Towards Perceived Space Representation using Brain Activity, Eye-Tracking and Terrestrial Laser Scanning

Gabriel Kerekes, Volker Schwieger

Institute of Engineering Geodesy, University of Stuttgart,
Geschwister-Scholl-Str. 24D,
70174 Stuttgart, Germany

Abstract. Deciphering how humans perceive physical spaces can lead to new reality capture methods and eventually replace measurement instruments like terrestrial laser scanners (TLSs). The current approach pursues this goal using non-invasive wearable sensors like Brain Computer Interfaces (BCIs) and mobile eye-trackers. Work in progress from static experiments shows that positions of targets on a wall at 4 m can be determined with differences up to several dm and better w.r.t. ground truth using homography.

Keywords. Space perception, TLS, human perception

1. Introduction

There are multiple methods of capturing reality and representing physical space. One method implies TLS scans and physical space is represented by point clouds. Similar to how a scanner measures only what it "sees", humans create a representation of their surroundings mostly based on vision and knowledge. Therefore, the question arises if human perception can be deciphered with non-invasive sensors and used to represent physical space similar to how a TLS measures it. The expected precision of this method is currently lower than the TLS one. Nevertheless, it may be fit-for-purpose for tasks like semantic segmentation of 3D scenes.

Perception of space happens in the neocortex of the human brain (Buzsáki & Llinás, 2017). A non-invasive approach for analyzing brain activity during an action is electroencephalography (EEG) (Bellmund et al., 2018). Additionally, space perception is mostly based on vision; therefore, eye activity

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is also used as input for this approach (Authié et al., 2017). Previous approaches as Plöchl et. al. (2012) also combined eye-tracking and EEG with the aim of eliminating EEG artefacts caused by eye movements, but the current one strives to use them. Similar ongoing research as Kastrati et al. (2021) aims at classifying the saccade (voluntary rapid eye movements) direction based on EEG signal analysis. Other related work (cf. Mlot et al., 2016, Hirzle et al., 2018) use gaze data to estimate position within ranges less than 1 m.

Complementary to these studies we take steps towards using the human perception as input for a close-range representation method that can eventually replace a TLS if the accuracy is satisfactory.

2. Experiments and preliminary results

The planned experiments combine data obtained from a Pupil Core mobile Eye-Tracker from Pupil Labs and an 8-chanel EEG BCI from Neuroelectrics for the brain activity. Ground truth geometry of a scene is defined by TLS, which is a 3D polar measurement system used to generate point clouds describing surroundings up to a certain range. Experiments are limited to indoor spaces, therefore a Leica BLK360 TLS is chosen. The accuracy of a single 3D point is 6 mm at 10m.

2.1. The Experiment

The experiment (fig. 1) can be described as follows: a subject equipped with the BCI and Eye-tracker stands in front of a wall at about 4 m distance with black & white targets fixed on it. The whole scene is captured by TLS.

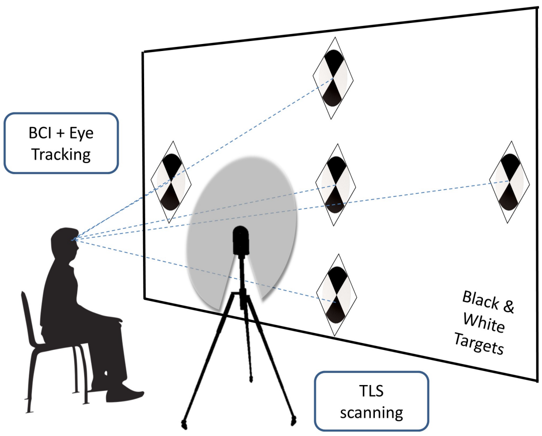

Figure 1. Example of experiment set-up.

While BCI and Eye-tracker data is recorded, the subject successively focuses on each target. The goal is to reconstruct the targets position based solely on EEG and eye-tracking data, practically making the TLS scan redundant if successful.

2.2. Up to now

First experiments were conducted with a subject facing the wall with 10 targets on it. After scanning, target positions were defined in a wall-based coordinate system.

Firstly, EEG patterns were analyzed in the BCI signals. The EEG protocol is defined with electrodes placed symmetrical on both brain hemispheres (Fig. 2).

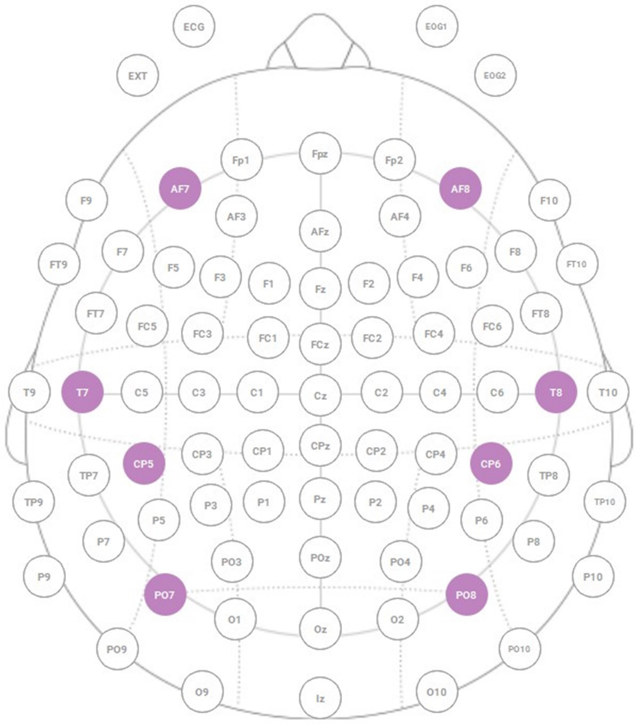

Figure 2. The 8-Chanel EEG Setup protocol

The intention is to differentiate between hemispheric brain activity and analyze patterns depending on a specific action of the observer. The subject was instructed to observe only three targets on the wall placed on a horizontal line. Additionally, between observations, the subject was asked to blink, since this is a clearly indefinable EEG artefact. Based on the EEG signal, it is possible to distinguish saccades performed by the observer (see fig. 3) especially due to the signals read from the electrodes placed near the forehead (AF7 and AF8).

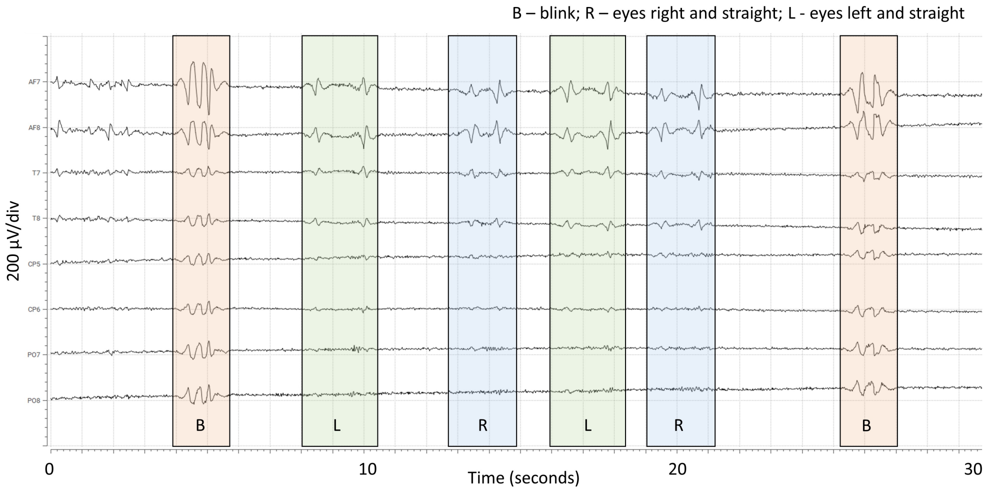

Figure 3. EEG signal

When the eyes performed a saccade from the center target to the left one, the AF7 signal shows a decrease of about 200 µV whilst the AF8 presents a mirrored profile. If the center target is fixed again, an increase of the same magnitude occurs in AF7 and AF8 gives the mirrored profile.

For the pursued goal, results are obviously unsatisfactory, since the only spatial information depicts if an observed target is on the left side or on the right side w.r.t. the previously fixed one.

Further on, gaze data from the eye-tracker is analyzed and the fixations (cf. Hering & Martin, 2017) identified in the world camera images were then projected with the help of homography (Luhmann et al., 2020) onto the wall-defined coordinate system. Afterwards, differences to the reference position (TLS scan) were computed. Three trials lead to the results presented in fig. 4.

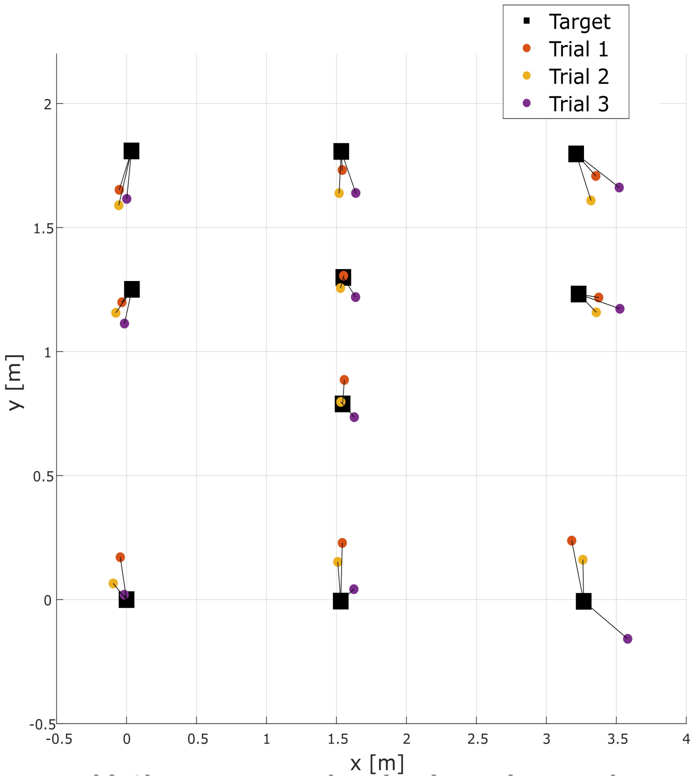

Figure 4. Fixations projected on wall (colored dots) and reference positions of the targets (black squares)

At this range, differences in both directions vary from 14 to 18 cm. This cannot be compared to currently available TLS precision, but can be better if fixation detection of the eye-tracker is improved. Additional depth-sensitive set-ups are foreseen to extend the current experiment.

3. Beyond findings

Currently, EEG can be limitedly used to discriminate between a left-hand side and right-hand side target, but not to precisely position it. Using gaze data captured with a mobile eye-tracker positioning accuracy on a plane reached the level of some dm. This approach presented intermediate steps towards using human perception for reality capture with the intention of establishing a connection between instrument-measured space and human-perceived space.

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