Nested Control of Assistive Robots Through Human Intent Inference

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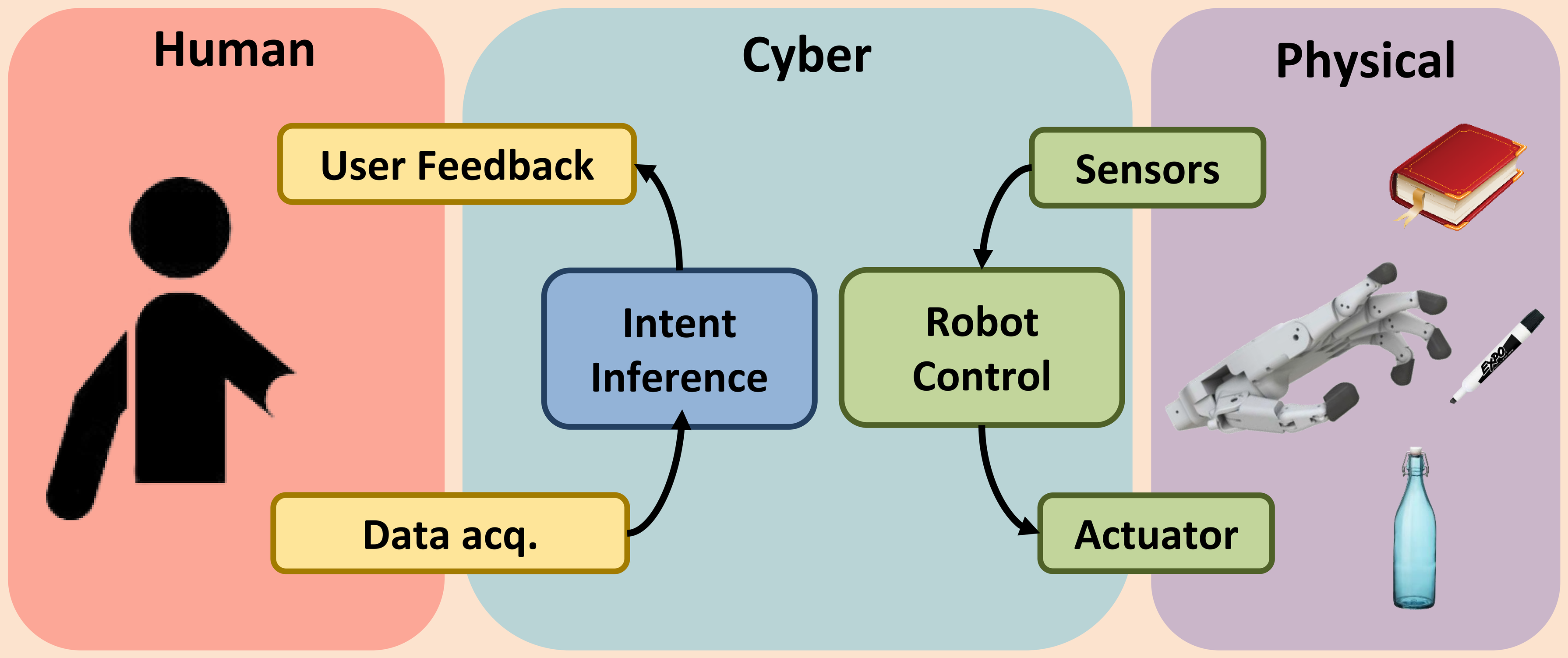
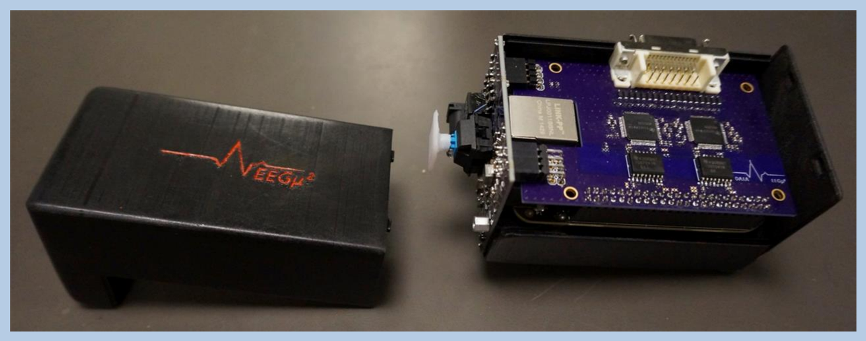
Motivation and Goal:

- Robotics has great potential for restoring or augmenting upper limb ability for individuals with motor impairments or amputations.
- A relatively small portion of individuals with upper limb motor impairments can benefit from invasive neural interfaces, due to complications like immune system dysfunction.
- Electroencephalographic (EEG) recordings and surface electromyographic (EMG) recordings provide a noninvasive alternative to intracortical arrays and peripheral nerve interfaces.
- Noninvasive physiological sensing for human intent inference can form a viable communication channel between the user and the prosthesis.
- Our goal is to explore EEG-EMG-context fusion approaches for human intent inference that tightly integrates with an intelligent physical interface to allow users to naturally control hand prostheses.



Intent Inference:

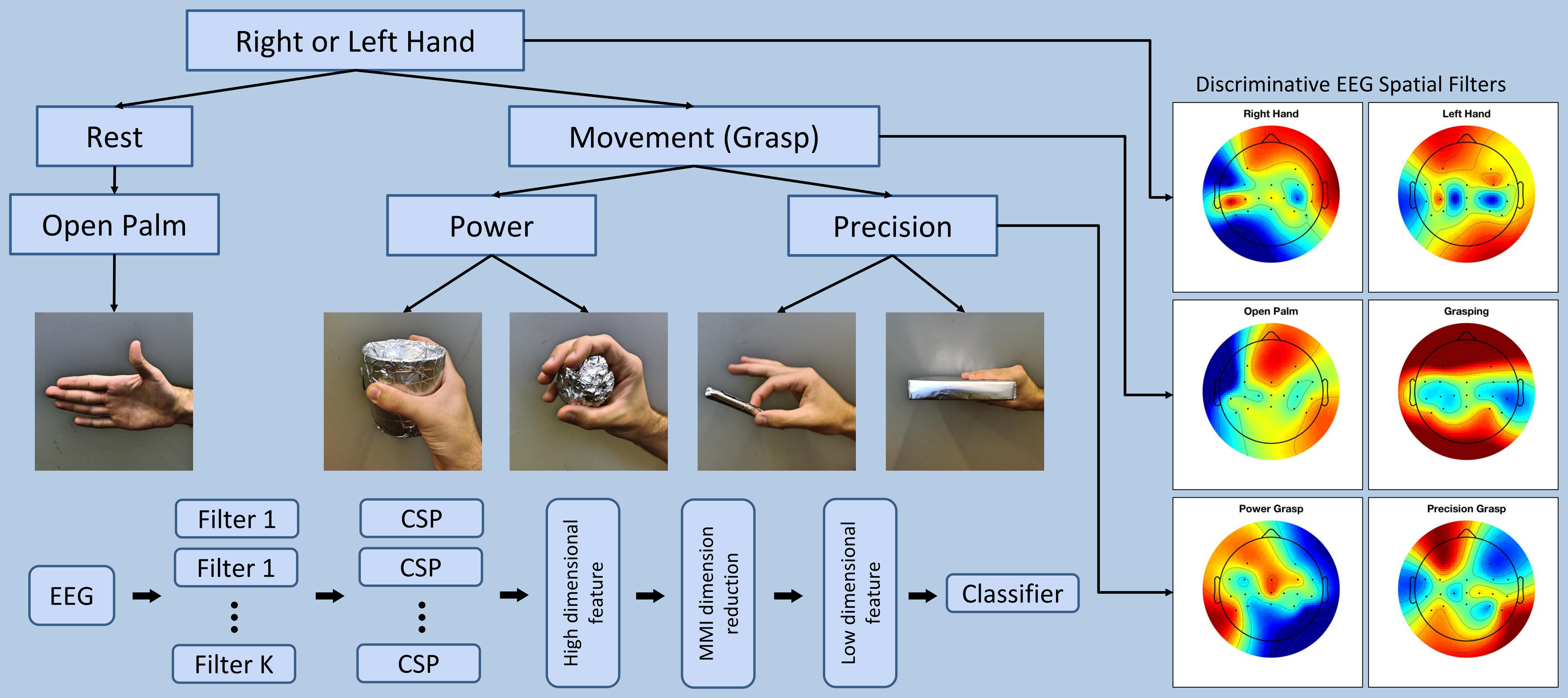
- Focus on high level human intent inference, leaving lower level details to the intelligent robotics module.



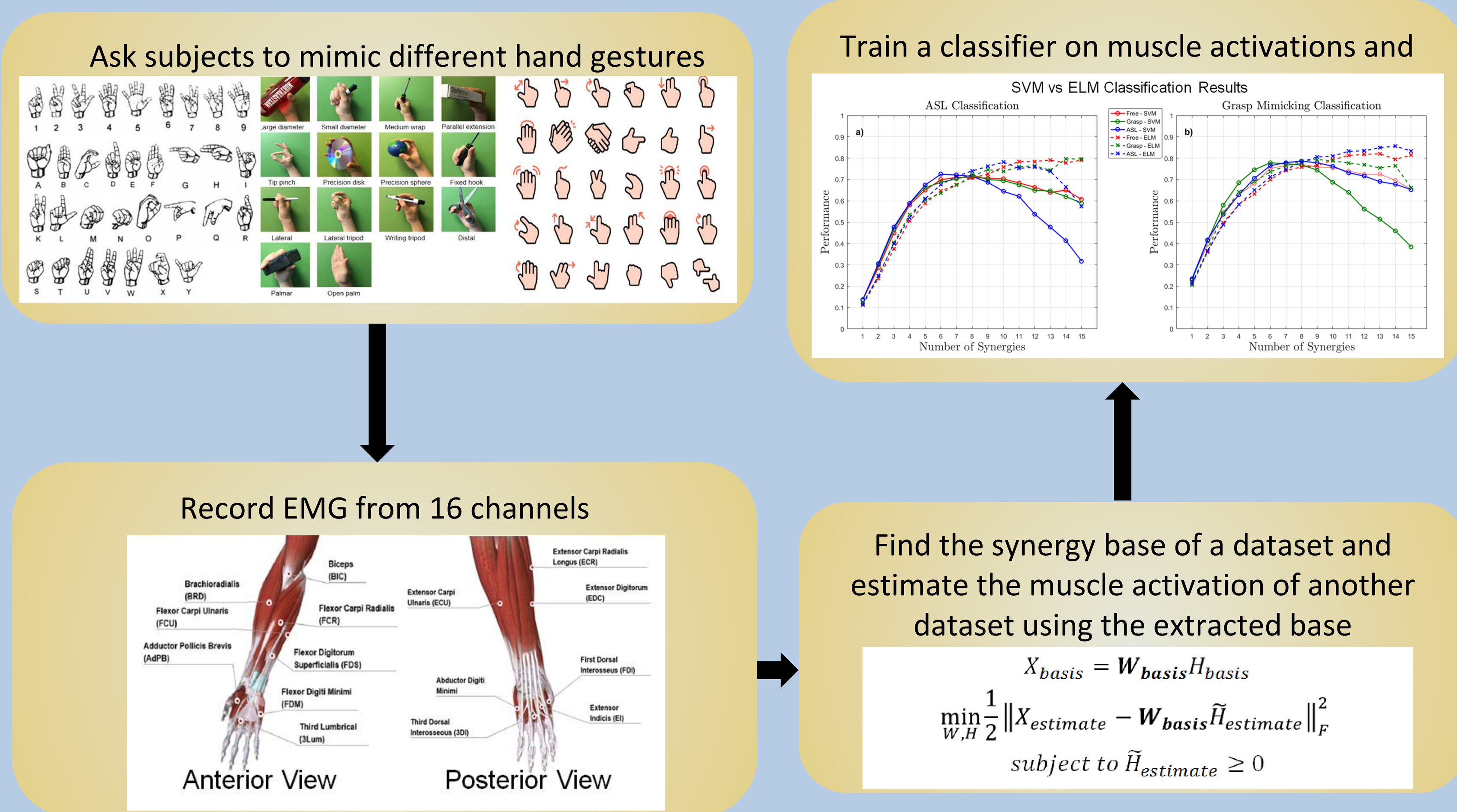
- **EEGu2**:
  - Acquisition: 16 channel EEG front-end, 24bit A/D
  - Input referred noise: 1.83uV
  - Real-time Processing: BeagleBone Black with ARM Cortex-A8 1GHz
  - Dual-chip solution
  - Allow implementation of faster control loops
  - EEG and EMG DAQ

EEG

- **Probabilistic classification:** optimally fuse context information with physiological evidence to infer desired action.

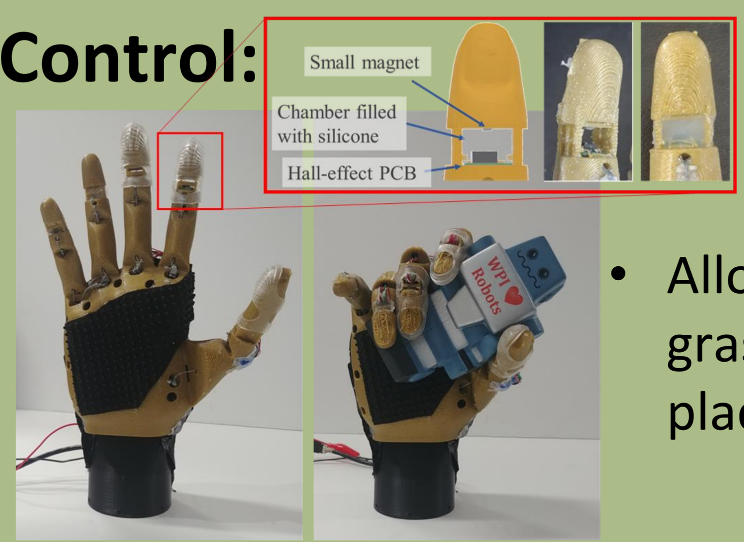


EMG

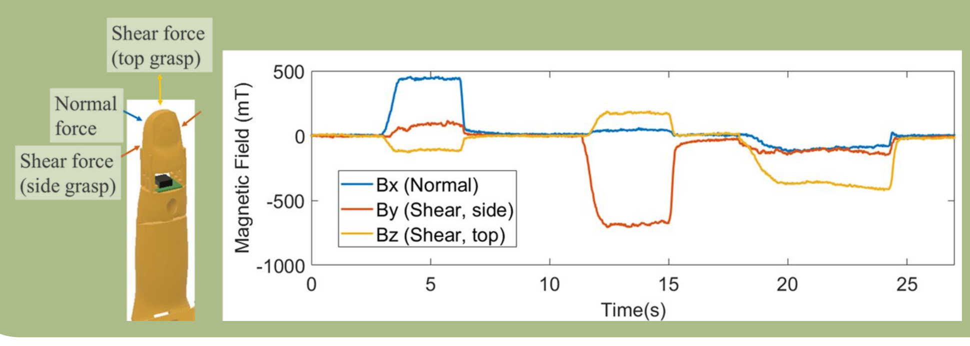


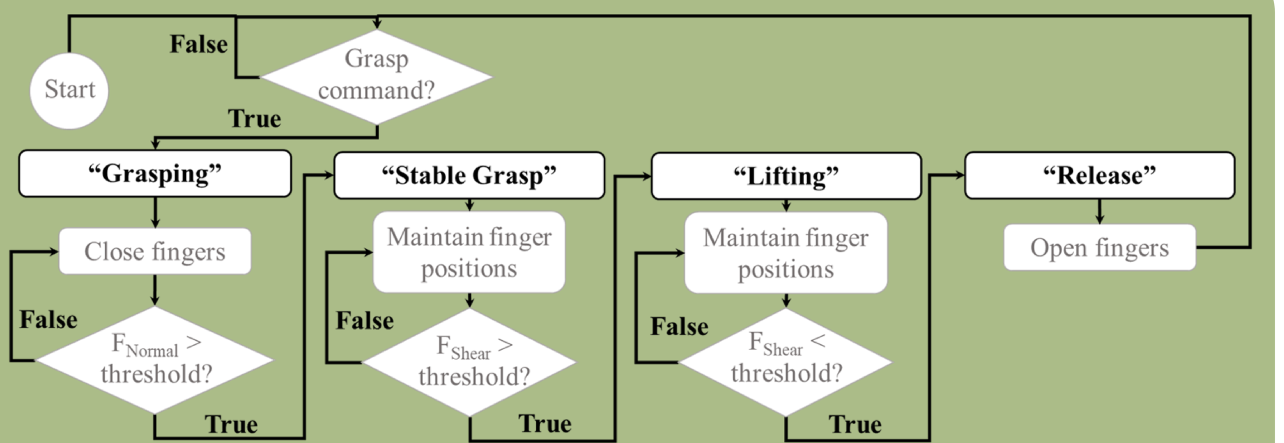
$$X_{basis} = W_{basis} H_{basis}$$
$$\min_{W,H} \frac{1}{2} \| X_{estimate} - W_{basis} \hat{H}_{estimate} \|_F^2$$
$$\text{subject to } \hat{H}_{estimate} \geq 0$$

Embedded 3D Force Sensors for Shared Control:

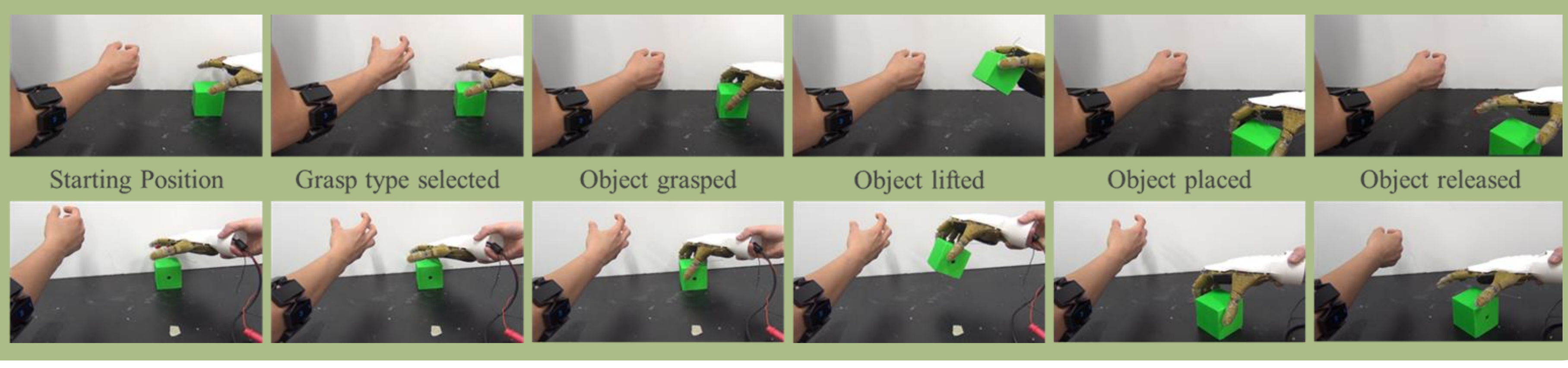


- Embedded Hall-effect sensors read forces in 3 directions
- Allows us to detect when an object is grasped (normal force) and lifted or placed (shear force)



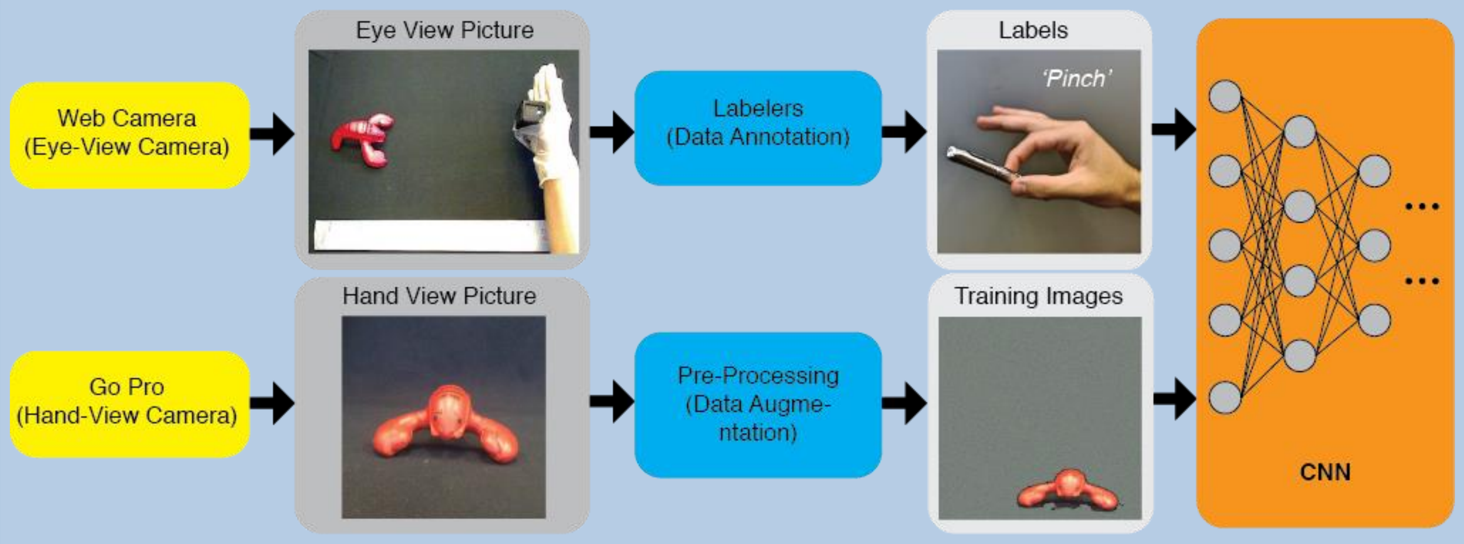


- Automatic grasp release to decrease user burden



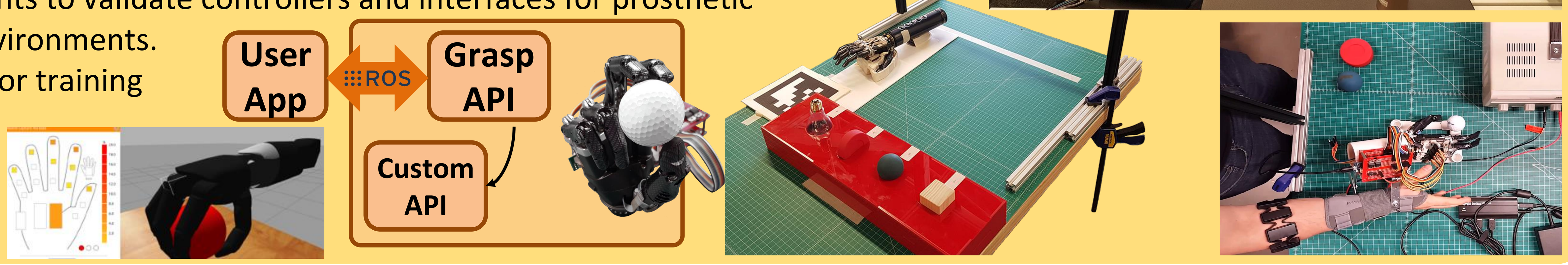
Visual Grasp Estimation

- Predict grasp type probability distribution based on palm camera
- Distribution represents user grasp preference given an object to manipulate
- Visual estimation will be merged with EMG inferred intent



Experimental Validation on a Robotic Prosthetic Hand:

- Position controller for a commercial prosthetic hand.
- A switched dynamical systems approach for EMG-based grasp classification.
- A risk-informed grasp quality metric.
- A particle filter method to fuse information from different sources.
- Design of experiments to validate controllers and interfaces for prosthetic control in smart environments.
- Creating a dataset for training multi-model grasp inference.



Embedded DCNN

- Use transfer learning from ImageNet neural networks
- Select efficient transfer source for embedded inference