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Specifics of Visual Perception of The Augmented Reality in The Context of Education

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Abstract

Paper deals with visual perception, which is a prerequisite for the functioning of augmented reality and very important area in the context of the use of augmented reality in education. The paper aims to analyse the specifics of visual perception and lists the characteristics of augmented reality systems and applications from the perceptual point of view. Characteristics of augmented reality from the point of view of visual perception reflect primarily the form and the nature of the added information, cognitive difficulty of processing information presented to a user, its decoding and processing, properties of augmented reality systems and their potential applications in education.

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Keywords: Augmented reality, enhanced reality, mediated reality, visual perception, information, education;

1. Introduction

Augmented reality (AR) we can characterize as a specific innovative technology or technologically induced perceptual environment based on the combination of perceived real environment and augmented, e.g. computer generated, elements (Milgram, 1994). According to Johnson (2011), augmented reality is characterized by adding computer-generated context information layer into the real world, which leads to enhanced reality. Heim (1998) defines AR as overlapping basic visual field with computer-generated data. AR can also be characterized as a

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technology, or a technological-perceptual concept, which involves a technological, perceptual and information aspects, which adds visual, sound and other virtual elements into the perceived reality, i.e. it makes use of the combination of real environment with intentionally introduced information, thus creating a new form of reality, which is information-richer than the original primary environment. This principle is realized through a number of ways, various technical devices and by its nature can function through all perceptual channels simultaneously or individually. Augmented reality systems can define by the following parameters: Such systems combine real environment surrounding the user with virtual elements, such systems are characterized by reactivity on real environment in real time (within the technological system of AR this is ensured by tracking system), and such systems when adding (registering) virtual elements into perceived augmented reality, they count on three-dimensional space of real environment. In an attempt to classify augmented reality systems more precisely, it is necessary to apply both the technological viewpoint based on the technical system and the resultant viewpoint characterizing the capabilities of the system through the properties of the realized AR, and finally perceptual viewpoint.

2. Perceptual, technological and resultant aspects of augmented reality

It is clear that individual perceptual fields significantly determine the nature and technical principles of augmented reality. When creating an augmented reality classification system based on the above, it is necessary to apply a perspective that reflects the given perceptual field; one must consider the AR system's method and capability of targeting the user's perceptual field with appropriate stimuli.

From the perceptual viewpoint, we can primarily assess the ability of the system to work with individual perceptual channels, i.e. to generate information such as visual, auditive, tactile, or olfactoric. The parameters defining the nature of the added information differ based on the type of the perceptual channel, with which the system is working, Even though augmented reality, by its nature, can be realized through all perceptual channels, this added information is in vast majority visual. This type of added information can be described by means of four parameters (Jeřábek, Prokýšek and Rambousek, 2013).

The first parameter includes the type of graphic data reflecting cognitive difficulty of processing information presented by a user, its decoding and processing; and also a type of visual information in terms of its technical processing and presentation. With the exception of speech, all the other ways represent transmitting or presenting visual data which can be provided by technical devices. Taking into technical principles of data presentation within AR systems, for a visual area we may divide added graphic information into the following categories (PT1-PT3): PT1 Texts and characters - PT2 Graphics and schemes - PT3 Realistic visualization. Although text and character processing may differ from the viewpoint of cognitive perspective, they are presented in one group in this paper since they both represent a similar type of visual information, and compared to PT2 group there are e.g. colour independent, however dependent on their orientation in space. By characters we mean all codes and symbols having generally or within a specific field the same meaning and they are thus also interpreted in this way (often irrespective of surrounding information). The second group consists of simple basic graphics and schemes gaining their meaning primarily in the context of surrounding visual information. The last group comprises realistically visualized information or image data in the form of photographs and films where quality value of the image (irrespective of colour depth) reaches the level of real visualization or tries to reach this level.

Dynamism of the image constitutes the second parameter of visual information from the perception perspective. An image can be static, kinetic or dynamic. This categorization is based on the extent of image motion within the image. The change of the image location or position in the perceptual field is not therefore considered as image motion as this motion concerns the whole image and there is no image change in the image itself (PD1-PD3): P-D1 Static image - PD2 Kinetic image - PD3 Dynamic image. Static image is an image in which no pixels change in the course of the time in terms of animation or evoking illusory motion. Kinetic image is characterized by a change of its picture elements in terms of colour and brightness in time, which we may define as picture animation, such as flashing pictures or simple graphic animations. From the perception perspective, dynamic image is the most difficult to process. It has cinematographic dimension compared to PD2 case. Resulting illusory motion includes a deeper information value compared to PD2. Into this category we may as well include an animated film perceived as one of the fields of cinematography.

Spatiality is the third parameter. From the perception perspective, it is primarily linked to the spatial depth. Perceiving the spatial depth is a complicated process and it is affected by a number of stimuli. The issue of the spatial depth is explored by e.g. Prokýšek (Prokýšek and Rambousek, 2012), who divides spatial visualization into truly and pseudo spatial visualization. True spatial visualization is visualization that evokes binocular disparity. Hence it is necessary to use binocular cues. When referring to pseudo spatial visualization, 3D illusion is also achieved however by using motion parallax, or based on monocular stimuli (Sternberg, 2002). Within spatiality, there are hence three possible variants (PS1-PB3): PS1 Two-dimensional visualization (2D) - PS2 Pseudo spatial visualization (2.5D) - PS3 Spatial visualization (3D).

Colour information is the fourth parameter. It is linked primarily to a display device representing augmented reality or its virtual element. In this connection, we may consider the extent of colour information as a value for colour depth of the device, or system. Current systems are able to display 24 bit depth in most cases, which can be described as a minimum value for full-colour display in the context of the perception of colours. Yet, in the field of augmented reality it is also necessary to include systems which work only with 1 or 8 bit depth for technical or other reasons (PC1-PC4): PC1 Monochrome images (1 bit) - PC2 Greyscale images (usually 8 bits) - PC3 More colour images (2 to 8 bits) - PC4 True colour images (24 bits and more). With specific displays (e.g. glasses), only visualization at PC2 or PC3 levels are possible for technical reasons. From the perception perspective, more colour images may seem richer than images in shades of grey although from a technical point of view colour visualization may even require a smaller amount of data. We consider the value of colour depth of 24 bits (PC4), known as True Colour, as a sufficiently representative value of colour information for real colour visualization. Higher colour depth (e.g. HighColour) is insignificant. Besides technical limitations for the use of other than full-colour visualization, there may exist physiological reasons as well or a reasonable purpose when constructing the system.

From the technological viewpoint, we may describe augmented reality systems through four parameters: The first parameter concerns the configuration of AR components, i.e. reality and virtuality. By configurating AR components we mean a purely technical solution of their mediating towards the participant, or in which part of the presentation axis (real environment – technical device – user) the components are allocated from the viewpoint of the participant's perception. If we disregard extreme cases of presenting data behind the receptors, within a technological viewpoint we may define three basic conditions of a virtual and real element configuration (TC1-TC3): TC1 both elements are perceived directly (from real environment) - TC2 a real element is perceived directly, a virtual element through a technical device - TC3 both elements are perceived through a technical device. The nature of control information constitutes the second parameter to describe AR systems from a technological standpoint. Control information is a necessary condition to meet the second fundamental AR system requirement, which is their reactivity on the changes of real environment in real time. Generally speaking, irrespective of the perception area targeted by augmented reality, the study defines the following three possible categories of control information (TN1-TN3): TN1 real environment parameter - TN2 intentionally-merged-into-the-environment artefact - TN3 user's parameter. The third parameter to describe AR systems from a technological viewpoint is the number of users, for whom the AR system is intended, in other words how many users can share the system simultaneously and perceive resulting reality. AR system can provide the effect of enhanced reality to one user only or to a bigger group of users. Within a bigger group, the system can fully provide a required effect either to all users identically or to a smaller part of the group only and for the remaining users augmented reality is limited in a certain way. The systems can be hence divided into three categories according to the number of users (TU1-TU3): TU1 single-user systems - TU2 limited multi-user systems - TU3 multi-user systems. The last parameter of a technological viewpoint is the support of interaction between user and system. By the support of interaction we understand an opportunity for the user to interfere with certain commands (gestures, sound commands, through a technical device, etc.) with the construction of enhanced reality, most frequently it is about influencing the form and amount of virtual elements. It is interference in otherwise automatically running application of the system, which alters the course of the algorithm. In this connection there are two basic situations that AR system can appear in (TI1-TI2): TI1 supports interaction - TI2: does not support interaction.

The resultant AR perspective primarily reflects the properties of the resulting environment and the relationship between virtual and realistic components from the user's perspective. These are the attributes which characterize the desired output of AR system applications, independent of both technical performance and the perceptual fields in which the system operates.

From the resulting viewpoint, we may describe the systems of enhanced reality by means of three and two subjective parameters from the AR user's viewpoint. The first objective parameter comprises a ratio of real and virtual component of AR in terms of Milgram virtual continuum (Milgram, 1994). The parameter aims to cover not only the ratio of the amount of individual components, but also the nature of the environment, which is the primary source of information. Augmented reality on one side and augmented virtuality on the other side can be considered the poles of this continuum. These are the values within the continuum as defined by the aforementioned extremes (RC1-RC2): RC1 Nearly exclusive representation of a realistic environment - RC2 Nearly exclusive representation of virtual elements.

The second objective parameter concerns information density of mediated AR, or the ability of the system to provide a user with information in low or high density. Similarly to the previous viewpoint, these values pertain to the defined levels of information density changes within the continuum. On one side, this continuum is defined by a state in which the resulting density is lower than the original. They are typical of examples in which virtual components aim to mask certain information within a real environment. On the other side, the continuum has a defined state with a high level of increase (RI1-RI3): RI1 Reduction of information density - RI2 Low information density – RI3 High information density.

The last, third objective parameter is the purpose of AR realization in terms of the relation of augmented information to original reality. Thus we can distinguish modified reality (e.g. "by taking away" information), augmented reality (e.g. adding existing but for the user inaccessible element), or enhanced reality (adding non-existing element) when the original environment is enhanced with information. Therefore, the possible augmented reality variants can be distinguished as follows (RU1-RU3): RU1 Mediated reality - RU2 Enhanced reality - RU3 Enriched Enriched.

Among subjective parameters, we may include a degree of authenticity of the resulting AR and the feeling of participation in AR when the user of enhanced reality can be a participant at the same time and becomes thus a part of AR or he or she is only an observer of arising AR. Both aspects are closely related to immersion, which the resulting AR environment features. The first aspect is, in essence, one of the defining parameters of the degree of immersion; the second then determines the nature of immersion.

With regards to the degree of realism, the participant perceives the complexity of the augmented reality environment in a certain way. Cases in which the environment either gives the impression of a "perfect illusion" (i.e. the maximum possible extent of realism), or an opposite, unrealistic illusion based on the incorporation of obvious virtual elements in a reality the participant cannot "believe", are some extreme examples of the degrees of realism within the augmented reality continuum (RR1-RR2): RR1 Maximum degree of realism - RR2 Minimum degree of realism.

The sense of participation in augmented reality is determined by whether the participant is an equal part of the AR environment, or only an observer of a computer-generated AR. Some authors (Zhen and Blackwell, 2013; Craig, 2013) distinguish between different types of AR configuration systems based on the so-called Magic Mirror and Magic Window systems. This division partly reflects the sense of participation aspect. First and foremost, the sense of participation in augmented reality is reflected by whether the augmented reality user is present within the augmented reality in terms of the perceptual field. Secondly, the sense of participation depends upon whether the user's AR role is active; i.e. whether or not they control the management element of the AR system. Based on these two conditions, it is possible to establish the three following states of participation RP1-RP3): RP1 Observer - RP1 Passive participant - RP1 Active participant.

One of the underlying criteria is the location in which augmented reality will be implemented. The criterion of location involves not only the place of execution, but also the parameters of said location such as lighting conditions, time variability, availability of electrical networks, the internet, GPS signals, etc., which can be described as organizational learning environment conditions. Additional criteria include the number of pupils for whom augmented reality must be implemented within a single system, and the pupil's position in relation to the augmented reality. The criterion of the pupil's position is primarily based on the resultant perspective regarding the sense of participation (RP-SP). In other words, whether or not the user is located within the augmented reality, or is merely its observer, thus determines the degree and nature of augmented reality immersion. Mobility is the fourth criterion and pertains to the mobility of the device itself and, therefore, the pupil's augmented reality environment. The final criterion relates to the performance parameters of the augmented reality content presentation.

AR systems can be described on the basis of the quality and nature of content presentation, a view which is largely based on perceptual aspects. It rests not only on the aforementioned perceptual characteristics, but also on aspects such as image resolution, the size of the perceptual field it offers the user, errors during the registration of virtual folders, as well as other parameters related to perceptions arising during the augmented reality experience. In this context, the presentation is also affected by the quality of the system's precision, such as its ability to eliminate errors associated with the process of combining realistic and virtual elements within individual spatial and temporal units. Problems related to system error rates have been discussed in many technically-oriented works that were focused on augmented reality. Such errors can include registration problems (inaccurate rendering of virtual folders in terms of the reality environment's coordinates), delay (delayed presentation of one or both AR folders, occurring within the device itself) and the issue of collisions between virtual objects and the reality environment (Azuma, 1997; Dunleavy et al. 2009). The first two problems in particular are closely related to the system's rate of susceptibility to technological errors related to augmented reality component configuration.

Systems which perceive the virtual component through the device are more prone to delayed content presentation, erroneous registration and direct perception of the reality component (the system responds insufficiently to rapid changes in management information, e.g. the rapid movement of a mobile device, during which registration is inaccurate). This problem primarily occurs in systems using GPS and mechanical sensors (mobile accelerometers and gyroscopes) which, due to the technical design of said sensors, cannot minimize their response time needs. Similarly, in systems based on scanning and image analysis which have a reduction in the demand for computing performance, images are not scanned and analyzed in a sufficient frame rate. In fact, from a technical perspective, the occurrence of such errors is more complicated and various technical solutions are influenced by various factors in conjunction with the basic software of the given systems.

To ensure the proper collision of objects, the system should have information about the 3D position of the reality object, against which it may subsequently compare the position of the virtual object. This process is performed according to an approach based on either the position of the reality object, or depth maps of the reality environment against which the position of the virtual object is being compared (Breen et al. 2003). It follows that it is necessary to analyse the system's reality environment to ensure correct object collision.

3. Didactic specifics of augmented reality

Didactic specificity is considered to be a concept shaped by the totality of features and possibilities of a given didactic resource which, in terms of supporting the achievement of educational goals, distinguishes it from other resources. The basic function and essential particularity of augmented reality (in terms of the most general understanding) is its ability to link reality with virtual elements and present them in a reality environment. In terms of application functionality, it is augmented reality's ability (as a technical resource) to provide the addressee with a real-time reality that is purposefully supplemented with information through which they can learn the nature of interpretation, management, content expansion and immersively encourage other things in order to achieve the stated didactic goals.

The primary didactic specificities of augmented reality can also be viewed as a means of mediating the perception of augmented reality, which would be very difficult to achieve using other technical resources. This sense of the perceived virtual component is enhanced by its close coexistence with the surrounding reality environment. This function of mediating sensation is enhanced through increased immersion of the given environment, which may be influenced by its own self-mediated content, the type of device, and the quality with which the given content is presented. In this context, augmented reality properties and functions are close, in part, to virtual reality. This is especially the case as it relates to immersion, interactivity, simulation phenomena and model situations. At the same time, they are based on functional and didactic-specific environments in which augmented reality works. An apparent connection can therefore be found between didactic-specific augmented reality and didactic-specific virtual reality, or the virtual educational environment.

Klopfer describes augmented reality as a means of offering students the opportunity to experience or observe digital simulation in the context of a real environment. Augmented reality allows for the application of model practices learned in artificial or training environments within a realistic environment. However, it is partly dependent upon the use of equipment which permits full or partial mobility of the participant (depending on the type of didactic situation), such as a mobile device or HMD. Its basic function of combining reality with virtuality provides an augmented reality environment and its perceptions with varying degrees of information density (either reduced by masking certain elements of the reality environment, or increased by the addition of richer informational elements), which allows for the adjustment of the cognitive load placed on participants.

In terms of the mutual relationship between added information and a realistic environment, the nature of augmented reality is reflected in the character of the didactic aspect of AR, as the user (i.e. pupil) finds himself in an environment that is deliberately designed to provide the appropriate conditions to fulfil the educational purpose. As regards the nature of AR, it significantly increases the variability of the resulting environment's didactic possibilities, as well as the methods with which augmented reality can be used. Of particular note is the significance of different content resulting from AR, as well as its emotional impact on the pupil (as compared to the original environment or independently presented virtual information).

Within the framework of mediated augmented reality (RU1), which is characterized by the removal of certain information from the user's perceptual field, it is possible to reduce the emotional impact of the surrounding reality. It can, for example, be modified to allow a pupil to gradually acclimate to the given environment; it can also assume a certain reduction of information density. As regards usability in the context of didactic situations, this is a significant form of augmented reality which should be especially considered in the context of cognitive load levels (extraneous cognitive load and intrinsic cognitive load) of the resulting environment, as opposed to those of the primary.

In enhanced augmented reality (RU2), it is possible to predict an increase in the level of content information as compared to the original environment, as the virtual component is significantly associated with the primary environment. The existence of added information is theoretically predictable, even though it may not be completely adjustable or known to the pupil. As regards didactic methods and functions, they can, in this case, accentuate a primary demonstration of realistic elements which are intrinsically inaccessible to pupils through conventional methods. Furthermore, the exposition and fixation of the curriculum, in conjunction with the principle of clarity, are fulfilled by placing relevant virtual elements, phenomena or happenings into a realistic context. Both of the above-mentioned forms of AR are based on the effort retain as much substance of the original reality in order to more or less modify this reality. To fulfil this purpose, AR must therefore be characterized by high levels of realistic components in terms of the ratio to realistic and virtual components.

The didactic use of enriched reality (RU3) resides particularly in the mediation of virtual content which, in actuality, is not possible, advisable or economical to realise (e.g. due to historical, geographical, physical or security reasons) without the use of augmented reality. In terms of the ratio of AR components, the primary environment (reality component) can be nearly entirely suppressed in order to increase the pupil's sense of perception of the added information. It can be expected that the growing importance of AR, in terms of accentuating the virtual component, will also result in the degree of virtual component representation increasing toward the extreme end of the spectrum (RC2) - nearly-exclusive representation of virtual elements.

With regards to the educational use of augmented reality, it can be based on the above-mentioned didactic-specific and aspects find a number of educational purposes that predetermine augmented reality in its use as a technical educational resource. The main educational functions common to all didactic situations using augmented reality can be regarded as adjusting the degree of emotional impact of the resulting augmented reality environment, and cognitive load adjustment. These functions predetermine the use augmented reality in education in many different forms and in various ways, which, with regard to the aforementioned didactic aspects examined in the context of resultant aspects, can be summarized by the following five principal educational purposes: 1. Increase in information value, 2. Exposition of temporally and spatially heterogeneous phenomena, 3. Simulation of phenomena, events and processes, 4. Acquisition and building of competencies in model situations, 5. Management activities

4. Conclusion

Augmented reality can become innovative didactical tool and contribute to a more effective and better quality education activities through enhancing the system of didactic tools and their functions and become thus a suitable tool for supporting cognitive processes in various educational fields. This presumption is based on the properties of augmented reality, which owing to the combination of the real world with augmented information in various forms of their relation can increase informative value of the perceived, or mediated content and simultaneously provide various levels of mediality, or modality when transferring information through various perceptual channels with the use of suitable forms of interaction of the perceiver with the content.

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