05/21 TJ STAR Presentation

Brain-Computer Interface Based RC Car Control Using EEG Technology and Arduino Integration

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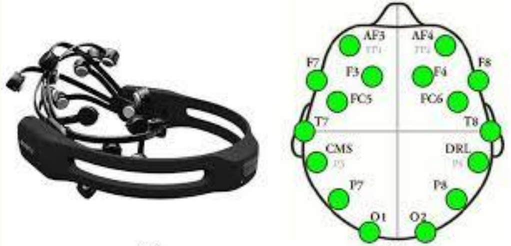
Problem

- Traditional RC car control (joysticks, remotes) limits accessibility and usability.
    - Particularly in assistive tech applications, STEM education, and hobby robotics.
- Requires manual input and fine motor skills.
    - Excludes users with physical disabilities or cognitive strain.
- Lack of intuitive control options for users unfamiliar with RC interfaces.

Background

- BCI (Brain-Computer Interface) enables hands-free control.
- EEG headsets like the EMOTIV EPOC X are affordable and accessible for hobbyist research.
- Integration with RC cars opens up applications in:
    - STEM education, rehab technology, and experimental control systems.



(a) (b)

Current Solutions

- Joysticks/Remotes:
  - Require dexterity and user training.
- Voice Control/Pre-programmed Routes:
  - Limited precision and adaptability.
- Gesture-based systems:
  - Still require limb movement.

Why is Ours Better?

- BCI allows cognitive-based control
  - No physical movement necessary.
- Enables inclusive participation in RC projects for individuals with physical limitations.
- Offers an innovative platform for exploring neuroscience, engineering, and robotics.

Novelty

- First to integrate EEG-based brain commands into RC car steering and motion control.
- Bridges neuroscience and embedded systems through Arduino-controlled drive logic.
- Highly adaptable for further modules like obstacle detection or speed regulation.

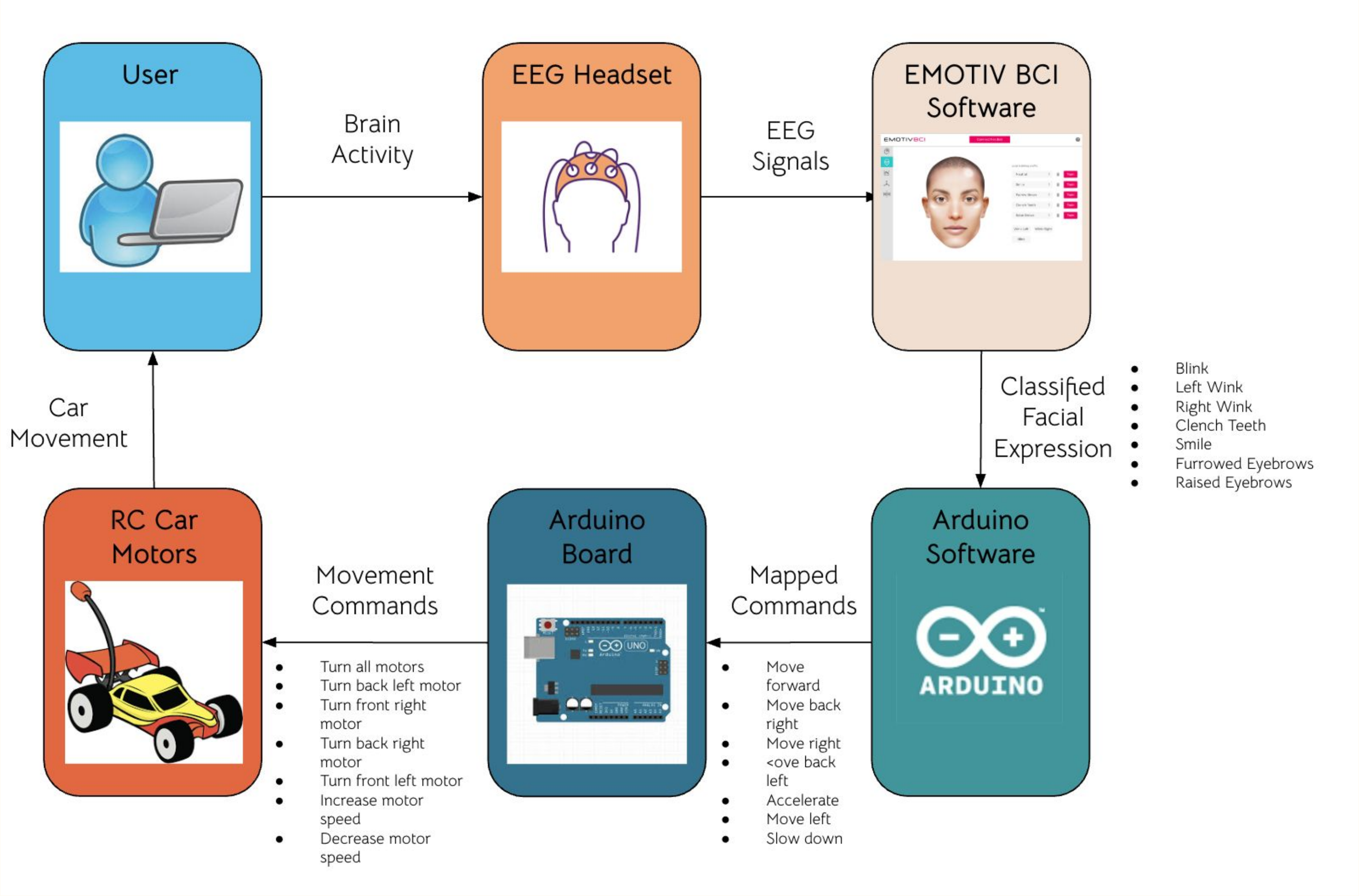
Impact

- Inclusive Technology:
  - By eliminating the need for manual controllers, our system makes RC vehicle operation accessible to individuals with physical disabilities or neuromuscular disorders
- Assistive Applications:
  - Could be extended to real-world assistive mobility tools
    - Motorized wheelchairs or smart home devices

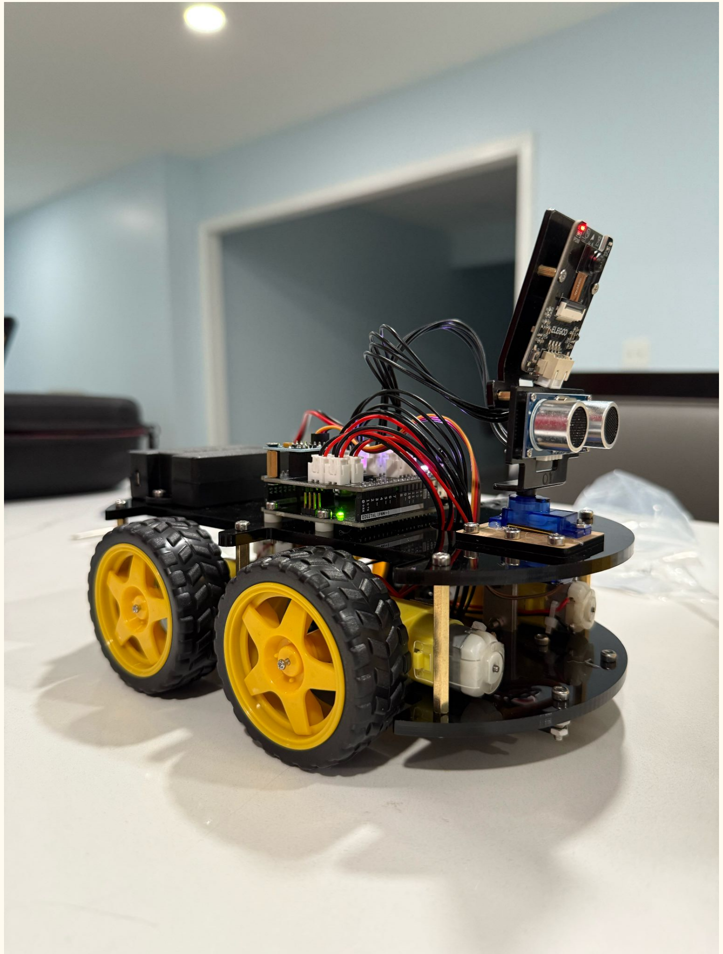
Method

1. EEG Signal Acquisition and Preprocessing
    a. Brain signals are captured non-invasively using the EMOTIV EPOC X headset. Signal noise is reduced through onboard filtering and pre-processing tools to ensure reliable processing.
2. Feature Recognition & Pattern Classification
    a. Using EMOTIV's built-in SDK along Python to distinct expressions from one another
3. Signal-to-Command Mapping
    a. Detected EEG events are dynamically mapped to specific vehicle controls
4. System Integration Via Arduino
    a. Classified commands are transmitted to an Arduino microcontroller, which interprets them to control the vehicle in real time.
5. Live Feedback & System Calibration
    a. Real-time adjustments are made based on vehicle-response, allowing the user to adjust signal timing and expressions.

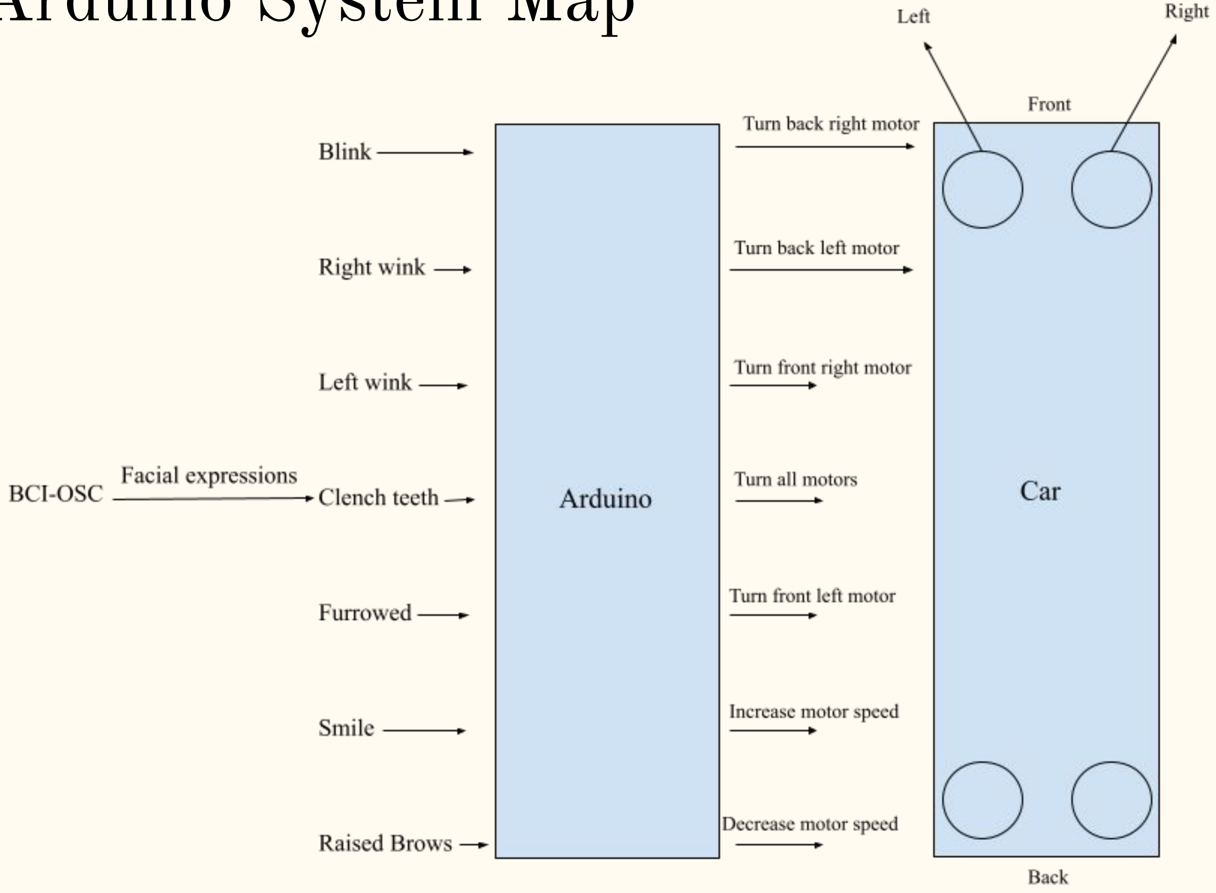
Systems Architecture



RC Car



Arduino System Map

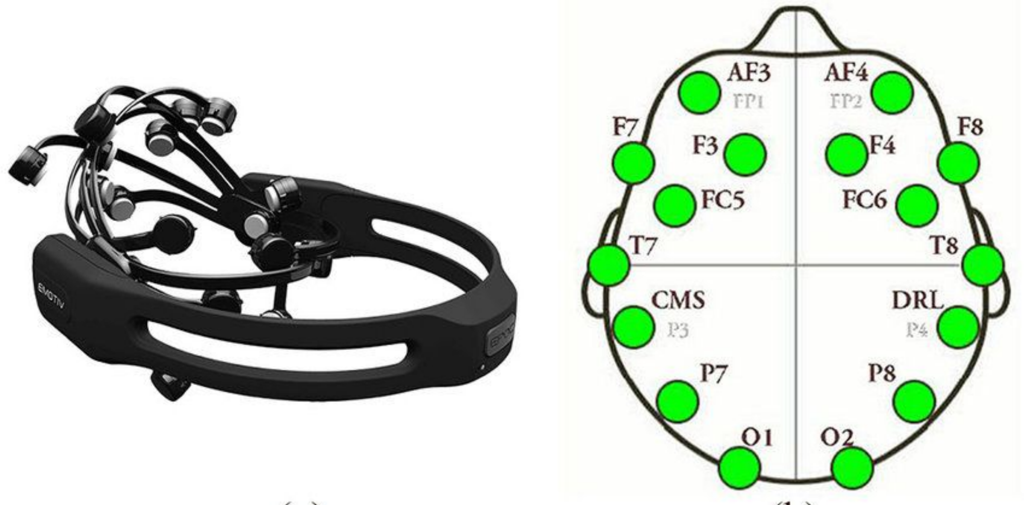


- Move car right -> Clench teeth + Right wink
- Move car left -> Clench teeth + Left wink

```
// Movement functions
void moveForward() {
  analogWrite(ENA, 200);
  digitalWrite(IN1, HIGH);
  digitalWrite(IN2, LOW);

  analogWrite(ENB, 200);
  digitalWrite(IN3, HIGH);
  digitalWrite(IN4, LOW);
}

void turnLeft() {
  analogWrite(ENA, 150);
  digitalWrite(IN1, LOW);
  digitalWrite(IN2, HIGH);

  analogWrite(ENB, 150);
  digitalWrite(IN3, HIGH);
  digitalWrite(IN4, LOW);
}

void turnRight() {
  analogWrite(ENA, 150);
  digitalWrite(IN1, HIGH);
  digitalWrite(IN2, LOW);

  analogWrite(ENB, 150);
  digitalWrite(IN3, LOW);
  digitalWrite(IN4, HIGH);
}
```

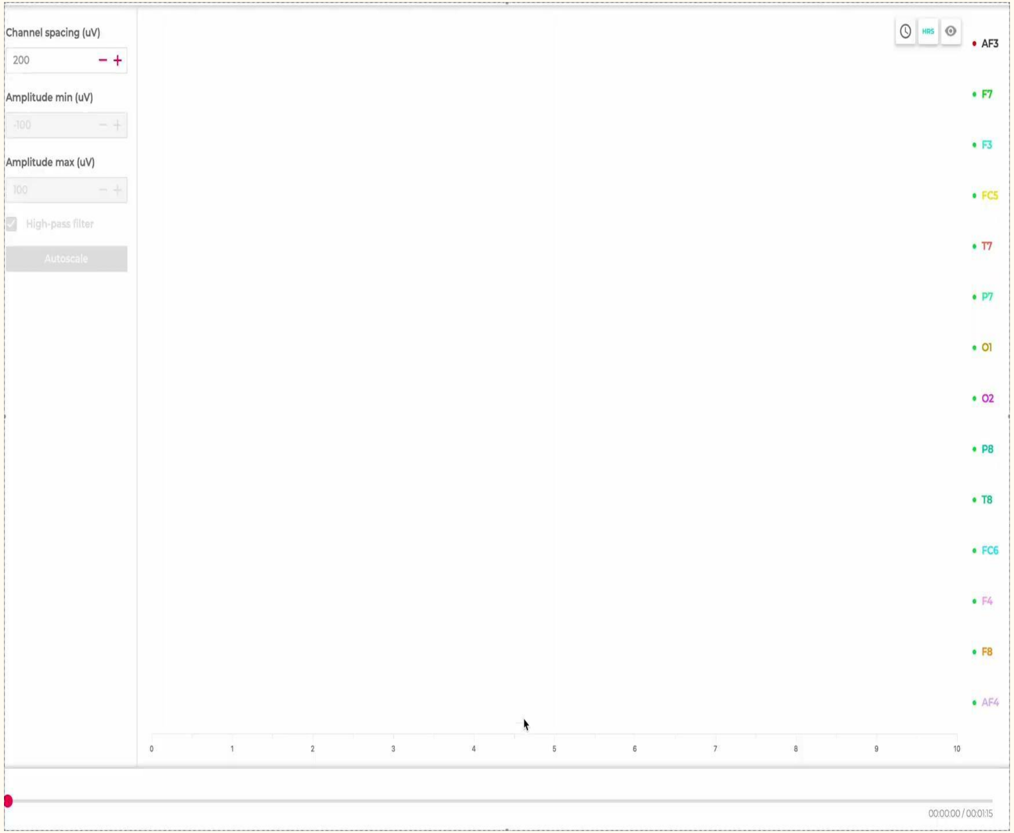
Emotiv Connection

- Desired Connection for all the nodes with green indicating a connected node
- We have all our nodes in proper places and are reaching 100% connectivity
- We are able to sustain 100% connectivity throughout all the training



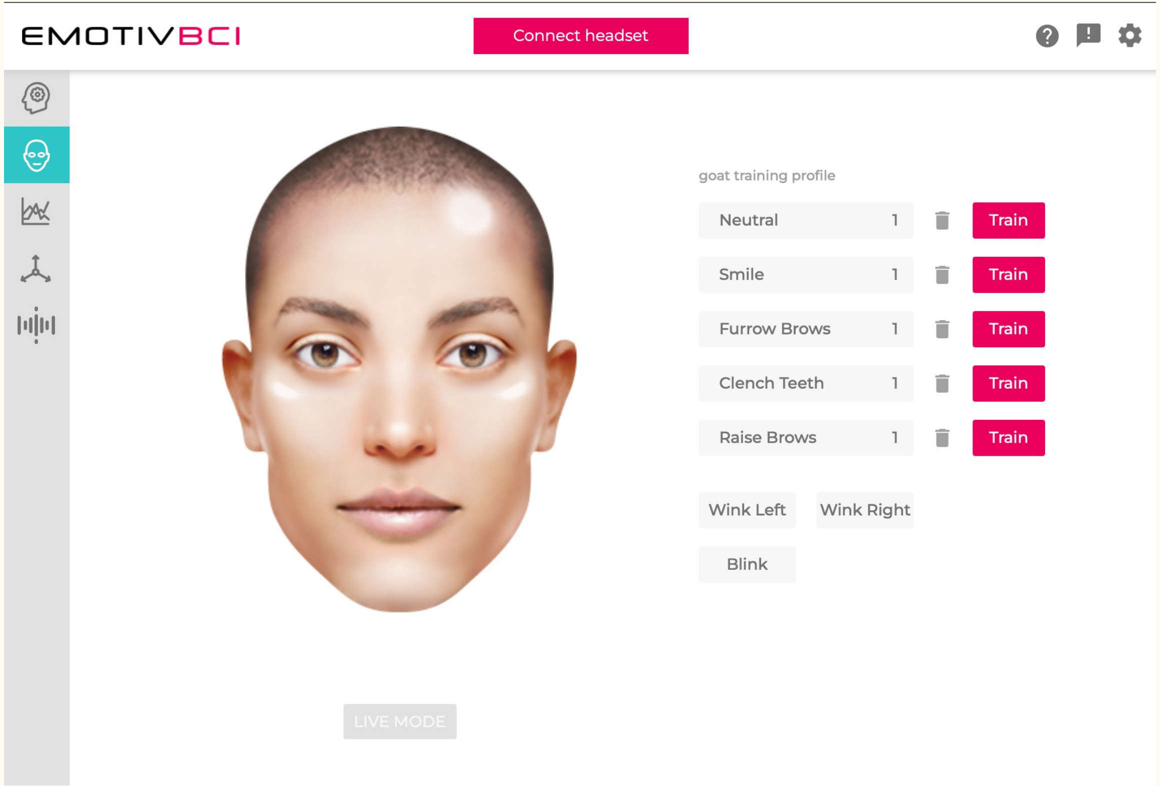
(a) (b)

Sample EMOTIV Run



- To our left you can see our raw data readings from our EEG
- Run times for expression:
  - Blink: 0:10-0:15
  - Left Wink: 0:20-0:25
  - Raised Eyebrows: 0:30-0:35
  - Furrowed Brows: 0:45-0:50
  - Smile: 0:55-1:00
  - Clenched Teeth: 1:05-1:10
- Raw Data

Classification



Data Processing

- Using EMOTIV BCI software for expression detection and SciPy for signal processing
- BCI OSC program conducts the real-time flow of data with immediate expression detection, sending the classified expressions to our Arduino IDE.
- During our testing, we processed fixation and data with Pandas and visualized our results with Matplotlib to see what we can improve

Results

Results

EEG Signal Behavior

- High packet loss and latency required 70+ trials for consistent signal recognition
- EEG input highly sensitive, leading to erratic motor responses during directional turns
- Facial expressions often needed to be repeated or held longer to register due to delay

System Stability

- Observed frequent instability in classification due to signal noise
- Reliable command recognition remained inconsistent under varied conditions

Latency & Responsiveness

- Measured latency ranged from 0.4 to 0.6 seconds
- Commands occasionally misfired or delayed, impacting real-time control fidelity

Operational Insights

- Motor activation confirmed, but precise movement control remains unteliable
- Environmental factors (indoor setting, electrical interference) may have affected node activation

Limitations

- Noise and artifacts in brain waves can lead to misclassification of commands
- RC Car motors have varying thresholds, which results in varied results for commands
- EEG signals vary between individuals, requiring some sort of normalization for proper control of the RC car
- EEG devices have limited electrode sensitivity and will require recalibration for performance

Conclusion

- The problem we addressed are the limitations that come with current methods of RC car control.
    - Traditional manual control requires immense effort.
    - Other methods such as swarm control overly rely on automated control, which leads to ethical issues.
- We were able to implement basic controls through our EEG. The RC car is able to move in all directions.

Future Work

- After TJStar, our goal is to adapt the EEG-controlled RC car system for assistive mobility and education, enabling hands-free vehicle control for individuals with physical impairments.
- We aim to improve the precision of brainwave-to-command mapping to ensure accurate movement control across diverse users.
- Future enhancements may include obstacle detection and path-following algorithms to improve safety and navigation in real-world environments.
- We will explore integrating mobile apps or wearable feedback systems to provide real-time performance data and improve user interaction.
- Long-term, we plan to develop modular kits for classrooms or therapy centers to make EEG-driven robotics more accessible in educational and rehabilitative settings.

References

1. *Al-Nafjan, A., Hosny, M., Al-Ohali, Y., & Al-Wabil, A. (2017). Review and Classification of Emotion Recognition Based on EEG Brain Signals. Cognitive Computation, 9, 843–859. https://doi.org/10.1007/s12559-017-9529-1*
2. *Pradeep, P., & Kumar, K. S. (2018). Brain Controlled Wheelchair Using EEG Signals. International Research Journal of Engineering and Technology (IRJET), 5(1), 1224–1228. https://www.irjet.net/archives/V5/i1/IRJET-V5I1224.pdf*
3. *Yeo, M. V., Li, X., Shen, K., & Wilder-Smith, E. P. (2009). Can SVM be used for EEG-based brain–computer interface? IEEE Transactions on Biomedical Engineering, 54(6), 1259–1266. https://doi.org/10.1109/TBME.2006.888830*
4. *Chaudhary, U., Birbaumer, N., & Ramos-Murguialday, A. (2016). Brain–computer interfaces for communication and rehabilitation. Nature Reviews Neurology, 12(9), 513–525. https://doi.org/10.1038/nrneurol.2016.113*
5. *Kumar, R., & Agrawal, N. (2020). BCI-Controlled Arduino-Based Car for Disabled People. International Journal of Engineering Research & Technology (IJERT), 9(5). https://www.ijert.org/bci-controlled-arduino-based-car-for-disabled-people*
6. *Naranjo, J., Parra, C., & García, A. (2021). Control of an Arduino-Based Car Using EEG Signals for Assistive Mobility. Procedia Computer Science, 192, 2369–2378.https://doi.org/10.1016/j.procs.2021.09.005*

Thank you! Questions?