Brain Computer Interface: An investigation in to BCI

Advances in cognitive neuroscience and brain imaging technologies have provided us with the ability to communicate directly with the brain. It has been made possible through sensors that can monitor the neural activity within the brain. This technology has been used to build Brain Computer Interfaces (BCI) that enables direct communication pathway between the brain and the object to be controlled or communicated to. It provides users with an alternate method for acting on the world.

Purpose

There were three main objectives for this body of work: investigate, prototype and evaluate brain computer interfaces. 1) The main goal of the project was to familiarise with the BCI technology and understand its various design methodologies and implementation. An extensive review of the current literature of BCI was carried out that included the history, design and applications of the technology. Various existing applications and tools were compared and studied.

2) The next step was to use this knowledge gained from the investigation and design a BCI system. The BCI system was designed using facial expression. The facial expressions smile, clench, furrow, smirk and neutral were chosen to drive the system. This system designed was then integrated to Nao humanoid robot to enable its control using facial expressions. Another BCI application developed was a skype dialler that enables a user to choose a contact from the dialler screen and call the selected contact using Skype.

3) A major focus of the project was the evaluation of BCI system. The accuracy and usability of the BCI system with facial expressions was analysed. A study was undertaken to determine the reliability and consistency of the signals caused due to facial expressions. This was achieved by conducting various experiments on users and by analysing the brain signal data collected during the experiments.

Design

After a careful consideration of the various technologies available to design the system, it was decided to use Emotiv EPOC neuroheadset. The Emotiv EPOC is one of the first commercially available BCI systems intended for normal and healthy users. The EPOC uses fourteen sensors and two reference points offering optimal positioning for accurate spatial resolution for tracking electroencephalographic activity originating from the brain at the scalp.

The Emotiv software comes with various detection facilities:

- **Expressive suite:** detects facial expressions from EMG and EEG activity
- **Affective suite:** detect levels of engagement, frustration, meditation, excitement, tension, boredom etc.
- **Cognitive suite:** detection of cognitive neuro-activities like “push”, “pull”, “lift” etc.
- **Gyroscopic data:** detects the change in orientation of the user’s head.

From the suites available it was decided to use the Expressive suite to create the brain computer interface as it required less training compared the other suites and the fact that facial expressions are easy to produce and are the same for everyone regardless of cultural differences. From the various expressions available, it was decided to use Smirk Left, Smirk Right, Smile, Furrow, Clench and Neutral as these were more voluntary and easy to produce. The other expressions that were available included eye and eye brow movements that were highly involuntary.

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Implementation

The system consists of Emotiv EPOC neuroheadset for reading the EEG/EMG activity from the user's scalp. This data read will be transferred to the embedded PC via Bluetooth. The signal processing operations provided by the Emotiv SDK processes these brain signals and also improves the signal to noise ratio. It is then converted to feature space using the pattern recognition algorithms. Both these procedures are implemented in the 'Expressive suite'.

The system was implemented in such a way that a person's brain activity was recorded for a 3 second time window. All the expressions detected in this time window would be recorded in a log file. The minimum time to get a reading from the sensor is 1 millisecond whereas the maximum time is 960 milliseconds. Depending upon the reading intensity we get processed expressions. These expressions are then processed to find the most prominent expression in the 3 second time window. An expression is termed the most prominent if it consists of more than 70% of the expressions detected in the time frame. The system would then output the prominent expression as the expression detected in the time window.

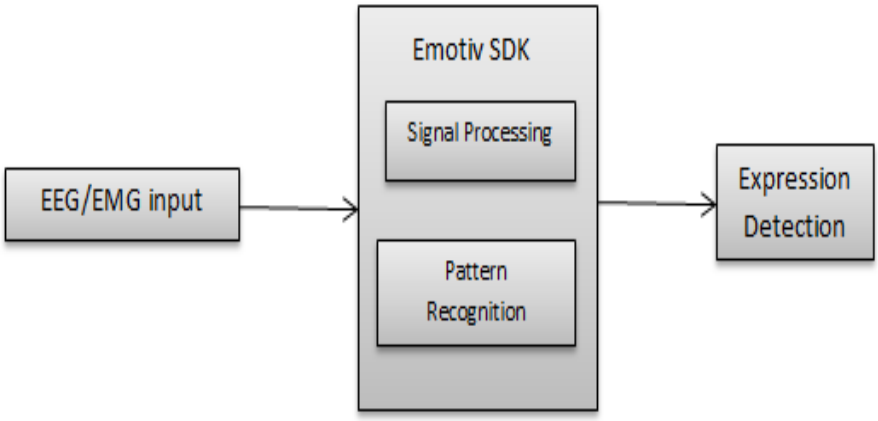

Figure 1: System Block Diagram

Integration with Nao and Skype

The system designed was used to produce two dimensional motions in Nao and used as a dialler for skype calling. The most prominent facial expression detected by the system would be mapped to a particular action in Nao/Dialler. Choregraphe and NaOqi SDK were used to integrate the BCI system designed with Nao whereas skype dialler was implemented using Skype4COM ActiveX component.

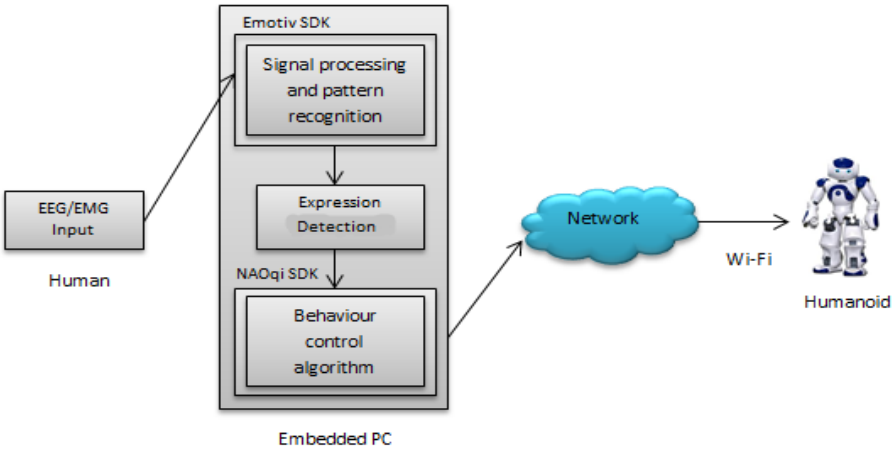

Figure 2: System block diagram for interfacing with Nao

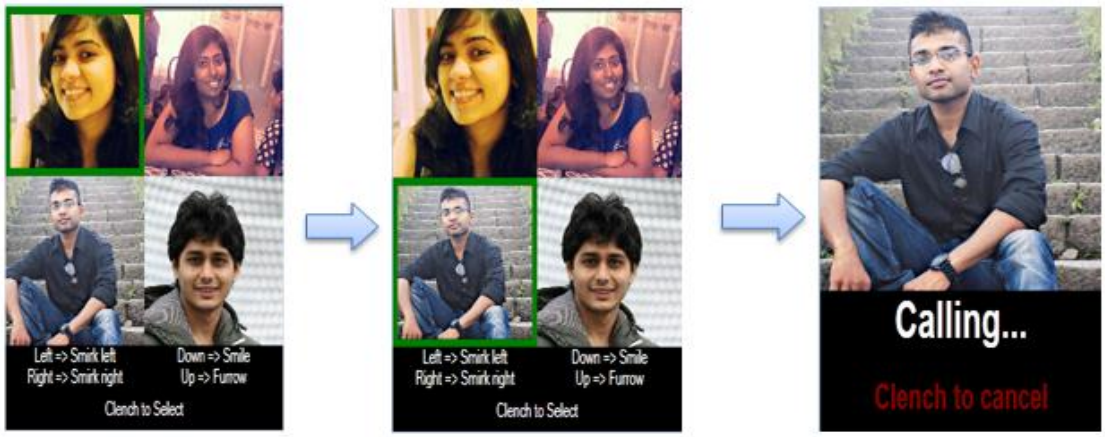

Figure 3: Skype Dialer. Smirk left, Smirk right, Smile and Furrow are used to navigate through the various contacts on the dialer. Clench is used to connect to the selected contact and also to disconnect an ongoing call.

Experimental Evaluation

An extensive study was conducted to determine the reliability of the brain signals caused due to facial expressions and the BCI system designed on them. The results revealed that the BCI system performed its functions better than chance. The experiments showed that the system was reliable. System has an accuracy of 60.413% with first time users and with learning this accuracy was shown to improve to 88.8% and a BCI system with feedback performed better than a system without feedback. It also established the need for training/learning before a user can correctly use such a BCI system. It was observed that sometimes some facial expressions like 'Clench' have strong detection signals than other facial expressions and the study reinforced the statement that brain activity varies greatly with people and that a person's brain activity.

Conclusions and Future Work

The presented work can be extended to more real world applications. Many of the BCI system designed are aimed to offer a new way to interact to the environment. These systems contribute to improve the ability of people who are dependent on others. The prototype system designed can be integrated to many everyday applications to help people improve their quality of life. The system designed can be extended to control a wheelchair and tele-robot with a two dimensional motion. Another application area is a BCI home automation control application, which would help people to interact with their home environment. BCI based communication systems are another area where the prototype design could be implemented. One such application is dasher. The system could be used to control the dasher using facial expressions to create text. Several other applications can also be integrated to the system like an IM chat that uses the facial expressions to send emoticons, web browser controlled by facial expression signals etc.