Walk Free Osteoarthritis

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2018

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Abstract

Osteoarthritis is a degenerative disease that mostly affects the cartilage, In osteoarthritis, the surface layer of the cartilage breaks and wears away. Osteoarthritis (OA) affects an estimated 40% of the adult population. Of these, only 10% seek medical advice and only 1% are severely disabled. Osteoarthritis is associated with the breakdown of cartilage in joints and can occur in almost any joint in the body. It commonly occurs in the weight-bearing joints of the hips, knees, and spine. It also affects the fingers, thumbs, neck, and large toe. Osteoarthritis of the knee can affect either one or both sides of the knee joint however it occurs more commonly on the inner side of the knee. Osteoarthritis can be caused by being overweight, old age, stresses on the joints from certain jobs and playing sports.The elderly can be discouraged to walk due to the immense amount of pain when walking hence our proposed solution is to create a knee brace that can alleviate the pain of the knee while assisting the user in walking.

Acknowledgements

This Final Year Project has been the most difficult assignment to complete but at the same time the most fruitful one as we have learnt a lot of things that were not taught during the lesson.

We would like to thank all the teachers for guiding us and giving us advice especially Mr Vincent. Although he was busy with his classes, he still makes some time for us to discuss our progress as well as the problems we faced. Mr Vincent has always been very patient with us. During the designing phase, Mr Vincent came down and did some researched with us in order to have a base design to work on. Mr Vincent has always been supportive of trying new ideas. We would like to thank Mr Vincent for his unrelenting support.

We would also like to thank Dr Khor and Mr Poh for their assistance on the Arduino and coding. Without their help, we would have taken a far longer time to complete what was required.

Last but not least we would like to thank Mr Chan and Mr Tay for their recommendations and their resources. Mr Chan thank you for so kindly providing us with materials to make this project a reality. Mr Tay for guiding us in theory and helping us find design problems and how to solve them.

This project will only be an idea without the help of our teachers. They helped and guided us even during the holidays. We are blessed to have such caring and awesome teachers.

In you, I've found a friend, philosopher, and guide. Whatever I did, you have stood by my side.

You've praised, you've punished, you've always been fair. Whenever I needed, you've always been there.

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Chapter 1: Introduction

Osteoarthritis is a degenerative disease that most commonly occurs to old people. Osteoarthritis mostly affects the cartilage which is the hard but slippery tissue that covers the ends of the bones where they meet to form a joint.

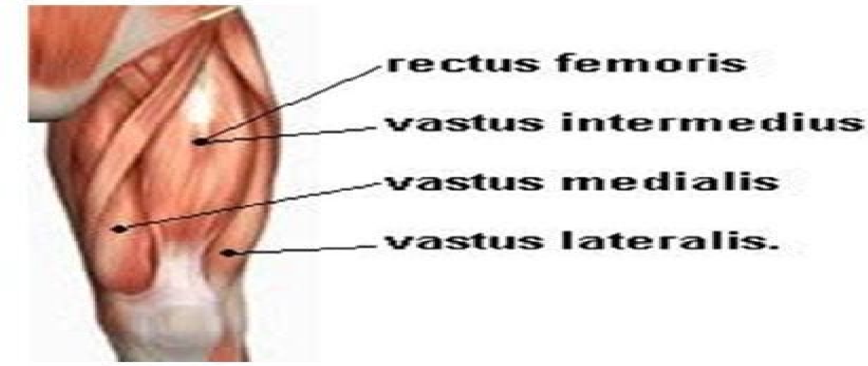
Healthy cartilage allows bones to glide over one another and absorbs shock from movement.

In osteoarthritis, the surface layer of the cartilage breaks and wears away. This allows bones under the cartilage to rub together, causing pain, swelling, and loss of motion of the joint. Osteoarthritis can affect any joint, but it occurs most often in knees, hips, lower back and neck, small joints of the fingers and the bases of the thumb and big toe. Through our research, we have found out that the osteoarthritis of the knee is common in people over 50 years of age, particularly in women.

In 2007 the Ministry of Health conducted a survey and found out that 23.7% of Singaporean adults age ranging from 18 to 64 years old suffer from arthritis which is a dramatic increase from the previous survey conducted which was only 7.4% of adults. Osteoarthritis can affect either one (unilateral) or both (bilateral) sides of the knee joint however it occurs more commonly on the inner (medial) side of the knee.

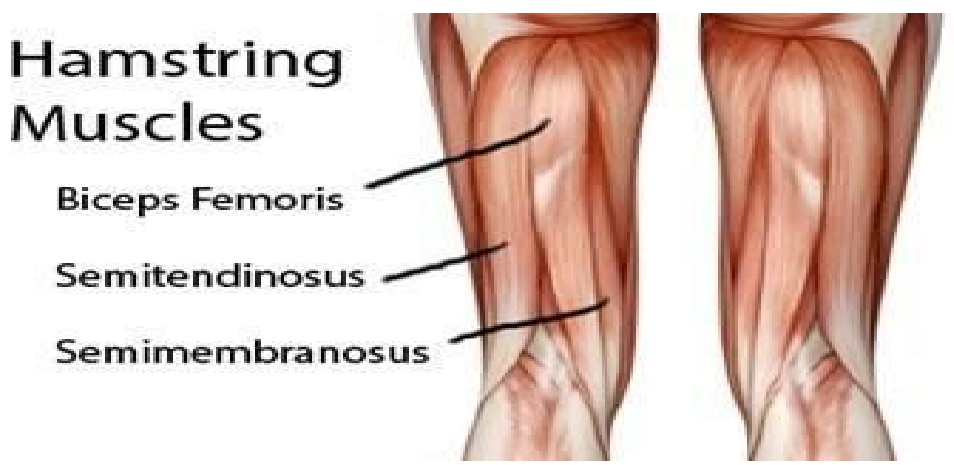
We decide to target the knee as it is an important part of the body we use and people are discouraged to walk due to the pain and are afraid to get surgery to fix it.

Quadriceps:



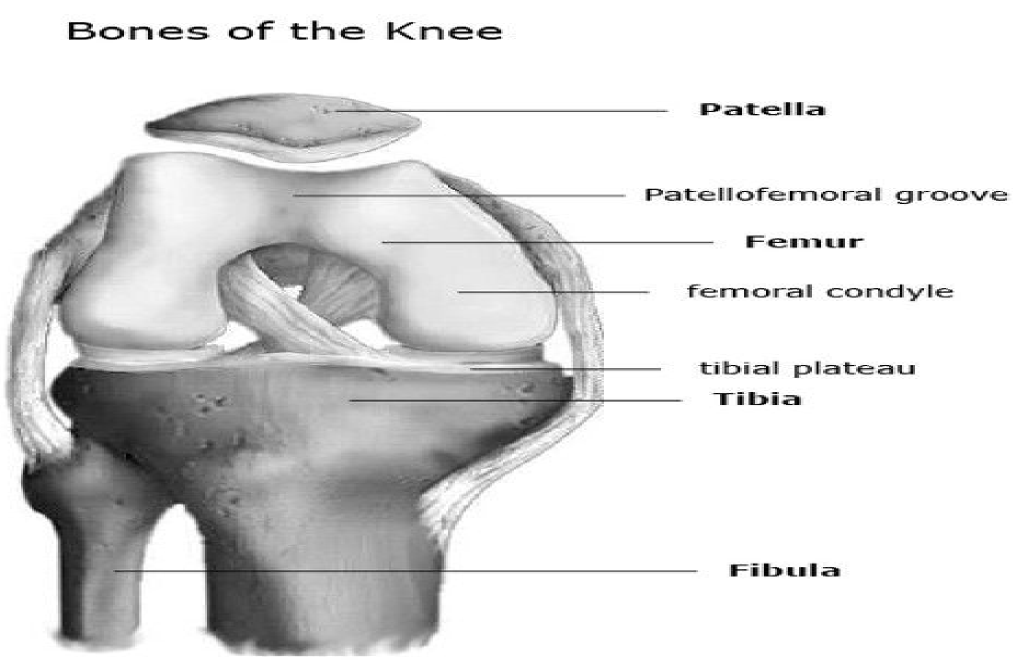
Location: Front of the thigh from the hip to the knee
Action: Straighten the leg
Common activities: Getting up from a chair, going upstairs
Common problems: Tightness, weakness, muscle tear, tendonitis

Hamstrings:



Location: Back of the thigh from the hip to the knee
Action: Bend the knee
Common activities: Running, twisting the knee
Common problems: Tightness, weakness, muscle tear, tendonitis

Knee Bones



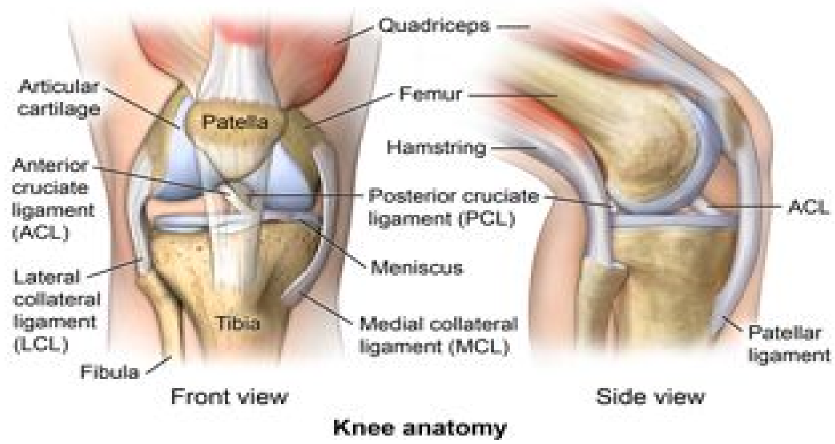
Tibia —commonly called the shin bone, runs from the knee to the ankle.It supports movement of the leg.

Patella—the kneecap is a flat, triangular bone; the patella moves when the leg moves. It's function is to relieve friction between the bones and muscles when the knee is bent or straightened and to protect the knee joint.

Femur—commonly called the thigh bone; it's the largest, longest and strongest bone in the body. The round knobs at the end of the bone are called condyles.It functions in supporting the weight of the body and allowing motion of the lower extremity.

Fibula—long, thin bone in the lower leg on the lateral side, and runs alongside the tibia from the knee to the ankle.Its function is to stabilize the ankle and supporting the muscles of the lower leg.

Ligaments



There are 4 major ligaments in the knee. The ligaments in the knee connect the femur (thighbone) to the tibia (shin bone), and include the following:

Anterior cruciate ligament (ACL). The ligament, located in the center of the knee, that controls rotation and forward movement of the tibia (shin bone) so as to stabilize the knee joint and allow for dynamic motions.

Posterior cruciate ligament (PCL). The ligament, located in the center of the knee, that controls backward movement of the tibia so as to prevent the femur from sliding off the tibia and to prevent the tibia from displacing posterior to the femur.

Medial collateral ligament (MCL). The ligament that gives stability to the inner knee and prevents the leg from over-extending inward.

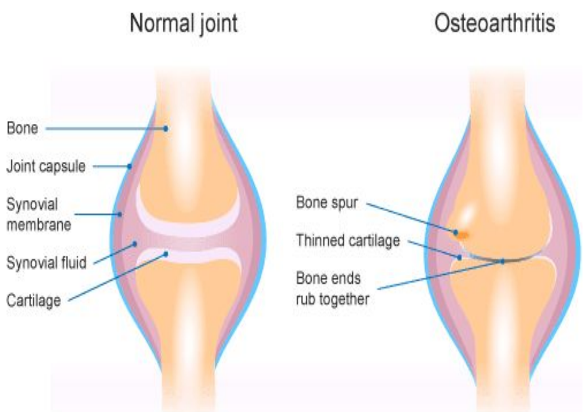
Lateral collateral ligament (LCL). The ligament that gives stability to the outer knee.

Patellar ligament – attaches the kneecap to the tibia which helps keep the kneecap in its proper position and also assists in the bending of the leg at the knee.

Where does the pain come from?

In the early phase of arthritis, the cartilage between the joints becomes worn and torn, as well as inflamed. The inflammation causes swelling of the cartilage, which leads to pain and irritation. The wear-and-tear process leads to loss of water in the joint, which causes the cartilage to become hard. Hardened cartilage makes moving the surrounding joint more difficult.
The damaged or missing cartilage causes friction between bones and other knee problems, which in turn cause knee pain and related symptoms.

Which part of the knee will feel the pain?



The femur and tibia bones will feel the pain as they rub and grind against one another in the knee joint due to the missing cartilage.

To compensate for the deteriorated or missing cartilage, the bones in the joint may produce small bony growths called osteophytes, or bone spurs. In turn, the bone spurs can create even more friction in the knee joint.

Cartilage does not contain nerves, so damaged cartilage is not the primary source of pain in knee osteoarthritis. Likewise, bone spurs are a normal sign of ageing and the presence of bone spurs alone are not a cause for concern. However, the friction between bones and other resulting abnormalities in the knee can cause discomfort and pain.

Chapter 2: Literature Review

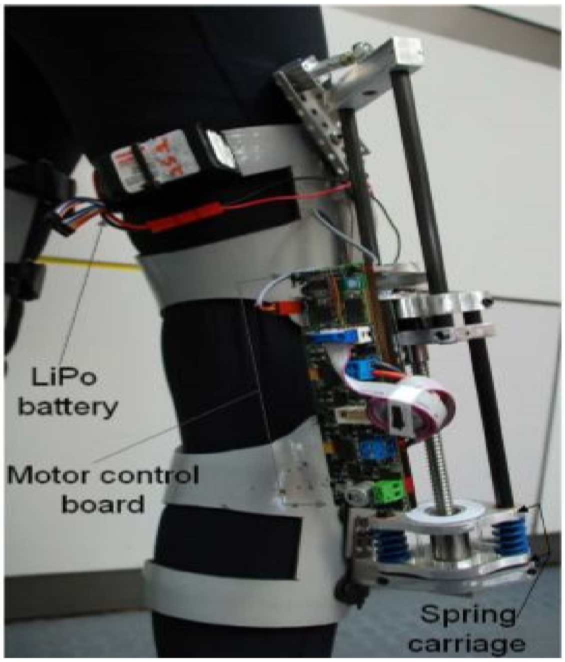
Guardian Brace Rehabilitator OA LP

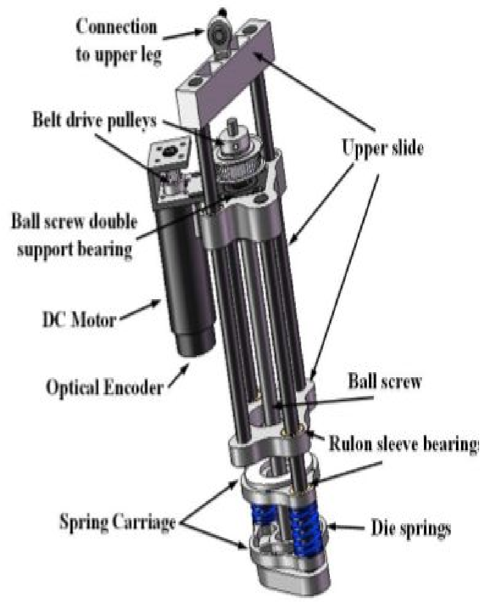
Guardian Brace is an improvement based upon the flaws of conventional static knee braces as it is *clinically proven* to strengthen leg muscles, correct foot placement, and build a proper neuromuscular memory to promote healthy walking mechanics for the patient. They rehabilitate lost or weakened leg muscles and remedies degenerative osteoarthritis.By using air bladders the brace is able to provide constant appropriate force at the knee.

Polycentric hinge was designed to follow the anatomical movement of the knee joint and has adjustable flexion and extension if needed.

Walk Free Osteoarthritis

Quasi-Passive Knee Exoskeleton by MIT





A motor-positioned spring is attached to the shank.This spring carriage is served to avoid contact with the upper slide during the swing phase of the gait and to come into contact with the slide and cause compression of the stance phase.A brushed DC motor actuates the nut via a belt drive and ball screw.The motor and mounting hardware are placed as high in the module as possible to minimize inertial loading of the leg by the device.The carriage containing the die springs is attached directly to the ball screw nut in this design and is served up and down with the movement upper slide to contact the bottom surface of the 'upper slide'.

TABLE I
DESIGN SPECIFICATIONS

Gear ratio (motor/spring carriage)	1mm/rot
Allowable range of knee joint motion	0-97 deg
Total gear ratio (motor/knee) @ 0 deg	112
Total gear ratio (motor/knee) @ 97 deg	947
Individual Spring stiffness	54.6 kN/m
Total Spring stiffness	109.3 kN/m
Max Continuous Force @ 24V	524 N
Max continuous torque at 44 deg	47.5 Nm
Intermittent (Stall) Force	6.4 kN
Operating Voltage	24 V

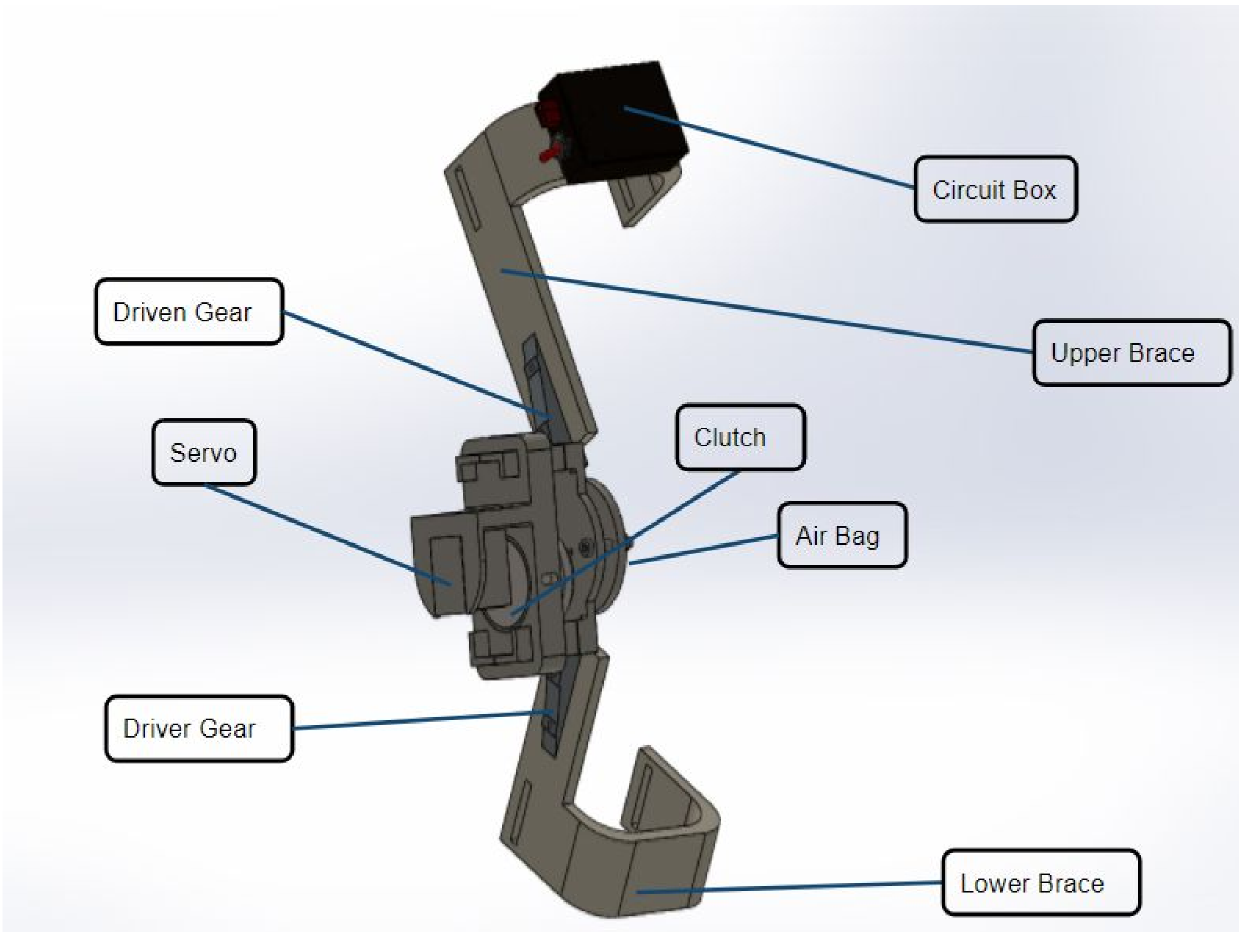
TABLE II
PHYSICAL PARAMETER SPECIFICATIONS

Actuator length range	0.27m-0.40m
Actuator Stroke	0.13 m
Connection location above knee	0.25 m
Connection location below knee	0.16 m
Angular offset of above knee location	10 deg
Contact surface area thigh	290 sq.cm
Contact surface area calf	283 sq.cm
Additional width (from external brace joint)	0.103 m
Lever arm from knee joint	0.070 m
Mass Parameters	
Carriage mass	694 g
Motor, control board mass	408 g
Battery mass	185 g
Brace mass	1179 g
Total Exoskeleton mass	2466 g

TABLE III
PERFORMANCE MEASURES

Frictional torque at knee @ 44 deg	~0.25 Nm
Load required to backdrive the carriage (3:1 belt)	~180 N
Max Spring carriage speed (@24V, 3:1 belt)	128 mm/sec
Rise time to max velocity (@24V, 3:1 belt)	0.15 sec
Max Spring carriage speed (@24V, 2:1 belt)	187 mm/sec
Max Spring carriage speed (@30V, 2:1 belt)	240 mm/sec

Chapter 3: Current Design



The current design uses servo motor to drive a gear like shaft which will drive the leg. This design was chosen as it was the most compact compared to our other prototype. This idea is lighter and is able to achieve a reliable movement.

Chapter 3.1: Mechanical Design

1) DC Servo Motor

Specs:
Output: Single
Operating Voltage: 7.4~12.0V (2~3S Lipoly)
Operating Speed: 0.18Sec/60° / 0.14Sec/60°
Stall Torque: 32.4kg.cm /53.1kg.cm
Rotation Scope: 0~280°
Size: 43X32X32.5mm
Weight: 81g
Spline: 25T
Ball Bearing: 2BB
Gear: Metal
Wire Length: 50cm
Bolt Pattern: 21.5x21.5mm
Operating Frequency: 1520us/333Hz, 900~2100us
Motor Type: Japan Brushless motor
Amplifier Type: 6A Treble Power MOS-FET
Gear Types: Stainless / Tungsten Steel

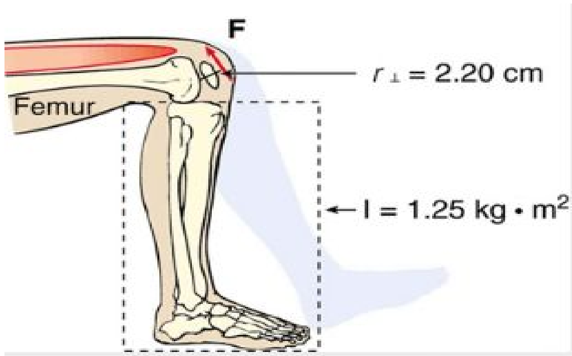
This is our current servo motor. Brushless DC electric motor also known as electronically commutated motors are synchronous motors powered by DC electricity via an inverter or switching power supply which produces an AC electric current to drive each phase of the motor via a closed loop controller. The controller provides pulses of current to the motor windings that control the speed and torque of the motor.

After researching and calculating we found out we need a minimum 20Nm. Cross-referenced to the formula stated on the next page. The figure below shows the range of motion at the knee.

Functional range of motion (ROM) at the knee

Activities	Knee flexion
◆ Normal gait/level surfaces	60°
◆ Stair climbing	80°
◆ Sitting/rising from most chairs	90°
◆ Sitting/rising from toilet seat	115°
◆ Advanced function	> 115°

Torque Calculation:



Patellar compression force

Activity	Force	% Body weight
Walking	850 N	1/2 x BW
Bike	850 N	1/2 x BW
Stair ascend	1500 N	3.3 x BW
Stair descend	4000 N	5 x BW
Jogging	5000 N	7 x BW
Squatting	5000 N	7 x BW

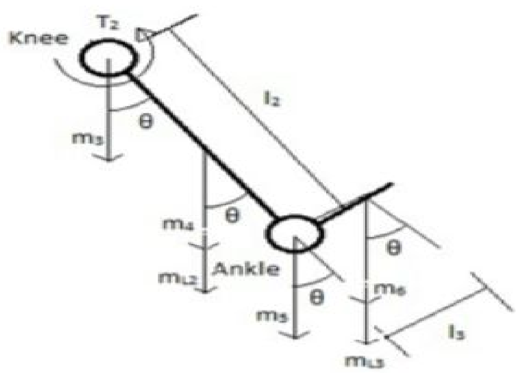
The total mass of our product(including battery) is 2.016kg

Based on our prototype:-

Torque = r x F

=(2.20cm/1000) x (850+(2.016x9.81)

=19.135Nm



$$T_2 = sin\theta\left[(m_4 + m_{L2})g\left(\frac{l_2}{2}\right)\right] + sin\theta[+m_5 g(l_2)] + sin\theta[+m_6 g(l_2)]$$

$$+cos\theta\left[(m_6 + m_{L3})g\left(\frac{l_3}{2}\right)\right]$$

To back up our calculation we found a journal that states that the torque required at the knee joint is 21.68Nm.It is higher than ours as their product has a different actuator than ours and they have an additional actuator at the ankle.

2) Electromagnetic Tooth Clutch

Model	Size	Torque [N-m]	Coil (at 20°C) Exciting voltage [V]	Coil (at 20°C) Wattage [W]	Coil (at 20°C) Current [A]	Coil (at 20°C) Resistance [Ω]
546-12-34	12	17.5	DC24	13.3	0.55	44.0

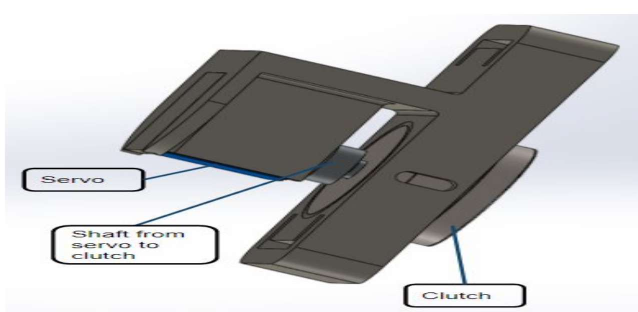
Heat resistance class	Allowable rotation speed of engagement [min⁻¹] NF	NS	Sawtooth	Max. rotation speed [min⁻¹]	Moment of inertia J [kg-m²] Rotor	Armature
F	50	30	100	1500	6.6×10^{-5}	6.0×10^{-5}

Number of teeth Full depth tooth, full	Sawtooth, full	Armature pull-in time t_a [s]	Armature release time t_{ar} [s]	Mass [kg]
200	25	0.035	0.040	0.5

A clutch is a mechanical device which engages and disengages power transmission especially from driving shaft to driven shaft. In the simplest application, clutches connect and disconnect two rotating shafts (drive shafts or line shafts).

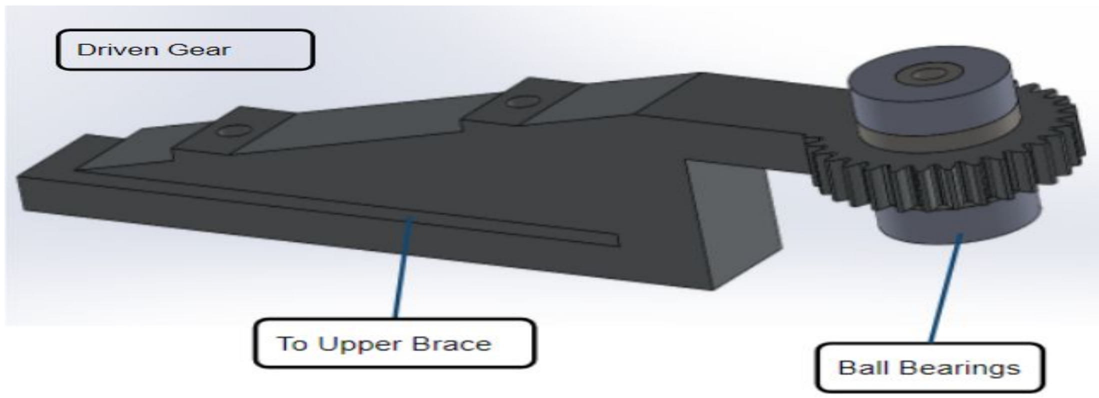
This clutch requires friction to work, this makes it unreliable for constant moving and shaking as the teeths of the clutch might not bite. A magnetorheological fluid (MR fluid) clutch is a type of smart fluid in a carrier fluid, usually a type of oil. When subjected to a magnetic field, the fluid greatly increases its apparent viscosity, to the point of becoming a viscoelastic solid allowing motion to be transmitted.

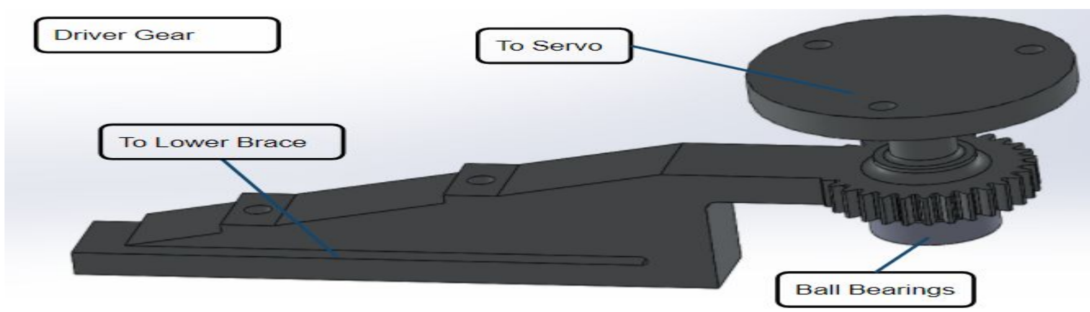
This allows for compliance, if the user wants to walk on his own he could disengage the clutch and take over. This will make it a Human Safe Robot.



How the servo and clutch are connected

3) Driven/Driver Gears



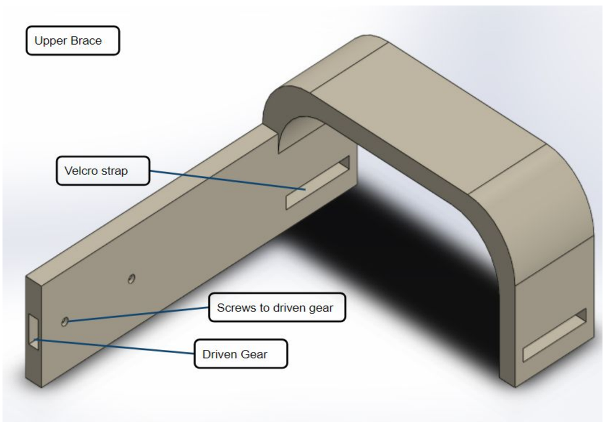


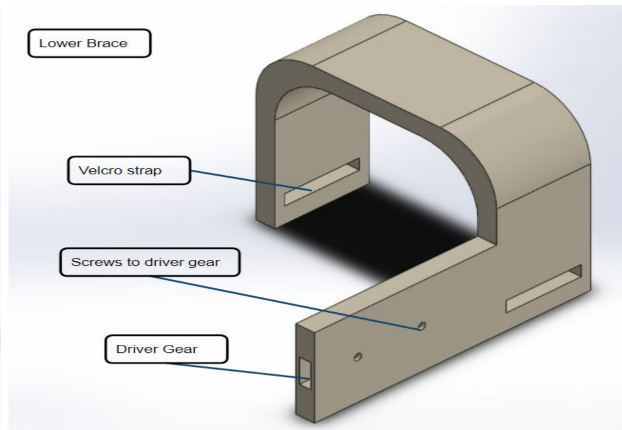
The gears are made in conjunction with our design needs. As the driven gear, we needed it to have a smooth rotation during actuation, hence we added ball bearing to increase its ability to rotate.

The driver gear went through multiple changes as it was our main actuator to receive motion from the servo. It used to be 2 different parts, a special head was connected to the shaft through the use of an interlocking system. We realize that the gear always break after a few runs. Hence we decided to make the gear and the head to be 1 piece to reduce the wear and tear in the gears. Ball bearing was added to reduce the friction in between the gear and the cover.

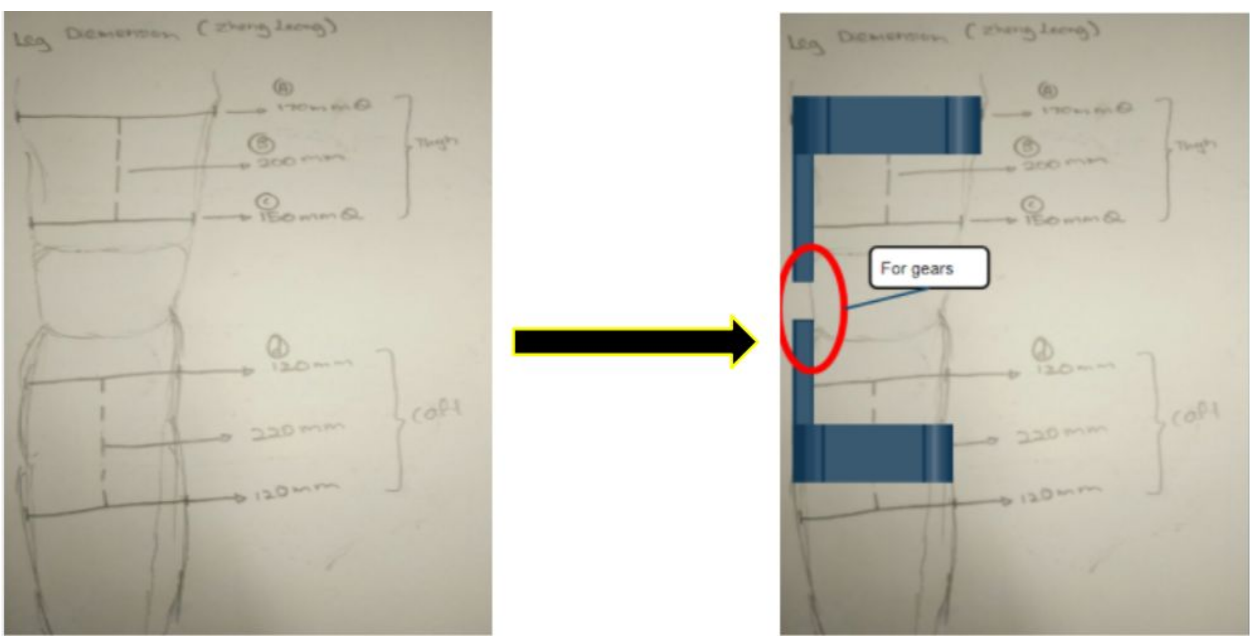
The gears are currently 3D printed, this causes it to be fragile and unable to support the weight of a human. However we have plans to fabricate it using aluminium alloy, this is to increase the rigidness of the gears. This will allow the gear to have a longer lifespan.

4) Upper/Lower Brace

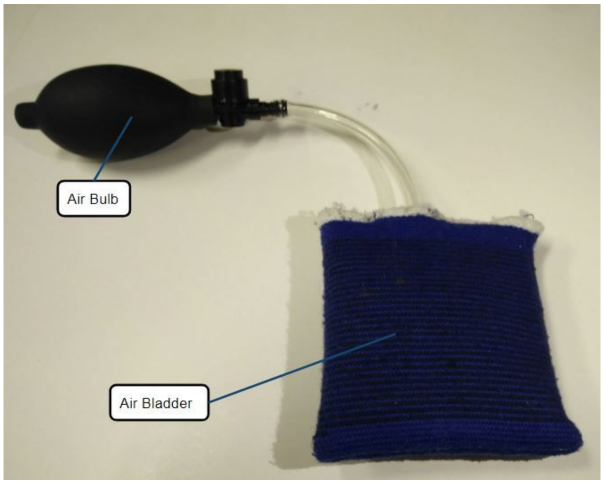


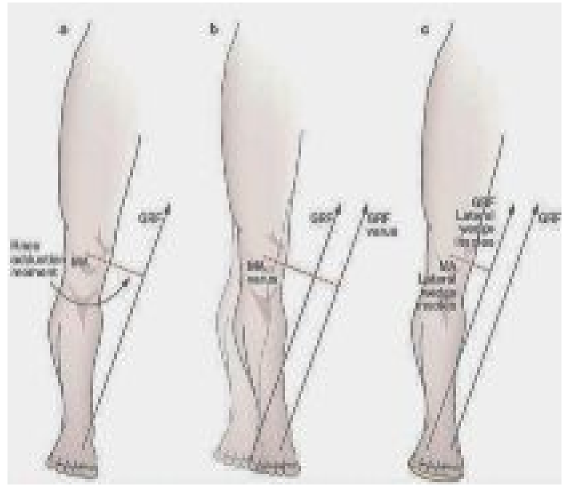


The leg brace is made to the dimension of Zheng Leong leg. The material of choice is polypropylene.The advantages of polypropylene are it is a relatively inexpensive material,it possesses high flexural strength because of its semi-crystalline nature and it has a low coefficient of friction.



5) Air Bladder & Air Bulb



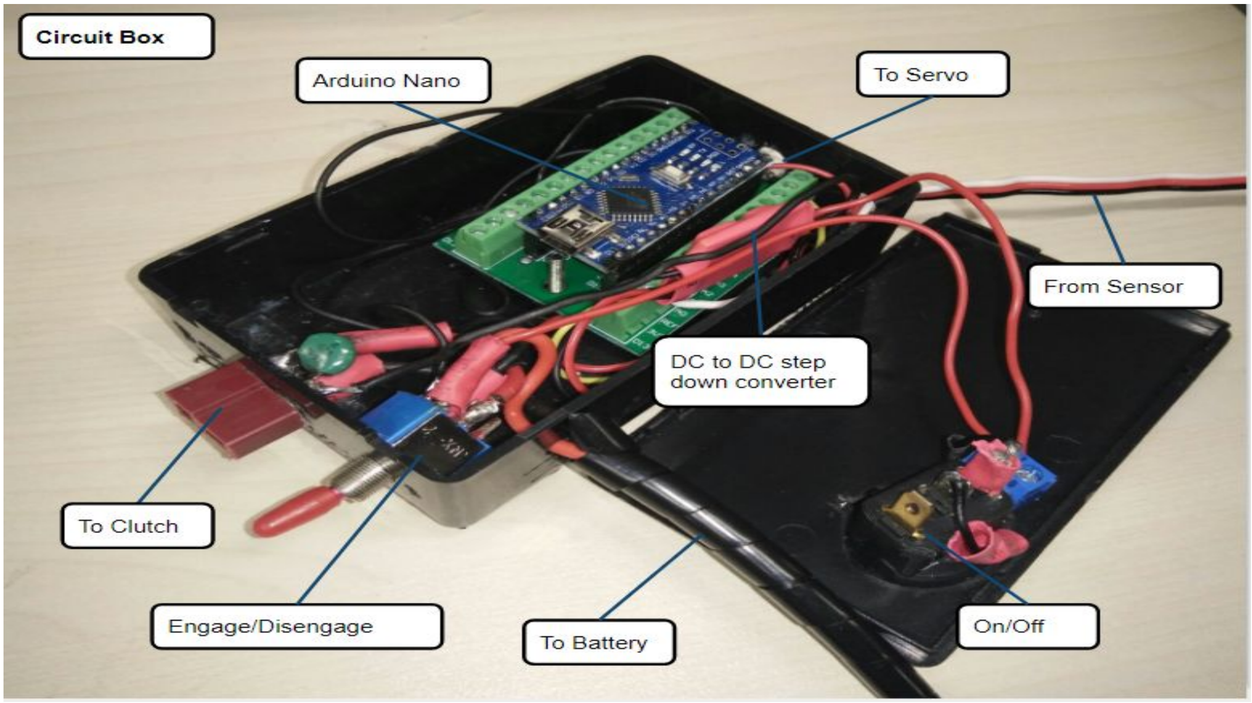


To back up our claim that the airbag is able to realign the knee we found a study that determined whether or not by incorporating inflatable air bladders would the net peak external knee adduction moment be altered.The results from that study states that “A 7.6% decrease in net peak external knee adduction moment was observed when subjects wore the knee brace not inflated compared with when they did not wear the brace. Inflation of the bladders to 7 psi led to a 26.0% decrease in net peak external knee adduction moment.”The conclusion that was derived from this study is that by implementing air bladders to an unloading knee brace it could improved the correction of the excessive peak external knee adduction moment

The airbag module is designed to inflate to the user desired pressure. It will realign the knee. This module will be mount using a velcro strap.

Chapter 4: Electronics Design

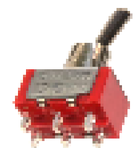
Circuit Box:



The Circuit box is designed to be compact, portable and user-friendly. The input and output are currently made easily accessible for easier troubleshooting by using connectors that can detach without unsoldering. Using a DC to DC step down converter will allow the circuit to run on a single battery which will reduce the weight and the need of an extra battery. Arduino Nano is used as it is smaller and compact compared to Arduino Uno. For the sensor, we will be using a stretch sensor. Two different switches are used, one being the on and off of the entire system and one for the engaging and disengaging of the assisted movement. In short, we have decided to go for functionality over appearance and this compact system is critical in allowing for a lighter knee brace.In the future, more sensor will be added to make our system be more reliable and have more functions.

Chapter 4 (Electronic concepts)

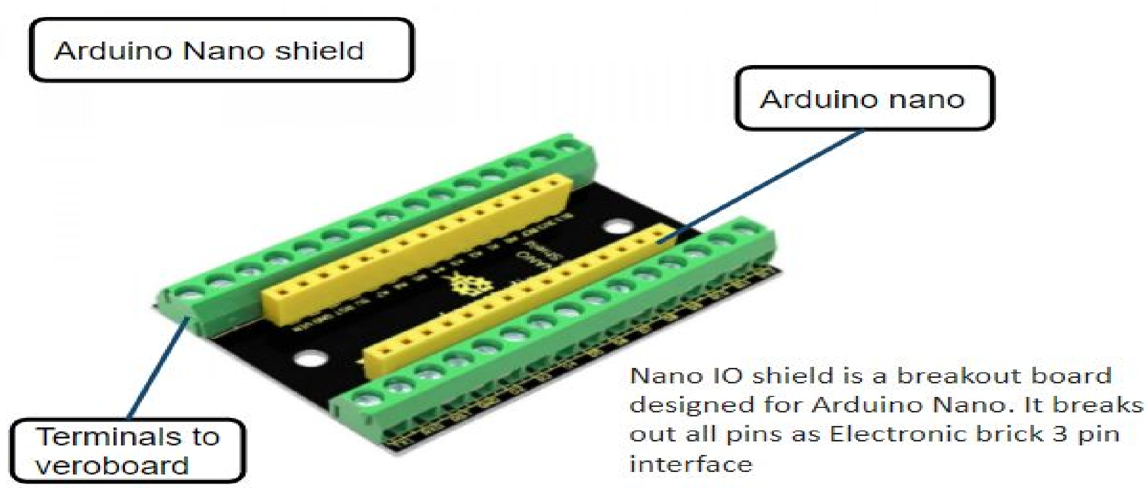
Switches



Switch A *Switch B*

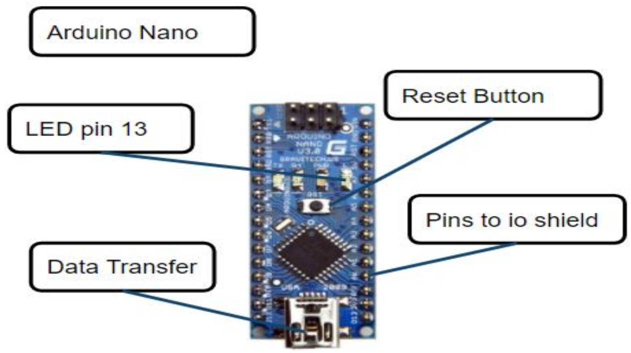
The system includes 2 different switches that has different jobs. Switch A is the main switch. Its job is to switch on the system when in use. Switch B is used to engage and disengage the clutch when the user wants it.

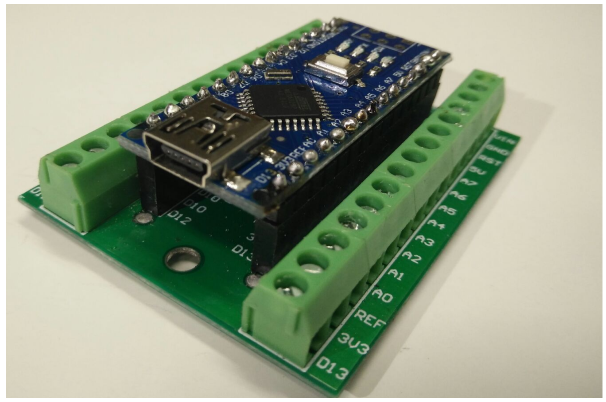
Nano shield



This is used to ease our troubleshooting, reducing both time and effort,using this will also make the wiring neater as compared to conventional soldering method.

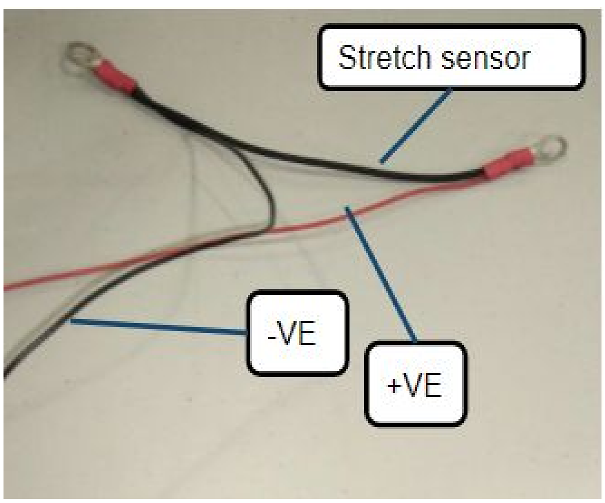
Arduino Nano

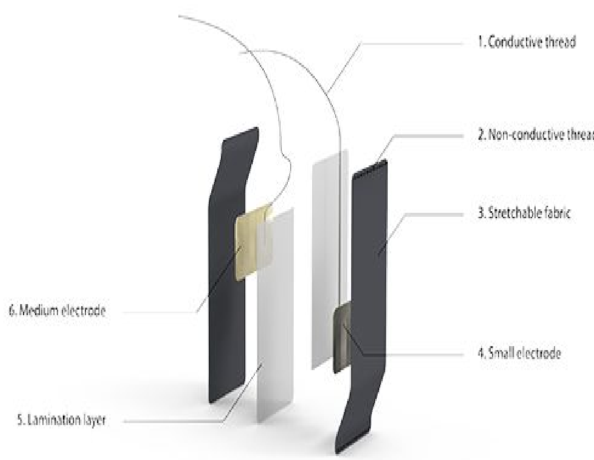




The Arduino Nano is a small, complete, and breadboard-friendly board based on the ATmega328P (Arduino Nano 3.x). It has more or less the same functionality of the Arduino Duemilanove, but in a different package. It lacks only a DC power jack, and works with a Mini-B USB cable instead of a standard one.

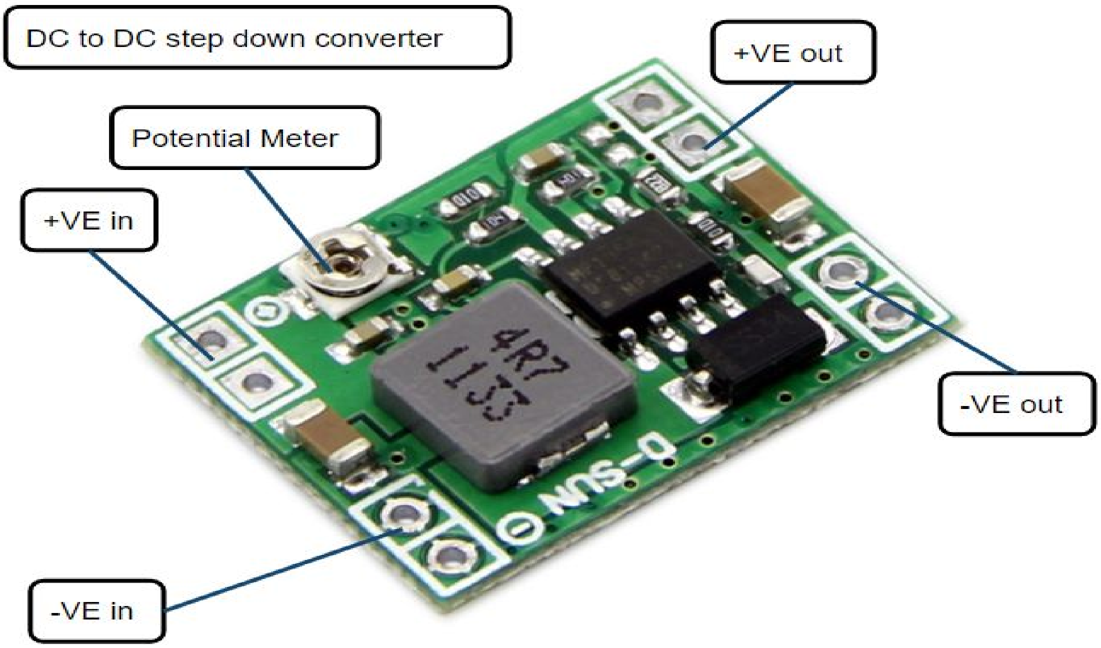
Stretch Sensor





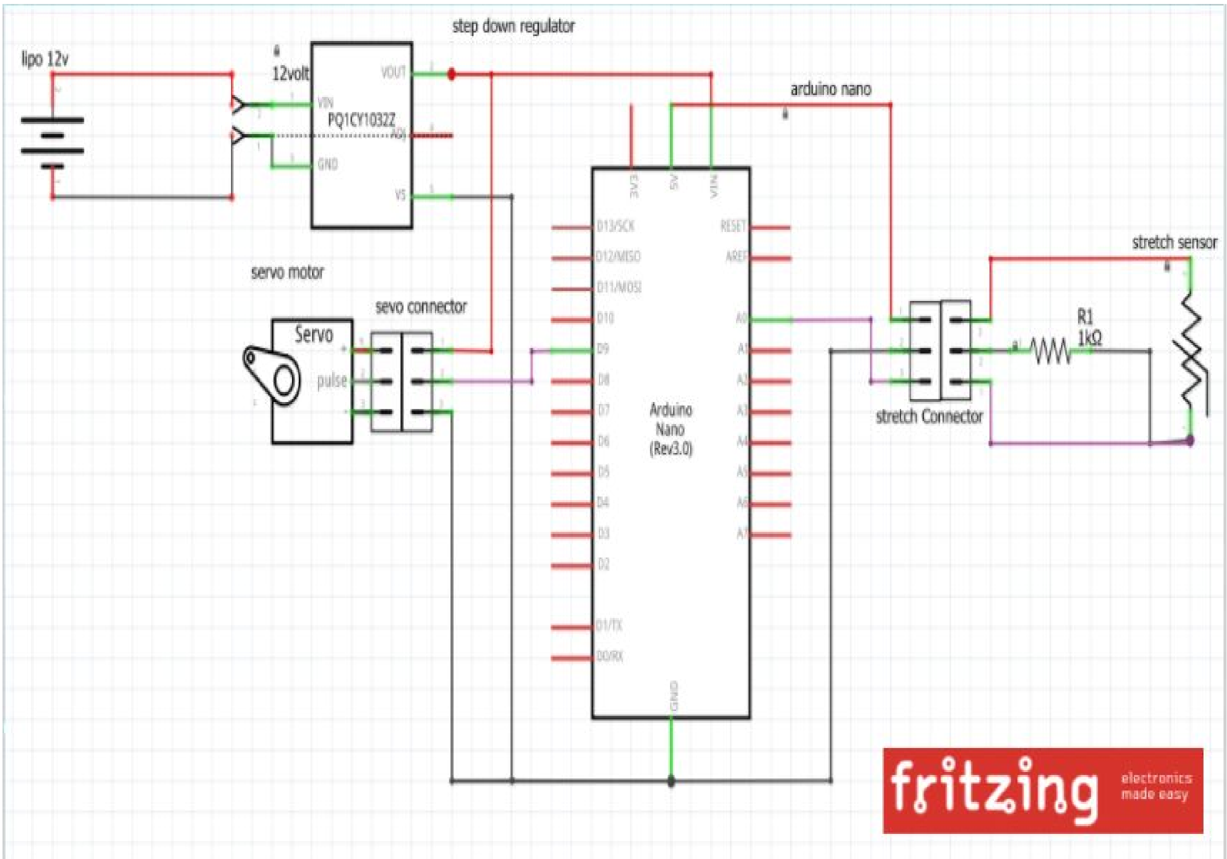
The flexible stretch sensor changes resistance when stretched. An unstretch sensor has a nominal resistance of 700 ohms per inch. As the stretch sensor is stretched the resistance gradually increases.

DC to DC step down converter



A DC-to-DC power converter which steps down voltage (while stepping up current) from its input (supply) to its output (load). It is a class of switched-mode power supply (SMPS) typically containing at least two semiconductors (a diode and a transistor, although modern buck converters frequently replace the diode with a second transistor used for synchronous rectification) and at least one energy storage element, a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter's output (load-side filter) and input (supply-side filter).

Schematic diagram

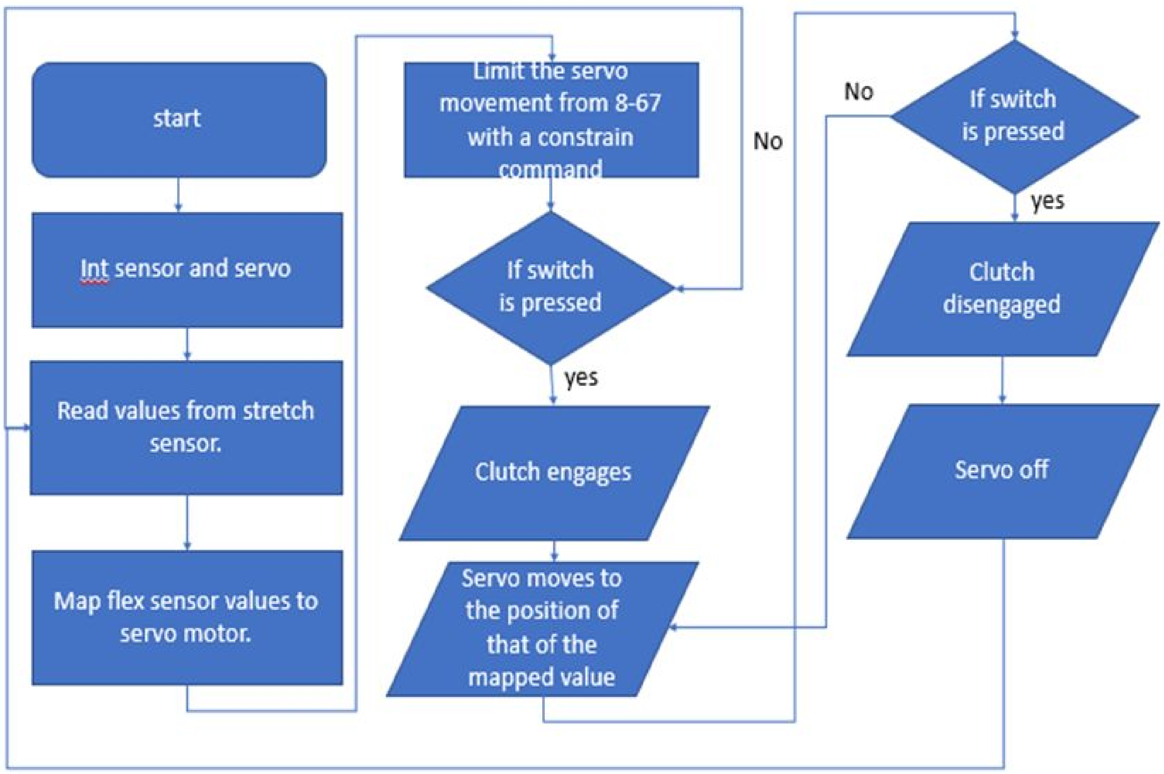


This is our schematic diagram. we used a software known as Fritzing. Fritzing is an open-source hardware initiative that makes electronics accessible as a creative material for anyone.

This website allows us to seek help from others online to give us advice. The website allow us to print a circuit board if needed.

Chapter 5: Software Design

Flow Chart



This flowchart shows the algorithm of the system that aids in movement. When the Arduino powers up, the sensor will begin reading the values of the stretch sensor. The value would then be mapped to that of the servo. The actuator would then move based on how much the value change and the cycle continues.

In Depth explanation

As mentioned above there would be two switches controlling the entire system. First, the user has to turn on the Arduino via switch A the main power switch, then the Arduino would be enabled, but at this stage, the servo and the clutch will still be disengaged, this is made in such a way as to prevent accidents from happening from the accidental pressing of the switch. At this stage the code from the Arduino would be read on loop, values of the sensors can be read using the serial monitor.

We built the sensor to be mounted on the opposite leg from the leg wearing the brace so as to bypass the problem of the leg not being able to move due to the brace restricting movement when engaged. Following this concept, the user will have to keep both legs in opposite directions, meaning the user will have to start off with one leg forward and one leg backward as if starting to walk. At this point, the user will engage the switch that is in control of the clutch and servo(switch B). The clutch and servo will be enabled together, and at this point, the leg will be able to move based on how much the other leg moves and thus this cycle repeats.

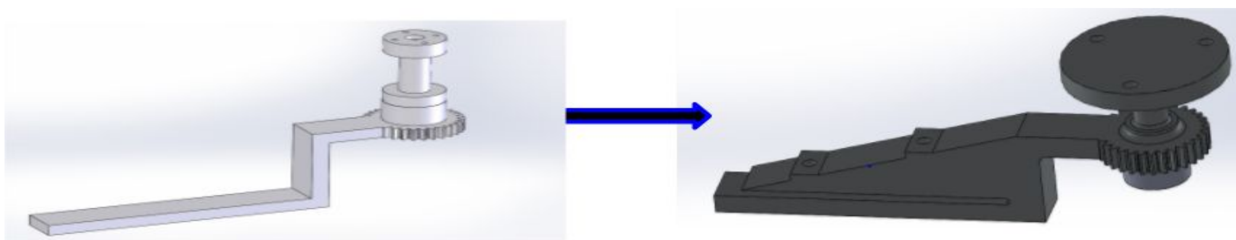
Whenever the user decides to disengage the assisted movement, he/she can trigger switch B which would give her free motion again. One more feature we implemented into this system is that whenever shes at rest or decides to disengage the system, servo power would be cut off which thus help in conserving power and also allows the system to cool down.

One more usage of this system is that this can be used as a standing support without any automated assisted movement. When the user decides to stand up, he/she can switch on switch B (clutch/servo) but leave switch A off. Doing this will enable the clutch and also send a single pulse that will toggle a holding torque in the servo. This would, in turn, cause the brace to be rigid thus helping the user bypass the load of the body through the brace.

Chapter 6: Testing, Evaluation & Improvements

Gear testing , evaluation & improvements

From our first prototype, the joint kept breaking due to poor design. We further research on the strength of shapes and found out that triangle is a good shape to use as any added force is evenly spread through all three sides . We added more bearing to allow the gears to rotate smoother.

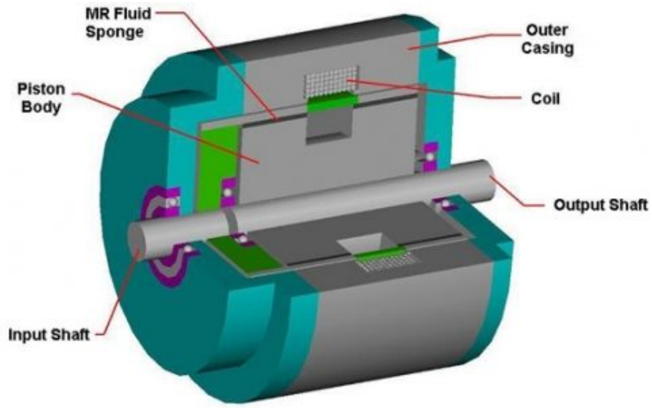


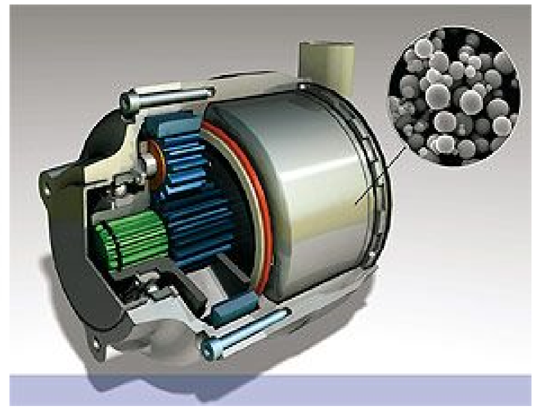
The new design have a longer lifespan compared to the prototype design. We have also filleted joints that are prone to breaking to strengthen the joint.

Clutch testing , evaluation & improvements

Currently the clutch uses friction to transfer motion. It is not reliable as the tooth might not be aligned when the clutch is engaging.

So we have looked into other clutch designs and found out an alternative that can be used in the future.



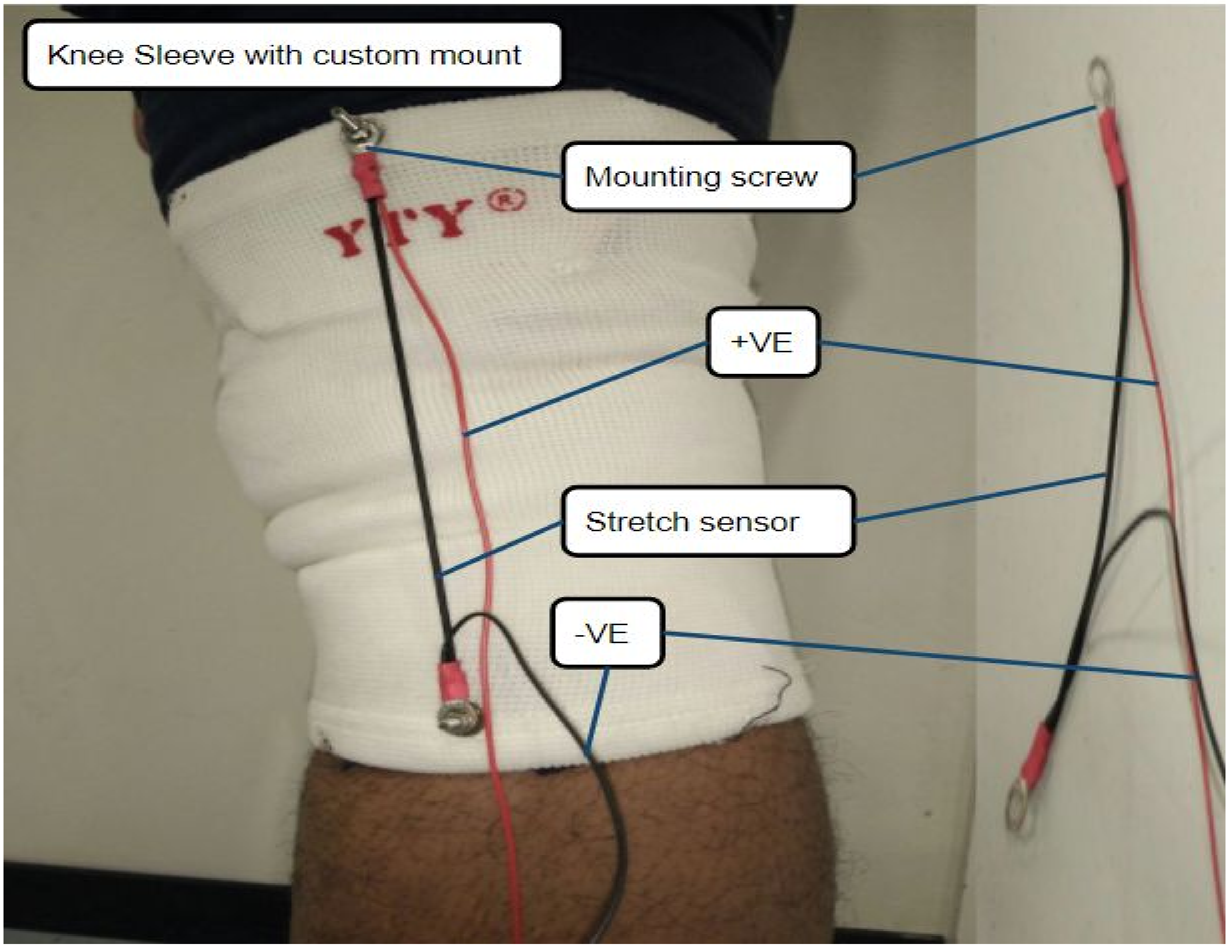


Sensor testing & evaluation

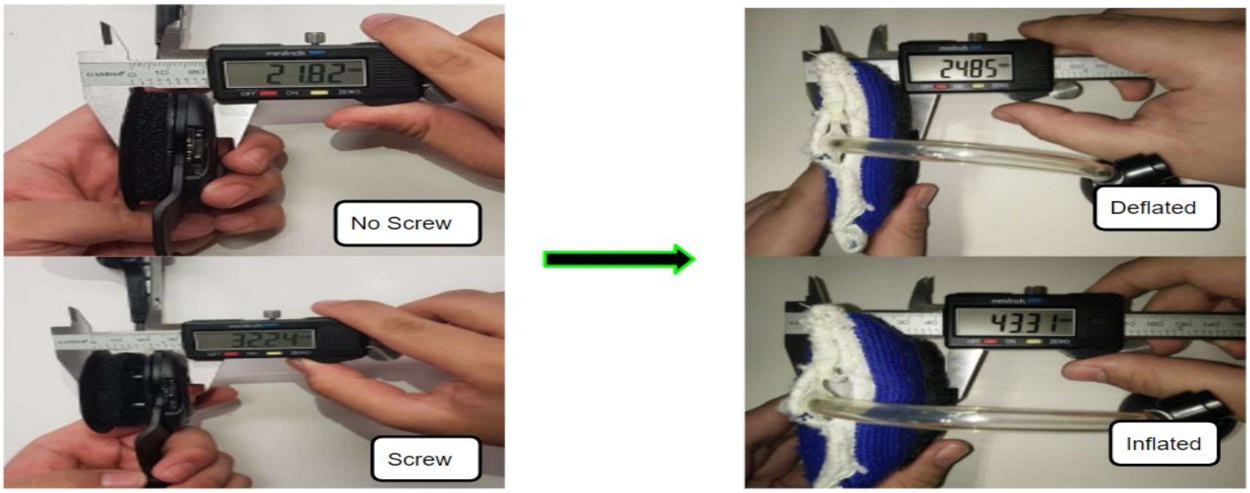
We wanted to use flex sensor to determine the position of the leg and to provide a relevant response. However the flex sensor was not reliable as it tends to slide off the brace. The reading was constantly changing, which caused us time to recalibrate the coding.

Hence we decided to change the sensor into the stretch sensor. It has helped us to achieve better results. We were able to customise a way to mount the sensor utilizing circular crimp.

Walk Free Osteoarthritis

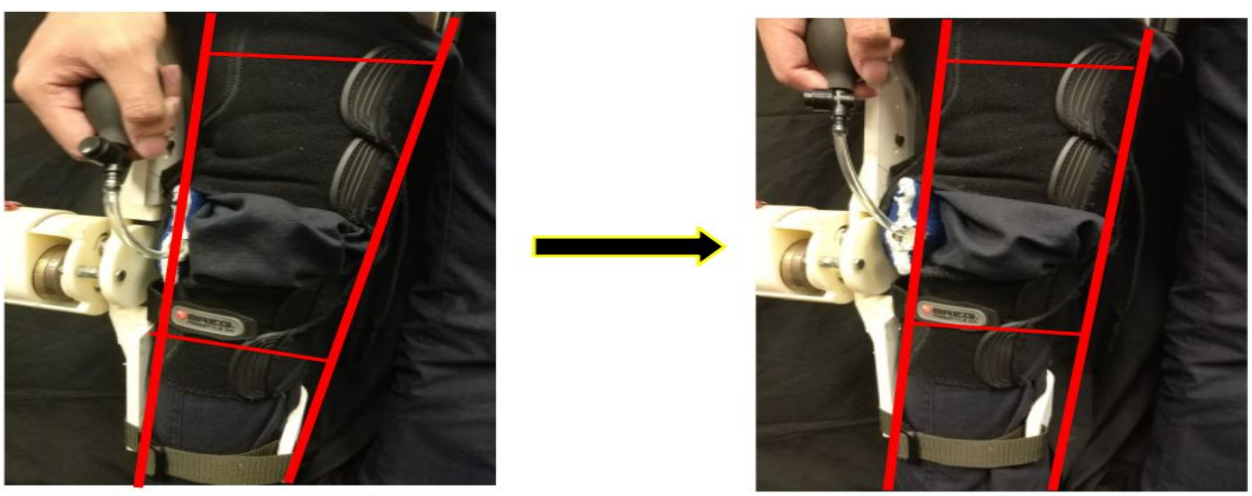


Pain relieving testing , evaluation & improvements



We test our air bladder and observed that it can expand better compared to a commercialise screw type(Freestyle® OA Knee Brace). The airbag can also change its expansion to suit the user. This will make the air bladder a better alternative.

We have plans to use a circular air bladder to better fit the design. This will allow the brace to have a better appearances and structure.



Air Bladder Deflated   Air Bladder Inflated

Chapter 7: Conclusion and Reflection

<u>Walk Free Osteoarthritis</u>

Conclusion:

Osteoarthritis will be rising problem for Singapore as Singapore has a significant increase in the people over the age 65 over the years.

Items		Latest Period	Latest Data	% Change (Y-o-Y) 1/	Previous Period Data	% Change (Y-o-Y) 2/
Resident Population Profile						
Age Structure 28/						
Below 20 years	'000	2017	827.5	-1.0	835.9	-1.1
20 - 64 Years	'000	2017	2,621.7	0.4	2,610.1	0.5
65 years & Over	'000	2017	516.7	[illegible]	487.6	6.1

In this 2 years of executing this project, we had to change the design multiple times to make it accurate and safe to use on a human. We have run a controlled test with a dummy leg, and achieved positive results. The final design is able to achieve the original aim of this project which is the realignment of the knee and assistance in walking.

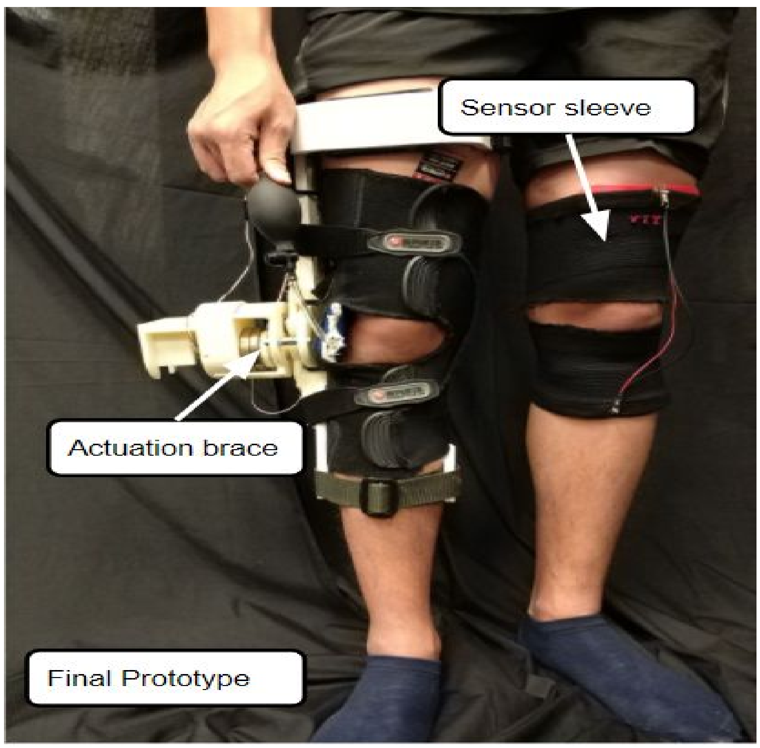
Using the air bladder to realign the knee is effective as the user is able to change its pressure to his/her comfort. Having air bladder can improve osteoarthritis condition as it pushes the bone apart,creating a space to reduce friction and pain to the user. This brace is meant to keep the knee from moving too far from side-to-side or from overextending and irritating a healing injury. Having the brace be bulkier may be necessary to make it hold the knee joint more firmly in place during strenuous activity.

We are creating a system to help the user bend his/her knee in a comfortable motion. The motion is created by a servo motor. The servo is accurate in converting pulse to a degree of rotation. This is needed to make a medical item as precision is required to prevent the worsening of the joint. Having a clutch is also necessary as it helps the robot to be safe for human use, at any time the user need or want to overwrite the system they can at anytiime disengage the clutch.

Walk Free Osteoarthritis

Having assistive knee brace can make life with joint pain a little easier. They can help you with tasks like walking, bending, standing up and help you also use less energy doing daily tasks like getting around to get a drink.

After physical therapy, using braces is extremely useful for the recovery process. They will help you stabilize your knee through all types of physical activity. People who use braces to walk around will have increased blood flow and the extra support provided by the brace will more likely help the user experience reduced pain over a long period of time.



However the current prototype is far from completion. We have plans to further improve the design, material choice, weight and many other component.

Chapter 8: Reflection

Izzat reflection:

This has been an inspiring project as I get to work on something that can benefit other people. Having to study the human anatomy, allow me to understand the pain of the people who are suffering in such condition. During the designing phase, I also got to learn designing and the strength of each shape. I got to use Solidworks to design an accurate design. Solidworks also allow simulation, which enables me to test the idea out before 3D printing.

Overall my journey has been a fun and meaningful. I am thankful for this opportunity.

Silvanus reflection:

I have learnt a lot over the past 2 years. Learning to prioritize and time management, these are important in order to have a functional team. I have personally learned how to think outside the box. A problem might seem to only one solution, however, with a dedicated team we can brainstorm many ideas. Having to evaluate the solution to find the best option is essential to cut down time spent in the ideation phase and fabrication phase.

I have learnt many things from this project. My main takeaway is that we have to utilize all the resources including materials, software and teachers. Seeking help from our teachers allow us to rectify problem we face.

Walk Free Osteoarthritis

Zheng Leong reflection:

I at first wanted to join this project as it is the closest I could get to nanotechnology at that point in time, but true enough this has tested my hands-on skills greatly. I was tasked to design and fabricate a circuit smaller than a phone and true enough managed to make it work, but still more room for improvement. I feel by far this has been the most meaningful project that has tested my values and motivation as a student. We had far too many setbacks but we managed to overcome it as a group.

Through this, we had definitely taught each other a few important life lessons that can be brought with us into adulthood, skills like perseverance, teamwork and confidence. Planning is also of importance in this project, my team have figured the hard way. We had this problem of us facing another new problem after one is fixed. I can say we cannot count the number of problems we faced with my 10 fingers.There's no ‘1’ or ‘0’ to this project, we can never say our project is working perfectly as we can certainly make improvements to this project. This project is not as simple as it looks, there are many limiting factors that have to be taken into consideration, factors such as human error and even wind affects our sensors, so this is a really great stepping stone that will help us in our future endeavours.

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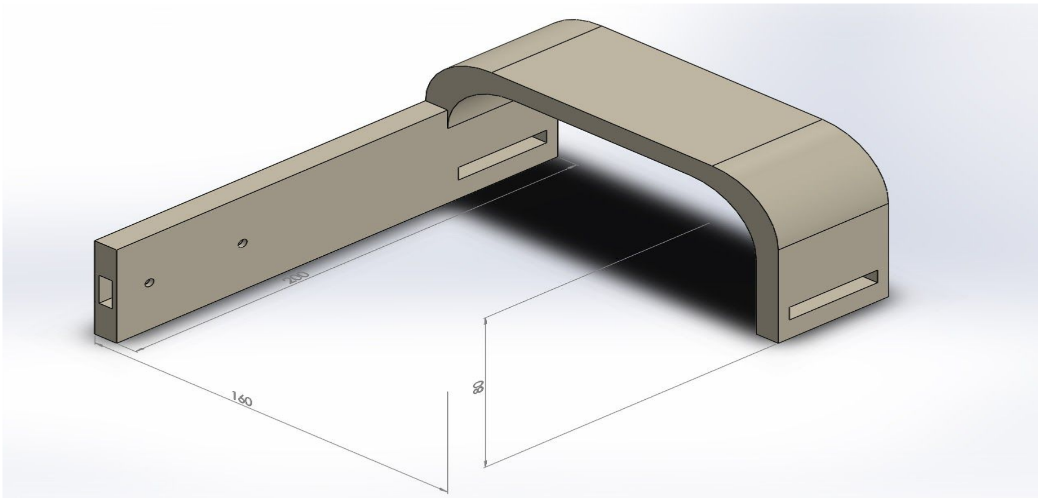
Annexes

Annex A:Mechanical Drawing

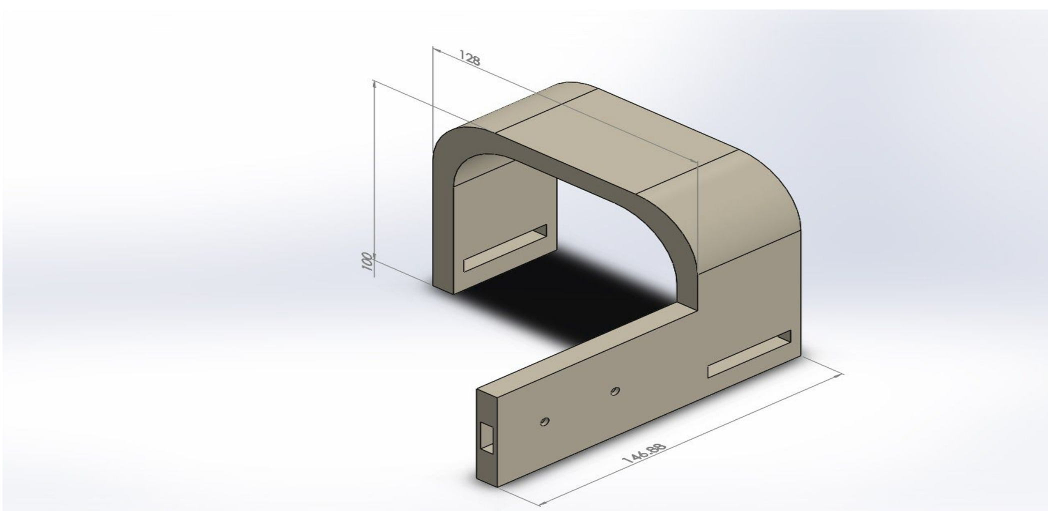


Thigh Brace:

Perimeter: 200mm x 160mm x 80mm

Circular Hole: Ø4mm

Rectangular Hole: 40mm x 6.75mm x 3mm

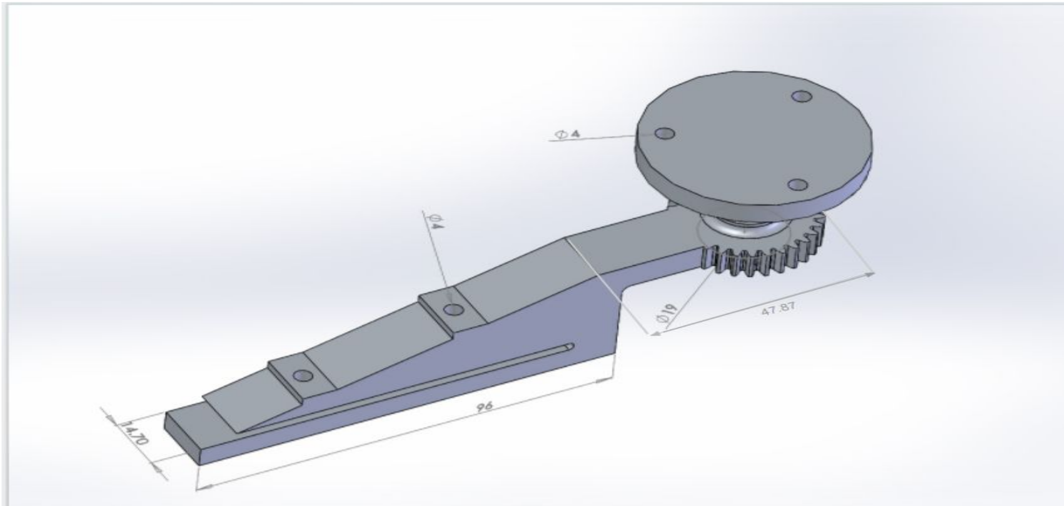


Calf Brace:

Perimeter: 147mm x 128mm x 100mm

Circular Hole: Ø4mm

Rectangular Hole: 40mm x 6.75mm x 3mm

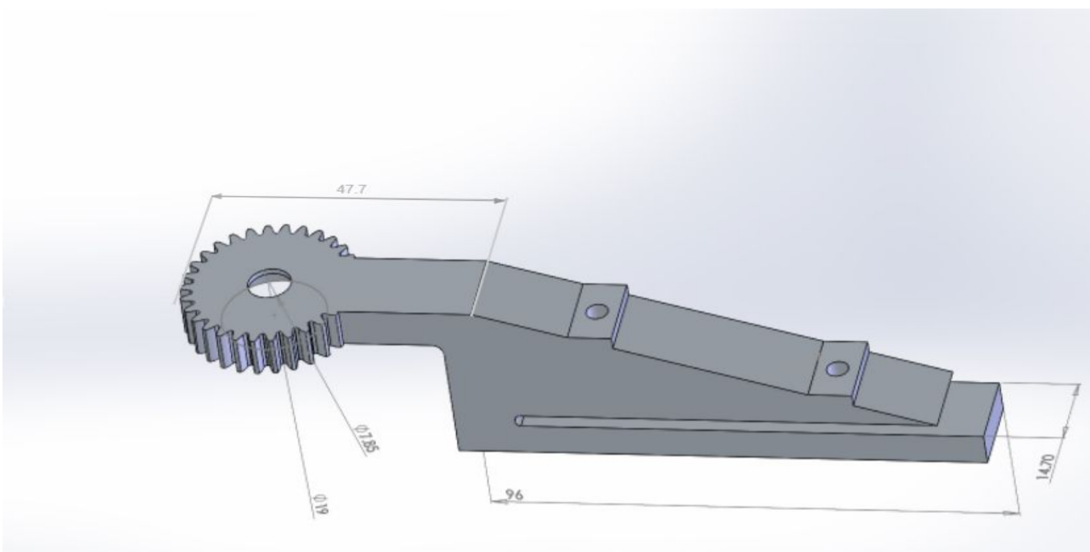


Gear like shaft to the clutch

Gear: 30 teeth

Inner Hole: Ø19mm x 7mm

Shaft length: 96mm

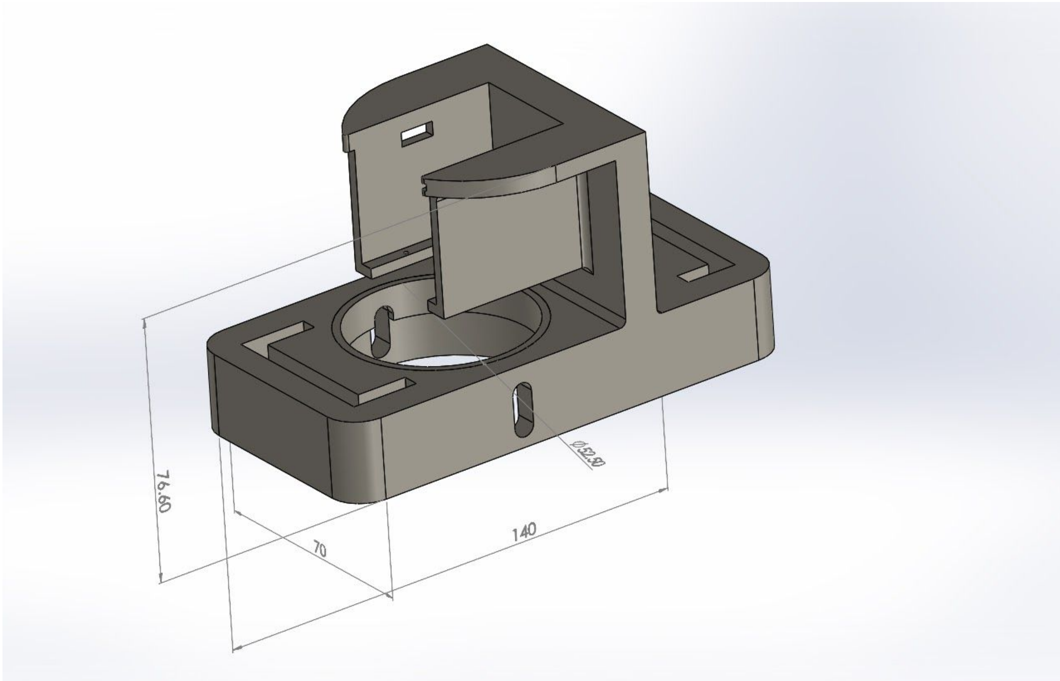


Gear like shaft to the clutch

Gear: 30 teeth

Inner Hole: Ø19mm x 7mm

Shaft length: 96mm

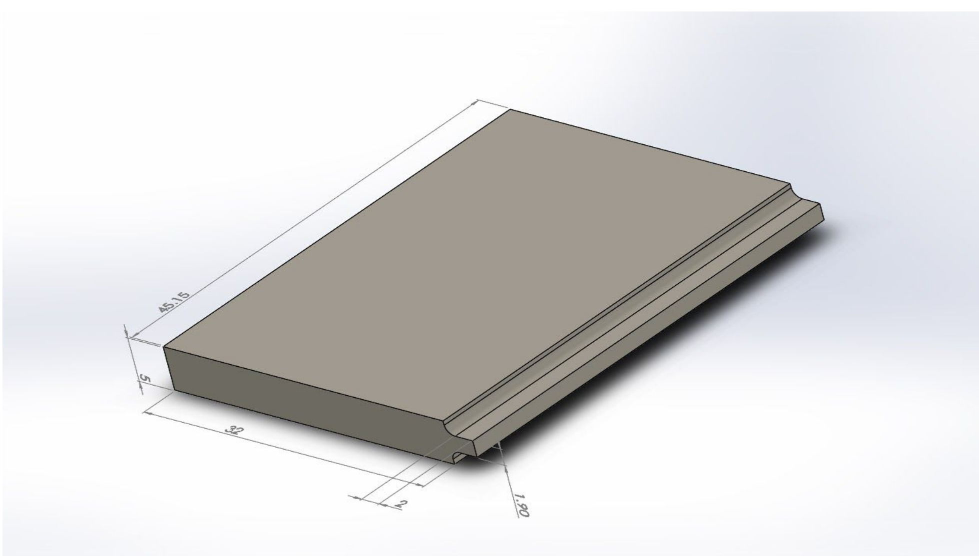


Clutch and servo holder:

Perimeter: 140mm x 70mm x 76.60mm

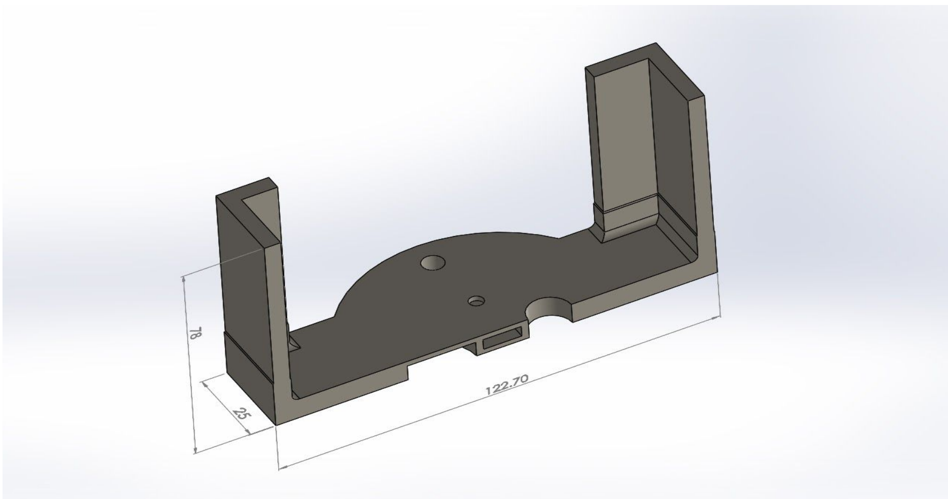
Inner hole: Ø52.5mm

Hole for the servo cable : 4.20mm x 10mm x 3mm



Back cover for clutch and servo holder:

34mm x 5mm x 45.15mm

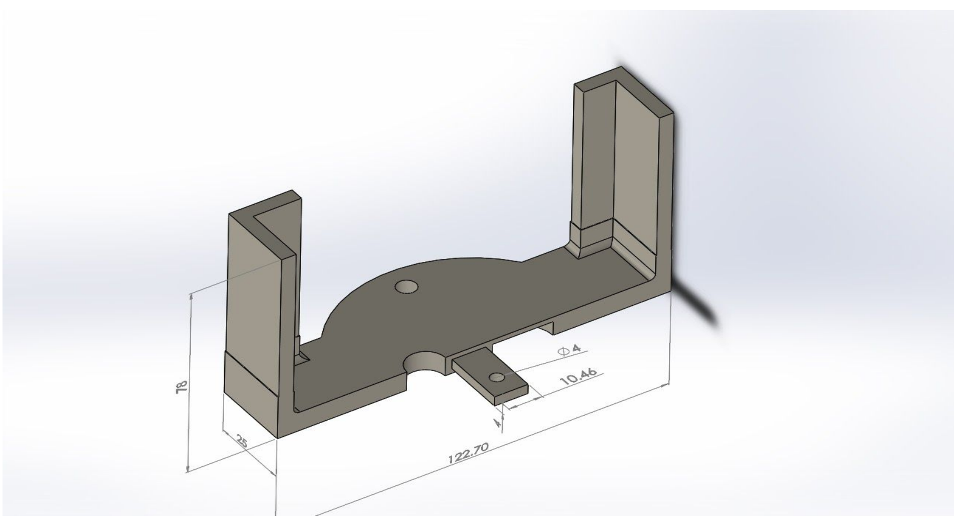


Holder left part:

Perimeter: 122.70mm x 40mm x 78mm

Circular hole: Ø6mm

Rectangular hole : 10.46mm x 4mm

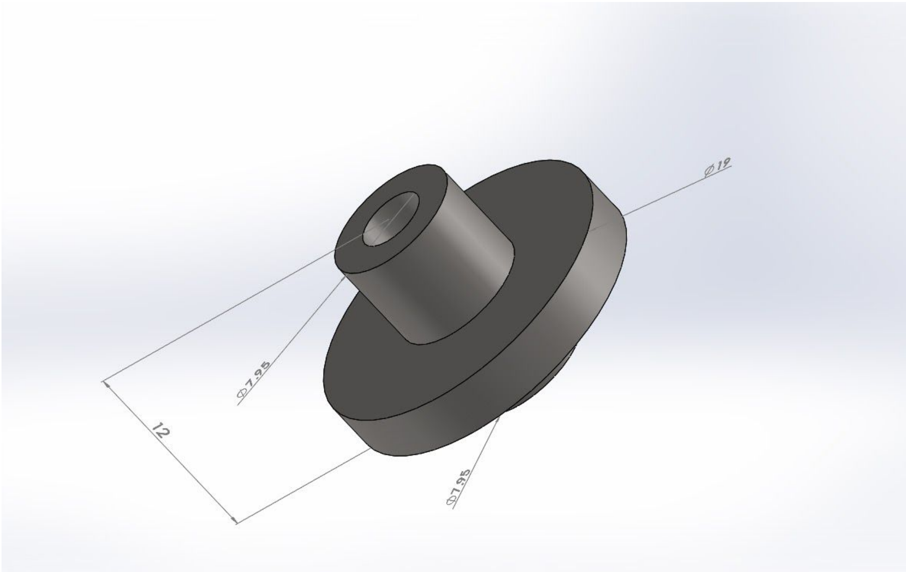


Holder right part:

Perimeter: 122.70mm x 60mm x 78mm

Circular hole: Ø6mm

Rectangular shaft : 10.46mm x 4mm

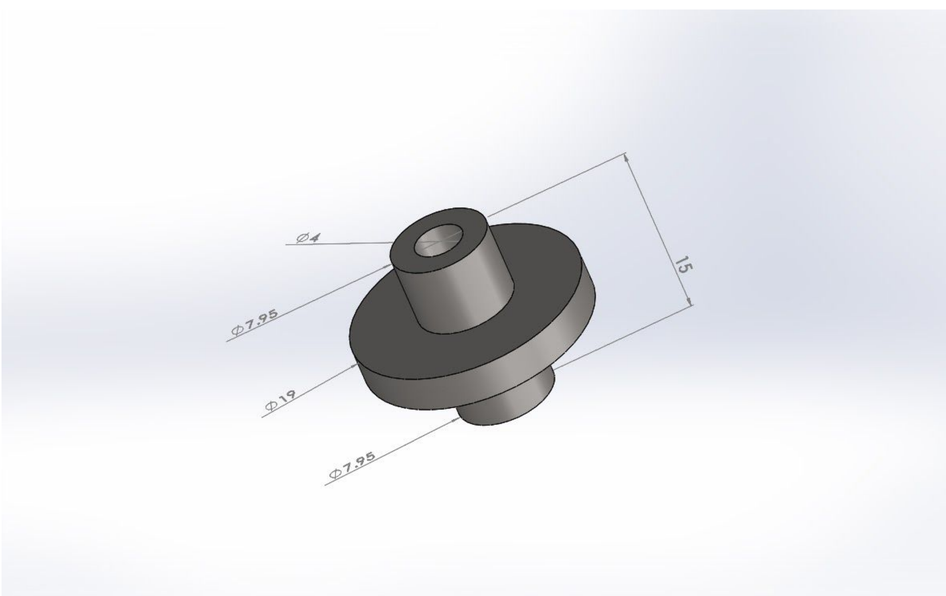


Ball bearing adapter 1:

Base: Ø19mm x 12mm

Top protrusion: Ø7.95mm x 6mm

Bottom protrusion: Ø7.95mm x3mm

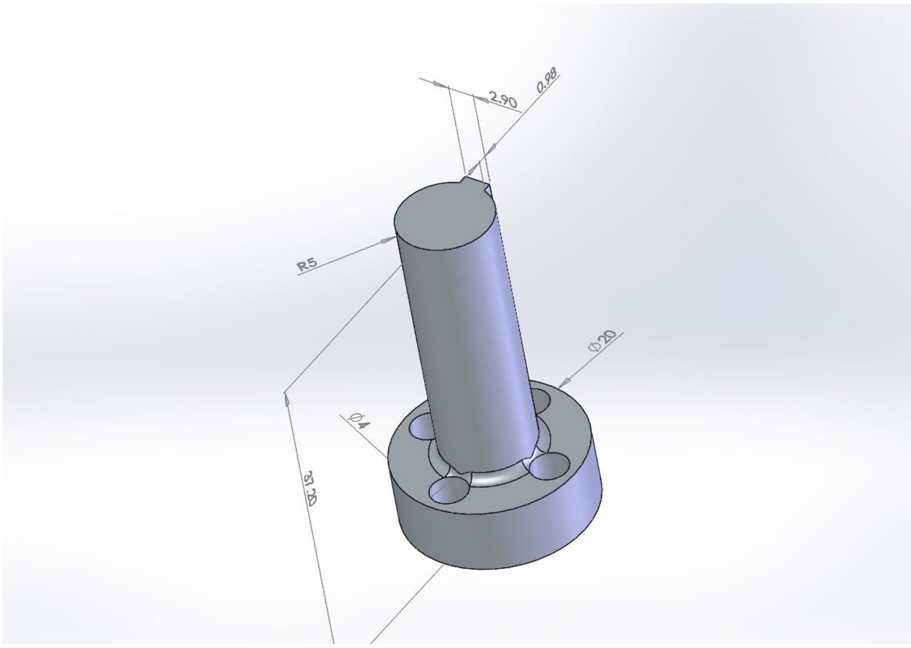


Ball bearing adapter 2:

Base: Ø19mm x 15mm

Top protrusion: Ø7.95mm x 6mm

Bottom protrusion: Ø7.95mm x 6mm



Locking shaft:

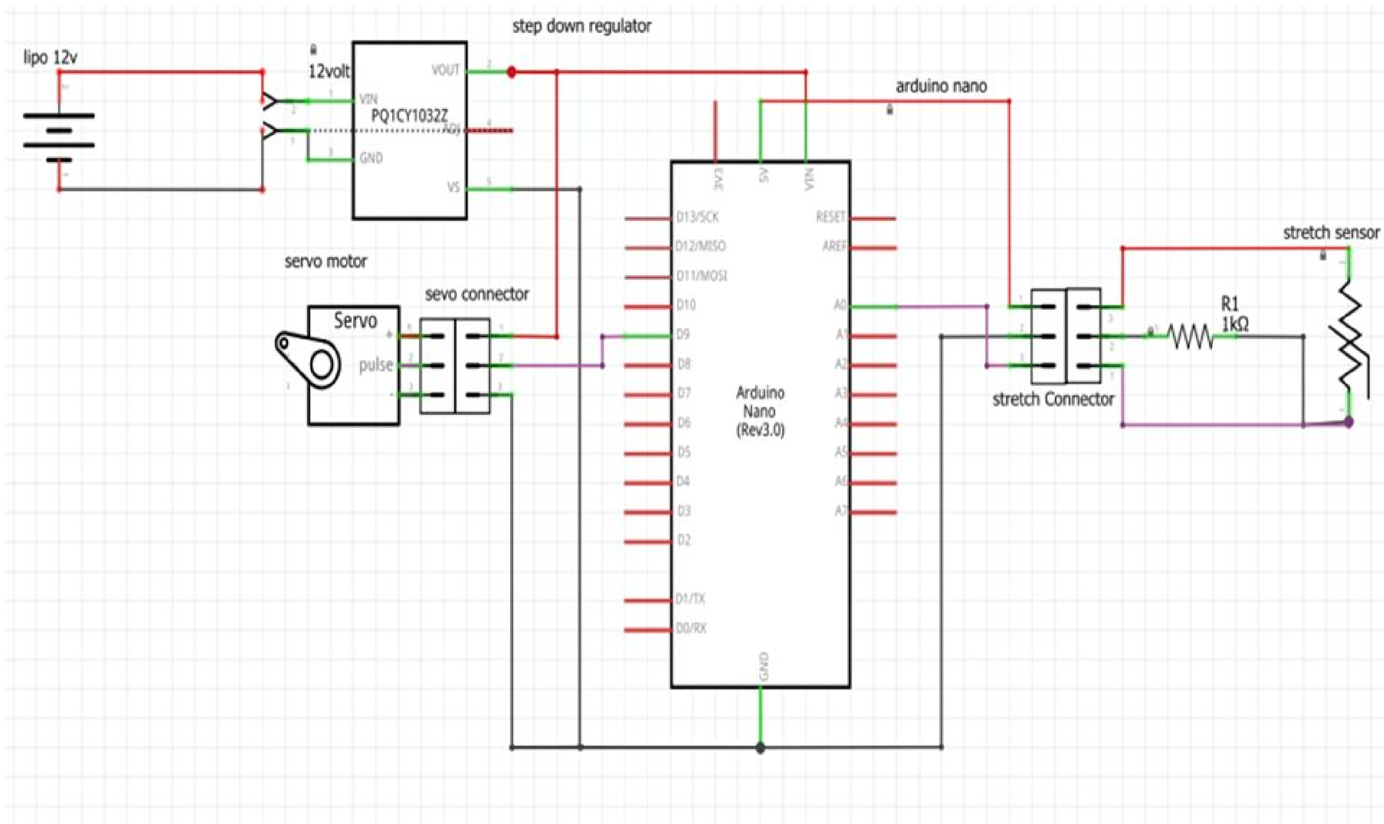
Base: Ø20mm x 37.20

Shaft: Ø10mm x 30mm

Lock : 2.9mm x 0.98mm

Holes: Ø4mm

Annex B:Electronics Design



Annex C:Arduino Code

```
#include <VarSpeedServo.h>

const int FLEX_PIN = 0;
VarSpeedServo myServo;
void setup() {
Serial.begin(9600);
myServo.attach(9);

}

void loop() {

int FLEX_PIN;

int servopos;

FLEX_PIN = analogRead(FLEX_PIN);

Serial.println(FLEX_PIN);

servopos = map(FLEX_PIN, 610, 585, 0, 40);

servopos = constrain(servopos, 5, 58);

Serial.println(servopos);

myServo.write(servopos,10);



}
```