Industrial Case Study of the MICA Support System for Warehouse Workers

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ABSTRACT

Returns caused by the delivery of incorrect items constitute a major problem for non-automated warehouses. Returns not only create extra costs, they also aggravate customers. Most errors in logistics occur during the picking process. MICA — a mobile assistance system for warehouse workers — unobtrusively navigates the worker on his way through the warehouse and effectively prevents picking errors using RFID technology. Therefore, MICA reduces error rates, job training periods, and the time required for picking and packing, leading to lower costs for warehouse operators and increased customer satisfaction.

In this paper you will read about a case study where the MICA prototype was field-tested in the warehouse of a medium-sized enterprise.

Categories and Subject Descriptors

J.7 [**Computers in Other Systems**]: Process control; H.5.2 [**User Interfaces**]: Interaction styles

General Terms

Economics, Human Factors, Management, Performance

Keywords

Assistance system, RFID, Navigation, Industrial Case Study, Warehouse

1. INTRODUCTION

Warehouses with human warehouse workers are confronted with returns caused by incorrect delivery of items. Partly this causes huge extra costs and certainly has potential to annoy customers. Thus the primary goal for warehouses is to eliminate errors or at least reduce their number.

Picking is the most problematic sub-process of logistics because of its high error-proneness [6]. Many different types of errors are known: picking of wrong types or quantities of articles, complete omission of an article type, and an insufficient quality of articles delivered [5]. All these errors cause high costs for manufacturers and warehouse operators. Either because extra shipments are necessary, or, in the worst case, because contract penalties have to be paid. Although humans constitute the soft spot in this process, completely automated solutions are not an option for most warehouses because human workers are much more flexible.

Figure 1: Lifting truck with boxes and RFID mounting of the second MICA pilot

During economic peak times warehouses are forced to employ unskilled workers in order to cope with increased workload. These unexperienced workers are not familiar with the structure and organization of the warehouse, but have to be operational in a short time. Nevertheless, work has to be completed without errors and under the same high time pressure that also skilled workers face. Picking errors and time pressure constitute the major problems for unskilled and skilled workers. Hence, there is a need for an intelligent assistance system that supports the workers. By preventing errors, it also reduces the pressure put on each single

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(a) Picking order selection

(b) Navigation support

Figure 2: Two screens from MICA's user interface

warehouse worker. An assistance systems for untrained employees needs to support as well experienced workers in their usual way of working and not force them to change habits.

For MICA we equipped a common hand pallet truck with localization technology and indoor navigation software to guide warehouse workers through the warehouse. RFID antennas read articles that are put into picking boxes on the truck. This prevents errors and also updates picking process status to enable the navigation system to lead the worker to the next article to pick. However, the *Interaction-by-Doing* principle implemented in MICA means that the worker is not patronized. Instead MICA recognizes the worker's actions without explicit interaction and is therefore capable of supporting her with the information she currently needs.

2. THE MICA PROTOTYPE

After a first prototype of MICA proved the feasibility of the concept a follow-up pilot project was set up in 2008 with the aim of studying MICA in a real production environment. Antriebs- und Regeltechnik GmbH[1] (ART), a medium-sized German enterprise, provided the testbed for MICA. The products of ART constitute a challenge for RFID, because they consist of metal parts, are stocked in metal shelves and are handled in metal baskets. This required several modifications to the original MICA system. ART faces the typical problems of non-automated warehouses, and at the same time is continuously looking for solutions that support their just-in-sequence and just-in-time services. ART actively supported and contributed to the pilot and also assembled the MICA hand pallet truck in their workshop.

The biggest change for ART resulted in the elimination of an explicit cross-check in their picking process: Previous to the introduction of MICA, workers went through the repository with a shopping-cart-like trolley. They collected articles, brought them to the shipping area, cross checked the articles, and put them into a new box on a pallet. Afterwards, they repeated all steps until the order was completed.

The manual cross checking process has now been replaced by MICA's tag identification during the picking process. A box-by-box cross-check to keep an overview is no no longer needed. The original MICA trolley is replaced by a hand pallet truck equipped with MICA technology (see figure 1). Thus, picking onto a pallet on the hand pallet truck accomplished in one step, which safes time compared to the former multi-step process.

The finger touch enabled Tablet PC is mounted at common eye level. It is tiltable and turnable so that people can adjust it to their personal needs.

Two batteries supply the Tablet PC, the readers for article identification and for positioning. A standard power supply cable for charging ensures that every worker can easily recharge the batteries. Full charging takes four hours so that it fits well between two working shifts. A fully charged battery supplies energy for ten hours of MICA-enhanced work so that an entire shift can work without having to recharge.

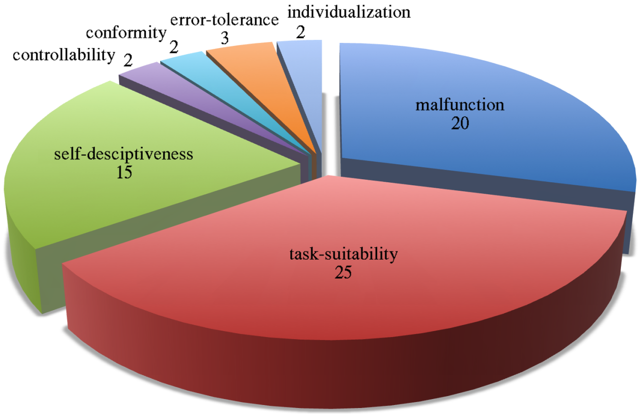
The MICA hand pallet truck is resistant against impact and scratches, electronic parts are protected. It is as easy to use as a normal hand pallet truck and fulfills safety at work guidelines. At the same time, hardware costs do not endanger profitability of the whole system.

3. USABILITY EVALUATION

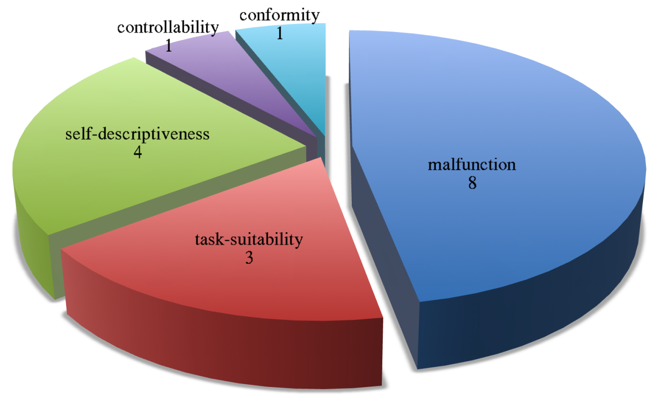
A considerable amount of effort was put into the design of the MICA GUI (screenshots see figure 2). It underwent several changes in the recent years: several internal design reviews, customization to the SAP design guide, translation from English to German, and an adaptation to ART processes. Finally, a usability study was conducted with ART warehouse workers.

A usability evaluation measures the extent to which specific users in their specific context achieve their goals effectively, efficiently and satisfactorily [3]. Effectiveness can be put on level with usability. A product, system or software supports effective processing of a task, if it provides all functions needed by a user to completely achieve his goals. Beyond that it can be rated as efficient if its functions are easily and intuitively operated. Satisfaction with the product, system or software results necessarily but not sufficiently from

[1] http://www.art-gmbh.de/engl/home.htm



(a) Violation of dialog principles and malfunctions



(b) Conformance with dialog principles and elimination of malfunctions

Figure 3: Results of the usability evaluation

situations where the user achieves his tasks effectively and without needless effort. This unfolds in a model of stages, which stimulates the presentation of results. Effectiveness constitutes a measure of the usability potential. Results of a user test represent the efficiency and satisfaction that is being measured with a questionnaire depending on the sample size for the usability study. Tests like the Software Usability Measurement Inventory (SUMI) [4] are recommended for sample sizes above twelve users. With lower sample sizes (like in our case) shorter questionnaires provide a rough impression of overall satisfaction. This is not statistically representative, but nonetheless delivers valuable information for usability assessments and suggestions for improvements.

We first conducted an expert evaluation of the interface with three experts. We identified 51 violations of requirements for the design of dialogs (according to ISO 9241-10 [2]). Most problems were related to violations of conformity with user expectations, error tolerance or self-descriptiveness. Additionally we identified and eliminated screens which had obsolete functions, like the registration and the task screens.

The original plan would have been to test eight workers, but as ART has only five people working in this section, this could only have been achieved with additional unexperienced workers. Furthermore, due to time restrictions this evaluation had to be conducted prior to the full completion of the system. In particular tests with RFID reader hardware and its interplay with the software were only partially completed. The evaluation of the MICA-pilot was therefore conducted with a limited set of three more experienced workers representing two thirds of the experienced workers in the section. The main reason for this limitation was that the system was still not completely robust and there was a risk that the system had to be rebooted.

Participants were presented real picking orders. Each usability test consisted of a short introduction that explained to the worker the nature of the test and the method of “thinking aloud”. Three investigators conducted each test: One investigator constantly stimulated the worker to comment each of his actions, while the two others took notes and pictures. All critical incidents were then collected and analyzed according to ISO 9241-10 and their specific violation of the dialog requirements. At the end of the test the workers were asked to complete a questionnaire measuring their satisfaction with the system. As expected this early testing revealed a potential for optimization. A series of critical incidents was assigned to 69 violations of dialog requirements that limit efficiency with respect to task completion (see figure 3). In particular a high number (20) of malfunctions occurred that limited the effectiveness of the MICA System. However, the tests revealed also many positive aspects of the system where the participants distinctively emphasized an unqualified success in conformance with the dialog principles, as well as eight malfunctions that were immediately eliminated during the test.

The results of questionnaire and interview indicate good satisfaction with MICA in spite of its malfunctions. Participants were confident that the system would simplify their picking process, save time and prevent errors. Specifically, they highlighted that search and identification of items when picking with MICA is much easier, less error prone and much simpler than picking without MICA. Violations of dialogue principles and identified malfunctions resulted in the revision of the MICA system and an improved version.

4. EVALUATION OF EFFICIENCY

In this section we present results of the MICA evaluation based on [1]. An economic evaluation of investments must always be based on solid investment appraisals. This in turn requires well evaluated data, describing the logistical process. Key economical measures of logisitic systems are *time*, *quality* and *cost*. To evaluate these data, the MICA pilot is implemented and tested in the ART warehouse.

To measure potential quality improvement and time reduction, as well as potential cost reduction, the paper based manual picking process is benchmarked against a MICA supported picking process. In particular, process times and failure rates are monitored. To evaluate the impact of MICA as a support system for (particularly unskilled) workers, both the manual picking process and the MICA supported picking process are tested with groups of skilled and unskilled workers. Additionally, we need to take into account the cost of processes implied by MICA and its monetary cost. We use common investment appraisal methods to calculate economic sense and an investment risc for this specific case.

The overall picking process divides into four sub-processes: *preparation*, *picking*, *inspection*, and *confirmation & hand over*. Picking and inspection times depend on item quantities. Preparation and confirmation & hand over are independ of item quantities. Using MICA, the item dependent process time is reduced by 36%, when used by skilled workers, and by 75% when used by unskilled workers. A significant processing time reduction of 46%, for skilled workers and 61% for unskilled workers is demonstrated for the item independent process time (see figure 4. Picking times are hidden due to data confidentiality).

The field trial focusses on two different error rates: error rate per order item (E_i) and error rate per picking order (E_o). E_i shows how many order items are picked mistakenly. E_o shows how many picking orders are processed mistakenly and in turn would result in a customer complaint. Without using MICA, the error rate per position is 0,48% / 4% (skilled / unskilled workers). More than this, a subsequent final cross-check of articles picked can not detect all picking errors. Thus the error rate per order turns out to be 14,3% / 25% (skilled / unskilled workers). In contrast, with using MICA, all of the human errors are detected, thus the error rate per item and per order drops to 0%, for skilled and unskilled workers.

The investment costs divide into one-time expenses and operating costs. One-time expenses are, for example, expenses for hardware, software, and infrastructure. Furthermore, assuming a good "confidence" in inventory data, according to correct and real time confirmations, dispatching can be organized more efficiently, thus "safety stock" can be reduced, yielding additional cost savings.

Based on experimental data, investment in MICA reaches a ROI of 38% at a yearly picking quantitiy of approximately 80,000 items. A typical amortization time of 18 months is reached at a yearly picking quantitiy of approximately 280,000 items. MICA demonstrates a substantial reduction of processing times, as well as a zero picking failure rate, both with a group of skilled and unskilled workers. Additionally, unskilled workers using MICA reached a picking performance almost as good as skilled workers. This shows very high potential of MICA for broad spread industrial use.

In summary the evaluation shows that MICA successfully supports complex picking processes. Potential customers are companies with small to medium sized goods, each of medium to high value, with inhomogeneous order structures and with high overall picking quantities.

5. CONCLUSION

Thanks to its multimodal interaction MICA is applicable to the changing environments of a warehouse. Calm computing principles make it usable for unskilled and experienced workers alike without having to interrupt their familiar way of working. The intuitive handling as well as support for every worker's experience level is assured by the Interaction-by-Doing concept. The new RFID-enabled hand pallet truck proves to scan 100% of the picked articles without interfering with the usual way of working. At the same time, no articles from the repository are accidently read.

The usability evaluation reveales that search and identification of articles is much improved with MICA. The results already indicate a good satisfaction with MICA in spite of early malfunctions. Participants are confident that the system would simplify their picking process, save time and prevent errors. It can be expected that the newly introduced interaction concepts and an improved MICA -system that overcomes the detected malfunctions and violations of dialog principles will fully satisfy users needs.

MICA's potential to reduce error counts and to speed-up picking processes in non-automated warehouses is shown in the economic evaluation. Enterprises with high picking quantities are offered a high potential to reduce costs. Even under high time pressure during economic peak times MICA helps unskilled workers to reduce picking errors.

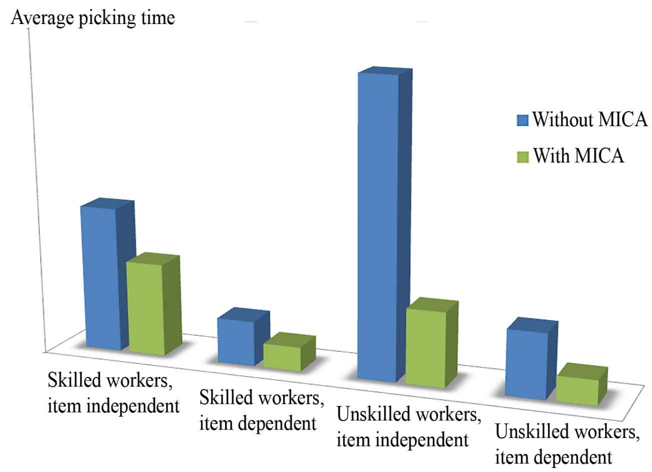


Figure 4: Picking Process Times

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