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Positioning of objects for real-time application of virtual reality

***Abstract**. Virtual Reality Applications that run in real time, often require to use of advanced measurement systems. Studies have shown that the application of hybrid solutions can be an alternative for dedicated but expensive Motion Capture systems. The article presents the preliminary results of investigations under the virtual environment uses for objects positioning industrial cameras and gyro sensors..*

***Streszczenie.** Aplikacje wirtualnej rzeczywistości, które działają w czasie rzeczywistym często wymagają użycia zaawansowanych systemów pomiarowych. Badania pokazują, że stosowanie rozwiązań hybrydowych może być alternatywą dla dedykowanych ale kosztownych systemów Motion Capture. W artykule przedstawiono wstępne wyniki z prac nad środowiskiem wirtualnym wykorzystującym do pozycjonowania obiektów kamery przemysłowe z oświetlaczami oraz czujniki żyroskopowe. (**Pozycjonowanie obiektów w czasie rzeczywistym dla zastosowań wirtualnej rzeczywistości**).*

Keywords: image processing, positioning objects in 3D, virtual reality.
Słowa kluczowe: przetwarzanie obrazów, pozycjonowanie obiektów w 3D, wirtualna rzeczywistość.

Introduction

Currently, more and more frequently we use modern methods of training of various professional groups. One of them are simulators using virtual reality environment. If the application requires "immersion" of trainee in the virtual environment [1] and interaction with the objects of the real world, it is necessary to use an appropriate measuring system. Such a system should allow for positioning of objects in 3D in real time with sufficient accuracy.

Nowadays there are several methods to obtain spatial information for the application of virtual reality. First of all the choice of solution depends on the size of the modeled 3D scene and scope of activities performed by the trainee [2]. In the case of small-scale solutions, it is possible to use eg. RGB-D camera, gyro sensors.

In situations when the trainee should move in space, there are used techniques such as Motion Capture (MoCap) or CAVE (Fig. 1).

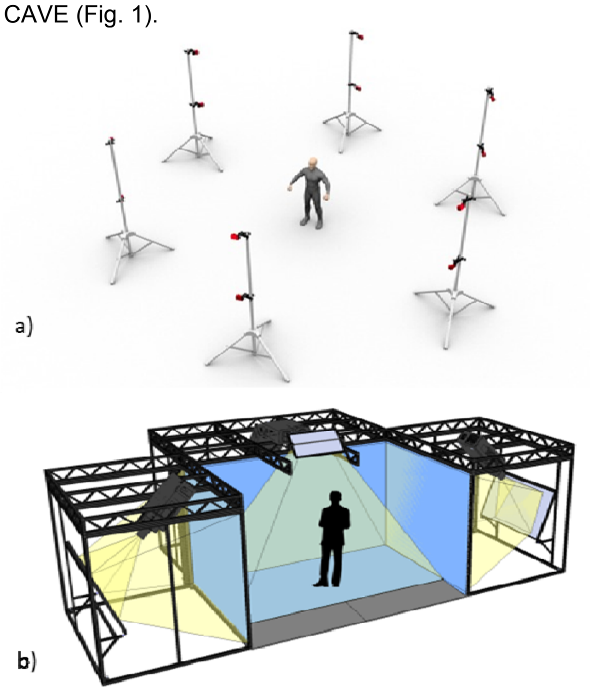

Fig.1. Systems: a) MoCap, b) CAVE [3]

Driving force of the development of technologies for VR environments is primarily entertainment industry. The need to offer more enjoyment from playing computer games carries to the engagement of all senses (eg. touch, smell).

Indirectly, this is a reason of the increase in the number of tools for creators of training and information systems using virtual reality technology. This is the aim of research carried out by:

- large companies (such as: Microsoft, Sony, Samsung, HTC)
- research centers (e.g. University of Salford, University of Texas at Dallas and San Antonio, Osaka University, University of Tokyo, University of Central Florida, Universit¨at Hamburg) as affiliated by available scientific publications,
- small emerging companies that start with the so-called Kickstarters (e.g. Oculus Rift, STEM System, Virtual Terrain Simulator, Gloveone, FOVE, Cyberith Virtualizer).

The investigations under the solutions for the so-called Augmented Reality (AR) were conducted for several years and finally enabled to start construction of the VR simulator [4,5,6]. From the application point of view of both AR and VR technologies can benefit from the same technical solutions in the field of positioning and locating objects in space. They differ from each other in the amount of information generated by computer. In the case of AR application computer-generated information is usually a small complement of the real world. VR applications is an environment wholly computer generated [7,8].

Dependencies between these two types of applications have been shown in Figure 2.

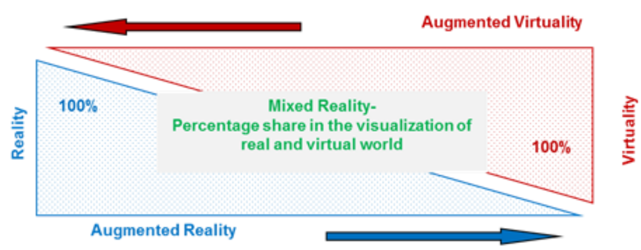

Fig.2. Diagram Reality – Virtuality

For VR simulator, the following elements should be taken into account:

- tracking of the trainee in a small area (room),
- introduction to the simulation of virtual objects having their representation in a real environment (the ability to use real objects). Was decided to use a hybrid solution combining the Motion Capture and MEMS sensors for determining the position and orientation of key objects in space.

Demonstrator of VR simulator

From the point of view of the planned VR environment the following elements are essential:
- training scenarios,
- way of trainee interaction with the virtual environment,
- intertwining of real and virtual world,
- the application of graphics engine (game engine),
- applied technologies to capture data about the scene objects.

The elements of hardware and software have been shown in Figure 3.

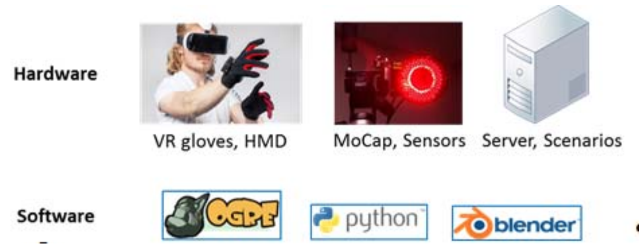

Fig.3. Components of VR training simulator

The proposed simulator for Border Guards is to implement three basic scenarios related to:
- automatic check – Gateway ABC,
- manual Check – type airport,
- mobile check in a train compartment.

For each of the scenarios a different type of VR applications was proposed to be used. In the case of gateway ABC – The trainee mainly oversees computer generated scenario from the third person point of view. Manual checks applies to immersion in the VR environment from the point of view of border guard that supports travelers approaching to the checkpoint. Mobile checks require the interaction with the travellers which are present in a train compartment. Each of the scenarios requires the different kind of measurement systems.

The main difficulty consists in the fact that the used measurement system must keep track of the real movements of the trainee (position and orientation of the head and hands) and transmit them in real time to the software, which synthesizes the virtual world (fig. 4). In addition, the selected objects of virtual environment are represented in the real world. Positioning of these objects is required to allow the interaction with each other.

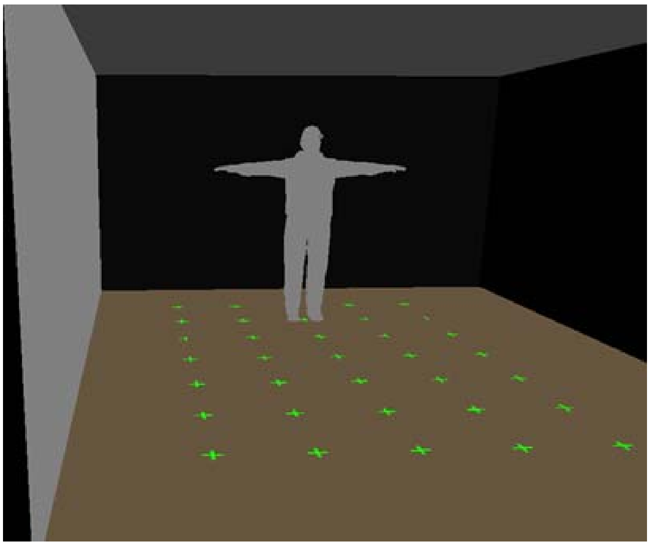

Fig.4.Virtual environment – the demo scene

Characteristics of the measurement system

Subsystem responsible for the location and orientation of objects in space is one of the basic elements of training simulator. The task of this measurement system is to provide information to the graphics engine on the position of the key objects. They have their representation in both the real world and the virtual environment. The key objects are the head and hands of the trainee in the implemented application. These objects are also selected device which can be used by a guard during check (fingerprint reader). The conducted works were aimed to find a solution that would fulfill the requirements for acquisition capabilities position several objects simultaneously. In addition, it is very important that the whole process of positioning was implemented with minimal latency. It is equally important that its accuracy does not cause discomfort in the visual perception through display-type HMD.

Preliminary tests were performed using a dedicated system Motion Capture – OptiTrack. The test system consisted of 12 cameras S250e:
- FOV: **56 °,**
- resolution: **832x832 (0,7MP),**
- the **number of frames per second: 250 fps,**
- latency: **4ms.**

Figure 5 shows a room with installed MoCap system.

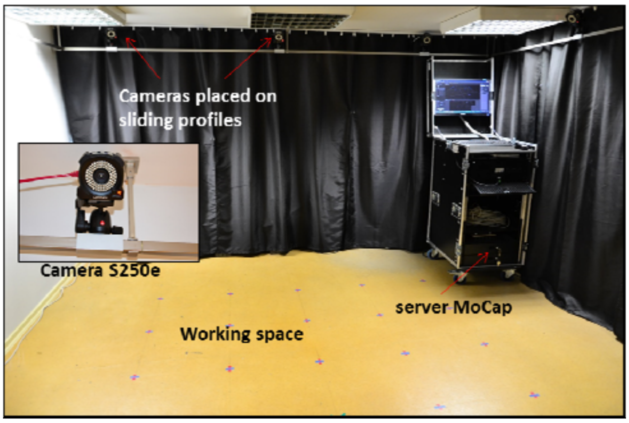

Fig.5. System MoCap – OptiTrack

By assumption, Motion Capture Systems offer the possibility of location and determination of the objects orientation in space. Properly calibrated cameras allow, through algorithmic analysis, to determine the location of retroreflective markers. Determining the orientation of the objects becomes possible when the unique for each object pattern will be created. The pattern (shown in Figure 6) must consist of at least 3 markers (3 points uniquely define a plane in three-dimensional space).

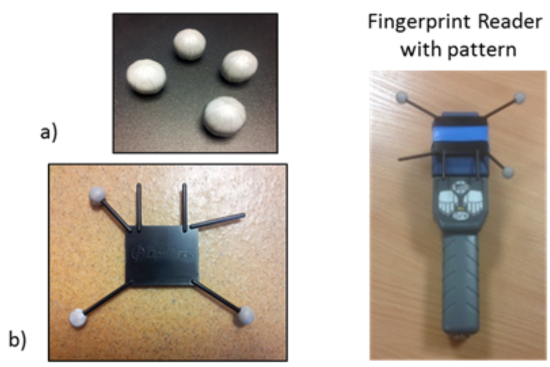

Fig.6. Retroreflective markers and patterns

Despite the satisfactory accuracy of location in space ~ 1mm determining the orientation (especially small objects) turned out to be disappointing ~ 1 degree. The reason of this is that the pattern could be recognized correctly, markers must be sufficiently spatially separated. This involves with the necessity of creating patterns with relatively large dimensions, which are not always handy or even possible to use. Even if the pattern is recognized, in the case of a small separation of markers, the fault in determining of the object spatial orientation is increasing.

The need to find another solution has led to the application of the hybrid method. Relatively expensive OptiTrack system has been replaced with a cheaper solution based on Basler cameras operating in the band NIR and NIR illuminators and filters.

Key parameters of the applied vision system:

- camera: Basler acA1300-60gmNIR 1280 x 1024, 60 fps,
- lens: V.S.Technology SV-0814H,
- filter: IR-PASS – HOYA infrared R72,
- illuminator: Emiter IR Harvatek HE1-240AC, 5mm, 850nm.

New cameras of vision system are similarly arranged in a training room. The MoCap-Basler has been installed on the ceiling of the room with dimensions of 5m x 3m and 2m height (fig. 7).

Fig.7. MoCap Basler

The second component of the hybrid system to determine orientation in space is a set of gyro sensors. Orientation sensors (shown in Figure 8) have been integrated with gloves and VR display HMD (Oculus Rift DK1).

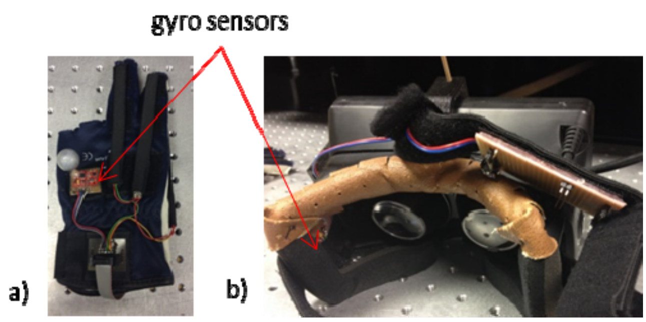

Fig.8. Orientation sensors connected to: VR gloves, HMD

Set of 12 Basler cameras with illuminators and filters plays a role of MoCap devices. Cameras are connected to the MoCap server (S-MoCap). The measuring system is powered by a special controller. It is also an synchronizer of cameras and illuminators. Vision system requires the preparation of binary masks for each cameras. It is necessary to eliminate artifacts during markers detection. Mocap Server application enables the selection of appropriate shutter speed for the cameras.

A two-step calibration of Basler-MoCap system has been proposed. The first stage deals with the calibration of the surface using a four-point calibration standard placed on the floor of the plane. The second stage is connected with the calibration volume with the use of a single-point mark. Calibration algorithm of the system and the determination of points in space was created on the basis of the model described in OpenCV 2.4.12.0 documentation.

The subsystem of object positioning is supported by 2 controllers. MoCap cameras are transmitting images to the server Mocap. This server determines the direction vectors for each of the markers detected in the image. These data, including the location of each camera, are sent to the virtual reality server (S-VR). Its task is to determine the coordinates of points in space for each of the markers detected in images. Data from the orientation sensors are transmitted wirelessly directly to the server VR using Bluetooth. VR System have been shown in Figure 9.

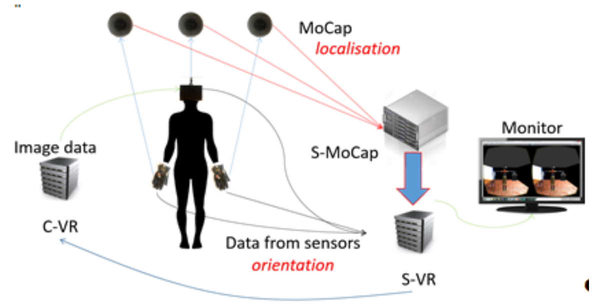

Fig.9. Virtual Reality System

All measured data are supplied to the graphics engine OGRE3D (open source) which synthesizes a virtual training environment (fig. 10). In this environment, both virtual objects (travelers, equipment) as well as real objects are presented: an officer and selected elements of its equipment. For the synthesis of the image for the trainee the computer of virtual reality (C-VR) belonging to a client is used. Image for the supervision of the training process is synthesized by the S-VR.

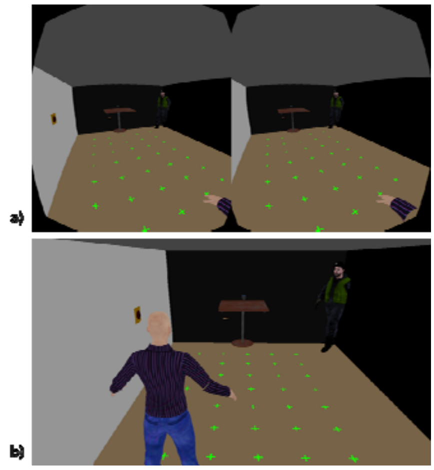

Fig.10. Synthesized images: a) first, b) third person perspective

The results of the test of object positioning

The most important thing for the correctness of a virtual scene generated by the graphics engine is the accuracy and stability of all determined parameters. In the proposed solution the following mechanisms were uses (fig. 11):

- the positioning one based on data from the MoCap system,
- two others for determining the spatial orientation – each of them characterized with a different precision.

The solution with the MEMS sensors (MPU6050, HMC5883L: more than 10 times more precise than the data from the test MoCap) were used to track the orientation of the hands and the head.

Basler-MoCap were applied to track the orientation only of the fingerprint reader.

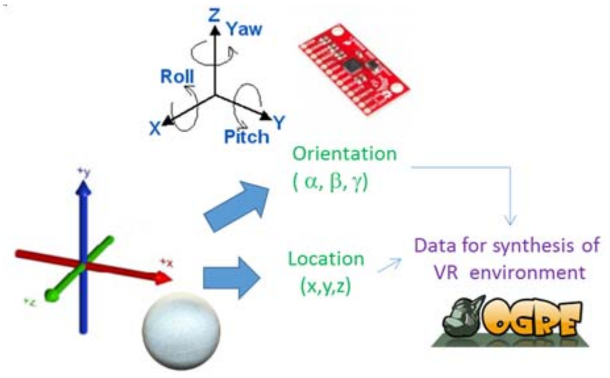

Fig.11. Positioned retroreflective markers on the hands and head

During the tests the selected objects were placed in several locations of the workspace (fig. 12). Relative changes in their position and angle, as also the stability of results, the most important for visuality, were evaluated with great accuracy.

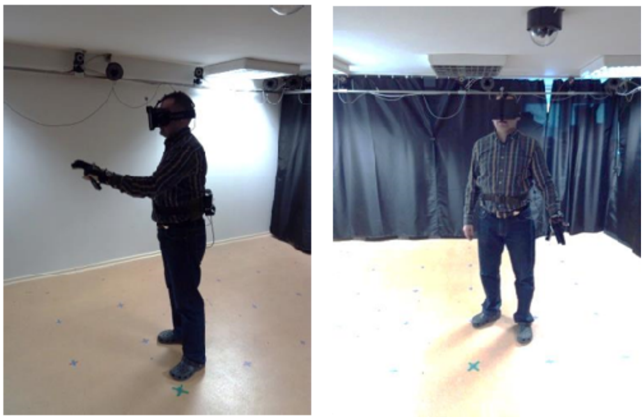

Fig.12. The examples of objects arrangements in the scene

The results from the tests of the hybrid system using markers and sensors placed on the head and hands as well as on the objects with the appropriate pattern have been shown in the table 1.

Table 1. Stability measurement of position and orientation

Type of measurement	Average value
Location markers using a system MoCap	~2mm
Orientation of objects based on data from the sensors	~0.05^0
Location pattern using a system MoCap	~10mm
Orientation pattern using a system MoCap	~2^0

Summary

Based on the hybrid system the experimental studies have demonstrated the ability to develop a fully functional measurement subsystem for virtual reality applications. The process of determining of the location and orientation of key objects in space has been split. Thus there is a possibility to develop an effective solution without the use of dedicated but expensive Motion Capture systems.

Numerous subsystem tests were made to show that the error to determine a position and orientation of objects in this case is less important than the achieved resolution and noise. Permissible errors during the determination of the position of the head and hands are 5 cm. Permissible errors during the determination of the orientation of the head and hands are 0.5 and 5 degree respectively. Resolution and noise during the determination of the position should not exceed 0.5mm. The resolution and noise during the determination of the orientation should not exceed 0.5 degree.

The important thing is also the total delay in the transmission of data, which should not exceed 50-80ms (transfer from sensors, image synthesis, wireless transmission HMD). It should be remembered that the set of measurement data must be generated for each frame of synthesized image – lowest level of the frequency 50 fps.

These parameters are very important because of the way we receive VR first-person perspective. The decisive factor is the impact on our senses. Not only the eyes but also:

- sense of balance (Does synthesized world keep up with the movements of the head?),
- kinesthetic sense (Do synthesized hand movements reflect the actual movement?).

These studies show how measurements systems are important for VR simulators.

These investigations on hardware and software solutions for the measurement systems used in advanced VR applications will be continued in future.

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