Augmented Reality in Order-picking processes – Advantages and Disadvantages

Nikola Ilanković
M.Sc.
University of Novi Sad, Faculty of Technical Sciences

Dr. Dragan Živanić
Ph.D.
University of Novi Sad, Faculty of Technical Sciences

Dr. Atila Zelić
PhD in Tehnical Sciences
Ph.D., University of Novi Sad, Faculty of Technical Sciences

Abstract

The efficiency of warehouses is one of the crucial factors concerning the efficiency of overall supply chains. As order-picking accounts for 55% to 65% of cost of warehousing operations, it is important to continuously improve the efficiency of it. It is necessary to apply new technologies to order-picking and thus improve results and reduce costs. The purpose of this paper is to explore present-day researches and knowledge about the usage of AR for pick-by-vision. The study is based on literature review and the goal is to explain advantages of this picking method, but also to point out problems that occur during picking, especially concerning comfort of pickers.

Keywords:
augmented rality, warehouses, supply chains

DOI: 10.29177/LIM.2020.1.4

1. Introduction

Within a logistics chain, products need to be physically moved from one location to another, from manufacturers to end users. During this process, they may be buffered or stored at certain places for a certain period of time. Many activities are carried out in a warehouse. Among them, order picking - the process of retrieving products from storage in response to a specific customer request - is the most critical one. It has long been identified as a very labor-intensive operation in manual systems, and a very capital-intensive operation in automated systems. The cost of order picking is estimated to be as much as 65% of the total distribution center operating expense. For these reasons, logistics professionals consider order picking as the highest priority activity for productivity improvements [1,2,4].

A material handling or logistic engineer will analyse slotting - where and how product is stored, and its volumes and speeds - in order to gather information on how well warehouse is laid out. This process begins with an ABC analysis, which will determine the articles that move the fastest (A articles), those that are intermediate movers (B articles), and items that are the slowest (C articles).

Once an engineer performs his analysis, distribution center may require a reconfiguration to optimize pro- duct storage prior to picking. Also need to rearrange storage infrastructure, including racking and shelving. The process of reconfiguring locations is commonly called reslotting.

Designing a successful order picking system requires as- king the right questions, analysing the right data, andapplying the right expertise.

Probably one of the best methods of improving an or- der picking productivity involves the implementation and maintenance of a slotting plan to properly loca- te product in the distribution centre. Proper slotting can result in labour productivity savings by shortening picker travel distances, depending on the slotting rules employed. Slot articles with similar handling characte-ristics in the same storage resource - full case together, partial case together, refrigerated items together. For similarly packaged, they should be dispersed in the slot- ting to avoid picking errors. For efficiency and ergono-mic reasons, slot fastest moving articles in the middle of carton flow rack shelf height, the so-called golden zone. Golden zone usual between 0,6 and 1,9 meters from the floor, depending on pick resource design. In this minimizes the bend and reach/search activities of the

order picker and also locate heavy/bulky items on the lower shelves to minimize the strain in lifting/lowering them. Heavy articles should be slotted at the beginning of the pick, to form a stable base for pallet and to avoid crushing lighter articles [3,5,6,7].
There are five most frequently applied technologies in the order picking systems: paper picking, pick-bylight, pick-by-vision, pick-to-voice and radio frequency identification. Finding the correct solution or combination of technologies is the most important factor in creating an efficient picking system [8,9].
The term pick-by-vision means an innovative concept in logistics enabled by the use of smart glasses, which, through WLAN technology, allow the transfer of information from the server directly into the field of view of the picker. Smart glasses belong to the class of AR devices. The real world that the user sees when they are worn is linked to the virtual versions displayed in the field of view. This is possible thanks to the screens, cameras and microphones they are equipped with. Through a bar code scanner, when a picker picks up a product, his glasses will turn green if the item is good or red if it is the wrong item, Figure 1.

Fig. 1. Pick by vision picking technology

The main advantage over existing pick-by-voice and pick-by-light systems is the display of all necessary information (position, item, quantity) in the field of view of the picker, which means faster information transfer. Smart glasses can also be used to determine the position of the picker in storage. Based on this, they can be used to manage virtual storage using graphical symbols (arrows, guidelines) that lead the employee to a specific location, Figure 2.
Augmented reality (AR) is a term that describes user's vision of the world enhanced by computer generated text, image and sound. With AR, digital information is set over the existing psychical world. Even more, AR is not only a displaying technology, it represents a real-time friendly user interface for interactions between humans and objects. The first appearance of the AR

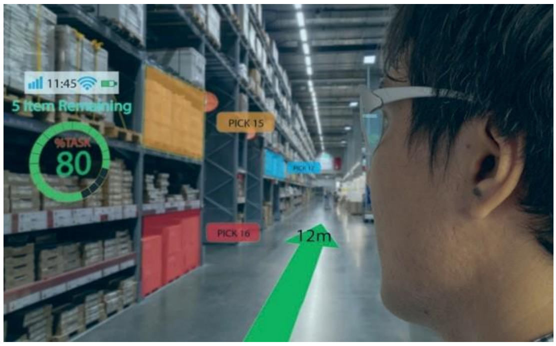

Fig. 2. View the field of view of the picker

was back in 1950s, but it was not seriously considered until the 1990s when it was used for military purposes. With the development of the internet and smart devices, the usage of AR was spread to various industrial systems. One of the areas where AR set good grounds is logistics. AR users can gain insight into information at anytime, anywhere, enabling accurate planning and quality execution of specific tasks which is vital for providing higher levels of customer service. There are several categories in logistics where AR can be implemented: warehousing operations, transportation optimization, last-mile delivery and enhanced value-added services. So far, AR is showing best results when used for warehousing operations. These operations are responsible for 20% of all logistics costs and order-picking accounts for 55% to 65% of overall cost of warehousing operations. By applying AR to order-picking and improving pick-by-vision techniques, there is a vast potential for cost reductions. AR mobile systems are consisted of head-mounted displays (HMD), cameras, wearable PCs and battery packs. The software used for AR vision picking provide real-time object recognition, barcode reading, navigation in the warehouse and continuous information flow between warehouse management system (WMS) and the picker. The main improvement for order-picking is the freedom of picker's hands and digital support during picking operations [10,11,12,13,14,15].

2. Opportunities and barriers concerning AR used for order-picking

In [16] possibilities and limitations of augmented reality applications in warehouse management were explored. Augmented reality is said to be viewed as one of the technologies that could lead to the next big wave of change in the industry. For this reason, two studies were conducted. The first involves interviews with experts in the field of logistics and augmented reality aimed at gaining insight into the current situation and

Operation	Potential use
Receipt of goods	Displays the unloading terminal to the driver of the incoming truck.
	Checking the goods received according to the shipment.
	Shows where goods should be left in the waiting area.
Warehousing	Notify the operator of the newly assigned assignment.
	View the location of the warehouse for incoming goods.
	View the image and details of the item to be stored.
	Show route to storage location.
	View the current status of the picker and the next step.
	Checking locations that require replenishment during storage.
Order-picking	Notify the commissioner of a newly assigned assignment.
	View the picture and details of the item to be selected.
	View the storage location of the item being commissioned.
	Display the selection route.
	A physical location tag with the required item.
	Information on errors and disorders.
	Bar code scan to see more information.
	Mark where each item should be placed.
	Provides information to prevent congestion on passageways.
	Oversees the condition and performance of the picker.
Shipping of goods	Display of used packaging.
	Showing the best way to store selected items.
	View the location of the shipping pallet.
	Display the order of each order by order type, destination.
	Display the appropriate loading area.
	Checking truck loading order.

Table 1. Potential use of augmented reality in storage operations [16]

future of technology. Other research involves a set of experiments using an augmented reality application, developed by the authors, with the aim of gathering user and examiner feedback based on hands-on experience. In Table 1. authors give a list of the potential use of augmented reality in four key warehousing operations. During the interview with twelve experts, there were seven characteristics that respondents identified as very important for the future adoption and application of augmented reality. Table 2. summarizes these characteristics and shows how many times each has been referred to by experts. In general, the vast majority of respondents saw good potential for augmented reality applications in warehouses, especially due to the fact

Function	Description	Number of mentioning
The user interface	It requires no special knowledge to use, easy to use and minimal interaction required.	8
Ergonomics	The device is comfortable to carry (balance, weight, etc.) and does not interfere with the user's view.	6
Scanning	It should be done quickly and with great accuracy using a high-precision autofocus camera, bar code or QR code reader.	5
The screen	Large enough to read information, wide view, in the natural field of view.	3
Battery	No extra device is needed to carry the battery.	3
Robustness	The device can be used in an industrial environment (ie they are dust resistant, can be dropped without breaking, etc.).	2
Programming	Simple programming, using a well-established programming language.	2

Table 2. Functional requirements from experts [16]

that there are a number of options and areas where it could be used. Through experimental testing, the authors concluded that the use of augmented reality in storage using wearable technologies such as goggles depends significantly on hardware and results can vary greatly between devices with different specifications. Table 3 presents the possible benefits of using this technology in warehouse operations.
The authors conclude that, although augmented reality

Fig. 3. Monocular and binocular HWD

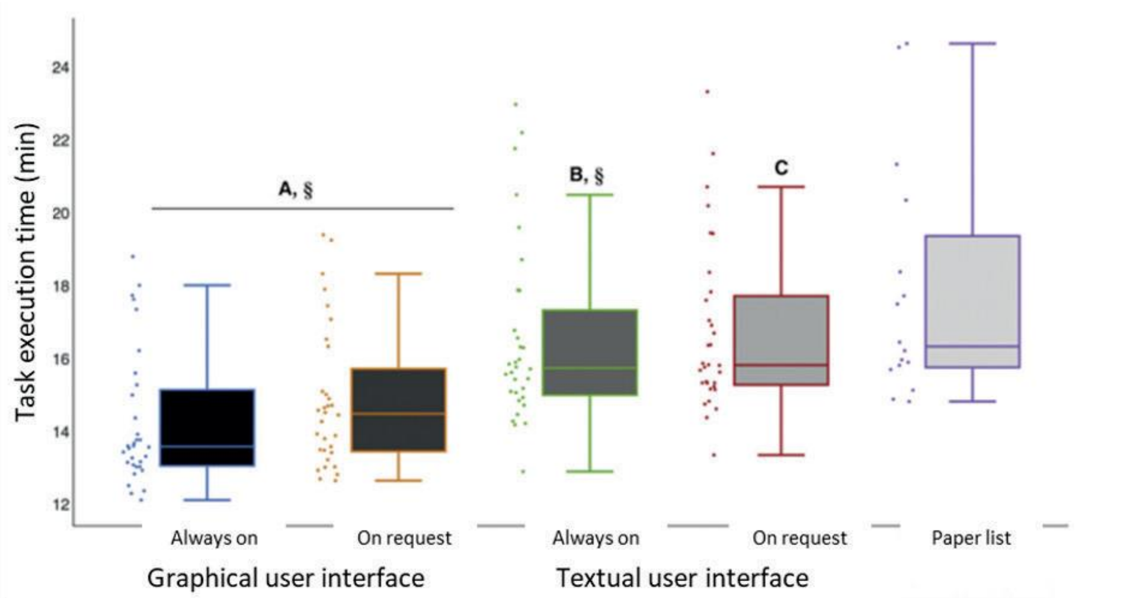

Table 4. Barriers to augmented reality use in warehouse operations [16]

Type of benefit	Justification
Reducing the number of errors	There is no need to remember the order of exclusion of goods.
	Display the image of the product in the field of view.
	Ability to view the following steps.
	An automatic double check can easily be done.
	If the operator is disturbed, his next steps are unaffected.
Greater flexibility	The unit has hands-free capability when the item / package is large in size.
	Information can be displayed anytime, anywhere in the warehouse.
	If the operator is confused, there is no need to walk to the station to check.
Improved reliability	Opportunity to share a video or photo of an error or contact an out-of-place manager.
	Less concentration required.
Increased speed	Reduces error rate, no re-work required.
	Avoids unnecessary travel to access fixed computers, carry scanners, etc.
	For certain operations, such as routing, it helps predict moves and result in faster movements (especially for seasonal workers).
Flexibility	It does not require a special environment while the user is carrying it.
	It may be suitable for disabled people, especially with regard to the use of hands.
Security	If the work is hands-free, it can be safer for the operator.
	The device may provide feedback and information for security purposes or an alert for imminent danger.
New technology	Brings enthusiasm to many young operators.
	From a marketing point of view, it shows that the company is adapting to the latest innovations.

Table 3. Expected benefits of augmented reality in warehouse operations [16]

Type of barrier	Justification
Hardware Restriction	Commercial scanners and smartphone cameras provide a faster and more reliable solution for scanning bar and QR codes.
	The battery cannot cover the entire working day. Alternative solutions with extra batteries carried by operators can be cumbersome.
	Processors overheat and slow down after prolonged use.
	Many of the available AR devices are not designed for continuous long-term use, which can cause comfort problems: headaches can occur, some users may need to wear glasses due to poor vision, central vision creates eye fatigue, a heavy-duty device, etc.
	With head-mounted devices, certain operations can be very slow compared to handheld devices (eg checking multiple incoming items).
Software Challenges	Programming languages are not standardized, making it difficult for developers to experiment with devices, develop their own applications, and connect devices to existing systems.
	Acceptance of the user interface is very important, simple and intuitive ways of interacting with the device are needed to avoid confusion.
	The screen does not adjust to automatic light changes (eg movement inside and outside the subject).
User Acceptance	Some users are reluctant to wear the device with their camera and microphone at all times for privacy.
	Confidentiality issues stem from the fact that AR devices can capture photos or videos with user data.
The price	The overall cost is high, especially if each user is considered to have their glasses (for hygienic reasons).
	Alternative IT solutions for warehouse management can be significantly cheaper.

Table 4. Barriers to augmented reality use in warehouse operations [16]

Model	Battery	Navigation light	Additional device required	Weight	Field of view	The price	The system
Epson Moverio BT-300	6 h with external battery	Yes	Yes	69 g	23°	850€	*Android*
Google Glass	1 h	Yes	Yes	42 g	14°	1500€	*Android*
Meta 2	Is powered by a cable	No	Yes	500 g	90°	1700€	*Windows*
Microsoft HoloLens	4 h	No	No	580 g	35°	5000€	*Windows*
Smart-Eyeglass SED-EI	2.5 h	Yes	Yes	77 g	20°	800€	*Android*
Vuzix M300	2 h	Yes	Yes	110 g	15°	1700€	*Android*

Table 5. Comparison of Augmented Reality Glasses [18]

is not considered a new technological development, its use in logistics operations is far behind compared to other industries. Some of the obstacles to why this is the case have been identified.

Table 4 lists the barriers to augmented reality use in warehouse operations, according to the authors. With the development of new technologies and the improvement of existing ones, augmented reality can soon be seen in many industrial processes.

3. Influences of augmented reality head-worn display type

In [17] the use of head-worn display (HWD) was investigated. This study explored how different display technologies (monocular and binocular HWD, Figure 3) and ways of presenting visual information affect gait performance.

The screen in front of one (monocular HWD) or both eyes (binocular HWD) causes practical problems, such as distraction and reduced situational awareness. From a workplace safety perspective, the author's findings confirm that caution should be exercised when engaging HWDs in work processes that require the worker to walk around. The use of HWD affects walking performance in terms of risk of slippage or falls.

In [18] an experiment was performed on the Augmented Reality concept using Microsoft HoloLens glasses. As there are several different AR glasses available that differ in many ways, the authors give a comparison of some of the latest glasses in Table 5.

Many interviewees said the experiment was fun. Most respondents complained that the glasses were too heavy and uncomfortable to wear. Also adjusting the glasses is difficult. Many subjects had trouble placing their glasses because they could not see the entire field of view completely, and the glasses slid downwards. Another technical problem, which was very common during the experiment, was that the glasses regularly lost their orientation. It has often been the case that respondents have to take a few steps away so that they can identify objects that are in front of them or are not directly in the center of the field of view. Due to the limited field of view, simple navigation showing arrows in the user's field of vision could be enhanced. The positive is that users have noticed that after very short, five-minute instructions, they can do their job very well. At the beginning of the experiment, people were skeptical about the new technology. Potential participants heard about the cybernetic problem and therefore avoided participating in the experiment. Only after some detailed explanations and reports from the first respondents did they agree to participate in the experiment. This

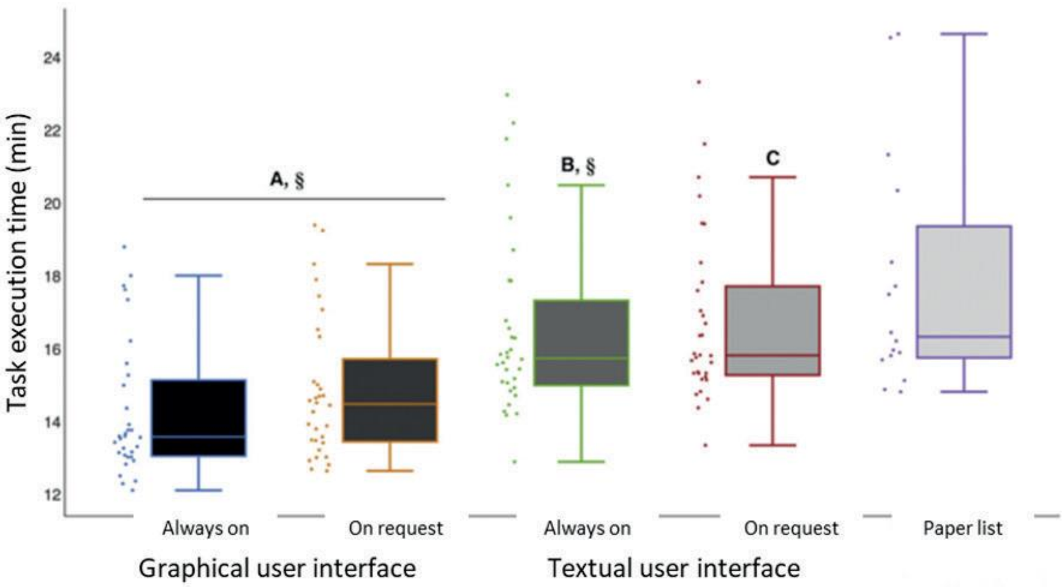

Fig. 4. Effect of information availability on order-picking time

study showed that AR has the potential to facilitate the commissioning process. However, this technology still requires further development, especially with regard to the comfort of wearing glasses.

In [19] effects of different types of HWD and user interface design (i.e. mode and availability of information) on job performance, workload, usability, and visual discomfort in a simulated warehouse environment were examined. Graphical user interface design reduced job completion time by 13% and error rate by 59% compared to textual user interface design, Figure 4.

In addition, the use of a user interface with a constant display of information versus an interface where the information is obtained at the request of the picker has resulted in a 4% reduction in the picking time, Figure 4 and Figure 5.

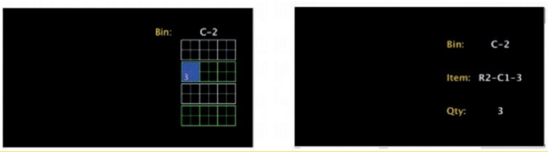

Fig. 5. Graphical (left) and textual (right) views of the user interface

This study examined how different HWD types and UI designs differ and how they may affect warehouse workers. User feedback suggested that neither monocular nor binocular HWDs fully meet the design requirements (eg device weight and display quality). The results of the experiment, however, support the professional use of HWD technology, while emphasizing the importance of user interface design in reaching this potential.

4. Evaluation of AR order-picking

In [20] the use of augmented reality on pick by vision picking technology was explored. Participants in the experiment wear a HWD-Head-worn display that visually displays all the information required for commissioning directly in the field of view of the commissioner. One of the most important things for this system is the graphical representation of the user interface, as virtual information must be displayed at the right time and in the right place, Figure 6.

The authors conducted an order series experiment comparing pick by vision picking technology with a common sheet of paper. Each of the 16 participants in the experiment had to make 14 orders using both techniques. Orders are selected in the same order for each technique. This means that each participant started with task 1 and finished with task 14. The results show that there is a slight difference between the mean values of the commissioning time, Figure 7. With pick by vision equipment, the respondents were about 4% faster than with the paper list.

The technique by which the subjects had to start the experiment was chosen at random. So, eight participants started with a pick-by-vision technique and eight with a list of papers. The authors noted an interesting effect. Participants were noticeably faster with pick-by-vison technology by 19%, but when they exempted orders from the paper list previously, Figure 8. The explanation

Fig. 6. System used in the experiment and possible visualization

for this effect is that subjects are more confident with pick-by-vision technique and are familiar with storage and flow work so that they can rely on AR technology. In this experiment, the error rate for a sheet of paper is seven times higher than for pick-by-vision technology, Figure 9. With pick-by-vision, only one mistake was made from the 1904 item selected.
The authors' results highlight the potential of pick by vision technology. They show that users are faster, make fewer mistakes, and that customer acceptance is high, but that there are still some problems. The biggest obstacle to transferring such systems from the exploration phase to practical applications is the hardware components, especially the wearable head unit (HWD) and the monitoring system. But there is a continued further development of these components as the gaming industry is slowly discovering AR and HWD will soon be part of everyday life within mobile multimedia applications. Therefore, HWDs will be used in industrial applications over the next five years.
In [21] different ways of visualizing work instructions based on augmented reality technology in the order-picking process using a wearable head-mounted display (HWD) were analyzed. The authors conducted three experiments to develop and refine the information display system. A total of 64 subjects were collected (18 in test 1, 34 in test 2, 14 in test 3) and a total of 5080 items were collected (1620 in test 1, 1940 in test 2, 1512 in test 3) from different boxes in storage. In the first experiment, the impact of visualization modes (1D, 2D, or 3D) on finding the commissary path is

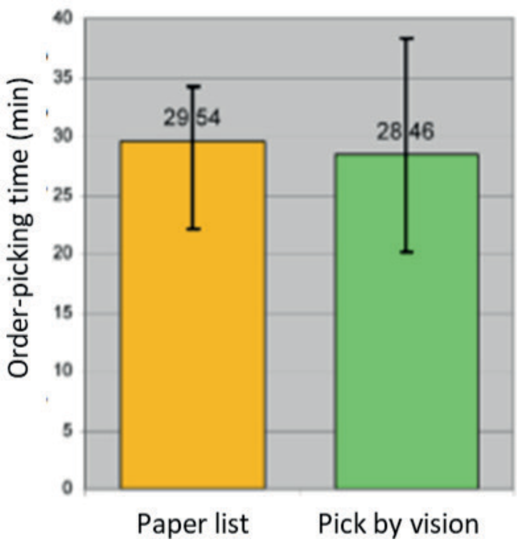

Fig. 7. Order-picking time

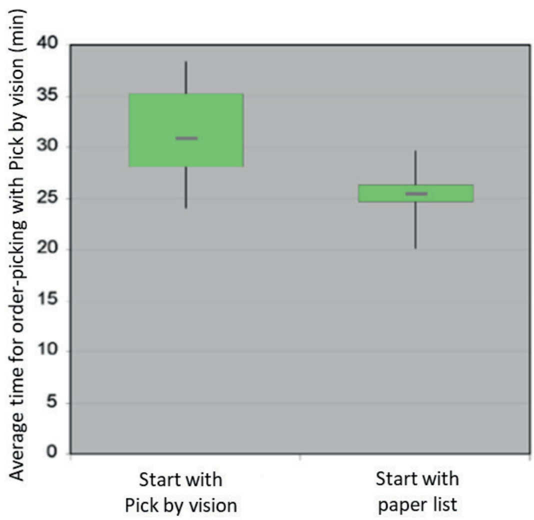

Fig. 8. The difference in picking time based on the choice of initial technique

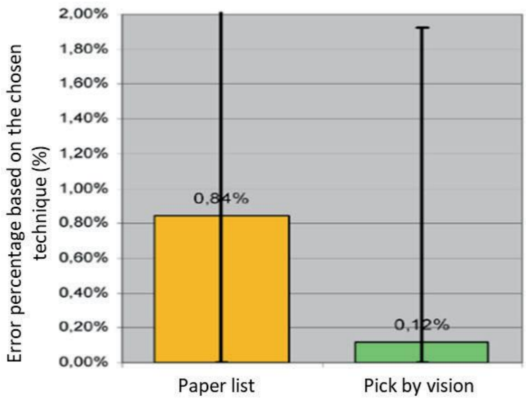

Fig. 9. Error rate depending on the choice of order-picking technique

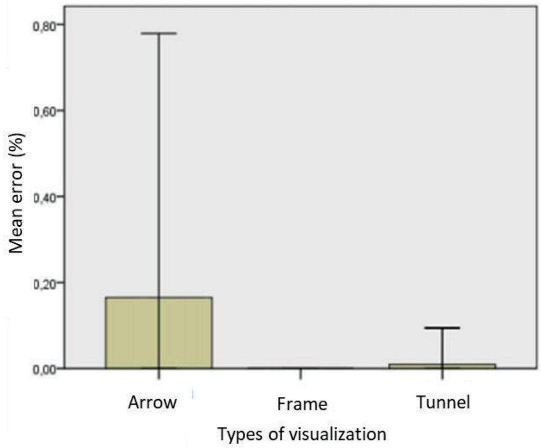

Fig. 11. Mean error for all three visualization modes

a) b) c)

Fig. 10. Different ways to visualize work instructions

checked. The results show no significant difference in time between 1D and 2D visualization, while 3D visualization was a few seconds slower than them. As many as 10 times more object selection errors occurred with 3D visualization than with 1D and 2D visualization. In most cases, the exclusion item is too high or too low, indicating depth of perception using augmented reality. This means that the AR-based system has a lower box size limit. Below this limit, the identification of the box becomes ambiguous. In another experiment performed by the authors, they reduced the size of the boxes from which objects had to be selected by 3D visualization. Three ways of visualizing the operating instructions were developed and compared, Figure 10. Under a) an arrow is shown, under b) a rectangular frame and under c) a tunnel.

Participants were asked to stand in front of a shelf and select items. It was not possible for them to see the entire shelf while standing in front, so participants had to move their heads to see the boxes to select. For all three visualization methods, they used the same orders, which was not obvious to the participants. The order in which respondents were required to use visualizations was permuted to offset the learning effect. Respondents had to start each exemption with their backs to the shelf. At the starting signal, they turned and performed the test. When they said „I chose!" They moved on to the next visualization at the touch of a button. At that moment, the system recorded the time and a simple harmonic sound indicated a change in the mode of visualization. When analyzing test results, errors when selecting boxes mostly occur with the arrow. The tunnel gave much better results, but people still made mistakes while the frame worked without error, Figure 11.

Analyzing the exclusion time, the following results were obtained for the excluded subject: 4,341 seconds for the arrow, 3,581 seconds for the rectangular frame, and 4,096 seconds for the tunnel, as shown in Figure 12.

Based on the experience of the previous experiments in the last, third experiment, the authors optimize the display mode from the second experiment. They use four modes of visualizing work instructions: the Square Tunnel, the Transparent Square Tunnel, the Square Tunnel Arrow, and the Round Tunnel, Figure 13.

The results show that during the experiment in which 1512 items were excluded; no participants chose the item wrong. Regarding the average time required to exclude an object, the following results were obtained: 6,602 seconds for the opaque S-tunnel, 6,265 seconds for the semitransparent S-tunnel, 6,038 seconds for

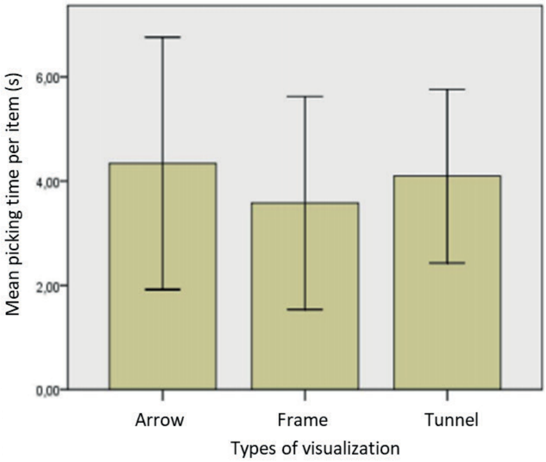

Fig. 12. Mean picking time per item

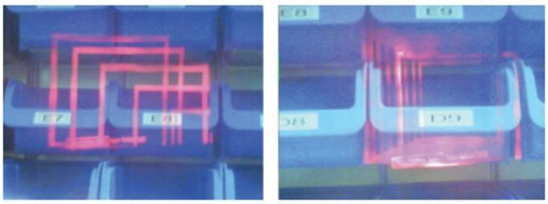

Fig. 13. Different forms of semi-transparent operating instructions display modes

the square tunnel arrow, and 6,039 seconds for the semi-transparent R-tunnel, as shown Figure 14.

The average median time to pick an item in the third experiment is two seconds longer than in the second experiment. The results show that both ways of visualizing work instructions are suitable for small warehouses, where people do not have to move much.

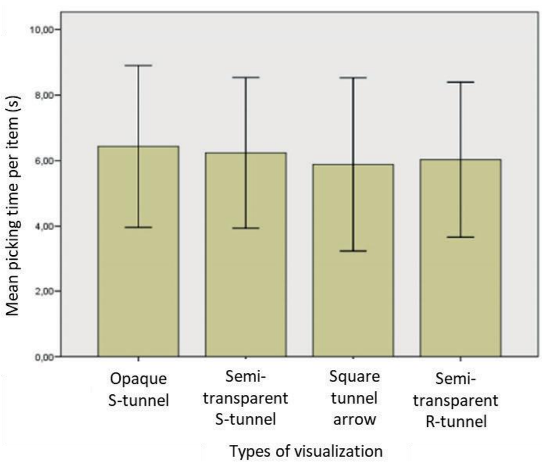

Figure 14. Mean picking time per item

4. Conclusion

The first appearance of the AR was back in 1950s, but it was not seriously considered until the 1990s when it was used for military purposes. With the development of the internet and smart devices, the usage of AR was spread to various industrial systems. One of the areas where AR set good grounds is logistics. AR users can gain insight into information at anytime, anywhere, enabling accurate planning and quality execution of specific tasks which is vital for providing higher levels of customer service. There are several categories in logistics where AR can be implemented: warehousing operations, transportation optimization, last-mile delivery and enhanced value-added services. So far, AR is showing best results when used for warehousing operations. These operations are responsible for 20% of all logistics costs and order-picking accounts for 55% to 65% of overall cost of warehousing operations. By applying AR to order-picking and improving pick-by-vision techniques, there is a vast potential for cost reductions. AR mobile systems are consisted of head-mounted displays (HMD), cameras, wearable PCs and battery packs. The software used for AR vision picking provide real-time object recognition, barcode reading, navigation in the warehouse and continuous information flow between warehouse management system (WMS) and the picker. The main improvement for order-picking is the freedom of picker's hands and digital support during picking operations. The present-day researches about the usage of AR for pick-by-vision were explored in this paper. The study showed advantages of this picking method, but also underlined common problems that appear during order-picking operations using AR technology, especially those one concerning comfort of pickers.

References

[1.] Živanić D. (2012): Logistics and material flows simulation as a foundation for optimum transport-warehouse systems choice. Ph. D. Thesis, University of Novi Sad, Faculty of Technical Sciences, Novi Sad

[2.] Živanić D. – Vujić G. – Kosec B. – Stoić A. (2014): Material flow enhancement in production assembly lines under application of zoned order picking systems, Metalurgija, Vol. 53, No. 4, pp. 681-684.

[3.] Živanić D. – Džinčić I. – Vladić J. – Đokić R. – Gajić A. (2014): Models of zoned picking systems in Excel, The 8th International Symposium Machine and Industrial Design in Mechanical

Engineering KOD 2014, Balatonfüred, Hungary, pp. 65-70.
[4.] Živanić D. – Vladić J. – Džinčić I. – Đokić R. – Gajić A. (2014): Simulation of material flow in the zoned order picking systems, 5th International Conference Transport and Logistics, Niš, Serbia, pp. 185-190.
[5.] Živanić D. – Gajić A. – Vladić J. – Đokić R. – Ristić Z. (2013): Property Of progressive zoning in the order picking systems, 11th International Conference on Accomplishments in Electrical and Mechanical Engineering and Information Technology, Banja Luka, Bosnia & Herzegovina, pp. 1053-1058.
[6.] Živanić D. – Vladić J. – Đokić R. (2011): Recommendation for choice of order picking methods and technologies, Machine Design, Vol. 3, No.1, pp. 51-54.
[7.] Živanić D. – Vladić J. – Đokić R. – Gajić, A. (2011): Zoning in the order picking systems, The 7th International Triennial Conference Heavy Machinery HM 2011, Vrnjačka Banja, Serbia, pp. F.31-F.34.
[8.] Živanić D. – Ilanković N. – Bojić S. – Radaković D. – Zelić A. (2019): The logistical approach to the analysis, modelling and simulation of material flow, LOGISZTIKA –INFORMATIKA –MENEDZSMENT, DOI: 10.29177/LIM.2019.1.43
[9.] Živanić D. – Ilanković N. – Zelić A. (2019): The logistical approach to the design of transportation systems, International Conference Sustainable Logistics 4.0, Belgrade, Serbia
[10.] Glockner H. - Jannek K. - Mahn J. - Theis B. (2014): Augmented reality in logistics: Changing the way we see logistics - a DHL perspective.
[11.] Ong S.K. - Nee A.Y.C. (2013): Virtual and augmented reality applications in manufacturing. Springer Science & Business Media.
[12.] Cirulis A. - Ginters E. (2013): Augmented reality in logistics. Procedia Computer Science, 26, 14-20.
[13.] Leitao P. - Colombo A.W. - Karnouskos S. (2016): Industrial automation based on cyber-physical systems technologies: Prototype implementations and challenges. Computers in Industry, 81, 11-25.
[14.] Khalid C.M.L. - Fathi M.S. - Mohamed Z. (2014): Integration of cyber-physical systems technology with augmented reality in the pre-construction stage. In 2nd International Conference on Technology, Informatics, Management, Engineering, and Environment, 151-156.
[15.] Gorecky, D., Garcia, R.C., and Meixner, G. (2012). Seamless augmented reality support on the shop floor based on cyber-physical-systems. In 14th International Conference on Human-computer Interaction with Mobile Devices and Services. ACM.
[16.] Stoltz M. – Giannikas V. – Mcfarlane D. – Strachan J. – Um J. – Srinivasan R. (2017): Augmented reality in warehouse operations: Opportunities and challenges. IFAC-PapersOnLine. 50. DOI: 10.1016/j.ifacol.2017.08.1807.
[17.] Kim S. – Nussbaum M. – Ulman S. (2018): Impacts of using a head-worn display on gait performance during level walking and obstacle crossing. Journal of Electromyography and Kinesiology. 39. DOI: 10.1016/j.jelekin.2018.02.007.
[18.] Bräuer P. – Mazarakis A. (2018): AR in order-picking – experimental evidence with Microsoft HoloLens. DOI: 10.18420/muc2018-ws07-0463.
[19.] Kim S. – Nussbaum M. – Gabbard J. (2019): Influences of augmented reality head-worn display type and user interface design on performance and usability in simulated warehouse order picking. Applied Ergonomics. 74. 186-193. DOI: 10.1016/j.apergo.2018.08.026.
[20.] Reif R. – Günthner W. (2009): Pick-by-vision: augmented reality supported order picking. The Visual Computer. 25. 461-467. DOI: 10.1007/s00371-009-0348-y.
[21.] Schwerdtfeger B. – Klinker G. (2008): Supporting order picking with Augmented Reality. 91-94. DOI: 10.1109/ISMAR.2008.4637331.