HumTouch: Finger gesture recognition on hydrogel-painted paper using hum-driven signals

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Abstract—We propose a passive touch sensor that can be implemented on semi-conductive materials, such as paper. This sensor detects electric currents leaked from a human body when touched with bare fingers. Such electric currents are mostly produced by AC power lines in the environment. We tested the potential of the sensor for gesture recognition by using a paper sheet painted with a hydrogel ink. A gesture classification algorithm combining the k-means method and Mahalanobis’ generalized distance could successfully classify 90% of the gestures drawn on the paper with a fingertip. Gestures including multi-directional lines and circles were nearly perfectly classified whereas digits, such as 2 and 8 exhibited difficulties with classification. The hydrogel ink can turn other non-conductive materials comprising woods and plastic into touch sensors, and such hum-based touch sensors are expected to find practical applications in gesture recognition.

Index Terms—Hum noise, touch sensor, gesture

I. INTRODUCTION

Most commercially popular touch sensing devices detect capacitive or resistive changes of surfaces when they are touched by humans. Although these principles are used for specific or designed surfaces, camera-based or force-sensing-based methods [1] are potentially used for turning any surface into a touch sensing medium. Nonetheless, they require structured environments and camera-based interfaces suffer from occlusion problems. Unlike these touch sensing techniques, hum-based touch sensors [2], [3] can be implemented on semi-conductive materials, such as stone and paper that commonly exist in our living spaces without large modification of environments. When a human touches a semi-conductive surface, a current in the human body caused by the electromagnetic field of AC power lines in the environment flows on the surface. It is then detected by an electrode placed on the surface. Hence, this sensor is a passive-type sensor and does not apply any energy to object surfaces. In addition, by using multiple electrodes placed on the surface, the touch position can be localized [4].

When using a hum-based touch sensor on a large area surface, applications involving gesture recognition can be realized. However, localization of the contact point using a hum-based touch sensor is not precise due to the environmental electromagnetic noises and non-uniformity of the material properties of the surface. Therefore, it is necessary to evaluate the gesture identification abilities of a hum-based touch sensor. In this study, we verified the feasibility of gesture recognition using a paper and hum-touch sensing method. This was achieved through the identification of one-stroke gestures that are frequently used for gesture interfaces by using a conventional gesture classification algorithm.

II. MATERIAL AND APPARATUS

A. Paper with hydrogel ink

We used a paper towel of 20 × 20 cm that was soaked into a polymer ink and dried. The formulation and constitution of the ink were chosen according to [5]. The same ink can turn other non-conductive materials such as woods and plastics into touch-sensitive surfaces. Although we used the paper in the present study, similar gesture performances are expected for woods and plastics.

B. Signal measurement

We placed four electrodes, one at each corner of the paper towel, as shown in Fig. 1, and measured the voltages detected using an oscilloscope. The measured voltage amplitudes changed according to the distance between the finger and electrodes [4] and the signal frequency was 60 Hz, which is equal to that of the AC power supply. We refer to these amplitude envelopes detected at the four electrode channels as \( v_i(t) \) \((i = 1, 2, 3, 4)\), as shown in Fig. 2.

III. EXPERIMENT

We recorded the voltage outputs from the four electrodes when seven types of gestures were drawn with a fingertip on the paper. The gestures comprised circles (CW, CCW), a vertical line from top to bottom, horizontal line from left to right, diagonal line from top left to bottom right, and Arabic numerals: 2 and 8. If straight line gestures in one direction...
The algorithms used for classification; a greater number of parameters would lead to more successful classification. In addition, we only used four types of parameters as a preprocessing before the use of linear classification algorithms. In the second equation sums up the absolute difference. The latter two parameters were computed for each gesture. The first equation sums up the difference between two neighboring velocity vectors whereas the second equation sums up the absolute difference.

We used the $k$-means method with Mahalanobis’ generalized distances to classify the gestures, each of which is defined by a combination of four-parameters. The centroid of each of the seven types of gestures was allocated on the four-parameter space. Then, when a new gesture was acquired, it was classified as the nearest gesture in terms of Mahalanobis’ generalized distance.

### V. RESULTS

Table I shows the ratios of correct gesture recognition by a leave-one-out cross validation. The mean correct recognition rate was approximately 90%. The rates for Arabic digits (2 and 8) were remarkably low.

Potential causes of miss-classification include distortion of the gesture trajectory on the dimensionless coordinates. Especially when the finger touches near the electrode, the coordinates computed using (1) and (2) nonlinearly correspond to the physical coordinates on the paper. Such problems can be solved by application of a nonlinear coordinate transform as a preprocessing before the use of linear classification algorithms. In addition, we only used four types of parameters for classification; a greater number of parameters would lead to more successful classification.

### VI. CONCLUSIONS

In this study, we verified the feasibility of gesture recognition using a hum-based touch sensing technique. Simple gestures, such as lines and circles drawn on a hydrogel-painted paper were classified at approximately 95% whereas digits of
2 and 8 were classified at approximately 70%. By adopting appropriate classification algorithms and feature parameters, the hum-based touch sensing technique can be employed in practical application.

REFERENCES


