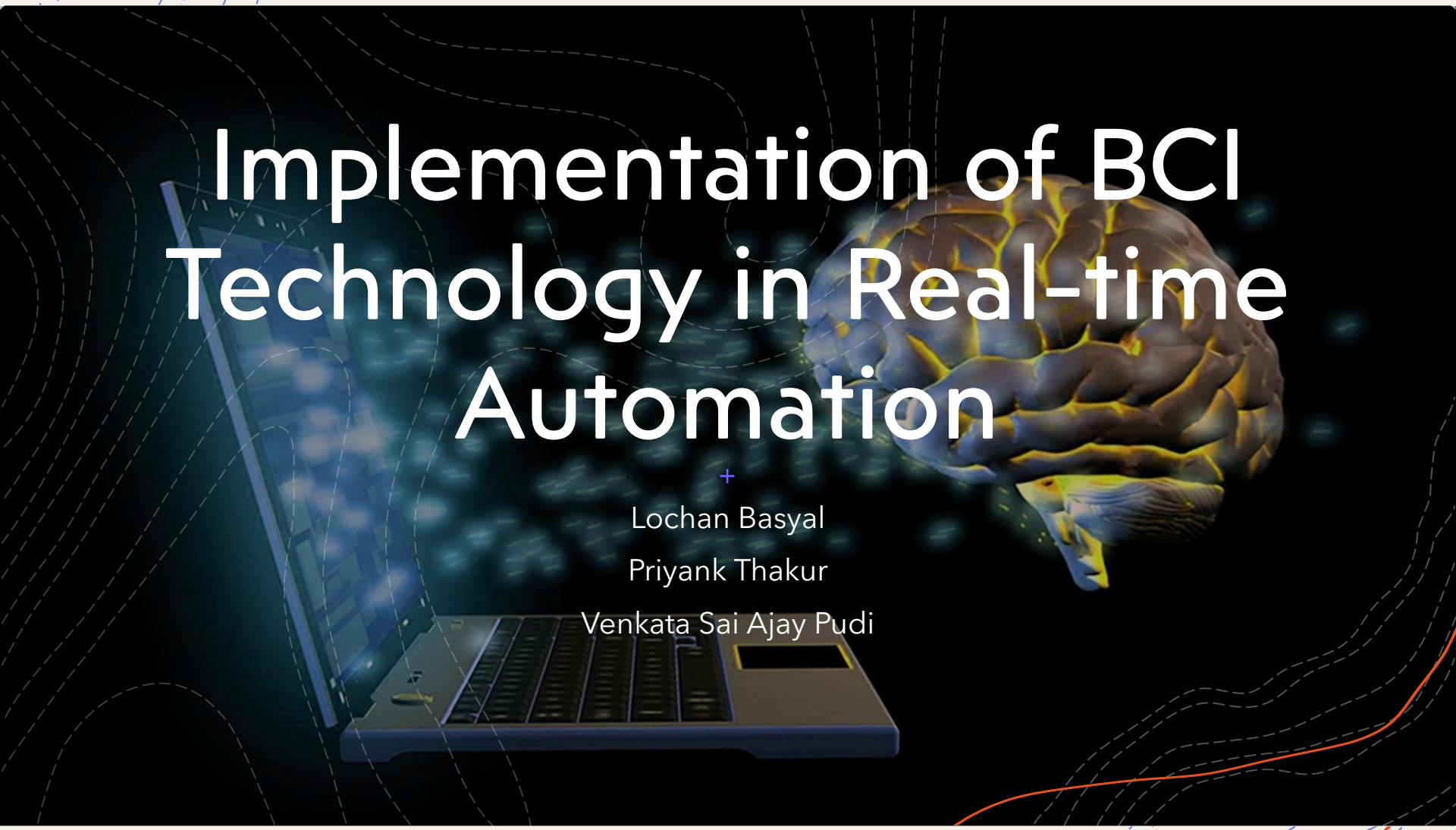
Implementation of BCI Technology in Real-time Automation



Lochan Basyal

Priyank Thakur

Venkata Sai Ajay Pudi

What is BCI?

- Brain-computer interface (BCI) is a fast-growing emergent technology, in which researchers aim to build a direct channel between the human brain and the computer or an external device.
- Provides a means for communication between the human brain and a computer, so the information in the neural activities in the brain can be exchanged with the computer. A Brain Computer Interface (BCI) is a collaboration in which a brain accepts and controls a mechanical device as a natural part of its representation of the body.
- Thus, BCI extracts electrophysiology signals from suitable components of the brain and process them to generate control signals for computers, robotic machines or communication devices.

Why BCI

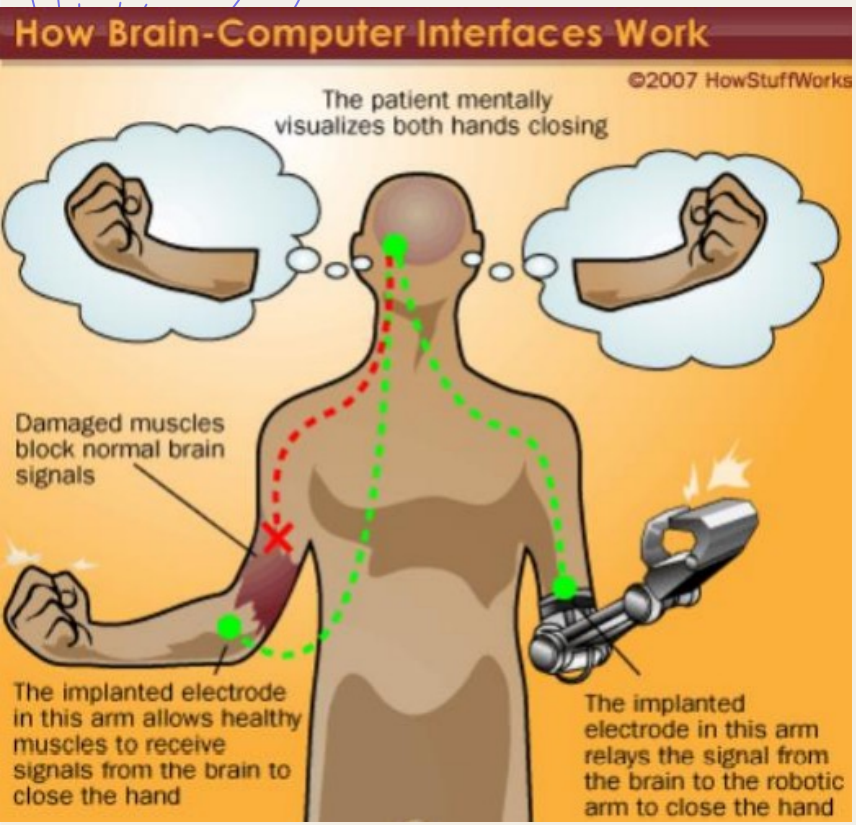
+ Make it possible to get a work done by just thinking about it.
+ Might help us better understand how the human brain works in terms of reorganization, learning, memory, attention, thinking, social interaction, motivation, interconnectivity, and much more.
+ Allows us to develop a new class of bioengineering control devices and robots to provide daily life assistance to handicapped and elderly people.
+ Several potential applications of BCI such as treating emotional disorders (for example, depression or anxiety), easing chronic pain, and overcoming movement disabilities due to stroke.
+ Expands possibilities for advanced human computer interfaces (HCIs), making them more natural, flexible, efficient, secure, and user-friendly by enhancing the interaction between the brain, the eyes, the body, and a robot or a computer.

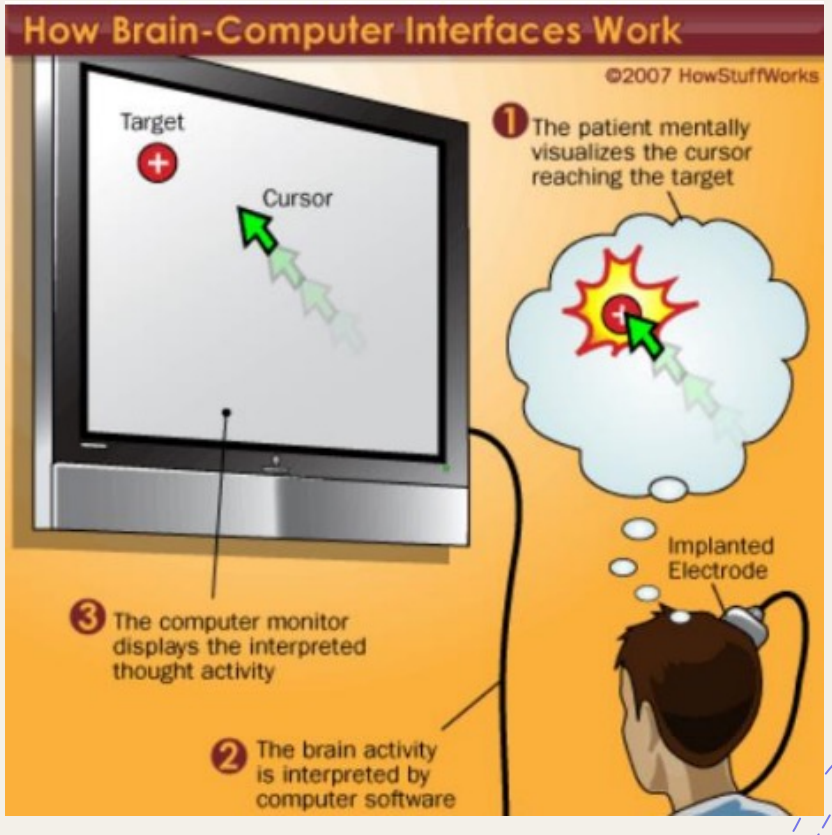
Earlier and Current Work

+ Algorithms to reconstruct movements from motor cortex neurons, which control movement, were developed in 1970s.
+ The first Intra-Cortical Brain-Computer Interface was built by implanting electrodes into monkeys.
+ After conducting initial studies in rats during the 1990s, researchers developed Brain Computer Interfaces that decoded brain activity in monkeys and used the devices to reproduce movements in monkeys and used the devices to reproduce monkey movements in robotic arms
+ Current and Future works include:
    - Neuralink project
    - GOOGLE Brain
    - Wheelchair Arm controlled by thought alone.

Neuroprosthetics and BCI

- Neuroprosthetics is an area of neuroscience concerned with neural prostheses—using artificial devices to replace the function of impaired nervous systems or sensory organs.
- The most widely used neuroprosthetic device is the cochlear implant.
- There are also several neuroprosthetic devices that aim to restore vision, including retinal implants.
- Neuroprosthetics typically connect the nervous system to a device.
- BCIs usually connect the brain (or nervous system) with a computer system.





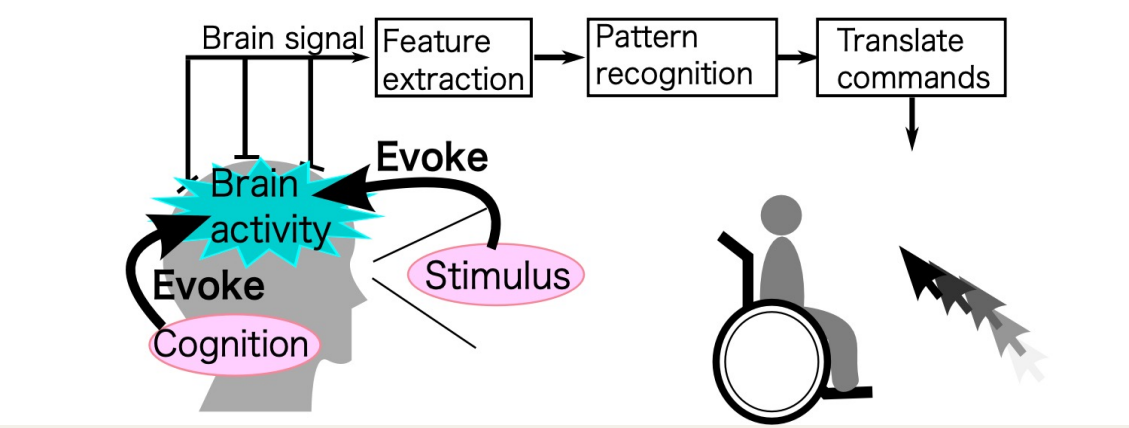
General overview of BCI System

Electric Brain

- Our brains are filled with neurons. Every time we think, move, feel or remember something, our neurons are at work.
- That work is carried out by small electric signals that zip from neuron to neuron as fast as 250 mph.
- Neural signals are essentially pulse streams. Over hundred billion neurons in brain, making their identification and understanding a complicated task .
- Signals characterized and classified according by pattern recognition and adaptive signal processing techniques etc.
- Techniques to readout brain are
- Electroencephalography (EEG)
- Magnetoencephalography (MEG)
- ElectroCortigography (ECoG)

BCI Components

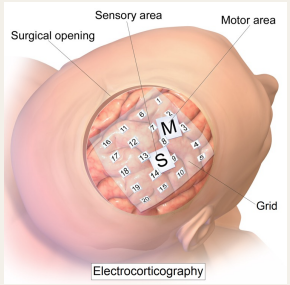
- Brain Activity Signals
  - Active Signal
  - Reactive Signal
  - Passive Signal
  - Hybrid Signal
- Brain Signal Acquisition
  - Invasive Approach
  - Non-Invasive Approach
- Feature Extraction
- Pattern Recognition and classification
- Command Translation



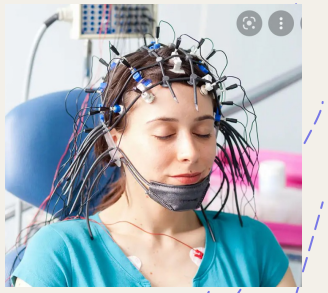
BCI Components

BCI Components(continued)

- Brain Activity Signals are generated in response to any stimulus or reaction to an event
- Brain Activity Signals are generalized into four types of signals:
  - Active Signal: generated by users who are engaged in cognitive tasks for the purpose of "driving" the BCI
  - Reactive Signal: generated as a response to stimuli (often visual or tactile)
  - Passive Signal: generated when users are engaged in cognitively demanding tasks
  - Hybrid Signal: A combination of above signals and possibly further signal acquisition.
- Brain Signal Acquisition
  - Invasive Approach: Neuron electrical activity recorded inside brain either using implants or implants
    - Signals are relatively strong (requires no amplification)
    - Ex: Electrocorticography (ECoG)
  - Non-Invasive Approach: Neuron electrical activity recorded on scalp through electrodes
    - Signals are generally very weak (requires amplification)
    - Ex: Functional Magnetic Resonance Imaging(fMRI), MagnetoEncephaloGraphy (MEG), ElectroEncephaloGraphy (EEG) (Most Widely Used in BCI Systems)



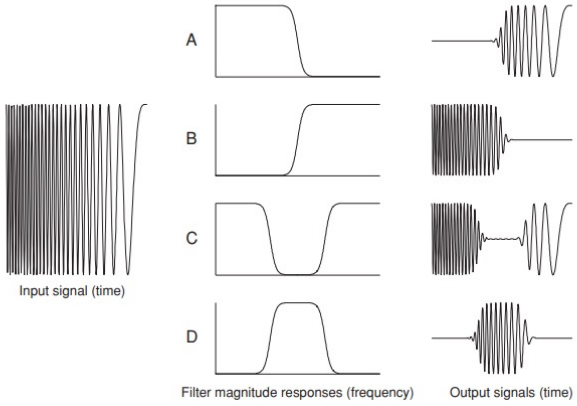
ECoG



EEG

BCI Components(continued)

- Feature Extraction
  - Process of distinguishing the pertinent signal characteristics from extraneous content and representing them in a compact and/or meaningful form, amenable to interpretation by a human or computer
  - Generally, involves conversion of signals to analog to digital for processing
  - Widely used Algorithms used for conversion of signals:
    - Fast Fourier transform (FFT), discrete wavelet transform (DWT), Heiberg–Hung transform (HHT), and independent component analysis (ICA)



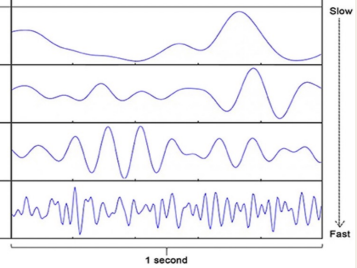
The signal on the left has a frequency that decreases linearly with time (known as a chirp signal) (x-axis is time). The middle column (x-axis is frequency) shows the magnitude response (i.e., the amplitude scale factor, or gain, applied) for each of the four filters: (A) low-pass; (B) high-pass; (C) bandstop/notch; and (D) bandpass. The signals in the right column (x-axis is time) are the outputs when the fi ters of the middle column are applied to the signal in the left column.

Source: Brain Computer Interfaces

BCI Components(continued)

- Pattern Recognition and classification
  - Pattern recognition is the automated recognition of patterns and regularities in data
  - Helps in translations of signal data into actions

Frequency band	Speed (Hz)	Mental state	Electroencephalography (EEG) recording
Delta	1-4	Deep sleep	
Theta	4-8	Drowsy	
Alpha	8-12	Relaxed	
Beta	12-30	Focused	



EEG Signal Classification

- Command Translation
  - Final step which includes actions to be issued to microcontroller to act on

What is real-time automation system?

Real-time automation: Immediate processing of data and Immediate feedback.

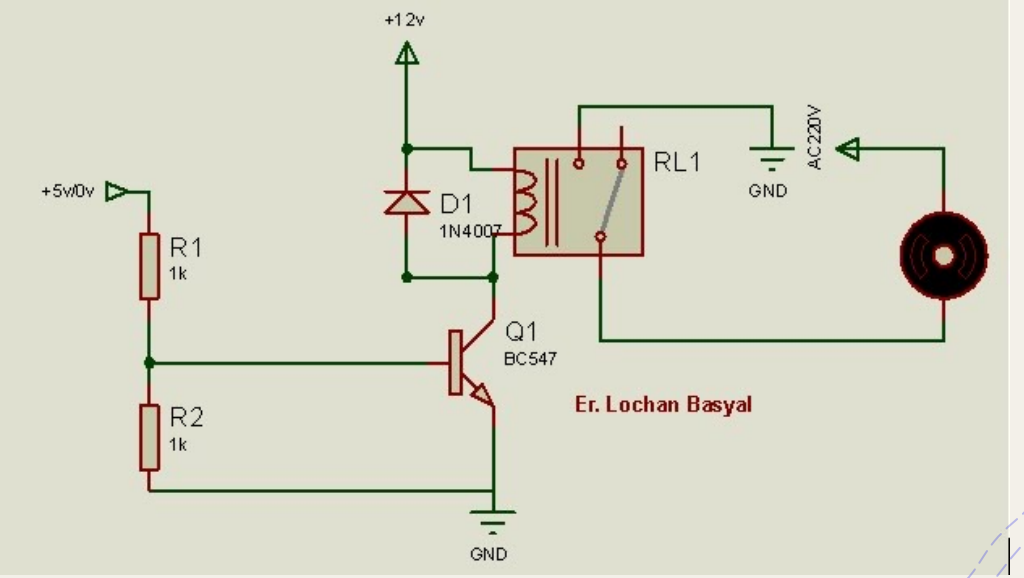
For instance; in our project, current electrical activity of human brain will generate a particular command which will control external environment (normally AC appliances).

Why embedded processor/controller for the implementation of this project?

What's going on inside microcontroller?

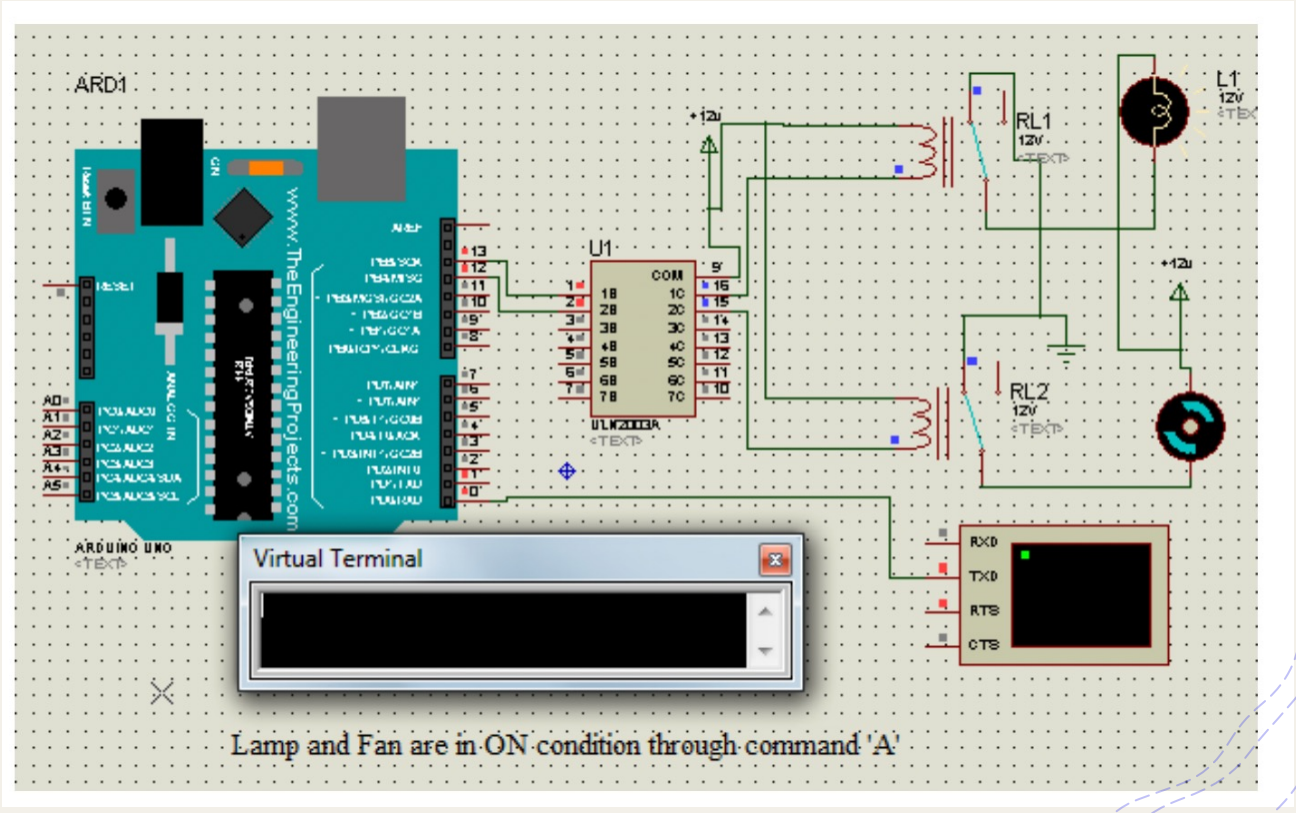
```
If (input command == predefined command)
Control();
```

How digital signal (either 0 or 1) can control external environment (AC Appliances)?



Circuit diagram to interface DC and AC

How a command can control AC appliances?



Virtual simulation of Real-time Automation System

Hardware Implementation of Automation System

Hardware Implementation

Why this project ?

1. To make an assistive device for the physically impaired people to live their life easily.
2. Witness of the advancement of technology in the field of real-time automation system.

References

1. Bonci,A.;Fiori,S.;Higashi, H.; Tanaka, T.; Verdini, F. An Introductory Tutorial on Brain– Computer Interfaces and Their Applications. *Electronics* 2021, *10*, 560. https://doi.org/10.3390/electronics 10050560

2. https://www.thedigitalspeaker.com/brain-computer-interfaces-change-relationship-computers/

3. https://www.newscientist.com/article/2232792-brain-activity-can-help-predict-wholl-benefit-from-an-antidepressant/

4.https://en.wikipedia.org/wiki/Electrocorticography#:~:text=Electrocorticography%20(ECoG)%2C%20or%20intracranial,activity%20from%20the%20cerebral%20cortex.

5.https://www.researchgate.net/publication/341684403_Electronic_Circuit_to_Interface_DC_and_AC_for_the_Automation_of_Electrical_Appliances

6. Lochan Basyal, “Smart Home Application: Lochan Control System”, IISF Young Scientists' Conference 2018, Lucknow, India

7. BRAIN–COMPUTER INTERFACES Principles and practices by Jonathan R. Wolpaw, Elizabeth Winter Wolpaw

8. Cromwell and Pfeiffer, Biomedical Instrumentation, vol.2

Thank You