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Augmented reality as a means of conveying picking information in kit preparation for mixed-model assembly

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ABSTRACT

Kitting is a materials feeding principle that is increasingly common in mixed-model assembly. Currently, there is no consensus within industry regarding how picking information should best be conveyed to support kit preparation and research on the topic is scarce. The purpose of this paper is to determine whether information conveyance through augmented reality can be used to support time-efficient kit preparation, considering the two commonly applied approaches of single-kit preparation and batch preparation. The paper presents a novel application of augmented reality and tests it in a realistic laboratory experiment. As a basis for comparison, a traditional printed paper list is also tested. In the experiment, augmented reality is competitive both in terms of time-efficiency and picking accuracy, both for single kit and batch preparation, which indicates that augmented reality can constitute a viable option for conveying picking information in kit preparation. Especially for the batch preparation, where more information needs to be displayed, the augmented reality application is associated with considerably better performance than the paper list. The paper suggests that future research efforts should include studies on augmented reality applied in an actual industrial setting over a longer period.

1. Introduction

In mixed-model assembly, there is often a multitude of different part numbers that need to be handled within the assembly plant and the feeding of parts to the assembly is critical. The materials feeding principle of kitting is increasingly common and has also received increasing attention in the research literature (Kilic & Durmusoglu, 2015). With kitting, parts are sorted into kits before being fed to the assembly stations, so that each kit contains parts for a specific assembly object (Bozer & McGinnis, 1992). This is closely linked to the concept of set parts supply (SPS), as described by Jainury, Ramli, Ab Rahman, and Omar (2014). Within mixed-model assembly, the contents of the kits generally differ, which means that during kit preparation, reliable information must be available of which contents each kit should have. Kit preparation is generally performed by manual labour, and the conveyance of picking information should be able to support performance of the picker in the areas of both efficiency (Hanson, Medbo, & Johansson, 2015) and picking accuracy (Brynzér & Johansson, 1995; Fager, Johansson, & Medbo, 2014; Hua & Johnson, 2010). There are numerous means of conveying picking information, such as traditional printed paper lists, pick-by-voice systems, and pick-by-light systems (Battini, Calzavara, Persona, & Sgarbossa, 2015; Brynzér & Johansson, 1995; Reif, Günthner, Schwerdtfeger, & Klinker, 2010). Currently, there is no consensus within industry regarding how picking information should be conveyed in kit preparation and research on the topic is scarce.

In warehouse order picking, it has been indicated that the use of augmented reality (AR) for conveying picking information can support both time efficiency and picking accuracy (Reif et al., 2010). However, while similar to warehouse order picking in many respects, kit preparation differs in that it normally takes place within a compact picking area, where the walking distances of the picker are relatively short and picking therefore occurs with a higher frequency (Hanson et al., 2015). Therefore, results from warehouse order picking are not directly transferrable to kit preparation. Moreover, kit preparation occurs in two variants: single-kit preparation, where kits are prepared one at a time, and batch preparation, where several kits are prepared together, during the same kit preparation cycle (Hanson et al., 2015). As both these variants are commonly occurring within industry, and display different characteristics, it is of interest to study how AR could support kit preparation in each of them. The current paper has the purpose of determining whether information conveyance through AR can be used to support time-efficient kit preparation, considering both single-kit preparation and batch preparation. In line with Azuma (1997) and Reif et al. (2010), the paper defines AR as any system which combines the

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real and the virtual world using 3D registration and which is interactive in real time.

Based on a laboratory experiment, set in a realistic environment, the paper compares a novel application of AR to a traditional printed paper list for conveying picking information, with respect to the time efficiency of the kit preparation. Paper lists are still a very common means of conveying picking information within many picking applications (Grosse, Glock, Jaber, & Neumann, 2015; Guo, Wu, Shen, & Starner, 2015). In line with existing terminology (e.g. pick-by-voice, pick-by-light), the two solutions used for conveying picking information in the study are denoted “pick-by-AR” and “pick-by-paper”. Based on the experiment, the paper provides quantitative evidence of how the efficiency, measured through the picking time, differs depending on which of the two picking information solutions is used and depending on whether single-kit preparation or batch preparation is applied. The paper further considers the number of picking errors that occurred during the experiment and the potential of the pick-by-AR application to support picking accuracy.

In the next section, a review of existing literature is presented. Thereafter, Section 3 presents the methodology applied in the paper. Section 4 presents the analysis and the results of the paper. In Section 5, a discussion of the results and their implications is presented, together with ideas for future research. Finally, Section 6 presents the conclusions of the paper.

2. Literature review

Much of the research that deals with picking information focuses on warehouse order picking contexts. Less has been published within the area of kit preparation.

In a warehouse order picking context, Battini et al. (2015) present a comparative analysis of different paperless systems for conveying picking information, including handheld devices with barcode and RFID scanners, pick-by-voice and pick-by-light. Schwerdtfeger, Reif, Günthner, and Klinker (2011) report on a process of exploring, evaluating, and refining solutions that use AR via a head-mounted display to support warehouse order picking. They present several findings regarding what type of AR visualisations are suitable to guide a picker. One type of visual guidance that is tested is a virtual 3D “tunnel” that appears to extend from the picker, showing the way to the picking location. Schwerdtfeger et al. (2011) find that the tunnel must be discreet in order not to obstruct the picker’s view of the real world. Reif et al. (2010) present an experimental study in a warehouse order picking context and find that information conveyance via a head-mounted display and a AR solution can enable a higher time efficiency than picking information conveyance via a paper list.

Some studies have considered picking information in relation to kit preparation or other types of picking in compact picking areas. However, none of the studies has considered AR for conveying picking information. In two experiments on kit preparation in an automotive assembly setting, Hanson et al. (2015) compared the picking time associated with batch preparation to that of single-kit preparation and found that batch preparation was associated with shorter picking time. In the study, picking information was conveyed to the pickers by use of a mobile digital display. Iben, Baumann, Ruthenbeck, and Klug (2009) present an experiment, conducted in a relatively compact picking area, constituted by one picking aisle, where a head-mounted display, conveying 2D information, was compared to a printed picking list. Picking was performed to a single bin, i.e. corresponding to single-kit preparation. Comparing the performance associated with each picking information system, Iben et al. (2009) found indications of the head-mounted display being associated with both higher accuracy and higher efficiency, but the results were not statistically significant. Guo et al. (2015) present an experiment comparing four different means of conveying picking information in a compact picking area. Picking was performed to three order bins, i.e. corresponding to batch preparation. In the study, information conveyance via head-mounted displays, conveying 2D information, and cart-mounted displays enabled to more efficient and more accurate picking than pick-by-light and pick-by-paper. Neither of the head-mounted displays used in the studies of Iben et al. (2009) and Guo et al. (2015) utilised AR for conveying information and neither of the studies considered both single-kit preparation and batch preparation.

Overall, the literature review indicates that knowledge is missing regarding how pick-by-AR can support performance in kit preparation, considering both single-kit preparation and batch preparation.

3. Methodology

The paper is based on an experiment conducted in a laboratory environment, set up to simulate kit preparation in the material supply to mixed-model automotive assembly. The experiment was designed in alignment with the systematic approach proposed by Coleman and Montgomery (1993). Hence, important steps of planning the experiment included the choice of response and control variables. In line with the purpose of the paper, the time consumption was chosen as a response variable. Moreover, the number of picking errors that occurred was chosen as an additional response variable and was studied to ensure that potentially low time consumption was not associated with an increased number of errors. Two control variables were chosen: the means of information conveyance and the batching principle, i.e. whether kits were prepared one at a time or in batches. The batch size applied, i.e. the number of kits prepared in each batch, was set to four, as this was found to be a size that was both industrially relevant and practically feasible for the picker to handle.

Corresponding to the focus of the paper, the experiment included picking information conveyed by means of AR. As a basis of comparison, the experiment further included kit preparation with picking information conveyed by means of printed paper lists. While there exist several other options, including pick-by-light and pick-by-voice systems, printed paper lists are still common in industry and thus constitute a relevant alternative. Based on an experimental study of kit preparation, Fager (2016) finds that paper lists can be associated with a picking efficiency that is similar to that of pick-by-light systems and higher than that of pick-by-voice systems.

The physical set-up of the experiment – in terms of kit preparation layout, storage racks, load carriers, and components – was designed together with logistics engineers from the automotive industry, with the aim of achieving conditions as realistic as possible for the experiment. Fig. 1 displays an overview of the kit preparation area used in the experiment. As the experiment was designed to simulate kit preparation in a mixed-model assembly setting, all kits had different contents.

The pick-by-AR application used in the study was developed for the Microsoft HoloLens hardware (www.microsoft.com), which means that the information was presented to the picker via a head-mounted display. Fig. 2 shows an example of the information presented in the pick-by-AR application. For each part number that should be picked, a discreet yet clearly visible virtual 3D “tunnel” guided the picker to the right bin. When the bin was within the picker’s field of view, a coloured circle and a number would appear in the bin, indicating how many components should be picked of the part number in question. This design was developed in line with the findings of Schwerdtfeger et al. (2011). During batch preparation, it was also necessary to provide the picker with information of which kit containers the components should be placed in. This was achieved by a graphic 2D representation of the four kit containers in the picking cart. The representation reflected the 2 × 2 pattern of the kit cart and was static in the picker’s field of view. After having finished picking and placing a part number, the picker would use a voice confirmation to indicate that the system should move on to the next part number. To clearly signal to the picker that the confirmation had been registered, the application was designed so that the virtual tunnel and the circle highlighting the bin changed colour