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Augmented reality for SCADA

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Abstract. Questions of construction of the Augmented Reality for application in SCADA-systems are considered. It is marked, that last years researchers from Russia actively started studying this branch. The author considers the augmented reality in a section of a reality-virtuality continuum taking into account restrictions of memory of the operator and social aspect of application augmented reality. Recommendations on environmental analysis and reading of data from display devices are given. The greatest efficiency of application augmented reality is seen in joint activity and carrying out of works which demand coordinated work. The necessity of the further researches for developing of network architecture, safety, confidentiality and protection against extraneous intervention is noted. Advantage of augmented reality is reuse of software, databases and knowledge. At the replacement of maintenance staff and users of SCADA-system there is no need to teach them all the knowledge and skills at once. They will receive them directly in the process of application.

1. Introduction

The augmented reality is penetrating more and more into different fields of activity, including education and industry. Since 1993, the annual IEEE Virtual Reality International Symposium has been held, and since 2002, the annual IEEE International Symposium on Mixed and Augmented Reality has been held, which discusses various issues in the construction of virtual, mixed and augmented reality. Since 2007, the IEEE International Conference on Industrial Engineering and Engineering Management and many other conferences have been held. At the same time, in 2010-2012 Russia was on the 18th place in the rating of countries by the number of patent applications on "virtual and augmented reality technologies". By 2015-2017, Russia has moved up by one place in this ranking. The leaders of the rating are organizations from the USA, China, Japan and the Republic of Korea. In a similar ranking of countries by the number of publications indexed by Scopus, Russia moved up from 42nd place in 2010 to 18th place by 2018. Realizing the importance of advanced technologies for the society development, the Ministry of Digital Development, Communications and Mass Media of the Russian Federation has created the Roadmap for "Trans-through" digital technology development "Technology of virtual and augmented reality" [1].

2. Augmented reality in a continuum of reality and virtuality

The mixing of physical and digital worlds defines the combination of real and virtual environments and becomes a part of the Reality-Virtuality Continuum (RVC) [2], [3]. The RVC describes the interactions between reality and virtuality. In RVC, augmented reality (AR) is the depiction of virtual objects in the context of the real world. Modern AR solutions on portable devices use an image from a real device and combine it with virtual content. Similar solutions exist for transparent (head-mounted) displays (for example, Magic Leap One Personal Bundle, Microsoft HoloLens 2, Epson MOVERIO, Everysight Raptor, Google Glass Enterprise Edition 2, Kopin SOLOS, Meta 2, ODG R-7, Toshiba dynaEdge AR100, Vuzix Blade Smart Glasses, ThirdEye Gen X2, Vuzix M4000). Modern AR applications also include tactile feedback and spatial sound [4], [5].

3. Considerations of operators' memory limits

The use of AR to increase the capabilities of SCADA-systems is an undoubted advantage, but it is necessary to develop special intelligent SCADA-systems with AR support and operators training this technology. And it is necessary to dose the amount of information submitted through AR, because operators may become dependent on system prompts and reduce the willingness to solve problems independently, and sometimes the inability to perform the same actions without using AR [6]. For this purpose it is suggested to reduce the flow of new information during operators' training because it is possible that the operator will not notice really important information. In addition you should remove insignificant or irrelevant information (representations) for the running process.

Cognitive load theory builds on the widely-accepted assumption that humans have limited working memory capacity and further asserts that each instructional condition imposes on working memory three types of cognitive load: 1) intrinsic cognitive load; 2) extraneous cognitive load; and 3) germane cognitive load [7], [8]. Whereas intrinsic cognitive load is determined by the complexity (i.e., “element interactivity”) of the learning task itself and germane load is associated with conscious, constructive processes used to construct mental representations, extraneous load does not contribute to learning. Furthermore, if working memory capacity is fully engaged in processes related to intrinsic and extraneous load, learners will have no remaining cognitive resources to allocate to germane processes, and little learning can occur. According to the Four-component Instructional Design (4C/ID) model [9], learning tasks should be ordered such that earlier tasks include lower element interactivity (i.e., low intrinsic cognitive load) and as learning tasks become more complex, instructional scaffolds should be provided to reduce extraneous load during transitions to more difficult material.

According the schematic theoretical model of concreteness fading the process of training operators is effectively carried out in three stages [10].At the first stage, training is carried out on concrete examples, when it is easier for an operator to interprete ambiguous abstract representations in terms of well understood concrete objects, and also the advantages of embodied cognition are used, which gives experience of working with physical and perceptual processes, which are limited and therefore give correct conclusions [11], [12]. The operator remembers a set of attributes (images, symbols, gestures, etc.) which will be used in the AR system metaphor when abstract symbols are related to real objects. After understanding the abstract concept in solving new problems, the operator will rely on this set of attributes [13]. At other two stages there is a move from real physical representation to graphic schemes and models, and then to usual abstract symbols [13].

This moment requires further research, since according to [14] the transition from abstract to concrete can sometimes improve learning.

Thus, in training, the intelligent AR system will adapt itself to the operator's gained experience in servicing systems and facilities. There will be a transition from a specific instruction of the required sequence of each action [15] to monitoring the execution of these actions and fixing the fact of execution of the embedded instructions.

4. Social aspect of AR application in SCADA

Most often purely technical aspects of AR environment design are investigated. Only recently it began to notice that it is necessary to consider social aspect of application AR. Users develop a sense of interconnection and psychological belonging to virtual artifacts in AR environment more, than in the usual virtual environment. A common environment in the interaction of several participants may disturb the sense of identity of users, as well as potentially threaten the sense of personal space and the sense of physical objects [16], [17]. The assessment of perception when using glasses and the hand-held device (smartphone) is studied in [18].

Sensors placed on the body can be used to transmit feedback to the AR system and interact with the operator. However, some actions are easier to perform in the street than in a public place, because some gestures are simply not permitted there [19]. To transmit control commands to the SCADA system, it is necessary to take into account that some gestures and movements of the operator may be related not to the control process, but to the performance of any other work, maintenance of the installation or random movements. It is necessary to further develop a special protocol to prevent the execution of wrong commands.

Also with the use of AR, there can be discomfort and a negative reaction to interpersonal disturbances [20].

It can be assumed that the use of AR in SCADA-systems will be more effective, if in addition to the execution of commands and sensor readings AR will visualize these processes using the familiar to the operator external environment, especially in remote management. In recent years, four different agents: voice-only, non-human, full-size embodied, and a miniature embodied agent [21] are used for this purpose. Besides, for an operator it is necessary to increase the level of user's perceived trust in the intellectual system. For example, for users of Internet of Things (IoT) devices using AR, the level of trust was much higher than only with Voice-activated Intelligent Virtual Assistants (IVAs) such as Amazon Alexa [22].

In the process of training for working with AR it is necessary to move from the virtual environment to the real world, when the operator is given only the necessary dosing information and is controlled and checked the correctness of his actions. It is suggested to use multi-level scenarios of data display [23] for different types of staff and qualifications, for example, displaying only the current temperature, its graph in the near future, its extrapolation to the future, or only a message in case of deviation from expected, etc.

Analogously, in order to present data, it is necessary to move from a real physical representation to an abstract one.

Nowadays AR is widely used directly for training process [24], though in our opinion it is more effective to use AR for large and complex systems [25], in which it is necessary to provide reliability and stability. The purpose of AR in SCADA-systems is abstract presentation of data to the operator in real time, overlaid on the natural environment [26] even on the go [27].

5. Analysis of the environment

It is possible to use the computer vision library OpenCV [28] for environmental analysis. To bind to the system it is suggested to use a markerless framework, which does not imply the use of fiducial markers [29] or even natural markers in the environment [30], [31]. At the same time, there is a problem of providing AR plasticity [32], [33]. Properties of the presented additions are modified according to the values of the use context, the platform applied and the properties of the environment [34], for example, scene illumination [35], user position, estimated by his distance from the target and the ambient noise [36]. Most often the image of the equipment itself is processed through a calibrated camera by ARToolKit [37] or SLAM framework [38], which can be replaced by a more advanced GLEAM [39]. It should be noted that it is necessary to eliminate the perceptual problem of perception of incorrect depth interpretation of graphical objects overlaid on the real world [40], [41]. This is especially shown in stereoscopic systems, head-mounted displays, are evolving towards endless screens and natural FOVs, in which it is necessary to become more accurate in the challenging X-ray visualization and the best support for occluded interaction. Note the three most influential factors: point-of-view, view stability and view displacement [42]. For a hand-held device, this problem is less relevant [43].

While getting information about the control object it is possible to use Internet of Things (IoT) technologies [44], in particular, to use a communicating-actuating network wherein sensors and actuators blend seamlessly with the environment around us, and the information is shared across platforms in order to develop a common operating picture (COP).

Optical Character Recognition (OCR) can be used to read data from sensors that do not have a digital output and communication interface, and then converted to a digital form [45]. And the analysis is possible for both digital and pointer devices with determination of the measurement scale [46].

6. Results and discussion

The greatest effectiveness of AR application will be achieved through collaborative activities and work that requires coordinated work. In this case, for multiuser AR the social aspect considered earlier becomes especially actual, and also network architecture [47], [48], safety, confidentiality and protection against extraneous intervention [49].

The advantage of AR is the reuse of software, database and knowledge. When there is a replacement of service staff and system users, there is no need to teach them all the knowledge and skills. They will receive them directly during application. The qualification requirements for the users are considerably reduced, but the requirements for the maintenance system (software, databases and knowledge, rules and models) are increased. Also there are fewer human errors and an opportunity to control its actions in real time. EcoStruxure Augmented Operator Advisor enables technicians to locate the right equipment and guides them step-by-step to complete the procedures.

Certain problems may present the possibility of AR operation without network access [50], in offline mode, but AR designers for industry offer the use of communication sessions and special tickets.

Despite difficulties with implementation AR in the industry, the advanced producers of automation means already offer ready decisions.

AR is necessary to apply first of all for serial products or for objects where the big replacement of staff, and also for difficult systems in which it is necessary to exclude human errors [51], [52].

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