Accented visualization application in interactive manuals for technical training and support

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Abstract. The capabilities of modern information and communication devices (tablets, glasses, helmets, etc.) that provide user interfaces with Augmented Reality (AR) are successfully used in education and maintenance support nowadays. The main benefits are concerned with the possibility to display the required information in the context of operations performed by the user. Technically it is implemented in the form of textual hints or visual 3D objects with highly realistic appearance and behavior. New features prompt new challenges: the user can be easily overloaded with lots of information, and some real objects that require user’s attention can be overlapped by virtual ones in one scene. In order to solve this problem and improve the usability and effectiveness of AR devices application in maintenance and education it is proposed to build adaptive user interfaces that consider the context and focus of the user. From information technology perspective this approach forms a promising area of application of high-potential technologies including machine learning and computer vision. In this paper there is presented an example of AR implementation as a part of an interactive manual, which provides adaptation and personalization based on the concept of accented visualization. Identification of objects and their classification is implemented using the artificial neural network.

1. Introduction

Modern automated systems implement interactive user interfaces in various industries including production, logistics, power engineering, medical care etc. The main challenge of their practical use is in finding a balance between the volume of information being visualized to a decision maker at a time and usability of everyday operations. Various sensors and telecommunication tools are capable of producing large amounts of data in real time; still their processing remains limited being hardly influenced by the human factor.

In order to avoid information overload and data excessive supply user interfaces are usually simplified and decomposed. The user should be supplied with the information necessary at the exact stage of business or production process. The corresponding limitations can be introduced by additional standardization of technologies and procedures that can help solving the problem. Nevertheless different users acquire and process the information in different ways depending on their education, skills and personality.

Therefore there appears a strong demand for adaptive user interfaces that provide personalization for the users considering their perceptual and learning style. Some research results in this area gained
positive effect in medical education and augmented reality (AR) based training [1–3]. One of the perspective areas of their application is the development of interactive manuals for technical training and support. Possible solution and use case are provided in this paper below.

2. State of the art
Interactive 3D user interfaces have taken the rightful place in education and training. There can be specified two main directions of their application in modern education: simulators and manuals. Simulators target training the basic skills and try to reproduce the real scene in the most possible realistic way. Manuals provide visual knowledge bases that capture comprehensive description of various aspects in the specific problem domain. An additional attention is usually given to semantic search that provides sophisticated navigation.

Both application areas come across the same challenge. Instead of targeting maximum reality the simulation solutions need to provide good enough environment to train the basic skills. For example, in surgery training it is not so important to reproduce the real surgery field rather than force the student performing repetitive actions with no mistakes [4]. The same problem is specific for interactive user manuals. While processing the huge volumes of related information captured in the knowledge base it is important to find the minimum portion required by the exact user at a time. To do this, the system should know the exact user requirements and understand the features of his/her perception.

The most illustrative cases of interactive user interfaces application in educational sphere are presented in automobile and aircraft industries [5, 6]. Implementation of automated systems with modern user interfaces in training of aircraft maintenance procedures helps the corresponding personnel receiving initial skills training in aircraft maintenance career with deeper insight and knowledge of system, procedural, and safety/hazard information.

Development of the modern human-machine interfaces as a part of advanced automated driver assistance systems provides new benefits in training for interacting with driving automation. Both the owner's manual and an interactive tutorial lead to an increased understanding of driving automation systems as well as an increased interaction performance.

An example of AR practical use in development, production and service is presented in [7]. The maintenance and training applications of AR in the aeronautical area present high efficiency considering the complexity of equipment and technological process and growing requirements for the personnel competence [8-10]. Functionality of interactive manuals can be implemented even by mobile devices [11]. The content is designed by experts step by step using the specifically designed expert/trainer editor. In the trainee mode, the system utilizes the existing object detection and tracking algorithms to identify the step scene and retrieve the respective instruction to be displayed on the mobile device.

Interactive technologies are widely implemented in modern education and training [12]. This is especially actual in technical education due to large volumes of information being processed and a necessity to present the educational material in the most illustrative and convenient way. Due to wide spread of these technologies there appears a new horizon of their development. Improving the efficiency of interactive technologies application requires additional efforts to choose the best way of 3D scene construction, feasibility and usability of interfaces, etc.

In order to increase the efficiency of 3D and AR technologies use for simulation and visualization of educational content there are developed new ways of user interfaces adaptation to specific users [13, 14]. Modern approaches consider the differences among individuals that have an effect on learning and propose to design and develop adaptive e-learning systems.

Therefore the user is put inside the "loop" of computer-human interaction [15, 16] that makes user interfaces context and focus dependent. It is proposed to involve the decision maker into the process of data processing and visualization by continuously interacting with the system, which helps to optimize the learning behavior of both humans and algorithms.
3. The solution of accented visualization

Accented visualization incorporates the algorithms of computer vision, objects identification, process contextual analysis and adaptive visualization using the AR user interface. The main idea is to formalize and capture the user behavior and compare it to typical patterns of standard and wrong procedures. In educational problem domain these patterns are predefined by teachers or highly qualified personnel. The main idea is to separate the deviations from typical behavior patterns caused by the lack of skills from those that respond to an insufficient user interface.

This knowledge can help finding the balance in the user interface sophistication. The system used as an interactive manual for technical training and support requires understanding the current actions performed by the user and provide informative or supervising data when needed. The following model was developed for this purpose.

Let us consider the number of actions $d_{i,j}$ performed by the user according to the process $p_j$.

Each action involves processing of a number of objects $w_k$. This means that the system registers a sequence of impacts that describe the user behavior in the form of event flow:

$$e_{i,j,k,l} = e(d_{i,j}, w_k, t_{i,j,k,l}),$$

where $t_{i,j,k,l}$ is the timestamp of the event; $e_{i,j,k,0}$ indicates the process start at time $t_0$.

The set of standard and wrong procedures can be specified as the following:

$$e'_{i,j,k,l,m} = e(d'_{i,j,m}, w'_k,m, t'_{i,j,k,l,m}),$$

where $m = 0$ for the standard pattern and $m = 1, N_m$ indicates all possible wrong patterns if exist; $t'_{i,j,k,l,m}$ represents the time (duration) from the expected start of the process.

The concept of accented visualization includes monitoring of the following decision-making points. Firstly, the system should discover and track possible mistakes. This means identification of equality of the user’s operations flow with one of the wrong patterns:

$$\sum_{m=0}^{N_m} \sum_{j,j,k,l} e'_{i,j,k,l,m} \cdot e(d_{i,j} = d'_{i,j}, w_k = w'_k, t_{i,j,k,l} - t_0 = t'_{i,j,k,l,m} \pm \xi) = N_t,$$

where $\lfloor x \rfloor = \begin{cases} 1, x = \text{true}, \\ 0, x = \text{false}. \end{cases}, \xi$ - allowable error (delay).

In order to avoid deviations from the standard process there secondly should be generated adaptive supporting hints in the form of events:

$$h_{i,j,k,l}(d_{i,j,k,l,m} + \xi) = \sum_{i,j,k,l} e'_{i,j,k,l,m} \cdot [1 - e_{i,j,k,l} \cdot d_{i,j} = d'_{i,j}, w_k = w'_k, t_{i,j,k,l} - t_0 = t'_{i,j,k,l,m} \pm \xi]$$

The statement (4) defines that the hint should be generated in case the event $e'_{i,j,k,l,m}$ finds no corresponding event among the sequence of user’s actions. Adaptation means that the hints are generated only at required times considering the possible place of their appearance in AR scene. This means that, in order to provide adaptation, an interactive guide should produce virtual entities that lead the data at the moments when the viewer’s attention should be drawn to specific objects.

4. Implementation to practice

The proposed educational solution is based on the analysis of user behavior according to the introduced model. Embedded software with intelligent decision-making support captures user behavior in the form of events and compares these event chains with typical operational scenarios. The analysis is performed during the period of the standardized procedure pattern using the cross-correlation functions. Such an
analysis allows identification of possible gaps in the viewer's perception, if no necessary attention is paid to certain scene objects when necessary.

User’s focus coordination is based on intelligent analysis of the process of production or maintenance. The system tracks user attention and adapts additional data introduced to virtual scene according to the current context. User’s focus is captured in the form of event chains and compared with typical scenarios. Context is a set of concepts that describe the current situation and background to determine the decision. Focus is a concrete object processed at a certain moment. Such fragmentation allows introducing a control loop, where the correct focus is generated according to context in real time.

Different users have various perception features: some prefer to obtain the maximum information displayed in the field of view, others try to reduce non-essential data, leaving an absolute minimum that is important. To capture the appropriate sample and device of the system according to the preferences of the user, there can be used a special eye tracking system that determines and controls the movement of the eyes using the front camera.

In addition to this an intelligent algorithm based on neural networks was introduced, which helps in the stable and reliable recognition and identification of the objects in view by a partial scheme. Among the possible neural network topologies (AlexNet, VGG16, GoogLeNet/Inception, etc.) there was chosen a Residual Network powered by Microsoft. ResNet-50 is a convolution neural network that is trained on more than a million images from the ImageNet database. It contains 50 layers deep with direct links between the neurons located by one level. Research results show that the recognition rate of objects successful identification using accented visualization if 93.2% comparing to standard technology that presents 36.9%.

The proposed approach was implemented in a specialized intelligent system for industrial manual operations control, developed by Open code LLC (see figure 1). The overall solution is used to identify gaps and failures of the operator in real-time, predict possible operating mistakes, and suggest better procedures based on comparing the sequence of actions to the experience of highly qualified operators. The objects are identified using the neural network and presented in AR scene generated by the tablet or interactive dashboard.

Virtual objects include two layers for all the identified objects (marked by blue) and hints for wrong or delayed operations (marked by red). Overlapping of irregular operating notifications with the corresponding objects does not interfere with the workflow and helps to attract attention in the required time and space.

![Figure 1. AR based control in the interactive manual for technical training and support.](image-url)
possible deviations and delays, evaluation of failures and gaps, and generation of recommendations in order to improve the process quality.

5. Conclusion
Implementation of accented visualization in educational purposes provides the unique benefit of higher adaptation and personalization of information technologies solutions that implement modern user interfaces. The approach is recommended for the developers of interactive educational systems and teachers that are interested in improving the efficiency of modern technologies application in practice. Next steps include evaluation and further distribution of the proposed approach. The results can be used, for example, when designing software for the following tasks: assessing energy efficiency factors in industrial companies [17], gathering information for decision-making [18], information security risk estimation for cloud infrastructure [19].

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References
[1] Ivaschenko A, Kolsanov A and Nazaryan A 2019 Focused visualization in surgery training and navigation Advances in Intelligent Systems and Computing 858 537-47
[2] Ivaschenko A, Sitnikov P and Katirkir G 2019 Accented visualization in digital industry applications Studies in Systems Decision and Control 199 366-78
[3] Ivaschenko A, Avsievičius V and Sitnikov P 2020 AR guides implementation for industrial production and manufacturing Lecture Notes in Electrical Engineering 641 715-23
[4] Kolsanov AV, Ivaschenko AV, Kuzmin AV and Cherepanov AS Virtual surgeon system for simulation in surgical training Biomedical Engineering 47 285-7
[5] Badler N, Sunshine-Hill B and Vincent P 2008 Extending interactive electronic technical manuals (IETMs) with real and virtual animated content for maintenance task training (88th Air Base Wing Public Affairs Office) p 41
[6] Forster Y, Hergeth S, Naujoks F, Krems J and Keinath A 2019 User education in automated driving: owner's manual and interactive tutorial support mental model formation and human-automation interaction Information (Switzerland) 10(4) 143-64
[7] Friedrich W 2002 ARVIKA: Augmented Reality for development, production and service International Symposium on Mixed and Augmented Reality (Darmstadt, Germany) 3-4
[8] Hincapié M, Caponio A, Rios H and Mendivil E G 2011 An introduction to Augmented Reality with applications in aeronautical maintenance 13th International Conf. on Transparent Optical Networks (Stockholm) 1-4
[9] Haritos T and Macchiarella ND 2005 A mobile application of Augmented Reality for aerospace maintenance training 24th Digital Avionics Systems Conference (Washington, DC) 5.B.3.3-5.1
[10] Ke C, Kang B, Chen D and Li X 2005 An Augmented Reality based application for equipment maintenance Lecture Notes in Computer Science 3784 836-41
[11] Nguyen T, Mirza B, Tan D and Sepulveda J 2018 ASMIM: Augmented Reality authoring system for mobile interactive manuals Proc. of the 12th Int. Conf. on Ubiquitous Information Management and Communication 3 1-6
[12] Lee K 2012 Augmented Reality in education and training TechTrends 56 13-21
[13] Shute V and Towle B 2003 Adaptive E-learning Educational Psychologist 38(2) 105-14
[14] Julier S, Livingston M A, Swan J E, Bailot Y and Brown D G 2003 Adaptive user interfaces in augmented reality Proc. of the Software Technology for Augmented Reality Systems Conf. (Tokyo, Japan) 1-8
[15] Holzinger A 2014 Extravaganza tutorial on hot ideas for interactive knowledge discovery and data mining in biomedical informatics Lecture Notes in Computer Science 8609 502-15
[16] Holzinger A 2016 Interactive machine learning for health informatics: when do we need the
human-in-the-loop? *Brain Informatics* 3(2) 119-31

[17] Kelchevkaya N R, Shirinkina E V and Atlasov I V 2020 Assessing energy efficiency factors in industrial companies *IOP Conf. Series: Materials Science and Engineering* 862 42001

[18] Mihaylov D 2019 A Way to Accelerate the Process of Gathering Information for Decision-making *International Journal on Information Technologies and Security* 4(11) 39-50

[19] Tsaregorodtsev A V, Kravets O Ja, Choporov O N and Zelenina A N 2018 Information Security Risk Estimation for Cloud Infrastructure *International Journal on Information Technologies and Security* 4(10) 67-76