Augmented Reality to improve EEG cap preparation

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Abstract—EEG (Electroencephalography) cap preparation needs a significant amount of time to prepare before actual measurements can be performed. This time is increased with EEG caps that need some form of gel or saltwater to increase contact with the scalp. In this thesis, we will try to use Augmented Reality with a Microsoft HoloLens to help in preparing an EEG cap by visualizing the contact quality of electrodes directly in the operator's vision on the patient's head. Additionally, Augmented Reality can be used to help align the cap on the patient's head in the first place. We hope to be able to decrease preparation time and increase recording quality by using this system.

1 Introduction

EEG (Electroencephalography) [1] is a method of recording brain activity. This is done by electrodes on EEG caps, which record brain activity by measuring voltages emitted from electrochemical processes in brain cell communication. Figure 1 shows an example recording consisting of multiple electrodes called channels. EEG recordings are often used in medical applications like the diagnosis of epilepsy or sleep disorders and fundamental research.

There are many different layouts of electrodes on a cap and several different types of electrodes. Some electrodes make contact with the scalp simply by touching it or have small metal probes. But there are also electrodes that use a conductive gel or water and salt to make contact with the scalp.

The quality of a contact can be measured in impedance. Impedance is similar to resistance but in AC circuits. Like resistance, the impedance has to be low for good contact and good measurements.

To be able to see and record data from an EEG cap in another room, the data has to be sent to different computers over a network. We're using the Lab Streaming Layer (LSL) [2] in this case. The Lab Streaming Layer is a system that handles the networking and the time synchronization for streaming measurement time series over a network.

The topic of this bachelor's thesis is to use Augmented Reality to visualize data from the EEG cap in the operator's view, which is supposed to help the operator prepare an EEG cap on the patient's head to achieve high-quality measurements. With Augmented Reality, it is possible to display computer user interfaces for the user on top of the real world. This is mostly achieved by wearing a headset like the Microsoft HoloLens [3], which has two displays, in front of the eyes of the user, built into it.

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Fig. 1: EEG Recording of multiple electrodes, each displayed as a row in a time series [1]

2 Motivation

2.1 Problem

The process of preparing an EEG cap includes aligning the cap on the head of the patient. It has to be aligned with the help of anatomical landmarks so that the electrodes on the cap are on the right spots on the head and measure the activity of the correct parts of the brain.

After aligning the cap on the head, some EEG caps need a conductive gel that helps to make good contact between the scalp and the electrodes. In the case of hair, it is crucial to use gel to have good contact. For a good measurement, all electrodes must have a low impedance and, thus, a good contact with the scalp.

This means that, after applying some gel to each electrode, the impedances of the electrodes have to be observed. In case there are still electrodes with a high impedance, some more gel has to be applied to the electrode to ensure a good contact.

Most EEG setups include a monitor, which is used to display instructions to the patient, or another device, which handles the recording of the EEG measurements. The operator can see the impedance values for each electrode on a monitor to be able to ensure good contact on each electrode. But this means that the operator has to look at the monitor and find electrodes with high impedance, then find these electrodes on the EEG cap and apply some gel. This process may consist of several iterations of looking at the monitor and finding electrodes on the cap, which takes time.

2.2 Key novelty and contributions

By using a Microsoft HoloLens [3] the tool, proposed in this thesis, will be able to visualize impedance values directly on the head using Augmented Reality. This means that the operator can see the impedance values on the EEG cap in 3D space and does not need to repeatedly look at the monitor and find electrodes that need correction. We expect this to help decrease the preparation time of the EEG cap. In addition to that, the proposed tool could also help in aligning the cap on the head. In total, the proposed tool aims at helping in the EEG cap preparation process and thus making it possible to achieve measurements of better quality while decreasing the time needed for the preparation steps.

3 Related Work

Song et al. [4] have already tried to use Augmented Reality to help align the EEG cap on a head. They used an Intel RealSense camera, which captures depth information alongside a normal camera image. This information is then used to find the face position and the electrode positions. The alignment still needs a reference, which is initially captured and then used in subsequent alignments. This leads to a good alignment of the EEG cap on the head with high repeatability. Song et al. were able to decrease the median of the overall positioning error of their proposed system in comparison to the 10/20 system applied manually by about 1,5mm.

Jeon et al. [5] also tried to improve EEG cap positioning on the head by using computer vision. They used a laser scanner and a normal camera with markers to align the EEG cap with a reference position on the head. But instead of AR, they used a normal display to visualize the current and target positions of the cap. Jeon et al. were also able to decrease the alignment error by using their proposed system in comparison to the 10/20 system applied manually.

But the proposed systems in these papers [4], [5] only help align an EEG cap on a patient's head, decreasing the time needed for preparation a bit and improving the positioning of the EEG cap. This thesis aims at helping to ensure good contact between the electrodes and the scalp.

4 Goals

1) The major mandatory goal is to implement a tool for the Microsoft HoloLens [3], which receives the measured impedance values of the electrodes and visualizes them for the operator preparing the cap.
2) To be able to determine the preparation time improvements compared to preparing a cap without the AR solution, a study has to be performed. The study is the second mandatory goal and includes measuring the time it takes to prepare a cap with and without the visualizations in the HoloLens and with different types of visualizations.

a) The first stretch goal would be to try to visualize not only impedance values but also the actual voltage measurements coming from the electrodes with the HoloLens to further help the operator improve the measurement quality.
b) The second stretch goal is to test different types of visualizations at the electrodes, trying to determine the most effective visualization that displays values as easy to see and understand as possible. Figure 2 shows some examples of visualizations that can be used.
c) The third stretch goal is to further improve the preparation time of an EEG cap by helping to place the cap on the head and align it correctly with anatomical landmarks.

Fig. 2: Examples of visualization types displayed on the EEG cap in AR

5 Approach

- To achieve the first mandatory goal it is necessary to send the measured impedance values to the HoloLens [3] by using the Lab Streaming Layer [2]. An initial test would be to just display the impedance values in a window in the view of the operator just like the normal monitor would.
- To be able to visualize the values directly on the EEG cap, some kind of head pose detection [6] and maybe face detection [7] are needed for tracking the cap on the head of the patient. In combination with a predefined model of the cap, the values would be displayed on the electrodes. To support the alignment of the values and the electrodes, OpenCV [8] can be used with object detection or some kind of edge detection. A game engine like Unity [9] or Unreal Engine [10] can be used to simplify the implementation of the UI and the 3D aspects of the visualization.
- To find the most effective visualization, some different types have to be tried out. One option would be to display colored circles around the electrodes, which change color according to the impedance values. It is also possible to use circles that behave like a progress

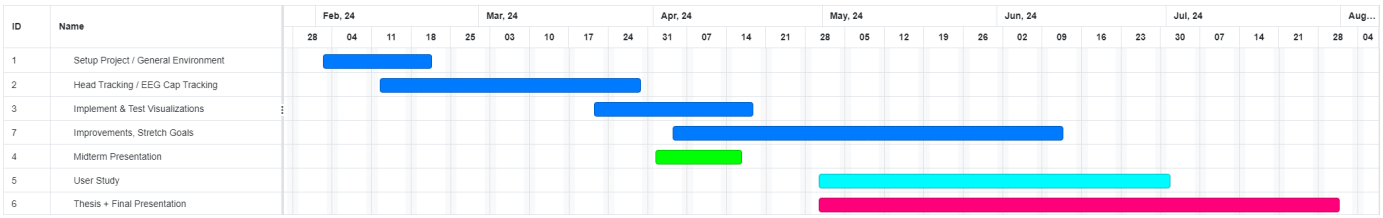

Fig. 3: Gantt chart including planned times for milestones

circle, displaying how good the impedance values are. Another option would be to highlight electrodes that need to be improved in some kind that the electrodes are easy to find on the head. Figure 2 shows some examples.

- Head tracking and face tracking can also be used to help align the cap on the patient's head by using the eye and, generally, the head position of the patient. This also includes the alignment of the extra electrodes, which are not on the cap but on external wires for the area around the eyes.
- Finally, to determine how much the visualizations help in the preparation process a study has to be performed. The study will collect the time needed for the preparation of the cap with and without the HoloLens. It is also possible to measure times for different visualization types to be able to see what visualization is the easiest to use. Additionally, the time needed to get used to the tool or the time needed to learn how to prepare an EEG cap could be measured.

6 Intended Outcomes

The intended outcomes of this thesis include a tool that can be used in the EEG cap preparation process, specifically for aligning the EEG cap on the head and the insertion of the gel into the electrodes. The tool should improve the preparation time by removing the extra time needed to look up impedance values for the electrodes to be able to ensure good contact for each electrode. It may also help in the preparation process in different steps and can be used to visualize different measurements in a more convenient or interesting way.

The source code will be open source, which means it can be used and improved by others in the future. This includes good documentation for others to understand the code and to be able to modify it.

7 Milestones

Figure 3 shows a Gantt chart containing the consecutive steps and showing when they will be worked on.

February will be devoted to setting up the general environment for the HoloLens. Initially, there is no complex or interesting visualization, but a first approach at receiving data with the Lab Streaming Layer.

The next step is to get head tracking to work to be able to display impedance values in 3D space on the patient's head. This will take some time throughout March.

After the tracking of the head and the electrodes works, the next step is to implement a good visualization for the impedance values in April. Multiple types of visualizations can be tested. Additionally planned this month are the midterm presentation, further improvements of the tool and the visualizations, and possibly stretch goals.

The study is planned to start sometime in May and will go on until June in order to have enough time. This time will also be used to work on the thesis and the presentation and, depending on the progress so far, also stretch goals.

Finally, July is used to finalize the thesis and presentation. But there is also a bit of spare time planned in July in case something comes up or needs more time than expected.

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