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A mixed environment for ergonomic tests: tuning of the stereo viewing parameters

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Abstract

Virtual Reality and related technologies are becoming a common practice in the design industry in general and more specifically in the automotive field. By the joined use of virtual prototyping methodologies it is possible to achieve the reduction of the time-to-market, as well as the costs deriving from the creation of physical prototypes. Ergonomics tests conducted in Virtual Reality environments can be successfully used to influence the design of products. We have set up a mixed reality environment that allows us to simulate and test postural aspects as well as various levels and modalities of users' interaction. In order to achieve a performing interaction, correct registration and visualization parameters must be carefully set for preventing possible interaction errors, such as pointing with precision to the assigned target. The paper presents a methodology for tuning stereoscopic properties of the mixed reality environments used for ergonomic tests of a car interior in order to achieve correct visualization and positioning parameters. The environment includes a virtual human controlled by an optical motion tracking system, physical objects onto which the graphic virtual environment is superimposed, and a rotatory haptic device for controlling the car on-board infotainment. interface.

Categories and Subject Descriptors (according to ACM CCS): I.4.8 [Image and processing and computer vision]: Ergonomic Analysis

1. Introduction

Virtual Reality (VR) based technologies, after more than twenty years of development, are spreading out in many different fields ranging from edutainment applications up to military or design fields. VR in general allows users to dive into a completely synthetic computer generated world where human senses are stimulated by a computer and at the same time actions of the users are able to influence the produced stimuli defining new interaction paradigms [BR05] Actually, most of the technologies now in use have been conceived long time ago. If we turn back to the past we can find out that the first Cyberglove was invented in 1984 and already in the early 60's the Sensorama simulator by Mort Heiling was the first example of Head Mounted Display (HMD). Stereoscopic vision has even been studied more than a century ago by Wheatstone. What makes the difference is that most of technical limitations deriving from computational costs and hardware set-up have now been solved and these improvements have made feasible to accomplish aspects related to high-quality visualization and good interaction performances. Virtual Reality can be interpreted at a broader extent, as clearly explained by Milgram in [MDG*95]. It must not be only interpreted as simple immersive reality, but in between it is possible to define a wider range of mixed technologies dimming to physical reality, named Augmented Virtuality (AV), Mixed Reality (MR) and Augmented Reality (AR). These new concepts based on the integrated use of different technologies have opened up new opportunities, new benefits, but also new complexities at system architectural level. In the design field of industrial products the use of VR technologies is becoming popular for porting most of the activities related to validation and testing of the To-Be product into the parallel virtual environment and, by consequence, avoiding the production of costly physical prototypes. The technique dealing with the simulation of the various aspects of a product performed in a virtual environment is named virtual prototyping. Virtual prototyping ranges from quantitative testings, such as those provided by structural analysis to mostly qualitative simulations such as visual photo-realistic rendering. For what concerns the interaction aspects with virtual prototypes, it is possible to find different kinds of applications, generally ranging from typical desktop-based up to power-wall or immersive HMD solutions. One of the industrial areas where virtual prototyping tools are mostly exploited is the car design field [MSM04], where the high costs of producing physical prototypes clearly justifies the investments in the acquisition of high-end Virtual Reality technologies, and the complexity of the technical virtual validation environments. To this regard, most applications [Bar04] are today based on immersive environments or low-complexity mixed environments. These environments try to simplify the complexity of the real phenomena. In fact, in an immersive environment actual motion and perception are relative and the human brain can easily adapt to the new condition, in a mixed environment [CGBF06]. The situation becomes more complex in case of coexistence of the virtual and the physical world into one perceptual space. On the other side, the use of mixed environment simplifies the rendering of interaction and simulations aspects. In fact, in a mixed-reality environment it is possible to have realistic kinesthetic feedback by directly touching an object, or it is possible to have direct interactions without the need to track the position of other body parts. In this case, a consistent registration between synthetic augmentations and the real environment is the most important target for having coherent interaction.

Our research group is investigating the use of immersive and mixed reality technologies for ergonomic analysis of vehicle design. The goal of one study concerns the analysis of a car driver's distraction related to the use of on board infotainment system. For this purpose we have set up an environment where the tester wears a HMD whose position is tracked by the VICON optical motion capture system. The HMD used is a see-through device displaying 3D graphics superimposed onto real physical objects in the scene, such as the armrest or a command knob. The knob is computer controlled providing a 1 degree of freedom (DOF) haptic feedback and is connected to a graphical user interface visible on a display positioned within the simulation environment in a position coherent with the real position of the onboard display within the car dashboard. A number of problems arose mainly dealing with the correct distance and depth perception measurement, besides the common superimposition problems typical of augmented applications. In this paper we address the issues related to stereoscopic vision in the mixed interactive environments we have developed for ergonomic analysis and describe the proposed solution which aims at providing more accurate and reliable simulation data.

2. The experimental set-up

Virtual Reality and Mixed Reality generally make use of different devices, sometimes instead some VR devices can be adopted for MR applications, as in our specific situation. To develop our experiment a specific hardware and software set up has been conceived by combining different commercial solutions deriving from Virtual Reality field, adapted to mixed reality, and one haptic knob developed on purpose. Specifically, we have used the following hardware and software components, explained in more details in the following:

- NVIS nVisor ST semi-immersive display
- VICON motion tracking system
- UGS Jack software
- Haptic knob (self made)
- Adobe Flash

2.1. Head Mounted Display

For the visualization of the interior of the vehicle we use a stereoscopic optical see-through head mounted display, the nVisor ST HMD. This device is a high-resolution optical see-through head-mounted display designed for mixed reality applications requiring a wide field-of-view format with superior SXGA image quality (http://www.nvisinc.com). High efficiency optics incorporating reflective-transmissive polarizers increase light-throughput, presenting a high-contrast virtual image while allowing 50% light transmission from the environment. The technical characteristics of this HMD can be found at [Ber06] and are the following: the horizontal field of view is 48 degrees (same of the adjusted field of view), the vertical field of view is 36 degrees, the resolution of the displays is 1280x1024 and finally the overlapping angle is 48 degrees. The use of this HMD allows us to obtain the simultaneous visualization of the virtual environment created with the ergonomic testing software UGS Jack (www.ugs.com/products/tecnomatix/human_performance /jack) and the physical environment consisting of a display visualizing the status of the connected haptic device. This technological solution has allowed us to quickly develop the testing environment. The user will continue to see himself inside the scene and that will increase his sense of presence within the environment. In order to improve the visualization of the user's arm we used a light directed to the subject. This contributes to increase the occlusion of the virtual objects with the real ones when this is demanded.

2.2. Motion tracking system

In order to obtain the head tracking in the way to orient the point of view as that of the user, we use the VICON 460 optical motion capture system (http://www.vicon.com). Motion capture is the recording of movement marked object by an array of video cameras in order to reproduce it in the digital environment. The Vicon system is composed by hardware components (high frequency cameras, IR flashes and data station) and software applications for the complete control and analysis of motion capture. A typical motion capture space comprises an area (the capture volume) surrounded by a number of high-resolution cameras (six in our configuration). Each camera has a ring of LED strobe lights fixed around the lens. The user, whose motion is to be captured, has a number of reflective markers attached to his body, in defined positions. The markers are spheres that reflect infrared light from the strobes back into the camera. For this full body capture, spheres of 14 millimeters diameter are used. Markers set-up consists fundamentally of the markers' correct positioning on the subject who is going to do the movements. It is necessary to stick them onto the user's body considering that they must be seen as clearly as possible by the cameras, and that they must fit at best with the digital human model previously created. As the subject moves through the capture volume, light from the strobe is reflected back into the camera lens and strikes a light sensitive plate creating a video signal. The Vicon Datastation controls the cameras and the strobes and also collects these signals, and then passes them to a computer on which the Vicon software suite is installed. VICONiQ 2.0 is the central application of the Vicon software suite used to collect and process the raw video data. It takes the two-dimensional data from each camera, combining it with calibration data to reconstruct the equivalent digital motion in three dimensions. This can be viewed in VICONiQ 2.0 as a virtual three-dimensional motion. After this reconstruction the data may be passed, live or recording, to other Vicon applications for analysis and manipulation or to third party applications such as those used for digital animation or virtual environments. In our case data are passed to UGS Jack (Fig.1). VICONiQ 2.0 is connected to Jack through the ViconProto Module that allows total body tracking. We have created a software macro for obtaining only the head tracking. In this way the system user will be able to see the environment from exactly the same perspective of the digital human.

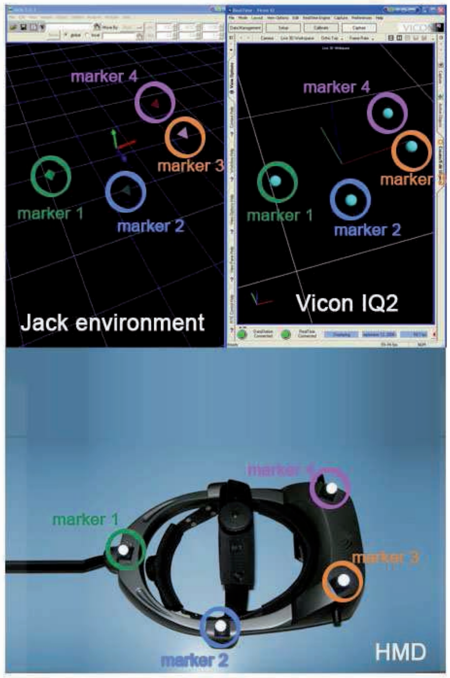

Figure 1: *HMD marker positioning.*

2.3. Ergonomic validation software

UGS Jack is an ergonomic and human factors tool to support designers to improve the ergonomics of product designs and workplace tasks in various industrial fields. This tool enables the users to position with a biomechanical methodology accurate digital humans in virtual environments permitting furthermore the assignment of different tasks and analyzing their performances. Jack digital humans can tell engineers what they can see and reach within virtual interactive environment, how comfortable they are, when and how they are getting hurt, when they are getting tired and other important ergonomics information. This information is used to define and design safer working organizations and more effective products without the requirement to develop physical prototypes. We have decided to use Jack because it allows developing and testing the virtual environment in a simple and effective way gathering important ergonomic data at the same time. We have developed a virtual cockpit using a CAD tool, which has been easily imported into Jack suite software package. Jack gives us the possibility to obtain the stereoscopic image from the eyes perception of the digital human. This function allows us to obtain two video signals to reconstruct the depth of the scene and therefore providing a stereo image to the HMD.

2.4. The haptic knob and interactive interface

The testing environment planned the possibility to test the use of an on-board infotainment system. In order to define the command interface of the infotainment system, we have developed a haptic knob connected to a visual interface developed using Adobe Flash. This configuration allows the final user to receive both visual and kinesthetic information. Designing a haptic interface is not a simple task, since it is directly in contact with the user that cannot be represented with a simple model or transfer function. This causes several problems that concur to make the device unstable [CDF06] [CSB95]. In order to simulate the behaviour of a real control, the haptic device must exert to the user a force (or torque in case of a knob) function of the position (and the velocity) of the control device itself. A device that performs this task can be then considered a 1 DOF active mechatronic device. The force considered on the haptic model is split into three components representing respectively elasticity, friction and viscosity.

For our specific experimental set-up we have defined seven different haptic behavior occurring in the different menus and context based controlled by the graphical user interface. Using Adobe Flash (http://www.adobe.com/flash) we have designed and displayed the interface related to the

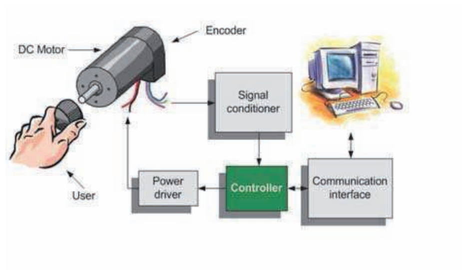

Figure 2: *Architecture of the haptic device.*

typical main in-car control functions (A/C, radio and navigation) in an extremely credible way. Secondly, due to the property of Action Script programming language it has been possible to define a graphical knob on the interface whose movements and actions were coherent with the haptic knob. Specifically thanks to the server-client settings it has been possible to establish a connection with the haptic controller and consequently to run the simulation in the physical environment of our set up.

3. Physiology of vision

Each one of us has different perception of the world and most of the body movements are based on the relationship of distances and kinesthetic feedback that the brain defines [Lov89]. The question is if it is possible to define a universal layout based on see-through HMD where absolute distances and depth are reliable. Computer visualization is based on a simplification of the visualization cues at different levels depending on the software package used (used libraries and intrinsic algorithm definition) and the output hardware (typically bidimensional with or without stereoscopic features). Between the two dimensions, human and computer-based, settings and visualization properties have to be constantly optimized.

Since the task of an immersive environment is intrinsically related to navigation and interaction in a three dimensional environment, depth perception is fundamental. Depth perception does not necessarily imply binocular vision; instead, some cues can help to improve the perception. When we perceive an image in a scene, it is possible to derive some relative data as interposition between the target object and another object placed in the scene whose occlusion itself defines a spatial depth. Furthermore, any objects we perceive with our eyes are related to a linear perspective and positioned in an environment where lights and shading subsists. The perspective itself defines a relative size of the object varying on the distance and the distance itself is conditioned in the natural world by aerial perspective, i.e the fact that farther objects have lighter colors. Besides these issues, monocular depth can be also provided by motion parallax (when a person observes an object and his moving, the perspective is continuously updated defining the depth of the scene) and occlumotor cues (that are defined by the movement of the muscles that move the eyes). On the counterpart binocular perception can define a stronger and more vivid sense of depth and can increase the sense of immersion in a given virtual environment.

Still, in order to set and be able to master stereo vision parameters within the computer graphic settings, it is important to comprehend the functioning of human stereovision at a physiological level. First of all, the world geometry can be described as Euclidean based, but indeed, the human eye, being spherical is working with a non Euclidean geometry since the 3D world is projected on the semispherical surface of the retina and this causes some complex non linear distortion of the perceived image. Secondly, the human vision is based on two eyes view with a horizontal visual field of 190°, and 110° of whose are based on overlapping binocular field. Because of the mechanism defined as *binocular disparity*, defined as the difference of two retina images belonging to the same world it is possible to get stereoscopic vision. Besides the eyes have different movement and arrangement possibilities to focus on a specific target. We can define as *accommodation* the property of the crystal in front of the retina to change its curvature to focus to closer or farther targets and *convergence* as the possibility of the eyes to rotate inwards to overlap the target in both retinal positions or *divergence* to rotate outwards to focus on more distant objects. Basically any object lying on the imaginary circle that runs through the 2 eyeballs keeping the attention on a target object (Vieth-Mueller Circle) is projecting an image on the corresponding fovea points. Objects that fall on corresponding retinal location are said to have zero binocular disparity and are said to lie on the *parallax* plane. If the two eyes are looking at one spot there will be a surface of disparity running through that spot. That surface is known as *horopter* [WKL*05]. Any object placed on that imaginary surface in the world will form images on corresponding retinal locations. Objects that lie in the horopter will be seen as single objects when viewed with both eyes; object significantly closer or farther away from the surface of zero disparity will form images on decidedly non corresponding points in the two eyes and will be perceived as to distinguished objects. This region of space in front of and behind the horopter, within which binocular single vision is possible is known as *Panum's* fusional area. Still it becomes of course possible to focus on objects placed father or closer than the horopter. It is then possible to define the concept of crossed disparity when the object in focus is closer than the horopter and by consequence the object placed will appear to be displaced to the left in the right eye and to the right on the left eye and specifically it will appear as lying closer to the point of view before the parallax plane. Vice versa when the object lays farther away then the horopter, the image will be defined as uncrossed since the object behind the horopter will appear to be displaced to the right in the right eye and to the left in

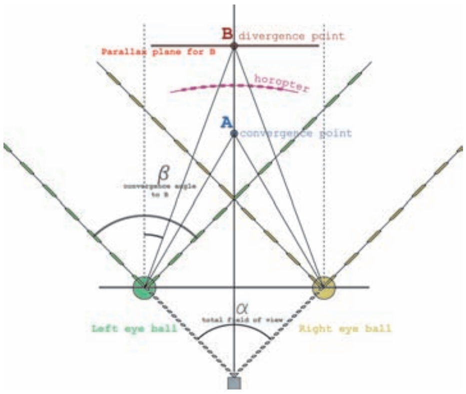

Figure 3: *Elements present the view field.*

the left eye and by consequence the stereovision will appear to be "behind" the parallax plane. The representation of the HMD parameters is slightly different, in fact we encounter two separate visions for each eye, with the overlapping area (the one which provides stereovision) coincident with the total field of view available for the given HMD. Intrinsically the HMD takes some limitations over. In fact the focus of the eye is fixed on the screen of the display and the gaze of the user on the screen is not tracked and by consequence the provided visualization is not physiologically adaptative to the depth of field and some inconsistencies may exist. Still the provided stereoscopic view can be defined as high quality because of the provided contrast and color displayed and the sense of immersion within the virtual environment. For what concerns UGS Jack, it is possible to define two different stereo settings, based on quad-buffer visualization mode (typically used for desktop based situations and by the use of shuttering glasses) and dual channel (typically used in HMD with dual channel input for a better stereo visualization). The stereo parameters of UGS Jack permits us to set some intrinsic and editable parameters. For example, it is possible to set the position of the camera, whether it has to be through Jack's eyes or independent and the aspect ratio of the visualization window. Editable parameters are four: eye separation, zero parallax distance, horizontal field of view and $\frac{1}{2}$ parallax angle. Beside the user adjustment of pupillar inter-distance, all the other parameters act directly set on the perspective visualization of the virtual scene and are connected to each other. Zero parallax distance can be defined as half distance between the first object in the scene and the farther object from the point of view of the virtual human. In our specific case the zero parallax distance was set behind the steering wheel in order to define a deeper visualization field. Concerning the HOV (Horizontal Field of View) it can be manually set and can vary from a minimum angle of 10° to 170°. The ¡ parallax angle is defined as the angle of rotation of the virtual camera on its axis to point the zero parallax plane from straight pointing. Some considerations have to be made. First of all, when the two windows are defined is possible to define the dimensions and by consequence the aspect ratio. The aspect ratio of the two windows is particularly important in order to grant a correct perspective view since it becomes the input information for the HMD and intrinsically defines the vertical field of view of the OpenGL perspective model based on truncated pyramid visual field.

Still it is important to highlight some limitations of UGS Jack as immersive tool. It is not possible to eliminate the upper interface widget and by consequence there is a distortion of the declared output pixels which results smaller than the affirmed value causing approximately 1% of vertical compression. Secondly some important visualization cues as depth haze or high quality shading are not available and by consequence the provided output visualization depth may look unrealistic. The target of any VR based simulation consists in matching the human visual properties and abilities with the virtual ones provided by the system in order to provide a performing and reliable interaction. In our specific application, where it was necessary to have an ergonomic validation tool within a virtual environment, we have found some misleading parameters for what concerns stereo viewing. In fact, even if qualitatively the visualization was coherent with the main parameters, we encountered misleading distances in absolute terms and inaccurate image superimposition to the physical environment. The objective of our work has concerned the tuning of the visualization system.

4. State of the art in mixed environment visualization tuning

See-through HMDs augment the user's view of the real world by overlaying or compositing three-dimensional virtual objects with their real world counterparts. Ideally, it would seem to the user that the virtual and real objects coexist. The real and virtual objects must be properly aligned with respect to each other, or the illusion that the two environments coexist will be compromised. This is difficult to achieve because of the precision required that has to deal at lest with position, perspective coherence and scale. The human visual system is very good at detecting even small mis-registrations, due to the resolution of the fovea and the sensitivity of the visual system to differences. Besides, to achieve a reliable interaction, correct positioning and dimensions of the virtual objects over the physical environment are directly dependent on a correct calibration and registration of the HMD.

Generally the main issues about HMD's registration, are about the following aspects:

- distortion in the HMD optics;
- mechanical misalignments in the HMD;
- errors in the head-tracking system;
- incorrect viewing parameters (field of view, tracker-to-eye position and orientation, interpupillary distance);

- end-to-end system latency.

The first four categories may be classified as static errors, because they cause registration errors even when the user keeps his head completely still. The 5th category, end-to-end latency, is a dynamic error, because it has no effect until the user moves his head.

Other problems are persistent when optical see-through HMD are used for mixed-reality applications and they can not be corrected by means of a registration. They are the following:

- lack in resolution that is due to limitations of the applied miniaturized displays. In fact the real environment can be perceived in the resolution of the human visual system while the graphical overlays suffer from a relatively low resolution.
- limited field of view is due to limitation of the applied optics and/or implicit field of view of the device.
- visual perception issues are due to the constant image depth. Since objects within the real environment and the image plane that is attached to the viewer's head are sensed as different depths, the eyes are forced to either continuously shift focus between the different depth levels, or perceive one depth level as unsharp. This is known as the fixed focal length problem [BR05].

A first example of registration is described in [AB94] where it was developed a registration set-up composed by a wooden frame. This wooden frame was used to compare the position and the orientation of virtual orthogonal extruded squares that form a coordinate system. The goal was relative to the registration of the intersection of the three virtual bars with the front left corner of the frame, where the three bars run along the edges that touch the corner. This task is a good registration test because it is easy to detect small position and orientation errors along the edges of the frame but the registration parameters are derived from human perception without experimental more precise measurement. In other successive works, instead, the registration task was based, substantially, on the use of a calibrated cameras to mimic the user's eyes, and therefore based on the consideration of known optical parameters. In [MT99] the authors mounted a camera inside the head of a physical mannequin where the eye would be located. Then they attached the head to a camera tripod and placed the *i-glasses*™/marker assembly onto it as if it were a real person. The head could be rotated through the use of the tripod controls. Note once again, that this experiment was performed strictly for the purpose of reporting objective results and gathering quantitative error measures. In the real set-up, the user wears the see-through display/tracker mark assembly and his eye becomes the camera for which the parameters are estimated. In [TN00] we find a setup similar to the previous one, but in this case the calibration is based on the alignment of image points with a single point in the world coordinate system derived from magnetic tracker emitters. In [GSW*00] it was developed a stereo method validated with a video see-through system. In [GTKN01] they propose to keep the projection matrix for the tracker camera without decompositing it into intrinsic and extrinsic parameters. The propagation of the projection matrices from the tracker camera to the virtual camera, representing the eye and the optical see-through display combination as a pinhole camera model, allows us to skip the most time consuming and potentially unstable step of registration, namely, estimating the pose of the tracker camera. In [CHA03] it was proposed a fast and easy off-line calibration strategy based on well-established camera calibration methods. This method does not need exhausting effort on the collection of world-to image correspondence data. All the correspondence data are sampled with an image based method and they are able to achieve sub pixel accuracy. In of these works the research was directed it was necessary to interpose a third medium like a camera or new referencing system to set up the calibration before the actual beginning of the analysis. This kind of approach involves some negative effect on the global calibration itself since the description of the system becomes exponentially more complex.

5. Proposed solution

In order to achieve correct perspective visualization properties and to increase the accuracy of the superimposition between the virtual and physical environment a specific set up has been designed. Generally in our scene we have four main elements that are: the tester, the virtual dashboard of the car superimposed on a block of foam, the haptic knob and a LCD displays with the flash interface that displays the infotainment navigation system. For the tuning session we use instead a block of foam of a known simple geometry, basically a prism, with the VICON reflective markers positioned over 3 faces.

Once tracked the block of foam we create with VICON IQ a subject that has the centre in one of the vertex of our block. This subject will be transferred to UGS Jack via the VICON proto module as a reference system. We then attach this reference system at the same vertex in the virtual model. So moving the real block also the virtual block will be rotated and translated in the same way. Then we track the head of the user by positioning some markers in an asymmetrical way over the HMD.

In order to obtain a coherent navigation within the mixed environment, it is necessary that the HMD is tracked by the motion capture system in correct way. The position of the virtual camera must coincide with the centre of the human view. Also in this case we create a VICON subject to be transferred to Jack. In this case the choice of the centre of the subject must be set extremely carefully because it will correspond within the jack environment to the position of the eye view camera. To prevent this kind of misleading visualization it has become necessary to refer the marker set to some HMD parameters. In fact the image is subject to three

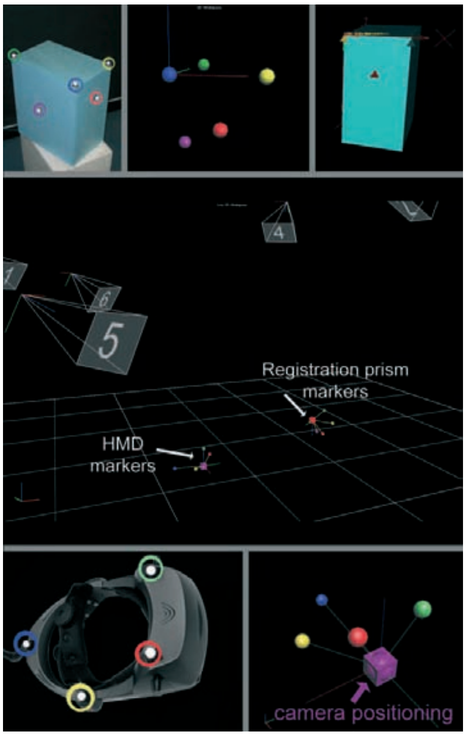

Figure 4: *Calibration Setup, marker positioning in the scene.*

Figure 5: *Calibration Phase.*

main different level of correction that are from UGS Jack to the window with consequent different aspect ratio properties, from this window to the HMD with a different aspect ratio and overlapping angles of view and from the HMD to the retina of the user. Furthermore also the orientation of the axis related to the subject are important because in Jack the camera is placed along the negative z axis. The right position of the centre is about 26 mm behind the HMD LCD, as described in reference manual, while the vertical position has been calculated for our specific HMD. Both the parameters have been finely adjusted around this two known numbers of variables in order to obtain better performances. If we affirm that in physical reality, as expected by the project, the distances between those object are fixed and defined, by consequence from the tester viewpoint there is just a single correct perspective referred to these object in the scene. In this way, being known the position and the movement of the main point of view of the tester, the perspective settings are implicit. Therefore the viewing angle of the tester within the HMD has to match with the performance of the two monitors and they have to match with the Jack's FOV. The Jack editable parameters to define a correct visualization are: HFOV, $\frac{1}{2}$ parallax angle ad the zero parallax distance and interpupillar distance. Once fixed two of the last three the third is defined because there's a simple trigonometric relationship between them:

$$\frac{1}{2}E_s = Z_p \cdot tan\alpha$$

where E_s is the Eye Separation, Z_p is the Zero Parallax Distance and α is the $\frac{1}{2}$ parallax angle as represented in the figure.

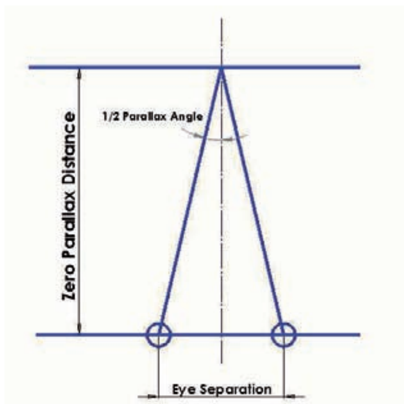

Figure 6: *Visualization parameters.*

The interpupillar distance, can be simply measured in the tester. So the only parameter left to tune is one between the

$\frac{1}{2}$ parallax angle and the zero parallax distance. The HFOV has been found in literature [Ber06], where we can see that the value declared from the manufacturer corresponds to that really perceived by the user.

In this way we reduced the tuning independent parameters just to one and so minimized the subjective error due to manual setting of the parameters. Moving the prism in the space we were able to see if our tuning brought to a correct perspective superimposition and a right stereo visualization, and good results in these terms have been achieved. This kind of setting involves some limited misalignment, but compared to the previous situations the error is minimized and perspective settings are coherent for any user.

6. Conclusion and future developments

The aim of this paper was to solve perspective and stereo problems for a particular mixed reality application related to ergonomic tests. The proposed solution has been a sort of calibration in which we an effort has been made to minimize the subjective aspects due to the devices and to the user, that we can find in the classical tuning calibration of the optical see-through HMD, by using some theory deriving from the literature. However we didn't create an automatic tuning algorithm to solve the problem, so in the future we are going to define a system directly using the resources of the tracking system that, considering the position of the tester and the intrinsic point of view, and the physical position of the marked object in the scene on which superimposition occurs, is able to calibrate automatically by calculating correct perspective parameters being know the distances and the angular relationships between the elements by creating a loop between VICON and Jack parameters. Futhermore we'll continue to pursue our research on dynamic virtual environments, to make mixed reality ergonomic tests become a reliable alternative to those in real environment, by integrating other senses as hearing and adding other haptic devices and more complex interaction modalities.

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