Optical-Based Prosthetic Hand Control

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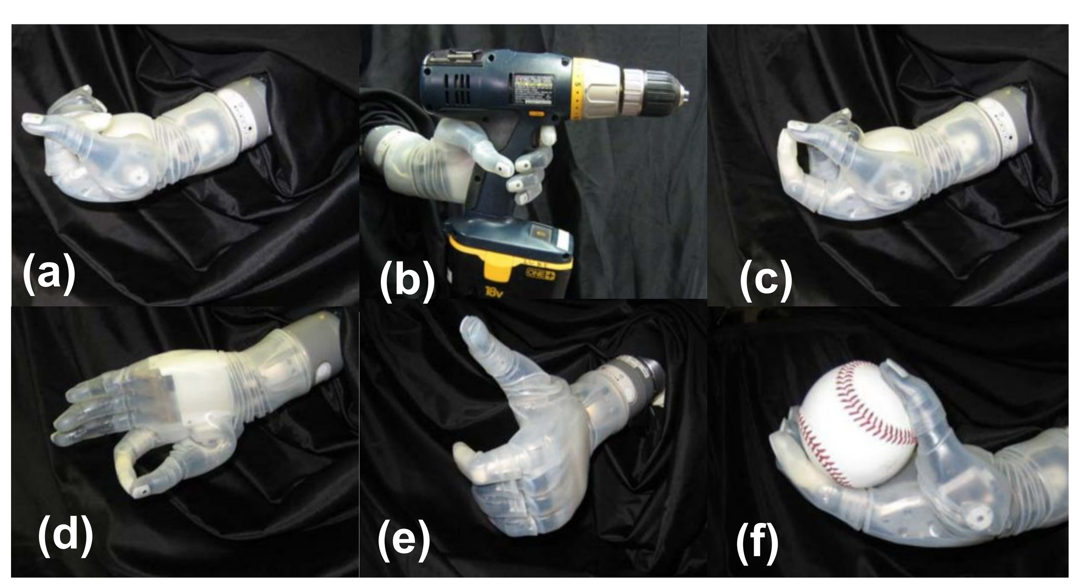
Background

People with upper limb amputations need reliable prosthetic hands with higher degrees of freedom and more precise control. Many technologies have been developed to advance the field, including body-powered technology, neural stimulation, and electromyography (EMG) control systems, but these methods still present user challenges. Further advancement in the areas of these existing techniques could mitigate some of their disadvantages and enhance prosthesis capabilities to achieve better control. We are proposing a new idea to solve the problem: integration of an optical imaging system.

Objective

We aimed to create an optical system to function with an EMG-controlled prosthetic hand that photographs the environment, recognizes objects, and tells the hand the grip needed to hold the object. Motor function of the hand will be controlled by EMG sensors.

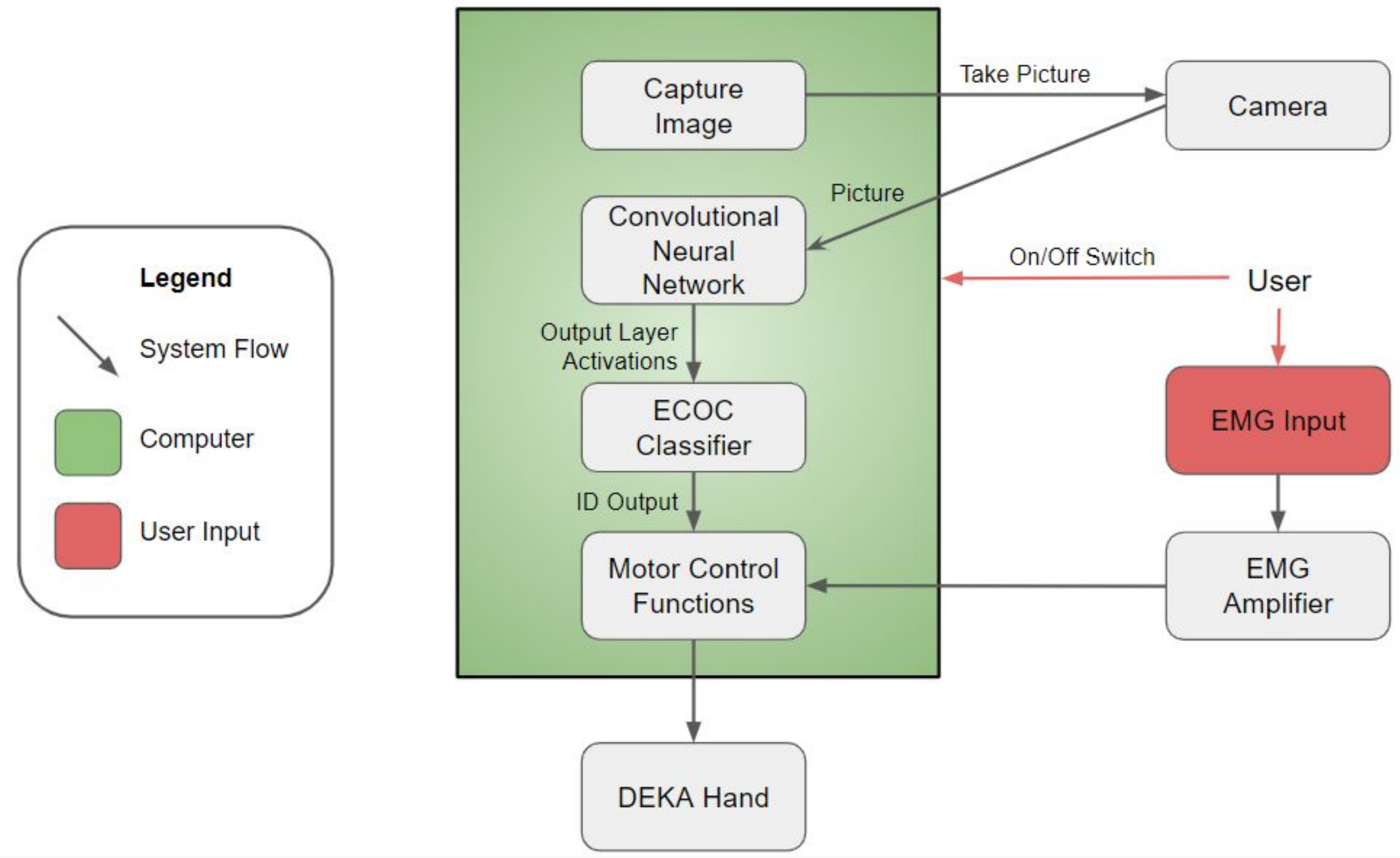
Current Prototype: The camera mounts to the heel of the DEKA hand and sends image data to the Raspberry Pi (encased in the armband with its battery). The Raspberry Pi sends grasp commands to the DEKA hand.



Optimal prosthetic hand grip postures corresponding to identified objects: (a) shows the power grip, (b) shows a tool grip, (c) shows a closed pinch grip, (d) shows an open pinch grip, (e) shows a lateral pinch grip, and (f) shows a chuck grip. Image source: LUKE Arm User Guide, DEKA Integrated Solutions Corp.

System Architecture

The user will activate the computer, camera, and prosthesis with a switch. The MATLAB script will process images taken by the camera at the palm of the prosthetic hand. Processing utilizes a convolutional neural network (CNN) and outputs the best grasp position for the object identified by the script. Grasping will be activated by EMG signals from the user.



System Architecture: The camera receives prompts from the computer (Raspberry Pi) to capture images, and these images are relayed back to the computer's MATLAB program for processing and analysis. The user powers the system using an on/off switch to the battery, and the user additionally transmits EMG signals (via the DEKA hand's standard control system) to the computer to control the prosthetic device's motor output of the appropriate grasp shape based on the program's object identification.

Methods

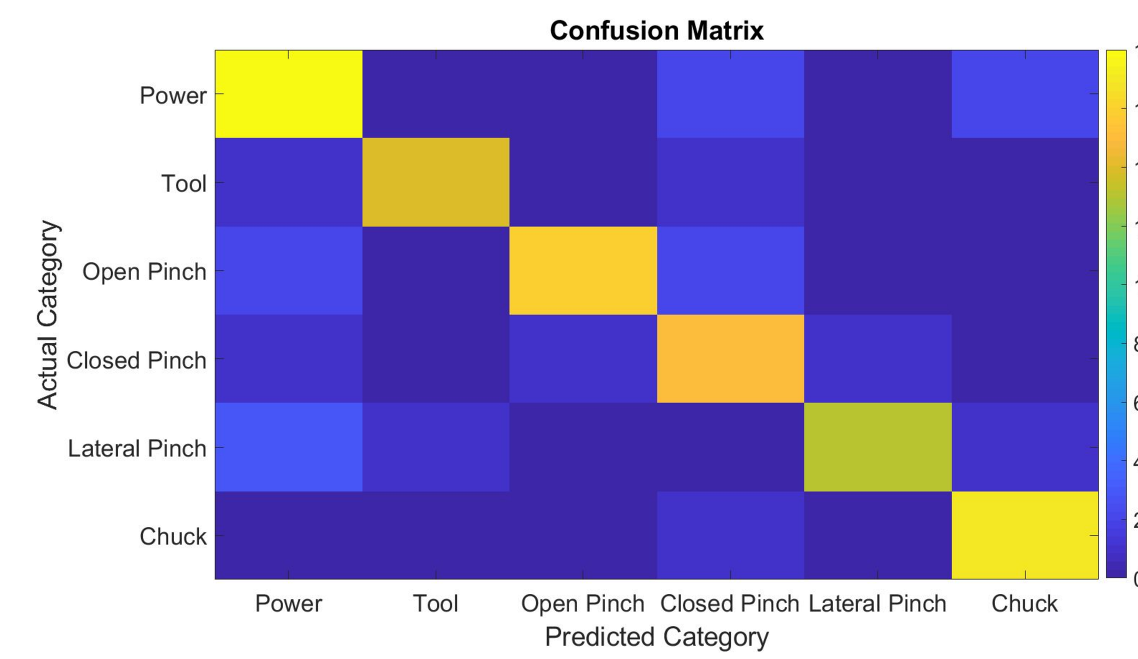
Using the ResNet-50 CNN MATLAB library for the base network, we extracted activations from the last fully connected layer. These activations were then passed through an error-correcting output code (ECOC) classifier. This allowed us to modify the network to fit our needs. We associated each grip with a commonly used object that could be picked up using that grip type. The control system then outputs the proper grasp shape to the DEKA hand.

Grip	Object
Power Grip	Water Bottle
Tool Grip	Hairdryer
Open Pinch	Earbuds
Closed Pinch	Pencil
Lateral Pinch	TV Remote
Chuck	Cell Phone

The DEKA hand is capable of performing six grasp shapes. These grips are associated with the optimal shape of the hand for picking up and interacting with certain objects.

Results

An evaluation data set consisting of 112 images not used for ECOC classifier training was used to evaluate the classifier's performance. The classifier was able to attain **83.04% accuracy** in object identification and grip choice from this data set. Although this level of accuracy is below our desired specification, the network is still capable of delivering a grasp output that would allow useful user interaction with the object it identifies.



Confusion matrix for the ECOC Classifier among a validation data set of 112 images. There is a significant trend on the diagonal, indicating that this network is effective at determining the proper grasp position.

Technical Specification	Goal Quantity	Measured Quantity
Network Accuracy	85%	83.06%
Battery Capacity	5000 mAh	13000 mAh
System Mass	300 g	416.6 g
Clock Rate	1.4 GHz	1.4 GHZ
RAM	1 GB	1 GB

Verification Results: Green indicates success and red indicates failure.

Clock rate and RAM were determined directly from the computer read-out values. System mass was determined by weighing and summing the masses of each component of the control system. Although we failed to meet this specification, manufacturing processes could easily minimize the weight of the system for future prototypes.

Discussion

This optical-based control system could simplify the user training that goes into EMG-controlled prosthetic devices, because the computer identifies the necessary grasp shape while the user must simply activate the device. Future considerations include additional object identifications and optimized grip posture outputs corresponding to the function of an actual prosthesis, like the DEKA hand.

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