Localization of Touch on Granite Based on AC Hum Noise

H. Elfekey, S. Okamoto, and Y. Yamada
Department of Mechanical Systems Engineering, Nagoya University
Nagoya, Aichi Prefecture, Japan

***Abstract*—Touch sensors are used as standard human to machine interfaces in many applications. However, current technologies that allow everyday objects to be used as touch sensitive surfaces are either expensive in terms of processing or hardware. In this paper, we propose the use of AC hum to implement a granite touch bar using three electrodes and demonstrate the localization of touch on the granite bar.**

Keywords—AC hum; touch panel; localization; granite

I. INTRODUCTION

Touch detection sensors are employed in many applications including smart phones and augmented reality systems. The localization of touch has been realized in various ways. For example, the traditional capacitive touch technique has been widely used for touch panels. Usually, capacitive touch panels require a very conductive surface such as indium tin oxide [1]. Touch localization can also be achieved by image processing, which does not require highly conductive materials [2]. Other techniques leverage infrared photo couplers and the effect of sound transfer [1]. All of the mentioned techniques use special surfaces or equipment installed on or around the surface. Furthermore, touch interfaces based on the abovementioned techniques typically lack the natural touch sense of materials because of the smoothly finished material surfaces [2].

We propose the integration of AC hum with everyday objects. AC hum can localize touch on a broad range of materials because it does not require highly conductive materials. As an example, we demonstrated the use of AC hum with modified acrylic paint in previous research [3]. In this paper, natural stones, such as granite, will be turned into touch interfaces by the AC hum touch technique. These techniques further allow indoor objects to be used as touch interfaces, preserving the haptic feel of their material surfaces.

II. THEORY OF OPERATION

The human body is affected by surrounding electromagnetic fields. This is because the human body contains minerals and salts, and thus it possesses conductive properties. Therefore, the nearby 220/110 V induces a voltage on the human body. This voltage can be channeled to a device by electrodes for processing [4].

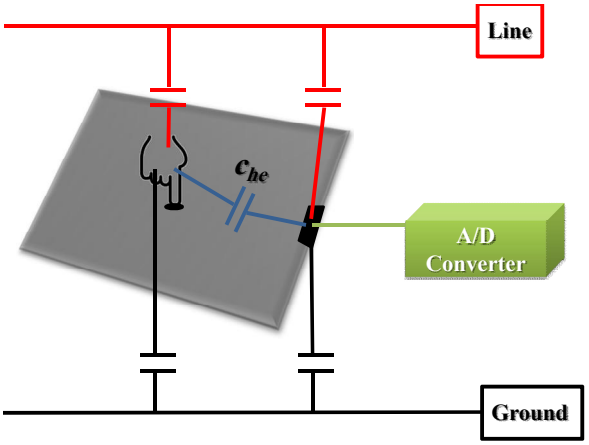

Fig. 1. Concept of the AC hum granite touch panel.

In the present study, we use granite, a type of natural stone, as a touch sensitive surface. The relative permittivity of granite ranges from 4 to 6 [5]. Therefore, AC hum (a 50/60 Hz sinusoidal wave) can travel through granite. In other words, a human finger touches the granite, and the electrodes mounted on the edges form capacitances, as shown in Fig. 1.

Although the magnitude of c_{he} is dependent on the location of the touch, it cannot be reliably used to calculate the touch position. This is because the voltage detected by the electrode depends on factors other than the touch location. For instance, the area of touch affects the voltage detected at the electrode. Therefore, more than one electrode is required to localize the touch location effectively. With the addition of an electrode, three more capacitances are added to the model presented in Fig. 1. For example, an additional electrode would yield two more capacitances between both the line and ground and the electrode and capacitance between it and the finger touching the surface.

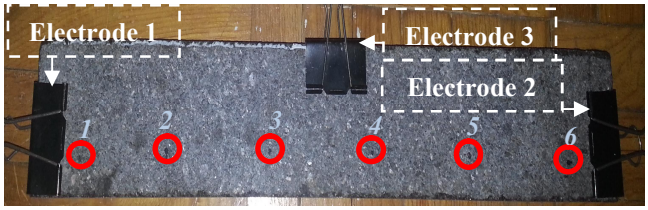

Fig. 2. Granite touch panel used with mounted electrodes.

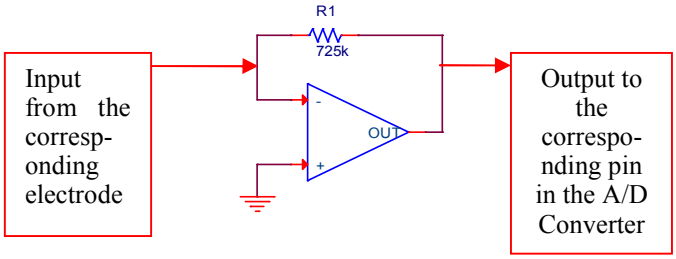

Fig. 3. Current-to-voltage converter circuit schematic.

III. Design and Implementation

In this paper, we demonstrate the use of surfaces as touch panels by AC hum. We use a granite bar (7 cm by 45 cm) that is commonly used for table tops and attach three electrodes to it as shown in Fig. 2. Each of these electrodes is connected to a current-to-voltage converter with the circuit shown in Fig. 3. The resistance R1 was chosen to be 725 kΩ empirically.

The signal processing algorithm begins with an analog-to-digital converter with a frequency of 50 kS/s for 100 ms or about 5 cycles of the AC hum. Then, a low-pass digital filter is applied followed by envelope detection to extract the average magnitude of the AC hum signal. Each of the mentioned steps is applied to each of the three electrode voltages. The following equation was used to localize the touch in the x-domain only:

$$x = (v_1+v_3)/(v_1+v_2+v_3), \quad (1)$$

where v_1, v_2, and v_3 are the voltages detected at electrodes 1, 2, and 3, respectively, as shown in Fig. 2. v_1 and v_2 are the voltages of the electrodes at the edges, while v_3 is the voltage at the middle electrode. The voltage at each electrode was averaged over 100 ms and used for the localization via the equation above.

IV. Experimentation and Results

In Fig. 2, six red circles indicate the location of the touch. They are each separated by 8 cm. Fig. 4 shows 50 samples for each touch location. A touch location is enumerated in Fig. 2 with the corresponding samples in Fig. 4. It can be observed that the samples fluctuate greatly. Fig. 5 shows the interpolated graph based on the averages of points in Fig. 4. The function interpolated was rational with a second-degree numerator and a third-degree denominator.

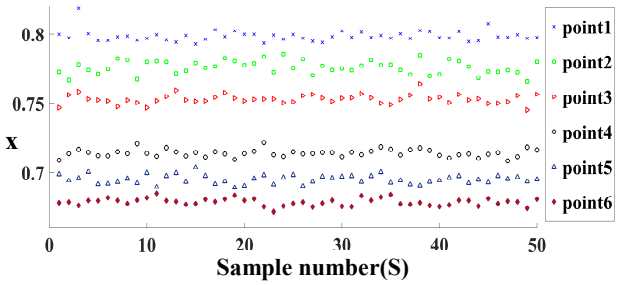

Fig. 4. Average ratio x from multiple touch points.

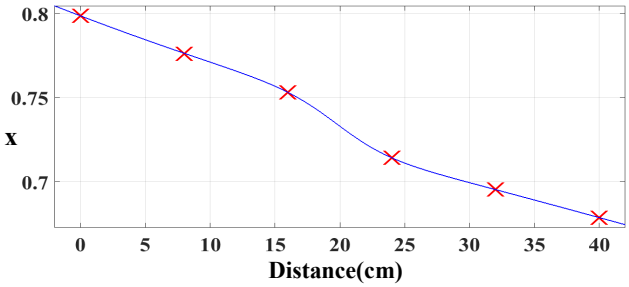

Fig. 5. The ratio x versus the actual touch distance.

V. Conclusion

In this paper, we have presented a methodology based on AC hum noise to use materials such as granite into touch sensitive surfaces. It can be noted that the AC hum average amplitude signal fluctuates, which affects the resolution of the signal adversely. A possible solution is to add electrodes which will be explored in the future.

Acknowledgment

This study was partly supported by MEXT/JSPS Kakenhi (17H04697).

References

[1] G. Walker, "A review of technologies for sensing contact location on the surface of a display," in JSID, Vol. 20, Aug. 2015.

[2] E. Bennett and B. Stevens, "The effect that the visual and haptic problems associated with touching a projection augmented model have on object-presence," in Presence, Vol. 15, no. 4, Aug. 2006.

[3] H. M. Elfekey, E. M. A. Bary and H. A. Bastawrous, "Flexible ITO-free touch panel based on the effects of extremely low frequency electromagnetic fields," in *2015 Int. Symp. on Cons. Electr. (ISCE)*, Madrid, 2015.

[4] H. Elfekey, H. Bastawrous, and S. Okamoto, "A touch sensing technique using the effects of extremely low frequency fields on the human body," Sens. J., Vol. 16, 2016.

[5] G. S. Baker and H. M. Jol, *Stratigraphic Analyses Using GPR,* Boulder CO: The Geological Society of America, 2007.