ProFi: Design and Evaluation of a Product Finder in a Supermarket Scenario

Ming Li
Computer Graphics &
Multimedia Group,
RWTH Aachen, AhornStr.55
52074 Aachen, Germany
mingli@cs.rwth-aachen.de

Oliver Sack
Human-Computer
Interaction Centre,
RWTH Aachen, TheaterStr.14
52062 Aachen, Germany
sack@comm.rwth-aachen.de

Katrin Arning
Human-Computer
Interaction Centre,
RWTH Aachen, TheaterStr.14
52062 Aachen, Germany
arning@humtec.rwth-aachen.de

Martina Ziefle
Human-Computer
Interaction Centre,
RWTH Aachen, TheaterStr.14
52062 Aachen, Germany
ziefle@comm.rwth-aachen.de

Luisa Bremen
Human-Computer
Interaction Centre,
RWTH Aachen, TheaterStr.14
52062 Aachen, Germany
bremen@comm.rwth-aachen.de

Leif Kobbelt
Computer Graphics &
Multimedia Group,
RWTH Aachen, AhornStr.55
52074 Aachen, Germany
kobbelt@cs.rwth-aachen.de

UbiComp'13 Adjunct, Sept 8-12, 2013, Zurich, Switzerland.

http://dx.doi.org/10.1145/2494091.2496007

Abstract
This paper presents the design and evaluation of ProFi, a PROduct FInding assistant in a supermarket scenario. We explore the idea of micro-navigation in supermarkets and aim at enhancing visual search processes in front of a shelf. In order to assess the concept, a prototype is built combining visual recognition techniques with an Augmented Reality interface. Two AR patterns (circle and spotlight) are designed to highlight target products. The prototype is formally evaluated in a controlled environment. Quantitative and qualitative data is collected to evaluate the usability and user preference. The results show that ProFi significantly improves the users' product finding performance, especially when using the circle pattern, and that ProFi is well accepted by users.

Author Keywords
supermarket scenario; micro-navigation; AR interface; shopping assistant; visual tracking; user study.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction
In recent years there have been many studies on indoor navigation, especially in the supermarket context, to guide customers in a large shopping area, which is known as macro-navigation [1]. However, when the customers reach the destination in a

supermarket, usually they are facing one or multiple product shelves with various brands and subcategories of products. The amount of visual information they need to process is still high, which can be confusing and cause prolonged searching for the intended product. To help users locate the target product on the shelf is referred to as micro-navigation [1]. Unfortunately, so far little research effort has been invested into the design and formal evaluation of such shopping assistants on the micro-navigation level.

In this paper, we introduce the design and evaluation of ProFi, a PROduct Finder application in a supermarket scenario. We focus on a micro-navigation shopping assistant to support visual search processes at the destination shelf and help users find their target products. In our prototype, an augmented reality interface is developed to locate target products for users, which utilizes computer vision techniques to detect and track a target product and highlights the target by overlaying a visual pattern on the camera live stream of a mobile device (see Figure 1).

According to visual search theories, visual attention is limited to a specific location with a predefined size ("spotlight metaphor") [3]. Spatial cueing theory assumes that objects within this spotlight are processed faster than objects outside this spotlight [8]. Spatial cues facilitate the detection and response to objects presented at the cued location. Accordingly, by providing visual patterns or cues about the specific position of the product on the shelf, users’ product search performance will be enhanced in terms of search effectiveness and efficiency.

Figure 1: AR interface of ProFi.

In order to assess the micro-navigation concept and the usage of visual cues in a supermarket scenario, we investigate the following hypothesis:

ProFi can reduce the visual complexity of the product searching task, and can improve the users’ product finding performance and satisfaction in a supermarket scenario.

Related Work

Indoor navigation in supermarkets has been addressed by many researchers [9,10]. But most of them concentrated on the macro-navigation scope. Shopping assistants focusing on micro-navigation have not been fully investigated.

Some studies focused on shopping persuasive technologies. For example, IBM [7] developed a shopping app based on visual detection and an AR interface on mobile devices to augment product information based on users’ preference and shop owners' interest. Similar vision recognition approaches are used in ProFi, however we focus on enhancing users' target searching process, which was not explored in [7]. Kalnikaite et al. [6] introduced a shopping assistant using a bar code scanner and LEDs to show health recommendations about products. Recognition solutions based on bar code scanner or RFID are not suitable for our case, since they require extra installation of equipment and need more user interaction.

In order to enhance micro-navigation, some researchers [1, 2, 12] proposed to use a controllable projector to highlight the target object or augment the shelf with extra visual information, e.g. advertisement and direction information. Comparing to their approaches, our solution does not require extra installation of projectors and projection surfaces. Moreover, the visibility of the projection depends on the light condition, which could be a problem in real supermarkets. [11] proposed an AR application using head mounted display to support order picking process of logistics. In our paper, we explore a solution for general customers using off-the-shelf mobile devices.

Implementation

Visual Tracking

Since ProFi focuses on improving users' product finding performance, our design goal is to fit ProFi seamlessly into users' walk-browsing shopping mode. Therefore we use visual recognition to detect targets.

We mount a mobile device on a shopping trolley, pointing the back-facing camera towards the shelf (see Figure 2 Right). While a user is walking and browsing products, the mobile device extracts features from the

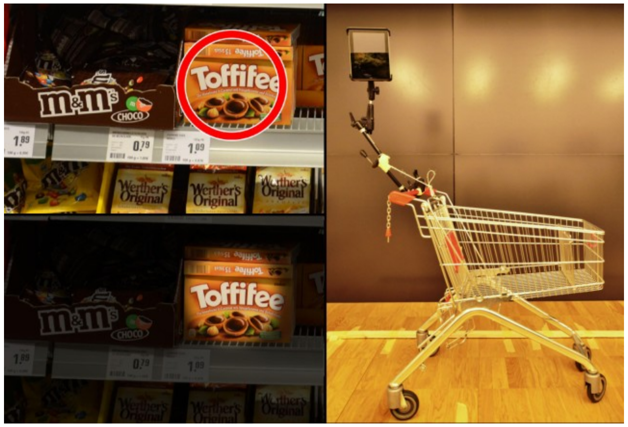

Figure 2: Left: Circle (upper image) and spotlight (lower image) patterns are used to highlight target products in the AR interface. Right: Our prototype configuration.

2D images captured by the camera and matches them against a target image database. The best matching result (to the current target product) will be returned as detected. The position of the target product in the input image will be used to render the AR overlay. There are several benefits for the vision-based approach. First, in a supermarket scenario the appearance of most brands is unique, so most of the products are detectable. Second, the visual recognition is performed locally in the mobile device. Thus there is no extra requirement to install external sensors or fiducial markers in the environment. In our prototype, Metaio SDK [5] is used for feature detection. Images of target products are pre-stored in the mobile device for matching.

AR Interface and Pattern types

In order to enhance product-finding tasks, we investigate two different pattern types to help users locate the target product, which are “circle” and “spotlight” (see Figure 2 Left). The circle marks the target product with a red circle when it is detected. The spotlight highlights the target product area and darkens other parts in the camera input.

Experiment

Setup

The prototype is evaluated in a lab environment which is equipped with a large touch-enabled display wall (back projection, 4.8 x 2.4 meters, 3072 x 1536 pixels). To simulate the supermarket environment, photos of product shelves were taken from real supermarkets and displayed on the wall (see Figure 1). The projected product images are of real size. We use a third generation iPad as the tracking device and AR interface, which is mounted on the shopping trolley in fixed position and orientation (the back camera pointing to the display wall), see the attached video. Quantitative data, i.e. task completion time and target touching accuracy, were recorded via the touch interface of the display wall system.

Independent variables

As independent variable the within-factor “pattern type” with the “circle” and “spotlight” was evaluated in contrast to a baseline condition, where no ProFi support was given. The second within-factor was “product distance”, i.e. if the target product was located close (i.e. on the left half of the shelf) or far (i.e. on the right half of the shelf) to the starting point. The position of target products in different conditions was aligned to the same levels on the display wall.

Dependent variables

As dependent variables we assessed *efficiency*, measured by completion time in sec. per trial and *effectiveness*, i.e. touch accuracy, measured by the number of touches per trial. User experience was assessed by rankings of the preferred pattern type and by satisfaction ratings on a six level Likert scale after each condition.

Procedure

First, a short tutorial for each ProFi pattern condition was given. At the beginning of each trial, participants had to position the shopping trolley at a marked starting point on the left-hand side of the display wall. Then, the name of the target product appeared on the display, which had to be read out loud and memorized. Following that, a shelf picture including the target product was displayed on the display wall. In the baseline condition (without ProFi assistance) the participant had to walk with the shopping trolley along the shelf (from the left- to the right hand side) and search for the product. As soon as the participant had found the target product he/she had to touch the product on the display wall. In the ProFi conditions, participants had to search for the product by focusing on the iPad screen, where the ProFi pattern was displayed. Each condition consisted of 6 trials, with 3 close product trials and 3 far product trials. The position of products (close vs. far) was randomized within each condition. Completion time recording started with the display of the shelf picture and ended when the product on the display wall was touched. After the ProFi conditions, user experiences were assessed. The overall duration of the experiment was about one hour.

Experimental controls
The baseline condition (without ProFi) was fixed as the first condition. The order of the following pattern conditions was balanced to control for sequence effects. In order to exclude effects of product familiarity on search performance, we empirically assessed the familiarity of products prior to the study and products with different familiarity levels were evenly distributed on the ProFi conditions. Participants' handedness was also assessed.

Sample
A total of 28 participants, 12 women and 16 men, in an age range between 20 and 41 (M=26.2; SD=5.4) took part in the study. Participants were mostly university students (technical communication science) and fulfilled a course requirement. 68% of the participants stated to shop 2-3x a week in a supermarket. While 39% participants reported to be familiar with the meaning of augmented reality, 23% of participants never experienced AR applications before.

Statistical analysis
Results were analyzed using ANOVAs with repeated measurements and t-tests for related samples. The level of significance was set at $p < 0.05$.

Results
Effectiveness: Touch accuracy was high; participants needed on average one touch per product. No effects of condition, position, handedness or sequence on effectiveness were found.

Efficiency: Using the ProFi led to a significantly increased search efficiency ($F(2,22) = 13.74$; $p < 0.001$): product search was the fastest in the circle condition (M = 7.76 sec., SD = 1.09), followed by the spotlight condition (M = 8.54 sec., SD = 1.27). In the baseline condition (no ProFi assistance) users needed on average M = 10.14 sec. (SD = 3.70, Figure 3 left). Search performance across all conditions was faster for close products (M = 7.14 sec., SD = 1.03) than for far products (M = 10.48 sec., SD = 2.76; $F(1,22) = 47.80$; $p < 0.001$, Figure 3 right).

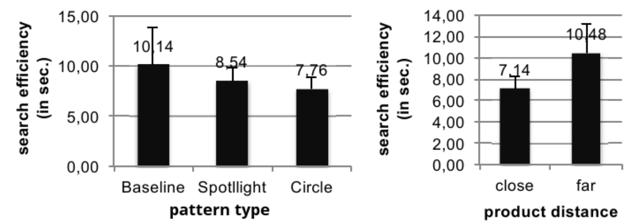

Figure 3: Search efficiency for pattern types (left) and product distance (right).

Moreover a significant interaction between pattern type and product distance was found ($F(2,22) = 30.50$; $p < 0.001$, Figure 4). Differences in search performance between close and far products dropped when using ProFi compared to the baseline condition. In the baseline condition the search performance difference between close and far products was 8.74 sec (with a better performance for close products). When being assisted by the circle, search performance for far products was only 2 sec. below search performance for close products. Using the spotlight produced an inversed pattern: search performance differences also decreased (0.73 sec.), but with a higher search performance for far products than for close products. This implicates that in the distant case, where the user has to process more visual content than the close case, the ProFi especially improves search performance.

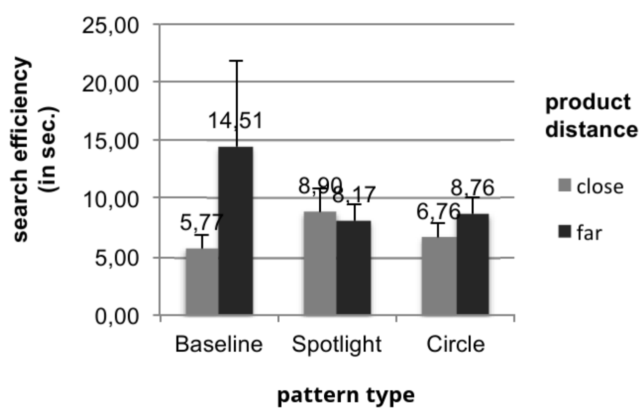

Figure 4: Interaction between pattern type and product distance for search efficiency (in sec.)

User experience: General satisfaction of using the ProFi assistant was high (M = 2.64 on a scale with 1 = max, 6 = min, SD = 1.19). Separate ratings of the two ProFI patterns showed, that users preferred the circle (M = 1.82, SD = 0.77) compared to the spotlight (M = 1.96, SD = 0.84, n.s.).

The sequence of conditions, users' gender or handedness did not significantly affect search efficiency and user experience ratings.

Discussion

We will now discuss the findings of the ProFi evaluation. Also, methodological considerations and future research questions are outlined.

Generally we found that the usage of ProFi in comparison to non-assisted product search leads to a higher and more stable search performance. Using visual patterns or spatial cues to support search processes in the supermarket scenario was proven to be successful. User experiences corroborate this finding: users were well satisfied with using the ProFi. Moreover, ProFi especially supports search performance for distant products outside the focus of visual attention. Looking more specifically at the ProFi pattern types, we found, that the circle was more advantageous in terms of performance and user experiences than the spotlight. We assume that the visual degradation in the spotlight condition, i.e. fading out all other products on the shelf except the target product, impeded the detection of the target product on the display wall. Speaking in terms of spatial cognition theories (e.g. [4]), the spotlight condition did not provide sufficient overview knowledge of the other products located on the shelf in relation to the target product. Accordingly, the spotlight pattern should be adapted in future studies by another visual pattern, e.g. color shifting outside area.

Although the presented ProFi is designed for quick shopping purposes, it could be adapted for other use cases, e.g. advertisement, or exploratory shopping. Moreover ProFi could be adapted to other groups, which might face problems with micro-navigation in supermarkets, e.g. older or visually impaired customers.

In the presented prototype the integrated back facing camera was used, due to its limited field of view and space constraints between shelves, only a few rows of products are visible in the AR interface. Future effort should be focused on solving such intrinsic constraints of mobile devices. For example, we can mount a wide angle lens to the back camera to increase the field of view, so that all rows on a shelf can be captured.

Due to different perspectives between the camera and our eyes, when participants shifted their attention from the AR interface to the environment (the display wall), they still needed to search for the target in a small area. To further enhance users' target searching process, we can equip ProFi with a controllable laser pointer or mobile projector, which points out the target directly in the real world [2, 12].

The experiment was carried out in a controlled environment, i.e. lighting and product orientation are static. In a real supermarket, it could be more challenging for the visual tracking. In future studies, a more stable visual recognition technique should be implemented and tested in a real environment. When applied in a large supermarket, the size of the image database will increase. We can use the user’s current position to restrict the image searching domain and thus speed up the query process.

As methodological consideration we found that the performance parameter “touch accuracy”, which describes the number of grasping movements the user performs till the right target is picked, is not sensitive enough for usability evaluations. Moreover, future studies should vary the walking direction along the supermarket shelf.

Conclusion

In this paper, we introduced ProFi, a product finder for micro-navigation in a supermarket scenario. A prototype was built using visual recognition techniques and an AR interface. To assess the usability, we conducted a user study in a controlled environment. Quantitative and qualitative data shows that ProFi, especially the pattern type “circle”, significantly improved the users' visual searching performance. In addition, the usage of ProFi was well accepted by participants.

REFERENCES

1. Spassova, L., Kahl, G., Krüger, A.: user-adaptive Advertisement in Retail Environments. In: Proceedings of the 3rd Workshop on Pervasive Advertising and Shopping, helsinki, Finland (2010).
2. Butz, A., Schneider, M., Spassova, M.: SearchLight – A Lightweight Search Function for Pervasive Environments. In Pervasive. (2004) 351–356.
3. Chun, M. M., Wolfe, J. M. Visual Attention. In B. Goldstein (Ed.), *Blackwell Handbook of Perception* (pp. 272-310). Oxford, UK: Blackwell Publishers Ltd (2001).
4. Downs, R. M., and Stea, D. Cognitive Maps and Spatial Behaviour: Process and Products. John Wiley & Sons, Ltd, Chichester, UK, Apr. 2011.
5. Metaio: http://www.metaio.com/
6. Kalnikaite, V., Rogers, Y., Bird, J., Villar, N., Bachour, K., Payne, S., Todd, P.M., Schöning, J., Krüger, A., Kreitmayer, S.: How to nudge in Situ: designing lambent devices to deliver salient information in supermarkets. In Proceedings of the 13th international conference on Ubiquitous computing (UbiComp ’ 11). ACM, New York, NY, USA, 11-20.
7. IBM Augmented Reality Shopping App: http://www.research.ibm.com/articles/augmented-reality.shtml
8. Posner, M. I., Snyder, C. R., Davidson, B. J. (1980). Attention and the detection of signals., Journal of Experimental Psychology: General, 109, 160-174

9. Kahl, G., Spassova, L., Schöning, J., Gehring, S., Krüger, A.: IRL SmartCart - a user-adaptive context-aware interface for shopping assistance. In Proceedings of the 16th international conference on Intelligent user interfaces (IUI ’ 11). (2011) ACM, New York, NY, USA, 359-362.

10. Black, D., Clemmensen, N., Skov, M.: Shopping in the Real World: Interacting with a Context-Aware Shopping Trolley. In Proc. of MobileHCI ’ 09 : Workshop on Mobile Interaction with the Real World, September 2009.

11. Schwerdtfeger, B., Reif, R., Gunthner, W.A., Klinker, Gudrun, Hamacher, D., Schega, L., Böckelmann, I., Doil, F., Tumler, J.: Pick-by-Vision: A first stress test. Mixed and Augmented Reality, 2009. ISMAR 2009. 8th IEEE International Symposium on , vol., no., pp.115,124, 19-22 Oct. 2009 doi: 10.1109/ISMAR.2009.5336484

12. Löchtefeld, M., Gehring, S., Schöning, J., Krüger, A.: ShelfTorchlight: Augmenting a Shelf using a Camera Projector Unit. Adjunct Proceedings of the Eighth International Conference on Pervasive Computing, Helsinki, Finland, Springer Lecture Notes in Computer Science, 2010