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

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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 8 directions of swipe gesture with high accuracy(93.5%). 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

Using body parts as an input sensing technique becomes popular research area in HCI community recently. It not only provides users control surroundings by simply performing intuitively gestures, but also comes as an always-available input device which lowers physical effort when user needed. Since the device is mounted to our body, it is important to be attentive for the comfort level which will determines the utility of the device. Many form factor of sensing technique are presented (e.g. wristwatches, rings, bends). However, using fingers to perform gesture on surface is already built in our daily which is widely adopted by users.

Every submission will be assigned their own unique DOI string to be included here.

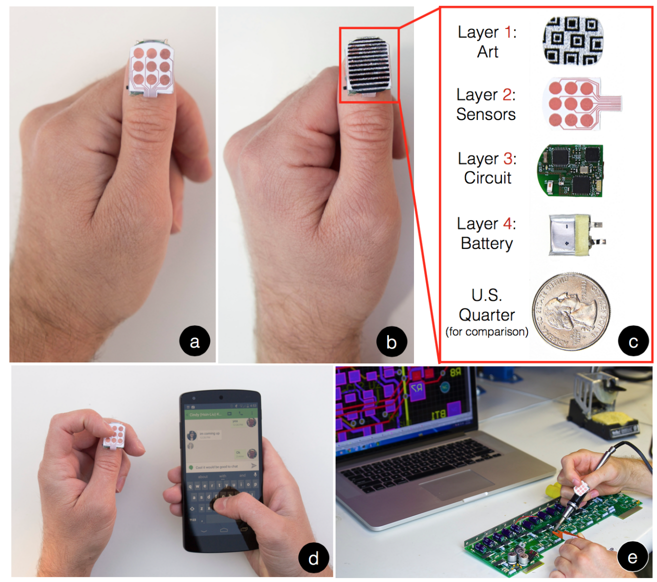

Figure 1. Nail+ THIS IS A PLACE HOLDER FOR Nail+

In this paper, we chose the fingernail as a input area which has no proprioception and the device on top of it can be easily forgotten by user. Furthermore, it is less disturbing and most promising place due to easy installation and erasing[6]. Lastly, Nail art is proposed in previous work, Kao et al.[7] implemented a nail-mounted device to sense swipe gestures on top of fingernail with decorations at top layer.

Previous research also demonstrated using nail-mounted device to explore new interactions. Hwang et al.[5] proposed a technique which senses the force pressure by detecting white region of fingernail using computer vision. FingerPad[1] presented a magnetic field on top of nail to sense input within fingers for private use. Kadomura et al.[6] also used a magnet on top of finger to enable interaction nearby smart devices with magnet sensor. TouchSense[4] used 3-axis accelerometer to detect finger postures to switch different modes of input. TapSense[2] use a acoustic way to identify the gestures that drawing on the wall. However, the interaction of the techniques are limited to particular sensing area such as the region that can sense touch or within camera site.

To explore better interaction of nail augmented device, we aimed to design a device that have no restrictions of input area which can enable user to perform gestures on surfaces around. The proposed technique will definitely be helpful in

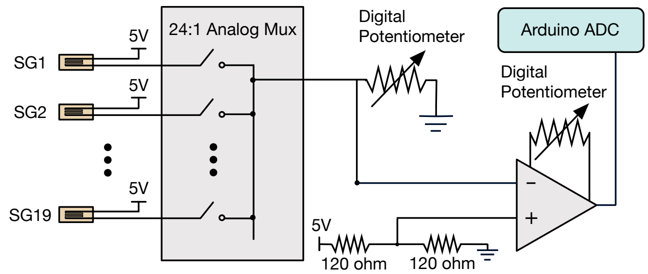

Figure 2. The complete circuit diagram. Note that SG stands for strain gauge. The 16:1 analog multiplexer is practically made up of 3 analog multiplexers.

enhancing the modality of finger interaction, and expanding the interaction space due to the gesture can be performed everywhere.(this should be changed as well because this is a copy from nailsense) Our prototype, Nail+ (Figure 1), use a 3×3 array of strain gauges sensor

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 the prototype 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 to fit on 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 remove. Based on above of requirements, we derived that using 0.2mm strain gauge is the appropriate solution for this prototype.

Hardware

We developed Nail+ using a 3×3 array of 120-ohm 0.2-mm strain gauges for sensing part (Shown in Figure 1). At the bottom of the strain gauges, we used a stretchable and flexible artificial-skin to stick sensors on user's fingernail. The size of it is about 1cm×1cm which is smaller than 1 cent of US dollar. And each of the strain gauge is directly wired to the computating 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).

The diagram of the computing hardware is shown in Figure 2. First, the multiplexers are sequentially selected to connect one of the strain gauges to read analog value. Once a sensor is selected, the sensor became 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

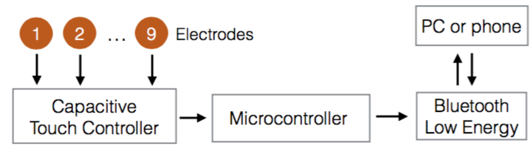

Figure 2. The system design.

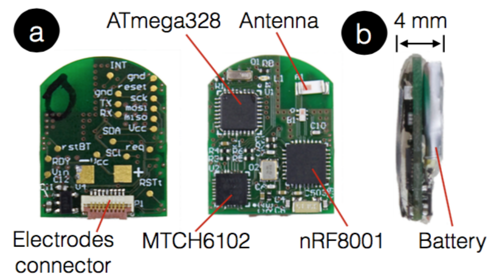

Figure 3. The complete circuit diagram. Note that SG stands for strain gauge. The 24:1 analog multiplexer is practically made up of 3 analog multiplexers.

valud of strain gauges lower or higher. Then, the final analog value is generated by the voltage difference on bridge and amplify the signal of the difference which is made by strains. Due to the requirement of very small strain from fingernail, we used two amplifiers to magnify the original analog signal which is approximately 4000 times of it. Finally, the digital potentiometer is used for calibrating the resistance when there is no forces apply and let the bridge is equal and the analog value will be zero.

Software

Since the different of the input data sets, we implemented two algorithm for specifically for swipe gestures which are sequentially and time based data (Motion mode) and finger posture which is a static raw data (Motionless mode).

Motion Mode

Motionless Mode

User Study

We recruited 10 participants (7 male, 3 female) from ages 20 and 24 (mean 21.2), and requested user to perform tap gesture on electronic load-cell to measure how much pressure applied on the surface. The result of this study is shown in Fig???. The average of tap pressure is 0.82N(SD=0.26).

SYSTEM EVALUATION

The goal of the study is to explore whether the system is capable for classifying different kind of finger posture angle. In order to collect the daily usage pressure on surface, we conducted a pre-user study.

Participants

We recruited 16 participants (13 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.

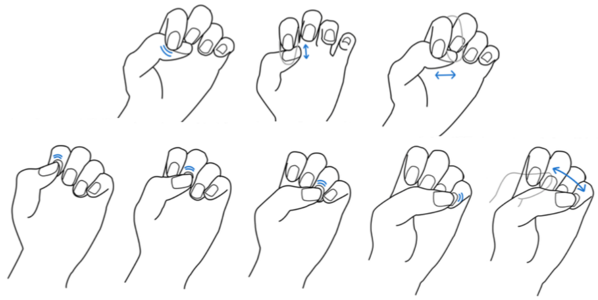

Figure 4. GESTURE SET, THE FIGURE SHOULD CHANGE BEFORE

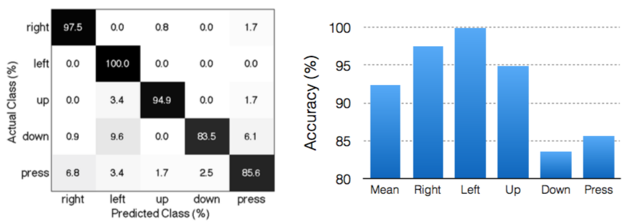

Figure 5. RESULT OF THE USER STUDY, THE FIGURE SHOULD CHANGE BEFORE

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 used for checking whether user is performing the right position and angle.

Task and Procedure

In each trail, the participants were instructed to adjust their finger pitch and roll angle which are selected from [3]. We only chose "some part of angle" which are easy to identify for users. The forces are chosen from pre-user study which in 0.6N, 0.8N, 1.0N 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 and instructed angle and force. Before each trail, participants are requested to return the initial position.

Results

EXAMPLE APPLICATION

Based on the advantage of Nail+,

LIMITATION AND FUTURE WORK

Hardware: The envisioned form factor of NailO should be comparable to that of a commercialized nail art sticker. To achieve this, we are prototyping a flex PCB version of the circuit with an integrated electrode layer. The flex PCB will conform to the curved surface of the nail. The battery life is the limiting factor for the size and lifetime of the device; we plan to explore wireless powering options, to remove the battery and allow perpetual operation. Input and Output: Beyond including the gestures in Figure 7, with flex PCB we can prototype robust 2 layer electrodes, turning the NailO into a X-Y coordinate touchpad. Along with the addition of an accelerometer, we can expand the in- put space to contact-less gestures. The system can also be- come an output device with the addition of LEDs or vibrators.

CONCLUSION

In this paper we present NailO, a novel nail-mounted input surface. The miniaturized hardware fits on a fingernail and wirelessly transmits data. We show that the system can de- tect gesture inputs in real-time with high accuracy (¿92). Also, we explored interaction scenarios using NailO as a re- mote control in hands-full or privacy-sensitive use cases. NailO also broadens input space when coupled with mobile devices. Further, NailOs customizable features fuses functional wearable electronics and cosmetics, which appealed to study participants. NailO is our first exploration; we plan to augment other cosmetic extensions to continue our study of cosmetic-inspired wearable technologies.

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