Synopsis for Major Project

Topic: NOIR: Neural Signal Operated Intelligent Robots for Everyday Activities

Student Name: Angothu Muni

Supervisor Name: Dr Alok Kumar

Introduction

Neural Signal Operated Intelligent Robots (NOIR) is a brain-robot interface (BRI) system that allows users to control robots using neural signals, specifically electroencephalography (EEG). This system enables users to communicate their intended actions to robots, which can perform a range of everyday tasks autonomously.

Literature Review

Brain-robot interfaces have evolved significantly, moving from button presses and gaze control to direct communication through neural signals. Current systems are often limited to specific tasks or require substantial training. NOIR stands out by supporting a diverse set of tasks with minimal training, leveraging advances in neuroscience, robotics, and machine learning.

Research Gap

While many BRI systems focus on single or limited tasks, NOIR addresses the need for a versatile, adaptive system capable of handling a wide range of complex activities in real-world settings. The challenge lies in decoding human intentions accurately and making the robots intelligent enough to adapt and learn user preferences efficiently.

Objective(s):

- Develop a general-purpose BRI system that can perform various everyday tasks using neural signals.
- Enhance the robot's ability to learn and adapt to individual users' intentions.
- Improve the efficiency of human-robot interaction through neural communication.

My Ideas to do more ,These are my thoughts how to improve and contribute more to my research base paper

1. Enhancing Signal Decoding Accuracy and Speed

2. User Adaptability and Personalization

3. Multi-Tasking and Sequential Task Execution

4. Robustness in Dynamic Environments

5. Integration with Other Assistive Technologies

6. Real-Time Error Detection and Correction

7. Minimizing Training and Calibration Time

8. Cross-Platform Compatibility

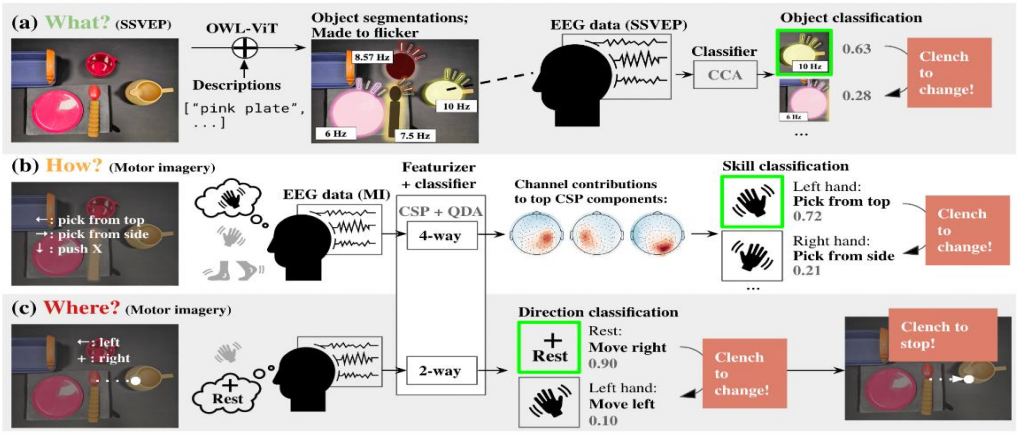
9. Exploring Ethical and Societal Impacts

10. Developing Training Simulators and Educational Tools

11. Enhancing User Experience Through Feedback

12. Extending Applications to New Domains

Methodology



Robots with Parametrized Primitive Skills

NOIR uses a modular neural signal decoding pipeline that breaks down human intentions into object manipulation, interaction type, and location. EEG signals are processed to determine what action the user wants the robot to perform. The robot is equipped with a library of skills that can be adjusted and learned from user inputs, using few-shot learning algorithms to reduce the need for extensive training data.

Intial Phase:Due to it involves robots,real time EEG signals and real time task execution so,limited resources for my project current have,so I want to implement a basic implementation by stimulation software like Gazebo, V-REP (now CoppeliaSim), or Webots with already available EEG signal from different platforms like PhysioNet

Target:After above successful,deal with real world with real robots and EEG signal

Timeline

1. Initial research and system design: 1-3 Weeks
2. Development of modular decoding pipeline: 4-6 weeks
3. Integration with robotic systems and testing: 7-11weeks

4. Data collection and performance evaluation: 11-14 weeks
5. Final optimization and user trials: 15-17 weeks
6. Report writing and submission: 17-20 weeks

Expected Outcome

- A functioning, intelligent BRI system that can assist users in performing daily tasks through brain signals.
- Improved interaction efficiency between humans and robots, especially for individuals with disabilities.
- Establishment of NOIR as a benchmark for future developments in general-purpose BRI systems.

Future expended outcomes

1.Improved real-time decoding algorithms will enable faster, more accurate control of robots through neural signals.

2.Personalized models will adapt to individual users, enhancing task accuracy and user experience.

3.The system will execute complex, multi-step tasks autonomously without reconfiguration.

4.NOIR will maintain high performance in unpredictable and changing environments.

5.NOIR will integrate with smart devices, creating a comprehensive assistive system.

6.Error detection and correction will enhance the system's safety and reliability.

References

[1] A. Hussein, M. M. Gaber, E. Elyan, and C. Jayne. Imitation learning: A survey of learning methods. ACM Computing Surveys (CSUR), 50(2):1–35, 2017.

[2] R. Zhang, D. Bansal, Y. Hao, A. Hiranaka, J. Gao, C. Wang, R. Mart´ın-Mart´ın, L. Fei-Fei, and J. Wu. A dual representation framework for robot learning with human guidance. In Conference on Robot Learning, pages 738–750. PMLR, 2023.

[3] L. Guan, M. Verma, S. S. Guo, R. Zhang, and S. Kambhampati. Widening the pipeline in human-guided reinforcement learning with explanation and context-aware data augmentation. Advances in Neural Information Processing Systems, 34:21885–21897, 2021.

[4] H. Admoni and B. Scassellati. Social eye gaze in human-robot interaction: a review. Journal of Human-Robot Interaction, 6(1):25–63, 2017.

[5] A. Saran, R. Zhang, E. S. Short, and S. Niekum. Efficiently guiding imitation learning agents with human gaze. In Proceedings of the 20th International Conference on Autonomous Agents and MultiAgent Systems, pages 1109–1117, 2021.

[6] R. Zhang, Z. Liu, L. Zhang, J. A. Whritner, K. S. Muller, M. M. Hayhoe, and D. H. Ballard. Agil: Learning attention from human for visuomotor tasks. In Proceedings of the european conference on computer vision (eccv), pages 663–679, 2018.

[7] R. Zhang, A. Saran, B. Liu, Y. Zhu, S. Guo, S. Niekum, D. Ballard, and M. Hayhoe. Human gaze assisted artificial intelligence: A review. In IJCAI: Proceedings of the Conference, volume 2020, page 4951. NIH Public Access, 2020.

[8] Y. Cui, Q. Zhang, B. Knox, A. Allievi, P. Stone, and S. Niekum. The empathic framework for task learning from implicit human feedback. In Conference on Robot Learning, pages 604–626. PMLR, 2021.

[9] A. Brohan, Y. Chebotar, C. Finn, K. Hausman, A. Herzog, D. Ho, J. Ibarz, A. Irpan, E. Jang, R. Julian, et al. Do as i can, not as i say: Grounding language in robotic affordances. In Conference on Robot Learning, pages 287–318. PMLR, 2023.

[10] W. Huang, C. Wang, R. Zhang, Y. Li, J. Wu, and L. Fei-Fei. Voxposer: Composable 3d value maps for robotic manipulation with language models. In 7th Annual Conference on Robot Learning, 2023.

[11] R. Zhang, F. Torabi, L. Guan, D. H. Ballard, and P. Stone. Leveraging human guidance for deep reinforcement learning tasks. arXiv preprint arXiv:1909.09906, 2019.

[12] R. Zhang, F. Torabi, G. Warnell, and P. Stone. Recent advances in leveraging human guidance for sequential decision-making tasks. Autonomous Agents and Multi-Agent Systems, 35(2):31, 2021.

[13] I. Akinola, Z. Wang, J. Shi, X. He, P. Lapborisuth, J. Xu, D. Watkins-Valls, P. Sajda, and P. Allen. Accelerated robot learning via human brain signals. In 2020 IEEE international conference on robotics and automation (ICRA), pages 3799–3805. IEEE, 2020.

[14] Z. Wang, J. Shi, I. Akinola, and P. Allen. Maximizing bci human feedback using active learning. In 2020 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), pages 10945–10951. IEEE, 2020. 9

[15] I. Akinola, B. Chen, J. Koss, A. Patankar, J. Varley, and P. Allen. Task level hierarchical system for bci-enabled shared autonomy. In 2017 IEEE-RAS 17th International Conference on Humanoid Robotics (Humanoids), pages 219–225. IEEE, 2017.

Annexure A: Base Research Paper

- NOIR: Neural Signal Operated Intelligent Robots for Everyday Activities (full text available in the main document).

Signature Of Supervisor /Mentor Signature of student