Redesign of the ALIMCO Hand

Product Design Project-II

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Masters in Industrial Design

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Approval

This is to certify that the Industrial Design project titled :

Redesign of the ALIMCO Hand

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Is approved for the partial fulfillment of his Masters of Design degree in Industrial Design.

Signature of the Project Guide:

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Declaration

I here by declare that the project report entitled “Redesign of the ALIMCO Hand” submitted by me to Industrial Design Centre, IIT Bombay in partial fulfillment of the requirement for the award of the degree of Masters of Design is a record of bona fide project work carried out by me under the guidance of Prof. B.K. Chakravarthy. I further declare that the work reported in this project has not been submitted and will not be submitted, either in part or in full, for the award of any other degree or diploma in this institute or in any institute or university.

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Place: IIT Bombay

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My special thanks to the workshop staff of IDC for their kind cooperation and help.

Abstract

Limb loss is a psychological burden upon the amputee. It is a stressful, irreversible event which may leads to a poor quality of life.

According to National Sample Survey Organization Estimates of the Physically Disabled Persons in India (1983), the total number of amputees in the country is about 424,000 (0.62 per 1000).

A prosthetic limb is considered successful if it can fulfill two conditions:

- Create an adequate cosmetic appearance
- Provide some functional restoration of the lost limb

After interviewing the primary, secondary and the tertiary users at BMVSS (Jaipur) and Alimco (Kanpur), the author found that preference was given to the cosmetic appearance of the artificial limb over functional restoration. It was also important that the product be frugal and cost effective to address the Indian context. This became the motivation of the project.

The final design provides enhanced gestures to the existing Alimco hand using improved linkages and lever mechanisms to grab onto articles of daily use such as cylindrical bottles, toothbrush, etc. The designed prosthetics arm also has proper hand proportions, texture and colour to resemble a real hand as prescribed by the users.

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1.0 Introduction

Limb loss is a burden, for the patient and for their care givers. It also imposes financial and psychological burden upon the amputee. Amputation of a limb is a stressful event for an individual. It is a surgical option in circumstances where salvaging a limb is improbable, and the remaining part of the limb tissue needs excision. It is an irreversible surgical option which results in bodily disfigurement. The patient is affected emotionally and this results in poor quality of life. The amputee may develop depressive disorder due to feelings of loss, self-stigma, and difficulty in coping with the impairment. The health-care service in India differ considerably than elsewhere. Mental health care access is very difficult and fragmentary.

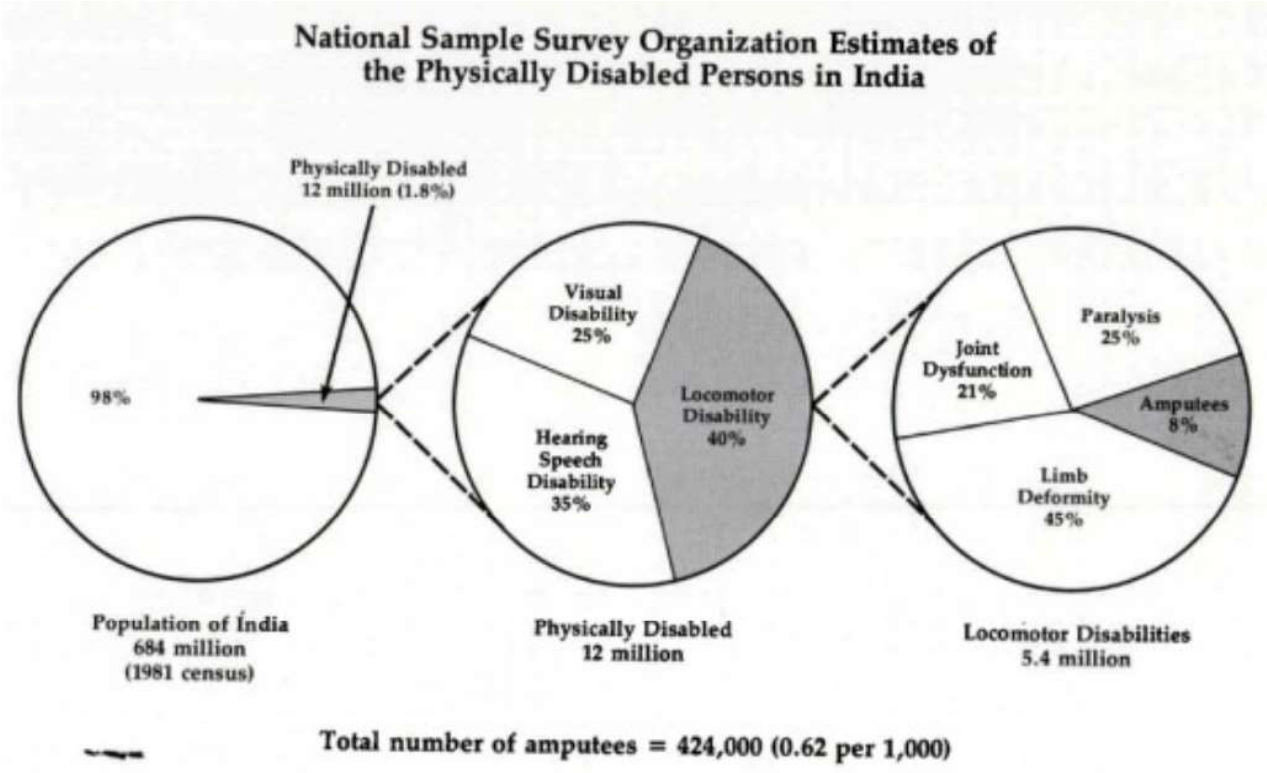
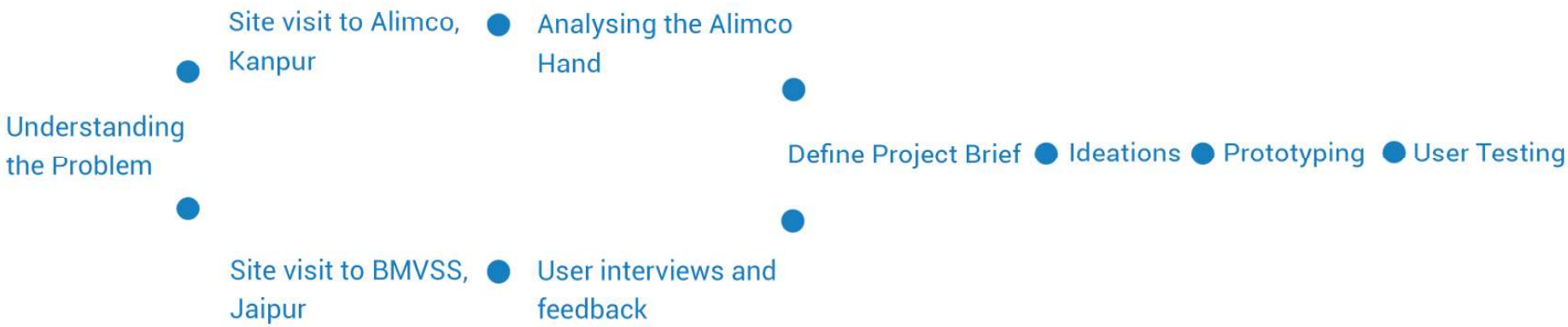


Figure 1: National Sample Survey Organisation Estimates of the Physically Disabled Persons in India
Source: A report on amputees, Dinesh Mohan, 1983 <http://www.oandplibrary.org/op/pdf/1986_01_016.pdf>

2.0 Road map of the project



3.0 Understanding the user

3.1 Bhagvaan Mahavir Viklang Sahayta Samiti (BMVSS)

A visit to Bhagvaan Mahavir Viklang Sahayta Samiti (BMVSS) was made by the author to understand the hardships faced by amputees in India. Physically disabled people come to this Centre because where prosthetic limbs are distributed here as charity.

BMVSS is an NGO in Jaipur, Rajasthan which provides assistance to physically impaired, including artificial limbs, calipers and other aids and appliances, free of charge.

It is known for the 'Jaipur foot' a low cost prosthetic leg, hence a lot of lower limb amputees are seen in the campus. The organization also gives away the 'Alimco' hand to upper limb amputees.

Further information can be gathered on the organization by visiting *www.jaipurfoot.org.*

Figure 2: A sight outside the entrance of BMVSS early in the morning where amputees from around the country wait for their turn to be fitted with a prosthetic limb.
Source: Shenoy Innovation Centre, IITB

4.0 Primary interviews

Several interviews were conducted at BMVSS to understand the depth of the problems faced by the amputees:

4.1 Dr. Ashok Mahnot (Centre Head)

“The main concern of the organization is to provide a technology which is suitable for Indian condition and the users. It is very important that the product be frugal and cost effective. People in India want a realistic looking hand with nails, color and even hair as social stigma prevails in the country.”

4.2 Dr. P.K. Jain (Chief Surgeon)

“The problem with an electric hand is that the patients who come here are not educated and require physiotherapy training to develop the muscles to work with the sensors. The patients who come here are not interested in physiotherapy. They do not have such time.”

4.3 Mr. Prashant Gade (founder of Inali foundation)

Inali foundation is a startup working in accord with BMVSS to develop cheaper alternatives to electronic prosthetic hands.

“According to the users, 70% of the product should be cosmetics. Appearance is preferred over function. One silicon glove costs about 19-20k, but its very realistic and customizable.”

4.4 New Alimco hand users

User 1: ‘We now have a photocopy of the natural hand so it is satisfying. I am very happy’.

User 2: ‘I’ll be able to lift the hands after a little practice’.

User 3: ‘Better than not having anything’

User 2: ‘The shirt sleeve will not swing at least. A lot of people on the streets will not know the difference’.

Figure 3: New user getting the below elbow Alimco hand at BMVSS, Jaipur.

4.5 Sumit (IITB student)

Sumit is an above elbow amputee who is a M.Tech student of IITB.
Interestingly, he got an Alimco hand from BMVSS few years back but decided he is better off without it. This is what he has to say:

"The experience I have with the Alimco hand is of one week. The problem was, if you want to move the hand you have to bring both your shoulders in front, this process is difficult to work with. The efficiency to perform an activity goes down. It disables you further.
I had to carry the weight of the prosthetic.
Traveling is also troublesome as one cannot carry it around. Also it is not useful for day to day life activity.
The material used is very tough so my residual arm pains when I put it on.
Electronic prosthetic arm doesn't demand the user to apply much force hence is preferable.
Docking and un-docking the prosthetic arm is also very difficult. Someone has to hold the limb in place, to tie the belt around the shoulders.
When I saw the mechanism I quickly figured out that it will not work for me.
Even if its not working, it should at least be lightweight so the rest of the body doesn't feel burdened.
I can work with one hand because of necessity, anybody would. At Least this much I expect from an artificial arm to support the good arm at activities wherever possible.
I don't think an artificial limb will empower complete efficiency like a real arm.
The Alimco hand is useful if its below elbow. But above the elbow prosthetics are very problematic.
In the beginning I thought a realistic looking hand is necessary but if the basic functionality is not fulfilled then aesthetics becomes secondary. It's a bonus if the artificial hand looks real."

4.6 Observations

To understand how an amputee carries out activities Sumit was shadowed for a day. The following are some observations:

There is mostly a need for a flat horizontal surface (ground or table top, etc) to handle any article or item so the amputee can change the grip of the good arm.

Some activities which were observed are:

- When folding clothes
- Arranging pens in a pen stand

Some activities where the residual arm is used primarily as an opposing action are:

- Using scissors to cut a paper (need table top)
- Keeping the bag open for the good arm to handle the items.
- Opening up a laptop screen
- Cutting nails

The time taken to do a task is more but Sumit can manage most of them. Some alternative methods used by him to hold the items are:

- Armpit grip (using the residual arm and the side of the chest)
- Shoulder to ear grip (when using the phone)
- Pressing the residual arm against a surface (opposing action)

Some tasks are difficult to do such as

- Lifting heavy boxes off the ground
- Tying a shoelace

Some tasks are not possible to do such as

- Working with hardwares and tools
- Unable to wash the upper side of the good arm
- Lighting a matchstick, etc.

5.0 Problems to address when developing artificial arm

How to attach the artificial limb to the body?

How to make it comfortable for the residual hand?

Movement of the elbow?

Movement of the wrist?

Grip options on the hand?

5.1 Attachment of the artificial arm to the body

The present shoulder brace/ belts:

- Does not have any kind of padding
- Need assistance to wear
- Leaves rashes on the skin after prolonged use like armpit and back of the neck

Figure 6: The harness provided with the kit worn by new users

Following are some suggestions which could help in improving the harness systems.

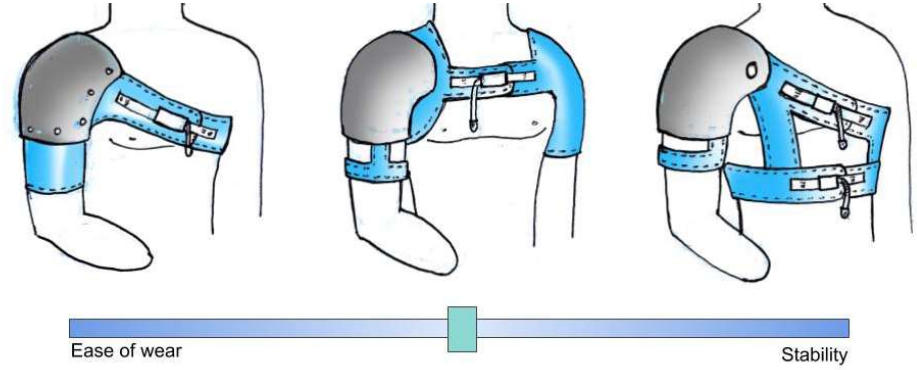


Figure 4: The braces could be made broad to distribute the pressure. There needs to be a good balance between ease of wear and stability.

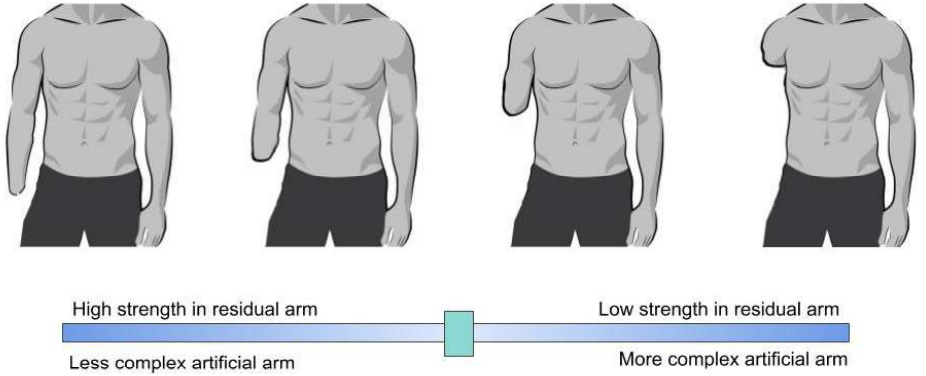


Figure 5: Varying length of the residual arm and its complexities.

5.2 Design of the stomp

The residual limb may have projected bones, thin skin and heightened sensitivity.
The current method of making a stomp involves PoP casting and thermo-forming. The resultant is a hard plastic material which is not very good with skin surface. Such stomps sometimes cause blisters, rashes, cuts and soring as they are unable to adapt to bodily changes.
Right now, patients have to visit Centre like BMVSS to get custom stomps made. But recent advancements in 3D scanning allows the volumetric data of the residual limb to be sent to the Centre. The Centre can use this data to plan out and make a custom socket which is unique to the users residual limb. This method would increase the comfort level of the amputee and encourage the use of the prosthetics. This would also save the patient valuable time and money spent on travel.

Figure 7: Residual arm

Figure 8: Identifying the pain and strength regions on the residual arm

Figure 9: Stitching a 3D mesh around the strong regions to provide support for the hand extension

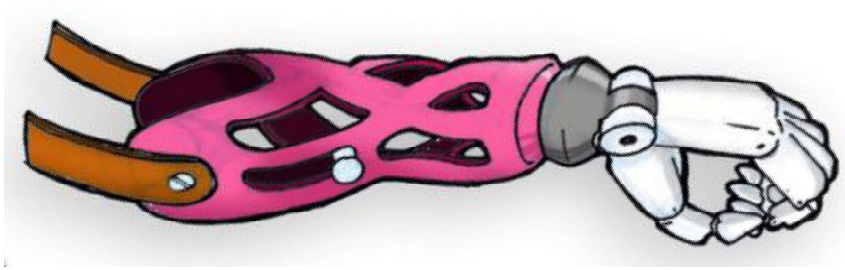


Figure 10: The resultant may be a 3D printed stomp which provides air circulation and is lightweight

6.0 Understanding the product and its manufacturing

6.1 Site visit to Alimco, Kanpur

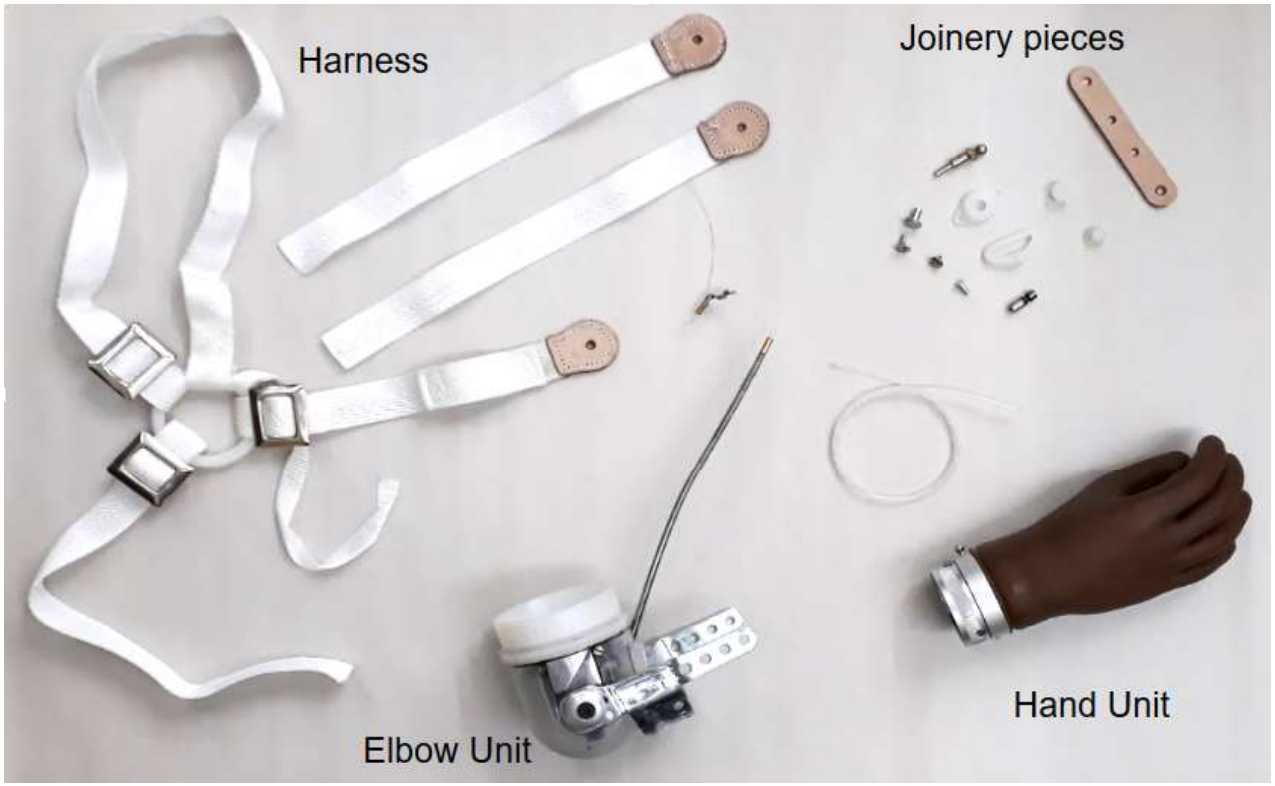
Alimco, Kanpur is the largest upper limb prosthetic arm provider to India.
Artificial Limbs Manufacturing Corporation of India (Alimco) is a Schedule 'C' Miniratna Category II Central Public Sector Enterprises, registered under Section 8 (Not for Profit motive) of the Companies Act 2013, (corresponding to Section 25 of the Companies Act, 1956) is functioning under the Administrative Control of Ministry of Social Justice & Empowerment, Department of Empowerment of Persons with Disabilities. The Corporation started manufacturing artificial aids in 1976.
The Corporation is the only manufacturing company producing various types of assistive devices under one roof to serve all types of disabilities across the country like:

- Calipers, Artificial legs and hands, Braces for neck & back socks and surgical boots
- Wheelchairs (manual & motorized), Tricycles(Manual & Battery Operated), Axilla & Elbow crutches
- Braille shorthand machine, Braille slate, Walking cane & stick
- Pocket type Hearing Aid, Digital type Behind the Ear (BTE) Hearing Aid.

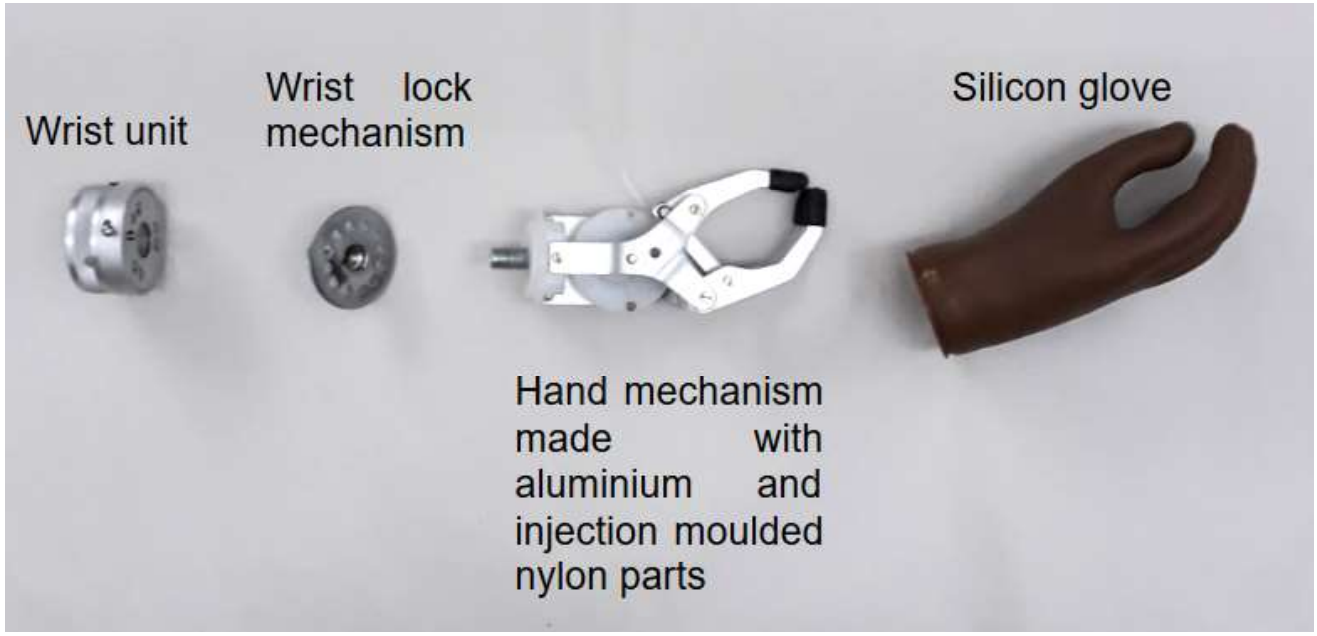
Figure 11: Assembled Alimco hands at Alimco workshop, Kanpur.

6.2 The above elbow kit by Alimco

Alimco makes kits to be sold at affordable prices, which are supplied to Centres like BMVSS for customization and fitting according to the patient. Currently, such kit is sold at about Rs. 6,000. The components are made of injection molded plastic parts, aluminum sheet punched into shape, stainless steel where strength is required, and all of these are put together in place by nuts-bolts and rivets.



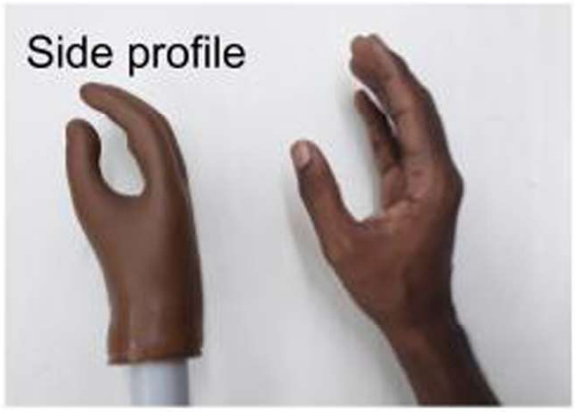
6.3 The hand unit: disassembled

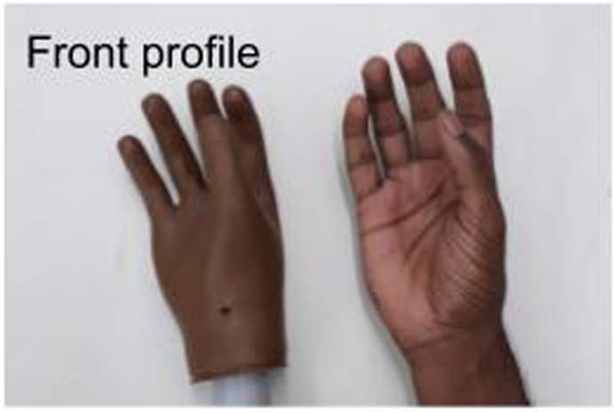


7.0 Analysis of the Alimco Hand

The hand unit was analised to find the following drawbacks:

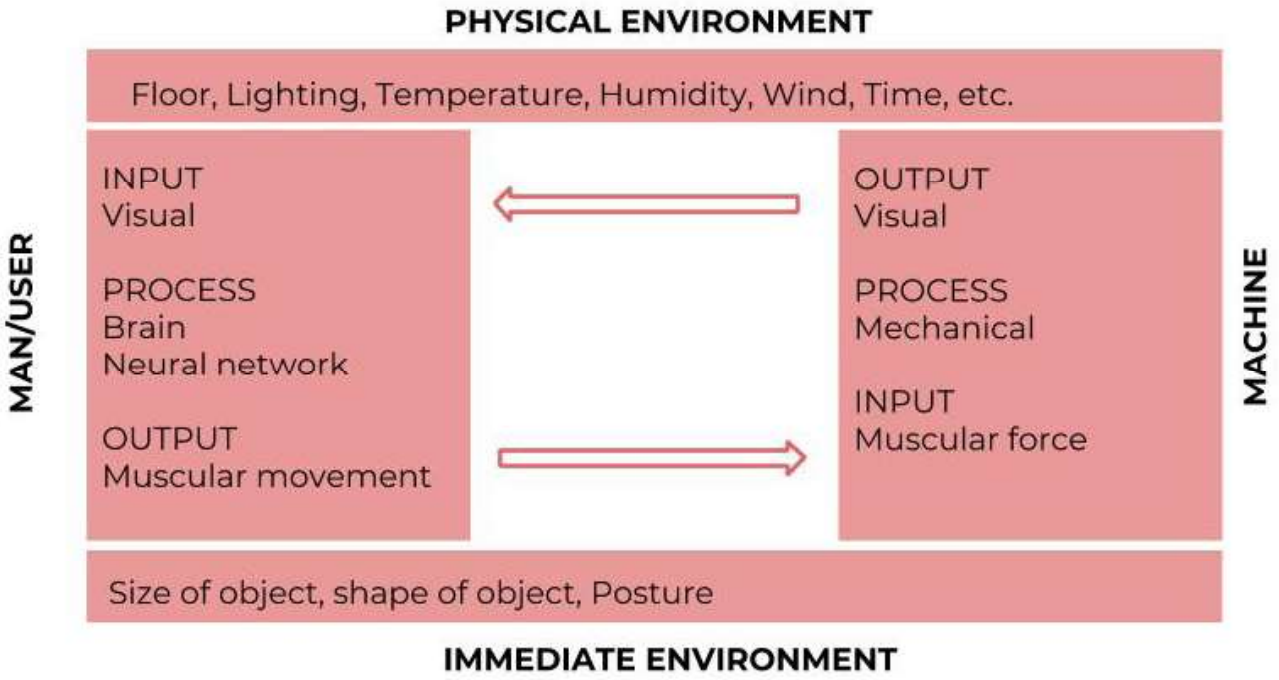
- Heavy (430gm)
- Proportions and shape of hand is not natural looking
- Aesthetics and colour of silicon glove is not pleasing
- The pulling wire is exposed and does not look natural
- Ring and Pinky fingers are stationary and do not contribute to the movement
- The wrist moves along the central axis only
- The hand grip opens only about 8.0 cm
- There is a gap of 2.0 cm between fingers when at resting position
- The palm cavity is small
- Harness limits the range of motion
- Only one gesture is provided'
- The user has to approach an object from the side
- Cannot pick objects off the ground.





8.0 Man Machine Environment (MME) Model

A man machine environment chart was prepared to understand the interaction of the prosthetic arm and the amputee.
The user is heavily dependent on visual sense.



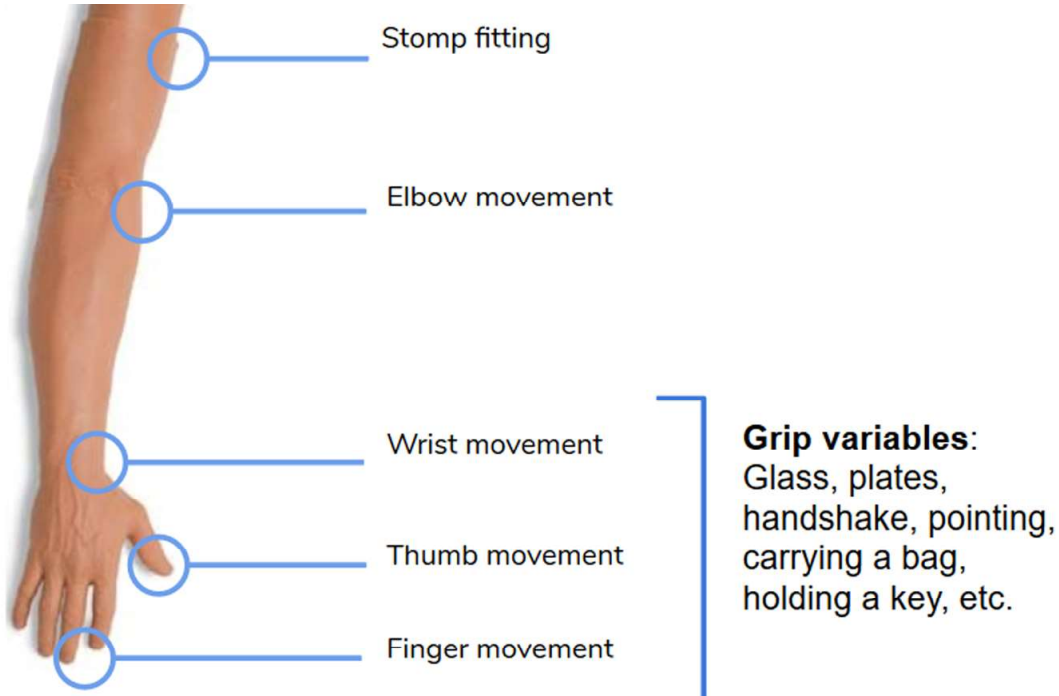
9.0 Design Brief

The project brief was prepared after the analysis of all the interviews conducted at BMVSS, Jaipur and from in IITB, Mumbai which is as following :-

To design a prosthetic arm which:

- Is easy and comfortable to wear
- Does not require complex movement of other parts of the body.
- Is lightweight.
- Is easy to understand and use.
- Have additional features like magnetic tip or hook.
- Look as realistic as possible.

10.0 Scope of the project



The primary scope of the project is limited to the mechanical hand unit.

The mechanical Alimco wrist is used as is.

The stomp is designed for below elbow amputees.

11.0 Upper Limb prosthetics

Any prosthetic hand is considered successful if it is able to fulfill two conditions:

- Creating an adequate cosmetic appearance
- Providing some functional restoration of arm and hand movements

A cosmetic (passive) hand can fulfill the following functions:

- Provide opposing function: for example stabilizing a paper while writing
- Psychological benefits: overcoming self-consciousness, societal pressure and phantom limb syndrome
- Postural benefits: restoring body symmetry, may also prevent associated muscular or skeletal problem emerging over time

The overall cosmetic effect is created by a combination of a convincing device:

- The correct wearing of the prosthesis, and
- Its correct integration into everyday life.

Figure 12: Still from the video of Bebionic official world launch in Leipzig, Germany. May 2010
Source: < https://singularityhub.com/2010/06/30/how-much-is-the-newest-advanced-artificial-hand-11000-usd-video/#sm.0004sppe01bmoel3yh72qsicd3yjv>

11.1 Functional Restoration of a prosthetic hand

Even the most advanced prosthetics cannot compete with a natural hand.

A prosthetics will require maintenance and adjustments or calibrations to accommodate changes to lifestyle demands or body dimensions.

An ideal prosthetic should be able to provide tactile sensation, proprioceptive feedback and have an aesthetic appearance.

A prosthetic can restore functional value by isolating a series of achievable functions, which make valuable a contributions to daily life.

It is inevitable that the resultant prosthetics would have a number of elements.

Functional restoration can be tricky as no designer can imagine the number of functions a hand can perform.

Figure 13: Examples of currently available prosthetic hands. Body-powered terminal devices and myoelectric hands interpret muscle signals from a patient's body to actuate battery-powered robotic motors.
Source: <https://www.researchgate.net/figure/Fig-Examples-of-currently-available-prosthetic-hands-Body-powered-terminal-devices-and_fig1_273914142>

Figure 14: Varying typology of prosthetic hand extensions and the adaptation of the Alimco hand.

11.2 Below elbow prosthetics available in India

The Myoelectric hand uses electronic sensory devices within the stomp.

Figure 15: Myoelectric-hand-prosthesis priced at Rs. 1.25 lakhs
Source: < https://www.indiamart.com/proddetail/myoelectric-hand-prosthesis-10559552148.html>

The artificial hand uses a harness that goes around the shoulder of the user to operate the hand.

Figure 16: Artificial-hand, body operated priced at Rs. 20,000
Source: < https://www.indiamart.com/proddetail/artificial-hand-10023408448.html

Figure 17: An expert from Dee Dee Labs demonstrates the working of the prosthetic hand.
Source: <https://indianexpress.com/article/cities/pune/pune-city-startup-to-develop-low-cost-prosthetic-hand-4667693/>

Figure 18: 14-year-old Sahil from Srinagar uses high-tech artificial limbs being produced by an Indian manufacturer to help disabled people gain limb function at Vinobapuri, Lajpat Nagar-II in New Delhi.(Raj K Raj/HT PHOTO)
Source: < https://www.hindustantimes.com/delhi-news/customised-high-end-prosthetics-that-don-t-burn-a-hole-in-your-pocket/story-a6p6VtyVzuXjwPriSrOhNO.html>

A Pune based startup called Dee Dee has developed a low-cost prosthetic hand. The product will be available for a cost in the range of Rs 1-1.5 lakh.

High-tech customized prosthetics for amputees are now available in India at half the price of imported ones that cost upwards of Rs 1.5 lakh. The makers use expensive 3-D printing technology to get the right shape and fit of the limb

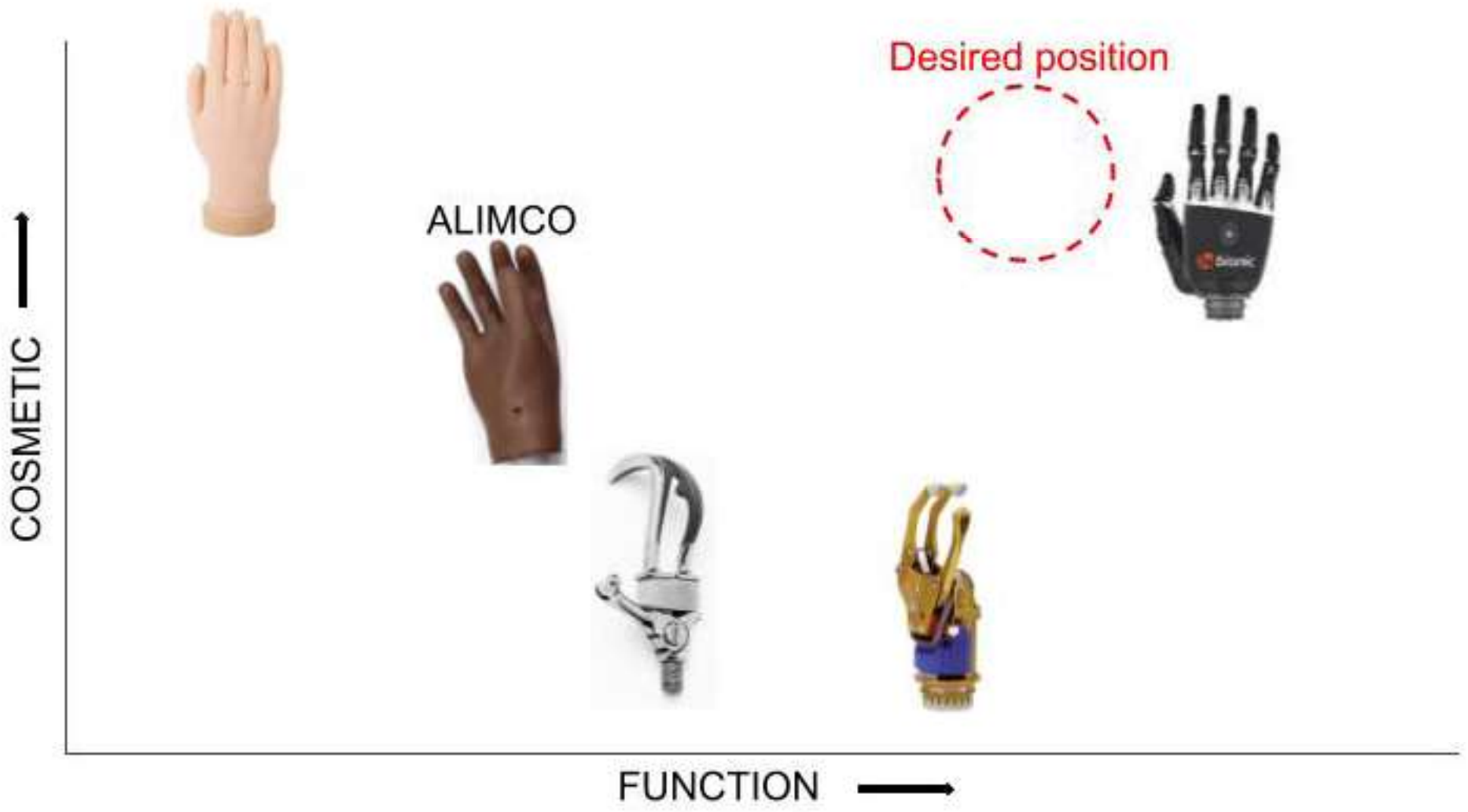


Figure 19: Schematic Cosmetic vs Function graph indicating the desired position to be taken by the redesigned Alimco hand.

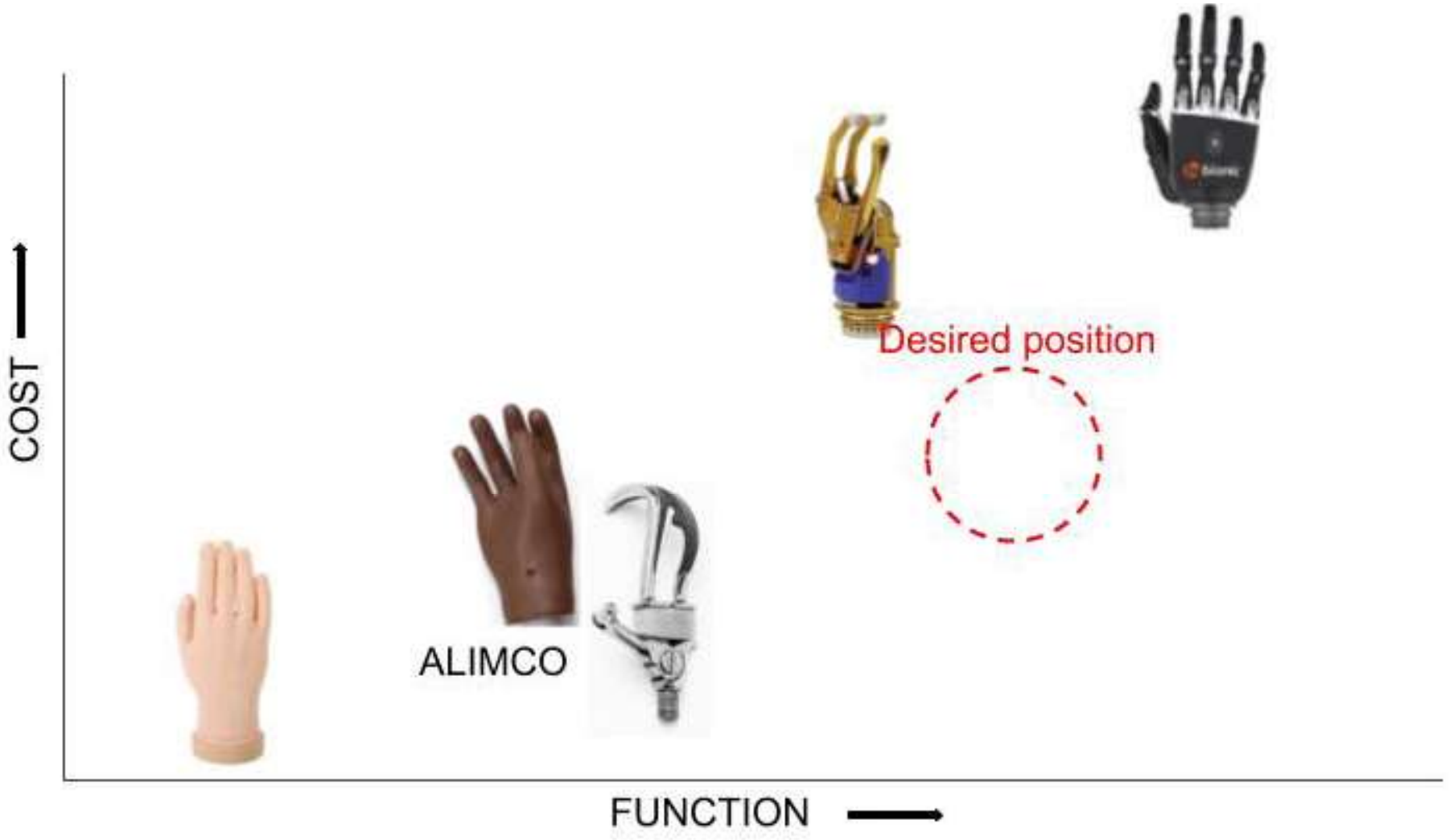


Figure 20: Schematic Cost vs Function graph indicating the desired position to be taken by the redesigned Alimco hand.

12.0 Design Objective

The battery operated Bionic hand have components like motors and integrated circuits which enables them to be programed to perform various gestures for different functions hence, are very expensive. These Bionic hands also have very sophisticated input systems which adds to the efficiency of the machine.
On the other hand we have the Alimco mechanical hand which is powered by a harness around the users shoulders, which has only one gesture i.e. opening/closing of the Thumb, Index and the Middle finger, but is cost effective, hence has more reach.
The design objective is to find a balance between these two diverse products which claim to provide a solution to the same problem.

The hand has to be able to perform function efficiently by holding onto varied objects/articles of different sizes using limited input or control.

Limited input of controls
As compared to a real arm

→

Economy of movements
To establish a gesture which would cater to a wide range of functions

Example:

Opposing action to grab objects like thread, stick, paper, etc.

The form allows to pull objects, pick up bags from ground, hang, etc.

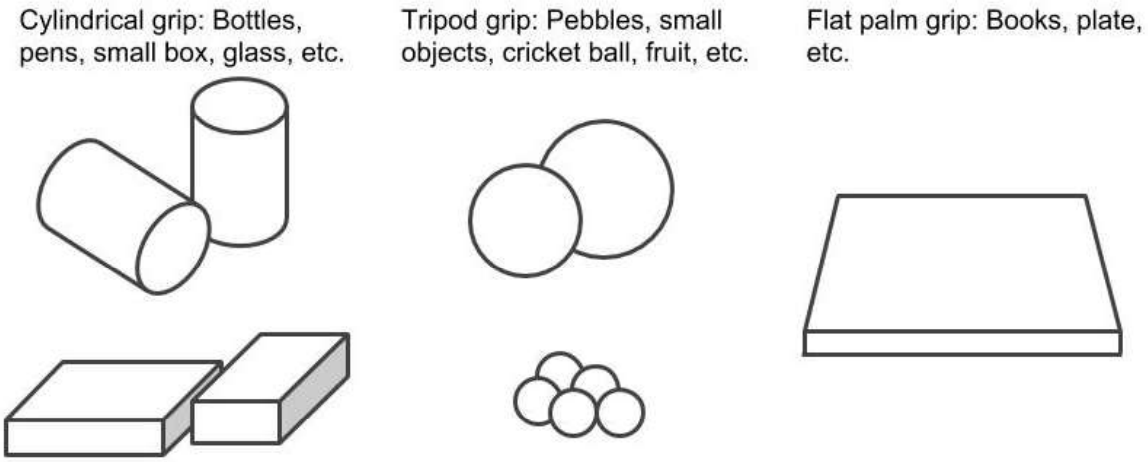
13.0 Gesture exploration

13.1 Shapes and sizes of objects

The Alimco hand provides a basic open/close gesture which is not adequate to hold the varied range of forms and shapes.

To hold a cylindrical object the user has to approach the article from the sides as there is no movement of the wrist. It is also very difficult to pick objects from the ground. Since there is no tactile feedback, the user has to rely on visuals only.

Any object can be held by the following categorized grips:

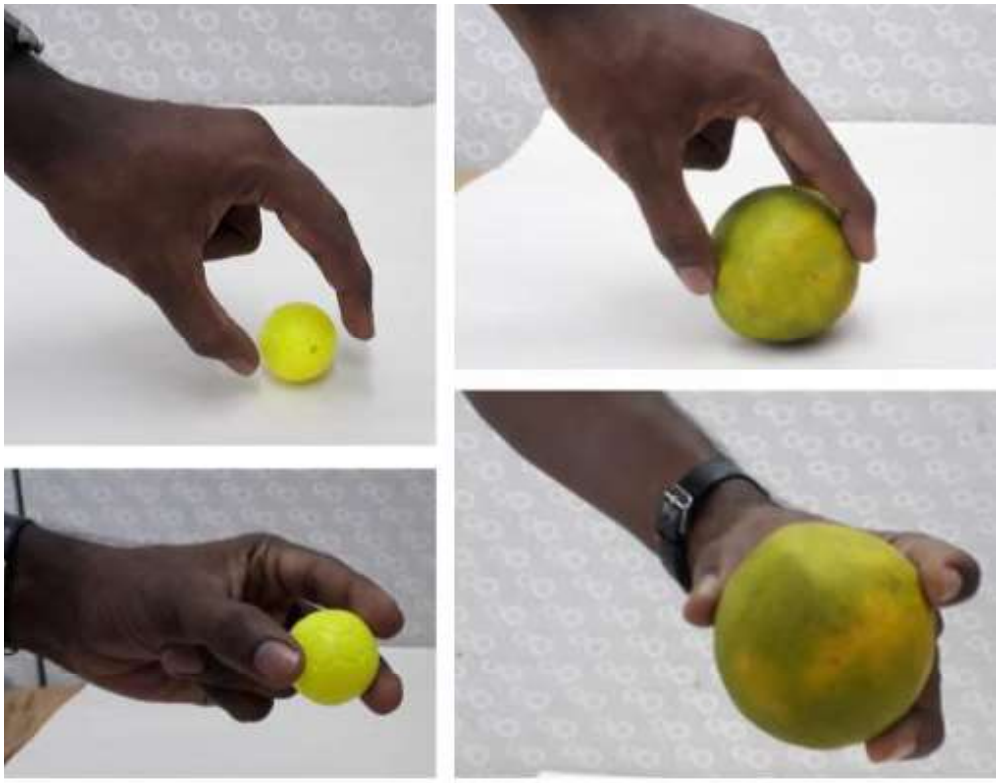


13.2 Picking cylindrical objects:

To pick objects from the table or the ground, the wrist has to move about 90 degrees outwards.

13.3 Picking round objects:

The three fingers (thumb, index and middle) grip or tripod grip is good to provide a stable hold around the object.



13.4 Picking thin objects:

The tripod grip also works to pick thin objects, provided the finger tips have good friction.
Example: pulling a card from a deck, holding a CD or even picking objects like mobile phone.

13.5 The ring and pinky finger:

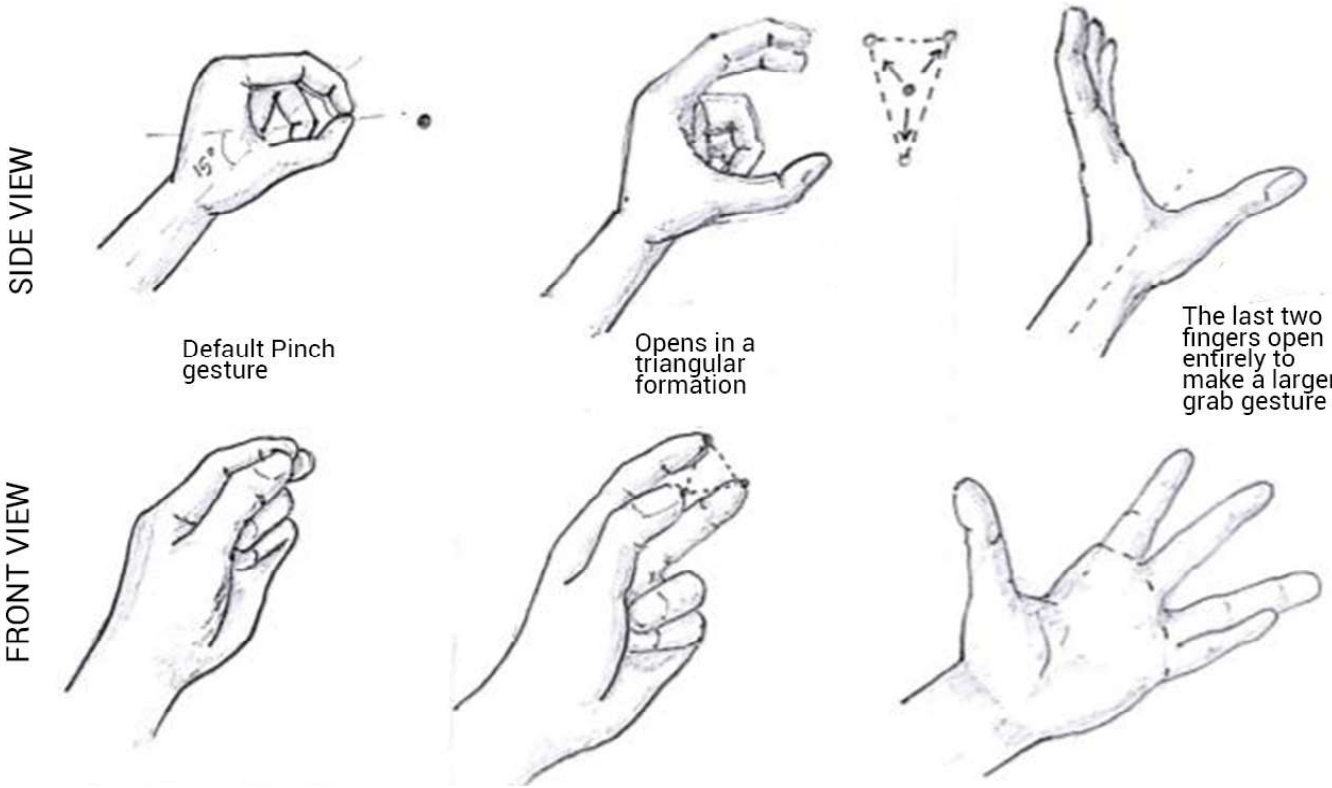
The ring and pinky finger have more joints, hence can hold thin objects.
Example: pens, toothbrush, etc.
The ring and pinky finger can also act as a support for the tripod grip.

13.6 Opposing function:

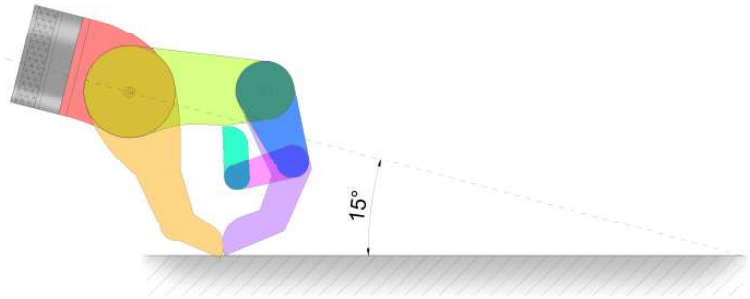
Like any passive hand, this hand can provide basic opposing function.

13.7 Consolidated Gestures:

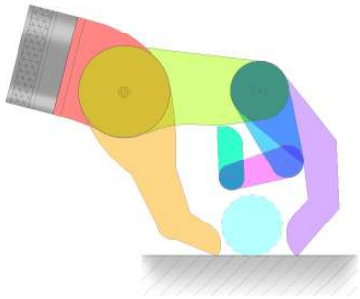
After the grip analysis a sequence of gestures was achieved. These sequence of gestures can pick or grab most number of objects, if not all. This two step gesture motion can reduces the number of inputs drastically to just one action.



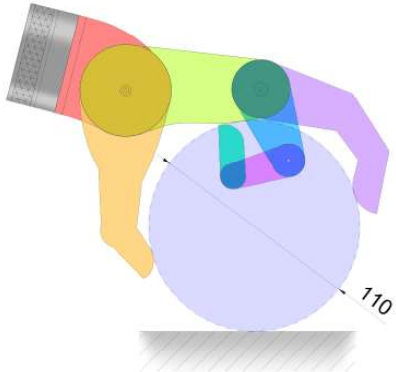
Resting Gesture. When the arm is at 15 degree to the surface of a table, the tips of the three fingers (Index, Middle and the Thumb) form a pinch hold.



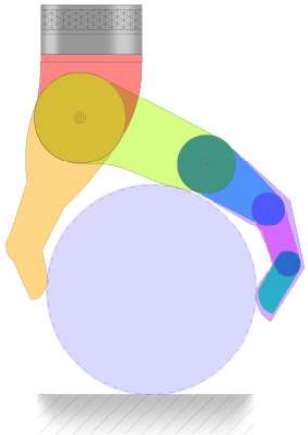
Only index and middle finger move to hold small objects against the thumb.



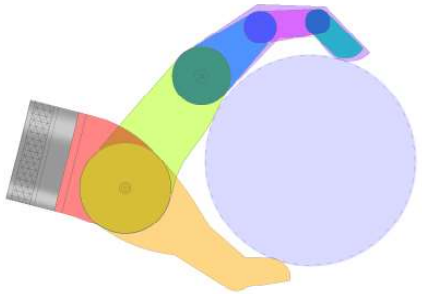
To grab large object (maximum dia of 110mm), the thumb moves.



The wrist moves outward to pick objects from the ground



The Ring and Pinky finger move with the wrist to take the profile of the Index/Middle finger.



14.0 Concepts

14.1 Concept 1- Forced open (Passive hand)

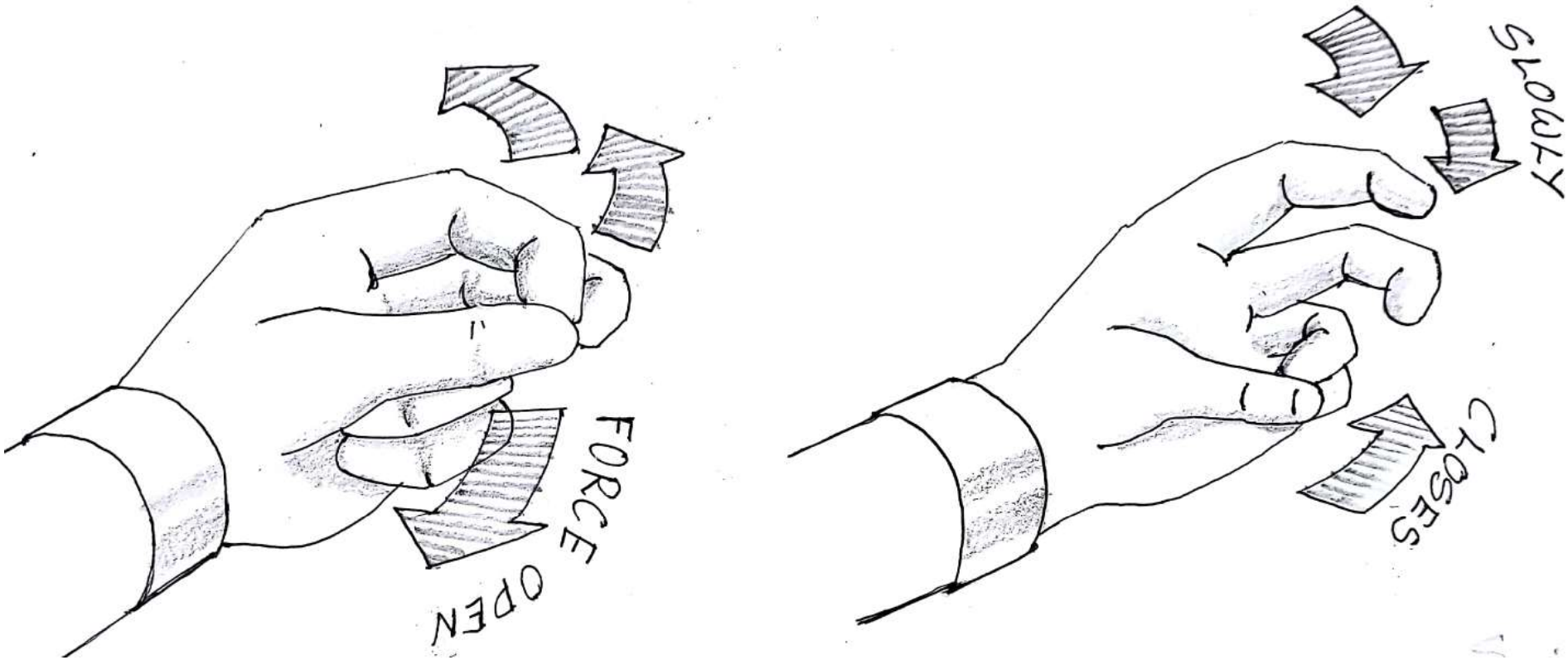


Figure 21: Forced opening. The thumb should be pulled to open the hand. The hand starts closing after a delay slowly.

Advantages

- Since no electronic components are used, the hand is light weight.
- The hand unit itself is used as an input device hence the controls are consolidated and compact.
- Simple spring loaded mechanism hence easy to repair.
- The stomp need not be designed to accommodate the hand.

Disadvantages

- The other arm is required to provide inputs to the artificial hand.
- Time consuming activity
- The grip strength cannot be varied.

14.2 Concept 2- Lever based Forced open (Passive hand)

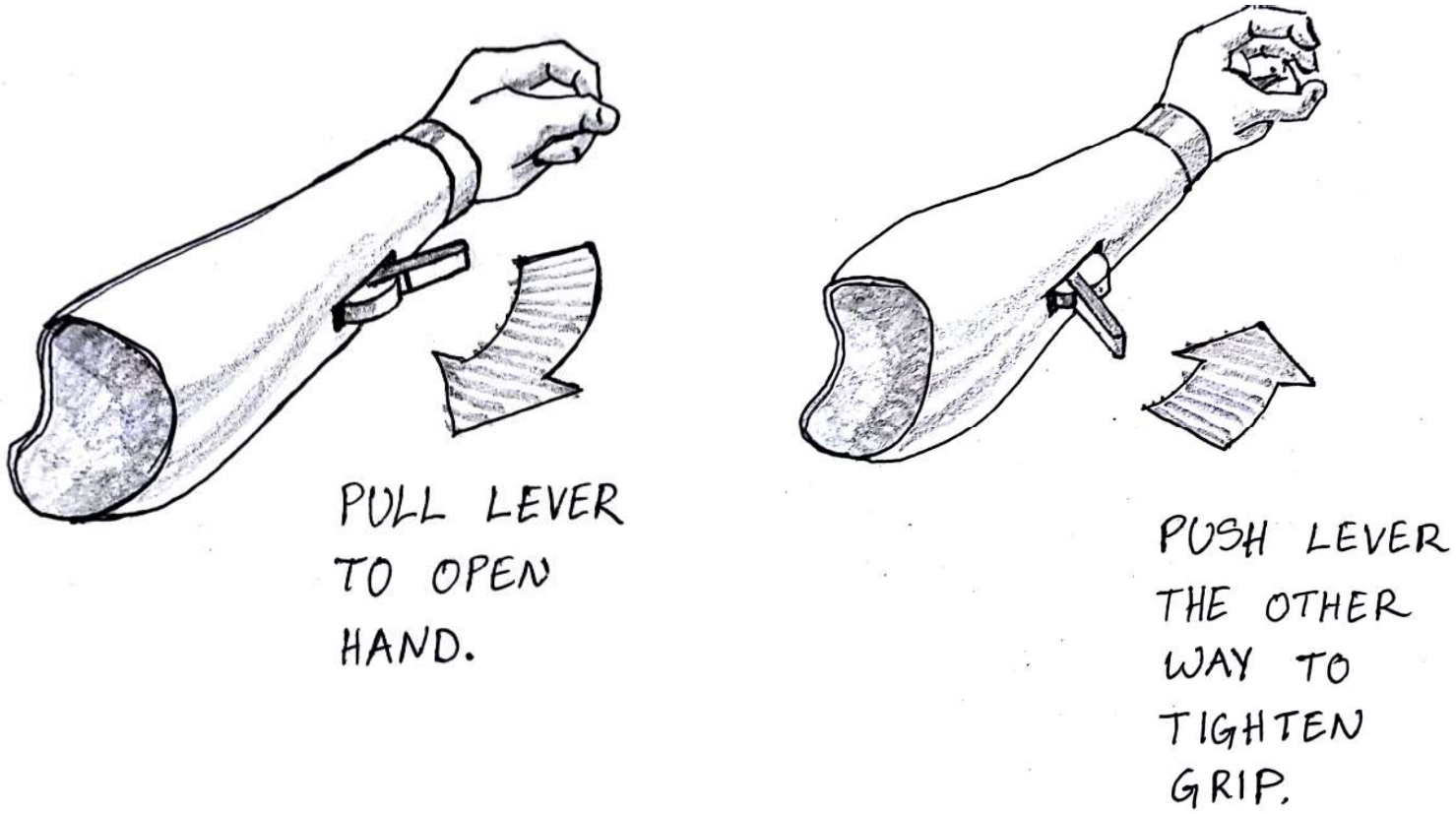


Figure 22: Lever based Forced opening. Hand closes slowly after release. The lever can also be locked at a place to manipulate the grip strength

Advantages

- Since no electronics are used, the hand is light weight.
- Simple spring loaded mechanism is easy to repair.
- The grip strength can be manipulated as the lever has an indexing feature to lock in place.
- The lever mechanism would be used to reduce the effort applied and can be neatly conceal.

Disadvantages

- The other arm is required to provide inputs to the artificial hand. The user can use a buckle on the belt around the waist to control the lever.
- The action is time consuming.
- The input is placed on the forearm so the sleeve of the shirt needs to be lifted up.
- The stomp needs to be designed to accommodate the lever.

14.3 Concept 3- Electric hand

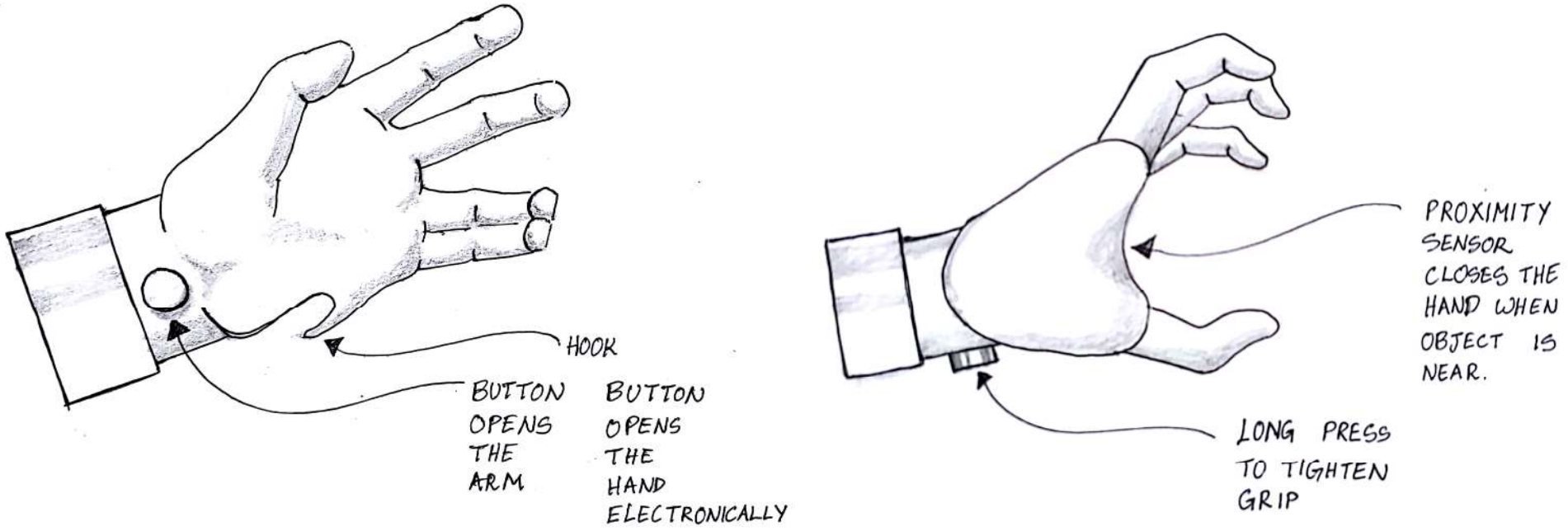


Figure 23: The button on the wrist would open the hand electronically. The sensor between the thumb and the index finger would detect an object and start closing slowly. One can long press the button to tighten the grip.

Advantages

- The time taken to perform the gesture action can vary.
- The opening and closing speeds can be programmed and controlled.
- The grip strength can be manipulated manually by pressing the button.
- The strength to operate the hand is less.
- The input is placed on the wrist so the sleeve of the shirt need not be rolled up.
- The stomp need not be designed to accommodate the hand.

Disadvantages

- The other arm is required to provide inputs to the artificial hand.
- Electronic components may be hard to repair.
- Since battery packs are used, the hand is heavy to wear.
- Use of electronics would make the product expensive.

15.0 Concept evaluation

Weight (including the stomp) - A major concern of the user is the weight of the prosthetic arm. No user would want to spend their energy in lifting the prosthetic arm. Battery operated prosthetic arm is heavier than mechanical arm.

Wearability - The conventional Alimco hand uses a harness which goes around the shoulders. It is time consuming to wear and inconvenient.

Ease of repair- The users should be able to repair the components with as little expertise and supervision possible.

Affordability - plays a great role in the success of the Alimco hand. The new design should not change this quality.

Ease of use- The present Alimco hand needs users to move their shoulders to operate. The users do not prefer this. Hence, in all the concepts the artificial arm's control point are near the hand extension. This feature ensures compactness and enables the ease of wearing.

Dependence on the good arm- The battery operated prosthetic arms mostly do not require any other specific body movements. The Alimco hand doesn't use the good arm, but is dependent on other movements of body part.

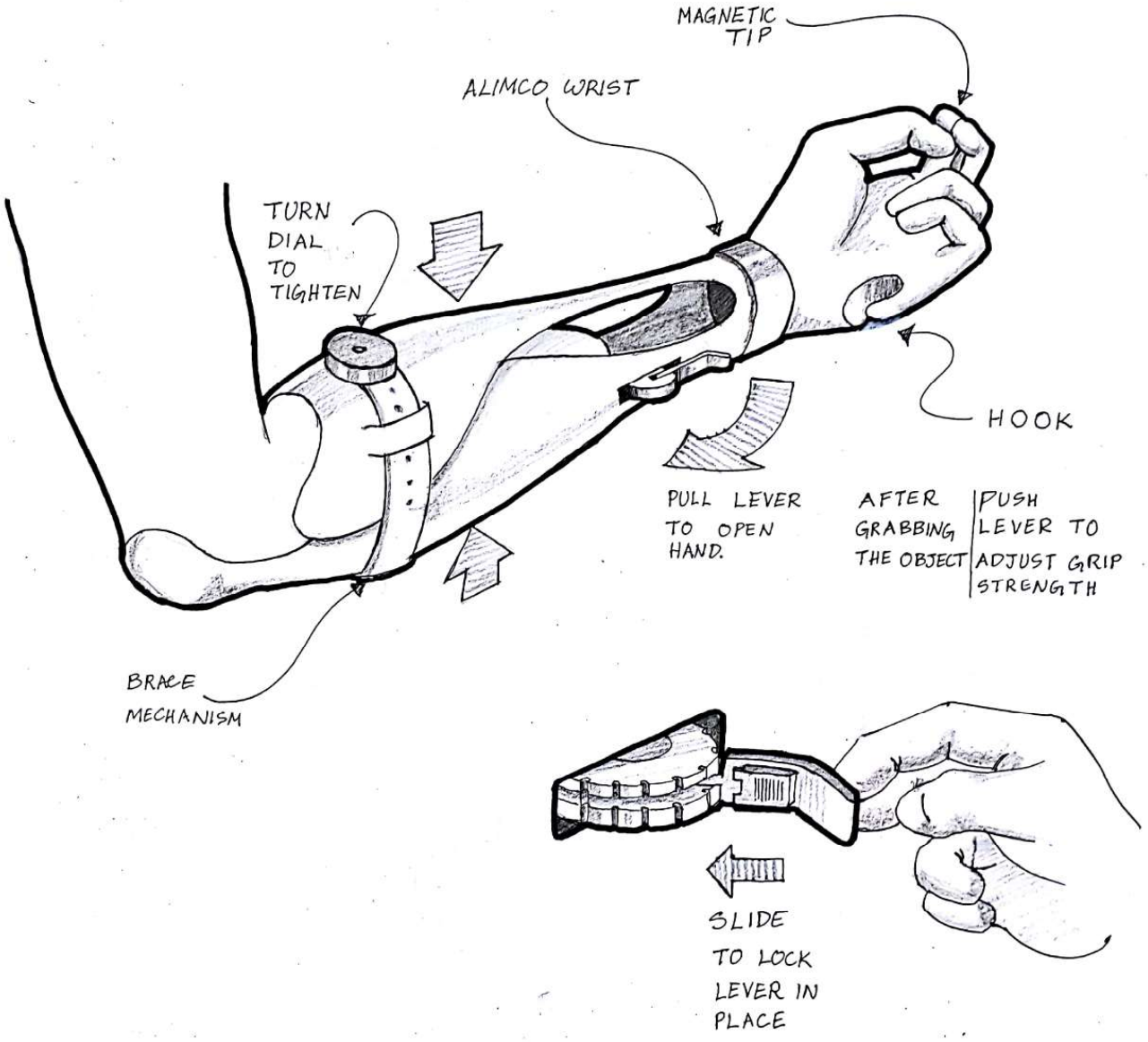
Time taken to operate- A battery or harness operated arm would take less time to operate than a lever based arm as more steps are involved.

Grip strength control- Delicate objects would require softer grip (like an egg). A prosthetic arm would not be helpful if the user is unable to control the grip strength.

Gesture speed- *A* reasonable speed can be set to let the user get close to the object as there is no tactile feedback. Visual feedback is the only aid to the user.

	Weight	Wearability	Ease of repair	Cost	Ease of use	Dependence on the good arm	Time taken to operate	Grip strength control	Gesture speed
Concept-1 Force open (passive hand)	Light	Easy	Very easy	Low	Easy	Yes	Less	No	Low
Concept-2 Lever based (passive hand)	Light	Easy	Easy	Low	Difficult	Yes	More	Yes	Low
Concept-3 Electrical hand	Heavy	Easy	Difficult	High	Very easy	Yes	Less	Yes	Varies

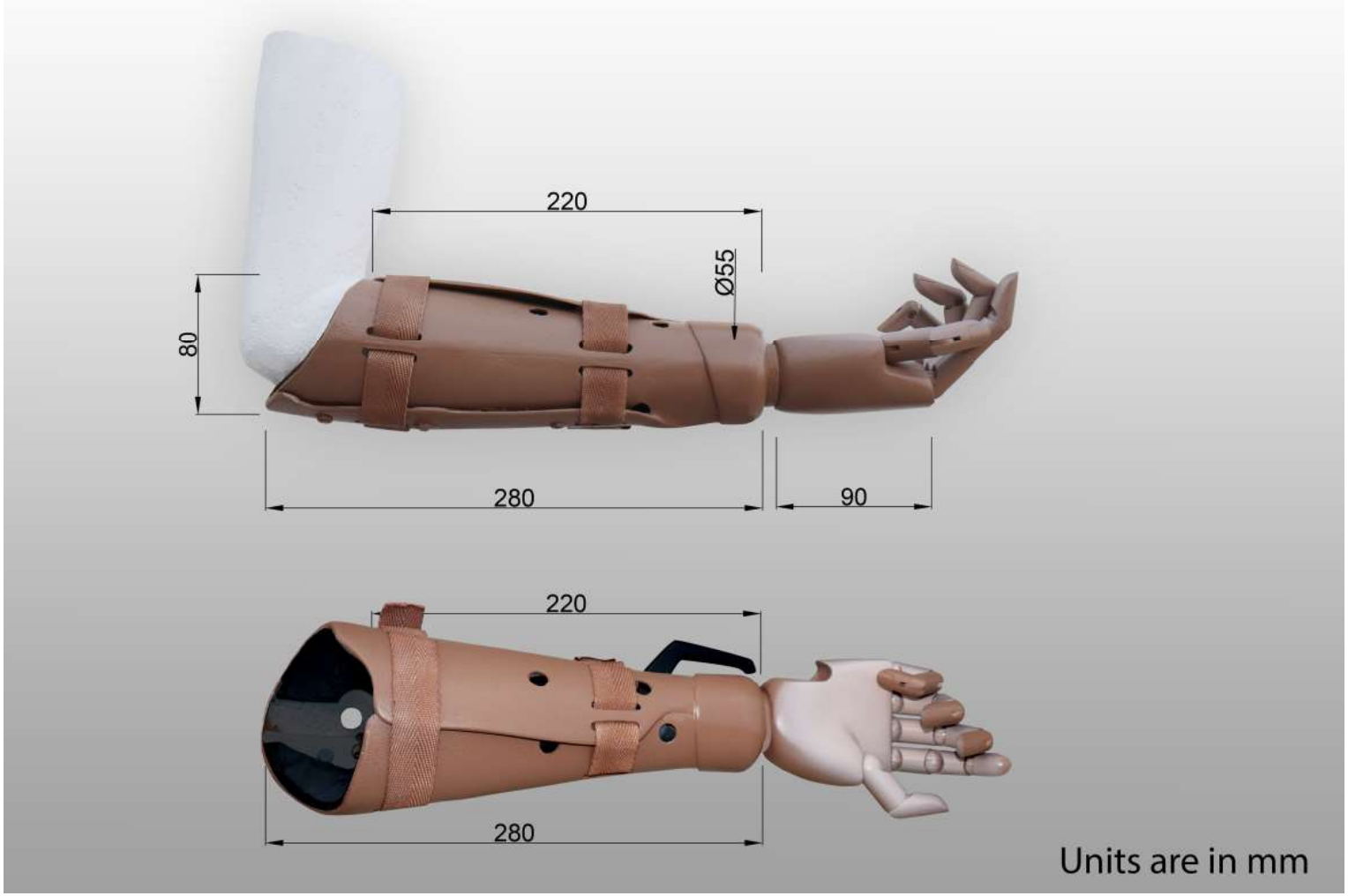
16.0 Final Concept

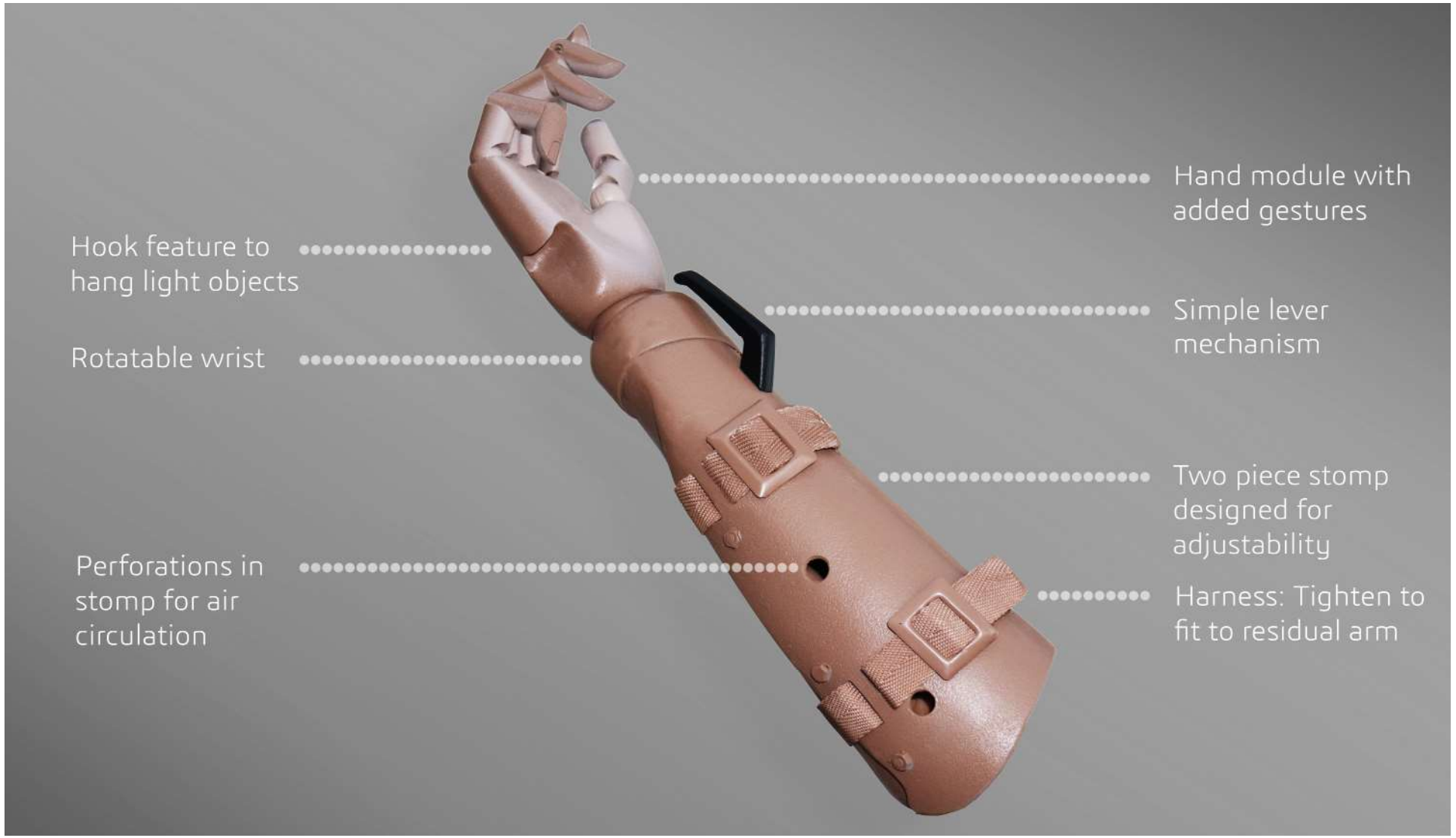


16.1 Model

Scale 1:1

16.2 Dimensions of the Prosthetic arm




Hook feature to hang light objects
Rotatable wrist
Perforations in stomp for air circulation
Hand module with added gestures
Simple lever mechanism
Two piece stomp designed for adjustability
Harness: Tighten to fit to residual arm

16.3 Salient features of the Final concept

The Stomp

The new stomp design would enable the user

- Two piece mold design to provide adjustability.
- The prosthetic arm is a consolidated device which is easy to mount and unmount.
- Perforations in stomp provide air circulation to the residual arm.
- Personalized paddings on the inner lining of the stomp provide optimum comfort.

The Lever Mechanism

The lever is placed on the forearm near the wrist.

- This allows the user to operate the arm when needed and prevent accidental movement.
- No training required as the lever mechanism is simple to understand.
- The lever mechanism can also adjust grip strength by simply pushing the lever in the other direction, thus tightening the grip after the object/article is held.

The Hand Mechanism

- Injection molded polycarbonate parts with stainless steel spin rivets are used to provide strength and reduce weight.
- Magnetic finger tips can be helpful in picking objects like keys and coins.
- For aesthetic purposes, the hand is made to look as real as possible.

17.0 Learnings

From the user-

The authors design journey began at BMVSS, Jaipur where amputees from different parts of India arrive to get a prosthetic limb.

After interviewing few amputees at the Centre it was clear that the user requirement was tending more towards cosmetic restoration rather than functional restoration.

The user already came to terms with the fact that no amount of technological advancements implemented into making of a prosthetic, will have limitations and cannot compete with a natural limb.

A passive natural looking prosthetic arm with no movement or function whatsoever, is of significant value. It helps with psychological issues like overcoming self-consciousness, societal pressure and phantom limb syndrome. It also provides postural benefits by restoring body symmetry.

From the Institutions-

Organizations like BMVSS in Jaipur and Alimco in Kanpur are established to make the lives of amputees better. These institutions have acclaimed international statuses for their noble cause and act as a beacon of hope for people with limb loss.

To meet the individuals who run these organizations during the site visits and to learn about their philosophy and ideology helped keep the author motivated throughout this project to add some valuable contribution to their vision of a better world.

The author was also able to generate empathy towards the amputees after the visits.

The author also learned about the manufacturing process of the Alimco hand, how the whole system functioned and the journey of the product from the factory to the end user.

From Sumit-

The author found a new friend in Sumit, who always provided valuable inputs and co-operation whenever required.

After close observation, the author was able to learn how an amputee is able to achieve various tasks using his good hand and alternative methods used to compensate for the lack of an upper limb.

The author after these observations was able to distinguish daily tasks into three categories i.e. easy, difficult and impossible with minimum resistance.

18.0 Future scope

Further scope of work required to bring the final concept to the market and the users are as follows:

- Meeting engineering consultants-
  to optimizing the mechanism to achieve the desired movement of the fingers.
- Getting user feedback-
  on the prototype of the optimized mechanical hand.
- Presenting the observations, conclusions and feedback of users to compliant organizations
  A formal presentation of the findings is to be made to compliant organizations like BMVSS and Alimco to get their opening and feedback on the final concept.
- Working towards a realistic look-
  Professional consultants who specialize in achieving realistic cosmetic look need to be integrated into the developing team.
- Feedback from the users-
  Further iterations are to be made after implementing the suggestions provided by the users and the compliant authorities.

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