Adaptive Augmented Reality: Plasticity of Augmentations

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ABSTRACT

An augmented reality system is used to complete the real world with virtual objects (computer generated) so they seem to coexist in the same space as the real world. The concept of plasticity [4][5] was first introduced for Human Computer Interaction (HCI). It denotes the ability of an HCI interface to fit the context of use defined by the user, the environment and the platform. We believe that plasticity is a very important notion in the domain of augmented reality. Therefore, we rely on it in order to introduce the concept of adaptive augmented reality. This concept is based on the triplet (user, environment and platform) constituting the context of use. Adaptive augmented reality can foster functional ability, ease of use and portability of new augmented reality applications. Thus, we describe in this paper three applications showing the adaptation of augmentation based on three variables: the scene illumination, the distance to the target and the ambient noise.

Categories and Subject Descriptors

H.5.1 [**Multimedia Information Systems**]: Artificial, augmented, and virtual.

General Terms

Algorithms, Measurement, Experimentation, Theory, Verification.

Keywords

Augmented Reality, plasticity, mobile computing.

1. INTRODUCTION

The term augmented reality was first used in 1992 by Tom Caudell and David Mizell to name the overlaying of computerized information on the real world. Subsequently, the expression was used by Paul Milgram and Fumio Kishino in their seminal paper "Taxonomy of Mixed Reality Visual Displays" [1]. In this paper, they describe a continuum between the real world and the virtual world (nicknamed mixed reality) where augmented reality evolves close to the real world, whereas augmented virtuality evolves close to the virtual world (figure1).

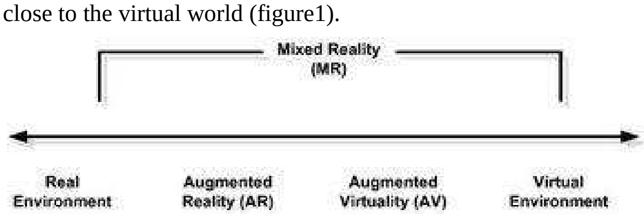

Figure 1. Continuum between reality and virtual reality

In 1997 Ronald Azuma developed a complementary definition which he completed in 2001 [2] and which, along with Milgram & Kishino's approach, gave two commonly admitted definitions of augmented reality. According to Azuma, an augmented reality system is one which complements the real world with (computer generated) virtual objects so they seem to coexist in the same space as the real world, which in both cases leads him to define the features of an augmented reality system according to the following three properties:

1. "Combining real and virtual". In the 3D real world 3D entities must also be integrated.
2. "Real time interactivity". This namely excludes films even if the previous condition is respected.
3. "3D repositioning". This enables virtual entities to be made to visually coincide with reality.

Displaying augmentations can be done with direct or indirect vision (thus inducing an additional mental load). In the case of direct vision, the display uses metaphors such as mirrors; smartphones open like windows onto the environment, vision through glasses or windows, etc.

All the definitions proposed in literature leave little room for multimodality. However, augmented reality has today exceeded the stage of repositioning virtual indices in a video flow and now also proposes sound and even tactile augmentations. To take into account the multimodal aspect of real world, we propose in our previous publication [3] a new definition of augmented reality: ***Augmented reality is the superposition of sensory data (digital or analog) to the real world, so that pursuing a definite goal; it seems to coexist in the same space as the real world.*** Our definition of augmented reality includes previous definitions to be more general.

Our current research study focuses on enhancing user experience in cultural heritage visits by using augmented reality. Like any other HCI interface, an augmented reality interface is sensible to the context of use. We assume that adjusting the augmented reality application to the context of use should have a positive impact on user experience. In this context, we find the concept of plasticity [4][5] related to Human Computer Interaction (HCI) very interesting. This concept denotes the ability of an HCI interface to fit the context of use, which is inherent to mobile computing and to the growing development of mobile devices (smart phones, tablets, etc.). We believe that plasticity should be a very important property in the domain of augmented reality. Indeed, display devices used by augmented reality are much diversified (HMD, video projection, glasses, etc.). Besides, augmentation perception is of a subjective character. The real scene is not static; it is subject to many changes related to the ambient noise, illumination, etc. Therefore, adaptive augmented reality by including the property of plasticity enables augmentations to fit the display devices, the user and the real scene. Adaptive augmented reality presents a promising concept that may foster functional ability, ease of use and portability of new augmented reality applications.

In the first part of this article, we detail the definition plasticity as presented in HCI. Then, we study the integration of this property to augmented reality through the concept of adaptive augmented reality. Three applications are presented in order to illustrate this concept. We consider this paper as an introduction to the concept of adaptive augmented reality. In our further publications, we will deal with measuring the effect of this concept on user experience through subjective studies.

2. DEFINITION OF PLASTICITY

Following the proliferation of computer terminals, HCI has evolved from a "hard" mode to a "plastic" mode. Thouvenin et al. [6] note that the property of plasticity has been introduced in response to the diversity of platforms. The term was inspired from materials that stretch and shrink to suit the heat, without being broken. By analogy, HCI interfaces could not be the same on big and small screens. Therefore, the idea of adaptation consists in hiding ergonomic inconsistencies between small and big screen versions. Thereafter, the environment was considered, then the user and the platform. The principal aim of plasticity is to convert HCI interfaces from centralized and sedentary to plastic, in order to dynamically redistribute them in the interactive area of the user.

Calvary et al. [4] [5] emphasize that plasticity enables HCI interfaces to fit the context of use defined by the user, the environment and the platform. In fact, plasticity is based on the recognition of the context of use. It computes the evolution of an interactive system depending on the context changes. In addition, the whole process of adaptation can be placed under the observability and / or the control of the end user via an Extra-HCI.

3. PLASTICITY IN AUGMENTED REALITY

3.1 State of the Art

Plasticity is a topic that has been little studied in augmented reality. For instance, Champalle et al. [7] used augmented reality in order to foster device transparency. Taking into account that HCI cannot be the same in small and big screens, they regulate the ergonomic inconsistencies between different screens sizes by using augmented reality. In this case, plasticity is used to ensure the HCI independence from screen size. In fact, augmented reality is proposed to compensate for small screen size of some devices. Small screens are augmented by adding digital supplements through the technique of augmented reality. The specific issue of their proposed application is to respect the perceptual continuity of the user.

In the next section of this article, we attempt to extend the notion of plasticity, well-known in HCI, to the augmented reality systems. Plasticity, as explained before, describes the adaptation of an application to the context of use formed by the environment, the platform and the user. At this stage of our study, we deal only with environment usually called real scene in the field of augmented reality. In this context, the environmental changes around the user of an AR system are detected. Therefore, the properties of the presented augmentations are modified to suit the new values of surrounding factors. The factors considered in what follows are: scene lighting, the position of the user estimated by his distance to the target and the ambient noise.

3.2 Distance to the Target

In this section, we focus on adapting the size of an augmentation depending on the position of the user, which is computed with respect to his distance to the target. The target means the point of interest (statue, monument, etc.) to be augmented. Obviously, the distance of the user relative to the point of interest, is used to set the value of the scale factor that should be applied to the augmentation.

Application

To illustrate the principle of the plasticity of augmentations, we have implemented an application that varies the size of augmentation with respect to the distance to the target. The scenario is as follows: The user stands in front of the Basque museum. Then, the AR application overlies a digital sign on the top of the museum's facade. As the user steps away from the museum, the application increases the size of the digital sign and vice versa. The size variation of the virtual sign indicates to the user if he is close or far away from the museum. To implement this scenario, the application needs to compute the following parameters:

- The relative distance of the user to the target (or point of interest)
- The scale factor of the augmentation

Distance Computing

There are several methods allowing user localization outdoor such as the GPS, the radio technology, the ultrasonic technology, the optical technology and the inertial technology. We adopted the optical method for its accuracy compared to other techniques. Indeed, our visual tracking method is based on PTAM [8]. Thus, the distance from the camera to the target is simply computed by finding the magnitude of the translation vector returned by the tracking algorithm.

Scale computing

The size of augmentation is trivially dependant of the distance from the camera to the target. Thus, the formula used to compute the augmentation scale is proportional to the target's distance:

$$\text{scale} = \frac{\text{maximum\_scale} \times \text{current\_distance}}{\text{maximum\_distance}}$$

Thresholds values for scale and distance have been experimentally determined. They are measured in scene unit which corresponds to opengl scene unit.

- maximum_scale : denotes the maximal scale of the augmentation. It is equal to 5.
- maximum_distance : denotes the maximal distance from the target, it is equal to 250 (in scene unit).

The figure below highlights the obtained results:

Figure 2. Plasticity of augmentations

3.3 Scene lighting

It turns out that the lighting of the real scene is very important for many augmented reality applications. Obviously, the ambient light affects the perception of the virtual data by the user. On the other hand, changing the lighting level of the real scene, depending on the ambient light, could be seen as scene augmentation. Therefore, the aim of this section is to augment the illumination of the scene based on the detected intensity of the ambient light. Subsequently, we detail our proposal for the technical implementation.

Technical principal

Bezryadin et al. [9] noted that the YUV color system, can be used for encoding audio-visual signal. In the YUV color space, the light intensity of a pixel, denoted Y, is called luminance. It is calculated by multiplying each component of the RGB model by the appropriate numerical coefficient, as shown by the following equation:

$$Y = 0.299r + 0.587g + 0.114b$$

Thus, to vary the intensity of light in an image, one should simply change the value of Y. Szeliski et al. [10] explained that to adjust the luminance value of an image, each pixel value should be multiplied by a parameter α, and then added to a parameter β. Assume that f (x) is the pixel of the source image and g(x) is a pixel belonging to the output image, we have:

$$g(x) = \alpha f(x) + \beta$$

The parameters α> 0 and β are respectively known, the gain and bias. Note that the function g (x) treats separately each of the three pixel components R, G and B. Thus, the precedent formula is used in order to vary the value of the luminance.

On the other hand, the smartphone of type Samsung Galaxy S2, includes a sensor for measuring the intensity of the ambient light. It returns the light intensity as a power of 10. The brightness detected in the dark is about 10 lux. The maximum intensity value is measured in the sunlight and it is about 10000 lux.

Figure 3. Android application for ambiant light detection

For the rest of this paper, we assume that maximum value of α is denoted max_α, and it is equal to 3. The maximum value of β is denoted max__ β, and is equal to 100. We denote by max_lum the maximum brightness detected by the ambient light sensor of the smartphone, and by curr_lum the ambient light value. In order to calculate the parameters of gain and bias, depending on the ambient light, we set up the following equations:

$$\alpha = \frac{\text{max \_lum}}{\text{curr\_lum} \times \text{max\_}\alpha}$$

$$\beta = \frac{\text{max \_lum}}{\text{curr\_lum} \times \text{max\_}\beta}$$

Now, knowing the new values of gain and bias, it is sufficient to calculate the red, green and blue values of each pixel of the frame.

Application

We remember the reader that the objective of our application is to adjust the lighting level of the scene to the value of the ambient light. In this sense, when the user is in full sunlight, the application enables to darken the camera frames. Otherwise, the application allows illuminating the real scene. For this purpose, β and α values should be reversed. The following figure shows the obtained results:

Figure 4. Illuminating real scene

In the figure 5, the left half of the screen represents the augmented scene.

3.4 Ambient Noise

The advent of digital sound suggests new opportunities for augmented reality. One can easily notice that there is a big similarity between the visual devices used by augmented reality and some of auditory devices. For instance, headsets of OST ("Optical See Through") type are analogous to the bone conduction headphones ("Audio Bone"). In addition, headsets of VST ('Video See Through ") remember the in-ear headphones.

We have seen that the concept of plasticity is essential for the HCI systems of mobile augmented reality. For audio, a good illustration of plasticity basically involves the adjustment of the level of sound. The sound is dependent on the hearing abilities of the user, with a level value ranging from 0 dB, representing the threshold of the perception of human ear. Sound's value can reach above 120 decibels for exceptional situations, and the harmful limit is estimated between 85 and 120 dB. The sound depends of course on the environment; it ranges from 0 to 30 dB in the country, from 30 to 50 dB in rest or relaxation spaces, from 50 decibels in the living areas. We should also note that weather conditions affect sound propagation.

Finally, the sound depends on the platform, such as the quality of the audio format and the performance of the sound card. We propose to adjust the properties of an audio augmentation with respect to the type of headphones and the noise level. For bone conduction headsets, the audio augmentation is added to ambient noise while the internal auditory canal remains fully functional. A headset or an in-ear earphone isolates the internal auditory canal, so that the surrounding noise is nevertheless perceptible. In general, a sound level meter is used to measure the sound level, in our context, we rely on the sound captured by the microphone of a Smartphone and generated in digital format.

There are several metrics to measure the ambient noise, and many applications can be downloaded to the smartphone. For averaging ambient sounds, we recommend using the application "NoiseTube" (http://www.noisetube.net/) available for Android as IOS , written in Java.

CONCLUSION

In this paper, we have attempted to extend the notion of plasticity well-known in HCI to the concept of augmented reality. In fact, we believe that augmented reality should be adaptive with respect to the environment, to the user and to the platform. For this purpose, we illustrated our concept of adaptive augmented reality by three applications which take respectively into account the size of augmentations, the illumination level of the real scene and the ambient noise. We think that there is still a lot of work to be done in adaptive augmented reality especially with the adaptation of the augmentations to the user and the platform. In our further publications, we will present experimental results related to the application of adaptive augmented reality in cultural heritage visits.

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