UAV Flight Control Using Brain Signal : A Brain Computer Interface (BCI) Approach Utilizing a Cloud Computing Infrastructure

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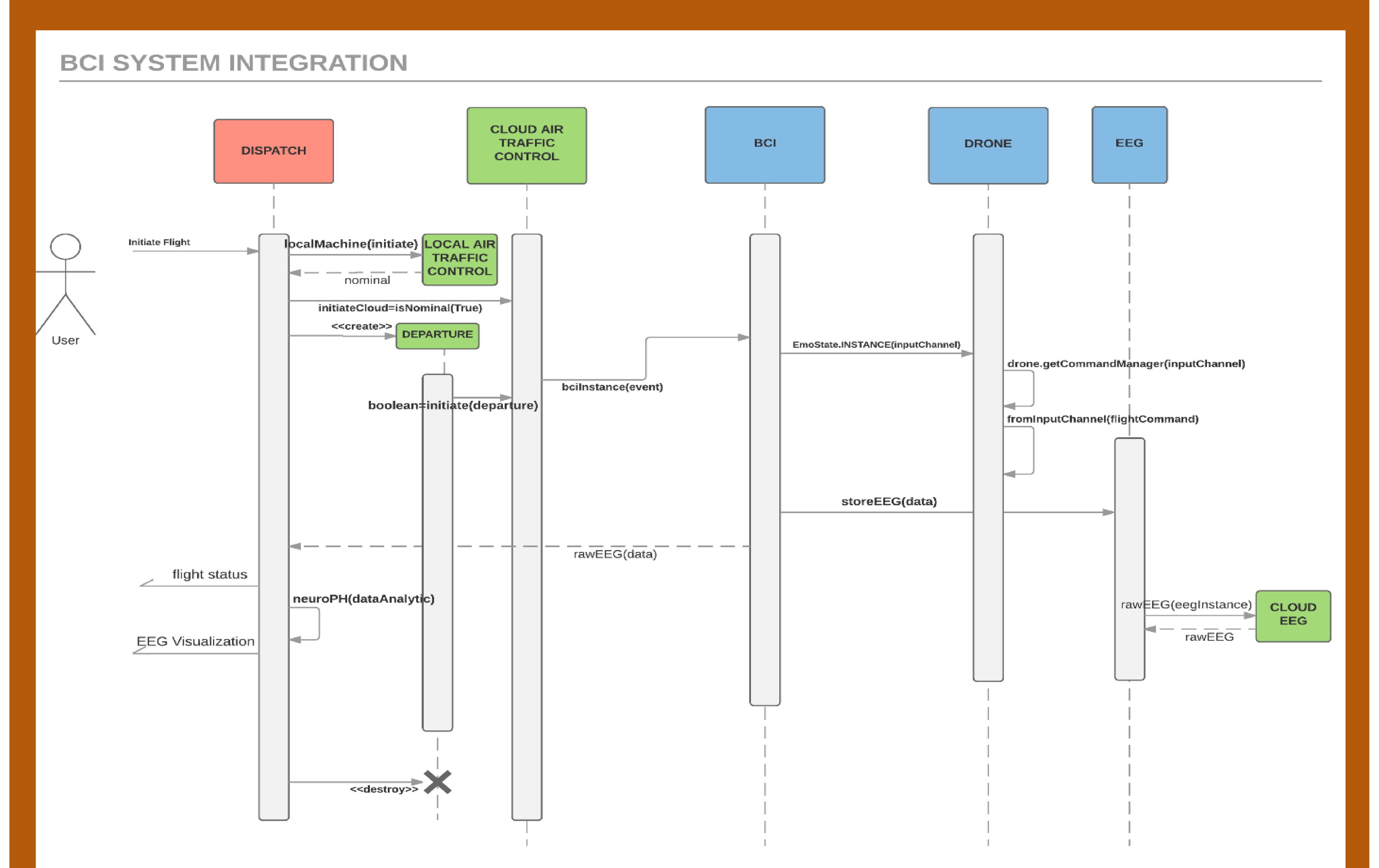
Abstract

Brain Computer Interface (BCI) is an innovative approach which involves detection, analysis and interpretation of electrical activities of neurons in the brain without using non-invasive interfaces. In this research, we propose to examine the application of BCI to the field of Unmanned Aerial Vehicles (UAV) where the complexity of existing UAVs' control and command systems is simplified by allowing to interact with the UAV's flight control using brain signal. We examine this capability by utilizing a cloud computing infrastructure and associated set of tools and algorithms [1].

Systems Integration

We developed a sequence diagram to design the system integration of BCI enabled drone command and control. In the design, a dispatch takes request to fly the drone. After nominal local machine & cloud system check, the dispatch initiates departure information to BCI device. The BCI activates a drone instance(take-off, hover, land). Real-time EEG data is streamed from the BCI, and is streamed to a cloud infrastructure. The respective flight status (take off, hover, land) is displayed to dispatch. A dispatch may choose to visualize raw EEG data to estimate accuracy of flight command & control executed using a BCI device.



BCI Signal Invocation

A BCI signal receives brain wave states with 14 bits 1 LSB = 0.51μV resolution and a bandwidth of 0.2 - 45Hz from 14 electrode channels placed on a scalp. These channels decode brain signals for emotional states, facial expressions, and mental commands (thoughts and intent). In this snippet code, a mental command instance is detected to invoke a command on a drone command & control unit [2].

Fig 2. Emotiv BCI

Fig.3 Emotiv BCI SDK

```
System.out.print("MentalCommandGetCurrentAction: ");
System.out.println(EmoState.INSTANCE
        .IS_MentalCommandGetCurrentAction(eState));
System.out.print("CurrentActionPower: ");
System.out.println(EmoState.INSTANCE
        .IS_MentalCommandGetCurrentActionPower(eState));
```

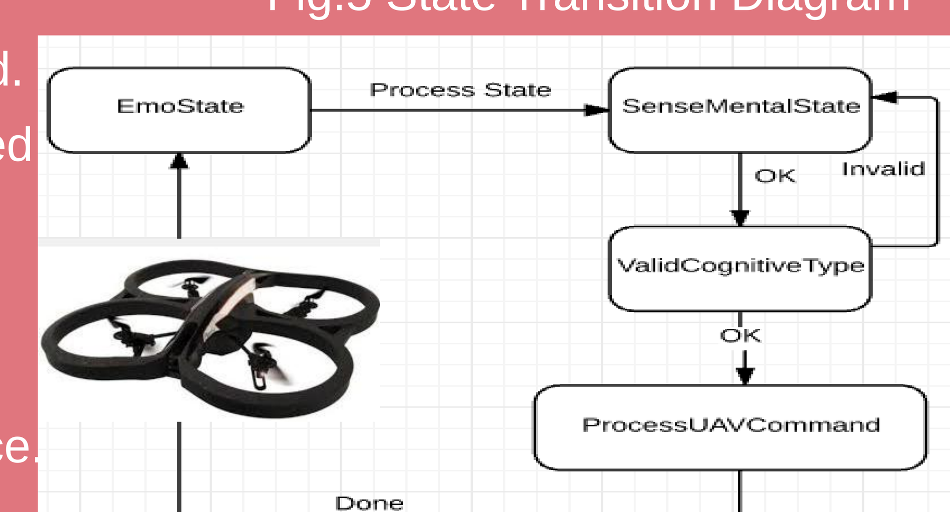
Drone Command & Control

A state transition diagram Is designed to illustrate BCI detected emotion state changes. The states to be simulated for this project are take-off, hover, and land. These states are invoked as shown in the snippet code when a valid cognitive command is decoded by a BCI device.

Fig.4 YADrone API SDK

```
IARDrone drone = null;
 try {
      drone = new ARDrone();
      drone.start();
}
drone.getCommandManager().takeOff();
drone.getCommandManager().waitFor(5000);
drone.getCommandManager().landing();
```

Fig.5 State Transition Diagram



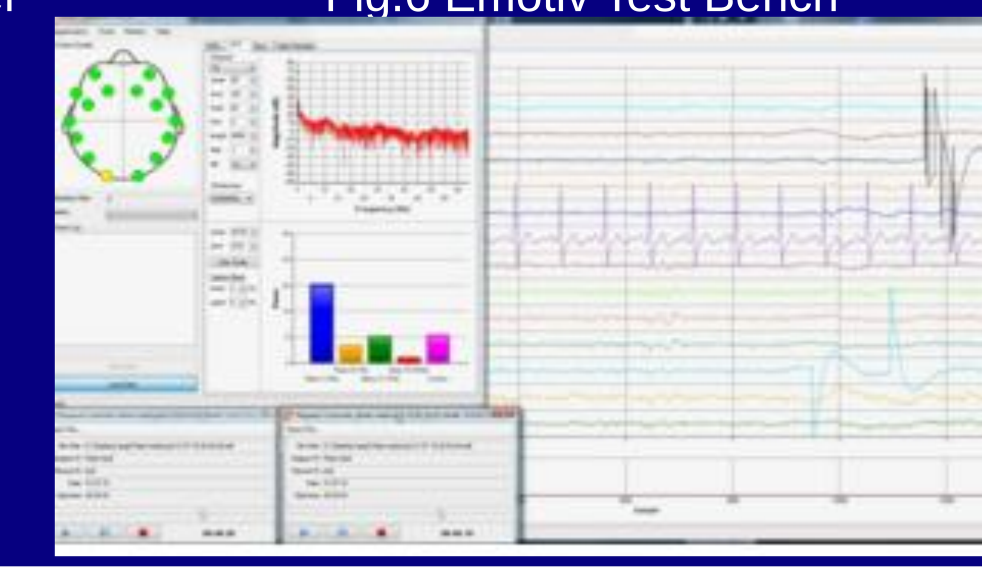
Cloud Architecture

A cloud computing infrastructure is utilized to simulate the command & control of a drone using BCI. The cloud infrastructure plays a role as a compute engine categorized into three clusters : first, initiating an instance of the flight module, secondly, processing of navigation commands, and thirdly, storage of real-time BCI data streams. In the first cluster, a Java EE framework will be deployed to an Amazon Web Service (AWS) cloud instance where all environment variables needed to simulate a flight will be initialized. In the second cluster, algorithms integrating the Software Development Kit (SDK) of drone and BCI will be executed at run time. In the third cluster, BCI data streams scanned across from 14 channels will stored in cloud database instances [3].

EEG Analytic

Test Bench provided by the BCI device manufacturer is utilized to display signal detection results from 14 electrodes. Filtered noises are built in digital 5th order Sinc flter, and desired signal thresholds are estimated to invoke desired drone states (take-off, hover, land) from a real-time BCI streamed data [4].

Fig.6 Emotiv Test Bench



Signal Analysis

Visualization on data captured from the BCI device is developed by utilizing a a neural network framework, Neuroph. Neuroph supports common neural network architectures such as Multilayer perceptron with Backpropagation networks which can be extended to fit BCI data.

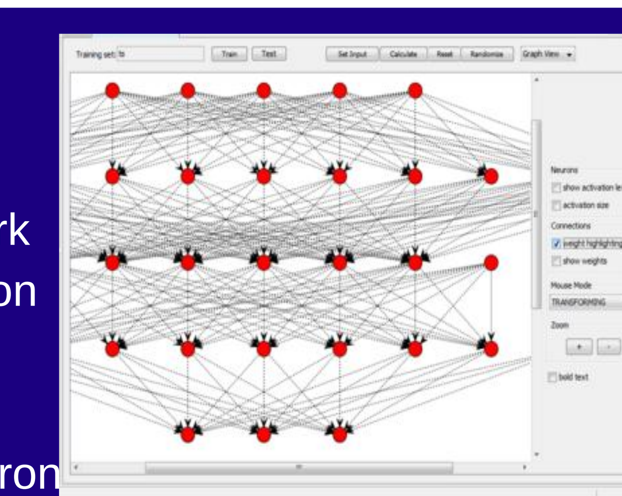


Fig.7 Neuroph Perceptron

Summary & Future Works

Integrating Machine Learning (ML) techniques between the perceptron developed in the neural network stack in one end with the BCI SDK stack in the other end aids to advance the command and control of the UAV. Applying ML leads to a multifaceted capability to the advent of commanding & controlling the UAV, such as to develop an Auto Pilot module where a trained ML takes over from a brain command in order to maneuver the UAV [5].

Works Cited

[1] Casey, B. (2015, December 18). In *Use The Force – Move a BB-8 Droid with Your Mind*.

[2] Liu, Y., Jiang, X., Cao, T., Wan, F., Mak, P. U., Mak, P. I., & Vai, M. (2012, July). Implementation of SSVEP based BCI with Emotiv EPOC. In *Virtual Environments Human-Computer Interfaces and Measurement Systems (VECIMS), 2012 IEEE International Conference on* (pp. 34-37). IEEE.

[3] Chen, M., & Xiang, W. (2015). Advances on Cloud Computing and Technologies. *Mobile Networks and Applications*, 1-2.

[4] Laboratory for Advanced Brain Signal Processing. (2006, December). In *Towards a Real Time Human Brain-Computer Interface with Neurofeedback: Improving Differentiability by Blind Source Separation*. Retrieved from http://www.brain.riken.jp/bsi-news/bsinews34/no34/research1e.html

[5] R. Asiimwe, A. Anvar, "Automation of the Maritime UAV Command, Control, Navigation Operations, Simulated in Real-Time using Kinect Sensor: A Feasibility Study", World Academy of Science, Engineering and technology 72, 2012.