Conception of an innovative order picking system by using a wireless sensor network

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Pick-by-Light is a widely used technology in manual order picking systems to support the employees by giving them visual information of the order. The available devices are generally wired, hence they are inflexible to restructurings associated with high installation costs. The focus of the research is the development of a wireless, flexible and low-cost solution by using wireless sensor networks to transfer information in an ad-hoc network. This kind of network is capable to organize itself, so adding and removing storage shelves respectively articles can be done without having to reconfigure the system. The approach used for the development of the new order picking system "Pick-by-Local-Light", is the v-model, a methodology for the design of mechatronic systems. This method lead to several concepts having been evaluated by deploying an extended use case analysis. The result is an innovative new information provision system making use of the employees' location for guidance and for approach-based extra functions.

Keywords: *Order picking, pick by light, tracking, commissioning, wireless sensor network, s-net.*

1. INTRODUCTION

Despite the increasing automation in the industry, humans are still indispensable in common logistic processes. Especially processes demanding complex handling actions like order picking can not be replaced by robotics yet. But manual work is often attended by high error rates compared to automatized actions. Therefore, in the order picking, some technologies have been established to guide the employees through the different states of order processing. One popular representative technology is Pick-by-Light [1]. Common Pick-by-Light devices are composed of a display, showing the picking amount, buttons (e. g. to confirm a pick) and an eye-catcher light, which helps the worker to quickly find the articles to be picked. In order to support more than one order picker in an area, this light can flash in different colors. Commercially available pick-by-light systems are usually connected by wire and the devices are mounted on profiles. Hence they are susceptible to restructurings of the warehouse. Furthermore wired connections cause high installation costs as well as a dependency on service providers installing respectively adapting the system. In defiance of these problems, wireless systems have been invented, but haven't been enforced in the industry because of short battery runtimes and high maintenance efforts. But new upcoming communication technologies created a source for further investigations about how to deploy them to transmit data of storage shelf displays. One possible wireless communication method is Bluetooth 4.0, which already has an energy-safe mode implemented.

However this protocol is not multi-hop capable, i. e. it is not able to extend the radio range by transmitting information over multiple devices, so Bluetooth is not suitable for this application case. [2] Those technologies, which are multi-hop capable, like ZigBee [3] or WirelessHART [4], based on the IEEE 802.15.4 standard [5], are in return not able to create a large, stable and particularly energy-efficient network. The technology, which is most suitable for the application scenario, is the s-net® system, recently developed by the Fraunhofer institute for integrated circuits [6]. S-net® belongs to the so called wireless sensor networks, which provide the possibility to transmit data by creating an ad-hoc multi-hop network with sole sensor nodes. This technology allows an energy-efficient communication in conjunction with a wide radio field by combining the efficiency of the time-division-multiple-access-(TDMA) method with the scalability and flexiblity of contention based protocols [7][8]. Moreover, the s-net technology offers some extra features like the locating of sole sensor nodes or the integration of individual sensors as well as actors. So if the order picker wears an extra s-net sensor node while working (picker node), the s-net based order picking system allows to add location-dependent reactions. The effort can either be to save energy, by activating just the devices being in a specific range, or to provide extra features like a position-based route-optimized guidance through the corridors. The application of it will be described in detail in the following.

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2. CONCEPTION OF A NEW ORDER PICKING SYSTEM

The approach used for the development of the new order picking system "Pick-by-Local-Light" is the v-model, a methodology for the design of mechatronic

systems [9]. Because of the system's mechanical, electronic and IT elements, it is designated for the application case.

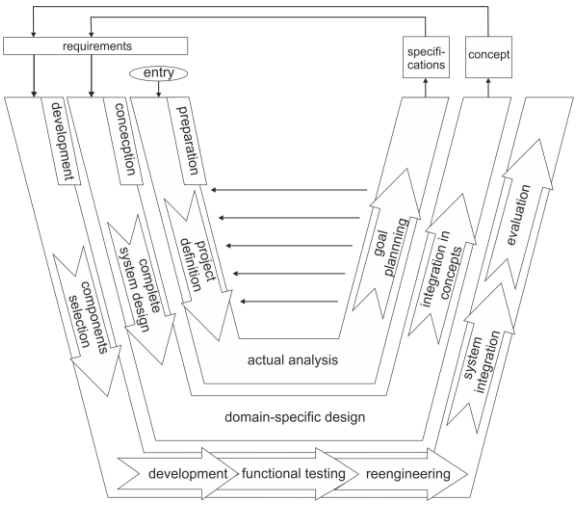

Figure 1: Approach for the development

In the first phase (see fig. 1), the analysis of the current state was in focus. A use case analysis turned out the most important requirements of a wireless order picking system. The data from the analysis and several warehouse visits led to a specification sheet, whereat the individual requirements were classified through the MoSCoW method [10]. During the conception period, the complete system design was elaborated by defining and evaluating variant concepts with the analytic hierarchy process method [11].

2.1 Analyzing the requirements

The development of a new order picking system should primarily be focussed on the demands the industry has. In order to achieve this, the investigation of the initial situation was the foundation for implementing necessary and innovative functions in the new product. Therefore a study was conducted, to interview experts of customers, service providers and manufacturerers.

The first examination was about the definition of the requirements to the system. The interviewees were asked about their expectations regarding the technique, logistical process, economy and ergonomic matters. The following evaluation showed, that a stable radio network (80,7%) is the most relevant requirement of a wireless order picking system. It is followed by a standardized connnection to warehouse management systems (77,6%) and a high availability (77,6%). Also important are logistical key performance indicators like the order picking perfomance rate (68,8%) and a low picking error rate (68,8%). These results were included in the specification sheet and classified by using the MoSCoW method, i. e. some requirements have to be (**M**ust), some should (**S**hould) or could be (**C**ould) fullfilled. The 'won't' (**W**on't) specified ones will just be integrated, if there is absolutely no argument against them.

The second investigation addressed the general framework of the conceived system. Therefore characteristics, the processes and data of existing Pick-by-Light systems were recorded during industry visits. In combination with the morphological boxes, that represent every kind of order picking system in the VDI norm 3590, three application scenarios for the predicted system were chosen [12]. In the first one, flow racks with SLCs (according to VDA 4500 [13] and 4504 [14]) are used to store small items. The commodity is ABC structured and only one worker is assigned to the order picking area. With regard to its importance, some variations of this scenario – e. g. more employees, shelf racks, corridor changes and quite larger as well as heavier goods – were also examined.

A second scenario covers order picking areas, in which the worker stays in an u-shaped area and has not to move while commissioning. Those kind of order picking zones are designed to have high perfomances and are, like in scenario one, designed for the commissioning of small items.

Scenario one and two handled small commodities, but the Pick-by-Local-Light system can also be used for larger items. Therefore, scenario three is about storing big goods, mainly packed on palettes. But due to long routes, the system is not the most suitable. Hence this scenario is rated very low in the conception of the development.

2.2 Complete system design

The preliminary studies were the base for the development of several concepts. A morphological box was the method used to detect various concepts.

Table 1. Distinguishing features of the concepts

Attribute	Specification			
Login	none	manual		automatic
Information provision	storage shelf display	mobile sensor node		terminal
Input device	storage shelf display	mobile sensor node		terminal
Visualization of a needed corridor change	none	optical		acoustical
		eye-catcher light	display	
Localization	yes		No	
Display to show extra order information	none	mobile sensor node		terminal

To sum it up, the most important attributes, that are significant for the logistical process, are presented in table 1. The login method describes the way the worker checks in to a specific commissioning area. It can either be left out completely, be done manually, e. g. at a computer, or automatically by using the location of the employee. The information can be displayed completely at the storage shelf displays, like conventional Pick-by-Light systems do, at a mobile sensor node (as it is realized as a wearable device) or at an extra terminal respectively monitor. The input, needed for the order picking process like the confirmation of a successful pick, can be entered at the shelf displays, the mobile

sensor node or also at a terminal. If the employee has to pick items from multiple corridors, notifications to change corridors would be helpful. This can be implemented either optically, for example by using an extra display, or by a specific sound. Haptical announcements were left out in the final version, because of energy saving reasons. Besides the possible utilization of the sensor nodes' localization feature, extra information – like the remaining positions of the order or a an upcoming corridor change – could be displayed to the order picker on different devices.

The combination of the listed attributes lead to two times four concepts, which at first differantiate regarding the amount of eye-catcher lights being active. Accordingly, all positions of an active order can be highlighted at the same time, i. e. every light is on, until all positions have been picked. Another approach is to guide the order picker by enlightning just the eye-catcher light of the current position, and by flashing the next position. The sequential way has the advantage, will a way more energy efficient and the worker is forced to follow the optimal way. But the latter can also be disadvantageous (and beneficial at the same time for the parallel way), because it can lead to dissatisfaction since the employee can not decide about his own route.

The remaining concept possibilites occur by combining different technologies with the wireless sensor network.

The first concept corresponds basically with the conventional pick-by-light technology. In particular, the sensor nodes are only integrated in the storage shelf displays, so just the way of communication is different.

In the second one, an additional sensor node is worn by the worker (e. g. at his belt), the sensor node integration into shelf displays is retained. The main reason for the extra device is to be able to get the employee's current position. The position will trigger the activation (and accordingly the deactivation) of shelf displays, which are (not) in the same corridor as the employee is. Furthermore, the assignment to a particular consignment area in the warehouse management system will be done automatically. When a worker enters a working place, the system allocates this area to him and the orders start automatically. The orders will be delivered as long as the order picker stays in the defined area. After having left, the order processing for this worker stops. Thereby the privacy is protected by not combining the worker's personnel matter with the sensor node. In particular, the warehouse management system only has the information, that there is a worker in an order picking area, but not which one.

In dependence on the second concept, the third one has an additional terminal for data input as well as output. Unlike in previous concepts, the worker can log in to the system with his account and assign a picker node to himself at the terminal. This association could be used to record perfomance ind icators in order to find improvement potentials. Another application for the terminal is to display extra information being useful for the order picker like the remaining positions, the location of the next position, the description of the article to pick or the necessity of a corridor change.

The last concept differs strongly from the previously described ones. The storage shelf devices have no longer displays integrated, because they are substituted by the display mounted on the picker node. So the shelf devices will only be used for the input (confirmation, amount changes, inventory) and the picking notification with the eye-catcher light. In this case, the picker node can be described as a wearable device, that presents information of the order and is worn preferably on a wristband. The transfer of the displays from shelf to wrist has the advantage of the shelf devices' energy consumption being significantly lower. The runtime of the picker's mobile sensor node is indeed shorter, but its battery only has to last for one shift, which is normally about eight hours. In addition, the worker can view the picking amount when walking to the next eye-catcher light (in case of a sequentially based picking). During the parallel picking way, the worker has to press the confirmation button at the shelf display first in order to get the information displayed. This substiantially raises the picking process time. Localization features within this concept will also be used as described in concepts two and three.

Table 2. Dis-/advantages of the different concepts

#	Disadvantage	Advantage
1	• Missing announcement of corridor change • Energy consumption	• Similarity to conventional system • High acceptance • Low complexity
2	• Energy consumption	• Reduction of deadtime • Corridor change announce-ment • High worker data security • High acceptance
3	• Low worker data security • High complexity • Low acceptance	• Visualization of extra information • Reduction of deadtime • Corridor change announce-ment
4	• Low compatiblity to other order picking systems • Raise of the deadtime • Low acceptance	• Low energy consumption • Visualization of extra information • Corridor change announce-ment

Each concept has distinct advantages and disadvantages (see table 2), so all concepts have to be evaluated methodically for choosing the appropriate demonstration to implement for a proof of concept. This was done by using the analytic hierarchy process, which extends the use case analysis by some consistency checks. The concepts were evaluated by the suitability to the defined application scenarios on the one hand and by the suitability to the requirements determined mostly from the use case study (see 2.1) on the other hand. The requirements that were used for the rating were: Acceptance, simplicity, energy consumption, development effort, error rate, flexibility, innovation degree, inventory ability, order picking performance, compatibility to existing technologies and the predicted availability.

Table 3. Results of the analytic hierachy process evaluation

concept #	Type	Rqm.	Sc.	Total
2	Sequentially	16,01%	17,04%	16,52%
4	Sequentially	17,24%	12,23%	14,74%
2	Parallel	11,91%	17,00%	14,45%
1	Sequentially	15,38%	10,84%	13,11%
1	Parallel	10,66%	12,97%	11,82%
3	Sequentially	11,02%	12,15%	11,59%
4	Parallel	10,29%	8,47%	9,36%
3	Parallel	7,49%	9,30%	8,40%

Table 3 shows the results of the analytic hierarchy process evaluation. Rqm. values indicate the suitablity to the predefined requirements and Sc. stands for the adequacy for the application scenarios. The last column "total" sums up the arethmetic mean of both values. As can be derived from table 3, concept two attained the highest total rating, mainly because of its fitting to the defined application scenarios and also regarding the predefined requirements. According to this, concept two will be the concept, being realized during the project.

ACKNOWLEDGMENT

The project (IGF 18139 N/2) is financed by the national research association for logistics (BVL, Schlachte 31, 28195 Bremen) and is promoted by the alliance for industrial research (AiF) as part of the programm for the promotion of industrial research (IGF) by the federal ministry for economics and energy based on a decision of the German Bundestag.

3. CONCLUSION

The aim of the research is to develop an order picking system, that combines the advantages of the conventional (wired) Pick-by-Light system like the high perfomance and the advantages of wireless products as the flexibility. This aim will be reached by the integration of a wireless sensor network into latest Pick-by-Light technology. An analysis of the current state showed, which requirements are the most relevant ones for an order picking system and built the foundation for the creation of new concepts in a morphological box. The main characteristic of the chosen concept is, that it uses the localization feature of the sensor nodes mainly to trigger position dependent actions. With regard to that, the login is done automatically, when the worker enters an order picking area. The information provision and the input remains at the shelf display. Required corridor changes are announced acoustically.

The realization of the concept will be the next task. At first the system's components will be selected and then tested individually for their energy consumption and for the general functionality regarding the complete system. Secondly, a demonstration setup will be build, that consists of 50 working storage shelf displays and mobile sensor nodes. Finally, the demonstration setup will be tested and evaluated in a testbed as well as in an industrial environment.

Possible applicants of the system can be found in nearly every producing industrial sector. But the focus lies on small and medium-sized businesses, that are faced with the challenge of frequently changing warehouse parts. The system allows to adapt the order picking system very easily to changing requirements of the deploying company and diminshes dependencies on external service providers.

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