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Augmented & Virtual Reality Applications in the Field of Logistics

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Abstract

Changing basic conditions in the field of logistics require intuitive planning methods as well as new ways of supporting and educating the operative staff. VR and AR show a great promise for that.

Keywords: logistics, order picking, process planning, training, evaluation

1. Introduction

The Virtual and Augmented Reality technology is finding its way into manufacturing. Successful applications can be found amongst others in stud welding in experimental vehicle construction with the help of AR or the virtual coverage of conceptual designs in VR (Friedrich, 2004; Ong and Nee, 2004). But the profitable usage of AR and VR in the field of logistics is still underachieved. Since the possibilities for optimizing logistics processes are almost exhausted, the industry is looking towards new technologies like AR and VR and their potentials. Thus, the department of Materials Handling, Materials Flow and Logistics (fml) of the TU München deals with the development and evaluation of AR- and VR-applications. This includes the AR- and VR-based layout planning of logistics systems, the AR support for logistics workers (particularly with regards to order picking), the human-integrated simulation as well as the training of logistics workers in virtual environments. In the field of logistics planning, the aim is to reduce times for planning factory layouts while increasing planning reliability. In manually handled logistics systems the focus lies on improving of operational processes with regards to both process quality and order processing speeds. Furthermore, the VR and AR technology can be used for new methods in practical in-house training for transferring the required knowledge to the learner without negatively impacting the productivity of running processes. This leads to well-trained logistics workers able to deal with the requirements of flexible planning and logistics systems and ensures their operations' high efficiency especially in ramp-up situations.

2. State of the Art

The basic conditions in the field of logistics have changed rapidly over the last years. The market is demanding customised products – e.g. 20 years ago automotive manufacturers offered three model series while nowadays they are offering nearly ten. According to this, the variants

within one series increase steadily. Thus, production and logistics systems as well as the workers within these systems have to become more flexible to fulfil the costumers' needs.
One of the most important processes in logistics is order picking. Order picking is the gathering of goods out of a prepared range of items following some customer orders. Mistakes arising from manually performed processes in order picking systems have a strong influence on the quality of delivery and the relationship between clients and suppliers. The business confidence will be influenced negatively, possibly leading to financial consequences. Due to the high variety of goods in order picking applications, machines can usually not replace the human being with his flexibility and fine motor skills (Gudehus and Kotzab, 2007). Because of its complexity, the manual order picking processes acts as a referee process for the work with virtual technologies at the fml. The state of the art in planning processes in logistic systems and the support of the operational workers inside these systems is described below.

2.1 Logistics Planning

Production lines and logistics networks need to be adapted continuously or may require even frequent rebuilding. Thus, planning tools are required that can quickly generate a detailed and well-proven model before the project's realisation. There are often a lot of possibilities for designing logistics systems for a certain application. With the help of computer based planning tools, the best one can be selected by virtual evaluation. Nowadays companies are accustomed to using 2D CAD (Computer Aided Design) and 2D simulation systems for the planning of logistics systems. One disadvantage of 2D systems is that you have to switch between different views. This increases the number of needless handling steps and thus isn't intuitive for the users. 3D visualisation finds a remedy to this problem. Common tools in design departments have a 3D visualisation and in the last years it has been used more and more often in planning tasks. But in spite of all this improvement, theses 3D tools are still limited to monitor based work places. The stereoscopic 3D visualisation of a VR system offers new chances (Ong and Nee, 2004) and an AR system allows the inclusion of the real environment (Pentenrieder and Meier, 2006). A VR planning tool with the virtual developed production and logistics layout offers a good platform for conversation due to the fact that everybody, from the planner up to the operative staff, has the same immersive view and the possibility of an intuitive manipulation. It is important for the planners to be accompanied and supported by operative staff during the planning process, so that these can bring in their experience. Especially in the case of order picking systems the complete system's design, e.g. if it is a man-to-goods or a goods-to-man concept, is essential towards success. There are no patent remedies for the design, so several variants have to be generated and evaluated in a virtual environment. The human integrated simulation can be used to test the system concerning performance or ergonomics, thus essentially improving the process.

2.2 Support of the Operative Staff

A lot of different techniques exist for order picking in warehouses (Gudehus and Kotzab, 2007). Conventionally the workers handle their orders with paper lists intuitive for human beings but laborious to handle. Modern systems go without paper work. They include mobile data entry devices still having a high handling effort but which are usually connected online to the warehouse management system processing the data (ten Hompel and Schmidt 2004). Nowadays pick-by-voice and pick-by-light systems are common in company's logistics. They were developed for hands-free work and the reduction of mispicks. Pick-by-voice supports the worker by giving him all instructions through the computer's speech output. Unfortunately, these systems face difficulties in noisy industrial environments and are usually not accepted by logistics workers. Compared to voice support systems, pick-by-light offers the worker visual aid by installing small lamps on each storage compartment. But these systems are inflexible and expensive. All technologies imply essential disadvantages so that logistics providers demand new ways of supporting the order pickers. AR can be a solution towards developing a new order picking system. First experiments were made with video-see-through head mounted displays (HMD) (Dangelmaier et al, 2006) and using different display techniques (Klinker et al, 2007). Unfortunately the very first experiments didn't include the integration into practical logistics processes.

Another important task in modern logistics applications is the operative staff's education. In many cases upfront teaching is still a common way of educating logistics workers. It offers the opportunity to teach several trainees at the same time. However, this kind of education usually indicates a loss of practice-orientation and cannot focus on the trainees' individual needs. A vocational education generally gives the opportunity to understand the logistics and its context as well as the trainee's future work contents. But the requirements posed by logistics and its processes to the future employer are usually too specific. Thus, after recruiting a new logistics worker companies fall back to using other educational methods. Besides the regular form of introduction, most workers receive a 'training on the job'. Compared to other types of education, the 'training on the job' is integrated into running processes and thus shows practice-orientation while not requiring any special utilities (like e.g. training classrooms, test facilities for trainees). However, regarding the degree of standardization, this type of worker training strongly depends on the education's quality, which in this case mainly translates to the instructor's qualification. Additionally, this method often requires a long period of training while none of the two workers is able to reach the demanded productivity. That's why new technologies that do not imply the disadvantages of common methods of education but use their advantages, are in great demand. Virtual and Augmented Reality, as a new form of E-Learning, provide or simulate practice-orientation while building upon the advantages of computer-aided education.

3. Augmented Reality in the Field of Logistics

3.1 Planning of Logistics Systems

Another application for AR in logistics is the assistance for the planning of logistics systems. AR allows comparing virtually planned facilities to the realities of manufacturing layouts, e.g. to generate and identify interfering edges (Doil et al, 2003). Hence, the fml developed in cooperation with metaio and BMW the tool 'roivis' (Pentenrieder and Meier, 2006).

Meanwhile, 'roivis' is a well-known tool in the industry for the planning of logistics systems: Because of the proliferation of options, it is often necessary to rebuild industrial facilities and the corresponding materials handling technology. Thus, parts of a production system will be modified without changing the CAD model used for the original planning. Thus, an up-to-date virtual model of the system doesn't exist. This problem can be solved by the using AR. If a system must be rebuild, e.g. because additional, modified or new components must be handled with the system, AR has

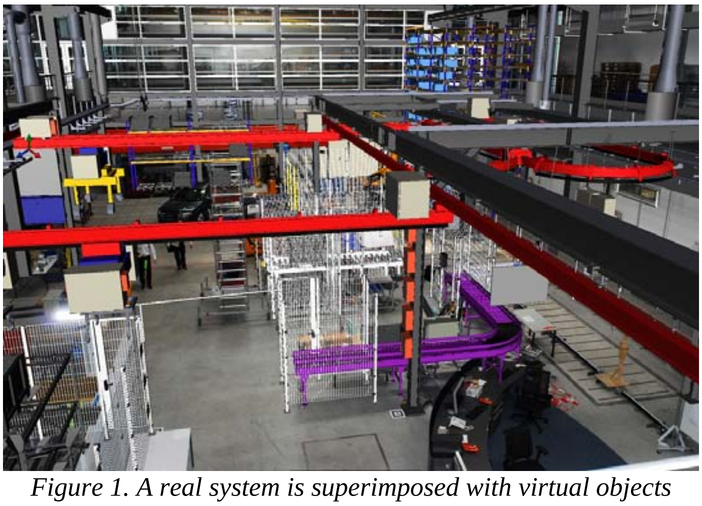

Figure 1. A real system is superimposed with virtual objects

considerable advantages. The actual state of the system can be included as well as the real basic conditions like the building's structure or lighting conditions. Therefore some targets have to be mounted on the system's critical positions. After taking a picture of these scenes with a digital camera, the photos are uploaded in 'roivis', where the virtual objects of the new components are integrated into the photo at the accurate position (Figure 1). Real interfering edges can be superimposed with virtual planes and so collisions with the new components can be identified. In this way planning can be performed without interrupting the production or a test with real components. Thus, AR allows for a more flexible planning of logistics systems and enables planners to react more efficiently to the quickly changing requirements of the market.

3.2 Pick-by-Vision

As mentioned above, order picking is one of the most important tasks in the field of logistics. In order to avoid errors, the worker must be supplied with information in an optimal way. Today, different techniques are used to prepare the information for the order picker. But they all have disadvantages and depending on the respective technology the error rate is between 0.1 and 0.8%. This means that 1-8 order items within 1.000 are faulty. There are different types of errors, e.g. a wrong item was picked or the amount is incorrect. Even one error within 1.000 is usually not acceptable to the customers (e.g. original equipment manufacturers), because each mistake can lead to the stop of the production line. To avoid the problem, it is necessary to support the order picker with information in an efficient way. This can be achieved by projecting all important data into the worker's field of view by use of a HMD (Figure 2). Thus, the data is permanently in front of his eyes, which results in reduced searching times. With the help of a tracking system it is additionally possible to display position and process-oriented information, e.g. 3D arrows show the way to the storage location and point at the picking unit. In this way the time for way finding can be decreased while mispicks can be avoided, thus yielding a higher quality of order picking. Because vision is the most important human sense, workers can orient better in the warehouse when receiving optical support. Thus, the Augmented Reality application is suited for supporting new workers during their familiarization phase as well as experienced workers during daily work in a warehouse to improve start-up phases or standard processes.

Figure 2. AR-based order picking

The fml developed an adequate system for the evaluation of the AR-based order picking. One of the most important things of this system is the Graphical User Interface (GUI), because the virtual information must be displayed at the right time and at the right position. A GUI was implemented following special AR guidelines (Bowman et al, 2004; Friedrich, 2004). For his daily work the order picker needs essential text information about the goods, e.g. storage locations, required quantities, part description. But with an AR system and the use of a HMD pictures and virtual objects relating to real objects (like arrows pointing at storing compartments) can also be displayed. For a good-working system not only the GUI but also the hardware is essential. Therefore different types of HMDs and ways of interacting with AR in a warehouse were analyzed. Finding the right HMD is difficult because industrial applications have certain requirements. The most significant requirement is that the worker has to wear the

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HMD over a shift of eight hours. Because of that, the HMD should be light and ergonomically designed, but also rugged and with an eight-hour battery operation. The field of view must not be limited due to reasons of employment protection. Thus, a Virtual Retinal Display was selected as display while interaction is performed through speech control, because this allows for a hands-free interaction with the AR-system. An adjusting knob was chosen as an alternative because speech recognition does sometimes not work faultlessly in industrial environments and order picking doesn't need a lot of interactions. The results evaluating a first AR system without tracking and with speech control can be found below.

4. Virtual Reality in the Field of Logistics

Virtual Reality becomes a more and more interesting tool for the planning of logistics systems due to the fact that both products and manufacturing or logistics facilities are nowadays being constructed with CAD tools. Because of this, 3D geometrical data is available to the planner in an early stage. The bidirectional connection between CAE (Computer Aided Engineering)-programs and the VR laboratory with its stereoscopic visualisation at the department combines the advantages of both technologies. Consequently, intuitive planning and realistic real-time 3D visualisation for the coverage of logistics planning are provided to each planner.

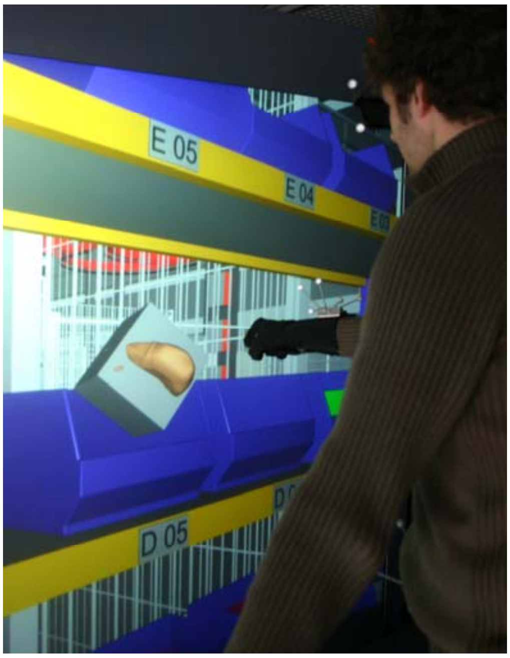

Figure 3. Planning and human-integrated simulation of virtual order picking systems

In addition to the existent equipment, a data glove and a treadmill were connected to the VR system (Figure 3). This leads to an immersive workspace for workers in planned order picking systems due to the fact that real order picking processes can now be rebuilt in the virtual environment. While the cyber glove allows for grabbing goods out of the storage location, the self-regulating treadmill allows for an intuitive walk through the virtual warehouse. In case the user is taking one step forward, the tracking-system identifies the user's movement and makes the treadmill move automatically to the opposite direction. Actually the user with his individual skills becomes part of a human-integrated simulation for order picking processes. Like in reality, the worker receives orders which have to be fulfilled. The developed virtual order picking system documents the trainee's way, searching and grabbing times, so it offers the opportunity to obtain data about throughputs in virtually planned manual order picking systems. As a result, cost-saving optimisations can be made during the planning period. Furthermore, the virtual order picking is used for preparing workers for processes in ramp-up situations because VR has generally a positive effect on training efficiency (Dede, 2006). As a consequence, the trainee's long-term learning results can be identified. The first experimental series already showed interesting results, but also potentials for optimisations.

5. Evaluation of the VR and AR based Order Picking

The experimental series compared four different types of order picking technologies:

- paper based order picking with picking lists
- pick-by-voice system
- Augmented Reality based pick-by-voice system

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- Virtual Reality simulation environment for order picking

While the AR and VR based order picking is still subject of research, the other two types of order picking are practically proved systems. The experimental series aimed at finding answers to several questions regarding the comparison of the different order picking technologies. On the one hand the chosen systems were studied quantitatively, considering process times and the amount of mispicks. On the other hand quantitative researches were made to discover aspects concerning acceptance, applicability for training, media cognitive load and usability. Furthermore, we collected the test persons' first impressions concerning the different technologies and concerning the degree to which constructive and procedural modifications could improve the tested systems.

5.1 Experimental Setup

All of the four order picking techniques used the same experimental setup, whereas the virtual environment was based upon the real storage. The study focused on the manual order picking called "man-to-goods". For this, an experimental hall consisting of four rows of racking with a total of 280 storage locations and a Virtual Reality laboratory are available at the department. The subjects for the experimental series were students and mechanists, each with a different scale of experience in order picking, AR and VR. For the statistical coverage the 17 subjects were asked to complete five orders with several order items for each of the four order picking techniques, whereas the orders' sequence was not changed for the different techniques. To avoid long-term learning results throughout the experimental series the stored items (cardboard boxes) looked almost all the same and the subjects were split into four groups completing the four order picking experiments with different techniques in a different sequence. The Warehouse Management System of the AR based order picking system generates a way optimized route through the warehouse which was also used for the other three order picking systems. At the experimental series' beginning the subjects' personal data (age, sex, experiences in the focused order picking technologies etc.) were collected. Afterwards the test persons had to perform the order picking using the different techniques following the general order picking process (Figure 4). At the end of each run with one of the techniques, the subject received a questionnaire dealing with human aspects and the used technology itself. Some of the results will be described in the following chapters.

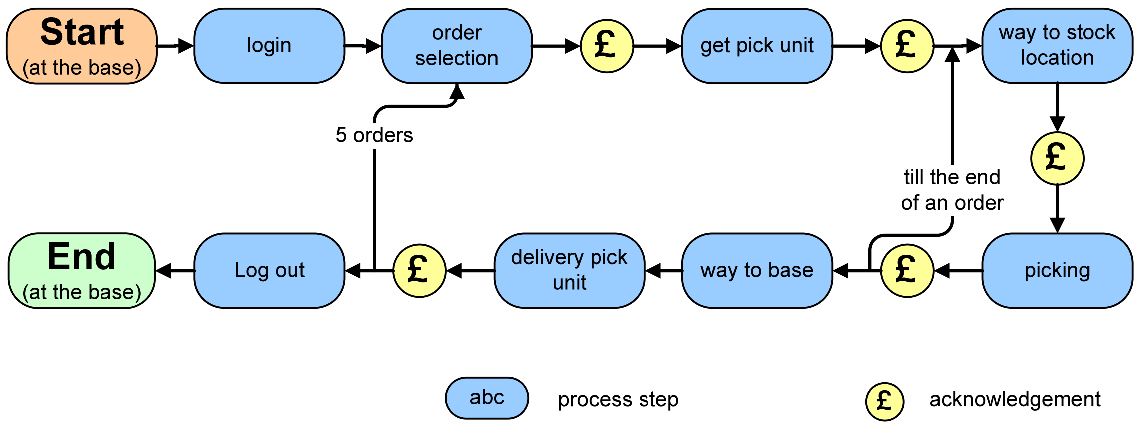

Figure 4. General order picking process for the experimental series

5.2 Subject's Impressions and Results concerning Human Aspects

The disadvantages of the Virtual Reality based order picking differed from the experiments in the real storage environment. The subjects found faults in the missing round sight because the projection wall couldn't cover the users' whole field of view. Furthermore, the subjects didn't

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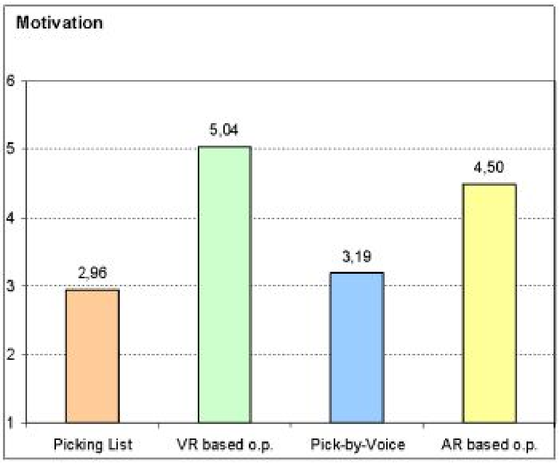
like the possibility of walking through walls and shelves, because there was no possibility of colliding with the virtual objects. Concerning usability, the integrated self-regulating treadmill came off badly. It seems that a muscularity conducted treadmill will perform much better. After all, the subjects could imagine Virtual Reality to be the best application for training logistics workers.

The biggest shortcoming of the Augmented Reality based order picking was the non-ergonomically designed HMD.

Generally, the motivation of the subjects during the processing of orders in the virtual environment and with the support of AR was the highest (Figure 5a). This refers to the open-mindedness of the students towards new technologies and their fun in dealing with them compared to the pick-by-voice and the picking list based order picking system. It has to be said that the used speech recognition for the pick-by-voice system and the Augmented Reality based order picking caused several problems leading to lower acceptance. Sometimes the speech identification disappointed, making the order instructions hardly understandable. Furthermore, the subjects were annoyed because they always had to wait for the speech instructions until they could continue with the order picking process. Additionally, the speech recognition sometimes interpreted the order picker’s voice in a wrong way, thus leaving out picks and causing a higher error rate for pick-by-voice. It should be said that these kinds of problems usually don’t appear in companies’ individual pick-by-voice solutions. Surprisingly the subjects did fewer errors when dealing with the Augmented Reality based order picking system including the same speech recognition. Probably the subjects put more focus on the visual support than on the speech instructions.



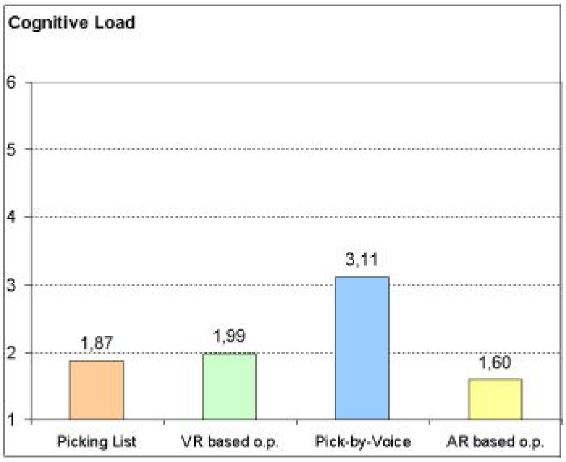


Figure 5a. Motivation of the subjects referring to the different types of order picking
Figure 5b. Subjects’ sensation referring to the cognitive load during the different picking processes

Another really interesting result of this first experimental series emerged in the subjects’ sensation referring to the cognitive load while using the different types of order picking techniques for their tasks (Figure 5b). Due to the difficulties with the speech recognition mentioned above, the pick-by-voice system appears to be the worst techniques.

All the more surprisingly, the cognitive load of the virtual environment was insignificantly higher compared to the other two order picking techniques. This result is pointing out that the virtual order picking processes are already coming close to reality although people had to get accustomed to interaction devices like the self-regulating treadmill and the cyber glove.

5.3 Results concerning logistics

Relating to order picking times and picking mistakes which are the most interesting from the logistics' point of view, the following aspects could be recognized:
The subjects using the developed Augmented Reality based order picking system were generally slower than in the case where they had to complete the orders with the picking list based system. This can be reasoned by two aspects. First of all, the integrated speech recognition led to a loss of time. Therefore new interaction devices (e.g. an adjusting knob that can also be pushed) may solve the problem. Secondly, the experimental storage was too small. The AR system's potentials can be utilized in bigger warehouses, because in this relation the AR support for way-finding will reduce searching times. Nevertheless the AR visualisation yielded a significant reduction of mispicks when compared to the pick-by-voice system.
The results of the human-integrated simulation of virtual order picking showed that order picking times in VR are actually higher when compared to the picking list based system. The "best" virtual order picker was 25% slower than the fastest real order picker. The reason for this gap could be identified in two main aspects. On the one hand, the tracked self-regulating treadmill took too much time. With the use of a manually driven treadmill the virtual way times should get closer to the real ones. On the other hand, the grabbing times were much higher than in reality. This aspect didn't concern the cyber glove itself but the implemented process for putting the virtual objects onto the picking trolley. Whereas in reality the goods were thrown into the picking bin the virtual order picker needs to place the goods more precisely onto the picking trolley, naturally yielding higher order picking times. This problem can be solved easily by implementing a bigger virtual space accepting the goods when they come close to the picking trolley.

6. Conclusion

In the first experimental series, the Virtual and Augmented Reality based order picking showed their potentials as an innovative way for the field of logistics: high acceptance and motivation of the users, comparable results for the learning success and the users' cognitive load. Nevertheless, the identified weak points (e.g. the time gap between virtual and real order picking and the badly working speech recognition) need to be revised for upcoming experimental series in bigger real and virtual warehouse environments.
Today's Virtual and Augmented Reality technologies already prove that they are opening up new ways of supporting logistics workers. With a continuous improvement of currently available hardware components, these technologies will more and more become a part of working life for logistics planners and operational workers. Of course, the profitableness of such applications plays an essential role. In some fields of interest, the Virtual and Augmented Reality will be irreplaceable; in other fields they won't be essentially required. As always, it depends on the company's individual conditions. Anyway, in a first step, these technologies can be the right choice when combined with common methods for planning and supporting logistics workers.

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