Smartphone-based 3D Orientation Estimation for Virtually any Published PC Game

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Abstract — *Modern smartphone devices provide valuable sensing capabilities that can be used in many context aware applications. Some applications need special sensing data that cannot be obtained directly from existing sensors or the available data is not reliable. This paper presents a method to derive an Android smartphone's 3D orientation from accelerometer, gyroscope and magnetometer data. The obtained orientation cab then be used to control virtually any published PC game. An experiment is provided as a proof of concept where a user can control a MIT Scratch PC game from his Android smartphone device.*

Keywords — *Smartphone device, motion sensors, accelerometer, gyroscope, magnetometer, orientation, MIT Scratch, PC game.*

I. INTRODUCTION

Android smartphones are supported with a large number of sensors that can be used directly or indirectly to provide useful information about the device and the user [1]. Sensors' data are directly used in many mobile applications to adapt the state of the application according to the state of the mobile phone [2]. For instance, the accelerometer sensor can be used to know the orientation of the mobile phone and accordantly change the application's layout.

On the other hand, the data from sensors are indirectly used in many context-aware applications to infer information about the user's state such as its location [3], the activities carried out by the user [4] and even its safety [5].

With the significant progress in display and communication technologies, games still attract many researchers to improve and use them in new frameworks such as training [6], learning [7], treatment [8] and rehabilitation [9]. These new frameworks require a deep interaction between the user and the game which necessitates the use of special and expensive control devices.

This work is an attempt to integrate already existing "cheap" smartphone devices into any PC game such that the user can control it using his own smartphone device. The proposed method does not require any modification of the target game.

II. RELATED WORKS

This section presents the recent works related to the use of smartphone devices as input control devices for PC games.

Most of the works presented in this domain proposed methods to use smartphones as emulators of existing game controllers. Vajk et al. [10] used a Nokia mobile phone to emulate the Nintendo Wii wireless controller. They used their proposed controller in a multiplayer driving game using the Microsoft XNA framework and they found that these new controllers can be both intuitive and fun.

On the other hand, some works proposed the fusion of the mobile phones capabilities with existing controllers to improve the gaming experience [11], [12].

III. ANDROID SMARTPHONES SENSORS

Android smartphones are provided by a set of hardware sensors to ensure the functionality of their applications. In this work, 3 sensors are used to estimate the 3D orientation of the device. These sensors are the accelerometer, the gyroscope and the magnetometer. A brief explanation of these sensors is given in the following subsections [13].

A. The Accelerometer

An accelerometer is a device that measures rate of change of velocity. It consists of a mass connected to posts by springs. When the base accelerates in a specific direction, it creates a reaction force on the mass making it moves in the opposite direction. The resulting change of the mass's position gives a measurement of the applied acceleration (see Fig. 1).

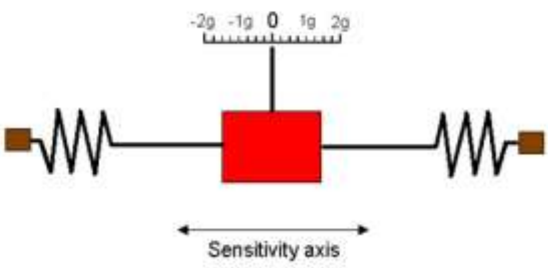

Fig. 1 An accelerometer

B. The Gyroscope

A gyroscope is a device that measures rate of change of angular velocity about around a particular axis. It consists of a spinning wheel connected to an inner frame. When the outer frame rotates in a specific direction, the wheel's orientation in this direction is unaffected (see Fig. 2).

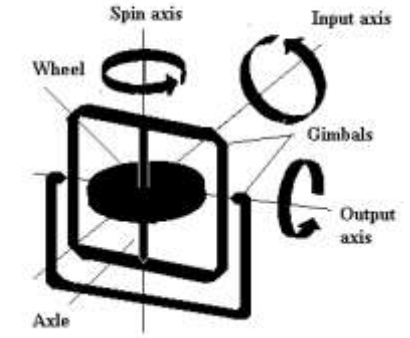

Fig. 2 A gyroscope

C. The Magnetometer

The magnetometer sensor detects changes in the earth's magnetic field by Hall effects. It is based on the concept of producing a voltage proportional to the strength and polarity of the magnetic field as shown in Fig. 3.

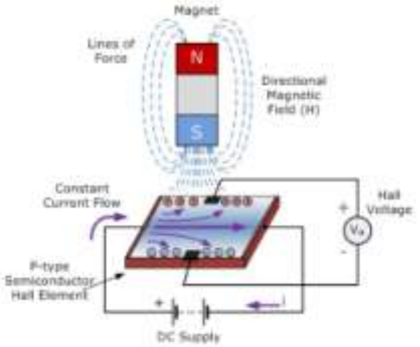

Fig. 3 The Hall-effect sensor

IV. 3D ORIENTATION ESTIMATION

Several approaches were proposed in literature to estimate the 3D orientation from the accelerometer, the gyroscope and the magnetometer sensors [14]. In this work, the approach developed in [15] is adopted and it will be explained in the following.

Fig.4 shows a block diagram of the adopted approach to estimate the 3D orientation. In this figure, Q is the quaternion encoding the Earth's rotation relative to the smartphone device, $Q^{\bullet}$ is the quaternion's derivative and $\Theta\ \Phi\ \Psi$ are the Euler angles. The symbols $-,+$ represent the algebraic subtraction and addition respectively, $\times$ represents the quaternion multiplication, $\int$ represents the time integration and PI represents a proportional integral controller.

The idea of the adopted approach, as shown in Fig. 4, is to correct the angular velocity measurements using the error between the estimated acceleration and magnetic field and the measured ones.

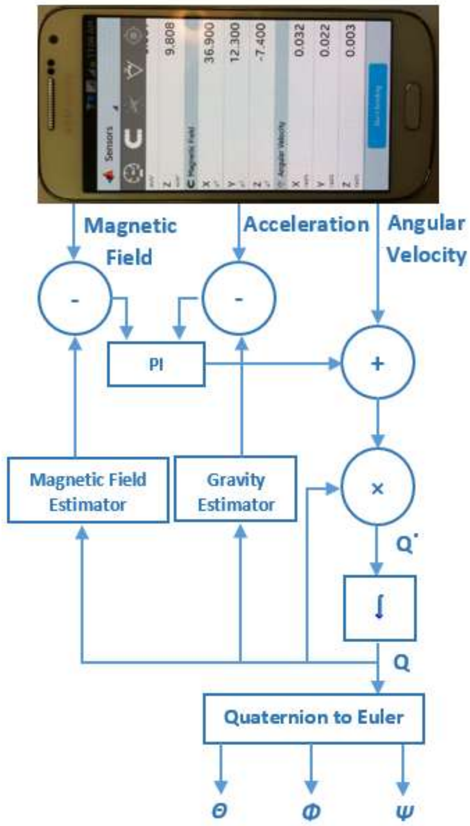

Fig. 4 3D Orientation estimator

V. MAPPING 3D ORIENTATION TO PC GAMES

Almost any PC game can be controlled form the keyboard using the arrows buttons or other buttons. This section explains how to map the Euler angles, estimated from the sensors of a smartphone device, to any set of buttons such that the games can be controlled by the Euler angles via these buttons.

Assume that the reset position of the smartphone device corresponds to the portrait mode as shown in Fig. 5. Assume also that the rotation of the device around z-axis corresponds to forward and backward movements and the rotation around x-axis corresponds to right and left movements.

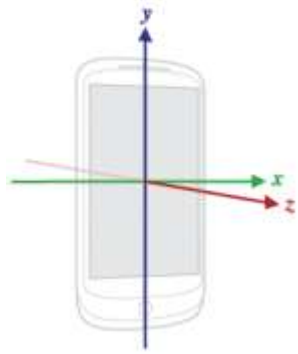

Fig. 5 3D coordinates of a smartphone device

Based on the above assumptions, the mapping given in Table 1 is proposed. It should be noted that the change of an Euler angle is calculated using an average moving filter.

Table 1 Mapping Euler angles to keyboard buttons

Euler Angle	Button	Movement
$\Delta\Theta > 0$	w	Forward
$\Delta\Theta < 0$	s	Backward
$\Delta\Psi > 0$	d	Right
$\Delta\Psi < 0$	a	Left

VI. EXPERIMENT

The experiment consists of a user carrying an Android smartphone on his leg by a special holder as shown in Fig. 6.

Fig. 6 A user holding a smartphone device

The smartphone is connected wirelessly to a PC and transmitting its sensors' measurements using MATLAB® Mobile™ App. A PC software acquires the sensors' measurements and estimates the Euler angles using the approach depicted in Fig. 4 and transmits an appropriate keyboard's button stroke according to the Table 1.

Any PC game can receive the keystrokes and move its character accordantly. In this experiment, a MIT Scratch game receives the keystrokes and moves a red rectangle accordantly as shown in Fig. 7.

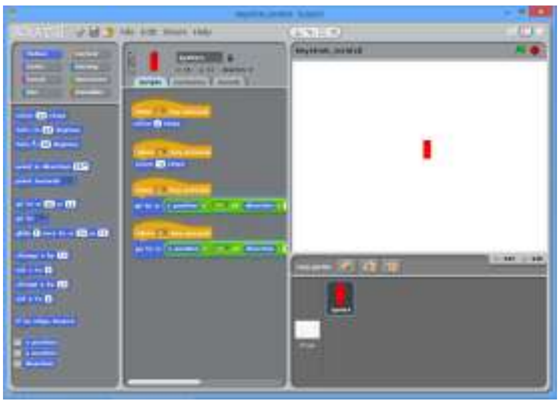

Fig. 7 An example of a PC game

The user can move his leg forward, backward, right or left and the red rectangle in MIT Scratch games will move accordantly.

VII. RESULTS AND DISCUSSION

Many experiments were carried out to test the proposed idea. Fig. 8 shows the estimated Euler angles from the accelerometer, the gyroscope and the magnetometer sensors.

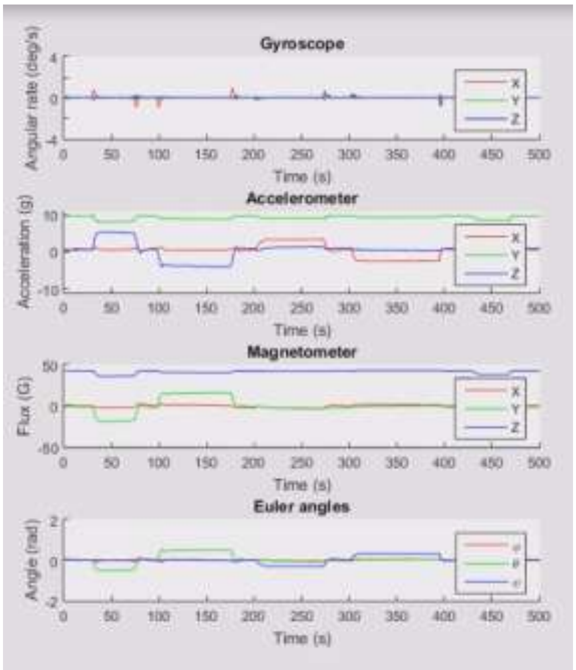

Fig. 8 Estimated Euler angles from sensors' measurements

Fig 9. Shows the real orientation of the smartphone device. It is clear that the estimated Euler angles are conformed to the real smartphone's orientation.

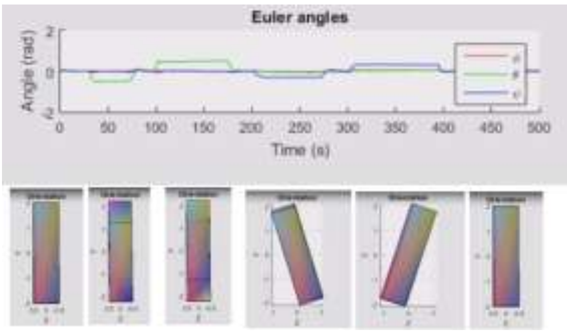

Fig. 9 Estimated Euler angles and real smartphone's orientation

Fig. 10 shows the movement of the red rectangle in MIT Scratch game according to the movement of the user's leg holding the smartphone device.

Experiments show that an Android smartphone device can efficiently be used to control virtually any published PC game.

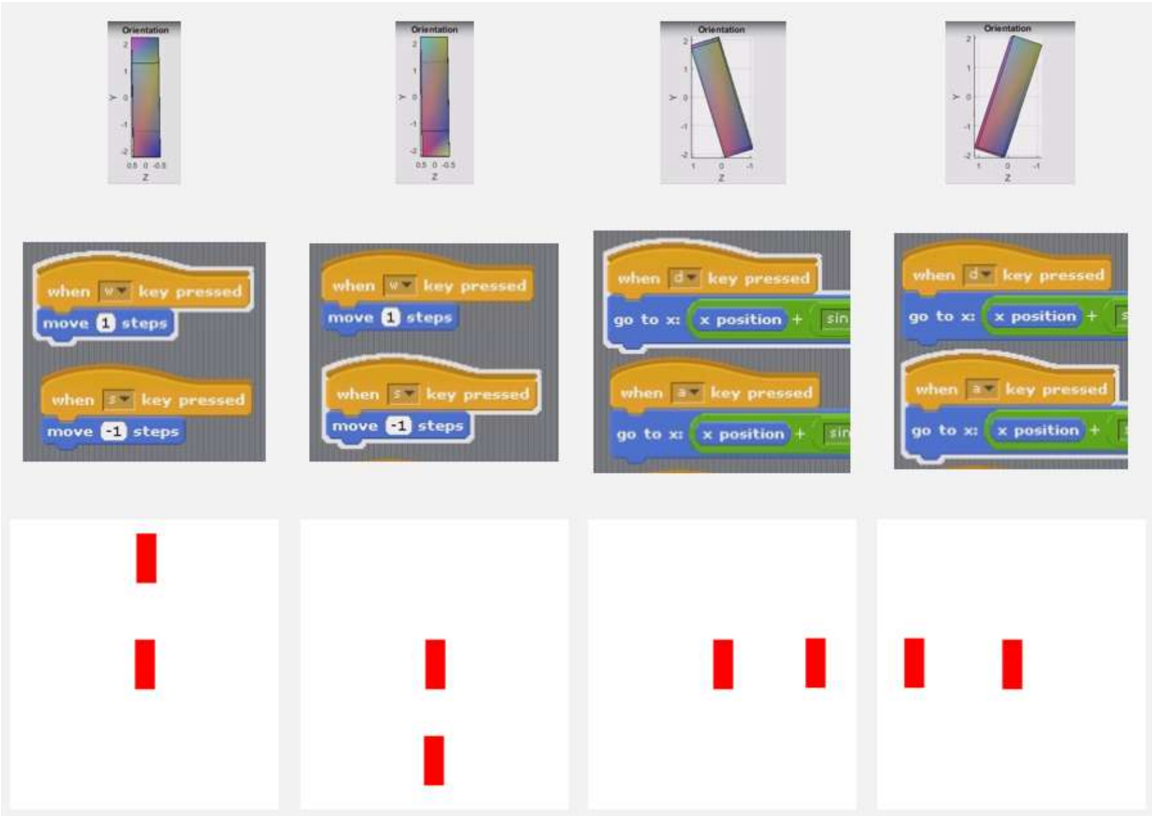

Fig. 10 Movement of the PC game's character according to the movement of the smartphone device

VIII. CONCLUSION AND FUTURE WORK

In this work, an Android smartphone device is used as a control device for PC games. The accelerometer, the gyroscope and the magnetometer sensors are used to estimate the 3D orientation of the smartphone device. This information is used to control a PC game.

As a future work, the proposed method will be used to control the position of the user in a virtual reality environment.

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