ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 4, April 2016

Sensor and Vision Fusion for Virtual Reality

Anushree Prabhu[1], Pranjali Borkar[2], Ajinkya Padwad[3], Harshada Patankar[4], Salil Vaidya[5]

Assistant Professor, Dept. of Electronics, V.E.S. Institute of Technology, Mumbai, India[1]

UG Student, Dept. of Electronics, V.E.S. Institute of Technology, Mumbai, India[2,3,4,5]

ABSTRACT:This paper proposes an easy to employ and feasible solution for implementing interaction with virtual environments, pertaining to applications at educational training and product designing. Aiming at achieving better interaction with non-immersive Virtual Reality, this paper describes the fusion of two technologies. The first technology integrates the real time values from the Micro-electromechanical System (MEMS) based accelerometer, gyroscope and magnetometer sensors atop the Inertial Measurement Unit (IMU), to get the required degrees of freedom for real time pose estimation. The other technology is based on Computer Vision for tracking of region of interest using image processing through Webcam. Both the technologies can be implemented simultaneously to achieve efficient pose estimation and precise motion tracking which aid the interaction with virtual objects. With these two easy to employ technologies implemented at low cost, the possibilities can be immense, and the scope for applications can be expanded to domestic as well as industrial applications.

KEYWORDS: Inertial Measurement Unit, Virtual Reality, Computer Vision, Fusion, Motion Tracking, Pose Estimation

I. INTRODUCTION

Virtual Reality (VR) is a combination of various technologies like image processing and controls. It includes features of both immersive and non-immersive interaction. Virtual Reality can thus be applied in the domains of gaming, healthcare, product designing and at simulations for military and educational applications as well [1]. Such applications need a robust and easy to employ system for real time motion tracking and seamless interaction with 3D objects.

An Inertial Measurement Unit (IMU) is a Micro Electromechanical Systems (MEMS) device that consists of accelerometers, gyroscopes and magnetometers on the same board which measure and provide the vibrational acceleration, orientation and magnetic forces acting on the device. The IMU contains three separate sensors embedded on the same circuit board [2]. The IMU, due to its ability to allow a computer to track an object’s position and orientation, is most popularly used in aircrafts, spaceships and missile launching vehicles.

Computer Vision includes the acquiring, analysing and processing of images and understanding real world high dimensional information and taking further decisions after processing [3]. Computer Vision can reconstruct a 3D scenario from its 2D images based on the structures present in the scene. The ultimate goal of computer vision is to model, replicate, and more importantly exceed human vision using computer software and hardware at different levels. This enables us to employ this technology for smooth motion tracking which in turn can aid the interaction with 3D virtual scenarios.

Nowadays, a plethora of technologies have been developed to implement interactive virtual reality systems. This includes the use of both open source as well as licensed proprietary softwares and hardwares. This project focuses on use of open-source technologies and proposes an easy to employ and feasible solution for implementing interaction with virtual environments, particularly focusing at the educational training and product design applications. Two technologies have been employed simultaneously for achieving improved motion tracking and good interaction. One of the technologies includes integration of the real time sensor readings from an IMU that sends the required degrees of freedom for real time pose estimation. And the other one is tracking of an off-screen pointer using image processing through webcam. Both the technologies, when implemented simultaneously, achieve efficient pose estimation and precise motion tracking. This can be used to develop an improved interaction with virtual objects.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 4, April 2016

II. COMPONENTS

A) Hardware -

Inertial Measurement Unit

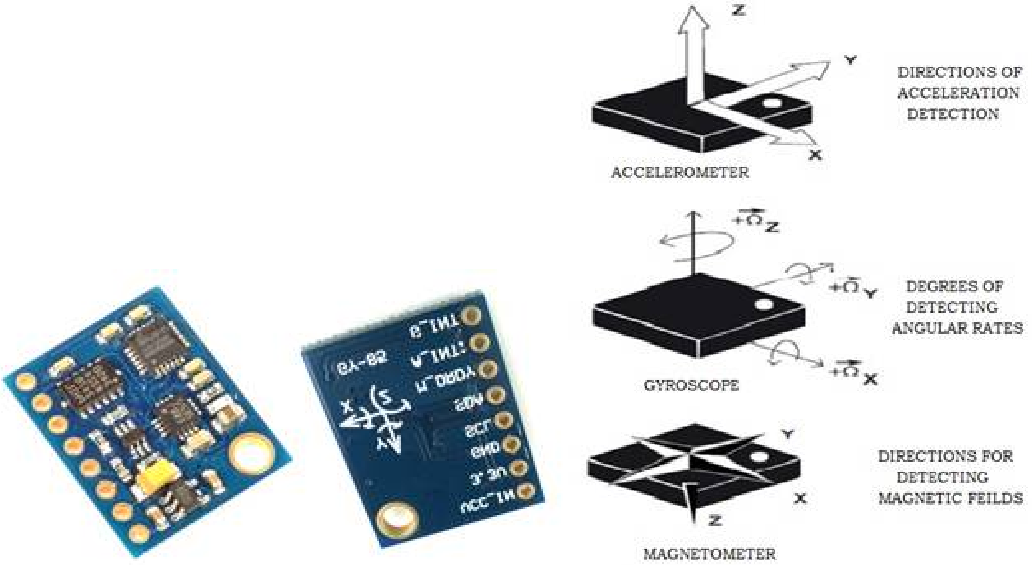


Figure 1. (a) The GY-85 Inertial Measurement Unit (b)Degrees of freedom at GY-85 IMU

The Inertial Measurement Unit (IMU) used in this project is the GY-85 as shown in Figure 1(a). This board basically consists of a 3-axis accelerometer (ADXL345), a 3-axis magnetometer (HMC5883L), a 3-axis gyroscope (L3G4200D). Usually employed at aircraft, an inertial measurement unit is an electronic device that measures and reports a craft's velocity, orientation, and gravitational forces, using a combination of accelerometers and gyroscopes, and also magnetometers. An inertial measurement unit works by detecting the current rate of acceleration using one or more accelerometers, and detects changes in rotational attributes like pitch, roll and yaw using one or more gyroscopes. Every sensor atop the GY - 85 IMU has the capability of communicating through the I2C protocol for data transmission. This makes it easy to implement and interface with microcontrollers. The degrees of freedom for different sensors can be best depicted as in Figure 1(b). The three GY-85 sensors used at this project are for measuring acceleration, orientation and magnetic field forces, as given below –

a) **Accelerometer-(ADXL345)**
The accelerometer embedded on the GY-85 device is the ADXL345 IC from Analog Devices. The accelerations are measured when the sensor is tilted and either the x-axis or the y-axis experiences a component of the upward acceleration, whose magnitude is proportional to the tilt angle. It measures acceleration along all three axes (x, y, and z) and has a resolution up to 13 bits. It can detect changes less than 1.0° as well. The chip can be calibrated and the new results stored on it for reusing. The ADXL345 supports the ranges of ±2g/±4g/±8g/±16g [4].

b) **Gyroscope-(ITG3200)**
The GY-85 uses InvenSense's ITG3200 to measure orientation. It can sense motion on all three axes. The ITG-3200 is the world's first single-chip, digital-output, 3-axis MEMS gyro IC which is optimized for applications such as gaming, 3D interfacing devices, and remote control. The ITG-3200 features three 16-bit analog-to-digital converters (ADCs) which carry out the digitizing of gyro outputs and an internal low-pass filter bandwidth [5]. It also supports I2C interfacing.

c) **Magnetometer-(HMC5883L)**
Honeywell's HMC5883L is a 3-axis digital magnetometer. The chip is popularly used as a digital compass. It

is used to sense the angle with respect to the magnetic north (not true north). There are anisotropic magnetoresistive directional sensors in this IC, which feature precision in-axis sensitivity and linearity. These sensors are designed to measure both the direction as well as the magnitude of Earth's magnetic fields. The range is from milli-gauss up to 8 gauss [6].

Microcontroller (ATmega328PU)

The central brain of this project is the 8-bit AVR RISC-based microcontroller by Atmel [7]. It combines 32 KB ISP flash memory with read-while-write capabilities. It has 1 KB EEPROM, 2 KB SRAM. It also has 23 general purpose I/O lines, 32 general purpose working registers, three flexible timer/counters with compare modes, internal and external interrupts,6-channel 10-bit A/D converter, serial programmable USART, 2-wire serial interface, SPI serial port, a watchdog timer with internal oscillator, and various power saving modes. The device operates between 1.8-5.5 volts. And it achieves throughputs of about 1 MIPS.

Bluetooth Module (HC- 05)

The HC-05 Bluetooth to serial port module is an easy to use module and has been designed for wireless serial communication. This module supports both master and slave modes of working. Embedded with an on-chip antenna, the module has typical -80dBm sensitivity and up to +4dBm RF transmit power. It has a 2.4GHz radio transceiver and UART interface with programmable baud rate [8]. This module makes use of CMOS technology and also supports the AFH (Adaptive Frequency Hopping) feature. In this project, the real time sensor values are transmitted from the microcontroller via Bluetooth module HC-05, to interface with the 3D virtual objects at the GUI.

Camera

In this prototype, the physical device to capture the live video / image input is the webcam interface connected to a computer. When the camera captures the input, it can then be sent to a remote location; the video stream may be saved and viewed. Unlike an online IP camera, which connects over the Wi-Fi or Ethernet, the 'webcam' used in this project is connected by a USB cable, or built into computer hardware, such as laptops. The webcam is used as a video camera connected to the network continuously for an indefinite time or for a fixed session, as programmed by the user. The motion tracking is facilitated by this camera, which feeds its inputs to a software for further processing.

B**) Software-**

Processing IDE

The prototype described in this paper makes use of the 'Processing' Integrated Development Environment (IDE) [9]. It is a flexible, free and open-source software that has an easy to use sketchbook. It is a language for learning how to code within the context of the visual arts that has applications in other fields as well. It has been built for the electronic arts, media art, and for the visual design communities. Processing is used a lot by people who are experimenting, making their own prototypes in interesting new conceptual and visual ways. Processing is also well-documented, which makes it highly accessible. This open source software has been used for our prototype to create 3D objects to depict virtual environment. The Processing IDE facilitates the reception of the real time sensor readings through the serial port. It also simultaneously works on the motion tracking algorithm based on colour marker tracking. The values from the sensor are the mapped onto the matrices of the 3D virtual objects for real time control of the orientation and translation. The robustness and ease of use makes it apt for our prototype designing.

III. SYSTEM FLOW MODEL

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 4, April 2016

Figure 3 depicts the system flow model of the project. As is visible from the block diagram, the real time readings from accelerometer, magnetometer and gyroscope are fed to the processing block for filtering. The readings from gyroscope which are an integral part of the further procedure are thus processed by using an algorithm based on Extended Kalman Filter (EKF) for better pose estimation [10]. We find the final corrected data using the past estimated values and the current values. This is as visible in the algorithm at Figure 4. The EKF thus helps to filter out the noise from the gyroscope readings, by constantly updating the vector of values. The basic hardware used during this process was the interface of sensors at the IMU with the microcontroller and HC-05 Bluetooth module for serially transmitting the values. A webcam is employed that captures the real time video stream for further processing. The real time video stream is worked upon by the motion tracking algorithm using a basic colour detection technique. Processing IDE is responsible for acquiring real time information serially from the microcontroller and also the real time video stream. The virtual environment is developed using the basic java-based programming for designing 3D objects. The estimated final values are then mapped onto the matrices of the 3D object for carrying out rotation and translation. This enables us to interact with the virtual reality environment.

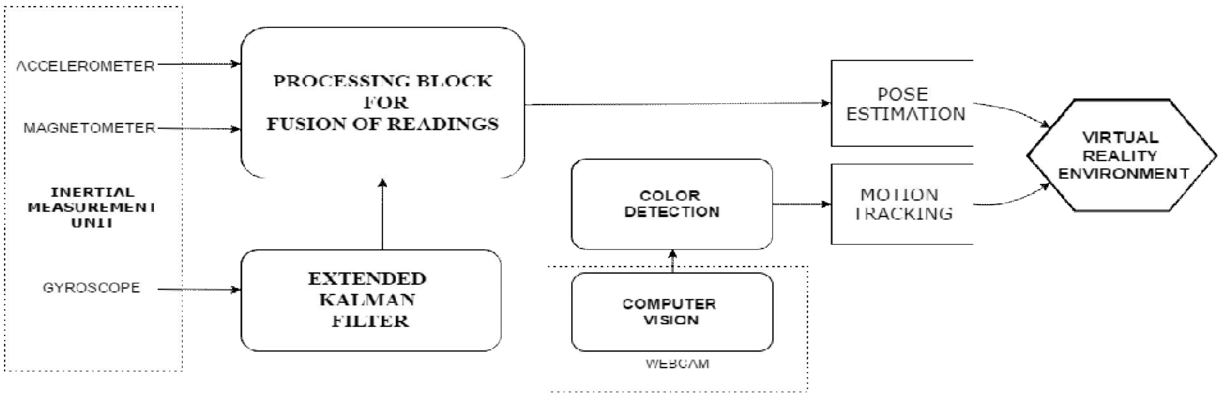


Figure 3. System flow model of the prototype

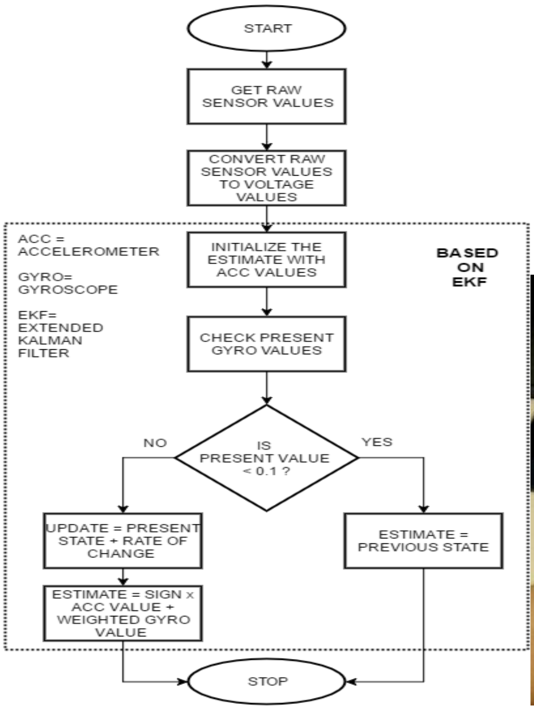


Figure 4. EKF based algorithm for pose estimation

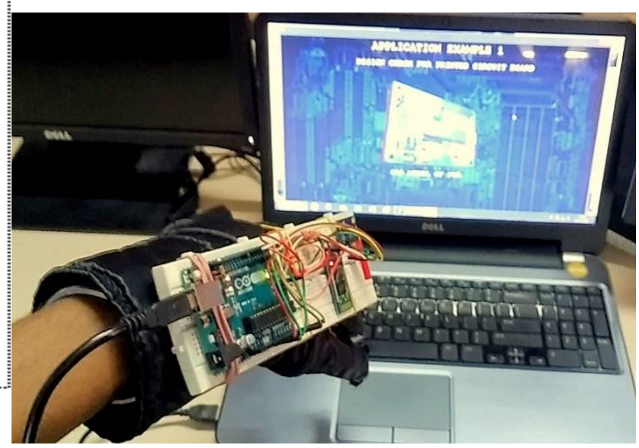


Figure 5. The prototype mounted atop a glove

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

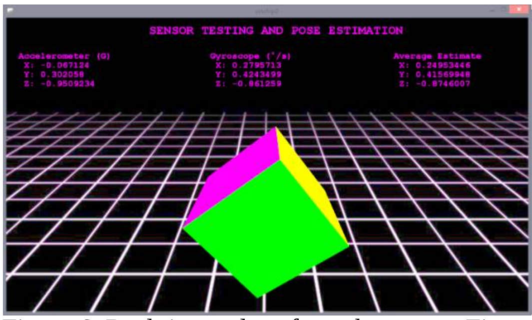
(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 4, April 2016

IV. RESULTS AND DISCUSSION

The prototype can be seen as in Figure 4. The prototype has been mounted on a glove for convenient movement of the IMU atop it. This prototype can be easily modified to suit different applications. After carrying out all the interfacing as per the flow diagram, we obtain the results for three different scenarios. The prototype testing yields the first result that depicts the real time sensor readings from the IMU as visible in Figure 5.

The sensor values then carry out the yaw-pitch-roll orientation of a 3D object, as seen in Figure 6. This yields an efficient pose estimation. The second result is as shown in Figure 7. It is an advanced implementation of the similar approach to achieve interaction with respect to pose estimation of 3D CAD model. The viewer can use the prototype to interact with the 3D CAD model's orientation by simply changing the orientation of the prototype itself.



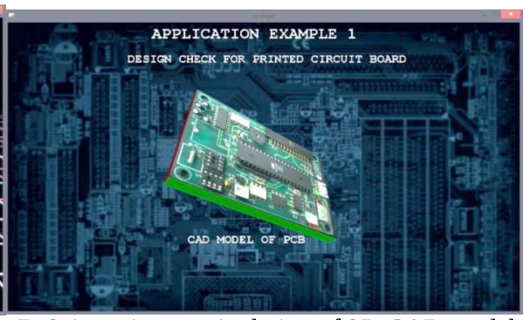


Figure 6. Real time values from the sensorsFigure 7. Orientation manipulation of 3D CAD model.

This is especially useful in product designing applications wherein our prototype comes in handy.

The final implementation of the fusion of the two technologies is as observed from Figure 8(a) and (b). It depicts the use of this prototype to interact with disparate components of a 3D Virtual Reality scenario. Not only the pose estimation but also the location (on the screen) of the selected 3D objects can be controlled now. This has been possible with the efficient motion tracking algorithm based on colour tracking as discussed above.

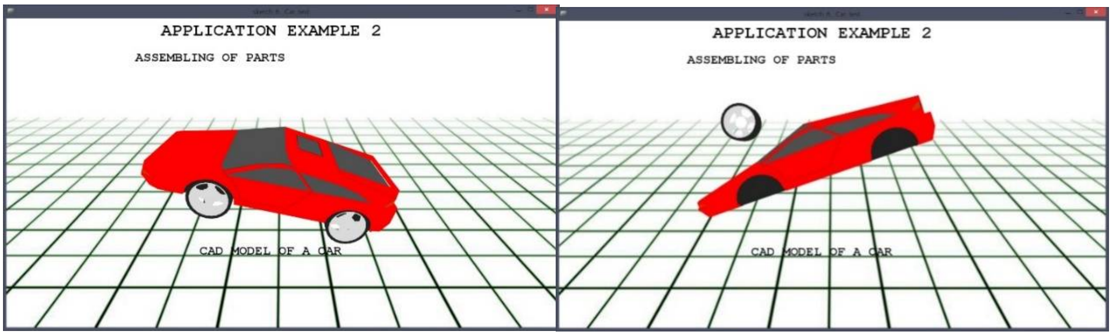


Figure 8 (a) CAD model of a car (b) Ungrouping and grouping 3D objects via motion tracking.

V. APPLICATIONS

The main applications for this project are as follows-

1. **Education**: Our prototype can be used to enable large group of students to learn different educational concepts via interactive access to three dimensional environment. It can be used to present complex models, geometrical shapes and structures in an accessible way to students which is both fun and easy to learn. Thus, it can help the students to understand concepts and remember them in a novel way. For example, if a chemistry teacher wants to demonstrate a certain chemical reaction to the students, (s)he can use our prototype to show the movement of atoms or molecules happening in the reaction in real time with the help of interactive 3D models, which the teacher can manipulate [11].

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 4, April 2016

2. **Product designing**: 3D modelling tools and visualisation techniques are an important part of any design process. Our prototype will enable design engineers to interact with their 3D CAD models and view from any angle as desired and gain a greater understanding of how it works [12]. Any flaws or imperfections in the design can be inspected in a better way then.
3. **Gaming**: In non-immersive gaming applications, a person can experience better interaction with a three-dimensional environment with a head-mounted or body-mounted gadget that uses such fusion technology. Some examples for gaming gadgets are Wii Remote, Kinect and PlayStation Eye. All these technologies track and send motion inputs of the players to the game accurately. Our prototype can be used for such gaming applications which, when developed more, can aid the motion tracking as well as pose estimation.

VI.CONCLUSION

Applications of Virtual Reality at low scale require easy to implement and robust interaction with 3D objects. We have implemented a novel way to achieve non immersive interaction with 3D Virtual Reality objects using fusion of two different technologies for simultaneous motion tracking and pose estimation. The Inertial Measurement Unit, with its three MEMS based sensors facilitate the manipulation of the orientation of 3D virtual objects via real time values. This is then coupled with the motion tracking algorithm through computer vision technology for smooth translation of the 3D virtual objects. The two technologies, when employed simultaneously, can aid the interaction with the 3D virtual reality scenarios. This prototype can then be developed further to suit more complex applications. Further, the prototype can be improved by making use of better sensors and more advanced algorithms for better interaction.

REFERENCES

[1] UpulObeysekare, Chas Williams, Jim Durbin , Larry Rosenblum, Robert Rosenberg, Fernando Grinstein, Ravi Ramamurti, Alexandra Landsberg, and William Sandberg, ‘Virtual Workbench - A Non-Immersive Virtual Environment for Visualizing and Interacting with 3D Objects for Scientific Visualization’ - Naval Research Laboratory, Washington, DC

[2] JD Hol, TB Schön, F Gustafsson, PJ Slycke- ‘Sensor Fusion for Augmented Reality’ , Information Fusion, 2006 9th International Conference.

[3] Thomas B. Moeslund, Erik Granum, ‘A Survey of Computer Vision-Based Human Motion Capture’, Elsevier, Volume 81, Issue 3, March 2001, Pages 231–268.

[4] ADXL345 datasheet - http://www.analog.com/media/en/technical-documentation/data-sheets/ADXL345.PDF

[5] HMC5883L datasheet - https://www.adafruit.com/datasheets/HMC5883L_3-Axis_Digital_Compass_IC.pdf

[6] ITG3200 gyro datasheet - http://www.invensense.com/products/motion-tracking/3-axis/itg-3200/

[7] ATmega328P Datasheet- http://www.atmel.com/images/atmel-8271-8-bit-avr-microcontroller-atmega48a-48pa-88a-88pa-168a-168pa-328-328p_datasheet_complete.pdf

[8] HC-05 datasheet - http://www.tec.reutlingen-university.de/uploads/media/DatenblattHC-05_BT-Modul.pdf

[9] Processing IDE - https://processing.org/reference/environment/

[10] Gabriele Ligorio and Angelo Maria Sabatini,‘Extended Kalman Filter-Based Methods for Pose Estimation Using Visual, Inertial and Magnetic Sensors: Comparative Analysis and Performance Evaluation’ - The Institute of BioRobotics, Italy.

[11] Youngblut, Christine- ‘Educational Uses of Virtual Reality Technology’ Final rept. Jan 96-Dec 97

[12] T.S. Mujber, , T. Szecsi, M.S.J. Hashmi,‘Virtual reality applications in manufacturing process simulation’ - Journal of Materials Processing Technology, Volumes 155–156, 30 November 2004, Pages 1834–1838.