Nail+: Sensing the Strains From Fingernail As Always-Available Input

1st Author Name
Affiliation
City, Country
e-mail address

2nd Author Name
Affiliation
City, Country
e-mail address

3rd Author Name
Affiliation
City, Country
e-mail address

ABSTRACT

We present Nail+, a nail augmented device that sense user's fingernail contour and bend when force is applied on surface. By using 3×3 array of 0.2mm strain gauges, Nail+ is small enough to fit on fingernail, and it is flexible and stretchable. We evaluate this interface in motion and motionless mode. The system can distinguish swipe gestures with high accuracy(93.2%). For motionless mode, it can achieved 85.6% accuracy for classifying with different kinds of finger posture. Since the device is always available input, it allows user to perform swipe gestures on surfaces around or touch postures on touch screen devices to enable different kinds of application usage. We also show some examples applications such as quickly swipe on surfaces around to control smart TV or touching on touchscreen devices to enable different application short cuts.

Author Keywords

Natural User Interface (NUI); Wearable electronics; fingernail; Strain gauges; Machine Learning; Nail pressure;

ACM Classification Keywords

H.5.m. Information Interfaces and Presentation (e.g. HCI): Input devices and strategies (e.g., mouse, touchscreen)

INTRODUCTION

Recent works has seen new proposal for nail augmented device in body-attach computing. Fingernail has been widely adopt due to its characteristic of non-perception area. And it also has the advantages of its non-obstructive and most promising place for easy installation and removing[9]. Moreover, nail art is proposed in previous work[12, 10]. We believe that using nail as mounted location will become more popular in the future.

Early works on fingernail mounted devices developed schemes to augment fingernail with a output of display and sensor. NailDisplay[12] tried to mounted a visual display on top of fingernail to avoid the big thumb problem on touchscreen. Ando et al.[1] proposed to put a small voice coil to

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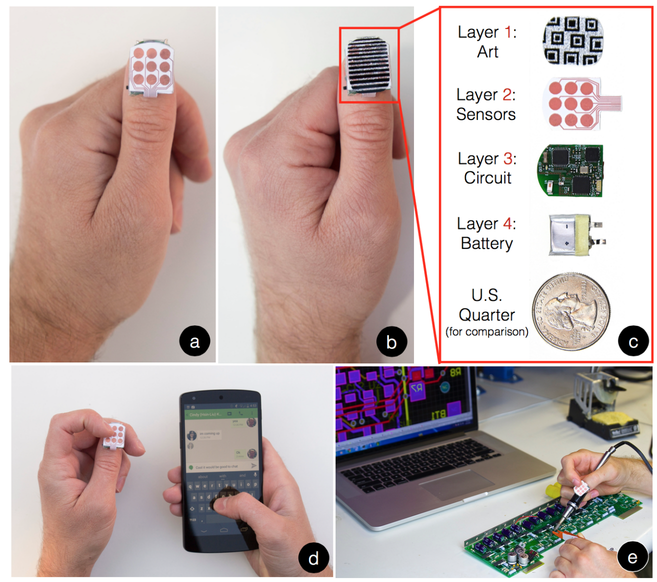

Figure 1. Nail+ THIS IS A PLACE HOLDER FOR Nail+

control the tactile feedback from surface by changing waveforms. More than that, FingerSight[5] implemented a device consisted with camera to extract the information from the surrounding. Previous research also demonstrated using nail-mounted device to enrich input area. NailO[10] proposed a capacitive sensor grid on top of the fingernail to sense swipe and tap gestures. uTrack[4] and FingerPad[2] added on the fingertip with a small magnet, and using a magnetic field tracks the finger movement. TouchSense[7] used 3-axis accelerometer to detect finger postures to switch different modes of input. These works has proved that the device on top of fingernail's advantages. However, these works only instrument the device on top of the fingernail without using the characteristic of fingernail itself.

This brings us to think about using fingernail as a input property proposed in [8], which used a computer vision for sensing force touch. There are also works using fingernail itself as a sensing part. Mascaro et al.[11] also implemented a nail-mounted device for observing changes in the reflection intensity on fingernail. (one more work!) However, the sensing technique of it still left in question for recognition of swiping gestures and it also is limited to sense a force which is not enough for out daily use.

In order to explore better sensing technique of nail augmented device, we aimed to design a device that achieved following designs. First, it has the ability of sensing simple gestures on surface like swiping and tapping. Second, it has no restrictions of input area which can enable user to perform gestures on surfaces around. Finally, it should comes with light and thin form factor due to the place of fingernail. The proposed design will definitely be a novel input device for increasing the mobility of touch screen. It also can be perform gestures anywhere without physical effort.

In this paper, we developed a prototype, Nail+ (Figure 1), use a 3×3 array of strain gauges sensor to explore the strains from fingernail as input technique.

In summary, the main contributions of this paper are as follows:

- A novel fingernail input interface presented and explores the ability of fingernail's strains as a input technique.
- We develop a nail-mounted prototype can detect swipe gestures and postures of fingernail.
- We conducted two system evaluations of this technique and implemented scenarios to explore interactions.

PROTOTYPE DESIGN

In order to design a nail augmented device to sense a touch or gesture on surfaces, we have few mainly requirements. First of all, the device must be small enough to fit within fingernail. Second, it should have ability of sensing slightly changes of the strain from fingernail. Last but not least, it has to be reusable and easy for installation and removing. Based on above of requirements, we derived that using a 2D array of 0.2mm strain gauges is the appropriate solution for this prototype.

Pilot Study : Human Behaviour and Size of Fingernail

Before developing device, we recruited 10 participants (7 male, 3 female) from ages 20 and 24 (mean 21.2) to find average width and height of fingernail. We also requested user to perform tap gesture on electronic load-cell to measure how much pressure applied on the surface in daily life for investigating the ability of strain gauges. The result of this pilot study, fingernail width is 1.145cm(SD=0.14) and height is 1.21cm(SD=0.17). And the average of tap pressure measured 0.82N(SD=0.26).

Hardware

We developed Nail+ using a 3×3 array of 120-ohm 0.2-mm strain gauges for sensing part (Shown in Figure 1). Below of the strain gauges, we used a stretchable and flexible artificial-skin to stick sensors on user's fingernail. The size of it only takes 0.9cm×1cm which is smaller than 1 cent of US dollar, and the thickness of it is 1mm. Each of the strain gauge is directly wired to the computing part. The computing hardware is consisted with an Arduino Nano board and two 8-to-1 analog switches(MAX4617, Maxim Integrated), a dual digital potentiometer (AD5231, Analog Devices), and two instrumental amplifiers (INA333 and INA122U, Analog Devices).

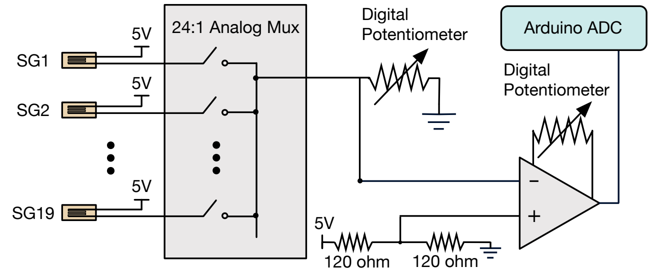

Figure 2. The complete circuit diagram. Note that SG stands for strain gauge. The 24:1 analog multiplexer is practically made up of 3 analog multiplexers.

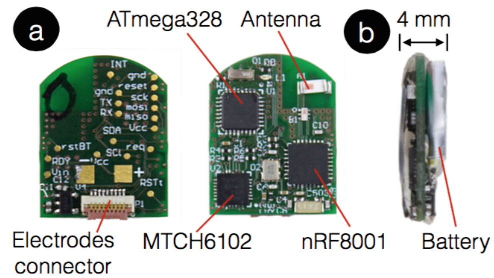

Figure 3. The complete circuit diagram. Note that SG stands for strain gauge. The 24:1 analog multiplexer is practically made up of 3 analog multiplexers.

The diagram of the computing hardware is shown in Figure 2. First, the multiplexers are sequentially selected to connect one of the strain gauges. Once one of the strain sensors is selected, it becomes one of the 4 resistors on the Wheatstone bridge. When the forces apply, the strain of fingernail let the sensor slight changed which caused the ohm value of strain gauges lower or higher. Due to the changes of ohm value, one side of the voltage in Wheatstone bridge also changed.

Since the requirement of sensing the slightly change of the strain from fingernail, we used two amplifier to magnify the difference on the Wheatstone bridge 4000 times. Finally, Arduino Nano read the final analog value from the amplifier's output. For the digital potentiometer, it is used for adjusting the resistance to let the Wheatstone bridge have no difference on both side during calibration.

Gesture / Posture Recognition

We used LIBSVM tool[3], a popular machine learning open-source library for SVM which is a way to distinguish the pattern by vectors. Since the different of the input data sets, we implemented two algorithm specifically for swipe gestures (Motion mode) and finger posture (Motionless mode).

In motion mode, sequentially and time based data is preprocessed by accumulate difference to the first data when the gesture begin. At the end, the sequentially data is processed to be one feature data. In motionless mode, raw data is directly used for machine learning. Finally, we scale each feature to the range of -1 to 1 and then train a multi-class SVM classifier with a Radial Basis Function (RBF) kernel.

SYSTEM EVALUATION

The goal of the study is to explore whether the system is capable for classifying different kinds of swipe gestures and finger posture angles in different kinds of pressure level.

Participants

We recruited 10 participants (7 male, 3 female) between the ages of 20 and 23. All participants are right-handed and drew with their right index fingers on the surface. Each participants received $5 after one hour experiment.

Apparatus

The apparatus is shown in Fig???. We used the load-cell which is the same in our pilot study. In this experiment, we put a 9DOF sensor on user's index finger, it is only used for checking whether user is performing the correct position and angle. The surface we used in our study is medium-density fibreboard.

Task and Procedure

Motion Mode

We chose 8 direction as shown in Fig???. Users are requested to perform swipe gestures shown on computer screen and press space from the beginning and the end of the gesture. On the desk, we draw 8 direction of line to insure swipe angle is correct. Each direction are collect 10 sets of sequentially data which has total 80 gestures for each user. Before the study, a calibration is needed for the first time wearing, and no calibration within this study.

Motionless Mode

In each trail, the participants were instructed to adjust their finger pitch and roll angle which are selected from [6]. We only chose some part of angle which are easy to identify for users. The forces are chosen from our pilot user study which are chosen as average force(0.8N), one SD forces(0.6N, 1.0N), two SD forces(0.4N, 1.2N) as presented in Fig???. The participants are asked to straighten finger during all experiment. In front of the user, there is a screen showing current(sensing from 9DOF and load-cell sensor) and instructed angle and force. Before each trail, participants are requested to return the initial position.

Results

Accuracy: is defined as the number of correctly classified samples divided by the total number of samples. *Accuracy:* is defined as the number of correctly classified samples divided by the total number of samples. *Accuracy:* is defined as the number of correctly classified samples divided by the total number of samples. *Accuracy:* is defined as the number of correctly classified samples divided by the total number of samples. *Accuracy:* is defined as the number of correctly classified samples divided by the total number of samples.

Motion Mode

The accuracy due to chance was 10%. Off-line accuracy was computed using 10-fold cross-validation of the evaluation data. The mean accuracy across all participants was 95% (SD: 2.7%). If we only consider four swipe gesture, the system can achieved 99.5%(SD: 1.2%). The misdetection is shown in Fig??, and the caused of the this due to the user use different posture angle for performing the same gesture.

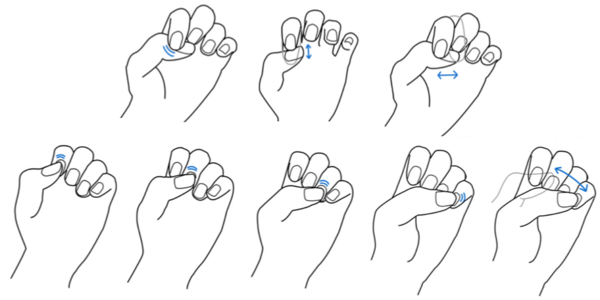

Figure 4. Swipe Gestures

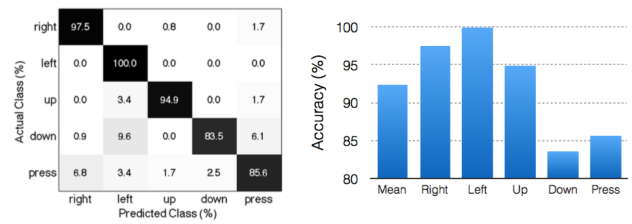

Figure 5. Motion mode: Confusing Matrix

Motionless Mode

The accuracy due to chance was 20%. Off-line accuracy was computed using 10-fold cross-validation of the evaluation data. The mean accuracy across all participants was 85.6% (SD: 3.7%). The misdetection is shown in Fig??, and the caused of the this due to the user sometimes perform postures directly using nail to touch the surface which caused strain gauges different value. We also run 10-fold cross-validation for our pressure value. It turns out that the device cannot distinguish the difference of slightly changes of pressure. The device only can distinguish the pressure level of difference with 90% accuracy when it comes to 0.4N with 1.2N.

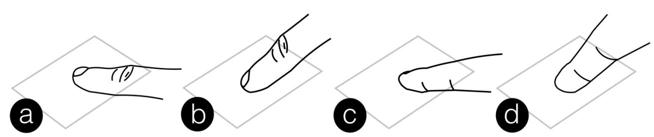

Figure 6. Posture Set: (a) pitch 15 degree, (b) pitch 45 degree, (c) pitch 15 degree and roll 45 degree, (d)pitch 45 degree and roll 45 degree

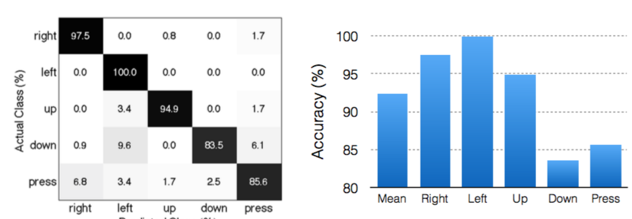

Figure 7. Motionless mode: Confusing Matrix

EXAMPLE APPLICATION

Based on the advantage of Nail+, we show two examples using this new interaction technique.

Remote control

LIMITATION AND FUTURE WORK

Gesture Input

CONCLUSION

In this paper, we implemented a new novel interaction technique which use the strains as input. We also developed a device called Nail+ which has the ability for exploring the strain from fingernail. The device for swipe gestures on surface can be ditinguished in a high accuracy(93.2%). For the finger posture, Nail+ can identify five different kinds of finger posture. The system is attractive for always-available input for surface around and unobtrusive.

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