Magnetic Interaction with Devices: A Pilot Study on Mobile Gaming

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Abstract
This work-in-progress paper presents a study of interaction techniques for mobile devices, with a focus on gaming scenarios. We introduce and explore usability and performance aspects of a novel compass-based control for tangible around-device interaction, and compare it with traditional mobile gaming controls, such as touchscreen thumbstick, swiping and tilt-based approaches.

Author Keywords
HCI; User Interfaces; Interaction Techniques; Mobile Gaming; Tangible Interaction; Magnetic Interaction; Usability; Mobile Computing

ACM Classification Keywords
H.5.2 User Interfaces; B.4.2 Input/Output Devices.

Introduction
Since the birth of video games, they were typically designed to work with directional keys or joysticks accompanied by certain action buttons. This scheme remained more or less the same in different video game platforms throughout time. However, with the advancement of portable devices (such as smartphones, wearables and smart glasses) manufacturers tend to remove hardware buttons and joysticks in favor of bigger touch screen displays. While

Figure 1. Control selection screen. (Controls' order was randomized for each player.)

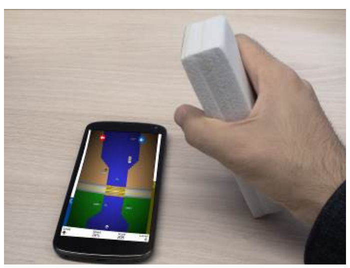

Figure 2. An ordinary whiteboard wiper was used as a magnetic joystick.

these displays have rich visual response, they provide very little tactile feedback. This issue is commonly addressed by the use of additional sensors, such as accelerometers and gyroscopes, which enable the player to control a game by manipulating the device itself [1]. Another solution, namely, third-party external controllers, require charging and careful handling.

In this paper, we explore a novel tangible interaction technique which leverages magnetometer (compass) sensor to track the position of a magnetic object manipulated by the user. The latter is represented by an ordinary magnetic whiteboard wiper. The performance of the magnetic control is compared with three mainstream interaction techniques on two games of different genres.

Related work

While multitouch screens have opened up new intuitive interaction techniques for various applications (such as navigation, panning and zooming), they also create a number of associated interaction issues. In particular, since display space and interaction space are the same in most cases, any touch interaction leads to partial occlusion of the display which may result in user missing valuable information [2]. These occlusions are known as the "fat finger problem" [3].

One way of solving this problem is separating the display from the touch space [4]. Certain handheld consoles include a touchpad on their back side as a method of back of device interaction (e.g. Sony PS Vita). Other devices may provide multiple screens, where one shows the game itself while the other one is used for secondary game information and touch input (e.g. Nintendo DS). This prevents more important game pixels from being occluded during the interaction.

Previous work on magnetic interaction with mobile devices is rather limited. Ketabdar et al. [5] presented an approach for recognition of gestures made around the mobile device with a magnetic object. After signal filtering and feature extraction, a decision tree was able to recognize six different gestures with 90% accuracy. In our work, instead of processing magnetic field dynamics, we employ simple calibration to recognize one of the five static compass readings.

Interaction techniques for mobile games

Several casual games of different genres were developed for this study. Each game supports the new magnetic interaction method as well as three traditional interaction techniques, namely virtual thumbstick, swipe and device tilt (see Fig. 1).

Virtual thumbstick is a straight-forward attempt to bring old gaming console experience to buttonless devices. Since the control is shown on a touch screen, it is prone to the "fat finger" problem and provides no tactile feedback to the player.

Swipe gestures are used in some of the most popular games (such as Angry Birds, Cut the Rope, Fruit Ninja). We use a simplified form, where swiping in one of the four directions instructs the game character to move in that direction, or perform acceleration (deceleration).

Device tilting method employs accelerometer or gyroscope sensor to identify device's orientation in space. The player moves the device to control the direction of game character's movement.

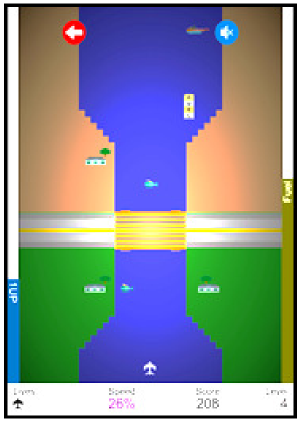

Figure 3. River Raid game used in this study.

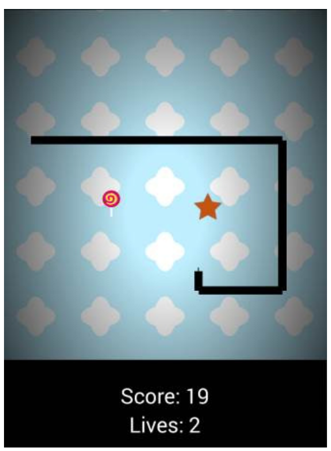

Figure 4. Snake game used in this study.

Medryk et al. [6] have previously compared tilt input with touch-based interaction on mobile games and found the latter to provide higher gameplay performance.

Magnetic interaction leverages smartphone's compass to monitor the position and orientation of a magnetic object near the device.

Implementation and early results

In this pilot study, we employ a magnetic whiteboard wiper in a way similar to traditional joysticks (Fig. 2). Changes in the magnetic field around the mobile device are monitored by a 3D compass sensor and are translated to movement commands to games. Recognition of one of the five joystick states (center, left, up, right, down) is achieved through a brief pre-game calibration, where the player is asked to move the joystick in the prescribed position. Calibration data is used as a training set for a simple nearest-neighbor classifier, which then recognizes current joystick state and sends the corresponding movement command to the game.

Our initial pilot study involved five subjects (researchers in computer science), playing River Raid (Fig. 3) and Snake (Fig. 4) games [7, 8] on a Nexus 4 Android smartphone. The players were given time to get accustomed with each game and interaction method.

In River Raid, the player controls a fighter jet with the objective to destroy as much enemies as they can without running out of fuel or hitting obstacles. Players can move the jet horizontally and control its speed using the vertical axis of the controller. In Snake, the player's goal is to guide the snake in a two-dimensional area and thus collect bonuses randomly placed there. The snake should avoid hitting its own body or field boundaries.

Both games collect objective performance metrics, such as: time to complete a level, score per level, high score and time per life. Subjective performance was evaluated by a questionnaire after each game. The questionnaires contained four questions about each interaction method for each game, followed by asking the participants to sort the techniques in their order of preference. The four questions about interaction methods asked the participants to rate (in five-level Likert scale) how fun, difficult, intuitive and responsive each method was.

According to the preliminary results, using magnetic joystick have resulted in relatively good gameplay performance in River Raid (Fig. 5), but not in Snake (Fig. 6).

Performance-wise, swiping gestures led the charts. This can be explained by the highest feeling of control – that is, the game reacted predictably, while for other controls there was some degree of uncertainty. The performance of magnetic joystick was affected by the drift of its placement during the gameplay. Since the base of the joystick was not fixed, and it had an asymmetric shape, the players accidentally moved it closer to or further from the device, thus affecting the accuracy of recognition.

Results from the River Raid questionnaires indicated that the magnetic joystick was the most fun, least difficult, most intuitive and most preferred interaction

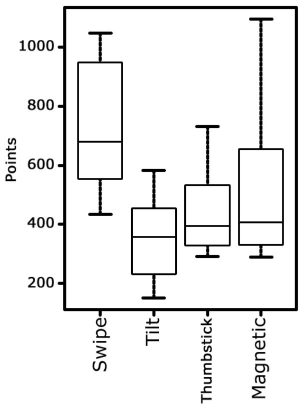

Figure 5. Total score achieved in River Raid

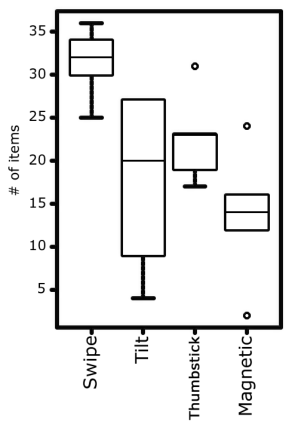

Figure 6. Total items collected in Snake

technique among all four. Surprisingly, however, it was reported being not as responsive as the others. These seemingly paradoxical results can be explained by the experience fluctuation model from the flow theory [9]. As all the test subjects had prior experience with the traditional interaction methods and considerable playing skills, they felt well in control and confident in the moderately challenging game. Lower responsiveness of the magnetic joystick made the game more challenging (while still within the capacities of the players) and therefore more joyful.

In the Snake game, however, magnetic joystick was not the preferred method of interaction (swipe and thumbstick were ranked as the first and second preferred methods). This can be explained by the asymmetric shape of the whiteboard wiper, which was easier to tilt in left-right direction than in up-down one. In contrast to the River Raid, which mainly uses left and right directions, Snake equally employs all four directions and their inequality may have led to suboptimal experience.

The described limitations can be attributed to the imperfections of the early prototype implementation which will be improved in future iterations. We also plan to address the drift issue, as well as to improve the responsiveness and accuracy of the magnetic joystick by replacing discrete state recognition with continuous position tracking. After improving the prototype, we will conduct larger-scale user testing in order to assess the characteristics of the compass-based tangible interaction for mobile games.

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