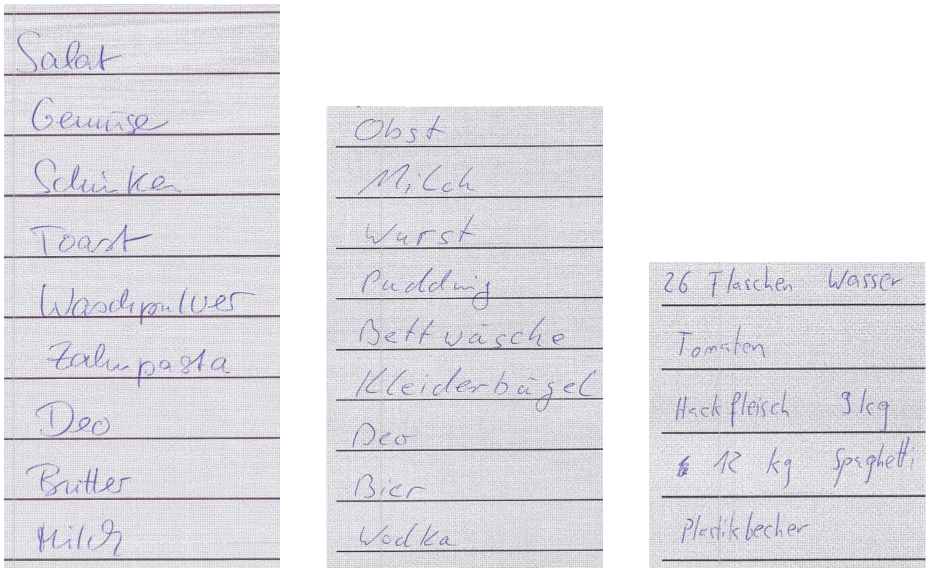

Fig. 5. Example shopping lists

the shop did not provide these items. In the future we will make use of larger knowledge bases.

The summarized results of the questionnaire appear in Table 2. As can be seen, most of the participants often go shopping and use a shopping list for remembering the items they would like to buy. Noteworthy, 80 % of the persons would like to use such a system in the future if it becomes available. The advantage of taking notes with a pen but having everything digitally available is considered as a great value of the proposed system.

Table 2. Results of the questionnaire

Question	Answer 1 (%)	Answer 2 (%)
How often do you go shopping?	$\leq$ 1 **time a week** (90)	seldom (10)
How often do you use a shopping list?	**often** (73)	seldom (27)
Would you like to use such a system?	**yes**(80)	no(20)

5 Conclusions

In this paper we have introduced a system which is able to recognize and understand handwritten items on a shopping list. By the use of a digital pen on specific paper the data is transmitted to a computer and the handwritten data is first recognized and then matched to an ontology in order to understand the intended things which should be bought. In our experiments we have seen that the performance of the system is already quite high and was improved by using specific string matching algorithms. However, in the future, the ontology has to be enlarged in order to enable users to write any items they prefer.

Further work for the future is to automatically generate user models of preferred items and used abbreviations. In a future scenario the system might be able to understand which specific kind of milk (brand, quality) is intended to be bought when the user just writes "milk".

An interesting outcome of a user evaluation is that most users would like to use the intended system in the future for their daily life. Especially those users who often use shopping lists when buying things would prefer that the proposed system is already available.

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