Drone Control Using Electroencephalogram (EEG) Signals

Aloaye E. Itsueli, Jonathan D. N. Kamba, Jeremie O. K. Kamba, and R. Alba-Flores
Department of Electrical and Computer Engineering
Georgia Southern University
Statesboro, GA, USA
ai02160@georgiasouthern.edu, jk17685@georgiasouthern.edu, jk17684@georgiasouthern.edu, ralba@georgiasouthern.edu

SoutheastCon 2022 | 978-1-6654-0652-9/22/$31.00 ©2022 IEEE | DOI: 10.1109/SoutheastCon48659.2022.9764002

***Abstract*— In this project, we present the development of a system that can control a drone using a headset sensor that detects electroencephalographic (EEG) waves from the drone's pilot when he/she performs facial gestures. The drone is controlled using specific facial expressions which are recorded using a commercial EEG headband, the OpenBCI EEG headband. The EEG headband uses electrodes to read the electric potentials from the brain. The EEG signals were recorded and analyzed using the OpenBCI GUI software. The data files recorded from the EEG headband were exported to Matlab to perform the signal conditioning, feature extraction, and design and training of the Artificial Neural Network (ANN) that was used to classify the facial gestures. For each data recording, three statistical values were computed: the standard deviation, root mean squared and mode. These values were used as the features for each facial gesture. The feature extraction data were used as the inputs to the ANN. The input to train an ANN consisted of a 9x45 array generated from the pilot performing fifteen recordings of each facial gesture. The target matrix was a 3x45 size, this is 3 classes and 45 recordings. The Neural Net Pattern Recognition tool from Matlab was used for the implementation of the ANN. After the ANN was trained to classify the 3 facial gestures, the output of the ANN was used to control the drone. The drone used in this project was a palm sized DJI Tello drone. Three facial gestures were selected to control the motion of the drone as follows: raising eyebrows, hard blinking and looking right. Results of the ANN training yielded a 97% accuracy in the classification of the facial gestures.**

Keywords— Electroencephalographic, Artificial Neural Network, drone, UAV

I. INTRODUCTION

In aviation, a drone refers to an unpiloted aircraft or spacecraft. Another term for it is an "unmanned aerial vehicle," or UAV. Drones are often used for multiple purposes in many fields such as surveillance and security, package transportation and photography [1].

Nowadays, anyone can have access to drones and use them for multiple purposes in many fields such as surveillance and security, package transportation and photography.

At the end of this project, we should have developed a system that allows users to control a drone without the need for manual controllers. This will play a big role in helping people with disabilities that do not allow them to manually control drones. Facial gestures and head movements can be matched with a specific action or sequence of actions for the drone to carry out. For example, in video surveillance, a look to the right can be translated to the drone surveying an area 50 meters to the right of the user and streaming the video, allowing the user to multitask.

For the purpose of this project, the DJI Tello Drone Model TLW004 was used. This drone is programmable using the Tello SDK which allows a connection to the drone using a Wi-Fi port.

Electroencephalographic (EEG) signals are signals generated from electrical activity in the brain. EEG signals are generated by neurons in the cerebral cortex that are perpendicular to the brain's surface [2].

In this project, the EEG signals from the brain were recorded and analyzed using the OpenBCI headband kit [3]. This headset uses electrodes to read the electric field potentials generated from the user when he/she performs neurological activities (e.g. focusing in a specific thought or performing facial gestures) and displays the signals as EEG signals. The recorded signals are displayed via the OpenBCI GUI software, allowing the user to visualize and analyze the data.

In analyzing the data, different statistical methods were used to extract the desired features. The statistical analysis was performed using MATLAB tools. Once the feature extraction was completed, the data were used for the training and testing of an Artificial Neural Network (ANN) that was able to classify the neurological activity generated by the user. After the neural network has been trained and tested to recognize the different gestures, the output of the ANN is used to control the Tello drone. Three different drone commands were selected and related directly to three different facial gestures that were executed in real time.

II. OPENBCI HEADBAND

The OpenBCI headband used in this project contains three electrodes which collected signals from the frontal cortex, refer to fig. 1, the 10-20 internationally EEG node placement system [3].

The different facial gestures were performed by the volunteers while wearing the OpenBCI headband, and the data collected from the electrodes were processed using the OpenBCI Cyton biosensing board. Three electrodes and two ear clips were connected to the Cyton board using the input channels. The data acquired from the Cyton board can be viewed and analyzed

This material is based upon work supported by the National Science Foundation under REU Site, award # 1950207.

978-1-6654-0652-9/22/$31.00 ©2022 IEEE

using the OpenBCI GUI software. The OpenBCI GUI software also allows the user to send the data collected to a third-party software. In this project, the data was collected at a rate of 225 samples per second sent to MATLAB as a table of values.

III. Data Collection and Feature Extraction

The facial gestures performed were: raising eyebrows, looking right, and hard blinking. Collecting the facial gestures consisted of the subject maintaining one gesture for 6.3s. Each session was separated by a 60s rest period. We used 15 sessions which provided us with good samples of each gesture because a given gesture may be slightly different each time it is performed by the subject.

The EEG signals were collected from three channels and recorded for a time length of 6.3s for each facial gesture performed by the volunteer. The collected data was saved in a table (voltage values). This table was then imported into Matlab, and the feature extraction process was performed by creating a Matlab code to compute three statistical parameters: the standard deviation, the root mean squared (RMS), and the mode of the recorded EEG signals.

IV. Artificial Neural Network

The Artificial Neural Network (ANN) was used to detect patterns in our data and differentiate facial gestures from each other. An input matrix containing our processed data was entered into the ANN and it returned an output matrix that indicates which gesture was being performed by the user [4].

A neural network is a network of artificial neurons programmed in software. It tries to simulate the human brain, so it has many layers of "neurons" just like the neurons in the human brain. As a result of the analysis of the data collected from the EEG signals, the ANN will associate the data collected to the corresponding facial gesture performed by the volunteer.

In order to train the neural network, MATLAB was used. The input data used to train and test the ANN consisted of a 9x45 matrix, this is, nine input nodes, (3 statistics for each of the 3 channels), and 45 columns that were generated from one subject performing fifteen recordings of each facial gesture (raising eyebrows, looking right, and hard blinking). The target matrix was a 3x45 size, this is, 3 classes and 45 recordings. Once the input and output matrices were created, we used them to train and test a network to fit the data set. To design the ANN, the Neural Net Pattern Recognition tool from Matlab was used.

To train the network, the data was divided, randomly, into three subsets. The first subset (70% of the data) was used for the training, the second subset (15% of the data) was the validation set, and the error was monitored carefully to avoid overfitting. The testing set (15% of the data) was used to provide an unbiased evaluation of a final classification model that was created on the training and validation steps.

V. Results

The results of the training, validation, and testing of the ANN is provided in the confusion matrix shown in fig. 2. From the results we can see that the ANN has an accuracy of 97%.After the ANN was designed and tested, it was used to send commands signals to the Tello drone. In the experimental part we were able to successfully control the drone using the 3 facial gestures selected for this project.

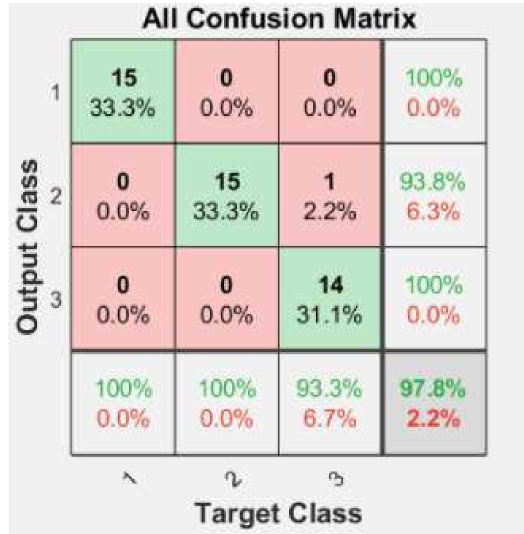

Figure 2. Confusion Matrix

VI. Conclusions and future work

We ran into a couple of problems during the development of this project. One of the challenges was finding the right statistical parameters to process our raw data from the EEG headband. After several testing stages, we found that the rms, mode, and standard deviation provided us the most consistent results during all the trials.

Another challenge we faced was selecting the right facial gestures that would work well in our application. We tried different facial gestures and we eventually selected raising your eyebrows, looking right, and hard blinking because these facial gestures gave us the most consistent results during the ANN trials.

Output of the neural network sent control commands via Wi-Fi to the drone to control the motion of the drone as follows: raise eyebrows (take off), hard blink (land), turn right (move to the right). As a starting point for this project, MATLAB has been selected because of its basic approach on machine learning and neural networks. With more libraries and a better overall interaction with the drone, Python programming will provide more practical and faster response, as well as a system that is easier to use.

References

[1] Howell, E. (2018, October 3). What is a drone? Space.com. Retrieved October 19, 2021, from https://www.space.com/29544-what-is-a-drone.html.

[2] T. Ros, B. R. Lanius, and P. Vuilleumier, “Tuning pathological brain oscillations with neurofeedback: a systems neuroscience framework”, Front Hum Neurosci. 2014 Dec 18;8:1008. doi: 10.3389/fnhum.2014.01008.

[3] OpenBCI EEG Headband Guide, https://docs.openbci.com/AddOns/Headwear/HeadBand/, last accessed Jan. 25, 2022

[4] https://www.ibm.com/cloud/learn/neural-network.