Prosthetic Hand with Dexterous Articulation for Grasping and Manipulation

Assistive Robotics and Manipulation Laboratory

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Motivation and Abstract

People with prosthetic hand have a set of capabilities with the pre-programmed motions and grasps, but there are still a wide range of tasks they can not complete. Current existing challenges are mostly within hand intelligence and hand incapability. We present a research platform to develop a prosthetic hand system with Inspire hand that executes articulated grasping and articulation through gaze detection and EMG-based. The system uses ROS2 to integrate electromyography (EMG) and gaze tracking, while using pre-recorded finger joint movements using a smartglove.

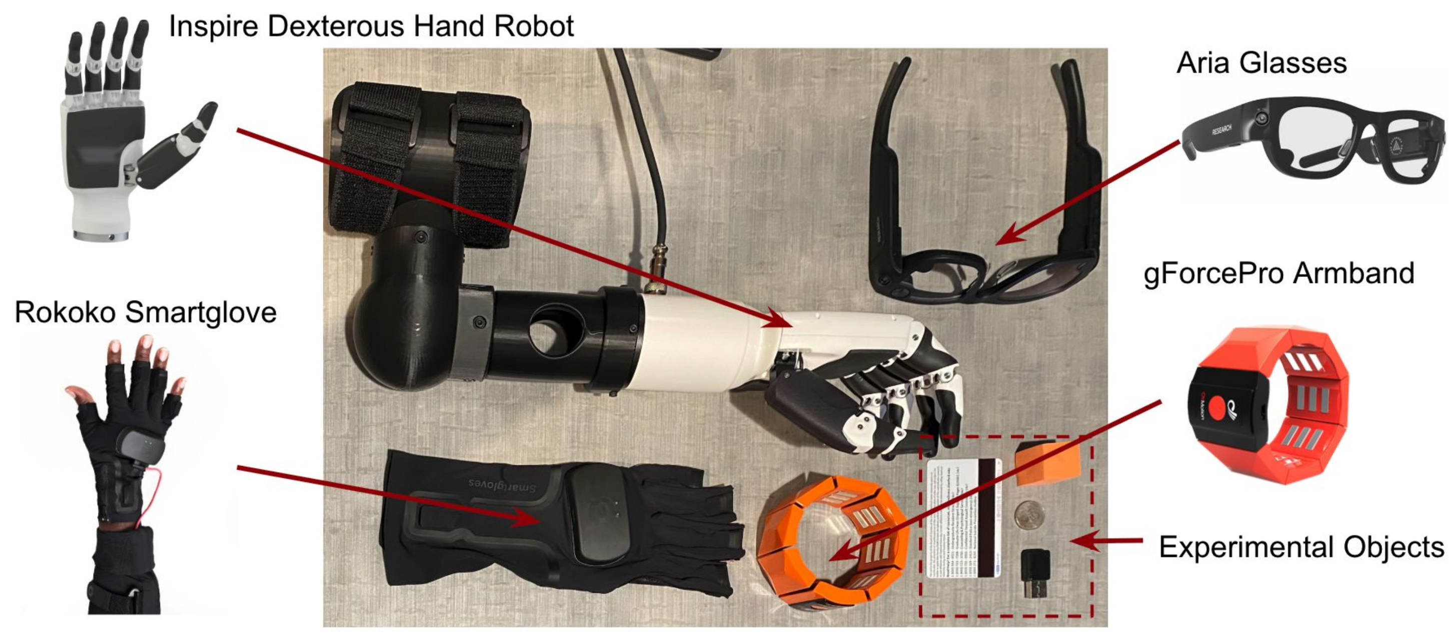


Fig. 1 *Setup of the experiment includes Inspire Dexterous Hand Robot, Rokoko Smartglove, gForcePro Armband (EMG), and Aria Glasses. The experimental Objects include a credit card, cube, coin, and a dongle.*

Background

- Controlling multi-fingered prosthetic hands remains challenging due to limited intuitive interfaces and the absence of reliable sensory feedback [1].
- Most commercial devices offer only one or two degrees of freedom, relying on vision and incidental cues for operation, which restricts complex manipulation [2].
- Techniques such as EMG pattern recognition, principal components analysis, and dimensionality reduction can map a few control inputs to coordinated joint motions, enabling more natural grasping [3].
- Combining intent recognition from gaze and EMG with proprioceptive, haptic, or augmented reality feedback could reduce user effort, bridge the gap between hardware capability and task execution, and expand the range of activities prosthetic users can perform independently [3][4].

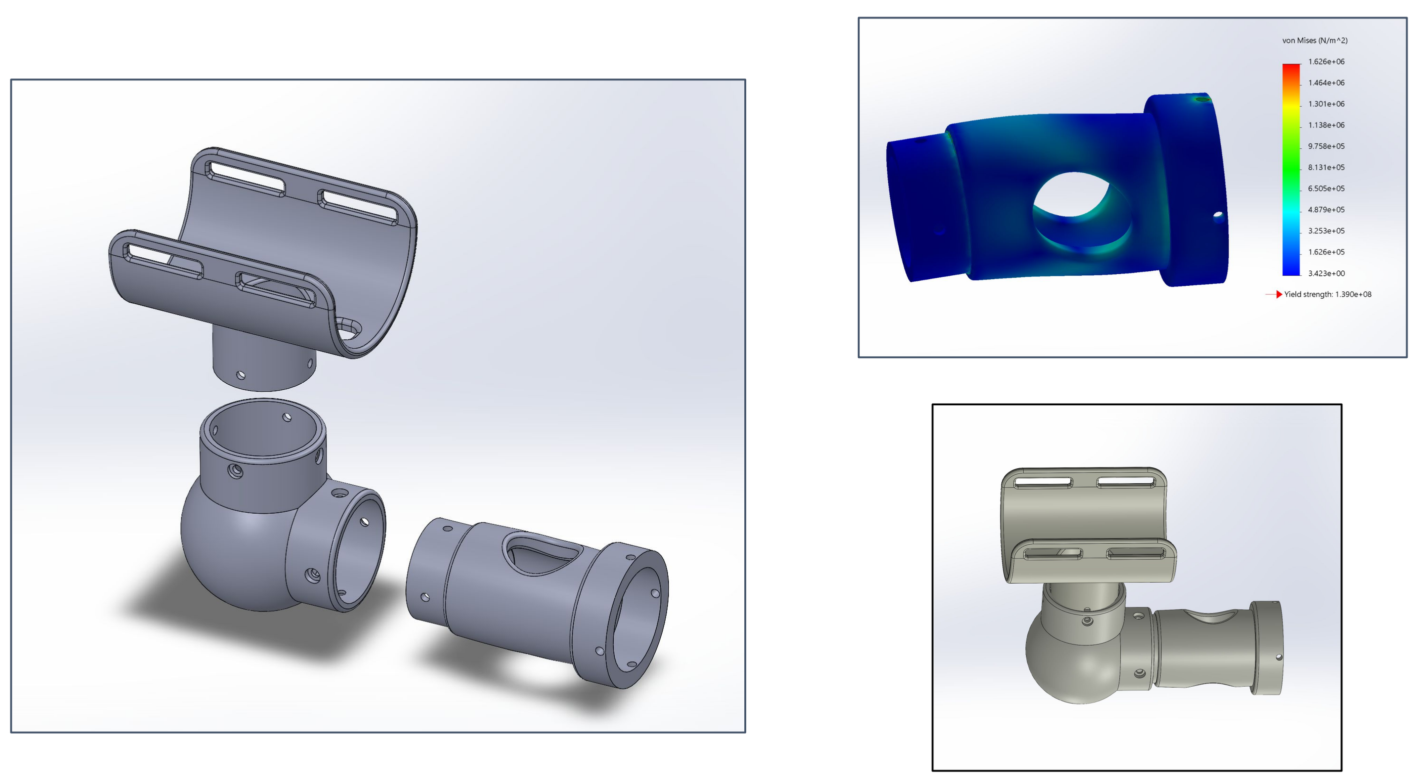


Fig. 2 *SOLIDWORKS assembly of the mount, which includes three parts, and FEM analysis of the forearm.*

Experimental Design

The articulated complex manipulation tasks we tested were the following:
- Grasping Cube
- Pinching Coin
- Sliding Card

Each tasks was chosen by its level of difficulty and grasping complexity. We divided each task into phases for the user to control via the EMG on the inspire hand; task phases were the following: go to pose, activate, and release.

Approach

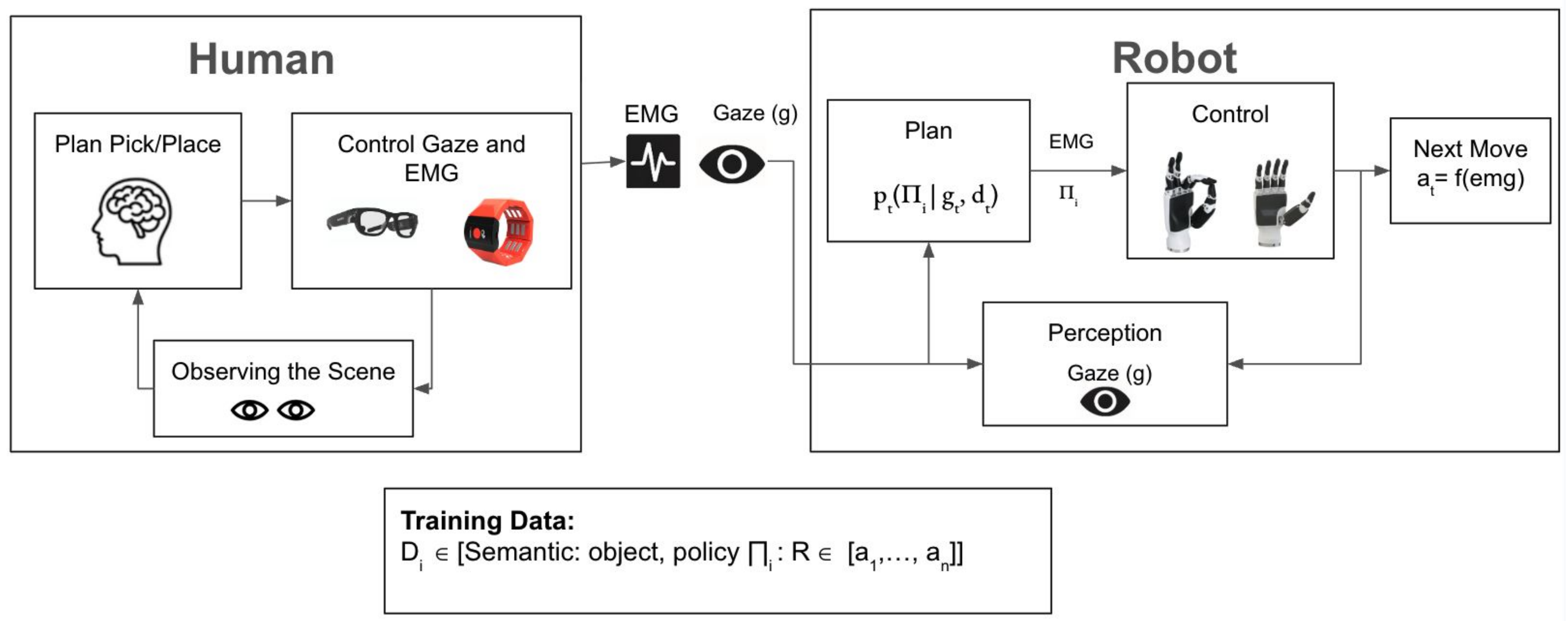


Fig. 3 *Control system explained through human and robot feedback loops. The human starts with commanding the EMG and visual feedback to recognize objects and perform grasp manipulation.*

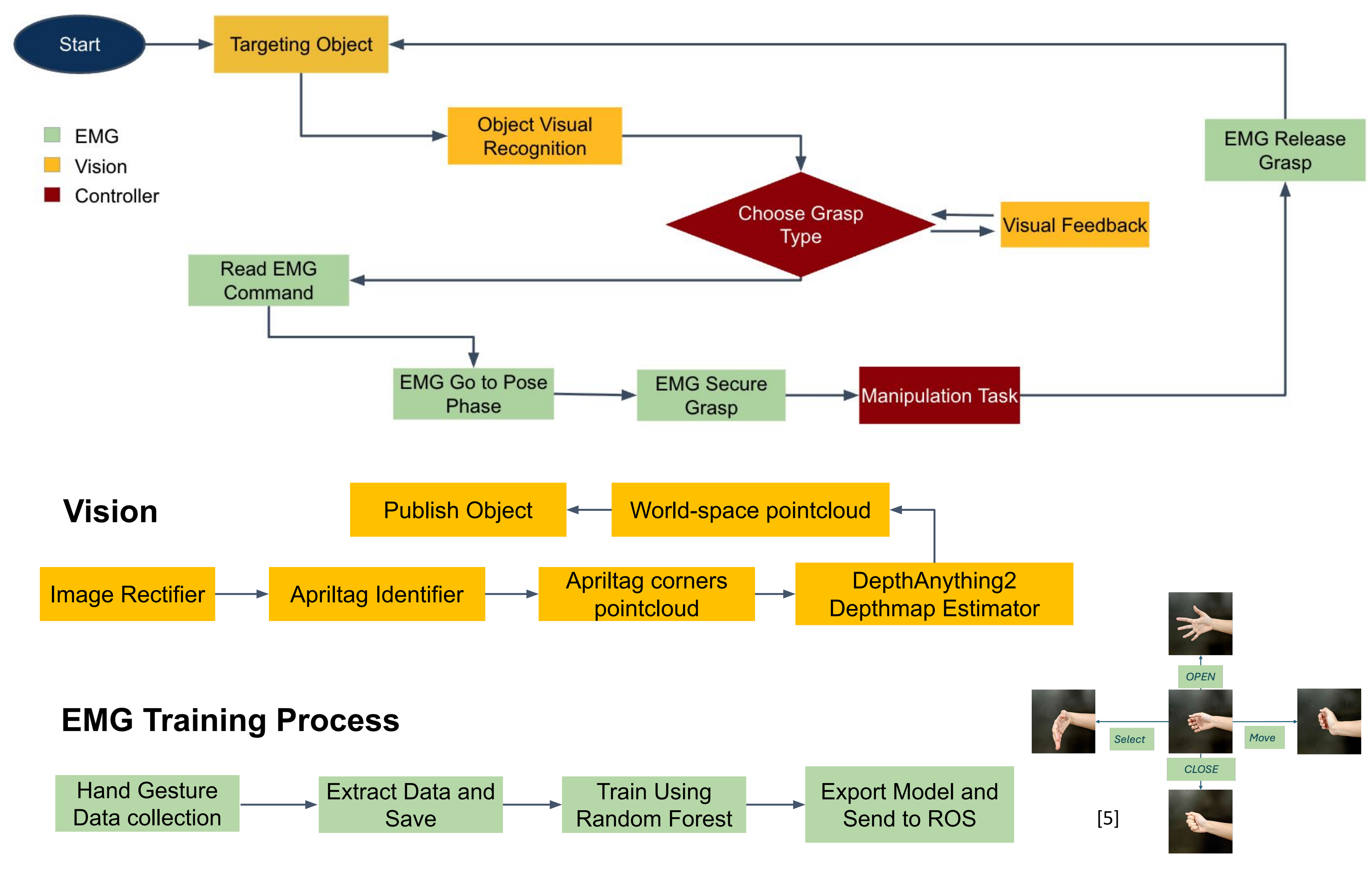
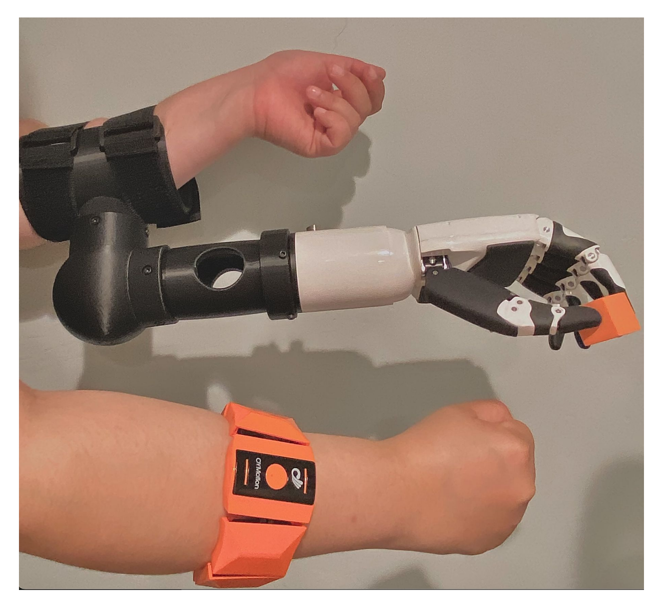


Fig. 4 *System state machine flowchart for the entire process. Aria glasses object, depth recognition, and EMG training process for hand gestures from the chart [5].*

Evaluation Task

- The proposed evaluation replicates a functional manipulation task using gaze and EMG-triggered execution of pre-recorded motions.
- We begin by capturing finger joint positions from a person wearing a left Rokoko Smartglove while performing a specific manipulation (e.g., pick-and-place of an object).
- The EMG wristband records muscle activity during a set of defined gestures [5]. The EMG data are recorded, labeled and saved as a csv file format, and then trained using a Random Forest classifier to recognize the gestures corresponding to different motion triggers.
- Once EMG training is complete, the saved Smartglove motions, stored as several phased motions, are linked to the classified EMG gestures.
- A ROS2 node listens to the EMG stream and activates the Inspire Robot, allowing bidirectional communication. The EMG gestures are read by the Inspire Robot which control the phases of the recorded Rokoko Smartglove data, starting with the go to pose, then secure grasp type, and finally release.



Method

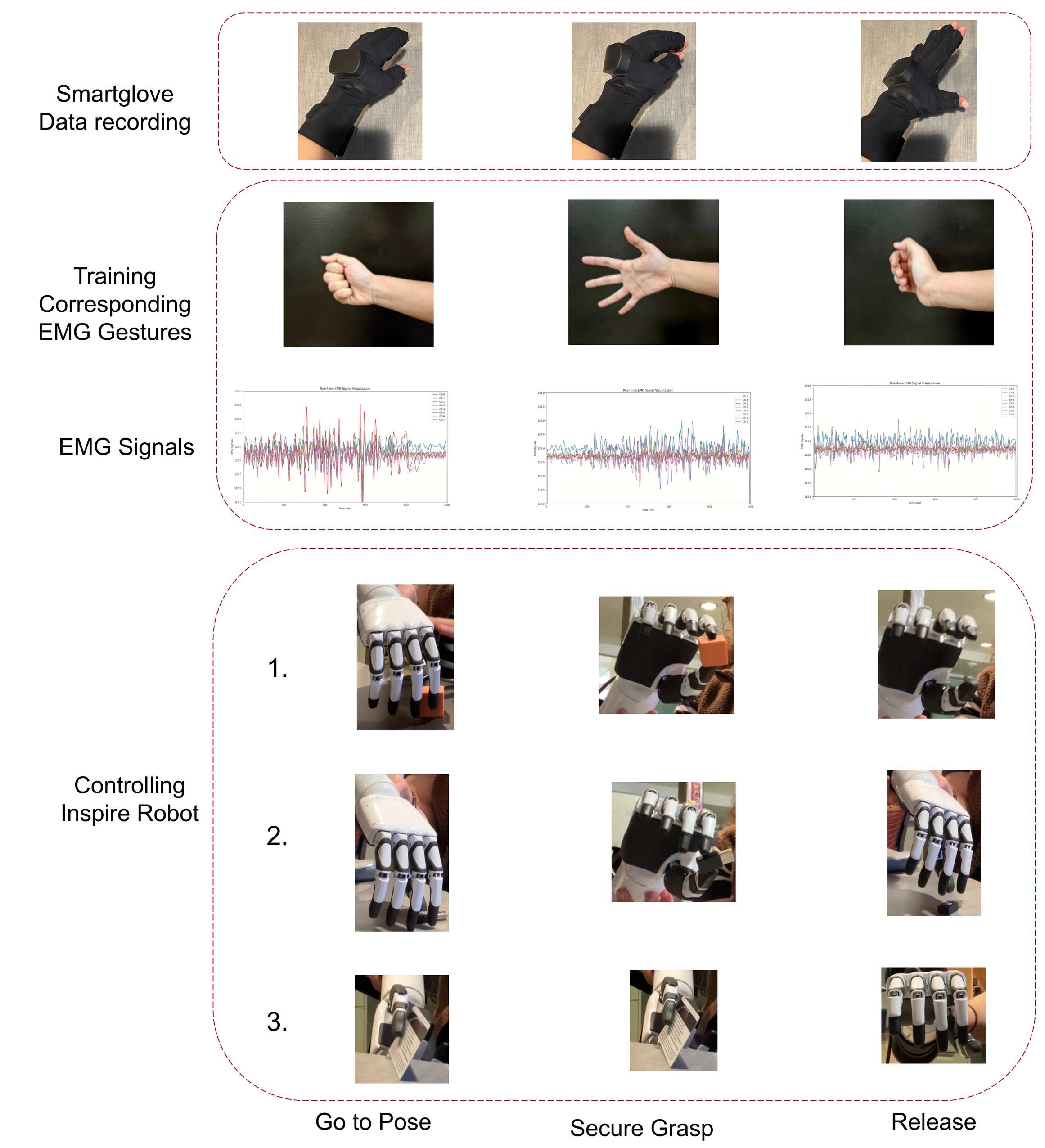


Fig. 5 *Data recording and training processes for Rokoko Smartglove and EMG, EMG singles corresponding to each hand gesture, and robot motions for three tasks performed.*

Results and Future Work

- Preliminary results are promising giving that all the current integrated systems work well together.
- We achieved the goal of creating user focused system that not only uses a robotic controller, but also includes the user in the loop, allowing them to provide feedback and control, while not needing previous knowledge of how the system works.
- The Inspire Robot was successfully able to complete all the tasks in the experimental design. Grasping a small cube, pinching a coin size object, and sliding a credit card. Further object experiment is need to further analyse the success rate.
- Future work will focus on integrating the Aria Glasses into this system, creating the gaze detection from the user to identify object depth and grasp type.
- Further experiments with users with hand amputee is needed to identify tasks that they would like to attempt at with this system for everyday living and grasping manipulation.

References

[1] C. Cipriani, F. Zaccone, S. Micera and M. C. Carrozza, "On the Shared Control of an EMG-Controlled Prosthetic Hand: Analysis of User–Prosthesis Interaction," in IEEE Transactions on Robotics

[2] Markovic, M., Schweisfurth, M.A., Engels, L.F. *et al.* Myocontrol is closed-loop control: incidental feedback is sufficient for scaling the prosthesis force in routine grasping.

[3] Matrone, G.C., Cipriani, C., Carrozza, M.C. *et al.* Real-time myoelectric control of a multi-fingered hand prosthesis using principal components analysis.

[4] H. Cha, S. An, S. Choi, S. Yang, S. Park and S. Park, "Study on Intention Recognition and Sensory Feedback: Control of Robotic Prosthetic Hand Through EMG Classification and Proprioceptive Feedback Using Rule-based Haptic Device,"

[5] Guptasarma, Shivani, and Monroe D. Kennedy III. "ProACT: An Augmented Reality Testbed for Intelligent Prosthetic Arms." *arXiv.Org*

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