Development of real-time motion capture system for 3D on-line games linked with virtual character

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ABSTRACT

Motion tracking method is being issued as essential part of the entertainment, medical, sports, education and industry with the development of 3-D virtual reality. Virtual human character in the digital animation and game application has been controlled by interfacing devices; mouse, joysticks, midi-slider, and so on. Those devices could not enable virtual human character to move smoothly and naturally. Furthermore, high-end human motion capture systems in commercial market are expensive and complicated. In this paper, we proposed a practical and fast motion capturing system consisting of optic sensors, and linked the data with 3-D game character with real time. The prototype experiment setup is successfully applied to a boxing game which requires very fast movement of human character.

Keywords: motion capture real-time, PSD, IR LED, emit marker

1. INTRODUCTION

In recent years, human computer interaction, or HCI has become an increasingly important part in the field of multimedia technology. It is widely believed that as the computing, communication, and display technologies progress even further, the existing HCI techniques may become a bottleneck in the effective utilization of the available information flow. For example, the most popular tool of HCI is based on simple mechanical devices – Keyboards and mice[1]. These devices have grown to be familiar but inherently limit the speed and naturalness with which we can interact with the computer.

The human motion data has been used widely in the several areas of computer-based entertainments, medical, sports, education, and industry. To be sure, there has been a lot of study concerned specifically with getting human motion data, but relatively little device has been noticed. Artificial characters in computer game or computer entertainments are

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controlled or moved directly by mechanical devices; mice, joystick, midi-slider and etc, but which show unnatural motion in display[2].

Human-like natural motion of characters in computer display has received much attention from computer game and animation developer. Research on human motion capture is still on its early stage, as the brevity of the bibliography attests [3]. Glove-based devices have been used to capture hands or/and arm joint angle, and spatial position. To get more natural motion and overcome awkwardness in using glove or other contact based devices, video based non-contact interface techniques have been introduced. Video based motion capture systems are still expensive and cumbersome for general user, further more not easy to compute 3D model parameters from visual images under real-time constraints. Several simple HCI devices have been developed, such as mechanical, magnetic, acoustic, optical etc. From the view points of real-time and expense, those devices could not satisfy the desktop system users in multimedia area[4,5,6].

In this paper, we present an optical, real-time motion capture system consisting of emit mark, high-speed sampling PSD receiver, and wireless transmitter. This motion capture system is no more cumbersome to use due to wireless transmitter, and does not put desktop system user to expense because PSD sensors are not expensive as compared with video camera system. The organization of this paper is to describe the overall system design characteristics, and shows its performance through a real system, and finally applies this system to a computer boxing game.

2. SYSTEM DESIGN AND IMPLEMENT

This chapter describes the hardware system design concept and its operation. As shown figure 1, the overall motion capture system consists of emit mark module, PSD motion-capture module for motion capture, and a computer with USB interface. This system operates as following procedure: First, remote signal control part (marked number 8 in figure 1) triggers off. Second, an infrared type receiver detects this trigger signal and operate the emit mark to emit infrared beam (marked number 1, 2, and 3 in figure 1). Third, the emitted infrared beam is captured by PSD sensor through infrared filter and focusing lens, then is focused on PSD sensor. Beam spot coordination on the PSD is delivered to the computer by USB after A/D converting. Finally, the computer calculates 3D human motion parameters of human character in real time. We realize this design concept to a prototype for computer boxing game.

2.1 PSD motion capture sensing module

The PSD motion-capture module consists of two PSD receivers, which calculates 3D data as the principle of stereoscopy. First, each PSD receiver calculates 2D position on its PSD sensor, spotted by infrared beam from the emit mark module. Second, disparity between two 2D positions on PSD can generate 3D coordinate of the emit mark module. Fig.2 shows the data flow diagram of PSD motion-capture module.

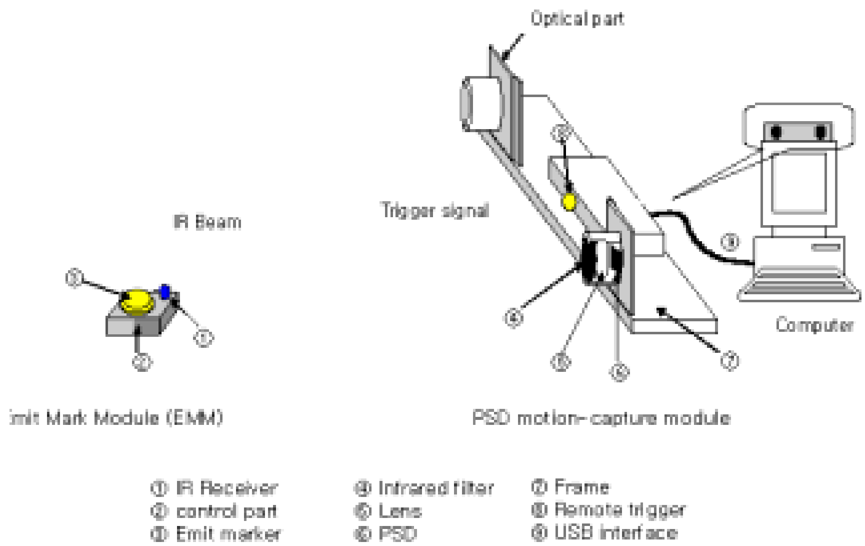


Fig. 1 Overall system Configuration

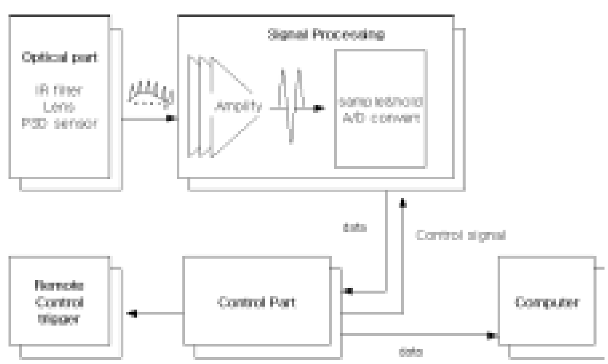


Fig. 2 Block diagram of PSD motion capture sensor module

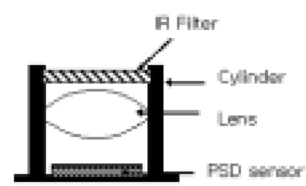


Fig. 3 Structure of the optical part

As shown in Fig. 3, the part of PSD sensor consists of an infrared filter, focusing lens, and PSD sensor. The size of the lens is relatively large as compared with that of PSD sensor, to gather infrared beam as much as it can. The focus of the lens should be chosen by considering geometry between the PSD sensor and the infrared emit mark module. The control part in Fig. 2 transmits trigger signal to each emit mark module in order, and gathers the replied infrared beam from each emit mark module one by one.

2.1.1 PSD sensing module

The pin-cushion type PSD sensor of S5991-01 model made from HAMAMATSU is adapted due to its high performance in real-time response and small signal distortion. Its size is 9×9mm, and Fig. 4 shows its photo sensitivity with wave length.

Fig. 4 Photo sensitivity of the S5991-01 model PSD

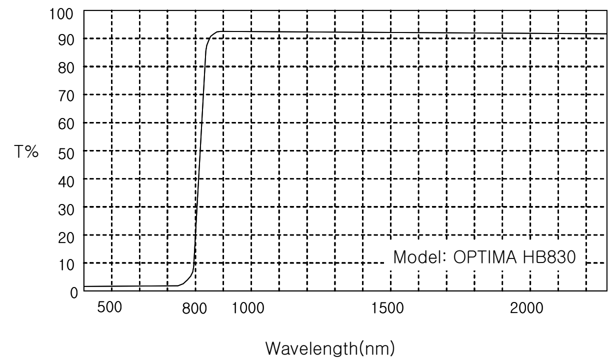


Fig. 5 Transmissivity of the IR-pass filter

As shown in Fig. 4, operating range of the PSD is 300nm ~ 1100nm and photo sensitivity is best around infrared range of 960nm. To reduce influence of other wave range beam, the infrared filter of its transmissivity shown in Fig. 5 is adapted. Considering the IR beam wavelength, 780nm of the emit marker, we can get best result to gather the IR beam.

Next, the focal length is determined by considering working range of human actor, the size of PSD. The working range of boxing actor is set approximately 1000mm×1000mm×1000mm. Fig. 6 shows image geometry including the working space of human actor, the lens in front of PSD, and PSD. The focal length satisfying this geometry is calculated by 8.919mm. So, a commercial lens of focal length, 10mm is chosen, which is the closest one to the focal length of 8.919mm. Fig. 7 shows the photography of the designed optical part in PSD motion capture module.,

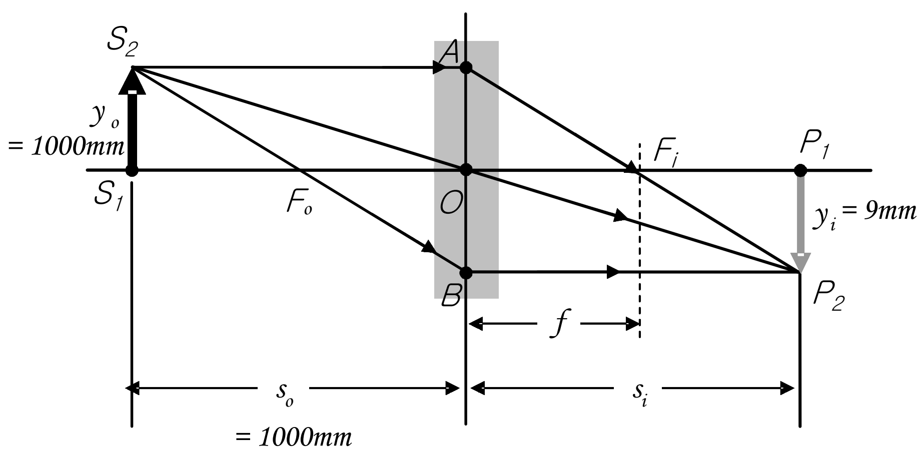


Fig. 6 Image geometry Diagram

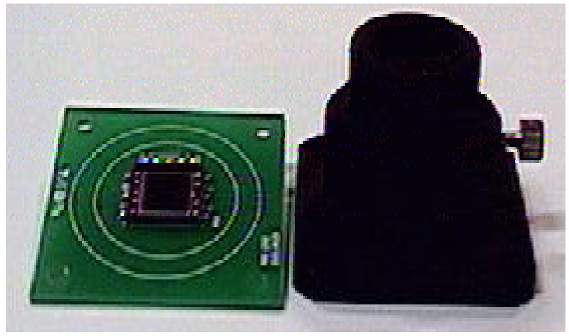


Fig. 7 Photography of the designed optical part

The power of analog signal generated by PSD closely depends on the distance between the PSD sensor and the emit marker. Automatic gain control algorithm is applied to get constant power of PSD output signal, even if the distance would vary within working range. Fig. 8 shows block diagram of automatic gain control scheme. The PSD output, X2 is amplified by four different gain values. Each amplified signal is converted as digital signal, and compared a reference value. Next, the compared result is feedback to amplifier module, and then selects different analog switch to get optimal gain value.

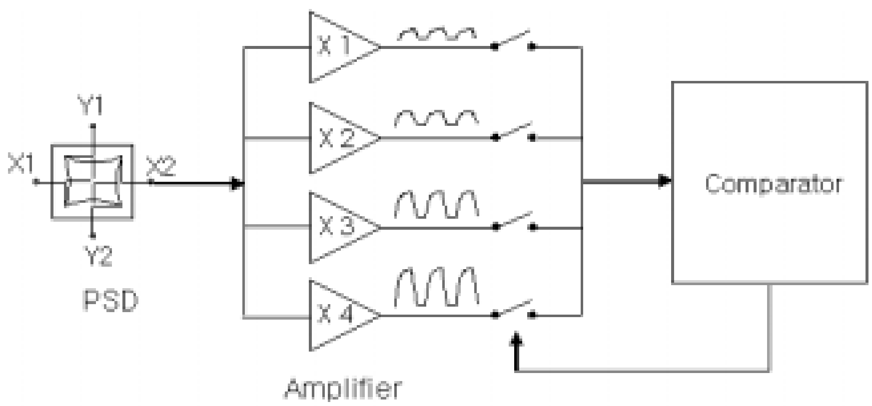


Fig. 8 Block diagram of automatic gain control

2.2 Emit mark module (EMM)

In this method, a human actor should attache several emit mark modules (EMMs) on his body, where he wants to capture motion. For example, to capture whole body motion, he just attaches one EMM on head, two EMMs on body, two EMMs on each leg, and one EMM on each arm. To get more precise motion data, more EMMs should attached on the interest points, for example, on face, fingers, joints, ankles etc.

The EMM communicates with the PSD motion capture module by using infrared communication. The PSD motion-capture module can not receive one more infrared beams at a time. Therefore, each EMM operates in order, after receiving its own trigger signal from the PSD motion-capture module. The IR receiver in the EMM is used to receive the trigger signal selectively within its own frequency band, which can reduce influence of outside light noise and infrared noise with different frequency. Fig. 9 shows photography of IR receiver in the EMM and a example of input/output signals. The IR receiver receives 37.9kHz frequency as input, and then gives back output signal. Detail specification of the IR receiver describes at Table 1. The emission angle, 85° of an IR receiver is not enough to cover moving human in boxing game. So, two IR receivers are put together into one unit in practical use.

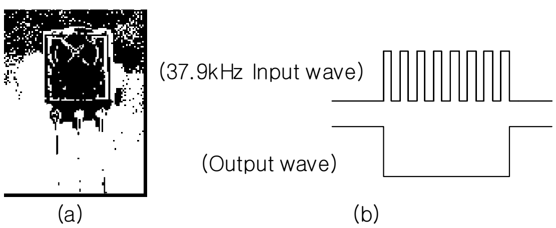


Fig. 9 IR LED emit marker

Parameter	Value
Emission angle	85°
B.P.F frequency(kHz)	37.9kHz
Peak Wavelength	940nm
Arrival Distance	10m
Output Form	Active Low Output
Operating Voltage	2.7 ~ 5.5V

Table 1. IR Receiver Specification

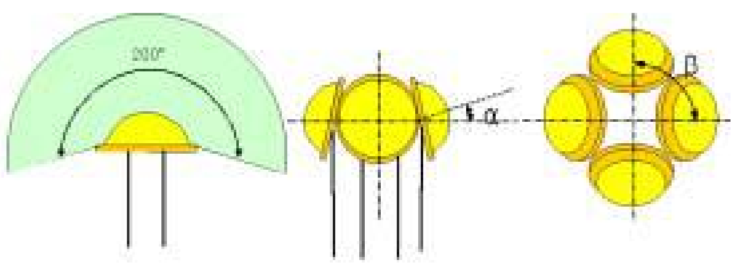


Fig. 10 The emit marker (α=25° β=90°)

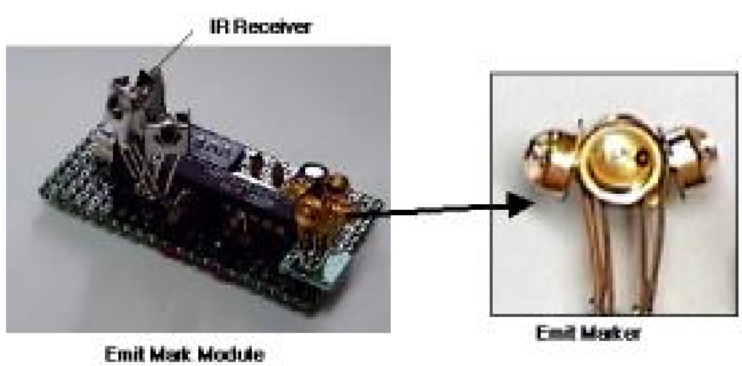


Fig. 11 Emit Mark Module (EMM)

After the IR receiver get the trigger signal from PSD motion-capture module, the emit marker in EMM should transmit signal to PSD sensor uniformly, no matter how human actor moves. As shown in Fig.10, four IR LEDs are used as the emit mark, which are assembled to emit IR beam in all directions as possible as they can. Fig. 11 shows proto types of finally assembled EMM including IR receiver, emit marker, and controller.

4. EXPERIMENTS

To evaluate the performance of experimental system, two experiments are performed for accuracy and real-time. The first experiment is to evaluate the measurement accuracy of the PSD motion-capture module. The second experiment is to evaluate the minimum time scanning the emit markers. Finally, we apply this experimental system to computer boxing game.

4.1 Accuracy test

Stereoscopy is the basic concept for the PSD motion-capture module to calculate 3D coordinate of emit marker. So, at first, the PSD motion-capture module and 3D working volume are obliged to be calibrated. As shown in Fig. 12, the calibration panel of 1000mm×1000mm installed 25 emit markers is set at the positions of 300mm, 500mm, and 700mm. Total 75 points of emit marker are used for calibration. After calibrating parameters of PSD motion capture module, the 3D coordinates of 75 points are re-calculated. Fig. 13 shows the measurement errors of the 75 points for each axis respectively. The maximum value of errors is 41mm, and the average value of absolute errors is 12.5mm.

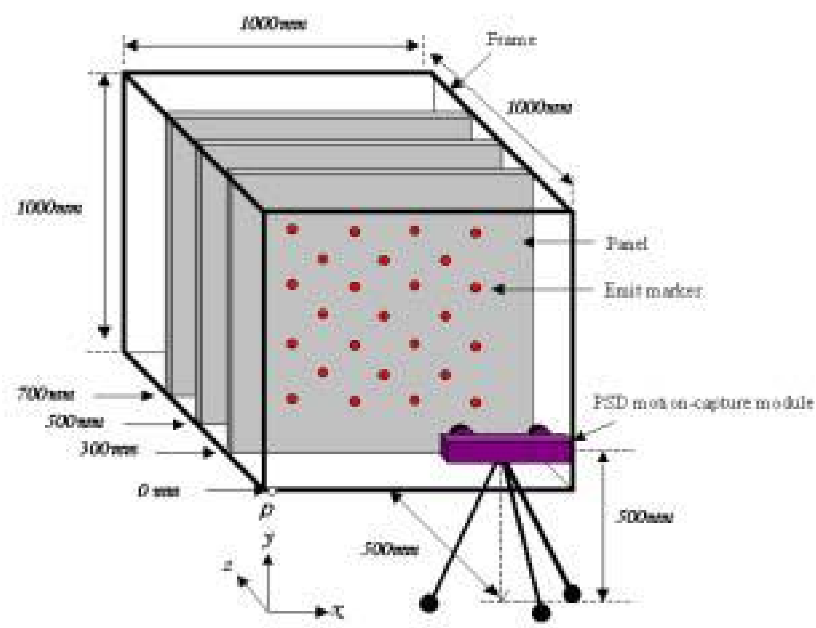
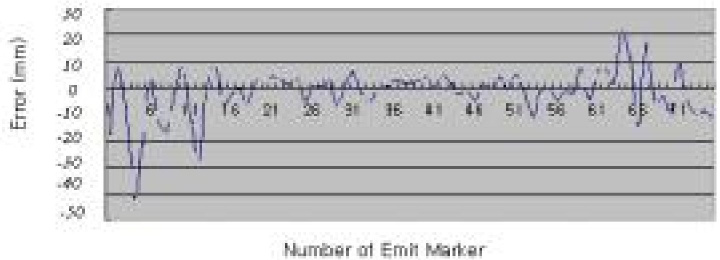
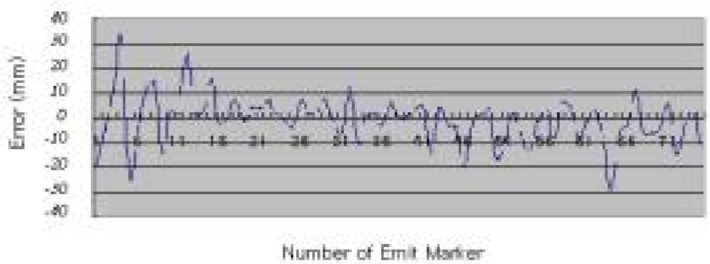


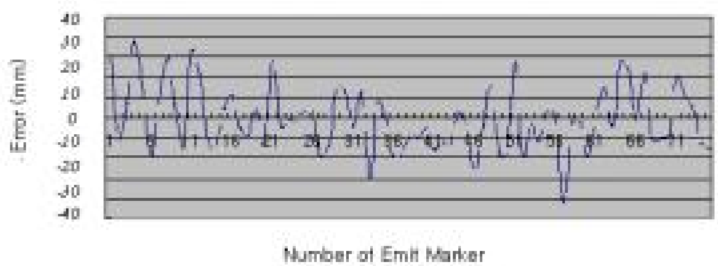
Fig. 12 Configuration of test system calibration



(a) X - coordinate error



(b) Y – coordinate error



(c) Z – coordinate error

Fig. 13 Measurement Error

4.2 Sampling speed

Based on design concept of the control part, total time from trigger signal to final 3D coordinate calculation of each emit marker can be predicted as follows: For the time of 200μsec, the PSD motion-capture module communicate with EMM by shooting trigger signal of 37.9kHz. After time delay of 20μsec, EMM turns on emit marker for 40μsec. Then, PSD motion-capture module receives IR beam from emit marker and converts to digital value through A/D convert for 320μsec. So, total time from trigger signal to digital data takes approximately 580μsec in PSD motion-capture module. This digital data is transmitted to PC through USB cable and converted to 3D coordinate for the additional time of about 200μsec.

In this experiment, three EMM are attached on head, left hand, and right hand of human actor, respectively. Ideally, it takes about 2.5msec for processing three EMMs (580μsec×3 + 200μsec + some time delay = 2500μsec). Practically, more time delay is given for high reliability. Experiment result shows average processing time, 5msec or 200frame/sec for three EMMs. This result is very fast in compared with the snapshot speed of video camera, 30 frame/sec.

4.3 Boxing game application

As shown in Fig. 13, the motion capture system is applied human actor making a gesture of boxer. Human actor attaches three EMMs on head and two wrists. A boxing game character in Fig. 13 mimics as following human actor successfully.

(a) Human actor

(b) virtual character in boxing game

Fig. 13 Boxing game application

5. CONCLUSION

Several kinds of motion capture systems have been proposed in multimedia area; animation, game, entertainment etc. The real-time and expense are important issues for practical motion capture application, especially for desktop user. In this paper, a real-time motion capture system for 3D on-line game has been developed with low price. From experiments, the developed system shows good performance of signal processing time, 200fram/sec in compared with camera snapshot speed, 30 frame/sec. The measurement accuracy of 3D coordinate of emit maker was evaluated by less than 41mm. This accuracy grantees playing general computer games, however seems to be not satisfactory for high precision application. In the next research, more efforts for increasing measurement accuracy of emit marker is required.

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