The Orientation Estimation for Smartphone as Object Pointing Device

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Abstract- Nowadays, smartphone is a useful daily tool for human, which is not limited for communication only. The smartphones can provide contexts from the sensors to help this extended use. By the inertial navigation system sensors of smartphone, it can produce orientation in 3D space. Thus, when combined with good 3D position measurement, the smartphone might act as interesting object pointing device. By this role, users might have interesting experience while visiting museum or other cultural sites. However, the smartphone's sensors tend to be noisy and unreliable. Hence, in this research, the orientation estimation for the smartphone will be studied to verify that its future role to be object pointing device is feasible. Then, the orientation sensors fusion using complementary filter will be performed to combine several smartphones sensors to estimate the 3D orientation. By this method, the smartphone has proved only having 0,747 degrees in its error. By this good result of orientation estimation, it might be possible for the smartphone to serve as interesting object pointer.

Index Terms- Context aware systems, Sensor fusion, Complementary Filter, Indoor Positioning

I. Introduction

DUE to its development, smartphone has been useful to aid human nowadays. It can provide several information which enrich human knowledge in daily life. For example, during a visit to museum or other cultural site, it can give information about objects which close to visitor smartphone's position. Normally, the context used in determining user's position is in 2 dimensions. However, the smartphone can provide both 3D position and orientation, which could be explored more in extremely precise scale.

The precise 3D position and orientation, up to centimeters scale, might be useful to act as a pointer to interesting object. Then, when pointed at correct direction toward an object, the smartphone can produce vibration which alerts its user that there's an interesting object at that direction. Thus, having this feature, the smartphone has the capability to increase the visitors' user experience in the museum and feasibly help visually-impaired person to be guided independently when he or she visits the site.

The two main components, 3D orientation and 3D position, could be derived from the smartphone's inertial navigation sensors [1]. Sensors which fall into that category are accelerometer, magnetometer, and gyroscope. Nevertheless, independent from the fact of their availability in middle class phone category, these sensors are still not capable enough to have good observations because of some disturbances and noises [2, 3, 4]. In addition, GPS (Global Positioning System) cannot be used in this case because of its poor performance inside a building [5].

Thus, in this research, we will try to improve the measurement of the orientation component regarding the smartphone as pointer. The position component is not considered because of the limited scope of this research. This orientation will be estimated using a fusion method which combine several measurements from the three smartphone inertial navigation sensors.

Previously, several researches have been conducted to handle these sensors' flaw and to improve the quality of these sensors. According to [6, 7], the orientation estimation can be improved by several methods. Researchers of [6] used the 3D orientation observation, while [7] only minimized the error of the heading (Z-axis orientation). Having performed the Constrained Kalman Filter [7], the orientation error in repetitive walking and turning 90° has been minimized to 0.8°.

In this research, the complementary filter [6, 8] will be used to do fusion toward two observations, the orientation based on digital compass (combination of magnetometer and accelerometer) and the angular velocity based on gyroscope. The novelty of this research is using the experiments based on the usage of smartphone as pointer by hand, of which orientation estimation will be deeply studied.

II. Proposed Method

The general idea of the method used in this study is depicted in Fig. 1. Inputs are obtained from Inertial Navigation System (INS) sensor of smartphones. First, the sensors' observation of magnetometer and accelerometer are pre-filtered. Next, Rotation Matrix API of Android acts as combiner for the two pre-filtered observations to yield digital compass observation, which provides the 3D orientation. On the other hand, gyroscope's angular velocity observation is directly combined with the orientation using complementary filter.

A. Complementary Filter

The complementary filter is used to combine two different measurements. The application of this filter is toward the angle estimation [6, 8]. This filter mainly consists of the low pass filter and high pass filter. Then, there are two important components also namely sample period and time constant. This filter has advantage to combine the slight noisy observations and easily disturbed observation, in this case are gyroscope and digital compass, respectively.

Considering there are two measurements: digital compass and gyroscope. The fusion using complementary filter can be written as (1), where the desired measurement $\hat{\theta}_k$ is angular position at time step k. Thus, the fusion result is the orientation estimation.

$$\hat{\theta}_k = \propto (\hat{\theta}_{k-1} + \omega_{k_{gyro}} \delta t) + (1-\propto)\theta_{k_{comp}} \quad (1)$$

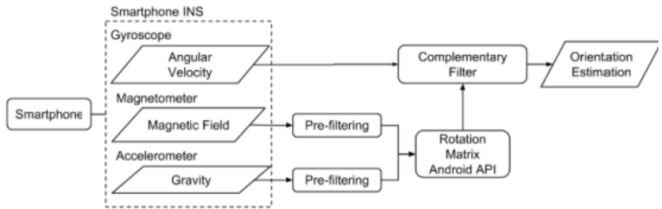

Fig. 1 Complementary filter application for smartphone sensors

III. Experimental Setup

Environment and parameters of the method is described as follows. Location of the experiment is COSTECH Laboratory where there are many electronic devices, which might disturb magnetometer's performance. The parameters of the filters, such as the window length of prefilter and estimation sampling time had been observed. These experiments yield prefilter window length of 10 and estimation time of 20 ms.

Two different experiments scenarios are performed to get different sight about the orientation estimation. Those experiments are aided by laser pointer attached to the smartphone.

The scenarios of the experiments are described as follows. First scenario is performed to measure the orientation estimation's stability for pointing the same object and same position. However, it risks the disturbance of hand and the displacement of the position of the smartphone before and after rotation. In the other way, the second scenario focused in how close the orientation estimation change to actual change when a rotation performed.

IV. Result and Discussion

The experimental results of the first scenario is presented at TABLE I. From the two experiments of the first scenario, it can be seen that the filter has performed an acceptable error of 11° difference by the Z-axis orientation before and after rotation. This filter's performance might affected by disturbance when smartphone held by hand or the misplacement of the position of the smartphone before and after rotation as explained before, even if existed a slight position difference. In addition, the Z-axis orientation can be disturbed also by the existence of numerous electronic devices in the location, which affect the magnetometer.

By different approach of the second scenario, the filter only measured a visible rotation by the Y-axis rotation because experimental objects used as reference were apart by height only. However, it gave a sophisticated result of 0.747° difference between the orientation estimation change and the actual change. This good result can occur because the measured axis (Y-axis) was mainly determined by accelerometer and gyroscope, which were not affected by magnetic disturbance like magnetometer. After all, this proved that mathematically, the orientation estimation using complementary filter can be considered for the smartphone's usage as pointer.

TABLE 1
THE RESULT OF FIRST EXPERIMENT: STABILITY TEST

Trial	Angle difference of before and after rotation (°)		
	X-axis	Y-axis	Z-axis
Object A	4,988	1,727	10,808
Object B	4,453	2,442	10,758

V. Conclusion

The 3D orientation estimation using smartphone can be tricky as its sensors give erroneous observation. Moreover, this issue become more important when the smartphone can be expected to be used as pointer, which possibly increase the user experience during several occasions, such as visit to museum.

However, those errors can be reduced using fusion of the sensors' data while in real-time responsiveness. This study has proved that use of simple sensor fusion can improve the quality of the estimation using all the inertial navigation sensors inside the smartphone in difficult location.

In the future, it might be possible to improve the orientation estimation quality by examining the disturbance's characteristics of certain location. Then, this study can be continued by taking the precise 3D position estimation into account. The precise position estimation does matter because a slight difference in position observation may lead to unfortunate object pointing mistake.

VI. References

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