MagiTact: Interaction with Mobile Devices Based on Compass (Magnetic) Sensor

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ABSTRACT
In this work, we present a new technique for efficient use of 3D space around a mobile device for interaction with the device. Around Device Interaction (ADI) enables extending interaction space of small mobile and tangible devices beyond their physical boundary. Our proposed method is based on using compass (magnetic field) sensor integrated in mobile devices (e.g. iPhone 3GS, G1 Android). In this method, a properly shaped permanent magnet (e.g. in the shape of a rod, pen or a ring) is used for interaction. The user makes coarse gestures in the 3D space around the device using the magnet. Movement of the magnet affects the magnetic field sensed by the compass sensor integrated in the device. The temporal pattern of the gesture is then used as a basis for sending different interaction commands to the mobile device. Zooming, turning pages, accepting/rejecting calls, clicking items, controlling a music player, and game interaction are some example use cases. The proposed method does not impose changes in hardware specifications of the mobile device, and unlike optical methods is not limited by occlusion problems.

Author Keywords
Around Device Interaction, Mobile Devices, Compass (Magnetic) Sensor, Magnet, Movement-Based Gestures.

ACM Classification Keywords
I.5.4 [Computing Methodologies]: Pattern Recognition, Applications – Signal processing.

General Terms
Algorithms

INTRODUCTION: AROUND DEVICE INTERACTION
Around Device Interaction (ADI) is being increasingly investigated as an efficient interaction technique for mobile and tangible devices. ADI provides possibility of extending interaction space of small mobile devices beyond their physical boundary allowing effective use of 3D space around the device for interaction. This can be especially useful for small tangible/wearable mobile or controller devices such as cell phones, wrist watches, headsets, etc. In these devices, it is extremely difficult to operate small buttons and touch screens. However, the space beyond the device can be easily used, no matter how small the device is. ADI can be also very useful for interaction when the device screen is not in the line of user’s sight.

ADI concept can allow coarse movement-based gestures made in the 3D space around the device to be used for sending different interaction commands such as turning pages (in an e-book or calendar), changing sound volume, zooming, rotation, etc. ADI techniques are based on using different sensory inputs such as camera [1], infrared distance sensors [2], touch screen at the back of device [3], electric field sensing [4], etc.

In this work, we propose ADI based on interaction with compass (magnetic field) sensor integrated in some mobile devices, using a properly shaped magnetic material. The user takes the magnet which can be in shape of a rod, pen or ring in hand, and draws coarse gestures in 3D space around the device (Fig. 1). These gestures can be interpreted as different interaction commands by the device. In the next section, we describe our approach in more detail.

OUR APPROACH: INTERACTION BASED ON MAGNETIC FIELD SENSOR
In this work, we demonstrate our initial investigations towards using compass (magnetic field) sensor integrated in mobile devices (e.g. iPhone 3GS, G1 Android) for ADI. In our method, we use a regular magnetic material in a proper shape to be taken in hand (e.g. rod shaped, pen, ring), to influence compass (magnetic) sensor by different movement-based gestures, and hence interact with the device. We demonstrate the use of this interaction in different applications such as turning pages, zooming, reacting to a call alert, and music playback.

In the Introduction, we mentioned to a few methods for ADI. Getting useful information from magnetic sensor is algorithmically much simpler than implementing computer vision techniques. Our simple yet effective approach also does not suffer from illumination variation and occlusion problems. Our technique does not impose changes or
adding huge number of extra sensors to mobile devices. For mobile devices such as iPhone and G1 Android, it is only necessary to have a properly shaped magnet as an extra accessory. In addition, considering the fact that the back of mobile device is usually covered by hand, optical ADI techniques (e.g. camera and infra-red based) can face difficulties for using the space at the back of device. However, since the interaction in our method is based on magnetic field (which can pass through hand), the space at the back of device can be efficiently used for interaction.

GESTURE RECOGNITION BASED ON MAGNETIC FIELD

The gestures are created based on moving the magnet (a rod or ring) by hand in the space around the device along different 3D trajectories. The gestures studied in this work are mainly based on movement of magnet in front or at the back of device in different directions with different periodicities.

The compass (magnetic) sensors provides a measure of magnetic field strength along x, y, and z directions. The values change over a range of -128 to 128. The compass sensor can be affected by the magnetic fields around the device, most importantly the earth’s magnetic field. In order to decrease the influence of these factors in gesture recognition, we calculate derivative of the signals over time. This is achieved by subtracting two consecutive values, and acts as a high pass filter which allows only evidences related to gestures appear at the output. The gestures are generated by rather fast movement of magnet (resulting in fast changes in magnetic field), therefore their evidence can be passed through a high pass filter.

The next processing step is feature extraction. The features we have used are mainly based on average strength of magnetic field in different directions, average piecewise correlation between field strength in different directions, and zero crossing rate (for different directions). All the features are extracted from high pass filtered signals. The beginning and end of each gesture is identified based on change of magnitude signal over a threshold. The mentioned features are extracted over a window marked by the beginning and end of gesture.

Final classification of gestures is done based on extracted features using a heuristically designed binary decision tree. The decision tree algorithm can run faster on the mobile device as compared to some statistical machine learning algorithms. Correlation between different directions, magnitude in different directions and zero crossing rate are used as basis for decision making and classification.

Initial evaluation of the algorithm has shown convincing gesture recognition results for 6 gestures and 5 users, reaching an accuracy over 90%. This is still initial results and at the demo level. Although actual interaction with our demo seems quite satisfactory, our ongoing studies show potential for obtaining even better classification results.

IMPLEMENTATION

We have implemented a demo application based on the presented method for iPhone 3GS. The interaction is used to turn pages left-right or up-down in a photo view and document view application, as well as zooming a map in and out. Zooming functionality can be also achieved using space at the back of device, so that the screen does not get occluded. The application can also demonstrate rejecting/accepting a call using our interaction method. This functionality can be achieved even when the phone is in a bag or pocket, and facilitates dealing with unexpected calls in an improper situation (e.g. office, meeting). In addition, the application demonstrates interacting with a music player for changing sound volume or music track.

REFERENCES


Figure 1