Assistive Robot with EMG Control

By

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INTRODUCTION

In everyday life, there is always a time when an able-bodied person wants to get an object from a table or a shelf. However sometimes it becomes difficult because the table is too long or they are too short, and the object is on the top shelf. One way to tackle the table problem would be to have the person stand and lean forward to get the object. For the shelf problem, they would need a stool. The problem with these solutions is that not everybody can achieve this.

So the question is "How would a person in a wheelchair tackle this problem?"

Before answering this, there is another question that needs to be answered 'How far can a wheelchair user reach?' Fig. 1 [1] and Fig. 2 [2] answers this question as it looks at dimensions associated with comfortable and extended reach ranges for a wheelchair user in the U.K. and the U.S. Looking at the data provided and conducting experiments, it can be concluded that a person in a wheelchair can reach around 400mm (horizontal depth) when the person leans forward, 1150mm (height) and 350mm (side depth) leaning sideways. Given this data, it can be said with a level of certainty that it would be difficult for a wheelchair user to tackle these problems. The easiest way to solve the first problem would be to go round the table but what if the table was pushed against the wall, then the answer would be to get help from some other person. For the shelf, they would require another person's help. Another big issue is that a wheelchair user would require certain criteria to be met to buy a house, which would mean the users would be limited to just a few houses.

Person	Access	Reach angle	Height (H)		Depth (D)	
			Comfortable mm	Extended mm	Comfortable mm	Extended mm
Wheelchair user	Front	+ 70°	1,000	1,150	90	120
		horizontal	(750)	(750)	180	230
		- 24°	650	650	120	200
	Side	+ 70°	1,060	1,170	100	135
		horizontal	(750)	(750)	220	310
		- 24°	665	630	165	230
Ambulant Disabled	Front	+ 70°	1,500	1,625	200	250
		horizontal	(850)	(850)	280	400
		- 24°	750	700	180	310

Note 1 Dimensions have been rounded to the nearest 5 mm.

Note 2 Dimensions in brackets are for the horizontal reference plane.

Note 3 It is assumed that any kneehole allows full reach capabilities.

Note 4 Maximum heights are measured from the 70° line; minimum heights from the -24° line

Note 5 For some activities, the recommended dimensions in the standard are extended beyond those resulting from the research trials on the basis of accepted practice.

Source: BS 8300 Design of buildings and their approaches to meet the needs of disabled people – Code of Practice.

Fig. 1 U.K. Code of Practice (BS 8300) [1].

The goal of this project is to tackle some of these limitations that wheelchair users face. Picking up objects on a table is a daily task for people. The project would be looking at robotic arms and how they can be used to aid wheelchair users to perform these simple daily tasks. Building up on this, the main objective of this project is to get a robotic arm to pick up an object from a table and give it to the user. The selection of the object will be done using two wireless (Myoware) EMG sensors, one will be selecting the object, and the other would be to tell the robot to execute the task. There will also be a camera and a user interface (UI),

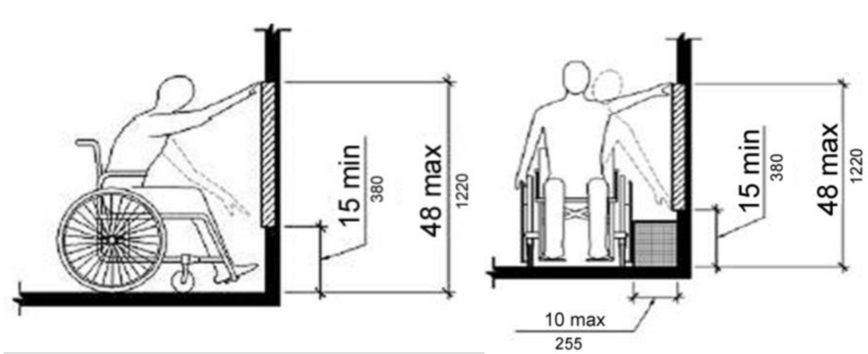


Fig. 2 U.S. standard for minimum and maximum point's (front and side) [2].

that would be used for object recognition, to give the user an idea of the robot's view and also show the current object that is being selected.

(The reason for selection of two EMG signals would be discussed in the Literature Review conclusion.)

PROJECT GOALS

The project will be divided into four parts or goals. The first part is to make two identical wearable devices that will be detecting signals from the integrated Myoware sensor and then sending them wirelessly to the receiver. The second part involves object recognition, which will be looking for objects that can be picked up. The third will look at the robotic arm, which would move, pick up an object and then place it closer to the user. The fourth would be to implement a middleware that communicates with all the devices and makes decisions on what to do. It will also send appropriate information through the user interface, so the user can give an appropriate task.

The complete sequence of the project is explained below (Chart 1):

The user will be wearing two wireless devices, one on each hand. These devices would be recording the EMG signal and passing it on to the middleware/computer. The middleware will then communicate with the robot and give it the coordinates that it needs to move to. The robot moves to the location and then comes back to its home position. This process will be repeated as many times as desired. The Screen/ User Interface will be showing the camera data and also where the robot is going to go.

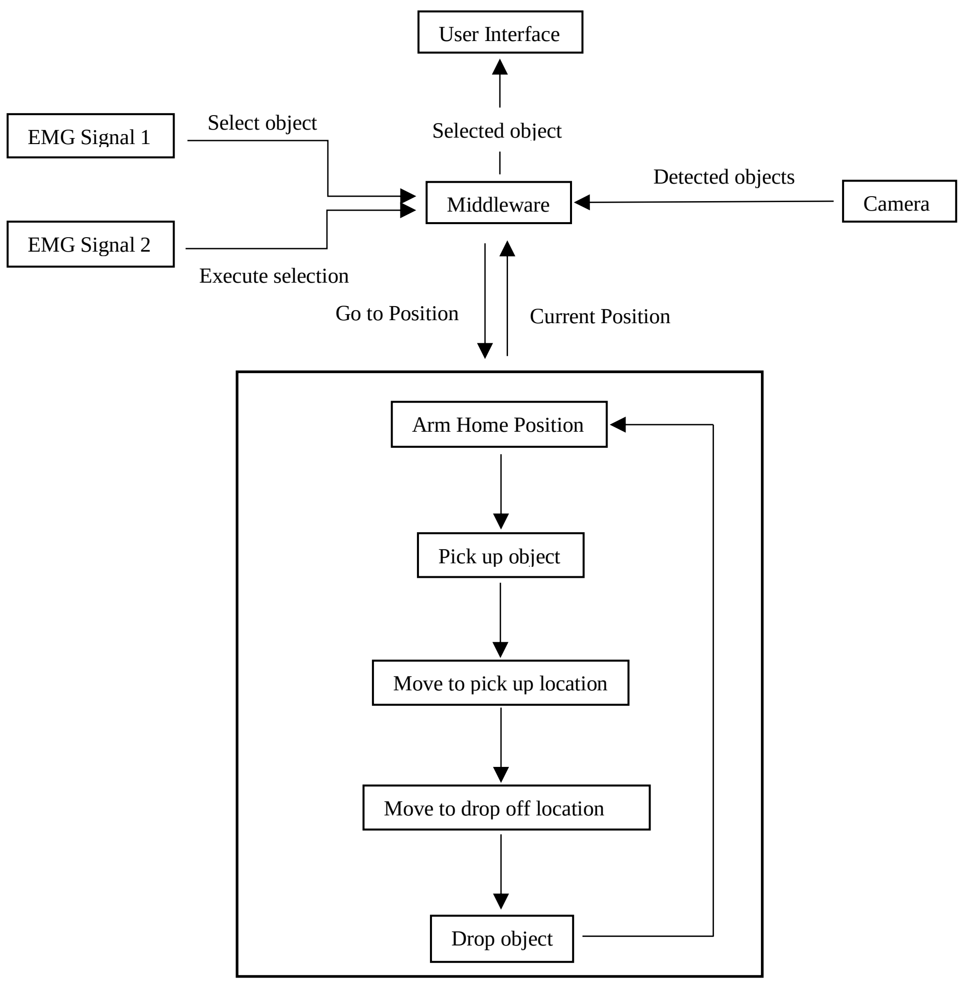


Chart 1. Complete sequence of the proposed system

LITERATURE REVIEW

This section would be looking into the goals and background of the project. To do this it will look at the different methods, techniques and sensors that could be used to complete the goal. It would also be looking at similar projects that have been done in the past. The conclusion will deal with why EMG is the better option and will also talk about how the project is different from the projects done in the past or if similar how the project builds/improves the previous project.

HUMAN MACHINE INTERFACE (HMI)

There are different ways to get input from the user. An effective device would be a mouse or a keyboard. But these devices would limit the users to a certain location i.e. they would have to have their hands go to a certain location all the time. It would be desirable to have a device that would get the signal from the user's current position. These could be done using technologies such as Electromyography (EMG), Eye tracking (ET) and Electroencephalography (EEG).

ELECTROMYOGRAPHY (EMG)

"EMG is the study of muscle function through the enquiry of the electrical signal the muscle emanates" [3]. EMG has been used for a lot of medical tests to assess the health of muscles and the nerve cells that control them [4] [5]. It is also being used in fields like rehabilitation and prosthetics [6], [7]. There are two different ways to get EMG signals, Surface EMG and Needle EMG. As the name suggests, for the former the electrodes are placed on the skin right on top of the muscle that is being tested. On the latter, a needle is inserted into the desired muscle to detect it is activity [4] [8]. For surface EMG there are different types of electrodes, to be precise there are three different kinds, pre-gelled electrodes, dry electrodes with gel applied directly on skin and dry electrodes [3] [9]. These also come in two different options disposable and reusable.

EYE TRACKING (ET)

"ET is a process that identifies a specific point in both space and time that is being looked at by the observer" [10]. In 2002 a survey was conducted to look at the practical applications of ET. This survey talked about using ET for neuroscience, psychology, and computer science. It also went on and talked about industrial engineering and marketing applications [11]. As technology has progressed, some of these applications have become reality and some of them have caught the interest of researchers. One of these interests has been on using ET for assistive technology. This is quite helpful for disabled people and can be used by anyone taking into account that most disabled people can move their eyes [12].

ELECTROENCEPHALOGRAPHY (EEG)

"EEG is a method of looking at patterns of oscillating electrical activity from the human scalp" [13]. Like EMG it is also being used for clinical tests, but here the observation is being done on conditions affecting the brain. It is also being used in Brain-Computer Interfaces (BCI) that look at linking the activity of the brain to perform an action on a computer or robot [14]. It is a very desirable method as it is very non-invasive procedure than other methods such as functional magnetic resonance imaging (fMRI) [15]. It is also desirable as there are a few different channels that could be used to get signals from.

Having an understanding of the three different ways of getting input from a user, it is quite clear about how these techniques could be used. It also showed the different ways on how they have already been used. Therefore a clear understanding can be made that the method, technique or sensor used would be different for each project as this depends on the goals of the project.

RELATED PROJECTS

There is a lot of research in the field of assistive robots and it is very likely that there are projects that look at some of the issues that were discussed earlier in this report. To get a much more in-depth view on different projects, it is not possible to look at all the different types of inputs mentioned above. The main focus would be on EMG and EEG as these are much more popular methods used than ET. ET is not going to be used as it requires a complex setup and is not viable for daily activities.

There are many ways that EMG and EEG can be used to do certain tasks. For example, recorded EEG or EMG signals could be used to control the movements of a multi-joint dynamic arm, another example would be to just get one binary signal from EEG or EMG and then used that to perform a skill already taught to the arm. Going much deeper there are also different methods of performing these tasks. These tasks and their methods are discussed in two categories EMG based and EEG based.

EMG BASED WORK

Proportional Myoelectric Control of Robots

In this study [16], the myoelectric signals are directly proportional to the output which is then used for control of prostheses, orthoses, and new human-machine interfaces. This is to give the user a friendly interaction and to try and improve on stress intuitive controls which have limited accuracy and functionality. The study reveals an emergence of new muscle synergy space when the user starts to identify the dynamics of the interface. Giving an example of how this could have an effect on long-term performance. The study also looks at control of a robot arm with this interface for reach to grasp tasks. The results showed that all subjects were confident and had good control of executing the task with the device without consciously thinking about the device.

Robot Control with Time-Varying EMG Signals

Similar to the previous study [16] this also records the data from EMG and then converts this into kinematic variables for control of a robot. Unlike the previous, this [17] only looked at control of a robot arm. And thus looks at control interface with natural motions. It also looks at changes in EMG signals with time due to electrode movement from the initial position and muscle fatigue. To use natural motions the motion of the upper limb was analysed and joint trajectories were extracted. For time variation a set of EMG classes were defined, where each class would be triggered with specific characteristics. The results showed that subjects were able to control the arm easily and also there were no changes in movement due to time [18].

EMG controlled Electric-Powered Wheelchairs

Different from the previous studies, this one [19] looks at using just three different shoulder gestures to control an electric wheelchair. These gestures are recognized by using EMG signals generated by the related muscle and comparing them to a pre-set threshold. Fig. 3 shows the commands executed with each gesture. The study also proposes a novel wearable device that for people with C4 or C5 spinal cord injury and above-elbow amputee. A double threshold method is also proposed in the study to discriminate a time difference of muscle activation. The results show that the proposed methods are achievable but need to be tested in a public environment that a controlled environment.

DEFINITION OF MOTION STATES AND COMMANDS BY SHOULDER ELEVATION MOTIONS

Left EMG	Right EMG	State	Command
on	on	0 / 1	Stop / Go forward
on	off	2	Turn left
off	on	3	Turn right
off	off	4	Preserve / Go forward

Fig. 3 Commands executed with each shoulder gesture [19].

EMG-Controlled Prosthetic Hand with Shared Control

To tackle problems of fatigue in multiple DOF prostheses, this study [20] looked at shared control where the control is divided into two parts a low-level control and a high-level control. This would help in grasping as the low-level controlled stability while the high-level deciphered the user's intentions. This study also looks at vibrotactile feedback and how it affected the user's performance. The results showed that the users were able to use the prosthetic hand. The success rate increased with more interactive control. This is good in terms of results but provided that this required more effort the subjects did not perform their best and preferred a less- interactive control. The vibrotactile feedback, on the other hand, did not affect the subject as proposed.

Embedded Human Control of Robots with EMG

The above studies mostly talk about how to use the EMG signals for a certain task or tasks. Most research that is conducted is always task or subject specific. This study [21] looks at a different approach where using abstract mapping functions the user is able to learn to control the artificial system just by learning how to control the EMG sensor. The results of this showed that the performance of the user is dependent on the familiarity of the user with the mapping function. This proved that the EMG could be used for different tasks as long as the user knew how to explore the task space.

Wireless Interface for an EMG controlled Robot Hand

The study [22] presents a wearable device that is enhanced to withstand interfering signals. This is especially needed when used for monitoring systems. To tackle this problem a patch-type module was designed this consisted of a flexible PCB with most of the components embedded. On the sides were the batteries, the microprocessor the Bluetooth module and the three electrodes. This device was also incorporated to convert the EMG signals to low-frequency amplitude signals so that it doesn't miss the instantaneous EMG signals that contain the control information.

Some other studies involving EMG are listed here:

- This study [23] involved comparing EMG signals from the neck and face and head orientation to a mouse cursor. This was to look at cursor control for individuals with tetraplegia. The results pointed out that while EMG exhibited high speed its performance was very low for other categories, especially diagonal movement.
- Similar to the time-varying signals discussed before [17] the study [24] proposed a non-linear incremental learning. This technique with time updates itself with training data which allows it to adapt with time.

- Another similar study [25] looks at continuously getting estimations for arm kinematic and using this to control exoskeleton robot for upper limb rehabilitation.
- This study [26] involves using targeted reinnervation surgery which helps to improve control of a prosthetic arm. This is mainly for high-level upper limb amputees. When there arena lot of control sources available. The results of this study showed increased improvement in function both objectively and subjectively.
- Quite different from the rest, this study [27] looks at using the EMG signals to not control something but is used to reduce tremors in the limb. This is done by having a power assist robot assisting in controlling the vibration of the tremor when the EMG is activated.

There are many more studies involving EMG but the above studies have given an idea of what has already been done and how this project can utilize this data and expand on it. It also gives information on what are the things that are needed to be considered to use EMG signals.

EEG BASED WORK

Reconstructing Three-Dimensional Hand Movements

The study [28] challenges the problem of not being able to extract information on the joint movements of the upper limb when using non-invasive EEG. In this study 55 channels are used to send neural data which then gets continuously decoded to get the 3D data of the hand velocity. The results were good enough when compared to the studies that looked hand kinematics and showed that only 34 channels were needed to get the measured and reconstructed velocity profiles. Another important discovery that was made in the study was that variable movement had a negative effect on the decoding accuracy.

High-performance Neuroprosthetic Control

A study [29] of two 96-channel intracortical microelectrodes implanted into an individual. The goal was to look at providing a solution to restoring some of the lost functions essential for activities of daily living. The individual got trained with a BCI for thirteen weeks to have the individual control a seven degrees of freedom prosthetic limb. During training, the neural signals were recorded and then calibrated to the individual form much better control of the prosthetic limb. The results presented showed a success rate of a mean 91.6 % on a target based task while the time and efficiency increased with time.

EEG controlled Wheelchair

Much similar one in EMG Based work this study [30] uses EEG signals. The difference becomes clear as in this study the user is provided with four auditory navigation commands. To make selection easier there are only two mental tasks presented. Signals recorded during a right-hand motor imaginary task or mental idle state. The results showed that driving around in a virtual environment was achievable but, on a wheelchair only received medium accuracy level.

Brain Machine Interface(BMI) based on Jaw Artifacts

This study [31] looks at reducing the training time required for using EEG signals and also need to be calibrated for every new session. The approach is to use two systems. The EEG signals would be recorded and then this data would be used to extract the EMG data which would be used to control the robotic arm. This could have been done by just using EMG signals on the cheeks but the idea of this study was to use the user's skill of controlling EMG signals and implement them with electrodes of an EEG. The results showed that this implementation is faster than using normal brain signals.

All of these studies have shown that it is much easier to control a robotic arm with EMG rather than EEG. There are too many factors involved in EEG that makes it a very difficult solution. The training time on its own is very long for a user on top of this it is very uncomfortable to wear for a long time. Having to go through this process is not good for the end user. It is good for clinical trials but EEG still needs a lot more research for it to become more commercial.

SIMILAR PROJECTS

Before going to the conclusion there are two more papers that should be discussed. These two have very similar goals when compared to the project goals of this paper. So these will be discussed in much more detail.

ASSISTIVE GRASPING USING EMG AND AUGMENTED REALITY AS A USER INTERFACE

In this study [32], different HMI's are used and tested upon. It also has a novel approach to different grasping techniques, this was done by looking at the geometry of the object. It also has an augmented reality interface which lets the user's plan grasps. The idea of this study was to be able to grasp known and unknown objects from a table. The HMI's used for testing were:

- Four Facial gestures (using emotions, facial movement, EEG responses and EEG)
- EMG placed behind the ear

The Four Facial gestures input, when used with participants, gave a number of problems. First of all, it took very long to set up and get the right threshold. The second was the frustration that the users felt due to the difficulty of using the technology.

The EMG, on the other hand, was easy to use and the user was able to complete the task. There were some problems with this as well like the control with the EMG as a cursor wasn't very accurate.

The results of this study give a detailed method for implementing a fully functional grasping system with some problems which have been tackled and therefore evolving the capabilities of the system.

DECISION AND CONTROL ARCHITECTURE WITH HMI

This study [15] looks at creating a semi-autonomous assistive device for people with upper-limb disabilities. Much like the one discussed before this too picks up objects and place them. The difference is that this study also looks at using the robotic arms as an arm replacement, therefore has a long list of skills library for different tasks. The approach taken was to use BrainGate2 Neural Interface System [29] that gives much more temporal and spatial resolution than others like EEG or EMG. For the hand system, a hand with soft robotics capabilities was chosen.

To make this study successful an assistive planner (Fig. 4) was implemented which selects the skill based on a binary trigger signal. The movement to the target though is done manually by the user. The study also looks at using this system with EMGs. Though this system was only used to look at reaching movements and did not use the assistive planner. The results of this study showed that a participant was fully able to use the interface safely. For the EMG part, there is more work to be done to fully use the proposed interface.

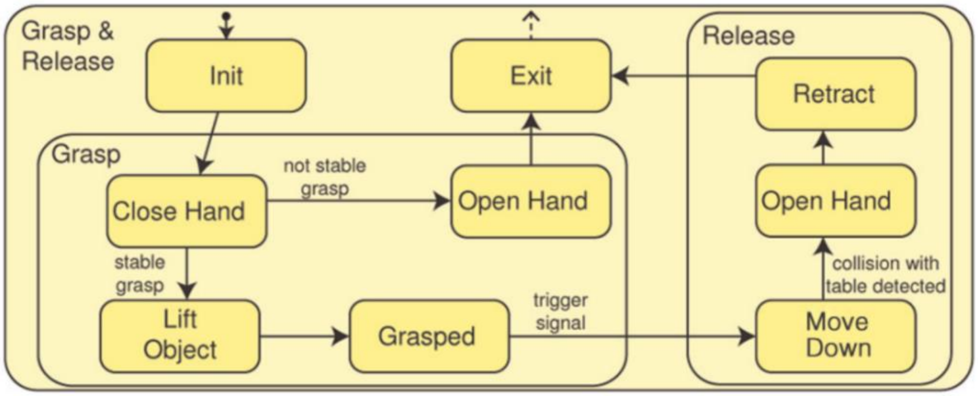


Fig. 4 Assistive planner for grasp and release [15].

CONCLUSION

After understanding about different HMI's and how they have been used in previous projects. It can be seen that EMG is a very non-invasive and safe interface to use to get signals from the human body. Looking at similar projects, Assistive grasping using EMG and Augmented Reality as a User Interface and Decision and Control Architecture with HMI, is quite clear that they have met the most of the objectives of this project. But there are some parts of the project that needs to be looked at and changed. The first issue is the electrode placement and also the number of electrodes, for both projects the electrodes are placed in very uncomfortable places and the second is even invasive, but this is due to the specific people that the project targets. The second issue is the fact that both systems give the user control to move a cursor/ arm to the object location which becomes very difficult for the user to control (this is also talked about in both the projects).

These issues can be easily be resolved and would be done in this project. The first issue is resolved by using just two EMG signals placed in the two arms, this is possible because the target of this project is wheelchair users with lower-limb disabilities. To resolve the second problem the user would only be given the option to select the object when the EMG sensor is triggered. This is easily done as the user just needs to jump through objects. When the right object is selected the user can trigger it through the second EMG signal placed in the opposite hand.

METHODOLOGY

This section looks at the goal and divides it into tasks to get an understanding of what would be needed to accomplish the main goal. The tasks are further divided into smaller tasks so that a time frame can be made. All of this data is then used to make a Gantt chart, to get a visual representation of the data.

TASK DESCRIPTION

TASKS-

1. **Final report literature review**
2. **Get signals from MyoWare sensor**
3. **Make wearable Device**
4. **Recognise objects with camera**
5. **Control the robot**
6. **Combine sensor and robot data**
7. **User Interface**
8. **Find the user and avoid objects**
9. **Final Report and Risk Assessment**

Sub-Tasks for each Task

1) **Final report literature review -** Read about similar projects.

2) **Get signals from MyoWare sensor**
   a) Study about EMG placement and find a good location for the sensor.
   b) Decide on what type of electrodes to use.
   c) Get a good threshold so that the microcontroller does not pass a signal when the user moves their hand normally.

3) **Make wearable Device**
   a) Look at different components needed for the device.
   b) Start designing the device.
   c) Make an appropriate decision on the type of battery to use.
   d) Make sure the wireless device is appropriate for the task.
   e) Start looking at what materials are available and what would be appropriate to use.

4) **Recognise objects with camera**
   a) Use the camera to find the object on the table.
   b) Filter out all the unnecessary objects found.
   c) Find out the distance of the object from the camera.

5) **Control the robot**
   a) Make the robot go to a location by just giving it the x, y and z data.
   b) After giving the robot the location it moves to the location and then after picking up the object, it gives it to the user.
   c) Look at different locations and decide on the best location to place the robot.

6) **Combine sensor and robot data –** Check if all the different parts can talk to each other.

7) **User Interface –** Make a UI so that the user can select the object and run the programme. The UI should show the live camera feed. It should also show the current object that is being selected. When the execute command is given the user should get a pop-up asking if the user wants to execute that task.

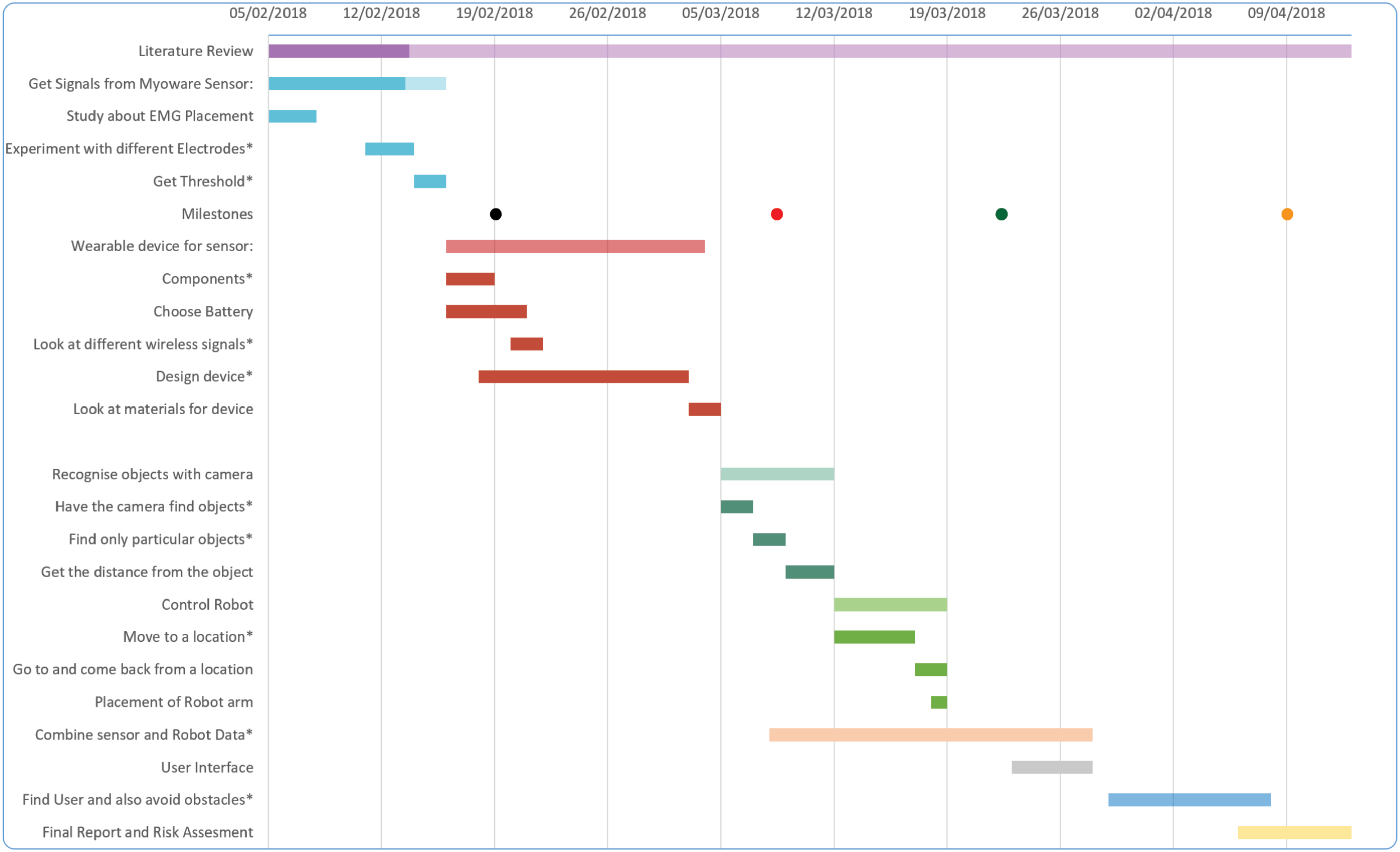
8) **Find the user and avoid objects**
   a) Find the user and avoid obstacles, decide if more cameras should be attached or to use a mechanical system which rotates the camera.
   b) If the camera finds other objects or moving obstacles use joint configurations that avoid them.

9) **Final Report and Risk Assessment –** write the final report and also complete the risk assessment

GANTT CHART

Sub-Goals and Tasks	Start Date	End Date	Duration (Days)	Days Complete	Days Remaining	Percent Complete
Literature Review	05/02/2018	13/04/2018	67	4.02	62.98	6%
Get Signals from Myoware Sensor:	05/02/2018	16/02/2018	11	7.37	3.63	67%
Study about EMG Placement	05/02/2018	08/02/2018	3	3.00	0.00	100%
Experiment with different Electrodes*	11/02/2018	14/02/2018	3	3.00	0.00	100%
Get Threshold*	14/02/2018	16/02/2018	2	0.20	1.80	10%
Wearable device for sensor:	16/02/2018	03/03/2018	15	0.00	15.00	0%
Components*	16/02/2018	19/02/2018	3	0.00	3.00	0%
Choose Battery	16/02/2018	21/02/2018	5	0.00	5.00	0%
Look at different wireless signals*	20/02/2018	22/02/2018	2	0.00	2.00	0%
Design device*	18/02/2018	03/03/2018	13	0.00	13.00	0%
Look at materials for device	03/03/2018	05/03/2018	2	0.00	2.00	0%
Recognise objects with camera	05/03/2018	12/03/2018	7	0.00	7.00	0%
Have the camera find objects*	05/03/2018	07/03/2018	2	0.00	2.00	0%
Find only particular objects*	07/03/2018	09/03/2018	2	0.00	2.00	0%
Get the distance from the object	09/03/2018	12/03/2018	3	0.00	3.00	0%
Control Robot	12/03/2018	19/03/2018	7	0.00	7.00	0%
Move to a location*	12/03/2018	17/03/2018	5	0.00	5.00	0%
Go to and come back from a location	17/03/2018	19/03/2018	2	0.00	2.00	0%
Placement of Robot arm	18/03/2018	19/03/2018	1	0.00	1.00	0%
Combine sensor and Robot Data*	08/03/2018	28/03/2018	20	0.00	20.00	0%
User Interface	23/03/2018	28/03/2018	5	0.00	5.00	0%
Find User and also avoid obstacles*	29/03/2018	08/04/2018	10	0.00	10.00	0%
Final Report and Risk Assesment	06/04/2018	13/04/2018	7	0.00	7.00	0%

* These tasks would involve testing of the design and the code



- Have the Myoware sensor ready to be integrated with the wereable device.
- The wereable device should be ready and be able to give signals.
- The Sensors, the camera and the robot should be working as needed to be properly combined.
- Have the system working properly so that the Final Report can be completed.

RISK ASSESSMENT

MIDDLESEX UNIVERSITY SCHOOL OF DESIGN ENGINEERING AND MATHMATICS

RISK ASSESSMENT

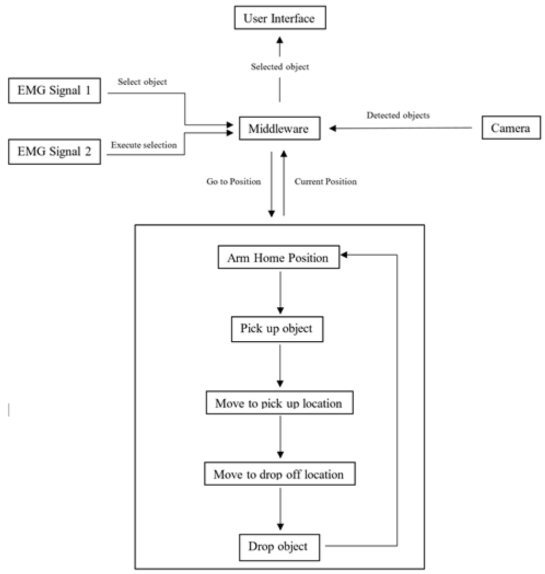
Department/School	Science & Technology, Design Engineering and Mathematics
Project	Assistive Robot with EMG control
Location/s	Middlesex University
Date or period this Risk Assessment covers	30/1/2018 – 15/5/2018
Persons Involved	Raj Manandhar – Dr Eris Chinellato – Puja Varsani
Principal Location address and Contact No.	Middlesex University, Ritterman Building

HAZARD - Pre-vetted Contractors - attach specific assessment		**HAZARD**		**HAZARD**	
Aircraft / "special" flying *	☐	Access/egress	☐	Machinery	☒
Armourers *	☐	Animals	☐	Manual handling (attach specific assessment)	☐
Costume/Make-Up Vehicle	☐	Audience/Public	☐	Mines/excavations/caves/tunnels/quarries	☐
Diving Operations *	☐	Communication Failure	☒	Noise (attach specific assessment)	☐
Explosives/Pyrotechnics/ Fire effects *	☐	Compressed gas/cryogenics	☐	Person with special needs	☐
Flying Ballet *	☐	Confined spaces	☐	Physical exertion	☐
Hydraulic Hoists (Cherry Pickers) *	☐	Derelict Buildings/dangerous structures	☐	Radiation ionising/non ionising	☐
Lasers *	☐	Electricity or gas	☐	Speed	☐
Location Catering	☐	Fire/Flammable material	☐	Tropical Diseases (e.g. Malaria - attach details of medical arrangements e.g. prophylactics, local hospitals and evacuation plan)	☐
Location Lighting Services *	☐	Fight sequence	☐	Vehicles/off road driving	☐
Hire of Lighting Equipment	☐	Glass	☐	Violence/ Public disorder	☐
Scaffolds *	☐	Hazardous substances/ chemicals/ drugs micro-organisms (attach specific - assessment)	☐	Water	☐
Smoke Effects *	☐	Heat/cold	☐	Weather	☐
Stunts *	☐	Hostile Environment: (attach confirmation of clearances from Senior Management)	☐	Working patterns/working hours	☐
Physical Effects	☐	Inexperienced performer or children **N.B.** for children, risk assessment must be provided to parents or guardian.	☐	Working at heights	☐
		Lifting appliances/ machinery	☐	Other	☐

Experts Engaged
List experts used, including pre-vetted contractors. Each pre-vetted contractor should be required to provide the significant findings of their risk assessment in writing. This information should then be included in, or appended to this form and reviewed with other activities and arrangements to check effective co-ordination.

Details of Activity

The user will be wearing a wireless device powered by two button cells. This device would be recording the EMG signal and passing it on to the middleware/computer. The computer will then communicate with the robot and give it the coordinates that it needs to move to. The robot moves to the location and then comes back to the home position. This process will be repeated as many times as desired. The Screen/ User Interface will be showing the camera data and also where the robot is going to go.



Hazards Identified and Risks Arising	
Communication Failure	The robot arm might not get appropriate commands from the user as it is a wireless devise. It might also get activated accidently when not in use.
Machinery	There would be a clear pattern that needs to be sent to the device before sending any commands. There would also be a location range set on the robot to make sure it does not go anywhere near the human. This would prevent the robot from going near the human even if a wrong command was sent. If the human went close enough the robot (Sawyer) itself would stop this is because it was designed to work alongside people and has a certification that meets the ISO requirements by TÜV Rheinland (ISO 10218-1:2011 and PLd Cat. 3).
Physical Exertion	If the EMG sensor is used too much, the user might feel fatigue and the muscles might start to hurt. The practical purpose of the project is to pick up and place the object closer to the user, so that the user can use it. This means that the user would not be using the EMG sensor continuously

N.B. THIS MUST BE SIGNED BEFORE THE EVENT CAN GO AHEAD

I have read the above and am satisfied that:

- It constitutes a proper and adequate risk assessment in respect of the programme activity and that the precautions identified above are sufficient to control the risks.
- Adequate arrangements are in place to communicate the risk assessment findings and to co-ordinate the safety arrangements of all those affected, e.g. site owners, engineers, contractors, freelances, resources, etc.

Signature of Head of Department/Project Leader ....Name

Date:

Details of Safety Training received ☐ Interactive ☐ Other (give details below)

Signature of person conducting this assessment
Name: Raj Manandhar
Date: 14/02/2018

Signature of person with designated responsibility for safety co-ordination

…………………………………………**Name**

Date

Review Date;

BUDGET

Student Number:	M00531244
Project Title:	Assistive Robot with EMG Control
Supervisor:	Dr. Eris Chinellato

Checklist of university resources required (delete rows if not applicable)	
	Comments
3D printing	
Solidworks	Used to design device
Arduino	Required for testing
Raspberry Pi	
Camera	
Sawyer	

Estimated Budget

Name	Link	Quantity	unit cost (ex VAT)	unit cost (inc VAT)	cost	Delivery
MyoWare Muscle Sensor	https://shop.pimoroni.com/products/myoware-muscle-sensor	2	26.67	32.00	64.00	
MyoWare Power Shield	https://shop.pimoroni.com/products/myoware-power-shield	2	4.17	5.00	10.00	
Biomedical Sensor Pad (10 pack)	https://shop.pimoroni.com/products/biomedical-sensor-pad-10-pack	1	6.25	7.50	7.50	
Non-Gelled Reusable Electrodes (10 pack)	https://www.robotshop.com/uk/non-gelled-reusable-electrodes-10pk.html	1	11.25	13.50	13.50	8.84
LiPo Battery Pack 105mAh	https://shop.pimoroni.com/products/lipo-battery-pack	2	3.75	4.50	9.00	
USB LiPo Battery Charger - 3.7V Single Cell	http://www.hobbytronics.co.uk/usb-lipo-charger	1	6.00	7.20	7.20	2.4
Arduino	https://uk.rs-online.com/web/p/products/7154081/?grossPrice=Y&cm_mmc=UK-PLA-DS3A-_-google-_-PLA_UK_EN_Semiconductors-_-Semiconductor_Development_Kits%7CProcessor_And_Microcontroller_Development_Kits-_-PRODUCT+GROUP&matchtype=&gclid=CjwKCAiAweXTBRAhEiwAmb3Xuy0deqArWgdBn5TxxSz1aJHBDwvUJydbMAICaj8AiU46aKGNOhzGBhoCh_EQAvD_BwE&gclsrc=aw.ds	1	15.16	18.19	18.19	
RaspberryPi	https://shop.pimoroni.com/products/raspberry-pi-3	1	26.67	32.00	32.00	
Raspberry Pi 7-Inch Touch Screen Display	https://www.amazon.co.uk/Raspberry-Pi-7-Inch-Screen-Display/dp/B014WKCFR4	1		59.90	59.90	
Camera	https://www.amazon.co.uk/Logitech-960-000355-Webcam-C250/dp/B002CNERDE/ref=sr_1_37?s=computers&ie=UTF8&qid=1518124790&sr=1-37&keywords=logitech+camera	1		12.27	12.27	7.3
Agfa Photo Lithium Coin CR2032 3v Battery - Pack of 10	https://batterywarehouse.co.uk/products/agfa-photo-lithium-coin-cr2032-3v-battery-pack-of-10?variant=27372906312	1		3.99	3.99	
RF receiver	http://uk.farnell.com/hoperf/rfm210w-433s1/receiver-module-433mhz-ook/dp/2759282?MER=bn_level5_5NP_EngagementRecSingleItem_1	2		2.76	5.52	
RF transmitter	http://uk.farnell.com/hoperf/rfm110w-433s1/rf-transmitter-module-ook-433/dp/2759281	2		3.29	6.58	
				TOTAL	268.19	18.54

REFERENCES

[1] (). *Comprehensive civil rights for disabled people*. Available: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/3695/inclusive-mobility.pdf. DOI: 05/02/2018.

[2] (). *Anthropometry of wheeled mobility*. Available: http://www.udeworld.com/wmdescriptionofresearch/wmforwardreach.html. DOI: 05/02/2018.

[3] J. R. Cram, *Cram's Introduction to Surface Electromyography.* Jones & Bartlett Learning, 2010.

[4] (). . Available: http://www.uhs.nhs.uk/OurServices/Brainspineandneuromuscular/Clinicalneurophysiology/Electromyography.aspx. DOI: 06/02/2018.

[5] (). . Available: https://www.mayoclinic.org/tests-procedures/emg/about/pac-20393913. DOI: 06/02/2018.

[6] I. Hussain *et al*, "an eMg interface for the control of Motion and compliance of a supernumerary robotic Finger," *Frontiers in Neurorobotics,* vol. 10, pp. 18, 2016.

[7] A. A. Adewuyi, L. J. Hargrove and T. A. Kuiken, "Evaluating EMG feature and classifier selection for application to partial-hand prosthesis control," *Frontiers in Neurorobotics,* vol. 10, pp. 15, 2016.

[8] G. Kamen and D. A. Gabriel, *Essentials of Electromyography.* Champaign, IL: Human Kinetics, 2010.

[9] D. J. Hewson *et al*, "Evolution in impedance at the electrode-skin interface of two types of surface EMG electrodes during long-term recordings," *Journal of Electromyography and Kinesiology,* vol. 13, *(3),* pp. 273-279, 2003. . DOI: https://doi.org/10.1016/S1050-6411(02)00097-4.

[10] V. Sundstedt, Blekinge Tekniska Högskola and Sektionen för datavetenskap och kommunikation, *Gazing at Games: An Introduction to Eye Tracking Control.* 2012; 2011*14; 14.*

[11] A. T. Duchowski, "A breadth-first survey of eye-tracking applications," *Behavior Research Methods, Instruments, & Computers,* vol. 34, *(4),* pp. 455-470, 2002.

[12] R. G. Lupu and F. Ungureanu, "A survey of eye tracking methods and applications," *Bul Inst Polit Iasi,* pp. 71-86, 2013.

[13] J. R. Evans and A. Abarbanel, *Introduction to Quantitative EEG and Neurofeedback.* 1999.

[14] S. Sanei and J. Chambers, *EEG Signal Processing.* 2007.

[15] J. Vogel *et al*, "An assistive decision-and-control architecture for force-sensitive hand–arm systems driven by human–machine interfaces," *The International Journal of Robotics Research,* vol. 34, *(6),* pp. 763-780, 2015.

[16] M. Ison and P. Artemiadis, "Proportional myoelectric control of robots: muscle synergy development drives performance enhancement, retainment, and generalization," *IEEE Transactions on Robotics,* vol. 31, *(2),* pp. 259-268, 2015.

[17] P. K. Artemiadis and K. J. Kyriakopoulos, "An EMG-based robot control scheme robust to time-varying EMG signal features," *IEEE Transactions on Information Technology in Biomedicine,* vol. 14, *(3),* pp. 582-588, 2010.

[18] P. K. Artemiadis and K. J. Kyriakopoulos, "EMG-based control of a robot arm using low-dimensional embeddings," *IEEE Transactions on Robotics,* vol. 26, *(2),* pp. 393-398, 2010.

[19] I. Moon *et al*, "Wearable EMG-based HCI for electric-powered wheelchair users with motor disabilities," in *Robotics and Automation, 2005. ICRA 2005. Proceedings of the 2005 IEEE International Conference on,* 2005, pp. 2649-2654.

[20] C. Cipriani *et al*, "On the shared control of an EMG-controlled prosthetic hand: analysis of user–prosthesis interaction," *IEEE Transactions on Robotics,* vol. 24, *(1),* pp. 170-184, 2008.

[21] C. W. Antuvan, M. Ison and P. Artemiadis, "Embedded human control of robots using myoelectric interfaces," *IEEE Transactions on Neural Systems and Rehabilitation Engineering,* vol. 22, *(4),* pp. 820-827, 2014.

[22] K. Lee *et al*, "A wireless ExG interface for patch-type ECG holter and EMG-controlled robot hand," *Sensors,* vol. 17, *(8),* pp. 1888, 2017.

[23] M. R. Williams and R. F. Kirsch, "Evaluation of head orientation and neck muscle EMG signals as command inputs to a human–computer interface for individuals with high tetraplegia," *IEEE Transactions on Neural Systems and Rehabilitation Engineering,* vol. 16, *(5),* pp. 485-496, 2008.

[24] A. Gijsberts *et al*, "Stable myoelectric control of a hand prosthesis using non-linear incremental learning," *Frontiers in Neurorobotics,* vol. 8, pp. 8, 2014.

[25] J. Liu *et al*, "EMG-Based Continuous and Simultaneous Estimation of Arm Kinematics in Able-Bodied Individuals and Stroke Survivors," *Frontiers in Neuroscience,* vol. 11, pp. 480, 2017.

[26] L. A. Miller *et al*, "Improved myoelectric prosthesis control using targeted reinnervation surgery: a case series," *IEEE Transactions on Neural Systems and Rehabilitation Engineering,* vol. 16, *(1),* pp. 46-50, 2008.

[27] K. Kiguchi, Y. Hayashi and T. Asami, "An upper-limb power-assist robot with tremor suppression control," in *Rehabilitation Robotics (ICORR), 2011 IEEE International Conference on,* 2011, pp. 1-4.

[28] T. J. Bradberry, R. J. Gentili and J. L. Contreras-Vidal, "Reconstructing three-dimensional hand movements from noninvasive electroencephalographic signals," *J. Neurosci.,* vol. 30, *(9),* pp. 3432-3437, Mar 3, 2010.

[29] J. L. Collinger *et al*, "High-performance neuroprosthetic control by an individual with tetraplegia," *The Lancet,* vol. 381, *(9866),* pp. 557-564, 2013.

[30] R. Ron-Angevin *et al*, "Brain-Computer Interface application: auditory serial interface to control a two-class motor-imagery-based wheelchair," *Journal of Neuroengineering and Rehabilitation,* vol. 14, 2017.

[31] Á. Costa *et al*, "A supplementary system for a brain-machine interface based on jaw artifacts for the bidimensional control of a robotic arm," *PloS One,* vol. 9, *(11),* pp. e112352, 2014.

[32] J. Weisz *et al*, "Assistive grasping with an augmented reality user interface," *The International Journal of Robotics Research,* vol. 36, *(5-7),* pp. 543-562, 2017.