Pressure Detection on Mobile Phone By Camera and Flash

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ABSTRACT

This paper proposes a method to detect pressure asserted on a mobile phone by utilizing the back camera and flash on the phone. There is a gap between the palm and camera when the phone is placed on the palm. This allows the light from the flashlight to be reflected to the camera. However, when pressure is applied on the phone, the gap will reduce, reducing the brightness captured by the camera. This phenomenon is applied to detect two gestures: pressure applied on the screen and pressure applied when user squeezes the phone. We also conducted an experiment to detect the change in brightness level depending on the amount of force asserted on the phone when it is placed in two positions: parallel to the palm and perpendicular to the palm. The results show that when the force increases, the brightness level decreases. Using the phones ability to detect fluctuations in brightness, various pressure interaction applications such as for gaming purposes may be developed.

Categories and Subject Descriptors

H.5.m [**Information Interfaces and Presentation (e.g. HCI)**]: Miscellaneous.

General Terms

Measurement, Design.

Keywords

Pressure Sensing, Mobile Phone, Flash Light, Camera

1. INTRODUCTION

Mobile devices are small and have limited screen space. As a result, researchers are attempting to add new vocabulary to the way we interact with these devices. Besides x/y axis based surface touch, interaction methods have expanded to shaking or other dynamic actions [21]. Among these methods, the addition of a pressure sensing mechanism is especially important as it has potential to greatly increase interaction vocabulary. There have been many previous proposals to add pressure sensors to the bottom or back of the mobile devices [4][15][23]. However while technically feasible, these proposals require a significant amount of capital investment and risk on the part of the mobile device manufacturers. The time between obtaining approvals for such new hardware to the actual sales of the devices can be quite long.

Therefore, we would like to propose a method of pressure sensing which circumvents any business risk on the part of the phone manufacturers by using sensors already embedded in commonly used mobile phone. This method involves the usage of the camera and flashlight of the mobile phone to detect pressure interactions. The main idea is to measure the changes in brightness when pressure is applied onto the phone when the phone is placed on the palm of the user. Similarly, this method can be also used to detect the pressure change when user squeezes the phone. Although mobile device manufacturers use a variety of camera and flash placement configurations, a large majority are placed on the back of the device in locations where our method is applicable. Therefore, this method can add both finger pressure and squeeze pressure functionality to most mobile devices at no extra cost to the phone manufacturers and consumers.

2. RELATED WORK

2.1 Pressure Sensing with External Sensors

Many studies focused on utilizing external sensors to detect the pressure exerted on the mobile devices. For older phones, Clarkson et al. [2] and McCullum et al. [14] proposed methods to replace normal keys with pressure sensing buttons, selecting multiple options by varying the single key press pressure. Ramos et al. developed "Pressure Marks", a method of using pressure sensitive stylus pens to combine multiple actions in one gesture, such as selecting and copying in one stroke [16]. Ramos et al. also proposed "Zliding", a concept to be utilized on mobile devices to increase the smooth integration of zooming via pressure input and to manipulate the parameters within that scale via sliding [18]. Heo et al. proposed "ForceDrag", prototyping a force sensitive resistor (FSR) on the back of a mobile phone to detect pressure [4]. This pressure is used as a modifier for inputs to enrich a touch drag action. Similarly, Miyaki et al proposed a single-handed UI scheme "GraspZoom", by attaching a FSR at the back of a mobile device to evaluate the effectiveness of pressure based control model [15]. Wilson et al. explores the potential uses of pressure inputs of one hand squeezing a mobile device to provide multiple potential inputs by embedding multiple FSRs at the back of the device [23]. Kimura et al. introduced a method that produces pseudo-haptic feedback from the hand by using device equipped with pressure sensors [8].

In addition to the creation of pressure sensing techniques, the usage and efficiency of these interaction techniques has also been studied. Ramos et al. reported in "Pressure Widgets" that humans could reliably differentiate 6 discreet levels of pressure when using continuous pressure devices [17]. Lee et al. evaluate the change in input performances when human tangential forces are applied on the mobile device screen, to guide a better UI design

AH '14, March 07 - 09 2014, Kobe, Japan

ACM 978-1-4503-2761-9/14/03Ⓢ$15.00.
http://dx.doi.org/10.1145/2582051.2582062

[11]. Heo et al. proposed "Force Gestures", prototyping a force sensitive case for the iPod touch to detect tangential forces and studying these forces gestures to create a better force gesture framework [5]. Stewart et al. explored the effects of pressure applied from the front, back or pinching from both sides of a device [19]. Wilson et al. studied the accuracy for humans to distinguish the pressure input on mobile devices [1]. Many previous proposals require the addition of new sensors to mobile devices. However, we believe the camera pressure sensing method outlined in this paper has the advantages in being able to sense pressure in both touch and squeeze gestures, while not requiring the addition of any sensor technology to the mobile devices. Additionally, this method is able to sense a continuous range of pressure in both gestures.

The concept of using camera and flash has also been used in many practical situations such as to detect the concentration of microbial cells using optical density [22] or to detect the turbidity of water [19]. FlyEye utilizes infrared light and camera, transmitting light through optical fiber to recognize grasp interaction by detecting the change in light reception when a hand covered a mobile surface[24]. Similarly, we aim to utilize the phone's built-in sensors to implement this concept.

2.2 Interaction Sensing with Internal Sensors

There are many studies that utilize internal sensors to create a new interaction vocabulary. Hinckley et al. leverages the combination of touch and motion gestures utilizing internal sensors to enhance interactions [6]. Strachan et al. utilizes linear accelerometer to detect human physiological tremor as an input for mobile devices [21]. Cuddly is a mobile phone application that aims to enhance the interactivity of soft objects [13]. This application utilizes the flashlight and camera of a mobile phone to be embedded into soft objects to detect the changes in pressure asserted on the objects.

Among the different interactions, pressure plays a huge role in creating a new interaction vocabulary. Many studies attempt to manipulate internal sensors to detect the pressure asserted on the phone. Goel et al. designed "GripSense", an application that utilize the mobile's gyroscope sensor and vibration motor to detect the pressure exerted on the screen and by the user's grip [3]. Hwang et al. proposed similar pressure input interaction by utilizing the built-in accelerometer to measure the level of vibration absorption induced by the vibration motor [7]. Boring et al. proposed the simulation of thumb pressure by measuring the through the measurement of contact radius of the fingers on the screen to create a single-handed interaction method for panning and zooming [1]. Similarly, we proposed to detect the pressure interaction by utilizing the internal sensors (the camera and flashlight) in a mobile phone.

3. PRINCIPLE

The concept here is to utilize the mobile phone's camera and flashlight to detect the changes in pressure applied on the mobile phone. As the human palm is soft, there is a small gap between the user's hand and the mobile phone's back camera when the user holds the phone (Figure 1). This gap allows a constant stream of light to reach the camera. However, when pressure is applied to the screen, the phone will be pressed onto the palm, reducing the gap and thus, reducing the amount of light reaching the camera (Figure 2). The camera preview obtained will be converted into mean RGB value and finally converted into mean brightness level. Figure 3 gives a better illustration of the camera preview when the screen is not pressed (left) and when the screen is pressed (right). Similarly, when user squeezes the device, the gap between the

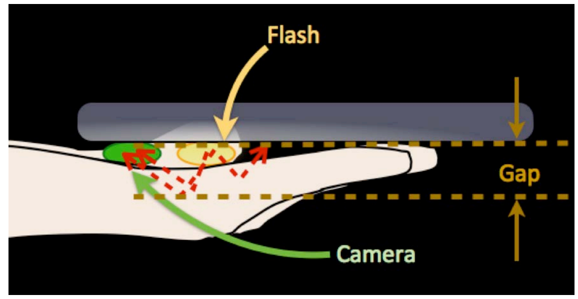

Figure 1. When no pressure is applied, there is a gap between the palm and the camera.

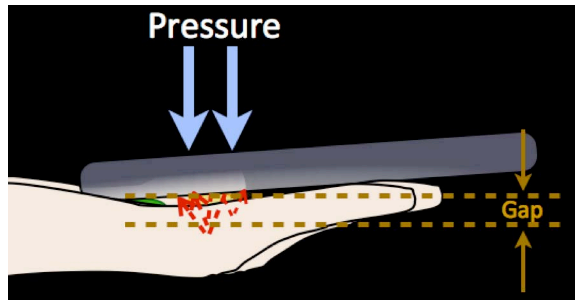

Figure 2. When pressure is applied, the gap will reduce causing the camera preview to be dark.

Figure 3. Screen illustrates brightness (left: not pressed, right: pressed).

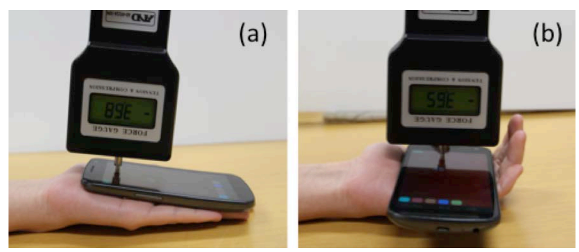

Figure 4. Experiment taken when phone is placed (a) parallel and (b) perpendicular to palm.

user's palm and the camera also changes. As such, pressure applied through a single handed squeezing of the device can also be detected.

An experiment was conducted to illustrate the brightness change when force is applied onto the surface of the phone. The phone was placed on the palm in two directions: (a) parallel to the palm and (b) perpendicular to the palm (Figure 4). These two placing methods are used to imitate the two gestures: (a) for when pressure is applied on screen and (b) for when pressure is applied by squeezing. The camera was positioned on the center of the palm. We used a force gauge (AD-4932A-50N by A&D) to detect the force asserted on the screen, and checked the brightness level at regular force intervals. Each reading was taken at an average of 3 readings. In order to reduce error, the initial starting point for each reading was taken at the same value: (a) at 96 and (b) at 101. Figure 5 illustrates the results of the experimentation.

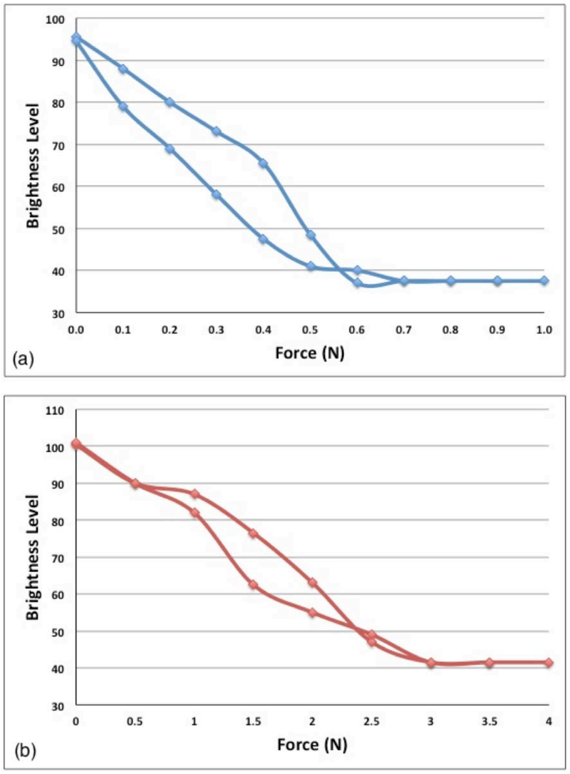

Figure 5. Results of Change in Brightness Level when Forces are asserted when the phone is placed (a) parallel and (b) perpendicular to the palm

From the results, we can observe that the brightness level reduces as the force applied on the screen increases when the phone was placed on both positions. Both graphs show a drop in brightness values to approximately 60. When the phone is placed (a) parallel to the palm, the minimum force to apply on the screen before it reaches minimum brightness value is 0.7N, while when the phone is placed (b) perpendicular to the palm, the minimum force is 3N. Any force values above these values did not show any changes to the brightness values. The reduction in brightness illustrated in both graphs shows that our method is capable of detecting the pressure asserted on the device. Normally, when one places the phone on a hard surface, regardless of the color, the minimum brightness level will be black. However, as observed in the graphs, the minimum brightness level when placed on the palm did not surpass 30. Similarly, when we observed the screen color at minimum brightness level illustrated in Figure 3 (right), we can observe that it is red in color. The reason for this is because red light can penetrate through our hands [9].

4. IMPLEMENTATION

We implemented the method on a Galaxy S SC-02b by using the Android SDK with Eclipse. In order to implement the application, there are two functions that have to be taken into account: the auto-exposure function and the compensation level. Majority of phones come with an auto-exposure function, a function that adjusts the shutter speed according to the surrounding lighting conditions. However, this function hinders the accuracy of the application and thus, it has to be locked. After locking this function, the lighting conditions have to be adjusted manually by adjusting the compensation level. After testing with many compensation levels, the minimum compensation value seems to be most suitable. Another point to enhance the interaction is by detecting different gestures such as how fast or slow the press is. There are two ways to implement this function. One is to obtain and compare the gradient differences between the fast and slow speed. Another is to obtain the amount of times pressure is asserted within a short time interval. Through that, all these functions can be used to create different applications utilizing other functions a mobile phone has.

5. APPLICATION

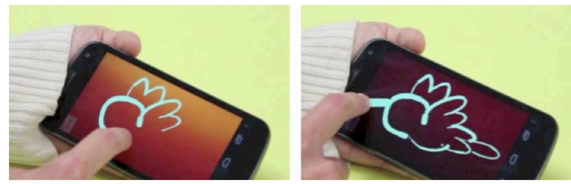

Figure 6. Painting.

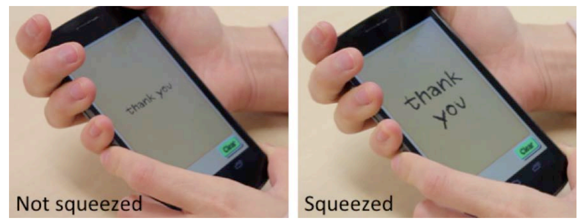

Figure 7. Sending different text size

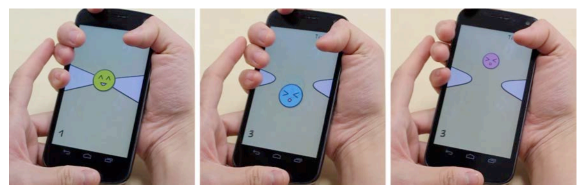

Figure 8. Game to catch falling character.

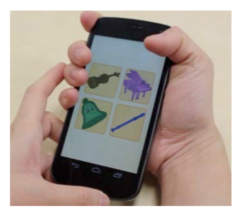

Figure 9. Musical instrument.

This section will introduce a few proposed applications utilizing this pressure sensing function. Figure 6 shows a painting application where the line thickness changes according to the pressure asserted. The brightness change is more obvious on the left side where the camera is placed. Using this function, we can create applications where user can take a picture and decorate the picture with lines or decorations that changes thickness according to pressure. Besides that, font size is a good way to convey emotions. We propose an emotional text message application by squeezing the phone to change the font size and to send it to others (Figure 7). Figure 8 shows a gaming application to catch a falling character. When user squeezes the phone, the hands in the screen will move in to capture the character. Lastly, Figure 9 shows an application where user can choose a musical instrument and squeeze to change the pitch of the sound.

6. LIMITATION AND FUTURE WORKS

One of the limitations of the application is that continuous usage of flashlight creates heat and requires a lot of battery power, causing the usage time to be limited. Besides that, every small movement will cause a small change in the brightness level. For the application mentioned above, these little changes do not have high influence on the applications. However, we have to improve its efficiency for applications that require better accuracy. This proposed method is also limited to mobile phone where the hands can cover the camera, within two gestures. For future works, we will implement the method in different phones as well as to test with different type of gestures. Current experiment only took the brightness change when pressure was asserted on the same position where the camera is placed. However, when the pressure is placed at points away from the camera, the brightness change will reduce. Therefore for future work, we aim to collect the brightness change data for different positions on the phone when placed at one direction, to get the relationship between the changes in brightness level when pressure is asserted at different position.

7. CONCLUSION

In this paper, we proposed a method to detect pressure asserted on a mobile phone by using the camera and flashlight of the phone. When the phone is placed on the palm, there would be a gap between the palm and the camera. When pressure is asserted on the phone, this gap will reduce, reducing the brightness captured by the camera. Thus, this method can detect 2 types of pressure gestures; pressure asserted on the screen and pressure asserted by squeezing the phone. We also conducted an experiment to show the change in brightness level when force is asserted on the screen of the phone when the phone is placed at two different directions on the palm. Results show that the higher force asserted will decrease the brightness captured by the camera. Using these data, we can implement diverse pressure interaction applications.

8. ACKNOWLEDGEMENTS

This work was supported by the Strategic Information and Communication R&D Promotion Programme (SCOPE) of the Ministry of Internal Affairs and Communications, Japan.

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