ENGG1000 S1 2018 Detailed Project Description

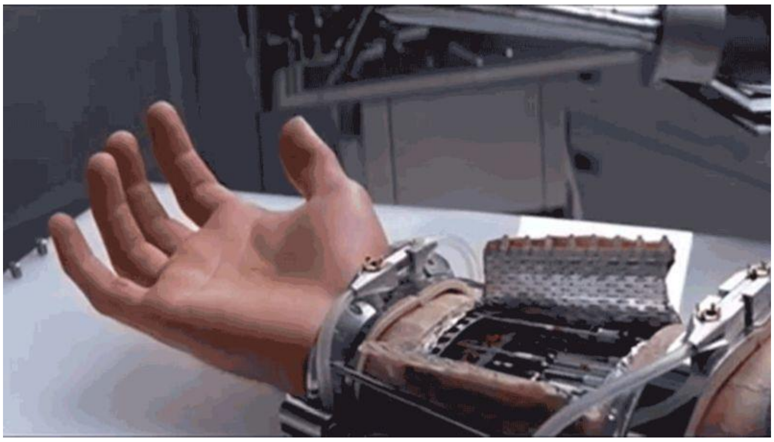
# Prosthetic Hand with Biological Interface

## Background

Hands are pretty, well, *handy*. They can lift heavy weights, repair watches, play a guitar, applaud the lecturer. They are a sophisticated and versatile instrument. Our hands can be gentle enough to pick a raspberry without squashing it, or take hold of an egg without dropping or breaking it. It can even be argued that hands were the major driving force behind the evolution of the human brain. Our upright posture freed our hands so that they could start *manipulating* things. Our brain then evolved in new directions because of the greater scope for doing. Hands are useful.

Loss of the use of a hand is therefore a serious disability. However, engineers around the world are trying to develop prosthetic hands that can interface with the patient's own body [1]–[3]. This will result in a seamless prosthetic, one that feels part of the user's body.

**You are to design and build a mechanical hand prosthesis, a device that will replace the function of one hand. The client is an amputee (with some upper limb function). The hand should be able to grip objects, and the gripping must be actuated using electromyography (EMG).**



## Design criteria

The prosthesis is to be fixed to a forearm. The existing hand must be held as a fist with no strap across the palm. It is assumed that the opposite arm has been amputated just above the elbow. The prosthesis will comprise a gripper of some sort, which will be activated using electromyography (EMG). Electromyography is the study of measuring the electrical activity of muscle during contraction. You can select which muscle/s can be used for actuation.

It may be built from materials bought in a supermarket, hardware, hobby or toy shop for less than $150 total. Junk is free. Any electrical components must be battery (not mains) powered. You must build the EMG measurement system yourself (including any amplification and signal conditioning). You cannot use a pre-built EMG measurement system. You will be provided with electrodes that can be attached to muscle, and an Arduino with a Bluetooth module. You will have access to 3D printers, laser cutters and CNC machines through maker spaces on campus, as well as some hand tools.

## Tasks

1. Pour water into a soft plastic cup and drink the contents without spilling. The elapsed time will be measured and judges will assess the degree of spillage.
2. An unrehearsed pick-up. Ten or more objects of different sizes and shapes will be placed on a table. You will pick them up in any order and place them in a basket. The number of objects transferred and the elapsed time will be recorded.

3. Press an arbitrary sequence of keys, which are communicated wirelessly, in real-time, to your system. Ideally this is a purely autonomous mode, not requiring direct user interaction – after all, we'd like not to have to worry about thinking about these mundane tasks. You'll be judged on the accuracy and speed.
4. Hands will also be assessed by judges for innovation, robustness, and aesthetic appeal.

## Tasks in Detail

### Water pour and drink

- Start with a bottle of water, one-half full, and an empty cup on the table, in the centre.
- At the signal, the contestant will pick up the bottle and pour water into the cup which is on the table. The cup must be filled up to the mark.
- The contestant picks up the cup and drinks the water. The timer is stopped when the cup is empty.
- Excessing spillage will be penalized, but we don't mind if you dribble a bit …

### Object pick up

- 15 common household objects are placed on a table along with a basket or bowl. These will not be known to the teams beforehand.
- At the signal, the contestant picks up the objects, in any order, and places them in the bowl. The clock stops when
  - two minutes have elapsed
  - the contestant has picked up all objects
  - the contestant decides to stop (and not waste time on the impossible).
- The number of objects successfully picked up and the elapsed time are recorded
- We will pick up dropped objects and rearrange objects if requested.
- The biggest object will be approximately $20cm^3$ and weigh ~3kg.
- The smallest object will be $1cm^3$ and weigh only a few grams.

### Key Press

- The prosthesis will be asked to pair with a test jig via Bluetooth.
- At the signal of the instructor, a code will be transmitted to the user's arm prosthesis.

- The clock will start, and the device will then autonomously input the code into the numeric keypad.
- Score will be based on accuracy and speed.

## Design Objectives and Evaluation

*The objective of the project is for your team to design and build a prototype device that will, within the given constraints, maximise the overall objective as defined by a Design Objective Function (D.O.F.).*

Your group mark for the prototype assessment will be calculated from the following equation:

$$\boldsymbol{DOF = P + EQ}$$

Each parameter within the *D.O.F.* is related to a specific design objective which you should attempt to maximise. Each parameter has a different weighting signifying its relative importance towards the overall design objective. ‘P’ represents the mark awarded for the performance of your prototype in the competition, and ‘EQ’ represents the engineering quality of your design. Each of these parameters will now be defined in detail. Performance is weighted as 80% of the DOF, and Engineering Quality as 20%.

### Performance *P*

The performance mark is broken up into a set of criteria based upon the functionality of the prototype. There will also be the opportunity for bonus marks. The performance mark is defined by the formula:

$$P = P1 + P2 + P3 + P4 + P5 + P6 + P7 + P8 + B$$

where:

| | |
|---|---|
| $P1 = 5$ | if a switch is used to turn the device on and off; |
| $0 \le P2 \le 10$ | if the device is able to pick up the water bottle, depending on how solidly it is gripped; |
| $0 \le P3 \le 10$ | that the device is able to pour the water in to the cup, as close to the mark as possible; |
| $0 \le P3 \le 10$ | that the water is drunk from the cup, with as little spillage as possible; |
| $0 \le P4 \le 10$ | based on the number of presented items that are successfully picked up and placed in the basket. |
| $0 \le P5 \le 20$ | calculated based on the time taken to pick up the objects, T(seconds), such that: $P5 = (120 – T)/5$, if $20 < T < 120$, or $P5 = 20$ if $T < 20$, or $P5 = 0$ if $T > 120$ |
| $0 \le P6 \le 10$ | that the device is able to correctly detect the transmitted sequence via Bluetooth; |
| $0 \le P7 \le 15$ | determined by how well the device is able to press the required keys on the keypad, with the required force; |
| $0 \le P8 \le 10$ | how well the system integrates all the above functions, including the manual and autonomous control modes. |

| | |
|---|---|
| *0 ≤ B ≤ 20* | bonus marks, for potential other innovations in this system. This is only available if the above basic functionality has been met by the system. |

## Engineering Quality *EQ*

You should be aware that the system that achieves the highest marks in performance may not represent the best engineering design. There are a host of other factors that are necessary for good engineering – usability, durability, manufacturability, ease of upgrading, etc. Additional marks are available for good design of your prototype, as subjectively assessed, based on four criteria:

1. **Robustness *R* (5 marks)**

This will be subjectively determined. The two major factors considered are

- how many times would be system be able to complete the task without requiring major service and
- how well the system would function if it was subjected to some trauma.

2. **Simplicity *S* (5 marks)**

A simple design is almost always the best design. Having fewer components and a less complex system will lessen the effort required to understand the system by future designers and people tasked with repairing your device. This will be determined subjectively by the judges.

3. **Aesthetic Appeal *A* (5 marks)**

There is more to engineering devices than developing functionality – how a device looks weighs heavily on how willing a person is to try out a new piece of technology, for example. It might be a good idea to consult people from a non-engineering discipline for input here.

4. **Innovation *I* (5 marks)**

This will be determined by the panel of judges based on the uniqueness of your design in comparison to the other entries. In general this is related to the way in which you utilise technology to perform the primary functions of the design and the degree of difference between your solution and the other competitors.

# Project Detail

Students completing this project have the choice of completing one of three technical streams – Electrical, Biomedical or Mechanical. Teams will consist of members from each stream. Once teams are formed, the team members will decide amongst themselves which team members will complete each stream. For teams to be successful, they must combine the knowledge acquired from each stream. This section describes the different sub-areas of this project, and how they relate to each stream.

## Electromyography (EMG)

Our muscles contract through a complicated (and very fast) chain of events, that usually involves an electrical signal being sent from the brain to the muscle cells. The contraction of each muscle cell results in a very small change in the voltage across the cell wall. Therefore, there is electrical activity associated with every contraction of every muscle.

Electromyography (EMG) is the technique for evaluating and recording electrical activity of skeletal muscle.

EMG can be used for diagnosis of muscular disorders, as well as for control of prosthetic limbs [4]. In the case of control, EMGs are usually used as a trigger signal, to actuate a motor or other function. In most subjects, the electrical activity of a muscle is obtained by attaching adhesive electrodes to the muscle. We will provide your team with electrodes to attach to the muscles.

Obtaining a useable measure of the electrical activity can be difficult. The electrical signal is very noisy, small in amplitude and can be inconsistent (depending on correct electrode placement). Your team will be required to design and build all the electrical circuitry (amplification, noise-removal, rectification) required to obtain an EMG signal that can be used to actuate a gripper system. Team members in the Electrical Technical Stream will gain theoretical and practical skills to design and build such circuitry. Team members in the Biomedical Stream will learn about the art of obtaining a useful ECG signal, and suggestions for what type of signal processing should be performed. Team members must communicate effectively to produce satisfactory EMG circuitry. Thought must also be given to making sure the electronics and connections are robust to the movement of the arm.

## Prosthetic Hand

There are many issues that engineers must consider when designing prosthetic hands. For instance, the prosthetic needs to be dexterous to enable the user to pick up small finicky objects. It needs to be durable to withstand day-to-day activities, comfortable for the user to wear for long periods, light enough to maneuver and be able to grip slippery objects.

In this project, your team must not only design a prosthetic that can complete the aforementioned tasks, but also interface with the EMG signal. This signal must be used to activate the gripper. The design of the gripper mechanism is left up to the team. You can use separate power sources for the gripper and for the EMG circuitry – **however no mains power is allowed.**

In the Biomedical Technical Stream, you will learn basic anatomy and physiology of the hand. You'll learn about electrical activity inside cells and how it can be measured. Expert lecturers in robotic manipulators, rehabilitation engineering and finger-grip physiology will provide your team with the anatomical insight required to build a suitable gripper. The Mechanical Technical Stream will provide insight into mechanical engineering principles which can be utilized in the bionic hand (as well as other components).

## Receiver

The third task involves the user receiving a keypad code via Bluetooth. The device must be able to interpret this code, and direct the prosthesis autonomously to enter this code via keypad.

The precise details of the Bluetooth transmission, in terms of pairing and data format, will be provided later in the session.

## Testing Procedure

*As the result from the testing of the systems accounts for a substantial part of the overall mark, it is strongly advised that this section be consulted both prior to, and during the design process.*

The testing of the devices will be conducted in a competition on **Monday of Week 13. The exact time, running order, and procedure of the competition will be advised closer to the date.** After the competition all teams will need to submit their system for 'impounding' and evaluation against the subjective design criteria. Whilst the systems are impounded, a panel of judges will assess each team's entry on the relevant subjective components of the D.O.F. described earlier (EQ). **The location of the competition will be announced later in the session.**

Teams should come to the competition well-prepared, with some contingencies in place should systems fail or not function correctly on testing day. In particular, students are cautioned against attempting last-minute modifications. No equipment will be provided to do so by the School on testing day, though the regular labs will be open during the time of the competition. Students may wish to bring any tools and materials to make running repairs if necessary.

Each prototype device will be given only one opportunity to demonstrate its functionality. The absolute time limit for each test run will be ten minutes – this includes the time for the team to set-up. Should a team fail to make the test run at their allocated time they will receive a mark of zero for that run – there will be no exceptions. More details of the testing procedure will be released closer to the date.

The final mark for testing will be the average score achieved by the device in the competition run, from a set of scores submitted by a team on independent judges.

**It is strongly suggested that teams understand the characteristics of any batteries that may be used to power the system. Very few batteries, if any, deplete linearly. Therefore excessive usage throughout the testing may jeopardise the competitiveness of the system. There are no guarantees that teams will be able to recharge their batteries during the afternoon.**

Prior to final competition testing, devices must first pass a Preliminary Test (appearing as 'Acceptance Testing' in the course timetable), that will be held two weeks before the competition. At this test devices must demonstrate some preliminary functionality. Details will be made available closer to the date.

## Acceptance Testing

The acceptance testing, held on Thursday of Week 10, requires the successful demonstration of the basic components that is required by a successful system. Groups will be asked to demonstrate the following basic functions:

(i) That it can pick up and turn a water bottle

(ii) That it can pick up an object close to the largest and smallest required by the competition

(iii) That it can pair with the Bluetooth test device, and receive a transmitted three digit code

In addition to the above, the group is required to demonstrate that it meets the design constraints in terms of Occupational Health and Safety requirements.

## Qualifications

Any system that does not comply with this specification and its amendments issued before test time will be disqualified. The specification will be as interpreted by the Design Scrutineers.

Questions about the specifications may be forwarded to your Design Team Mentor in writing at any time. Rulings will be made and generally posted to your group's section of the Moodle discussion tool within 48 hours of submission. Questions should be submitted in a form that can be answered with a simple "yes" or "no". Questions may be formulated in the form of drawings or sketches.

**ALL RULINGS WILL BE FINAL!**

## Safety

Safety is of paramount importance in all engineering pursuits. You are required to carry out a risk assessment of the device prior to testing. Students are encouraged to embrace risk management in their own activities and produce the corresponding risk assessment documentation. As appropriate, protective clothing, footwear, safety glasses, or full masks should be worn by students working on devices during construction and testing, as directed by lab staff or mentors. Systems that are deemed by the officials and judges to be hazardous will not be permitted to run.

## Eligibility

The prototype system must be designed and built by engineering students registered in ENGG1000, without the help of either design or construction from anyone not registered in the course. Faculty members, graduate students or university technicians may be used as consultants for specific information. All external references must be acknowledged – failure to do so constitutes an act of plagiarism.

## Resources

The following list is not exclusive or exhaustive – its purpose is to help you get started.

## Materials

Any materials may be considered for use. No toxic, radioactive, or dangerous materials however will be allowed. This check must be submitted as part of the Design Proposal assessment. If this is not included, the team's prototype system will be considered as non-compliant and deemed ineligible.

A limited range of electronics components (e.g. integrated circuits, transistors, diodes, LEDs, but not motors and not unusual or very specific components) will be available from the EE&T Electronics Workshop (EEG15). To request these, you will need to (i) show a sketch of your circuit diagram to a lab demonstrator and (ii) fill out the component request form at **http://engg1000.ee.unsw.edu.au/component-request-form.pdf** and have this signed by the demonstrator. For those of you doing the electrical stream of the course, if you don't already own one, you are strongly advised to purchase your own prototyping board (or "breadboard"). These can be conveniently purchased from the Electrical Engineering School Office for $15.

Further, Create UNSW is an excellent source for electronic components and advice on electronics in general:

http://www.createunsw.com.au/

Create UNSW regularly opens stalls on campus – see the above website for details.

Teams wishing to purchase other electrical equipment may consider trying Jaycar (Bronte Rd, Bondi Jn; York St, City, Botany Rd, Alexandria) as an alternative to Dick Smith (Westfield Bondi Jn; Moore Park Supa Centre; Westfield Eastgardens). There are also a number of electrical wholesalers, one of which is Salmon Bros located in Surry Hills. Also there is a Hobby Shop on the south side of the Kingsford roundabout along Anzac Parade which should have plenty of interesting bits and pieces.

Raw materials like wood can be obtained from hardware stores such as Bunnings Warehouse. Scrap is great, but make sure the material is strong enough for your purpose.

## Workspaces

At UNSW, ENGG1000 students will have access to maker spaces in the Michael Crouch Innovation Centre (MCIC) and Willis Annexe. These maker-spaces have 3D printers, laser cutters, CNC machines etc. Students must attend a 2-hour induction before they can use the equipment. Students can access this space in their own time. More detail on how to complete the induction and access these facilities will be given in the lectures and made available on Moodle under Resources.

In addition, the Electrical Stream will have access to electronics labs for building and testing the EMG circuitry, while the Biomedical Stream will have access to a small workshop with hand tools. Students in the Mechanical Stream will have access to the mechanical labs and workshop.

A final parting message... GOOD LUCK!

## References

[1] N. Wang, K. Lao, and X. Zhang, "Design and Myoelectric Control of an Anthropomorphic Prosthetic Hand," *J. Bionic Eng.*, vol. 14, no. 1, pp. 47–59, 2017.

[2] M. Tavakoli, C. Benussi, and J. L. Lourenco, "Single channel surface EMG control of advanced prosthetic hands: A simple, low cost and efficient approach," *Expert Syst. Appl.*, vol. 79, pp. 322–332, 2017.

[3] D. Karabulut, F. Ortes, Y. Z. Arslan, et al., "Comparative evaluation of EMG signal features for myoelectric controlled human arm prosthetics," *Biocybern. Biomed. Eng.*, vol. 37, no. 2, pp. 326–335, 2017.

[4] J. R. Cram, G. S. Kasman, and J. Holtz, *Introduction to Surface Electromyography*. Gaithersburg, MD: Aspen Publishers,Inc, 1998.