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Non-Contact Gesture Recognition Using the Electric Field Disturbance for Smart Device Application

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Abstract

A non-contact gesture recognition algorithm for smart device application using electronic disturbance is proposed in this paper. Our method secures an enough recognition distance for real smart TV application. Input patterns of the non-contact electrometer EPIC (Electric Potential Integrated Circuit) sensors are projected into two dimensional movements in a preconditioning process. Change of surrounding electronic field caused by moving hands has been observed mainly around band of 10Hz. Butterworth IIR filter, and Kalman filter are used to minimize the signal noises. Our proposed recognition process using PCA, K-Mean, and adaptive DTW algorithms can successfully identify five different gestures with more than 90% correct classification rate.

Keywords: *Gesture recognition, EPIC sensor, NUI, EMI, DTW*

1. Introduction

NUI (Natural User Interface) is a recently emerging HCI (Human Computer Interaction) technology which recognizes human body language, vocal, and other human gestures. NUI has evolved from CLI (Command Line Interface) based on commands, then GUI (Graphic User Interface) based on graphic and now into natural sensing technology including voice recognition as well as body action recognition [1, 2]. Unlike GUI which clicks an icon, NUI controls user's natural voice, action and his/her writings. However, voice recognition in 1964, writing recognition in 1982 had a limit to apply to machine even though its processing techniques are believed to be possible. The machine is now on stage being able to understand users' writing, action and voices. The NUI's ultimate goal is to provide for people to use its system without any discipline.

Non-contact electrometer sensor has been designed by having ELF's pass band and high gains to detecting ECG, EMG, EOG, EEG [3, 4]. In this planet, electronic filed exists anywhere and objects having polarity cause perturbation and occur temporary changes. This change frequently happens in extremely low frequency fields. Such an extremely small change can be detected by the non-contact electrometer sensor with high gain.

Electric field strength from source drastically decreases as the distance is getting far. Since non-contact electrometer chips are located on TV-bezel, we also have to consider extreme low frequency EMI. Since subtle changes of electronic noises around the sensors might damage to the entire data, appropriate methods such as grounding, shielding, absorption, and filtering are required to remove such EMI noise. In this paper, we also developed EMI minimizing as well as compensating algorithms in this ELF for more accurate gesture recognition.

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In Section 2, we discuss our proposed preprocessing method. In Section 3, an adaptive DTW gesture recognition algorithm is proposed. In addition, the performance results are analyzed according to warping area and detecting distance. In final section, conclusion and future research's direction are followed.

2. The Proposed Data Preprocessing for Gesture Recognition

In the earth, when the surrounding environment has no change, electrostatic fields stay still. However, physical movements having polarity change this time invariant field to time-varying field. EPIC sensors detect such changes in the electric field and transform this electric disturbance to a sequence of electric potentials as shown in Figure 1.

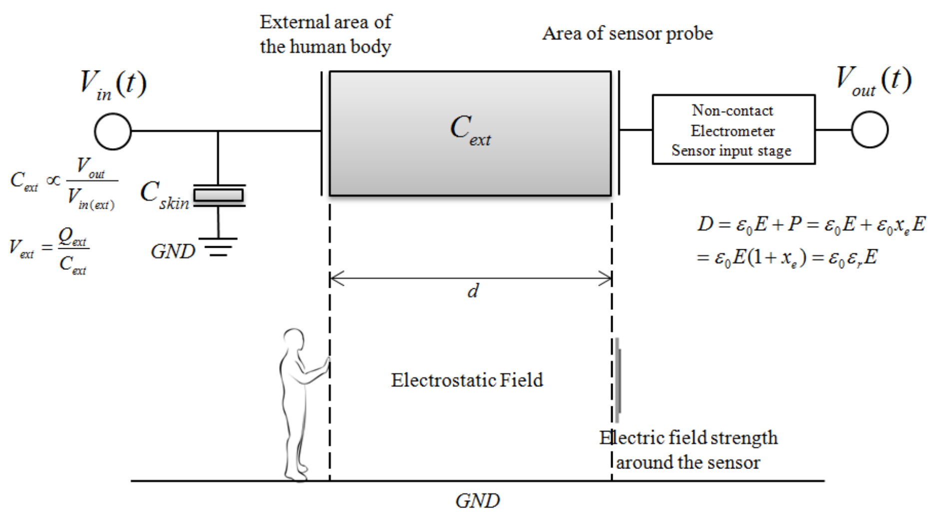

Figure 1. The system environment using the electric field disturbance

Figure 2 shows our proposed gesture recognition process. AC signals detected by EPIC sensors are transformed to DC digital voltages. In this preprocessing stage, noises from sensors are removed. Additional 3-second calibration is conducted after the target movement stops. This, regardless of target movements, is the process of removing the noises resulting from basic surrounding environment.

Event generating time interval is detected by calculating a target's velocity within EPIC sensor's detecting range. We accumulate data for 1 second after the target's movement starts, and then perform normalization process for gesture recognition after this. Input gesture data are compared with trained results for a set of predefined gestures through the DTW recognizer. Then the gesture with minimum difference is selected and identified as a classified one.

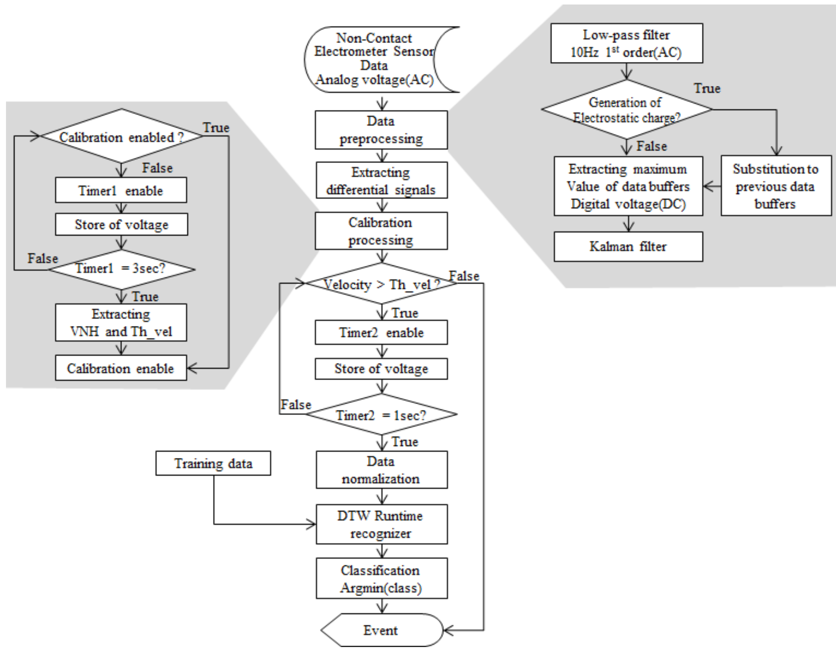

Figure 2. The proposed gesture recognition process based on DTW

The gesture recognition algorithm implemented in this paper obtains targets' two dimensional movements by using two differential signals from four different EPIC sensors. In the beginning stage, a 10Hz low-pass filter and an algorithm extracting the maximum value among 84 data samples are applied to extract two featured data from the target movement. Kalman filter was applied to minimize DC-type data noises transferred from each non-contact electrometer sensors [5].

The reason to use 10 Hz cut-off frequency in the low pass filter is that the electronic disturbance signals mainly occur from under electric field disturbance caused by the movement of the target occurs under 10 Hz frequency. Figure 3 shows signal changes under 500 Hz according to a target's movement, where the unit is dB/1V. Additionally, in order to secure the credibility of the analysis results, we take out data in rate of 60 times per second and obtain their average value. Butterworth IIR second-order 10Hz low-pass filter is applied to a series of signals from EPIC sensors. The coefficients used in the Butterworth filters are shown in Table 1, and the comparison results of simple IIR first-order and second-order 10Hz low-pass filter are shown in Figure 4.

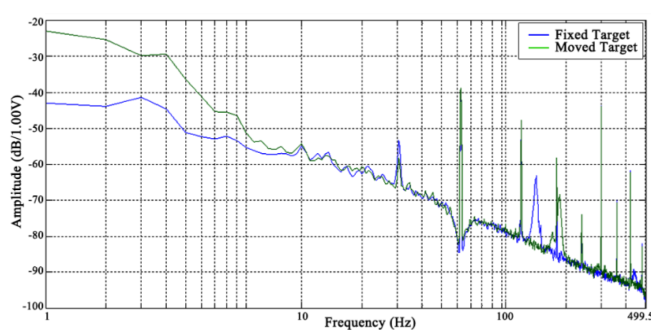

Figure 3. The analysis of frequency band changes according to the presence movement of target

Table 1. Coefficients of Butterworth 2th 10Hz IIR LPF

Coefficient	Constant value
Forward [a0]	1.98222892979252
Forward [a1]	-0.982385450614123
Feedforward [b0]	0.0000391302053991443
Feedforward [b1]	0.000782604107982887
Feedforward [b2]	0.0000391302053991443

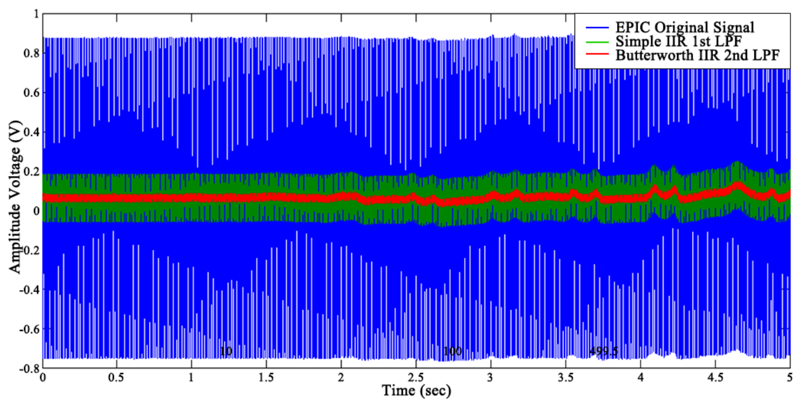

Figure 4. The comparison results between a simple 1st-order 10Hz IIR LPF and Butterworth 2nd-order 10Hz IIR LPF

3. Gesture Recognition Algorithm based on DTW

We use as feature data for gesture recognition in next stage, two differential signals, A-B and C-D, which face each other in a diagonal direction among four EPIC sensors: A, B, C, D, located on a smart TV (16:9) as shown in Figure 5. In indoor environment, major noise detected by the sensors is PLN (Power Line Noise). It is removed through data preprocessing stage. Then linear data are extracted and used for measuring 2-dimensional target movement.

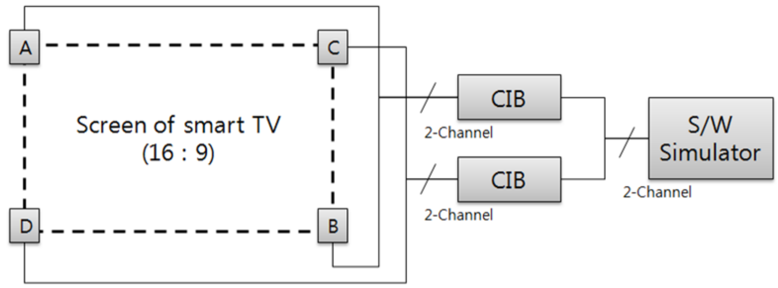

Figure 5. The test environment of NUI system using 4-channel non-contact electrometer sensors

In this paper, the characteristics of the gesture are analyzed using the extracted data after data preprocessing. Through this process, gesture classification can be performed, and gesture identification to one of a gesture set is executed when target's gesture occurs. An implemented gesture set is shown in Table 2.

Table 2. Implemented gesture set

Number	Gesture	Usage for smart TV	Image
1	Left to right	Increase the channel number	→
2	Right to left	Decrease the channel number	←
3	Spreading both arms	Zoom in	←→
4	Fording both arms	Zoom out	→←
5	Clapping two times	Gesture mode on/off	→←→←

We use the DTW algorithm as a run-time classifier so that a trained gesture with maximum similarity to an input gesture can be found among 5 trained gestures. DTW, a typical template matching based pattern recognition algorithm, can provide high classification rate even with a small amount of training samples. Meanwhile, we take quantization step since the DTW algorithm spends more time than other recognition algorithms. Figure 6 shows 4 different warping paths; PT = 0, 1/2, 1, 2. We analyze its CCR (Correct Classification Rate) according to each warping range.

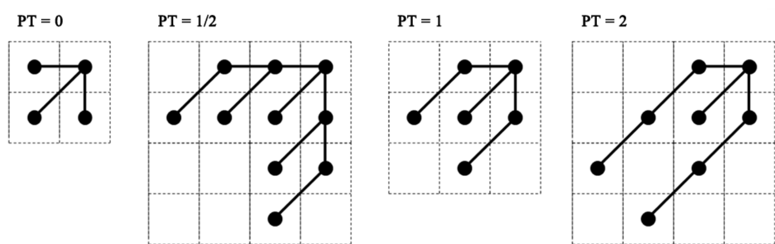

Figure 6. Four different warping paths

4. The Experimental Results

In our experiment, gesture input data of EPIC sensors on a TV- bezel are measured in three different distances (1m, 2m, and 3m) between a target person and a smart TV as shown in Figure 7. For each gesture, twenty tests per person are taken twenty times and the experiments are conducted in a group who trained and are not trained for checking correct understanding rate. The results are like Table 3, which correct recognition rate has been conducted. P (Person) indicates a participant in the correct recognition rate which also indicates the CCR.

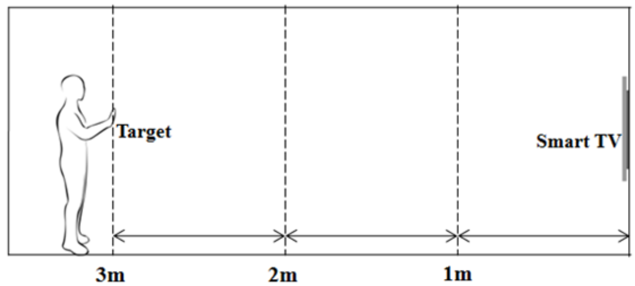

Figure 7. The environment of performance analysis by distance

Table 3. The correct classification number by distance between a target and a TV

	P #1			P#2		
Distance	1m	2m	3m	1m	2m	3m
Total test	100	100	100	100	100	100
Gesture 1	18	18	17	20	14	13
Gesture 2	17	15	19	20	20	19
Gesture 3	17	16	16	15	15	14
Gesture 4	20	20	18	17	15	15
Gesture 5	20	19	18	18	16	15
Total CCR	92%	85%	88%	90%	80%	76%

Table 3 shows a result performed when warping path, PT, equals zero. In Figure 6, in case of PT = 1/2, 1, 2, each correct recognition rates result from test taken with both of training participant and non-participants. The distance between target and sensor is 2m. Performance in CCR is the best in case of PT = 1/2 in which CCR is 2% higher than case of PT = 0. However, performance results from other warping paths are worse than that in case of PT = 0. The results in case of PT = 1/2 is shown in Table 4.

Table 4. CCR in case of warping path (PT=1/2)

	P #1	P #2	P #3	P #4	P #5	Total CCR
Total test	100	100	100	100	100	92%
Gesture 1 CCR	18	20	20	19	17	94%
Gesture 2 CCR	19	20	20	19	19	97%
Gesture 3 CCR	15	18	17	17	18	85%
Gesture 4 CCR	15	19	20	20	19	93%
Gesture 5 CCR	17	19	20	19	16	91%

5. Conclusions

In this paper, we propose and implement a non-contact gesture recognition method using electronic disturbance. Performance results are analyzed based on our proposed DTW gesture recognition algorithm in terms of distance and warping path. To apply the EPIC based NUI system to smart TVs, this paper adapts 4-channel EPIC sensors arranged to measure differential voltages from two pairs of diagonal EPICs. Proposed data preprocessing scheme is consisted of a Butterworth second IIR low-pass filter, a Kalman filter, Anti-electrostatic algorithms, a converter from EPIC input to DC signal, and a calibration algorithm.

In this paper, proposed gesture algorithms can be used only for case of single target. Thus, we plan to continue to develop the methods that can be applied for multiple input signals at frequency domains.

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References

[1] A. Valli, "Notes on Natural Interaction", http://www.citeulike.org/user/eckel/article/4324923, **(2005)**.

[2] W. Liu," Natural User Interface-Nect Mainstream Product User Interface", IEEE, CAIDCD, **(2010)**.

[3] M. Venkataramanan, "Biosensor can monitor you heartbeat from a distance", http://www.newscientist.com/blogs/onepercent/2011/11/sensor-monitors-yourheartbeat.html?DCMP=OTC-rss&nsref=online-news, **(2011)**.

[4] S. Connor, "EPIC: A New Epoch in Electric Potential Sensing", http://www.sensorsmag.com/sensors/electric-magnetic/epic-a-new-epoch-electric-potential-sensing-8961, **(2011)**.

[5] G. Welch and G. Bishop, "An Introduction to the Kalman Filter", UNC-Chapel Hill, TR 95-041 **(2006)** July 24, USA.

[6] E. Keogh, "Exact Indexing of Dynamic Time Warping", Proceedings of the 28th international conference on Very Large Data Bases, **(2002)**, pp. 406-417.

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