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Finger Stroke Detection by Fabric Touch Panel with its Application to Stuffed Animal Robot

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Abstract: We propose a fabric touch panel and a detection algorithm for human stroking motions, with their application to a stuffed animal robot. Stuffed animal robots are often used as an effective therapy. Fabric touch panels are applicable to stuffed animal robots for interfaces. The sensor of the proposed fabric touch panel is made of cloth sewn with conductive threads. We applied the needle thread adjustment function of a sewing machine to fabricate the sensor of a fabric touch panel. Then, we constructed an algorithm discriminating human finger stroking motions based on frequency analysis. We found that ten human stroking motions could be discriminated. Finally, we applied the fabricated fabric touch panel and stroking recognition algorithm to a stuffed animal robot. We confirmed that the stuffed animal robot could perform the assigned movements successfully according to ten stroking motions.

Keywords: fabric sensor, touch, finger stroke

1. INTRODUCTION

Demand for mental therapy for elderly people and patients with mental illnesses is increasing. Stuffed animals and stuffed animal robots are often used as an effective therapy [1]. Stuffed animal robots have built-in sensors to communicate with users, but such sensors partially or completely impair the softness of the stuffed animal robots. Soft stuffed robots are more effective in relieving psychological and physiological stress than hard robots. In this paper, we propose a fabric touch panel and a detection algorithm for human stroking motions. A fabric touch panel is composed of cloth and conductive thread. We will fabricate a wearable device that drives a stuffed animal. The proposed touch panel detects human stroking motions, and the wearable device drives a stuffed animal according to the detected stroking motions.

2. CAPACITIVE FABRIC TOUCH PANEL

2.1. Structure

Here we use a capacitive fabric touch panel to detect human stroking motions. The sensor of this fabric touch panel is made of cloth sewn with conductive threads [2]. During capacitive sensing, a conductive thread is repeatedly charged and discharged to generate a parasitic capacitance between the thread and the ground. When a human finger comes into contact with a conductive thread, another capacitance is generated between the human finger and the conductive thread. Contact between the conductive thread and the human finger can be detected from the change in the total capacitance corresponding to the conductive thread. Multiple conductive threads are placed on the front and back sides of the cloth to detect the contacting position of the cloth. On the front side, conductive threads are placed in y direction, and on the back side, conductive threads are placed in x direction. The x coordinate of the contacting position can be detected by measuring the capacitance of the conductive threads on the front surface, and the y coordinate of the contacting position can be detected by measuring the capacitance of the conductive threads on the back surface.

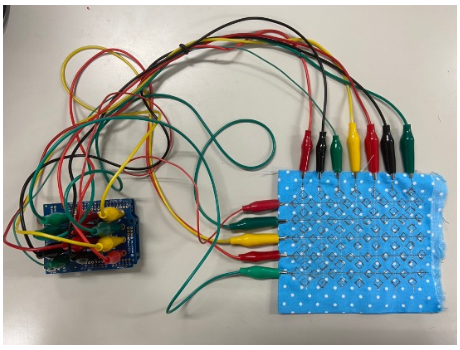
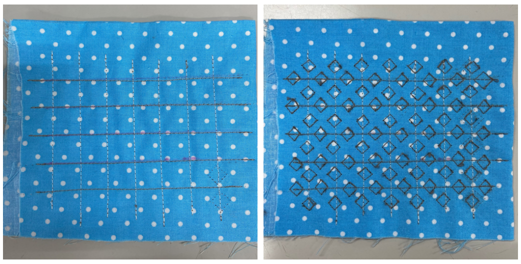


Fig. 1 Fabric touch panel

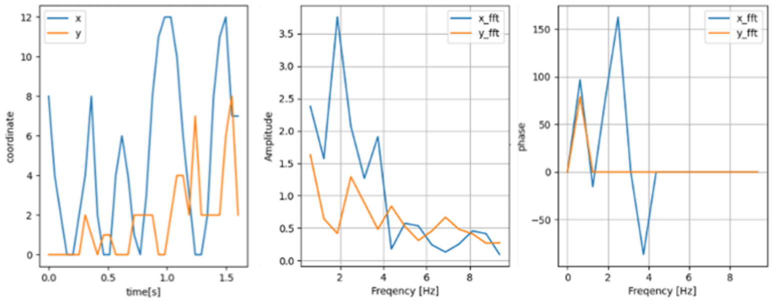


(a) (b)

Fig. 2 Fabric with conductive threads sewn

Figure 1 shows a prototype of capacitive fabric touch panel. This touch panel consists of a sensing fabric and a circuit for capacitive sensing. For sensing fabric, we used conductive threads Smart-X (Fujix Co., Ltd., Japan). This fabric is commercialized and can be applied to sewing machines. For capacitive sensing circuit, we used Adafruit MPR121 (Adafruit, U.S.A) connected to Ar-

† Shinichi Hirai is the presenter of this paper.



(a)signals (b)amplitude (c)phase

Fig. 3 Example of measured coordinates with their amplitude and phase spectra

duino. This MPR121 performs charging/discharging and capacitance measurements on 12 electrodes and sends the results to Arduino. In this report, we fabricated a 7×5 sensing fabric and measured the capacitance of 12 conductive threads using an MPR121.

2.2. Fabrication

The sensor of a fabric touch panel has multiple conductive threads placed on the front and back sides. A sewing machine is used to sew multiple conductive threads onto fabric. It is required to avoid contact between the conductive threads placed on the front and the conductive threads placed on the back. Since the conductive threads on the front side and the conductive threads on the back side are perpendicular to each other, there is a risk that the conductive threads may contact each other in normal sewing methods. In this report, we apply the needle thread adjustment function of a sewing machine to fabricate the sensor of a fabric touch panel.

We use a conductive thread as the upper thread and a non-conductive regular sewing thread as the lower thread. By intentionally tightening the needle thread by the needle thread adjustment function, the needle thread (a conductive thread) is sewn so that it is stretched out on the surface of the fabric.Then, the fabric is turned over, and the needle thread (a conductive thread) is sewn on the back side. This method allows conductive threads to be sewn on both sides of a single piece of cloth, avoiding contact of conductive fabrics at intersections.

Figure 2(a) shows a cloth with conductive thread sewn on both sides. The dark colored threads are conductive threads, while the white threads are non-conductive regular sewing threads. We find that the conductive threads and white sewing threads intersect. Additionally, we sew conductive threads in diamond shapes, avoiding the intersections, as shown in Fig. 2(b). Since intersections are avoided, the diamond-shaped conductive threads are either in contact with the conductive threads on the front side or with the conductive threads on the back side. As a result, even with diamond-shaped threads, the front conductive threads and the back conductive threads do not contact each other.

With this fabrication method, we can fabricate the sensor using a single piece of cloth, making the sensor be thinner. Additionally, it is easy to repair the sensor when conductive threads are frayed.

3. DETECTION OF HUMAN FINGER STROKES

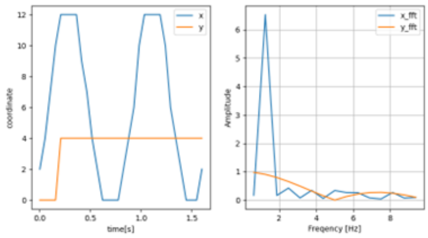
We apply a fabric touch panel to human-machine interface. In this report, we classify stroking motions into the following categories:

- horizontal motion (speed: slow, middle, fast)
- vertical motion (speed: slow, middle, fast)
- rotation (clockwise/counterclockwise)
- diagonal motion
- stationary contact

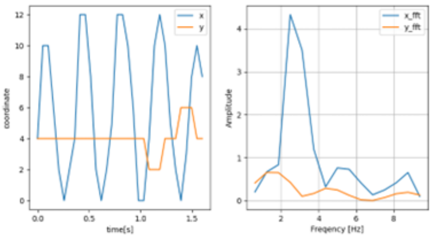
For horizontal and vertical motions, we distinguish motion speed in three categories: slow, middle, and fast. For rotational motion, we distinguish direction of rotation. As a result, we have ten categories to be classified.

We construct an algorithm discriminating human finger stroking motions based on frequency analysis of measured sensor values. An example of measurement is shown in Fig. 3. Figure 3(a) shows measured coordinate values, Fig. 3(b) shows their amplitude spectra, and Fig. 3(c) shows their phase spectra. Based on amplitude and phase spectra, we distinguish finger stroking motions.

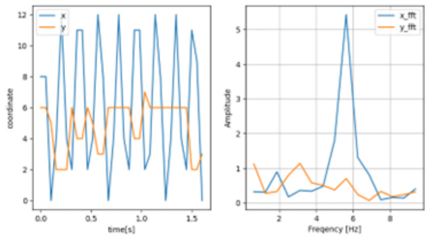
Figure 4 shows the measured coordinates and their amplitude spectrum when a finger strokes a fabric touch panel in the horizontal (x-axis) direction. As shown in the figure. In this case, the maximum value of the amplitude spectrum in the x-axis direction is larger than the maximum value of the amplitude spectrum in the y-axis direction. Also, the frequency where the amplitude spectrum reaches its maximum depends on the stroking speed. Figure 5 shows the measured coordinates and their amplitude spectrum when a finger strokes a fabric touch panel in the vertical (y-axis) direction. As shown in the figure, the maximum value of the amplitude spectrum in the y-axis direction is larger than the maximum value of the amplitude spectrum in the x-axis direction. Also, the frequency where the amplitude spectrum reaches its maximum depends on the stroking speed. Figure 6 shows the measured coordinates and their amplitude spectrum when stroking diagonally. In this case, we have little difference in the maximum values of the amplitude spectra in the x direction and the y direction. These results suggest



(a)slow

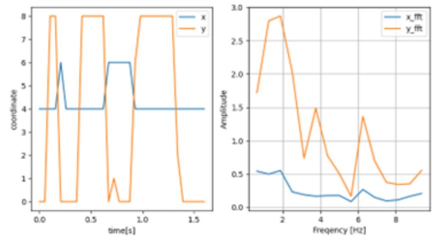


(b)middle

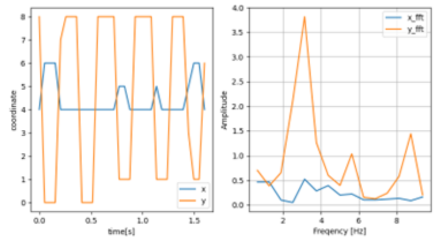


(c)fast

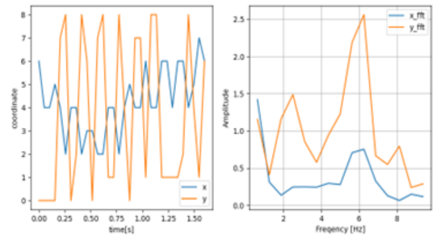
Fig. 4 Measurements for horizontal stroking motions



(a)slow



(b)middle



(c)fast

Fig. 5 Measurements for vertical stroking motions

that the stroking direction can be determined by comparing the maximum values of the amplitude spectra in the x and y directions. Furthermore, the stroking speed can be determined from the frequency where the amplitude spectrum is maximum.

A low-pass filter, band-pass filter, and high-pass filter were used to identify the stroking speed. The cutoff frequency of the low-pass filter and high-pass filter is 3.5 Hz, and the passband of the band-pass filter is 2-4 Hz. We obtained the maximum amplitude spectrum of each filter output and compared the three maximum values. When the maximum value in the low-pass filter is larger than the other two, we determined that the stroking speed is slow. If the maximum value in the band pass filter is larger than the other two, the stroking speed is determined to be middle, and if the maximum value in the high pass filter is larger than the other two, the stroking speed is determined to be fast.

Figure 7 shows the measured coordinates and their amplitude spectrum when a finger rotates on a fabric touch panel. Figure 7(a) shows the result for clockwise rotation while Fig. 7(b) shows the result for counterclockwise rotation. We find that when stroking motion is circular, the amplitude spectra reach their maximums at the almost same frequency in both x and y directions. Additionally, the difference of the phase spectra at the frequency is almost $\pm\pi/2$. Thus, we determined the stroking motion is circular when these conditions were satisfied. The circular motion is counterclockwise when the phase spectrum difference is around $-\pi/2$ and is clockwise when the difference is around $\pi/2$.

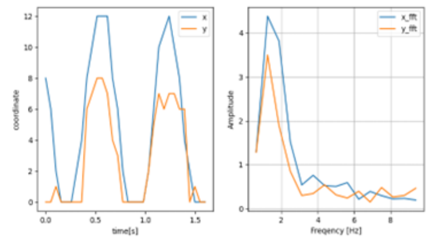
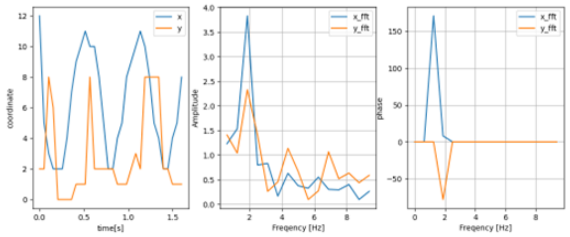


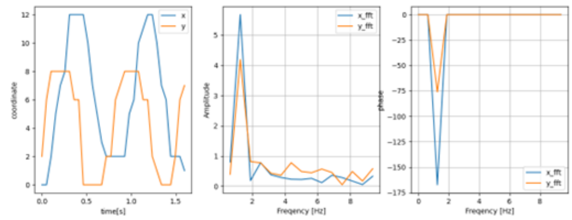
Fig. 6 Measurements for diagonal motion

4. APPLICATION TO STUFFED ANIMAL ROBOT

We apply the fabricated fabric touch panel and stroking recognition algorithm to a stuffed animal robot. We used a wire mechanism shown in Fig. 8 for driving the wearable clothes for a stuffed animal. Several wires in tubes pass inside and outside of the clothes. Wire ends are fixed to the ends of the sleeves. The other wire ends are connected to winders consisting of motors and pulleys. Figure 8(a) shows a windier and Fig. 8(b) shows the

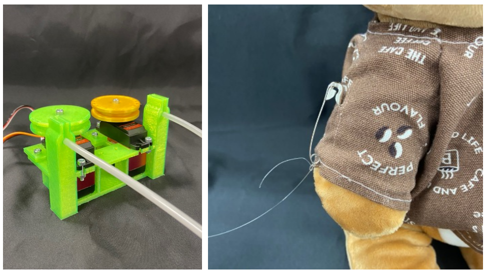


(a)clockwise



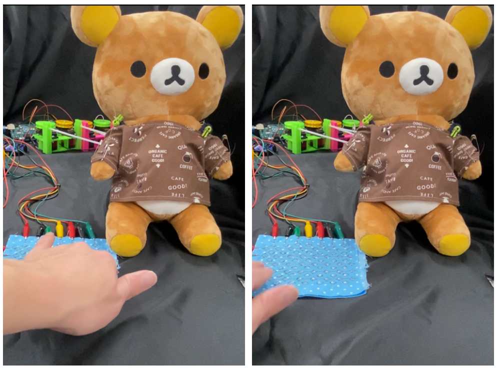
(b)counterclockwise

Fig. 7 Measurements for rotational stroking motions



(a)winder (b)wire end at sleeve

Fig. 8 Winding mechanism



(a)adduction (b)abduction

Fig. 9 Addution and abdution for horizontal slow stroking motion

end of a sleeve where a wire is fixed. Arduino is used to control the winders.

We assigned horizontal slow stroking motion of a fabric touch panel to adduction and abduction of the right arm of a stuffed animal. Figure 9(a) shows the adduction state, and Fig. 9(b) shows the abduction state. We confirmed that the stuffed animal repeatedly performed adduction and abduction movements by horizontal slow stroking motion. We assigned horizontal middle-speed stroking motion of a fabric touch panel to extension and flexion of the right arm of a stuffed animal. Figure 10(a) shows the extension state, and Fig. 10(b) shows the flexion state. We confirmed that the stuffed animal repeatedly performed extension and flexion movements by horizontal middle-speed stroking motion. We assigned horizontal fast stroking motion of a fabric touch panel to medial and lateral rotations of the right arm of a stuffed animal. Figure 11(a) shows the medial rotation state, and Fig. 11(b) shows the lateral rotation state. We confirmed that the stuffed animal repeatedly performed medial and lateral rotations by horizontal fast stroking motion. We also assigned the other seven stroking motions to different movements of a stuffed animal robot and confirmed that the stuffed animal robot could perform all assigned movements successfully according to stroking motions.

(a)extension (b)flexion

Fig. 10 Extension and flexion for horizontal middle stroking motion

(a)medial rotation (b)lateral rotation

Fig. 11 Horizontal rotation for horizontal fast stroking motion

Currently, fabric touch panels are not attached to stuffed robots. In future, we will attach a cloth touch panel to a stuffed animal robot so that the stuffed animal robot performs movements corresponding to the stroking motions on the fabric touch panel attached to the robot.

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