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Design of Dry Electrodes for EEG Based BCI Systems

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Abstract. In electroencephalography (EEG) based BCI systems, one of the crucial design issues is to acquire high fidelity EEG signals and to provide convenient installation to users. Electrodes are the key components which measure EEG signals from user's scalp. In this paper, we aim to introduce a design of dry electrodes for BCI systems. The proposed electrodes are equipped with six spring loaded probes. They are capable of acquiring EEG signals of good enough quality without usage of conductive gels. To verify the performance of proposed electrodes, we measure contact impedances under various spatial and temporal positions and compared them with those of conventional wet electrodes. Experimental results show that average impedance of proposed dry electrodes is slightly higher than those of the wet electrodes. The impedance difference between proposed dry electrodes and existing wet electrodes is shown to be insignificant without conductive gels. We anticipate to improve the impedance values of proposed dry electrodes by adding an extra electrical circuit.

Keywords: EEG, Dry electrode, Impedance

1. Introduction

Brain-Computer Interface (BCI) systems can acquire user's intentions by analyzing the user's neurophysiological signals. The intentions are then translated into control signals which computer or external machines can understand. In these systems, electrodes are the most important part because this part may affect the signal quality severely. Because amplitude of EEG signals is very small, the signals are easy to be affected by various noise sources such as physiological interference, i.e., electrooculograms (EOG). Moreover, due to usage of conductive gels, electrode installation is also inconvenient and time-consuming. Therefore, development of improved EEG electrodes which provide high fidelity EEG signals and easy installation is one of the most important challenges.

Recently, researchers have studied about dry electrodes for solving these challenges. Dry electrodes are defined as those that do not require the use of conductive gels for installation process. Thus, a user can conveniently attach them to its scalp without any hair arrangement. In this paper, we aim to introduce our dry electrode, show their performance (contact impedance), and compare them with that of conventional wet electrodes.

2. Dry Electrode Design and Impedance Test

2.1. Dry electrode design

Our dry electrodes are equipped with six probes of spring loaded type. These probes contract their length maximum 2 mm when they compressed. This structure provides flexibility and geometric adaptation between the sensor and the irregular scalp surface. Because the probes are easy to touch with the user's scalp through the hairs, any hair preparation is not needed in their installation process. For these reasons, the proposed electrodes provide both a convenience of installation and an appropriate adhesion to measure high fidelity EEG signals simultaneously. Fig. 1 is a picture of the proposed electrode and a diagram showing its structure.

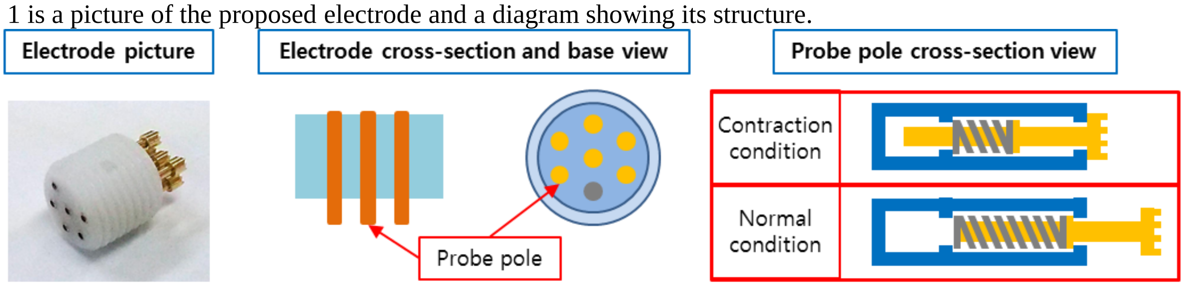

Figure 1. *Dry electrodes picture and structure diagram. Diameter of the proposed electrodes is 8 mm and length of each proves is 3 mm.*

2.2 Impedance test

To verify the performance of the electrode, we measure the contact impedance and compare that with those of conventional wet electrodes. In acquisition of EEG signals, existence of electrical impediments such as hair, outer skin layer, and sweat may lead to a lower contact capability. To make sure of the contact capability, we can evaluate the contact impedance before measurement of EEG signals. The impedance can be obtained by measuring the voltage difference between a reference electrode and a target electrode [Malmivuo and Plonsey, 1995]. A lower impedance means a higher contact capability, and the possibility of high quality EEG signal acquisition.

In order to measure the electrode impedance, we utilize EEG acquisition system named RZ5 neurophysiology workstation, PZ3 low impedance preamplifier and impedance check application (made by Tucker-Davis Technology). Our comparison target is general wet electrodes, named StarDisk(made by Hurev). In the impedance test, we used a single male subject. We measured the electrode impedances at Cz, Fz, and Pz positions based on international 10/20 system. We also recorded the change in impedance from 2 seconds out to 60 seconds. Reference and ground electrodes are installed on the right and the left ear lobe respectively. Note that the wet electrodes use the conductive gels for their adhesion in the installation process.

3. Results

Table 1 summarizes the impedance comparison of both electrodes under various spatial and temporal positions. Owing to the usage of conductive gels, the average impedances of wet electrodes is slightly lower than those of proposed dry electrodes (31. kΩ vs. 19. kΩ). However, according to impedance record of Cz position, the impedance difference between two electrodes is shown to be insignificant without conductive gels.

Table 1. *Comparison of contact impedance between dry electrode and wet electrode. We record the impedance values at the 3 electrode positions(Cz, Fz, Pz) and from 2 seconds until 60 seconds.*

Electrode	*Dry Electrode Impedance*			*Wet Electrode Impedance*		
Section	*Cz*	*Fz*	*Pz*	*Cz*	*Fz*	*Pz*
2s	26 kΩ	46 kΩ	29 kΩ	21.6 kΩ	13.3 kΩ	25.8 kΩ
10s	25 kΩ	39 kΩ	31 kΩ	21.4 kΩ	13.5 kΩ	24.2 kΩ
20s	25 kΩ	36 kΩ	31 kΩ	21.2 kΩ	13.4 kΩ	23.1 kΩ
30s	25 kΩ	36 kΩ	30.8 kΩ	21.2 kΩ	13.2 kΩ	22.5 kΩ
40s	25 kΩ	36 kΩ	30.5 kΩ	20.8 kΩ	13.1 kΩ	22.2 kΩ
50s	25 kΩ	36 kΩ	30.6 kΩ	20.5 kΩ	13.2 kΩ	21.7 kΩ
60s	30 kΩ	37 kΩ	30.2 kΩ	20.4 kΩ	13.2 kΩ	21.1 kΩ

4. Discussion

The impedance values of proposed dry electrodes are slightly higher than those of the wet electrodes. But, the proposed dry electrodes do not required the usage of conductive gels. Therefore, the proposed dry electrodes provide advantages such as convenient installation and feasibility of long-term. We expect that the impedance values of proposed dry electrodes can be improved by adding an extra electrical circuit like impedance converter.

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References

Malmivuo J, Plonsey R. Bioelectromagnetism: Principles and Application of Bioelectric and Biomagnetic Fields, *Oxford University Press, New York*, 1995.