Magnetic Ring Motion Controller For VR Headset

Charles Han, Ke Xu*
Electrical Engineering, Stanford University

Abstract

For the modern state of art Virtual Reality (VR) headset, the controller being used such as joy sticks, keyboard, or mouse are either bulky or not intuitive to use. To provide a solution for this problem, we proposed a magnet ring motion controller with intuitive gesture control. The magnet ring movement is detected by the Inertial Measurement Unit (IMU) mounted on the VR headset, and further recognized as gestures to control the virtual object. Compared to traditional VR controller, our controller system using magnet has smaller form factor and less power consume.

Keywords: magnetometer, motion control, virtual reality

Concepts: human computer interaction

1 Introduction

1.1 Motivation

VR headset has been gaining popularity over the past few years. The application of VR headset has also brought a lot of attention. Currently a lot of gaming system has been built to follow the trend. Moreover, a lot of new controller system for the user to interact with the virtual scene has been invented as well. However, most of those systems involves a lot of bottoms, and a complex learning curve for the user to really get used to the controller system.

To fill this gap, we have incorporated gesture control system using a magnet ring on users hand. The example application game we used here is the helicopter. Helicopter has 3 tilt control and 2 linear control, which makes 5 DOF of control in total. Tilt is realized by the head movement of the user, which is detected by the IMU. Then we use the magnet ring controller to control the forward and up motion. Left and right movement is realized by having the user looking left, then the camera is looking at that direction, and the forward gesture helps the helicopter to move that direction.

With these very intuitive gestures, the controller helps greatly with user's interaction with the gaming world.

1.2 Related Work

There were a few works that has been done. A patent published by Google, is actually doing very similar work. They invented a magnetometer-based gesture senor based on wearable devices. It is very inspiring to find that they looked at each axis separately to develop the detection algorithm.

The Oculus paper(Lavelle) which developed the head tracking used all 9 DOF fusion inspired us of calibration method as well.

The last reference that we found is a patent who built a navigation system based on the camera-based gesture. Even though it was published almost 20 years ago, but their concept of human and computer interaction is very important to our work. We very much think that this magnetic ring controller would help user to enjoy the immersive virtual world.

*E-mail:hcs@stanford.edu

2 Hardware and Software Setup

All hardware are self-built, and here are some information about the hardware that we used:

1. Head mount display housing: ViewMaster VR Starter Pack (Shown in Figure 1)

2. Magnet ring (disassembled from Google Cardboard): the diameter of which is 1.9 cm (Shown in Figure 1)

3. Display: Topfoison 6 inch 1080p LCD

4. IMU: InvenSense MPU-9255, both the IMU and the Arduino is mounted in the front of the display housing

5. Microcontroller: Arduino Metro Mino

6. Cables: USB cables (for Arduino and LCD driver board power) and HDMI

Figure 1: *Magnet ring and the Viewmaster VR headset in the 3-axis coordinate system.*

The Software environment are also listed here:

1. Arduino: to get readings from the IMU.

2. Unity: to set up virtual environment and controller.

3. Matlab: to calibrate measurements from the magnetometer and to analyze the magnet gesture data.

3 Magnetometer Calibration

The idea of using Magnetometer is inspired by the pigeon using magnetic field to find their way to home. Then because for a lot of VR devices only uses 6 DOF fusion so magnetometer is not fully utilized. Same way, the change of magnetic field can be used to track hand gesture too. And the idled magnetometer can be used as well.

3.1 Streaming

Streaming has been a big problem at the beginning in order for the magnetometer to read magnet correctly. After a lot of effort debugging, we found out what the issue is. The main problem for the IMU that we have is the connection problem. It is really crucial to have the jumpers connected tightly to prevent them swing relative to the IMU when rotating around.

3.2 Measurement

To do the calibration, first the IMU is rotated along the three axis, and the data is recorded. Then the goal is to fit them into a unit spherical. The reading forms a off-axis skewered sphere, and rotating them along every axis is to make sure that the data covers most of the sphere, so that we have enough data to calibrate and fitting.

3.3 Fitting

After obtaining enough data, the off-axis skewered sphere need to be first centered at the origin (0,0,0) then scale every axis so that the sphere is with unit size using the perform lease square root method.

More detailed illustration can be found in the Figure 2 below.

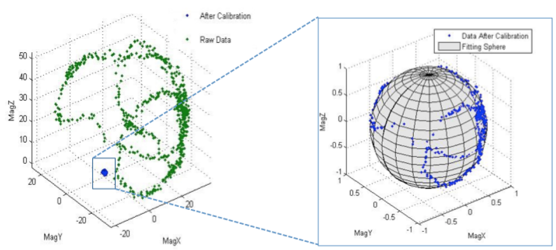


Figure 2: *Magnetometer measurement calibration. Left graph has both raw data and the calibrated data. Right graph shows the calibrated data that are corrected to fit in a unit sphere.*

4 Gesture

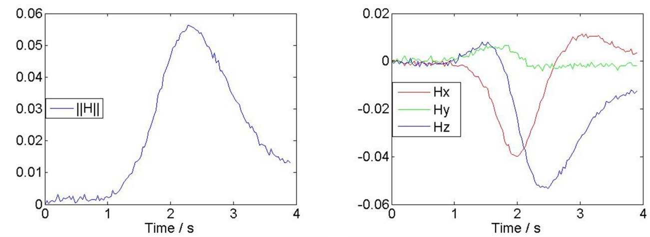
4.1 Gesture Measurement

There are three different gesture that we test based on the three axial direction of the magnetometer: magnet moving from left to right, up to down and near to far (specified in Table 1). Then we go ahead to take measurements of those three gestures (Figure 3).

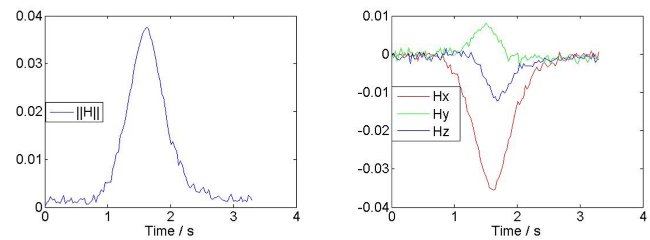
Table 1: *Viewmaster mask and the magnetic ring. Coordinates represents the gestures starting point and ending point. Coordinate system according to Figure 2. Coordinate units are in centimeters.*

User perspective	Starting position	Ending position
Gesture 1:left to right	(8, 0, 2)	(-8, 0, 2)
Gesture 2: up to down	(0, 5, 2)	(0, -5, 2)
Gesture 3:near to far	(0, 0, 2)	(0, 0, 8)

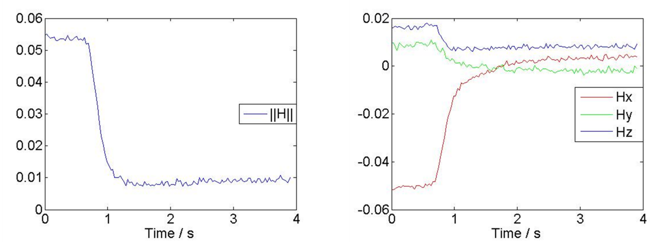
After measurement, the magnetic field H is measured, then $||H||$, H_x, H_y, H_z are analyzed separately to study their change with the magnet movement.



(a) Gesture 1 magnetic field vs. time. Left: change of ||H||. Right: change of $\overrightarrow{H_x}$, $\overrightarrow{H_y}$, $\overrightarrow{H_z}$



(b) Gesture 2 magnetic field vs. time. Left: change of ||H||. Right: change of $\overrightarrow{H_x}$, $\overrightarrow{H_y}$, $\overrightarrow{H_z}$



(c) Gesture 1 magnetic field vs. time. Left: change of ||H||. Right: change of $\overrightarrow{H_x}$, $\overrightarrow{H_y}$, $\overrightarrow{H_z}$

Figure 3: *Three magnet gestures measurements.*

4.2 Gesture Detection

Gesture detection algorithm was built on the observation above. As the user wave his/her hand with the magnet ring coming closer or far away from the magnetometer, the magnitude of the magnetic field or $|H|$ would change dramatically which we use as the flag trigging from the static detection state to the gesture detection state. However, as we enter the gesture detection state $|H|$ are no longer representative of different gestures, hence, we used the derivative dH_x, dH_y and dH_z i.e, the acceleration of the magnetic field to develop the gesture recognition algorithm, shown as the state diagram below (Figure 4):

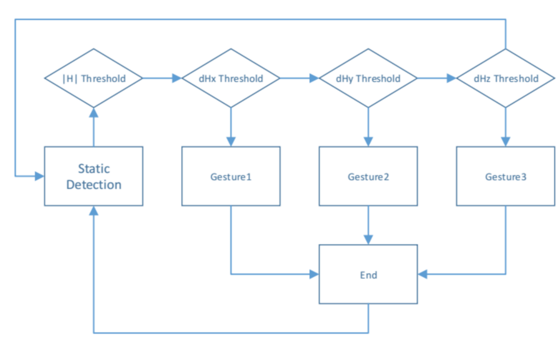


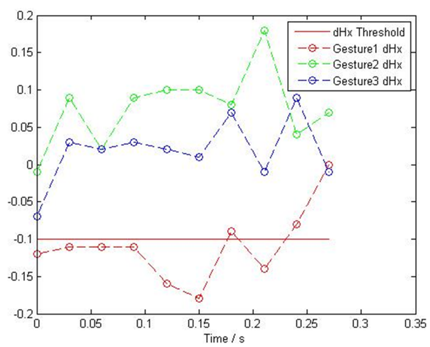
Figure 4: *Gesture detection algorithm.*

4.3 Gesture Latency

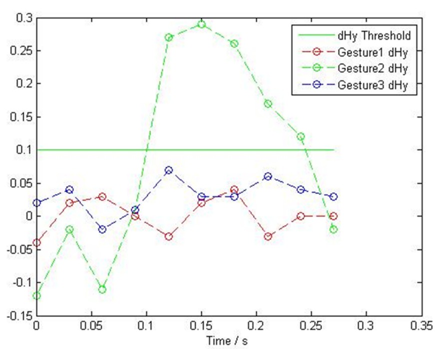
Latency is a critical target value in gesture detection and control. In our scheme, the average gesture posing time is about 1s within which about half or 500 ms triggers the gesture detection state.

Since we use four continuous readings from the magnetometer to detect the fluctuation of $|H|$ and the magnetometer is sending readings every 30 ms, the shortest time for entering the detection state would be 120ms. That is to say, during the 500 ms gesture detection state, we still need 120 ms more to actually perform the gesture control. In order to prevent misinterpretation of gestures and to improve the robustness of the control system, we set the gesture control time to 0.3s.

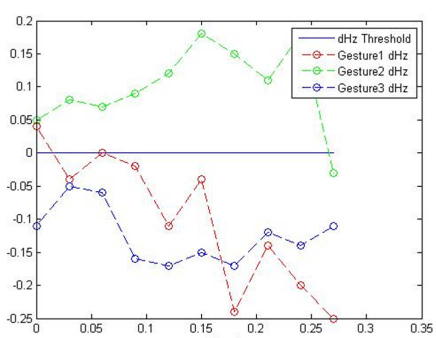
To find the appropriate threshold for the detection of each gesture, we looked them individually, found the threshold for each of them, shown below as Figure 5,



(a) dHx for each gesture vs. time. The threshold is set to catch most of gesture1



(b) dHy for each gesture vs. time. The threshold is set to catch most of gesture2



(c) dHz for each gesture vs. time. The threshold is set to distinguish gesture3 from gesture2

Figure 5: *Gesture recognition using three magnetic components.*

5 Application

As briefly mentioned in the beginning, this magnet ring gesture control will be implemented in a helicopter controlling game.

5.1 Virtual Environment

The setting of the scene is a terran and a helicopter always starts at its original position on the ground. The gamer would try to lift the helicopter up and control the direction of where it goes, and the speed to discover the whole map.

Since the helicopter has the head rotation to change the view direction, at this setting, the gesture 1 is actually incorporated with the head rotation and forward movement. So at this specific game there are only gesture 2 and gesture 3. Thus a updated state diagram is made:

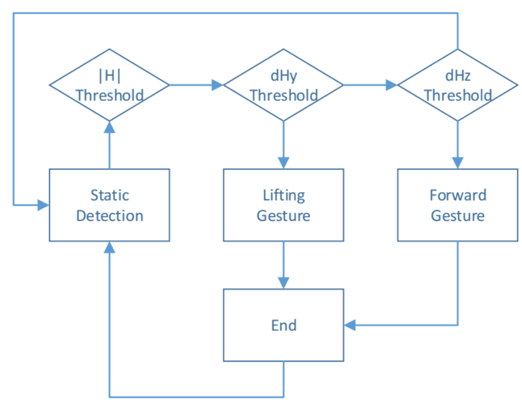


Figure 6: *Updated gesture detection algorithm.*

5.2 Helicopter Control Panel

The user would wear the magnetic ring and place the ring near the IMU sensor. The movement of hand should be about 2 cm away from the sensor to insure accuracy.

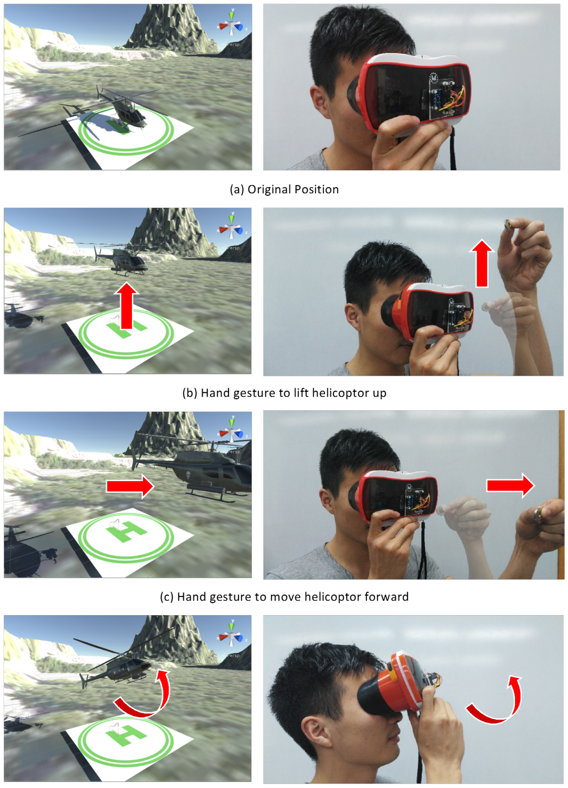
To lift the helicopter up, the user would swipe the magnetic ring up, then the helicopter would gradually take off. After that, when the helicopter is in the air, the user can choose to use gesture 3, it is the section c in the control panel illustration figures as well, to accelerate the helicopter's speed of moving forward. When they want to turn left, the user can simply look at left then swipe the magnet forward to move the helicopter forward. These control gestures are very intuitive, and the user can quickly pick up what do to.

Moreover, the physics model is all incorporated so that when the user doesnt do anything, the helicopter will gradually sink, until it lands to the ground.

This application of helicopter shows the proof of concept of using the magnetometer as sensor and the use of a magnet ring as a controller.

6 Conclusion and Future Work

Compared conventional VR controller, our design have several advantages:



(a) Original Position

(b) Hand gesture to lift helicoptor up

(c) Hand gesture to move helicoptor forward

(d) Head movement to tilt plane

Figure 7: *Updated gesture detection algorithm.*

1.No need of additional controller, no extra sensor and less battery consume;

2.Small form factor suitable for mobile VR;

3.Covering multiple DOF with intuitive gestures.

For future work, the control system need to be more robust for detection, latency should be reduced, and more gesture could be incorporated by machine learning.

Acknowledgements

We would like to acknowledge the support and advice given by Prof. Gordon Wetzstein and Robert Konrad.

References

KEYES, E., JOHNSON, M. P., AND STARNER, T., 2015. Magnetometer-based gesture sensing with a wearable device, Sept. 22. US Patent 9,141,194.

LAVALLE, S. M., YERSHOVA, A., KATSEV, M., AND ANTONOV, M. 2014. Head tracking for the oculus rift. In *Robotics and Automation (ICRA), 2014 IEEE International Conference on*, IEEE, 187–194.

LYONS, D. M., 2001. System and method for permitting three-dimensional navigation through a virtual reality environment using camera-based gesture inputs, Jan. 30. US Patent 6,181,343.