Detection of Tangential Force for a Touch Panel Using Shear Deformation of the Gel

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Abstract

Many capacitive touch panels detect the position and contact area of the user finger, and can estimate the vertical force from the change in the contact area. However, they cannot detect and measure the tangential force. This research aims to enable the measurement of tangential force using a gel layer, which deforms when a tangential force is applied. By measuring the finger motion of the user, we can estimate tangential force from the gel spring ratio. Using this input method, any part of the touch panel surface becomes a joystick, or virtual objects can be modeled by deforming them with the fingers.

Author Keywords

gel; shear force; tangential input; touch panel;

ACM Classification Keywords

H5.2. Input devices and strategies, Haptic I/O, Interaction styles

Introduction

Touch panels have become commodity items, especially since they were adopted as an interface for portable device. The capacitive touch sensing method that has primarily been used in recent touch panels enables multi-touch sensing, hover sensing, and even force sensing.

On the other hand, the force sensing is limited to the vertical direction. The vertical force is estimated by the change in the contact area resulting from the deformation of the fingers. If the direction of the force is available, we can add new input methods such as pushing tangentially and dragging, which is distinguishable from conventional sliding or swiping. We may also use any part of the touch panel surface as a joystick, which is applicable for video games.

In this study, we developed a new measurement scheme that can sense tangential force on the touch panel with a simple non-powered method using only a transparent gel layer. Preliminary results of the measurements are presented.

Related Work

The development of 3 degrees-of-freedom (DoF) force distribution sensors has a long history in the field of robotics, especially for adding high functionality to robot fingers [1].

In the field of HCI, Shimojo et al. developed a tactile display that can be used as an input device for people with visual impairment [2]. They used a 6 DoF force sensor attached beneath the tactile display, and estimated the finger position and force direction. Harrison and Hudson placed joysticks between the display and touch panel to obtain shear force [3]. However, in these methods, contact location was limited to a single point.

Vlack et al. developed GelForce [4], which used transparent gel with embedded color markers and a camera. It captured displacement of the markers and obtained the force vector distribution by solving the inverse problem. Sato et al. applied this method to a portable device using an embedded camera [5]. Kakehi et al. applied the method to a tabletop interface [6]. Sakamoto et al. developed the Wrinkle Surface [7], which detected surface force by measuring wrinkle patterns generated by the force on a soft and clear gel sheet. They realized new force input methods such as "Push", "Thrust" and "Twist". Most research that realized the measurement of 3 DoF force on touch panels used cameras beneath the top surface, which limits its practical use.

When we apply a tangential force, the finger should shift. Therefore, one direct way to estimate tangential force with an existing touch panel is by measuring the movement of contact location. However, we must distinguish between tangential force from swiping, since both of them are observed as a movement of contact location. This distinction might be possible by measuring fingerprint patterns [8], but much higher resolution sensing is required than is presently achieved. Exchanging tangential force input for other gestures, such as rolling of the fingers might be a practical alternative [9], but it requires specific training. Heo and Lee proposed the method of distinguishing between drag operation and tangential force by measuring the contact area (vertical force) and the speed of the touch movement [10]. The method

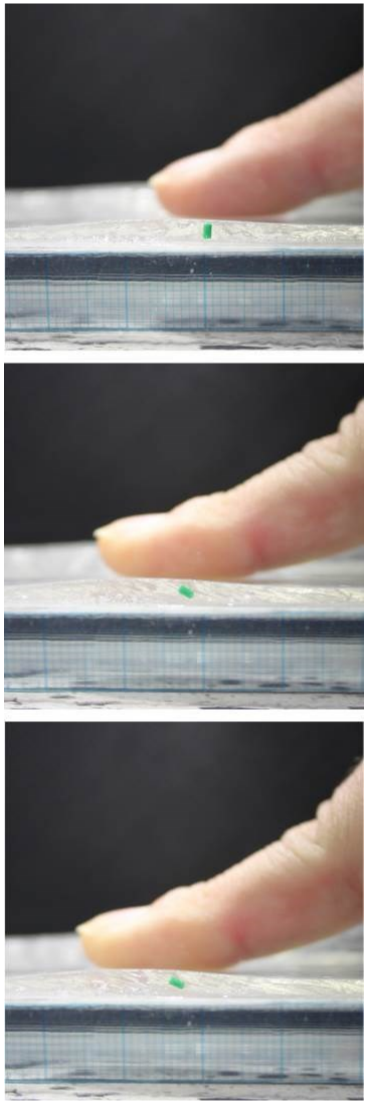

Figure 2: User’s finger displacement on the sheet

doesn’t need camera setups or user’s training. However, the use of the speed of the touch movement makes users conscious about the speed. Furthermore, the authors mentioned that errors between tangential force and drag operation were inevitable.

Method

We propose a new structure that can roughly obtain the tangential force using only the functions of existing touch panels.

Figure 1 shows the basic structure. It is composed of two layers on a touch panel, a hard coat layer on a soft gel layer. The hard coat layer is a 0.15 mm thick PET sheet (Digio2, NAKABAYASHI CO., LTD.), which is flexible enough to propagate the force of the fingers of a user onto the soft gel layer, while protecting the surface and preventing direct adhesion of the soft layer to the fingers. The soft gel layer is about 1.5 mm thick silicone gel (KE-1052, Shin-Etsu Chemical Co., Ltd.). With a small shear module (4.9×10^2 N/m^2), the gel is easily deformed by the finger force.

Comparing vertical and horizontal deformability, the vertical displacement is limited because the layer is not thick, and the gel is almost incompressible (i.e. Poisson’s ratio is about 0.5 so that horizontal expansion must be accompanied with vertical compression). Moreover, the hard coat layer prevents the soft gel protrusion on the touch panel surface, which normally forms wrinkles such as that used in Wrinkle Surface [7].

However, tangential displacement (i.e. shear deformation) is not limited by this incompressibility. Our prototype showed that the average finger force moved a few millimeters to a 1 cm tangential displacement. The large tangential deformation led to the idea that the approximate movement provides information on the tangential force by assuming linear elasticity (i.e. Hooke's law, F=kx) (Figure 1). Figure 2 shows the behavior of the displacement of the finger of the user on the sheet.

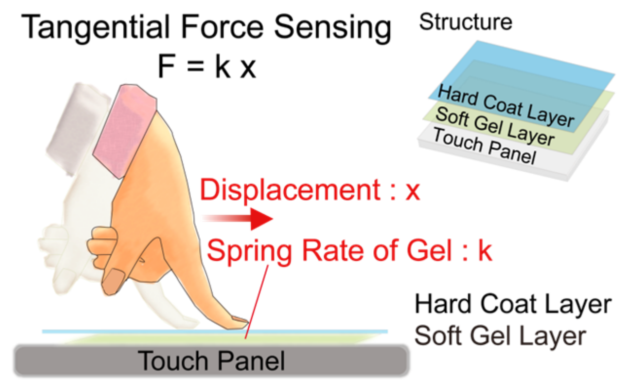

Figure 1: System for tangential force sensing

When there is no slipping of the finger of the user, the displacement is directly related the tangential force. In terms of using finger displacement, our method is similar to Heo and Lee’s work [10] and also needs to discriminate between tangential force and dragging. On the other hand, our method “magnifies” motion associated with tangential force, which enables more accurate force estimation (Experiment 3).

Evaluation

We evaluated the method by comparing the real force and displacement. The system is composed of a smartphone that has a capacitive touch panel (GT-I9300, SAMSUNG) mounted on a 3 DoF force sensor (DSA-03A, Tec Gihan Co., Ltd.) (Figure 3). The sensor value could be seen by the participants throughout the experiments.

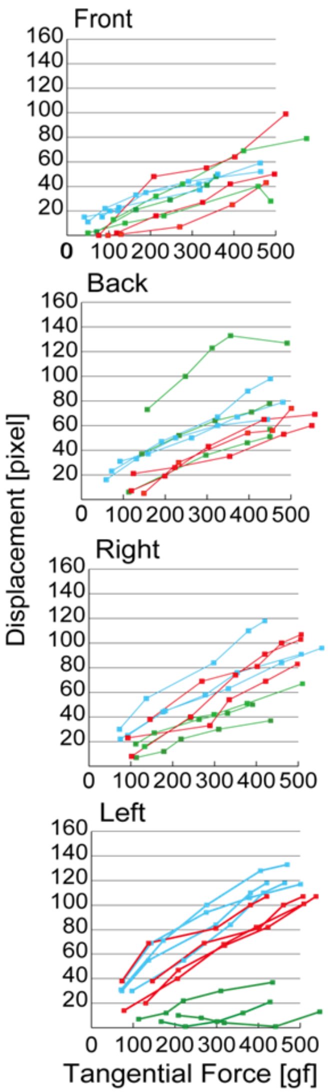

Figure 4 Relationship between the tangential forces and finger displacement

Experiment 1: Tangential force sensing

We recruited three laboratory members (age: 21-23, all male). We asked them to place the index fingers of their dominant hands on the center of the touch panel, and exert a tangential force while exerting sufficient minimal vertical force to prevent any slipping. We also asked them to gradually increase their tangential force from 100 gf to 500 gf by observing the value on a PC monitor. The directions of force were front, back, right and left, and we obtained two sets of data simultaneously; the displacement of their fingers on the touch panel and the tangential force measured by the 3 DoF force sensor (Figure 3). The trial was carried out 12 times per person (4 directions × 3 repetitions).

The results are shown in Figure 4. Directions of the tangential force are front, back, left and right. The results showed that, in this system, there is a linear relationship between the tangential force and the displacement of pixels. On the other hand, the slope of each graph is different between participants, which might be the result of different vertical pressure or different size contact areas.

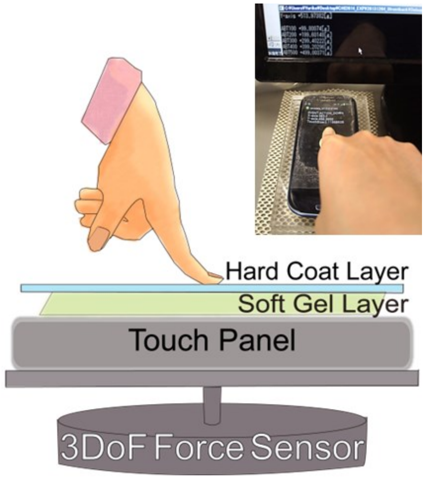

Figure 3: Experiment configuration

Experiment 2: Comparison with vertical force sensing

We compared the accuracy of the measurement of the tangential force using the displacement of the finger of the user with the vertical force using the change in the contact area. We considered that the system is practical if the accuracy is the same or higher than the accuracy of the measurement of the vertical force, which has been used in practice.

We recruited the same members as in Experiment1. We asked them to place the index fingers of their dominant hands on the center of the touch panel, and exert a vertical force. We then asked them to gradually increase their vertical force from 100 gf to 500 gf by observing the value on a PC monitor. We obtained two sets of data simultaneously; the change in the contact area and the vertical force measured by the 3 DoF force sensor. The trial was carried out three times per person. The results are shown in Figure 5.

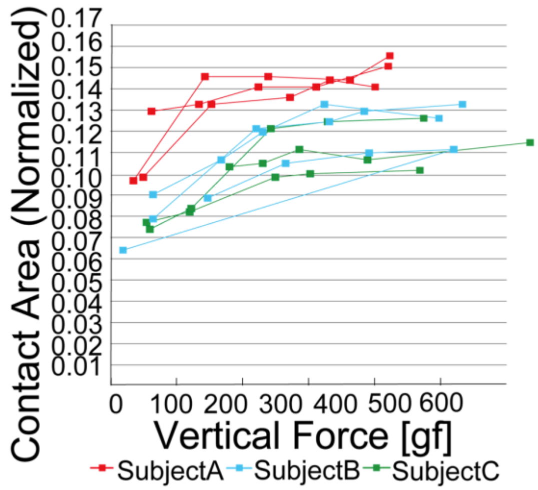

Figure 5: Relationship between the vertical force and the change in the contact area

The results also showed that there was a linear relationship between the vertical force and the change in the contact area. There was also large variety between participants, which is similar to our results in experiment 1. Therefore, we may say that our approach for tangential force measurement is comparable to existing vertical force measurement method that is adopted in current touch panel.

Experiment 3: Comparison with the case without soft gel layer

We compare the accuracy of the measurement of tangential force using gel with not using gel. We recruited three laboratory members (age: 23, all male). To set the friction coefficient constant, we also put the same hard coat layer on the touch panel without gel.

Figure 6 shows only the result of tangential force to the front. While the other three directions did not show apparent difference between using gel and not, in the case of front, there was apparent difference. Without gel, the finger displacement is often decreased while the tangential force was increased. On the contrary, such the phenomenon is rare in the case with gel. We suppose that without gel, the effect of rotation along pitch axis was not negligible, while it became relatively small with gel.

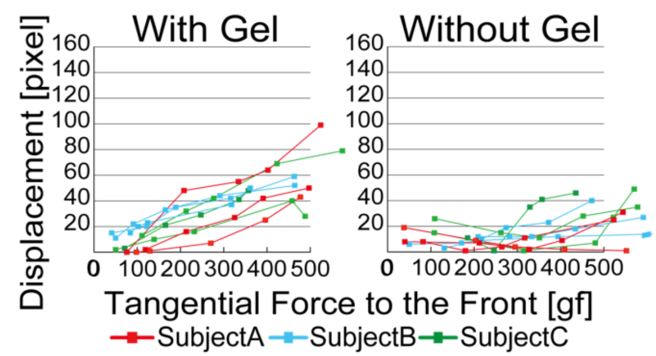

Figure 6: Comparison of with and without gel layer for tangential force to the front

Application

We introduce an application scenario of our tangential force measurement. It is to use it as joystick.

GelDrive

In this application named GelDrive, we control the handle of a car simulation game using the device (Figure 7). The car steering wheel is displayed on the touch screen and the user rotates the handle with a tangential force using two thumbs.

Figure 7: A user playing GelDrive

Conclusions

In this study, we proposed a new measurement scheme that can sense tangential force on the touch panel with a simple non-powered method. The system is composed of an incompressible soft gel layer and flexible coat layer. Shear deformation of the soft layer can be used to estimate tangential force. The experimental results showed that the the system can be used for an approximate estimation of the tangential force and the merit of using gel. We also showed an application using the tangential force input. Our future work will include simultaneous vertical and tangential force measurements and 3d force input.

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