GyroTouch: Wrist Gyroscope with a Multi-Touch Display

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Abstract. We present GyroTouch, a multi-modal approach to the use of a digital gyroscope in a watch form-factor and a multi-touch desktop display with the aim to find properties that can yield better navigation in 3D virtual environments. GyroTouch was created to augment multi-touch gestures with other devices. Our approach addressed 3D rotations and 3D Translation used in navigation of virtual environments. This work also includes an algorithm for estimating angular velocity for any given axis, using only one previous sample.

Keywords: Multi-touch · Gyroscope · Modern input devices · Multi-modal · Multimodal input

1 Introduction

The emergence of new widely accessible input technologies such as Microsoft Kinect, Leap Motion, and iPad, among others, in the past few years has created opportunities to improve user interaction. The introduction of digital smart watches has also allowed to find how multi-modal interaction can benefit different types of interaction between users and computer systems. In particular, our interest lies in 3D navigation in virtual environments.

When developing gestures to aid the navigation of 3D worlds, one can find several methods, including multi-touch interaction. However, one of the primary limitations of multi-touch displays is the 2D nature of their surface. This limitation can be circumvented by creating custom 2D gestures to map the 3D equivalent input actions. In pursuit of a more realistic 3D experience, augmenting or complementing the multi-touch display gives the users a more natural interaction. We have explored the development of a fast, natural and accurate real-time 3D navigation technique using multi-touch by augmenting (or complementing) it with commodity devices (e.g., Nintendo WiiMote, Leap Motion), in order to find a more intuitive user interaction. We also want to provide a simple algorithm in the spirit of the $1 algorithm [1] and the Rubine algorithm [2], which have shown that simple solutions using commodity devices can be as efficient as more complex algorithms. We showed an algorithm in [3] which

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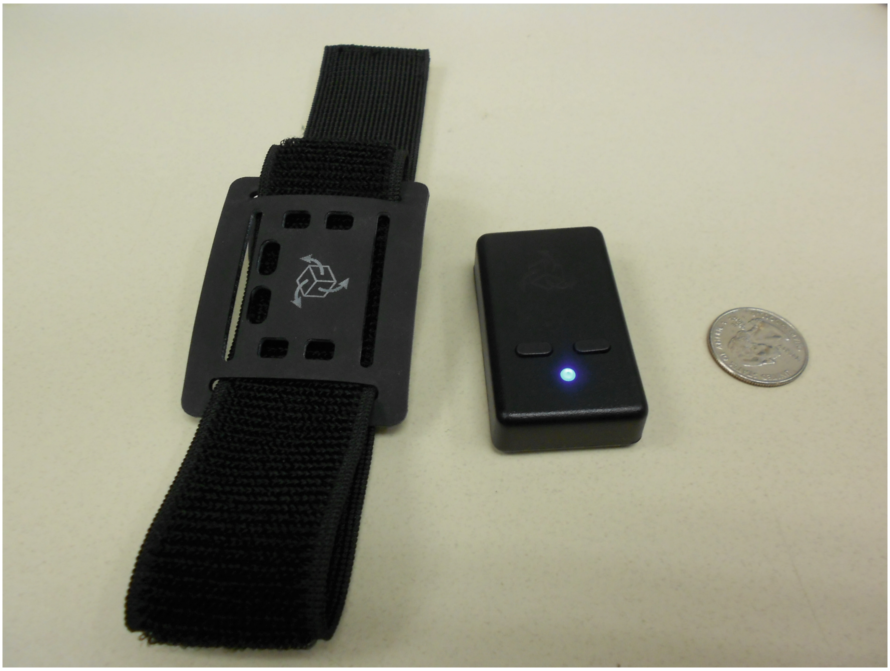

Fig. 1. 3 Space sensor and strap

demonstrated a simple approach to recognize some touch gestures, as shown in Algorithm 1. These efforts are is also aligned with recent work on multi-modal touch and pen input [4].

The proposed solution uses standard multi-touch gestures (e.g., rotate with two fingers) and a Microelectromechanical System (MEMS) that has a 3-axis Accelerometer, a 3-axis Gyroscope and a 3-Axis Compass (YEI's "3 Space Sensor"). This approach can be used to complement the multi-touch displays which may lead to a better user experience.

The work is novel when it comes to complementing multi-touch devices with gyroscopes. The ability to use additional sensors in a watch wristband is realistic and not invasive. In addition, Algorithm 2 uses simple computations to estimate the rotation angle for any given axis using only two samples received from the MEMS module.

We are inspired by the quest of the ubiquitous computing as proposed by Weiser [5] and the vision of the ultimate display by Sutherland [6]:

> "The ultimate display would, of course, be a room within which the computer can control the existence of matter. A chair displayed in such a room would be good enough to sit in. Handcuffs displayed in such a room would be confining, and a bullet displayed in such a room would be fatal."

Algorithm 1. GestureDetection

```
top ← traces.getTop(windowSize)
bottom ← traces.getBottom(windowSize)
tGrip.x ← top.getGrip.x
tGrip.y ← top.getGrip.y
bGrip.x ← bottom.getGrip.x
bGrip.y ← bottom.getGrip.y
spread.x ← iTrace[1].x − iGrip.x
spread.y ← iTrace[1].y − iGrip.y
swipeDistance ← sqrt(spread.x^2 + spread.y^2)
for t = 1 to traces.Count do
    i.x ← tTrace[t].x − tGrip.x
    i.y ← tTrace[t].y − tGrip.y
    f.x ← bTrace[t].x − bGrip.x
    f.y ← bTrace[t].y − bGrip.y
    di ← sqrt(i.x^2 + i.y^2)
    df ← sqrt(f.x^2 + f.y^2)
    iSpread ← iSpread + di
    fSpread ← fSpread + df
    angle ← atan2(f.y − i.y, f.x − i.x)
    rotAngle ← rotAngle + angle
end for
iSpread ← iSpread/traces.Count
fSpread ← fSpread/traces.Count
rotAngle ← rotAngle/traces.Count
zoomDistance ← fSpread − iSpread
rotDistance ← rotAngle/360.0 ∗ 2 ∗ π ∗ swipeDistance
return Gesture With Highest Distance
```

Algorithm 2. Rotation Algorithm for a Gyroscope

```
Ensure: midLevel=0 & unitDegree = 1 for 3Space Sensor
roll ← rawdata.roll − midLevel
rot.x[0] ← rot.x[1]
rot.x[1] ← roll
omega.x[0] ← omega.X[1]
omega.x[1] ← roll.x[1]/unitDegree
x ← angle.x[1]
angle.x[1] ← x + T ∗ ((omega.x[1] + omega.x[0])/2)
return angle.x[1] as roll
```

2 Related Work

Multi-touch interaction for 3D environments has been explored before for domain-specific applications (e.g., [7]). There have also been attempts to augment the multi-touch experience. For example, Z-Touch [8], developed by Takeoka et al., captures a depth map to add the z-axis to the touch display. However, the Z-Touch has limitations and it is not a commodity device. Augmenting the touch with a

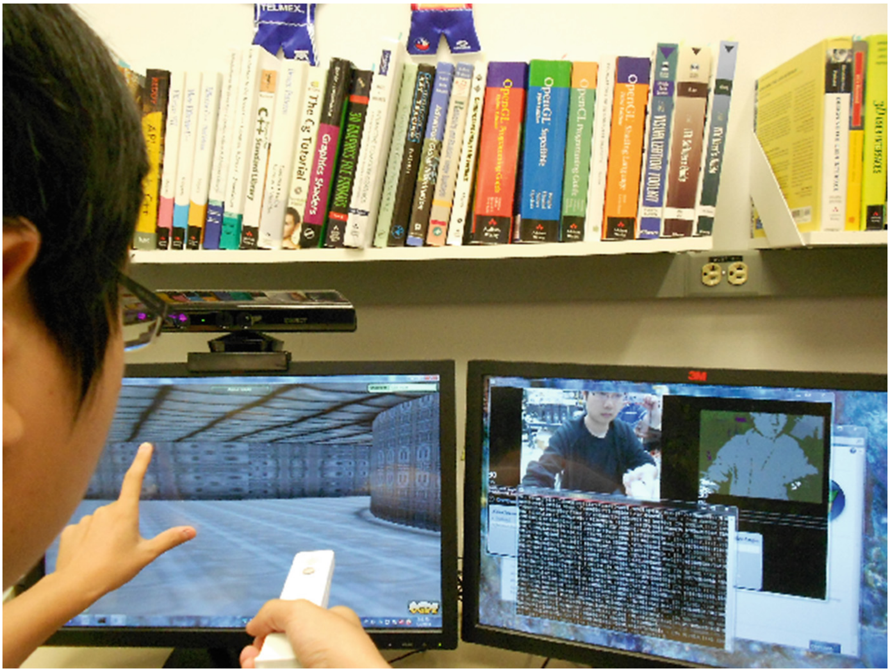

Fig. 2. 3M multi-touch display and WiiMote motion plus

force sensor has also been tried [9]. Vision has also been used to complement touch with Microsoft Kinect [9]. Similarly there are Apple iOS or Android OS devices that allow users to combine touch with some MEMS components (e.g., Accelerometer). As stated in the introduction, there have been different efforts that us the bi-manual model [10–12] using pen and multi-touch [4,13–16]. Additional multi-modal efforts include free-air and multi-touch [17], gaze and touch [18], pen and touch for games [13], pen and touch for problem solving [19], among others [20,21].

3 GyroTouch

"We have developed **GyroTouch** using Visual Studio running on a Windows 7 platform with a 3M 22" multi-touch display and a MEMS module by YEI Technology (3 Space Sensor, shown in Fig. 1). The first iteration of **GyroTouch** was done with the WiiMote, as shown in Fig. 2. Currently, we are using the 3 Space Wireless Sensor in the non-dominant hand, as shown in Figs. 3 and 4. The dominant hand is used for the multi-touch interaction. For our 3D rendering, we have used OGRE3D. We believe that combining both devices gives the user the freedom to use the hands for some of the rotations and translations, while keeping the tactual feedback intact for other gestures.

Our approach is to use our multi-touch algorithm to detect swipe, zoom and rotate gestures on the display surface. This allows us to use the touch for

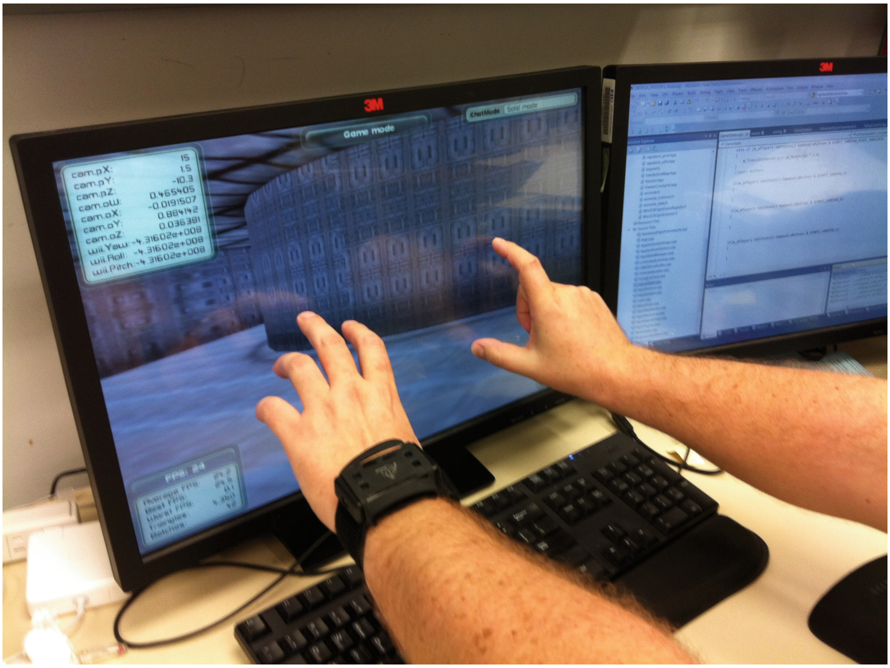

Fig. 3. 3M multi-touch display and gyroscope (left wrist)

translating in x and y (using two-finger swipe). For z translation, we map a one-finger swipe (same direction as the y-axis) to the z translation. For the rotation about the z-axis (yaw), we use the 2-finger touch rotation as it is commonly done with touch tablets. In order to keep the interaction as natural as possible, we complement the touch with the gyroscope for rotations about the x-axis (roll) and the y-axis (pitch) using the gyroscope.

Our touch detection method, described in [3], consists of finding certain characteristics for each gesture using a very fast and simple algorithm. The gyroscope found in the MEMS, shown in Figs. 3 and 4, is used only to indicate the roll and pitch rotations, whereas the third rotation is indicated via the touch interaction. Algorithm 2 shows the integration over time of the gyroscope signal, using the current and previous samples, required to obtain the angle of rotation about the x-axis. The same applies for each of the other two axes. The sensor already provides data processed by a Kalman Filter. In addition, we filter data within a threshold, calculated when the sensor is initialized, in an idle position. The sampling rate varies depending on the sensor. We are using a sampling rate of 160 Hz (with a possible maximum for this device of 800 Hz). This gives us the period $\boldsymbol{T}$ to be $1/FS$ or $1/160$. Since the data is already normalized, there is no need to use the ***midLevel*** and the ***unitDegree*** variables in Algorithm 2. Hence, we set them to 0 and 1 respectively. It is important to point out that this

Fig. 4. Gyroscope in idle state

is not always the case for all devices. For example, for the WiiMote (as shown in Fig. 2), it is necessary to set the midLevel at 2^{13} and the unitDegree at 8192/592.

4 Discussion

Our goal was to explorer the initial feasibility of combining both of theses devices. Preliminary trials we conducted showed that there is further work needed to accomplish this type of multi-modality but it is possible. An important challenge was to determined when the gyroscope is idle. The easiest way, yet not desirable, is to leave the handle idle, as shown in Fig. 4. Another option is to make the gyroscope only active when touch is not active, but that will remove the multi-modality that is desired. Adding a button to the watch to activate it, was not desirable on this type of design either. Therefore, the best way to overcome this still needs to be studied further. The other problem is that gyroscopes have noise, which yields a less stable indication of input devices. In the case of pen and touch [4], the action with the pen provided a more predictable input.

Multi-modal interaction it does have benefits. Smart watches may become more pervasive allowing the watch to become another input device for virtual environments and graphical interfaces. The main benefit of using a gyroscope (and other sensors such as accelerometer and compass) is that it provides a natural reading of rotations and translations for the third dimension. It is also expected that noise removal on these devices will keep improving, making it a viable option.

When developing multi-modal interactions, we adhere to the recommendation of Bowman and colleagues: "Match the interaction technique to the device" [22, p.179]. Each device has its complexity, its strengths and weakness. Also, a more formal study is needed to find out what gestures are appropriate for GyroTouch. An approach that seems reasonable to follow is finding a user-defined gesture set, as it was done for multi-touch in [23]. Finally, while formal quantitative evaluation is very important, initial trials are important to improve the interaction [24].

5 Conclusion and Future Work

We have shown a simple method for real-time 3D Navigation using multi-touch and gyroscope devices. Our next step is to provide additional gestures for new devices including multi-touch displays and inertial navigational systems. We will look at combining multiple devices to create a fusion algorithm to enhance the user experience. There are important questions to address. For example, how can the accelerometer, gyroscope and compass serve to improve the touch interaction? The next step is to find how the utilization of those sensors mentioned provides a better user interaction when combined with multi-touch. This should include the study of the properties of each of the devices, as done by [4] in his pen+touch study, as well as to find common gestures that work well with this interaction. Every incremental effort towards ubiquitous computing helps to get closer to vision of Mark Weiser [5]:

> "The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it."

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