PROOF OF CONCEPT FOR AN AUTONOMOUS CNC PERCUSSIVE MASSAGE MACHINE PROTOTYPE

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ALEXANDER JOSÉ MAGNUSSON AMORÓS

Abstract

The purpose of this project is to develop a prototype massage-machine, using two existing technologies: Computer Numerical Control (CNC) and Percussive Massage Treatment (PMT). Then demonstrate that an autonomous massage machine can be beneficial for a wide range of users. The development of the project will be divided into research, assembly, programming and testing. Moreover, a business plan under the Lean Startup technique will be in parallel progress.

The Gastrocnemius muscle, commonly know as the calf, will be the muscle chosen to be treated. Concentrating on that muscle area for the machine to work on, will help limiting the dimensions on the project and making the project more feasible. After some research on the different topics regarding the project, CNC machines, state of the art massage technologies, PMT tools, muscle anatomy; a design for the CNC structure will be created based on an existing one and right after, the PMT tool that will act as the CNC's spindle.

The next step was to order and assemble the parts according to the drawings, connect a controller board and begin programming the massages. To begin, the movement will be programmed to be under a remote control that the user will hold at all times, giving the option to stop the machine in case of emergency or malfunction. The progression will be to model a standard gastrocnemius muscle into a Computer Aided Design/Manufacturing (CAD/CAM) software and generate the commands to travel along the modeled muscle.

Finally, tests were held on participants to address the feeling and easiness of using such a design, hopefully proving to be useful and beneficial.

Keywords: CNC, PMT, Lean Startup, Gastrocnemius, CAD/CAM.

Resum

Aquest projecte té com a objectiu desenvolupar un prototip que uneix dues tecnologies: el Control Numèric per Ordinador (CNC) i el Tractament per Massatges Percussius (PMT). Es tracta d'una prova de concepte de que una màquina de massatges autònoma, dissenyada d'aquesta manera, pot ser beneficiosa per diversos usuaris. El desenvolupament del projecte es divideix en quatre fases: investigació, muntatge, programació i proves. Paral.lelament, s'executa un pla de negocis basat en la tècnica Lean Startup.

En primer lloc, s'ha escollit el múscul gastrocnemius, més conegut com a bessó, com a zona de treball de la màquina, amb la finalitat de delimitar la regió i aconseguir una major viabilitat en l'elaboració del projecte. Cada una de les àrees del projecte van sustentades d'una recerca extensiva per, finalment, crear-ne un disseny de l'estructura CNC, inspirat en un d'existent. En aquest cas, però, l'eina PMT actuarà com la claveguera de la CNC.

En segon lloc, s'han construït les parts del prototip de la màquina, enllaçant-los a una placa controladora i, seguidament, s'ha elaborat la programació dels massatges. L'usuari disposa d'un comandament a distància en tot moment, permetent posar en funcionament o aturar la màquina quan es desitgi. Posteriorment, s'han fet servir mides estandaritzades del múscul en un software de Disseny/Fabricació Assistit per Ordinador (CAD/CAM), generant un model digital que es podrà convertir en un seguit d'ordres que el prototip entendrà, obtenint el moviment a la màquina real.

Finalment, s'han realitzat proves per obtenir el màxim de crítiques i opinions respecte a les sensacions i la facilitat d'ús, amb la intenció de demostrar que pot ser pràctic, eficient i beneficiós.

Paraules Clau: CNC, PMT, Lean Startup, Gastrocnemius, CAD/CAM.

Resumo

O projeto têm como objetivo o crescimento dum protótipo de máquina que mistura dois tecnologias ja existentes, Control Numerico por Computador (CNC) e Tratamento de Massagem Percussivo (PMT), como prova de conceito que uma máquina autónoma de massagems desenhada desta maneira pode aportar um beneficio a uma grande variedade de usuarios. La evolução do projeto sera dividida em investigação, montagem, programação e provas. Aliás, um plano de negocio seguindo a tcnica "Lean Startup" sera desenvolvido em paralelo.

Foi escolhida a região do músculo gastrocnemius, conhecido popularmente como pantorrilla, onde a máquina vai funcionar. Dessa forma limita-se as dimensões e consegue-se um projeto acessívei. Após a investigação dos diferentes tópicos que constituem o projeto, o desenho para a estrutura CNC sera criado baseado numo ja existente com a diferença que a ferramenta PMT é o fuso da CNC.

O paso seguinte, será montar as partes do protótipo, conetar uma placa controladora e começar a programação dos massagems. No inicio, o movimento sera controlado por um mando a distância que o usuario vai aguardar o tempo tudo, tendo a opção de parar a máquina em caso de emergência ou defeito. A progressão continua com a modelagem do músculo gastrocnemius num software de Desenho/Fabricação Assitido por Computador (CAD/CAM) e gerar os comandos para viajar aoredor do modelo.

Finalmente, provas seram feitas em usuarios para perceber o estado deles e a facilidade de uso da máquina com esse desenho, esperançosamente demostrando ser útil e beneficiosa.

Palavras-chave: CNC, PMT, Lean Startup, Gastrocnemius, CAD/CAM.

List of Figures

List of Tables

Acronyms

ATC Automatic Tool Changer. 43

BOM Bill of Materials. 56

CAD Computer Aided Design. 43

CAM Computer Aided Manufacturing. 43

CB Control Board. 46

CNC Computer Numerical Control. 12

DIY Do It Yourself. 44

DOF Degrees Of Freedom. 26

EA Electronics Assembly. 62

HA Hardware Assembly. 62

JTK Joy To Key. 67

MG Massage Gun. 11

MVP Minimum Viable Product. 63

PMT Percussive Massage Treatment. 11

POV Point Of View. 55

PSU Power Supply Unit. 46

ROI Return On Investment. 63

ROM Range Of Motion. 11

RPM Rotations Per Minute. 48

Contents

1 Introduction

Exhaustion, fatigue, weariness, or debility all refer to the same state of physical or mental health. It is not an uncommon experience for the human race, it is not a new feeling either, and it will be recurrent for as long as we live. Moreover, it does not matter your gender, ethnicity, job, or lifestyle since it makes part of being alive, using your body and mind.

Nevertheless, it can be smoothed, resolved, treated, or rectified. Failing to do so can have an irreversible effect on muscles, impact productivity and affect perceived happiness and well-being. Despite this, there is no need to worry since we already rest and relax in many different ways, even developed techniques to achieve it quicker and better. Ranging from sleep, the simplest and most natural but time-consuming solution, to more complex, commercialized, and dependent, however focused and faster, physiotherapist massage treatments, self-applied muscle stretches, meditation, contrast baths, vibrating sofa chairs, or, more recently, percussive massage treatment (PMT) therapy.

Briefly explained, PMT therapy consists of repetitive hitting of the muscle fibers. State-of-the-art PMT tools, also known as massage guns (MG), accomplish it through a motor connected to a slider-crank mechanism (Figure 1) only that the slider is a cavity where different applicators can be attached, ready to hit muscles. Figure 2 shows an exploded view of the inner workings of commonly available PMT tools, and a detailed explanation is in section 2.2. PMT therapy has been present for a long time, however MGs are still new, and recent studies conclude it is beneficial for most people. Generally, it discharges the muscle under treatment, provides a relaxed feeling, serves as a pain relief for post-workout, increases range of motion (ROM) (Konrad et al., 2020) and can be used to help treat strains or other injuries when supervised by a professional (Capritto, n.d.). In the past few years, new companies as

well as known brands in the well-being business sector rose by manufacturing and selling MG to athletes, elite sports players, and gym enthusiasts.

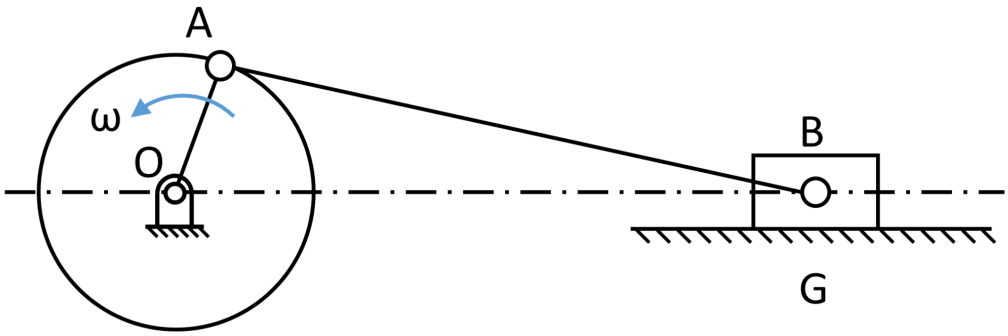


Figure 1: Machine design of a slider crank mechanism.

Source: https://www.freeaptitudecamp.com/velocity-analysis-slider-crank-mechanism-graphical-method/

Additionally, MGs are usually designed with the thought of being a self-applied massage treatment, making it possible for the user to hold it properly to provide greater usability and precision (Martin, 2021) while cutting out the middle man. Despite this, an individual trying to reach difficult areas, like the back muscles, will be challenging and add discomfort to the customer. Moreover, ignorance on how, where, and when to apply MG reduces their efficacy and can have harmful effects (Chen et al., 2021). The buyer would fall responsible for learning the correct ways of using the tool. To solve both issues, an extra pair of hands from a licensed professional would suffice, despite beating the purpose of making MG a self-treatment tool.

Another possible solution, tackling the above-mentioned issues while maintaining the integrity of MG as a self-treatment device, could be Computer Numerical Control (CNC) machines. This technology is used for tool manipulation, semi-automation processes, and manufacturing. CNC machines are built to move in three directions orthogonal to each other and some cases,

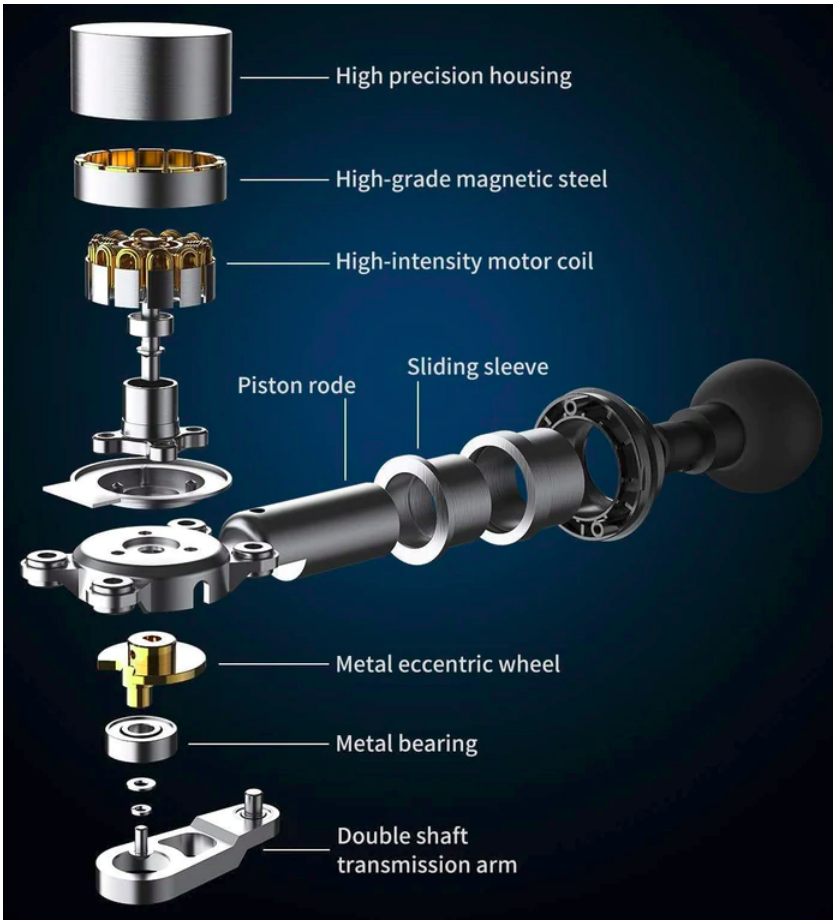


Figure 2: Exploded view of a PMT tool.

Source: https://renpho.com/es/products/r3-massage-gun

even rotate along with them. Usually, one of the directions is fixed, which makes the base of the machine, while the gantries (movable parts) of the remaining two directions travel above and around the designated working area (where the manufactured material is secured). Electric motors controlled by commands sent from the computer to the machine's controller board make the movement possible. A software program transforms a designed piece into numerical code (G-Code), generating the commands that orders the motors if they have to move and where to. The most common actuator is a router,

called the spindle, and is in charge of subtracting the material until the designed piece is the left. Depending on the machine's specifications, motor torque, router strength, and drill bits, it can cut wood, steel, acrylic, and other hard plastics. Its precision and speed make it a reliable and independent manufacturing machine for small-scale manufacturing.

For that reason, having the work-piece of the CNC be a human and adjusting its spindle to be an MG, an autonomous muscle treatment machine can be born out of the partnership of both technologies.

1.1 Problematization

Some research to address whether there exists a real problem to be solved with such an idea of joining CNC and PMT, having the just mentioned concepts in mind.

In recent years, self-treatment products for stretching muscles and post-workout muscle pain relief, such as foam rollers and massage balls, have gained popularity. The developed implementation of a vibrating component for foam roller showed benefits in ROM performance (Cheatham and Stull, 2018; Garcia et al., 2018; Sohel and Rahemun, 2019). It shows it solves the real problem of ROM improvement and many active members are willing to learn and use it. Nevertheless, they lack consistency, and there is a significantly steep learning curve to apply it correctly, which requires discipline and experience in applying it to oneself. Incorrect use would not show any benefits and could provoke more pain. Therefore it is recommended to use with caution (Bartsch et al., 2021; Freiwald et al., 2016). Moreover, there are compromises in the perceived feeling of relaxation by the fact that it requires the user to partially support their upper body weight (Thygerson et al., 2021) to find the appropriate locations. They are also limited to certain muscles due to their large design (Martin, 2021).

Another product in the relaxation market is the massaging chair, which has been on the market for years, bought to rest after a long day. There are many techniques used, and vibration or automation movement of the rolling balls are the main ones. Even though it can have a high perceived relaxation, they become repetitive quickly, and it may focus on areas that might not require treatment, worsening the condition of the user. Their fixed pattern limits the customization, and they cost more.

On another note, recent events regarding the spreading with much ease of a virus, has called for humanity to stay distanced and avoid physical contact with others and even more so, if they have been near many other people, causing a higher chance of infection. Imagine how the physiotherapist environment has been affected since they are not only working with their physical body, they require close contact for long periods and treating many different clients. Such a massage machine that could be controlled remotely or even be autonomous, would keep customers coming and continue their treatment without having to increase their or the physiotherapist's chances of infection. Nevertheless, such a treatment should not be taken as a substitute for the experienced physiotherapist, since they have better patterns and organic shapes of massaging as well as direct and constant feedback of how the muscles are responding and the knowledge to treat them.

Finally, the increase in gym openings, alongside gym memberships and overall health concerns, implies more people doing sports. Therefore, expanding the chances of injuries, demanding better ways to avoid them, and quicker treatment from not so solicited physiotherapists. Nevertheless, the body has many muscles under stress during workouts, and since it has yet to be proven it is a valued and welcomed solution addressing all of them in this project would not be feasible or efficient.

1.2 Justification

Upon deciding what part of the body to address for the proof of concept, I would like it to be meaningful and prone to common or repeated injuries or soreness. Many different exercises, workouts or sports use a combination of muscle groups while other tend to isolate the muscles worked. Anyhow, even for those who follow a more sedentary lifestyle, the lower limbs are daily used and tend to be popular when complaining on perceived fatigue. They hold us standing up and moves us around, even when you do not focus on strengthening those muscles, you can not avoid using them.
Moreover, PMT has only be shown to improve ROM on lower limb muscles (Konrad et al., 2020; Martin, 2021). Being this project a proof of concept, the dimensions of the machine should be limited and provide a good cost-benefit ratio.

For that reason, and as other articles have done, I decided to start and focus on the gastrocnemius muscle, commonly known as the calf. As added justification, lower limb injuries are third in list of most work injured body parts (National Safety Council, 2020) and also third for common injuries in professional football players (Werner et al., 2017). Furthermore, once a calf has been strained, it is prone to get injured again sooner (Green and Pizzari, 2017), needing better and constant care which can get expensive when a professional physiotherapist is applying it. Also, the incidence of calf strain is increased with age, making it more likely that those who keep training will require treatment.

Despite this, calf strain is not recommended to be fully treated by percussive massage, but only when recovered to maintain health of the muscle or with the supervision of a professional and in a gentle manner (Capritto, n.d.). Moreover, the referenced studies do not show any consistency on the pressure applied or trajectory done on the muscle, rising the hypothesis that

they would benefit of such a machine able to provide constant, accurate, precise and homogeneous application of PMT to each participant.

To conclude, PMT is a massage treatment beneficial for all kinds of active members of society by increasing ROM on lower limbs, reducing muscle soreness (Konrad et al., 2020; Martin, 2021) and relaxing, however dependent on somebody else to apply it. For that reason, CNC technology will be joined, supplying an autonomous and remote controlled aspect, and restricting the working area of the outcome machine, covering only the gastrocnemius muscle.

The percussive output will also be limited, since PMT can reach high frequency vibrations that will have an impact on the CNC design and structure. Throughout the development there is risk of going above budget, not getting the materials on time or receiving them faulty, delaying the build.

Lastly, the end product will become a proof of concept of a machine thought to be demanded by:

- Physiotherapists as a way to treat injuries under their supervision (Capritto, n.d.), improving efficiency and cost effectiveness.
- Rehabilitation centers to avoid long time contact during high risk of infection periods and provide yet another type of autonomous treatment.
- Sports teams and athletes that need constant discharge (Green and Pizzari, 2017; Introcaso, 2020; Werner et al., 2017).
- Gyms that want to provide a good health service for previous and post workout (Konrad et al., 2020) or simply for relaxation of the muscles after a long day.

Furthermore, proving a success of the concept, future research would lead towards making the machine able to identify injuries or affected areas and increasing the working area to other muscle groups.

1.2.1 Requirements and Constraints

There are some conditions the design should check and that are crucial for the development of the project.

- The design should be simple and easy to mount/dismount.

  Since this project has to focus more on the joining of the technologies, a simple CNC design will be sufficient and leave more time for the adaptation of PMT to CNC.

- The structure and overall machine has to be sturdy.

  PMT is a vibration treatment method which will have a big effect on the CNC structure if those vibrations are not calmed or absorbed. The PMT spindle will have its own shock absorbent components but the stronger and sturdier the CNC structure, the more reliable it will be on the long run.

- Movement in at least three axis and having a working area covering the entire gastrocnemius muscle.

  The user should remain still and avoid movement so that the machine does all the travelling.

1.3 Goals

1.3.1 General Goals

The aim of this project is to develop a prototype, serving as a proof of concept, capable of administrating automatic massages to the gastrocnemius muscle (known as the calf) in order to reduce healing times and/or relax the muscle with the use and combination of CNC and PMT technologies.

1.3.2 Specific Goals

The more detailed goals along the development are:

1. Proving that PMT is beneficial and used, declaring a probable market niche.
2. Understanding the anatomy of the gastrocnemius muscle and program a healthy massage sequence.
3. Finding and reproducing a CNC design easy to build and structured in modules.
4. Developing a spindle that works as a PMT and can be securely attached to the CNC design.
5. Testing and deliberating whether it proved or not the concept.

1.4 Scientific Methodology

Taking into consideration the eventual function of the prototype to develop in this project, the purpose of the research is to get an overview of what is most likely to work as a solution to join CNC and PMT to treat a certain muscle.

Therefore, to accomplish the before-mentioned goals, a bibliographic review, followed by experimental tests, will be done. The former is needed to understand properly both technologies, how they can affect each other and the most suitable way to fuse them. Moreover, fundamental knowledge about the gastrocnemius muscle and the way to massage it using percussive techniques, is necessary for programming the movements without injuring the users. The later experimental tests will confirm such a solution worked, as well as including feedback to redesign and improve the prototype.

To acquire the just mentioned knowledge, the bibliography review will be done following the concepts listed here:

- State of the art on massage machines

  To tackle the solutions found now a days and have a reference point to compare the project's prototype as well as do a market study.

- PMT

  To understand the mechanism basics and how it will affect a CNC structure.

- Muscle anatomy

  To comprehend how muscles react to percussive treatment and the best way to apply it and avoid injuries. Furthermore, proving it has a positive impact.

- CNC

  To find an open-sourced design from which the prototype will be based on and be able to build one from the ground up.

For that reason, this project will be using Google search engine and Google Scholars to find scientific papers on the topics listed above, focusing on how percussive massage affects the muscles, data regarding lower limb injuries, a state of art research and future aspects of automated massage systems. Keywords used for the search were: PMT effects, gastrocnemius muscle treatment, PMT risks and benefits, percussive massage improvements and massage robotics, among other terms.

2 Research Review

2.1 Bench-marketing Competitors

Whenever someone thinks of a massage machine, a vibration chair comes to mind or maybe those attachments you can put on a regular chair that have rotating spheres moving in a repetitive pattern. These have been in the market for a long time, and still are.

Figure 3: State of the art massage chair available in the market.

Source: https://www.kollecktiv.com/

However, the relief they bring can get annoying quickly and it is limited to the machine's program, it does not offer a customized massage, meaning that the control is not on the users hand. Some can even be dangerous, provoking pain or injuries (Grant Moore [Moore], 2020; Japantimes, 2016). Since human bodies vary in shape, form and muscle or fat content and so should the intensity and movements of the machine. Moreover, this products are

usually thought to be used on a perfectly still body and in a particular pose, however in real practice, the area applied can be wrong or shifted without the machine knowing. Newest versions have accounted for those issues and have body perception or sensors (see Figure 3), making the machine adapt to the user and not opposite. Despite this, the prices tend to go deliberately up.

Other automated massage machines use water pressure, those found in many spa's or pools. These are great but need a large amount of water to be fulfilled and have fixed jets rising the same issue as the chairs or cushions, however it permits the user to move freely and apply the pressure as he or she sees fit and to most parts of the body, since the medium is water. Nevertheless, in case of failure I can imagine that the repair of such a machine will not be quick, easy nor cheap.

Figure 4: HydroMassage Model Lounge 440X

Source: https://www.hydromassage.com/products/lounge-440x/

More modern options found are hydro-massage tables from HydroMassage (see Figure 4) or Sidmar companies. It consists of a stretcher built out of a water-filled mattress and movable pressure jets to push the water into the

laid user. They have full or half body reach and give full control by implementing an user interface screen to select intensity, type of massage and location of the jets. These stretchers claim to provide a relaxing massage for post-workouts, pain relief and for stiff muscles. Even though it gets all the benefits out of the water massages without the need of large amounts of the liquid, it still can not do massages in other parts that are not the back side of the body. Nevertheless, the fact that the user lays in a water mattress enables him or her to fully relax the muscles, since they are "floating" and the user interface is very advanced, providing fully customized treatments, save configurations for each user and even supply entertainment while the massage is being done.

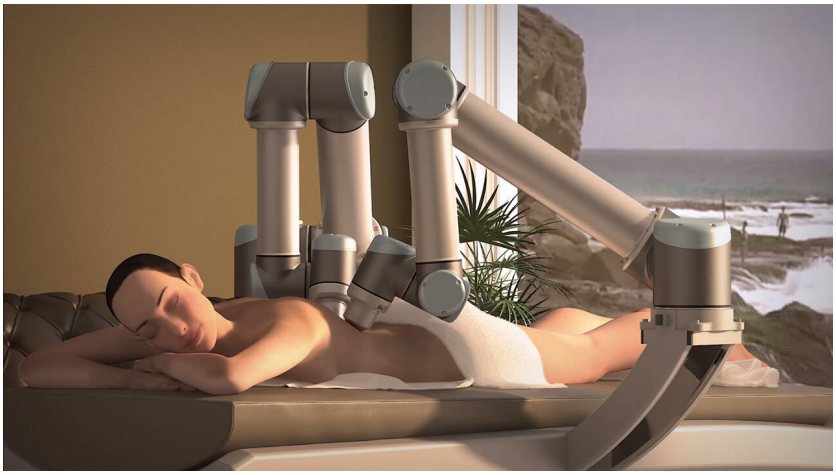


Figure 5: Massager Robotic's product render.

Source: https://massagerobotics.com/

The last examples on state of the art for massage machine are collaborative robot arms with different attachments from Massage Robotics or Capsix Robotics companies, Figures 5 and 6 respectively.

Figure 6: iYU Pro Capsix Robotics.

Source: https://capsix-robotics.com/

They have programmed collaborative robot arms to apply a massage as close as possible to the physiotherapists, with their knowledge's and protocols. The "hand" has different detachable tools, making possible different styles of massage and the arm has full body reach.

Furthermore, it knows where it is applying the massage at all times, by using a camera hanged over the stretcher the body position of the user is constantly updated and it can see how is she or he facing, making it possible to apply to both sides of the body (facing up or facing down). The capability of full body reach and both sides makes this robot able to massage all the muscles from our body.

Capsix Robotics (Figure 6) has developed a user interface to program the massage before laying down, a screen to watch over the robotic arm with the footage capture by the camera on top and a remote to change the pressure of the massage.

On the other hand, Massage Robotics (Figure 5) chose voice recognition to communicate with the machine and applied a second arm to work simultaneously.

Lastly and on a personal note, I found these last two examples of the newest concepts, to be closer to my project. This idea of using robot arms is what I had had in mind to develop following this thesis, in case of success.

2.1.1 Learned aspects

After this brief research I noted what I should avoid and what works in massage robots or machines.

- I believe that by focusing on CNC with PMT technology first, instead of start with a robotic arm, I might get a lower price and still implement most of the features. However, the working area will be significantly smaller, fewer degrees of freedom (DOF) and only one kind of massage technique.

- Building the machine around a stretcher instead of making an installation or having the robots attached to an existing stretcher is typical among the findings. This is a good point to observe since I had doubts on how to design the CNC, if as all-in-one with the stretcher or as an attachment that could be removed if needed.

- Customization is key on all the newest concepts as well as the control. Making the machine able to read the body position and muscle condition builds confidence in the safety of usage.

- Applying heat to aid the treatment is mentioned and used by some of the machines however not all, maybe it is not a requisite but still good to keep it in mind.

- The power of having different tools would help reaching different muscles and applying all kind of techniques, therefore a modular design for the spindle (ease of tool change) would proof beneficial and most likely would become a demand.

2.2 Percussive Massage Treatment Therapy

Percussive massage consists of a series of repetitive percussion in a designated area of the body with a constant frequency and force. The first known use of percussion in massage treatment is traced back to Johann Georg Mezger in 1868 when he created the Swedish massage technique Tapotement (College, n.d.). Tapotement is a rhythmic percussion administered with the hands by the practitioner, there exists five types of this technique, depending on how the hand hits the body (Wikipedia, 2021b). Such treatment is still used today and, in many countries, Swedish massage is known as the classic style of massage (Wikipedia, 2022a), since it was the first to organize the specific techniques (College, n.d.), serving as a base for future Occident style of massaging.

The next known use of percussion in physical treatment, occurs during World War II by the hand of Robert C. Fulford. Fulford was a doctor of osteopathy medicine (D.O.) and practitioner by the time the United States joined the war in 1941. The meaningful event called several other of his colleagues to duty, leaving him and other two medical doctors to handle much of the city's health. Fulford had a wide background and remembering his past working experience in factories, he thought to find a way that a machine

could help in his osteopathic tasks the same way it helped the workers save wear and tear on mundane activities. Therefore he started to try different vibrators but it was not until he got his hands on a Foredom Massager that he was satisfied (Richard W. Koss, D.O., -; Yadava, 2010).

Figure 7: Foredom massager brochure.

Source: https://cdn.ymaws.com/www.opso.org/resource/resmgr/2017OMT/Foredom.brochure.pdf

The Foredom Massager (Figure 7) is made by Foredom Electric Company, a division of Blackstone Industries LLC., which focuses on flexible shaft rotary power tools since 1922 (Blackstone Industries, LLC., 2018a, 2018b). Fulford

continued his career and shifted his attention away from PMT, putting to sleep the use of a mechanical tool as a percussive treatment among physicians.

Finally in most recent times, such a concept woke up and is rising. The awakening happened in 2007 with the invention of the massage gun by Dr. Jason Wersland, a chiropractor. Wersland suffered from a motorcycle accident at that time and the recovery was not successful, making him feel pain throughout the day and unable to do common daily tasks.
From his own story, he claims feeling the need of a repetitive strong movement in the area of pain for longer periods of time and more often. That idea, tied with his knowledge as a chiropractor, gave him the drive to begin prototyping and developing a proof of concept with regular power tools (Dr. Jason Wersland and Therabody, 2021).

Figure 8: Therabody range of products.
Source: https://www.therabody.com

Eventually, he created the Theragun and founded Therabody, pioneers in massage guns and one of the more popular brands in percussive massage treatment tools from nowadays (Figure 8). Most of the other brands and companies were inspired by his product and the popularity it was gaining in the sports field, creating the market for MGs that exists today.

2.2.1 Mechanism analysis

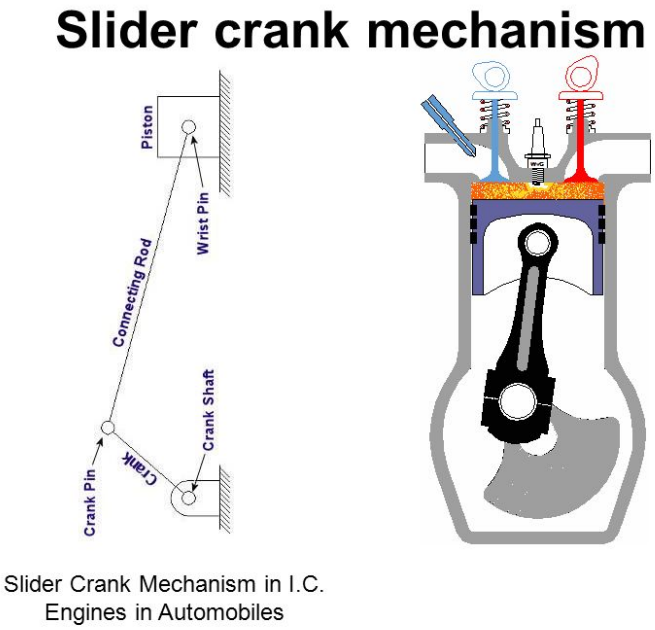


Figure 9: Slider-crank mechanism in car engine.

Source: https://slideplayer.com/amp/10788503/

Now that the small history has shown this invention was born and used from the necessity, of their creators or applicants, let me explain in deeper detail how the percussion is achieved on the massages guns. As briefly mentioned in the introduction, the inner workings of most of nowadays PMT tools, the so-called massage guns, is a typical slider-crank mechanism. Such

mechanism is widely used all around the globe in a daily basis, for example, in the engines of automobiles (Figure 9).

It consists of a four-link mechanism: three revolute joints and a prismatic (sliding) joint. It contains a crank providing the rotation, an eccentric plate or cranks-shaft, a connecting rod, the slider and guides. These parts, through their joints, have the main function of transforming circular movement into linear or vice-versa.
There are two different styles of slider-crank mechanism depending on the symmetry of the back and forth movement: in-line, when the pivot point of the crank is coincident with the axis of linear movement; or off-set when the line of travel of the prismatic joint does not pass through the base pivot of the crank (Brigham et al., 2013; Mukkawar et al., 2018; Wikipedia, 2022b).

Figure 10: Inner working of low-cost MG used in prototype.

Source: Own picture.

On this document, the rotation to linear movement will be explained for a slider-crank in-line mechanism, corresponding to the mechanism found inside MGs and for the one used for the prototype of this project (see Figure 10).

Following Figure 9, the different parts are, as mentioned, the crank (in this case the crank is the DC motor), the eccentric plate (other designs have a crank-shaft instead to obtain the desired eccentric rotation), the connecting rod and slider with guides.

The rotation of the motor makes the eccentric plate rotate, since they are directly connected to each other (first revolute joint). The plate's eccentric pivot has one end of the connecting rod attached to it, here is the second revolute joint. When the plate moves according to the motor, its pivot moves along a larger diameter creating a range of movement for the connecting rod to travel with it.
The other end of the connecting rod is attached to the slider (third revolute joint), constrained lineally by the guides (prismatic joint). Since it gives the freedom to move back and forth, the connecting rod does not find resistance to follow the eccentric pivot point along its diameter, however by making so, the slider end also follows that movement and outputs the linear movement reciprocally, limited by the guides to keep the movement along the linear axis.

2.2.2 Key aspects of a PMT tool

For massage guns, the principle is the same, only they substitute certain parts: the crank is an electric motor, the slider is an open-end to which you can attach different "heads" to provide different styles of massage.
They usually include a battery to keep the mechanism running and a controller board for the motor, which determines the frequency of the rotation. When the slider-crank mechanism is applied in PMT tools, it is based on three concepts that govern the way it should be used: frequency, amplitude and torque (Dr. Jason Wersland and Therabody, 2021; García-Sillero, Benítez-Porres, et al., 2021).

Frequency is the speed at which the machine will hit the muscle, higher frequency, more often it will hit the muscle (higher speed). Units in Hertz (Hz).

Amplitude is how much the head (slider) will travel, the distance from maximum outwards point to maximum inwards point. This characteristic is important for the muscle, claiming that a higher amplitude will reach deeper tissues of muscles (Dr. Jason Wersland and Therabody, 2021). Without amplitude or with small values for amplitude, the hitting factor disappears, making the massage a vibration massage instead of percussion. That is why a minimum of amplitude is needed to get the benefits claimed by PMT. The amplitude is governed by the mechanism designs and is fixed, units in millimeters (mm).

Finally, the torque corresponds to how much power the machine can withstand when applying it to the body. It is also known as the stall force, since it is the pressure you can apply to the motor before it stops (stalls). Therefore, torque is essential to make the machine work in a wide variety of users constantly and to achieve deeper percussion into the muscles when needed.

Controlling the values of these three concepts in PMT tools makes it possible to use it for different applications, getting the most out of it. For example, a high amplitude, frequency and torque will be good for a percussion treatment before a workout, while a smaller amplitude will supply a vibration-like massage for a relaxation session post-workout.

Despite this, most of the products only let you control the frequency settings, which is the speed of the motor. Torque and amplitude are restricted by motor specifications and mechanism design accordingly. Over the next

section it will be explained how muscles are arranged and the best ways to apply these concepts and the PMT tools to them as well as the studies found claiming its benefits and dangers.

2.3 Muscle Anatomy

Being the purpose of the project a creation of a machine that will be applied to a muscle group of the lower leg, a basic research and explanation of these will be covered in this section. The lower leg group and particularly the gastrocnemius muscle will be explained in further detail and finally, how PMT can be implemented and its effect.

All humans are made from a combination of systems working together with different functions to provide life to our bodies. The musculoskeletal system is our main structure and allows us to move. It is made from the muscular and the skeletal systems, which main component are the bones that provide attachment points and support for muscles. This linkage is possible thanks to tendons, aponeuroses (flat tendons) and fascia (connective tissue) (Beverly Henderson, 2020; Gordana Sendic MD, 2022; Roberts, 2016).

These components providing the union between both systems, as well as muscles, fall under the muscular system which is in charge of movement and action. Breaking down further, we find there are three main types of muscles: skeletal muscle (voluntary), cardiac muscle and smooth muscle (involuntary) (Roberts, 2016). Each of these have a distinctive structure and function in the body system. For the sake of the project, only an explanation of the skeletal muscles will follow, since the gastrocnemius muscle falls under this category and is the focused muscle for the machine.

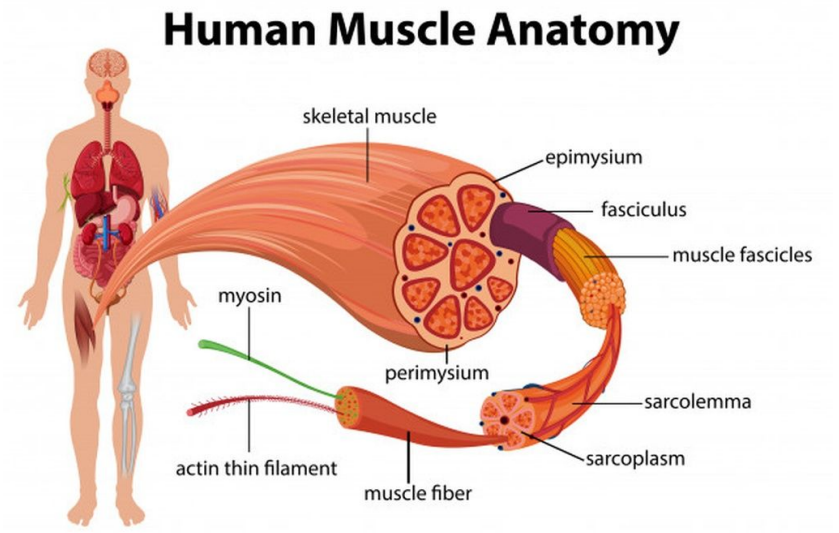


Figure 11: Anatomy of human muscles.

Source: https://i.pinimg.com/originals/4c/30/1e/4c301e75cb63be4e1f6ce724b1ab4757.jpg

Skeletal muscle, also known as striated muscles, vary in shape and structure according to where they are positioned and its function. Nevertheless, they share the microscopic features and what they are made of: parallel bundles of muscle fibers. Following Figure 11, one skeletal muscle is made out of many muscle fibers formed by many cells merged together. Each fiber is surrounded by endomysium, connective tissue to separate fibres from one another. Many of these fibres put together create the fascicle, which is itself surrounded by perimysium, protecting from other fascicles. Joining many fascicles makes up the whole muscle and again, it will be covered in a layer of fascia, called epimysium, avoiding friction between muscle groups (Roberts, 2016).

From the outer to the inner, a muscle is made by a layer of fascia (epimysium) that holds a bundle of fascicles. These fascicles are covered in per-

imysium which contain many muscle fibers, each of them surrounded by endomysium. Looking deeper, each fibre is made out of muscles cells joined together, packed with myofribils containing two types of protein filament, myosin and actin (Roberts, 2016).

2.3.1 Lower Leg Muscles

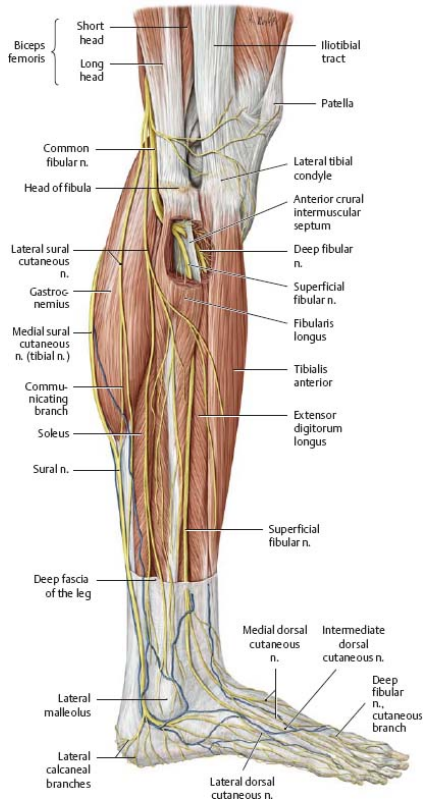


Figure 12: Side view of the lower leg anatomy.

Source: https://doctorlib.info/medical/anatomy/29.html

The area enclosing the lower leg muscles begins in the knee and ends at the ankle. Within this portion it is found two major bones (tibia and fibula), six main muscles (gastrocnemius, soleus, tibialis anterior and poste-

rior, plantaris and peroneus), a major tendon (the achilles tendon) and three main nerves (tibial, fibular and sural nerves). All of these components and others that fall into a secondary role, make it possible for the average human to stand, walk, run, jump, kneeling, crouching and lifting, all part of most common and daily activities (Jon Johnson, 2021).

Depending on whether the subject is bearing weight and the direction of the foot, different muscles are activated. For example, the gastrocnemius muscle and soleus perform the majority of plantar flexion, that is when the flexion of the ankle is directed to the sole of the foot, in other words by standing on the toes (Aarti Sareen, n.d.; Crompton et al., 2021).

Figure 13: Lower leg drawing on plantar flexion.
Source: https://www.kinetic-revolution.com/calf-strain-running/

The arrangement of the muscles can be seen on Figure 12 and this small research will focus only on the posterior side, which makes up the calf. It contains the gastrocnemius as the largest and most superficial muscle, and the soleus underneath it (Roberts, 2016).

From the beginning of the document it has been mentioned that the muscle to be worked by the machine is the gastrocnemius, besides all reasoning above, because of its large size and proximity to the surface.

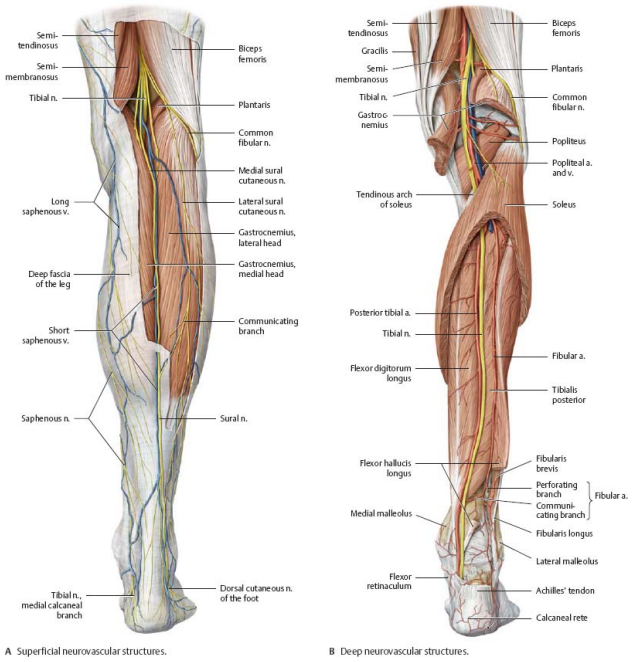


Figure 14: Posterior view of superficial nerves in lower leg.

Source: https://doctorlib.info/medical/anatomy/29.html

The gastrocnemius muscle is made out of two heads (medial and lateral) which origins are in the femur and from the knee joint capsule. Both heads run individually until the middle part of the calf, where they join to form a muscle belly, later inserting into the posterior surface of a wide tendon. This tendon gradually narrows and eventually joins with the soleus and into the achilles tendon right at end of the foot (Aarti Sareen, n.d.; Niamh Gorman MSc, 2022).

Finally, it can be seen in Figure 14, that there is a superficial vein and nerve that are positioned in between both gastrocnemius heads: the short saphenous vein and the sural nerve (Binstead et al., 2022; Webster, n.d.).

2.3.2 PMT and Gastrocnemius

Now that there is an overview of muscles and the anatomy of the gastrocnemius, it will be shown how PMT can affect it according to recent studies and it will be hypothesized how it can be best applied to it.

First and foremost, PMT tools like the MG, are a rather new concept that only a few years ago gained popularity and began being used by many, both professionals and amateurs. Therefore, there are not a lot of studies tackling the issue of its benefits and the ones found tend to have a small group of applicants. Despite this, the research keeps going and most of the referenced papers are very recently researched. To avoid a conflict of interest, their conclusions will be shown alongside contrary beliefs.

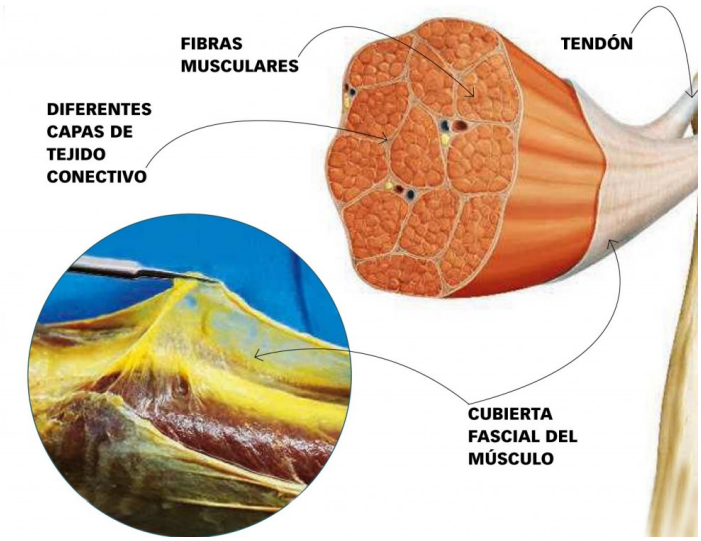


Figure 15: Fascia location on muscle structure and real life example.
Source: https://www.escaladaosteopatia.com/post/fascia-y-osteopatia

As mentioned above, fascia is a layer surrounding the muscles to avoid friction between them. Moreover it also covers the organs in the body and makes up soft connective tissues that create most connections in the body. It is described as a tensional network including joint capsules, intramuscular connective tissue, ligaments and tendons (Schleip and Müller, 2013).

The fascia can tighten, reducing ROM of a joint, muscle strength and soft tissue extensibility. To overcome the tightness, myofascial release therapies can be used. Such techniques aim to manipulate soft tissue and there are three types: direct, indirect and self-myofascial release. The PMT tool is a recent addition to the self-moyfascial release group, providing similar benefits to traditional techniques (Martin, 2021). This serves as a positive argument to having the machine's area of work in a muscle that has a good amount of fascia.

As grasped from the anatomy of the gastrocnemius, there is a large portion from the muscle that is part of the connecting tissue, besides the muscle itself being covered by fascia as well.
Moreover, (Lakhwani and Phansopkar, 2021) are undergoing a study to assess whether PMT could improve the tightness in the calf caused by plantar fasciitis. The research was submitted as a protocol and with conclusions to be drawn once it can be done.

In a more general aspect, PMT has shown to have a positive effect on lower extremities muscles by improving its ROM and reducing muscle soreness without affecting the strength (Konrad et al., 2020), pain reduction, increased blood flow, improved scar tissue, decreased lactate, reduced muscle spasms, increased lymphatic flow, inhibition of the Golgi reflex, increased range of motion, and better recovery based on the principles of fascia connective tissue treatment (García-Sillero, Benítez-Porres, et al., 2021; García-

Sillero, Jurado-Castro, et al., 2021). Lastly, it proved to be an effective method to delay the loss of movement velocity in the bench press exercise (García-Sillero, Jurado-Castro, et al., 2021).

Despite this, all research applied the PMT tool for periods of five to ten minutes with a soft applicator attached to it and performed by a researcher, which claims to hold constant pressure and apply the massage equally to all the participants.
Moreover, the sample size is not large enough to be amused by the findings. Also their recent addition to the worldwide market without proper indications can lead to incorrect use and cause serious damage. A case report from a Chinese cyclist showed that repetitive malfunction of the technology lead to a break down of muscle tissue, leaking protein into the bloodstream. Without treating this issue it can lead to Rhabdomyolysis (Chen et al., 2021).

Finally, it should be avoided any area that contains veins or nerves close to the surface, especially for long periods of time and if a hard attachment is being used. Since the gastrocnemius muscle has one vein and one nerve running the mid-section, it will be taken into account when programming the massage trajectory and reduce frequency or avoid the area as much as possible.

2.4 CNC

Eventually, this project leads to the creation of a CNC machine and therefore, it is intended to show a basic research of the different styles of CNC, how they work and their benefits or disadvantages as well as how it would fit the project's goal of attaching a PMT tool as the spindle.

CNCs can be separated into router/gantry style or mill/fixed style. The former has a movable gantry making it possible to travel above a fixed table where the material is placed. The latter has the gantry fixed and the table

with the material is the part moving. The main components of a CNC shown in Figure 16 are:

- Gantries: Linear movement system
- Spindle: The tool
- Controller: Executes commands
- Fixture table: Place where the machine stays
- Work-piece: Material to be manufactured

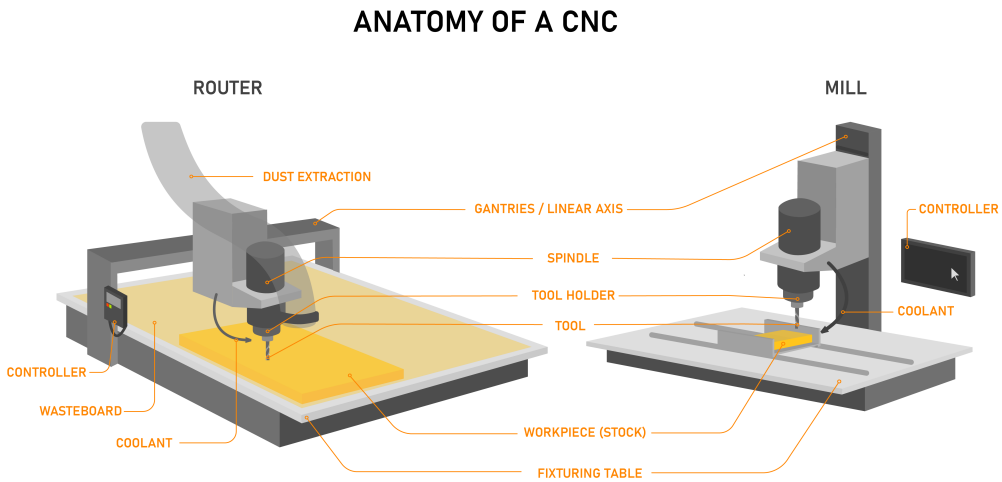


Figure 16: Anatomy of CNC machines

Source: https://www.making.unsw.edu.au/learn/cnc$_b$*asics*/

As mentioned in the introduction, CNC stands for Computer Numerical Control and the control is usually along three axis (X, Y and Z). The axis it moves along translate to the DOF of the machine and some industrial grade CNC can have up to five DOF (see Figure 17). Axis are attached to one another and at the end, the tool (also known as spindle). Different tools

could be applied and some CNC's even allow tool change during operation, also known as Automatic Tool Changer (ATC) (Wikipedia, 2021a), however the most typical is a router with drills. Therefore, CNC is a subtracting and machining manufacturing method (Overby, 2010), taking away part of the material being machined until the final part is left. The part is first designed in a CAD software, then sent to a CAM software which task is to plan the manufacturing of the designed piece and finally convert those instructions into something that the machine will understand, the numerical code named G-Code. G-Code sends the commands followed by the coordinates to which the machine should move next.

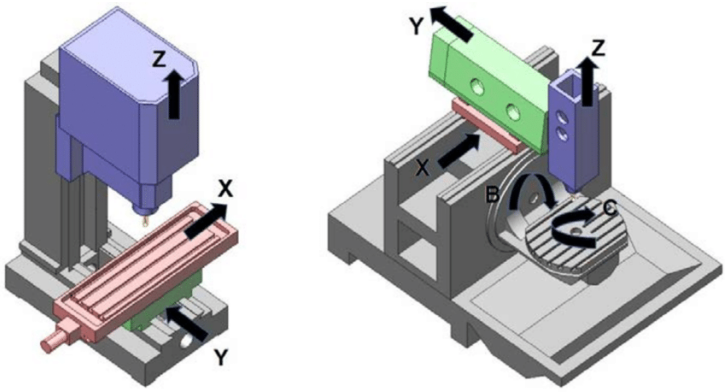


Figure 17: Visualization of 3 axis and 5 axis CNC machine

Source: https://www.researchgate.net/figure/a-3-axes-CNC-milling-machine-b-5-axes-CNC-milling-machine$_fig4_305954209$

Since I will be working with muscles as the material and PMT as the spindle, this CNC machine will not subtract nor manufacture. In spite of this, the process might be quite similar to begin with, where a model of the muscle will be designed in a CAD program and then sent to the machine as if it had to carve that model, only that the end tool will be a MG.

Ideally, the PMT-CNC should have at least five DOF, one for each dimension in real life objects (X, Y and Z), one rotating along Y axis (RY) and a last one rotating along X axis (RX), to ensure that the tool reaches the sides of the gastrocnemius muscle and hits it as perpendicular as possible through-out all the muscle surface and in the direction of muscle fibres (García-Sillero, Jurado-Castro, et al., 2021; Konrad et al., 2020). Despite this, the project will begin with a basic three-axis CNC, leaving the attempt of a fourth one (RY) in case of extra time.

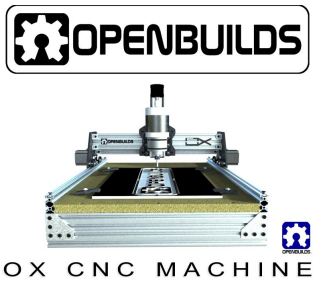
Therefore, the goal of this research is to find an open design to copy and modify, helping me reduce time spent in the design process. It should not be forgotten that this project is not about the CNC technology on itself but a way to join it with PMT and its application.

2.4.1 Designs

In alliance with the before mentioned requirements of section 1.2.1, it was found that many Do It Yourself (DIY) designs are available. They move in three dimensions, are simple enough to replicate and adapt it to this particular project. Most use extruded profiles making it easy to mount and even easy to change or add other features. Other designs use additive manufactured parts which makes the replica straight forward and quick. Furthermore, there is plenty of documentation for these kind of designs since other people have done it already.

Table 1 summarizes the research done on the various DIY CNC designs, showing the final considerations and some key points that weighted the balance into choosing the final design.

Table 1: CNC Designs Analysis

OX		
Advantages • Strong and sturdy • Easy assembly • Well documented • Customizable	Disadvantages • Gantries carry all motors • Heavy • Not modular	
WorkBee 1050		
Advantages • Rigid • Gantry carries two motors • Well documented	Disadvantages • Heavy • Not modular	
MPCNC		
Advantages • Easy build • Affordable manufacturing • Customizable • Light	Disadvantages • Use of five motors • Low stabilization • Weak	

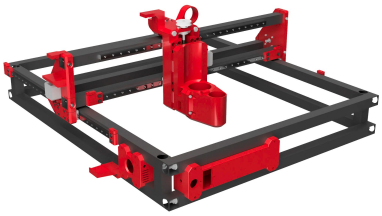
Ivan Miranda's CNC

Advantages

- Affordable manufacturing
- Video assembly

Disadvantages

- Gantries carry all motors
- Paid files
- Fixed design



2.4.2 Electronics

Correspondingly, once taken care of the structure side of the hardware regarding the CNC machine, a small overview of all the electronics involved to accomplish movement and control will follow. The electronics components necessary for the machine to start moving are:

- Power Supply Unit (PSU)

  Provides all other components with electrical energy. It takes the alternate current (AC) electricity from a wall outlet of 220V 50Hz and will transform into direct current (DC) electricity needed by electronics. The output will depend on control board, stepper motors and drivers specifications and energy requirements.

- Control Board

  It will be in charge of communication with the computer software and with the motors through the drivers. The physical connection is made by a cable that stays permanently linked to both computer and control board (CB). The CB will hold an open-source software capable of decipher G-Code sent by the computer's software.

G-Code is a programming language where each line is a different command for the CB, which it will have to understand and share accordingly to the motors to accomplish such orders. Usually the CB is referred to as a small computer, widely versatile to configure according to the task to be done. There are many options in the market for CB that will take on this role, some are specifically made for CNC/3D printer use and others will require an additional board mounted over the CB, called shield. The shield is specifically made for DIY CNC's, simplifying the connections from the CB to the steppers. It already contains the pins and layout to connect other features, such as emergency stops, limit switches and control over the CNC's spindle. The most viable options for the project are:

Figure 18: CB assembly (Arduino UNO with CNC Shield and motor drivers). Source: https://ingeniotics.com.mx/product/cnc-shield-v3-arduino/

-Arduino MEGA + RAMPS shield (DIY inclined)
-Arduino UNO + CNC shield (DIY inclined) (Figure 18)
-BlackBox CNC Control (plug-and-play, ready to use style)
-Spark Concepts-xPRO (plug-and-play, ready to use style)

- Stepper Motors

  They supply the machine with movement which is obtained in combination of some mechanical components (belts, lead screw and wheels), to ensure the transmission and conversion of rotation to linear movement. Stepper motors have a significant difference with servo or DC motors in the control aspect. Steppers are preferred over the other in CNC machines due to their high pole count, offering precision drive motion without requiring encoders. This is possible thanks to the way they work, by energizing the different coils which become magnets and makes a rotation of the shaft. Each movement from one coil to another is a step. The angle moved between coils is called step angle and it is specified by the motor, usually 1.8^{o}, meaning 200 steps for a complete cycle. Thus, the number of steps required to move a certain distance can be easily calculated by the CB. Stepper motors also provide high torque at zero speed, however it reduces significantly when increasing rotations per minute (RPM) (Bill Lackey, 2018; Bill Porter, 2019; Motion Control Online Marketing Team, 2017).

- Motor Drivers

  Responsible for making possible the interaction of the motors with the micro-controller or CB. Both of these components require different current to work efficiently, however it can not be used both at the same circuit since either the CB will be damaged by driving higher current or the steppers will not work as required due

to low current provided by the CB. That is where the driver is useful, since it will step-up or step-down the current required as well as limit it to avoid over charge. In other words it is controlling the phase current. Moreover they take care of sequencing the phases, being in between the CB and the motor, it reacts to the step commands and translates into on-off patterns for the coils on the stepper (Bill Porter, 2019).

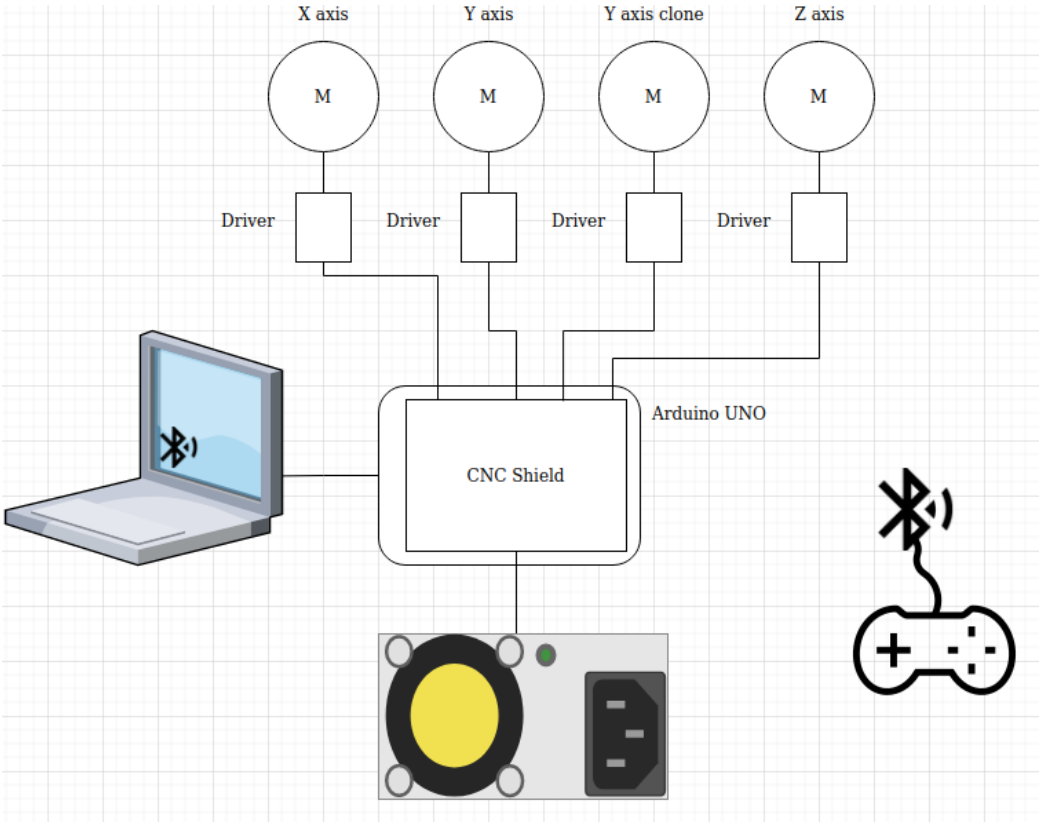


Figure 19: Simple electronics connections diagram.

Source: Made using https://app.diagrams.net/

Other not listed components, such as limit switches, emergency stop button or remote controller are not required to achieve motion of the CNC machine. Nevertheless, they are mandatory to ensure a proper use and work of the machine, as well as safety measures. The diagram in Figure 19, aids to visually understand a general overview of the electronics connections.

2.4.3 Security measures and ISO 15066

Working with electronics require the use of electricity to function, thus if not handled correctly and safely it can become a danger. Moreover, when a machine is constantly connected and will be applied to a human being, it should accommodate safety measures to avoid electricity to reach the user and to provide enough control to make it stop in case of malfunction. Furthermore, measurement of the sort adapted for the electronics components will protect those which are more expensive to replace, reducing as well the repair time, aiding in debugging the error and increasing the life-time of the machine overall.

For that reason, this section will go over some common protective measurements for both users and machine as well as a review of the ISO norm 15066 that tackles regulations for industrial collaborative robots.

- Crimping cables with appropriate terminal

  Ensures contact between controller, actuators and energy supply. Avoids non-solid wires to get loose, decreasing chances of short-circuit.

- PSU On-Off switch with fuse

  Protects the electronics from high electricity input and provides a gentle way to turn off the machine.

- Grounding aluminium profiles

  Avoids electricity flowing through an user or operator in case of loose wire contacting the frame.

- Emergency stop switch

  Provides a fast way to stop the operation in case of danger.

- Remote controller

  Gives control of the machine to the user, avoiding undesired areas.

- ISO 15066

  This norm is for industrial collaborative robots, which have a different use and handle external objects, rarely having a human as the manipulation. Therefore, most of its measures can not apply directly to the project's prototype. Nevertheless, there are sections which can be generally applied to robots:
  -Hazard identification elimination
  -Risk assessment
  -Enabling device requirements
  -Power and force limits in contact situation
  Identifying hazards before operation makes it possible would rise issues to be fixed with safety measures similar to the ones mentioned above. Despite preparing the machine and eliminating as many hazards as possible, it should be assessed the risks the product implies. For example, there is risk of injuring oneself if applying without knowledge, there is risk of malfunction of the algorithm that could potentially trap the user under the machine. For these cases, protective measures already cover the solution, however the user needs to be informed about it. Lastly, the norm dictates two different kind of contact situations, again, for industrial applications. Adapting it to the project, it can be said that

the case of undesired contact is quasi-static contact, were the human part in contact does not have a quick escape route, meaning, it is temporally trapped. The power and force are limited according to the table found on annex A.2.

3 Methodology

This section will address all theoretical observations gathered above and aim to develop the proof of concept prototype of a CNC massage machine using a PMT tool. The designs were developed using Autodesk Fusion 360 software under educational license. Furthermore, the premises of UVic-UCC workshop were used in the manufacture of the machine's gantry plates, completing the rest of the assembly in my ancestor's place with the use of common tools and drill. All material needed was acquired from ThingiBox, with whom I worked a partnership for the project, and BangGood for some extra pieces and electronics. Finally this report is written in Latex under OverLeaf online editor.

On top of that, the project has been granted the opportunity to be part of the Santander Explorers entrepreneurship program through the TFG Innova provided by UVic-UCC. Santander's program is a modified version based on the lean startup technique for developing start-ups from Eric Ries (Ries, 2011). Therefore, a business plan and a market study will be created in parallel.

3.1 Project Planning

Project planning plays a very important role, since it will be the future reference and guide. Therefore, a good plan is key for a good project thus any decision made now, will save the thought process later, making it more comfortable to put myself at the task at hand.
The project development will be carried out following the steps depicted in Figure 20 which consist of three main stages: research, hardware assembly and software implementation and a last conditional stage of testing and feedback. Furthermore there are five milestones to accomplish along the development that match the schedule seen in Figure 21.

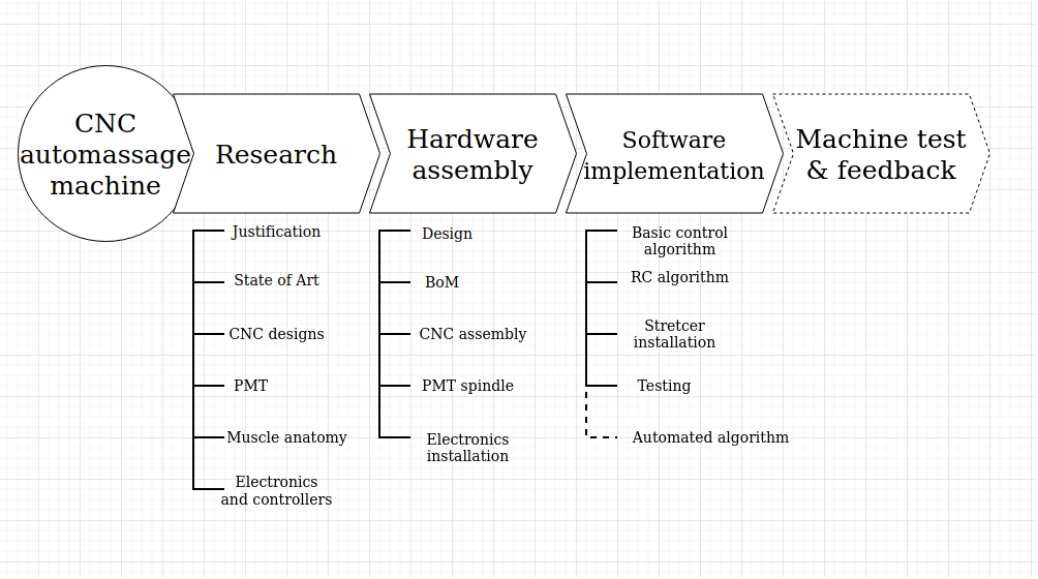


Figure 20: Visual diagram of the thesis plan.

3.1.1 Milestones

Research (Milestone I)	-Justification. -State of Art. -CNC designs. -PMT (percussive massage tool). -Muscle anatomy and experts interview. -Electronics and controllers.
Hardware assembly (Milestones II & III)	-Designs. -BOM. -CNC assembly. -PMT spindle. -Electronics installation.
Software implementation (Milestones III & IV)	-Basic control algorithm. -RC (remote control) algorithm. -Stretcher installation. -Testing. -Automated algorithm.
Future development (Milestone V)	-User Interface. -Computer vision implementation. -Real market test.

Figure 21: Relation between milestones and scheduled stages.

3.1.2 Scheduled tables

Table 2: Detailed schedule for research stage

Project division		
Area	**Tasks**	**Description**
Research	Justification [2 h]	Look for data that justifies creation of machine or find new point of view (POV).
	State of Art [3 h]	Obtain latest news on PMT and massage tools and or machines as well as desktop CNC development.
	CNC designs [8 h]	Choose a structure and how many degrees of freedom (DoF) should the machine have.
	PMT [8 h]	Exclusive search on how this technology works and how to adapt it for a CNC machine.
	Muscle Anatomy [5 h]	Understand how is better for the PMT to hit the muscle, how is the shape of it and direction of muscle fibers.
	Electronics and Controllers [8 h]	Find out which are the adequate motors, drivers, boards.
Estimated time: 3 weeks		
Beginning: 10/01/2022 — Ending: 13/02/2022		

Table 3: Detailed schedule for hardware assembly stage

Project division		
Area	**Tasks**	**Description**
Assembly	Design [2 w]	Establish and create a CAD design of CNC machine and of the PMT adapted spindle.
	Bill of Materials (BOM) [5 h]	Create first shopping list and order for project building and development.
	CNC assembly[2 w]	Put together the structure of CNC machine.
	PMT spindle [2 w]	Assemble the adapted spindle and join to previously mounted structure.
	Electronics installation [1 w]	Connect all electronics and controller boards.
Estimated time: 8 weeks		
Beginning: 14/02/2022 — Ending: 10/04/2022		

Table 4: Detailed schedule for software implementation stage

Project division		
Area	**Tasks**	**Description**
Implementation	Basic control algorithm [2 w]	Implement a program for the prototype to move as asked.
	Remote controlled algorithm [1 w]	Implement a program for the control of the machine through a hand controller.
	Stretcher installation [1 w]	Assembly of the prototype into a fixed stretcher for test runs.
	Testing [1 w]	Get some participants to try and obtain feedback. Fix possible mistakes and errors.
	Automated Algorithm [–]	Implement a program for the machine to run on it's own.
Estimated time: 5 weeks		
Beginning: 11/04/2022 — Ending: 15/05/2022		

3.1.3 Cost estimation

Table 5: Overview of project material cost

Item	**Value**
Profiles	100 €
Motors	200 €
Drivers	20 €
Controller Board	30 €
Controller Shield	30 €
Power Supply	80 €
CNC Plates	20 €
Belts and lead screw	20 €
Bearings	10 €
Nuts and screws	10 €
Working area	10 €
3D printed parts	15 €
Replacements	20 €
Unexpected	50 €
Expected total amount: 615 €	

This is a greatly overlooked of what I expect to spend for each main item of the machine. The engineering hours are not taken into account since it would make it undesirable to develop or fund and very difficult to track, since it is not a fixed time. Anyhow, I will calculate an approximation considering the time estimation from section 3.1.2, averaging at five hours a day, five days a week and with salaries[1] from both Spain and Brazil.

[1]Salaries taken from https://es.indeed.com/career/ingeniero-en-mecatronica/salaries https://www.salario.com.br/profissao/engenheiro-de-controle-e-automacao-cbo-202110/

Table 6: Engineering cost

Total project time	**Spain**	**Brazil**
400 h	16,19 €/h	51,2 R$/h
Total added cost	6.476 €	20.480 R$

3.2 Design: SLAX JTM v1.0

There are some conditions the design should check and that are crucial for the development of the project.

- The design should be simple and easy to mount/dismount.

  Since this project has to focus more on the joining of the technologies, a simple CNC design will be sufficient and leave more time for the adaptation of PMT to CNC.

- The structure and overall machine has to be sturdy.

  PMT is a vibration treatment method which will have a big effect on the CNC structure if those vibrations are not calmed or absorbed. The PMT spindle will have its own shock absorbent parts but the stronger and sturdier the CNC structure, the more reliable it will be on the long run.

- Move in three axis and having a working area covering the entire gastrocnemius muscle.

  The user should remain still and avoid movement so that the machine does all the travelling.

Due to it's strength, extensive documentation and recordings, easy to redesign and fit new purposes and manage to stay in the border of the budget,

I have chosen to follow OX Open Builds CNC design. Nonetheless, I will add some features from the WorkBee 1050, including a C-Beam aluminum profile for the X axis and getting a similar final shape.

Figure 22 shows a sneak peak on the design I am currently working on.

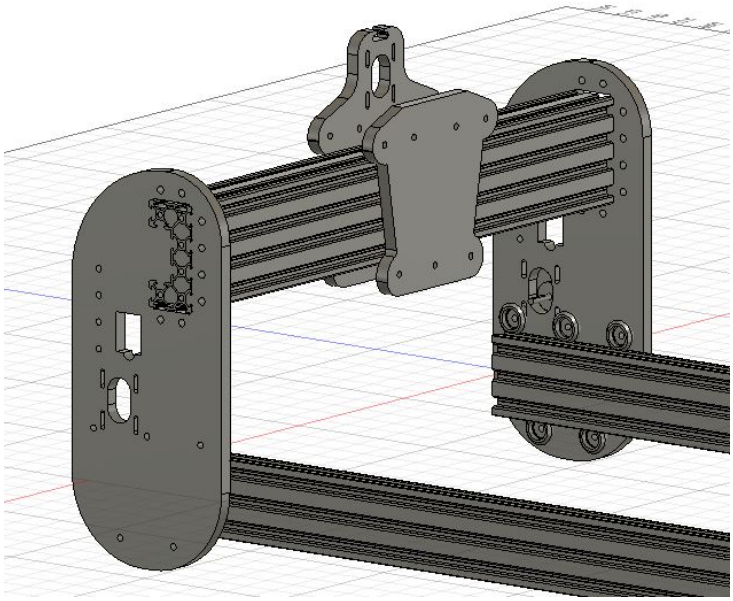


Figure 22: First sketches of PMT CNC machine, designed using Fusion 360.

3.2.1 Bill of Materials

Appendix B holds the detailed BOM, separating for each component of the machine and with the sources they were bought from. Its large size makes it aesthetically wrong to add at this point of the document, therefore, Table 7 is the update of Table 5 simplifying the generated BOM and leaving it to the reader's desire to check the more extensive one.

Table 7: Project material cost

Item	**Value**
Profiles	110 €
Motors, Drivers, Controller boards	35 €
Power Supply	23 €
CNC Plates	18 €
Belts and lead screw	32 €
Bearings	79 €
Nuts and screws	31 €
Working area	26,5 €
3D printed parts	0 €
Replacements	0 €
Unexpected	35 €
Approximated total amount: 390 €	

The expected cost against the actual cost is surprisingly significant, however it makes sense seeing that it was found a kit including all the motors and controller boards for a very low price. Another surprise is the increment in bearings cost, it was not foreseen that the wheels would be so expensive. Since the gantries need a minimum of three sets each, the expense quickly added up.

Overall, it is a fairly decent cost for a first functional prototype. Furthermore, the design permits re-using many of the same pieces saving expenses in future developments and releases.

3.3 Assembly

The construction of the prototype at this point is straight-forward. Table 8 gathers the key points from the prototype build process. Nevertheless, the elaboration of a detailed guide, can be found on section 4.1 under Table 9, showing the full process of assembling the prototype.
Throughout the building, some upgrades and issue rose that will be covered under future developments.

Table 8: Overview of assembly steps

Step 1	Gather and modify materials
Step 2	[Hardware Assembly (HA)] - X/Z carriage pt. I
Step 3	[HA] - X/Z carriage pt. II
Step 4	[HA] - Y carriage
Step 5	[HA] - Base and Y members
Step 6	[HA] - Join sub-assemblies and install motion
Step 7	[Electronics Assembly (EA)]: Software installation and test
Step 8	[EA] - Software configuration and first machine test
Step 9	Join PMT tool and test
Step 10	[EA] - Connecting a Wii Nunchuk remote controller

4 Results

Personally, a powerful result stands out from the rest: the learning outcome. Specially regarding the range of topics, because not only engineering concepts were learned. Finance, business start-up developments, Latex programming language, body anatomy and muscles composition, planning and organizational skills were subjects deeply explored.

Academically speaking, the biggest result was the working prototype of a machine brought alive from thoughts. Furthermore, analyzing its manufacturing process it is a smooth and inexpensive process. With this document as a guide, one can easily reproduce this project. Optimization of the build processes would lower the cost further and the assembling time.
Nevertheless, at the moment of writing this document, there is still room for improvement on the prototype but also from the budget. From the 650 € expected cost, there is 200 € left.

This numbers are interesting, specially from the business side of the project, since that leftover can be spent to obtained a true minimum viable product (MVP) and start pitching the idea.
From the Explorers entrepreneurship program, granted through TFG Innova of UVic-UCC, a monetizing strategy came out. The findings showed that by spending 500€ in machine costs and putting it to the service of physiotherapists, the machine's return on investment (ROI) would be of two months approximately. Even less if it proves to be a successful answer to physiotherapist's problem on escalating their business. For detailed information, refer to appendix D.

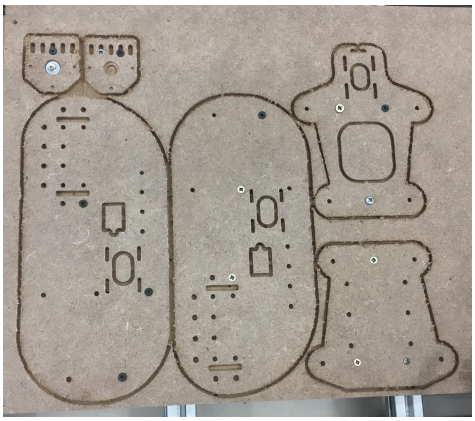
4.1 Instructions Guide

Table 9: Assembly steps

Step 1: Gather and modify materials

Tasks

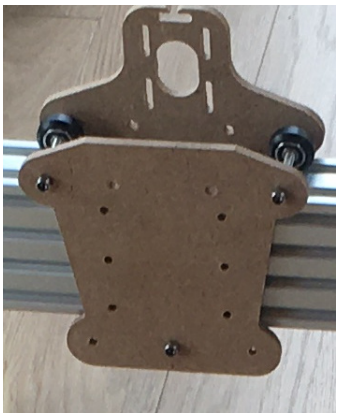
- Purchase list of materials (see Annex BOM)
- Tap holes and cut to length aluminum profiles
- Manufacture gantry plates



Step 2: [HA] - X/Z carriage pt. I

Tasks

- Insert 60 mm M5 screws through top and bottom holes of front side of X gantry plate.
- Add 6 mm spacer + wheel + 16 mm spacers + wheel + 6 mm spacer
- Add back side of X gantry + locknuts.
- Adjust bottom eccentric wheels for C-Beam profile grip.



Step 3: [HA] - X/Z carriage pt. II

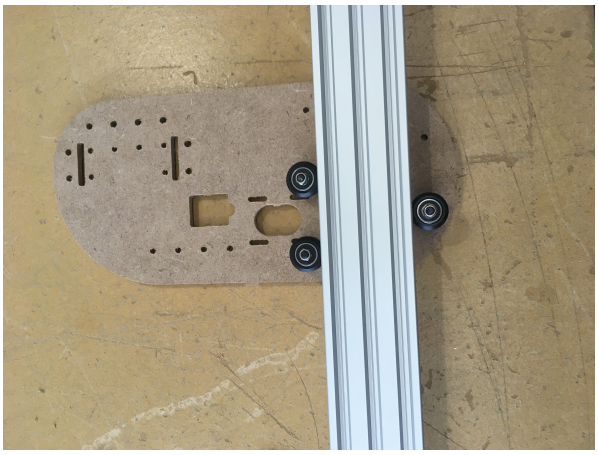
Tasks

- Add Z end-plates to 200 mm 20x40 V-Slot profile and mount motor to it with 40 mm M3 screws.
- Secure threaded nut to front plate and add threaded screw to motor through flexible coupling.
- Close sub-assembly by adding bottom end-plate with a bearing.

Step 4: [HA] - Y carriage

Tasks

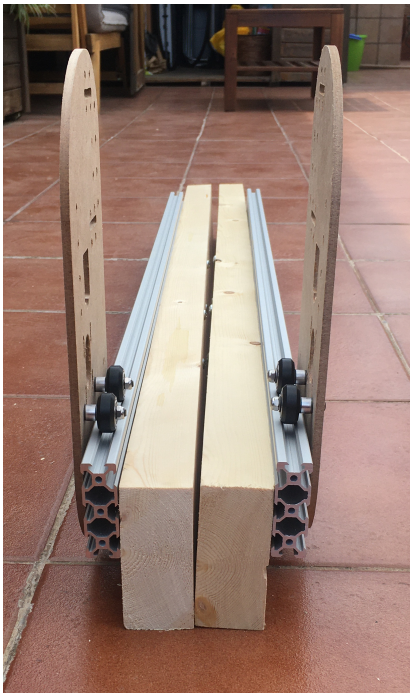
- Insert 30 mm M5 screws through top and bottom holes of both Y plates.
- Add 6 mm spacer + wheel + locknuts.
- Adjust bottom eccentric wheels for 20x60 V-Slot profile grip.
- Mount motors to plates with 20 mm M3 and spacers.



Step 5: [HA] - Base and Y members

Tasks

- Drill holes into fir wood corresponding to the holes on 20x60 V-Slot profiles and secure with 60 mm M5 screws.
- Distance both Y base wood strips 460 mm and add pieces of MDF board to hold the distance.



Step 6: [HA] - Join sub-assemblies and install motion

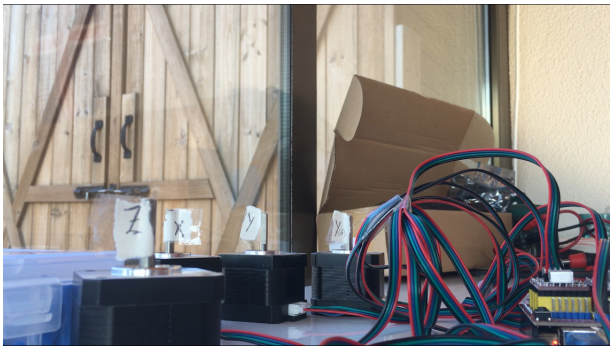
Tasks

- Run X/Z sub-assembly through C-Beam and secure Y plates to each side. Use 15mm M5 screws and corner brackets.
- Run the previous step through Y members installed in the base and align.
- Get two 1 m and one 500 mm strips of GT2 belts, insert in the Y members and C-Beam cavities correspondingly.
- Secure one end of each belt with T-Nuts, run under wheels and over motors' pulleys and fix to the other end with proper tension.

Step 7: [EA] - Software installation and test

Tasks

- Download all appropriate software. Install in a computer the G-Code sender and build into Arduino the GRBL program.
- Connect all components according to (Bertus Kruger, 2013; Maker Group Global LLC., 2018) and run first test.

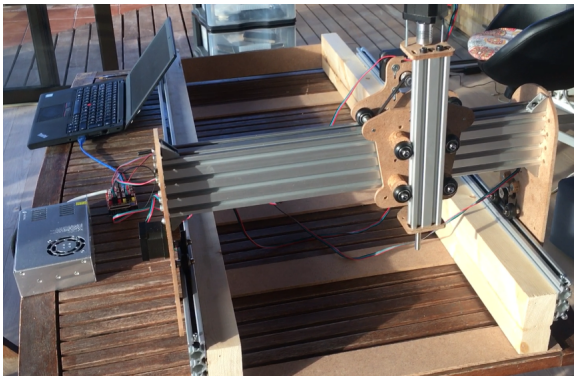


Note: Checking at gradual points during the assembly provides an easy step back and debug issue.

Step 8: [EA] - Software configuration and first machine test

Tasks

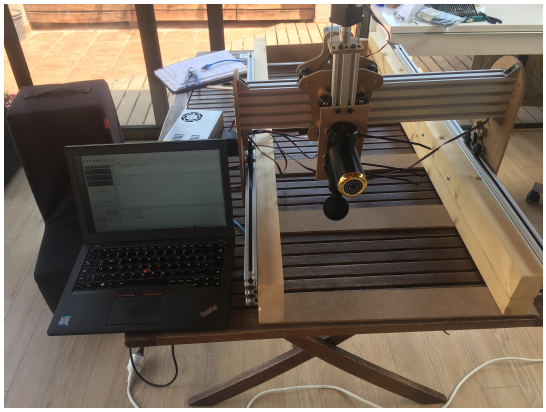
- Remount motors and connections.
- Run move commands, adjust belt tension.
- Send command of known distance and compare with actual travel.
- Update configuration values for step/mm and travel limits.
- Add limit switches.



Step 9: Join PMT tool and test

Tasks

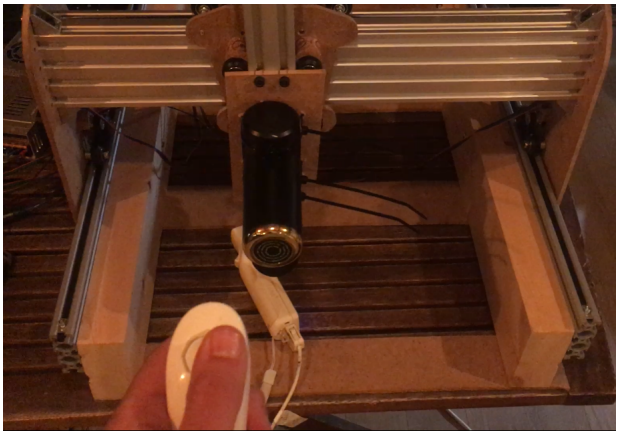
- Secure MG to MDF and drill two holes 20 mm apart.
- Screw tool plate to 20x40 V-Slot profile.
- Turn PMT tool on and start CNC machine. Send a code of continuous moves and place arm to feel.



Step 10: [EA] - Connecting a Wii Nunchuk remote controller

Tasks

- Install drives for Wii remote (Julian Löhr, 2015) and connect through Bluetooth.
- Download JoyToKey (JTK) program, reroute keyboard to game controller detected by PC.
- Open Universal G-Code Sender program and enable keyboard control. Remap the keys enabled from the Wii remote, already configured through JTK and try moving the machine by remote control.



4.2 Future Development

At this point, there are immediate improvements that would benefit the prototype outcome. These upgrades will be tried for the defense day. Furthermore, one passive result of the project is its next reasonable steps of evolution:

- Tests

  An evaluation of the operation of the prototype that includes a massage and a survey is ongoing during the time for this document delivery. Additionally, a health tracker found in many nowadays "smartwatches", would provide better knowledge of the participant's sensations. Unfortunately, due to bad organization it is moved to future work.

- Shock adsorbing for PMT

  Improvement of Z axis carriage will five strength and confidence on PMT tool use. In fact, some research has already been done, finding a damping material called Sorbothane which could reduce vibration if inserted in-between the PMT tool and the spindle's holder (Sorbothane, 2022) and different articles suggesting multi-stage balancing techniques for reciprocating applications (Levecque et al., 2011).

- Redesign and adaptation to stretcher

  With all the journey done so far, improvements for the design were spotted. For example: shortening Y axis and improving its connection to the base.

- Protocol for algorithm creation

  Entering more on the programming side of the project, achieving a template code would prove beneficial to use one program for

multiple users. Similarly to CNC machines, defining reference points at the beginning of the execution can provide the rough measurements of the new user and base a gastrocnemius model of his or hers sizes. Likewise "set to zero" feature of CNC machines. In this application, the machine should know how low to go to achieve a soft contact point and the user muscle limits.

- PMT development

  One important upgrade is to have a own-made MG which is more integrated with the CNC, instead of using one that was designed with the thought of operating it by hand. This would reduce weight, expenses and improve user experience. No battery is needed for the PMT tool since it can grab the power from the PSU.

  The mechanism is simple and the parts needed are cheap, since we are cutting the product added value of MG. Moreover a control by PC could be possible, achieving control of the frequency, one of the key aspects when applying PMT therapy.

5 Conclusions

This document gathers the development of a massage machine prototype made from unifying two existing technologies for the first time: CNC and PMT tool.

Different studies evaluating MG effects, prove it increases ROM on lower leg muscles, reduces delayed onset muscle soreness and provides a relaxed feeling among other beneficial features, tackling the first specific goal. However, there is room for improvement on those research since most contain small amounts of participants, underestimating their positive conclusions regarding the use of PMT tools.

Anatomical models of the gastrocnemius muscle show its shape and position in the lower leg, as well as its proximity to other muscles, veins and nerves. Further research makes it clear how the muscle fibers are oriented and good measures on how to apply PMT to them, providing enough knowledge to clear the second specific goal. Therefore, the travel of a MG should be parallel to the muscle fibers direction, focusing on the two big heads and belly of the gastrocnemius. It is also recommended to avoid excessive use in the vertical mid-section, where the short saphenous vein and the sural nerve run across and over the muscle. Specifically if a hard applicator is attached to the massage tool.

An analysis of all the requirements for the project lead to the completion of the third specific goal by using the open-source OX OpenBuilds CNC as starting platform. It was chosen because its structure is made of aluminium profiles that are easily mounted, making it simple to add new parts to it. Its customizable approach makes it possible to include features from other designs, for example, reducing weight without affecting the structure's rigidity is managed by having a C-Beam profile as the X-axis gantry.

Regarding the last two specific goals, number four, which aimed at a development of the PMT spindle itself, and number five, testing of the machine; were not accomplished. Due to bad time-management, the design and implementation of a PMT tool suited for CNC machines lost priority and instead, an already made product was purchased and adapted. Nevertheless, the research shown demonstrates it can be reproduced and it was gained the knowledge to do so.
As for the testing, it will be done as part of the future development and with the thought of delivering for the day of the thesis defense.

Finally, a prototype has been built, proving that the concept outlined in this project can have a positive outcome, assisting individuals on the application of percussive therapy in the lower leg area. An economic analysis of the commercial viability showed that this equipment has a ROI of two months.

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Table A.2 *(continued)*

Body region	Specific body area		Quasi-static contact		Transient contact	
			Maximum permissible pressure [a] p_S N/cm^2	Maximum permissible force [b] N	Maximum permissible pressure multiplier [c] P_T	Maximum permissible force multiplier [c] F_T
Hands and fingers	17	Forefinger pad D	300	140	2	2
	18	Forefinger pad ND	270		2	
	19	Forefinger end joint D	280		2	
	20	Forefinger end joint ND	220		2	
	21	Thenar eminence	200		2	
	22	Palm D	260		2	
	23	Palm ND	260		2	
	24	Back of the hand D	200		2	
	25	Back of the hand ND	190		2	
Thighs and knees	26	Thigh muscle	250	220	2	2
	27	Kneecap	220		2	
Lower legs	28	Middle of shin	220	130	2	2
	29	Calf muscle	210		2	

[a] These biomechanical values are the result of the study conducted by the University of Mainz on pain onset levels. Although this research was performed using state-of-the-art testing techniques, the values shown here are the result of a single study in a subject area that has not been the basis of extensive research. There is anticipation that additional studies will be conducted in the future that could result in modification of these values. Testing was conducted using 100 healthy adult test subjects on 29 specific body areas, and for each of the body areas, pressure and force limits for quasi-static contact were established evaluating onset of pain thresholds. The maximum permissible pressure values shown here represent the 75th percentile of the range of recorded values for a specific body area. They are defined as the physical quantity corresponding to when pressures applied to the specific body area create a sensation corresponding to the onset of pain. Peak pressures are based on averages with a resolution size of 1 mm^2. The study results are based on a test apparatus using a flat (1,4 × 1,4) cm (metal) test surface with 2 mm radius on all four edges. There is a possibility that another test apparatus could yield different results. For more details of the study, see Reference [5].

[b] The values for maximum permissible force have been derived from a study carried out by an independent organization (see Reference [6]), referring to 188 sources. These values refer only to the body regions, not to the more specific areas. The maximum permissible force is based on the lowest energy transfer criteria that could result in a minor injury, such as a bruise, equivalent to a severity of 1 on the Abbreviated Injury Scale (AIS) established by the Association for the Advancement of Automotive Medicine. Adherence to the limits will prevent the occurrence of skin or soft tissue penetrations that are accompanied by bloody wounds, fractures or other skeletal damage and to be below AIS 1. They will be replaced in future by values from a research more specific for collaborative robots.

[c] The multiplier value for transient contact has been derived based on studies which show that transient limit values can be at least twice as great as quasi-static values for force and pressure. For study details, see References [2], [3], [4] and [7].

[d] Critical zone (*italicized*)

A.3.3 Relationship between pressure and force

For the purposes of evaluating the contact scenario for a collaborative robot risk assessment, both the force and pressure values need to be calculated and considered.

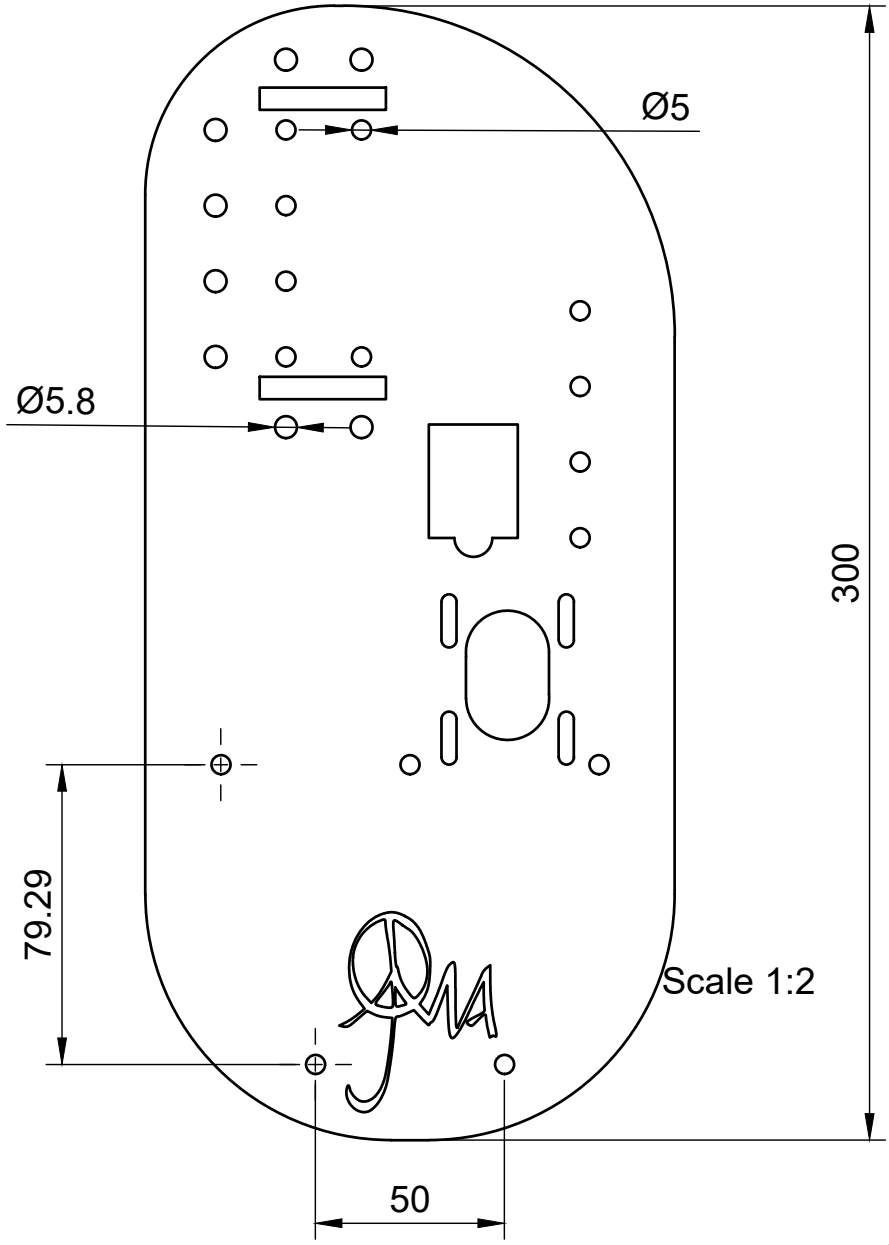
EXAMPLE 1 In the event of an operator intruding into the tool area of a running robot system, the hands could be clamped by parts of the tool or workpiece. The resulting force value could be well below the force threshold limit value. In such a case, the pressure limit would likely be the limiting factor.

EXAMPLE 2 In the event of contact with a body region with a padded machine surface with a relatively large surface area or a body region with a higher proportion of soft tissue (such as the abdomen), the resulting pressure value could be well below the pressure threshold limit value. In such a case, the force limit would likely be the limiting factor.

Assembly / Component	Product	Qty	Unit Cost	Build Cost	Source
Base					
Main members (Y)	95x45x2400 [mm] Fir wood strip	**1**	**21.95 €**	**21.95 €**	https://www.fesmes.com/ca/llistons-de-fusta-raspallada/91546400-llisto-fusta-d-avet-raspallat.html
Cross members (X)	2440x1220x5 [mm] MDF board remainings	**0.25**	**18.00 €**	**4.50 €**	https://www.fesmes.com/ca/taulers-mdf/80587000-tauler-mdf-prim-cru.html
X axis					
Members	500 mm C-Beam 40x80 V-Slot	**1**	**18.00 €**	**18.00 €**	https://www.ebay.es/itm/283518774498
Rigidity support	500 mm 20x40 V-Slot	**1**	**19.36 €**	**19.36 €**	https://store.thingibox.com/es/openbuilds/610-419-extrusion_v-slot_2040.html#/2571-tipo-1m_gris
X gantry plates	2440x1220x5 [mm] MDF board	**0.25**	**18.00 €**	**4.50 €**	https://www.fesmes.com/ca/taulers-mdf/80587000-tauler-mdf-prim-cru.html
Wheels	Solid wheel kit excentric	**2**	**6.30 €**	**12.60 €**	https://store.thingibox.com/es/ender-3/749-786-kit_rueda_POM_V-slot.html#/2934-tipo-625rs_excentrico
	Solid wheel kit	**2**	**5.09 €**	**10.18 €**	https://store.thingibox.com/es/ender-3/749-785-kit_rueda_POM_V-slot.html#/2933-tipo-625rs
Motion elements	GT2 1000 mm timing belt w/ steel reinforcements	**1**	**2.42 €**	**2.42 €**	https://store.thingibox.com/es/mecanica/518-714-correa_gt2.html#/2457-tipo-gt2_ancho_6mm_x_1m_reforzada_con_acero
	GT2 pulley : 20 teeth, 6,35 mm bore	**1**	**2.91 €**	**2.91 €**	https://store.thingibox.com/es/mecanica/281-18-poleas.html#/2373-tipo-gt2_20_dientes_o635mm
Stepper motor	NEMA 17 motors with Controller board kit	**0.1**	**35.35 €**	**3.54 €**	https://www.banggood.com/TWO-TREES-CNC-Shield-+-UNO-R3-Board-+4x-A4988-Stepper-Motor-Driver-+4x-4401-Stepper-Motor-Kit-for-3D-Printer-p-1510212.html?rmmds=myorder&cur_warehouse=CZ
Y axis					
Members	1000 mm 20x60 V-Slot	**2**	**26.62 €**	**53.24 €**	https://store.thingibox.com/es/openbuilds/744-819-extrusion_v-slot_2060.html#/2571-tipo-1m_gris
Y gantry plates	2440x1220x5 [mm] MDF board	**0.65**	**18.00 €**	**11.70 €**	https://www.fesmes.com/ca/taulers-mdf/80587000-tauler-mdf-prim-cru.html
Connecting corners to X axis	90 cast corner	**4**	**1.46 €**	**5.84 €**	https://store.thingibox.com/es/openbuilds/708-669-soporte-esquina-90-v-slot.html#/2860-tipo-para_v_slot_2020
Wheels	Solid wheel kit excentric	**2**	**6.30 €**	**12.60 €**	https://store.thingibox.com/es/ender-3/749-786-kit_rueda_POM_V-slot.html#/2934-tipo-625rs_excentrico
	Solid wheel kit	**4**	**5.09 €**	**20.36 €**	https://store.thingibox.com/es/ender-3/749-785-kit_rueda_POM_V-slot.html#/2933-tipo-625rs
Motion elements	GT2 1000 mm timing belt w/ steel reinforcements	**2**	**2.42 €**	**4.84 €**	https://store.thingibox.com/es/mecanica/518-714-correa_gt2.html#/2457-tipo-gt2_ancho_6mm_x_1m_reforzada_con_acero
	GT2 pulley : 20 teeth, 6,35 mm bore	**2**	**2.91 €**	**5.82 €**	https://store.thingibox.com/es/mecanica/281-18-poleas.html#/2373-tipo-gt2_20_dientes_o635mm
Stepper motor	NEMA 17 motors with Controller board kit	**0.2**	**35.35 €**	**7.07 €**	https://www.banggood.com/TWO-TREES-CNC-Shield-+-UNO-R3-Board-+4x-A4988-Stepper-Motor-Driver-+4x-4401-Stepper-Motor-Kit-for-3D-Printer-p-1510212.html?rmmds=myorder&cur_warehouse=CZ
Z axis					
Member	500 mm 20x40 V-Slot	**0.5**	**19.36 €**	**9.68 €**	https://store.thingibox.com/es/openbuilds/610-419-extrusion_v-slot_2040.html#/2571-tipo-1m_gris
Z end plates	2440x1220x5 [mm] MDF board	**0.1**	**18.00 €**	**1.80 €**	https://www.fesmes.com/ca/taulers-mdf/80587000-tauler-mdf-prim-cru.html
Spindle	Low-cost Massage Gun	**1**	**26.00 €**	**26.00 €**	https://www.amazon.es/Muscular-Uplayteck-Masajeador-Ajustables-Cabezales/dp/B08YYW5P6P/ref=asc_df_B08YYW5P6P/?tag=googshopes-21&linkCode=df0&hvadid=513350852778&hvpos=&hvnetw=g&hvrand=10472992490131694805&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=1005427&hvtargid=pla-1231400660289&th=1
Wheels	Solid wheel kit excentric	**2**	**6.30 €**	**12.60 €**	https://store.thingibox.com/es/ender-3/749-786-kit_rueda_POM_V-slot.html#/2934-tipo-625rs_excentrico
	Solid wheel kit	**2**	**5.09 €**	**10.18 €**	https://store.thingibox.com/es/ender-3/749-785-kit_rueda_POM_V-slot.html#/2933-tipo-625rs
	Flexible coupling : 5 mm x 8 mm	**1**	**3.15 €**	**3.15 €**	https://store.thingibox.com/es/mecanica/526-157-acopladores.html#/2430-tipo-flexibles_5_a_8mm_o19mm
Motion elements	Lead screw : 8 mm	**1**	**12.59 €**	**12.59 €**	https://store.thingibox.com/es/mecanica/584-837-barra_roscada_trapezoidal.html#/2630-tipo-tr8x8_300mm
	Lead screw nut : 8 mm	**1**	**3.08 €**	**3.08 €**	https://store.thingibox.com/es/mecanica/585-344-tuerca_tr8x8.html#/2633-tipo-largo_15mm_laton
	Bearing	**1**	**0.00 €**	**0.00 €**	Owned
Stepper motor	NEMA 17 motors with Controller board kit	**0.1**	**35.35 €**	**3.54 €**	https://www.banggood.com/TWO-TREES-CNC-Shield-+-UNO-R3-Board-+4x-A4988-Stepper-Motor-Driver-+4x-4401-Stepper-Motor-Kit-for-3D-Printer-p-1510212.html?rmmds=myorder&cur_warehouse=CZ

Other hardware material					
Screws	M5x10 mm	**48**	**0.10 €**	**4.80 €**	Ferreteria Mella (Local hardware store)
	M5x15 mm	**15**	**0.10 €**	**1.50 €**	Ferreteria Mella (Local hardware store)
	M5x25 mm	**5**	**0.10 €**	**0.50 €**	Ferreteria Mella (Local hardware store)
	M5x30 mm	**15**	**0.11 €**	**1.65 €**	Ferreteria Mella (Local hardware store)
	M5x45 mm	**6**	**0.11 €**	**0.66 €**	Ferreteria Mella (Local hardware store)
	M5x60 mm	**13**	**0.12 €**	**1.56 €**	Ferreteria Mella (Local hardware store)
	M3x20 mm	**12**	**0.08 €**	**0.96 €**	Ferreteria Mella (Local hardware store)
	M3x40 mm	**4**	**0.10 €**	**0.40 €**	Ferreteria Mella (Local hardware store)
Nuts	M5 Nylon insert lock	**50**	**0.07 €**	**3.50 €**	Ferreteria Mella (Local hardware store)
Washer	M5 1 mm	**40**	**0.03 €**	**1.20 €**	Ferreteria Mella (Local hardware store)
T-nuts	Drop-in M5	**20**	**0.59 €**	**11.80 €**	https://store.thingibox.com/es/openbuilds/594-369-conector_t_v-slot.html#/2655-tipo-m5_aluminio
	Belt holder M3	**6**	**0.44 €**	**2.64 €**	https://store.thingibox.com/es/mecanica/280-678-conector_T_openbuilds.html#/2595-tipo-m3
Electronics					
Power supply	Newstyle power supply 220V to DC 12V 20A 240W	**1**	**22.99 €**	**22.99 €**	https://www.amazon.es/dp/B07DKZJBY7/ref=pe_27091411_487056151_TE_item
Controller	Arduino UNO + GRBL shield kit	**0.2**	**35.35 €**	**7.07 €**	https://www.banggood.com/TWO-TREES-CNC-Shield-+-UNO-R3-Board-+4x-A4988-Stepper-Motor-Driver-+4x-4401-Stepper-Motor-Kit-for-3D-Printer-p-1510212.html?rmmds=myorder&cur_warehouse=CZ
Motor Drivers	HR4988 kit	**0.4**	**35.35 €**	**14.14 €**	https://www.banggood.com/TWO-TREES-CNC-Shield-+-UNO-R3-Board-+4x-A4988-Stepper-Motor-Driver-+4x-4401-Stepper-Motor-Kit-for-3D-Printer-p-1510212.html?rmmds=myorder&cur_warehouse=CZ
Limit switches	X, Y and Z limit switches	**6**	**0.95 €**	**5.70 €**	https://store.thingibox.com/es/electricidad/552-239-interruptor_fin_de_carrera_micro.html#/2532-tipo-con_palanca
Emergency switch	Emergency stop switch	**1**	**3.12 €**	**3.12 €**	https://www.banggood.com/N-or-O-N-or-C-Emergency-Stop-Switch-Push-Button-Mushroom-4-Screw-Terminals-p-918865.html?rmmds=myorder
Remote Controller	Wii Remote + Nunchuk	**1**	**0.00 €**	**0.00 €**	Owned
Shipping					
Total cost for shipping	Shipment additional cost is already included	**0**	**0.00 €**	**0.00 €**	

Machine	**Product**	**Total cost (€)**	**Total cost ($R)**	Exchange rate (2/06/22 @ 22:20 UTC)	
SLAX JTM v0	Prototype	**388.23 €**	**2,003.27 €**	5.16	Bill of materials for project thesis of Alexander José Magnusson Amorós



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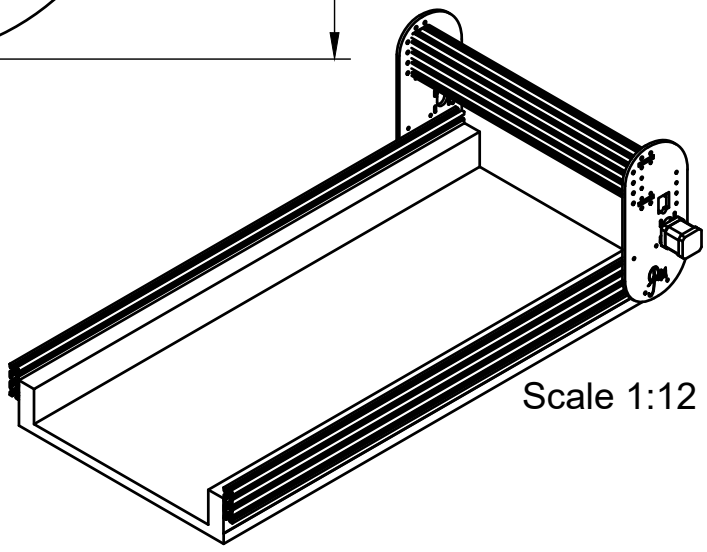

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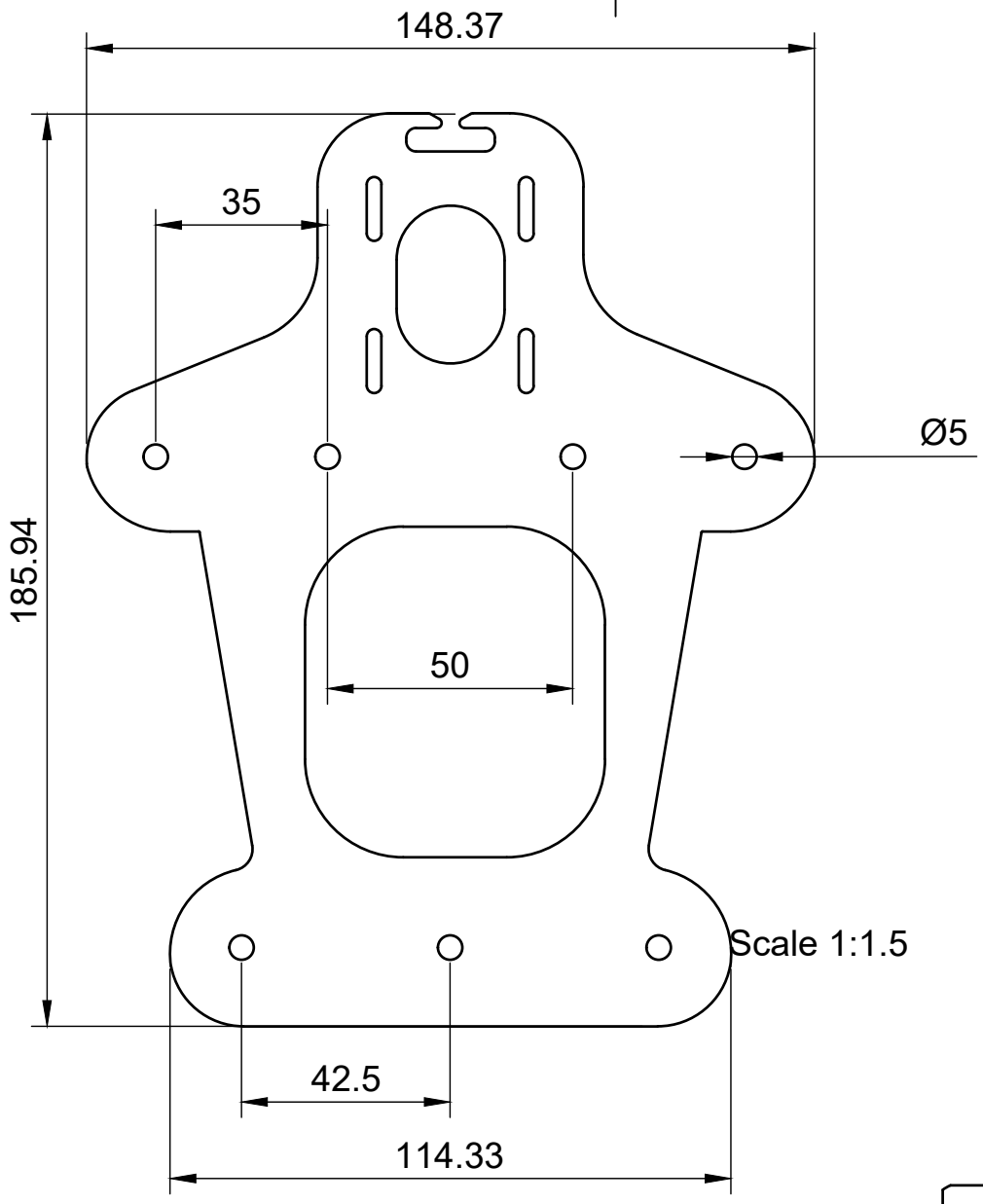
		Title: Y Gantry Plate	DWG No.: 1
			Rev. / Date of issue / Sheet: 1/3



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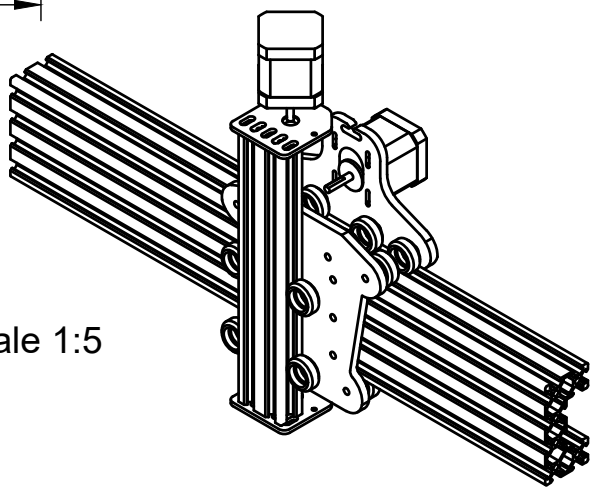

Scale 1:5

Dept.	Technical reference	Created by	Approved by
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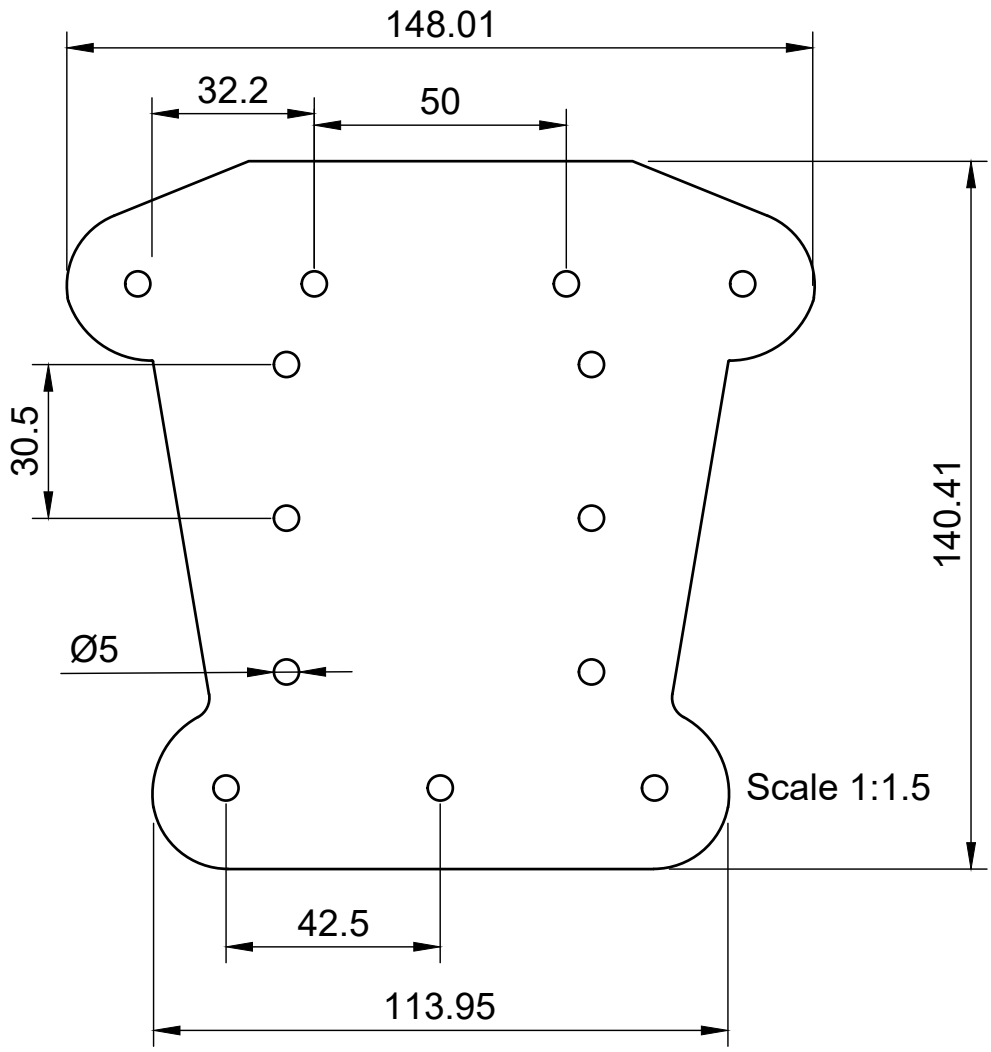
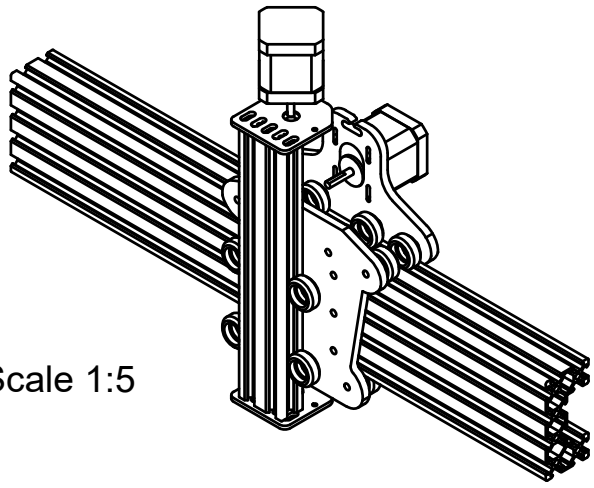
		Title: X Gantry Plate	DWG No.: 2
			Rev. / Date of issue / Sheet: 2/3





Scale 1:5

Dept.	Technical reference	Created by	Approved by
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		Title: Z Gantry Plate	DWG No.: 3
			Rev. / Date of issue / Sheet: 3/3

Physiotherapist	Without Slax	With Slax at 3%/c	With Slax at 4%/c	With Slax at 5%/c	
Clients in a day	8	11	11	11	clients
Income (30€/c)	240	320,1	316,8	313,5	€/day
Income (40€/c)	320	426,8	422,4	418	€/day
Income (50€/c)	400	533,5	528	522,5	€/day
	Growth	25,02	24,24	23,44	%

Slax	Renting a 3%/c		Monthly (20 labor days)	
At 30€/c	9,9	€/day	198	€/month
At 40€/c	13,2	€/day	264	€/month
At 50€/c	16,5	€/day	330	€/month

Slax	Renting a 4%/c		Monthly (20 labor days)	
At 30€/c	13,2	€/day	264	€/month
At 40€/c	17,6	€/day	352	€/month
At 50€/c	22	€/day	440	€/month

Slax	Renting a 5%/c		Monthly (20 labor days)	
At 30€/c	16,5	€/day	330	€/month
At 40€/c	22	€/day	440	€/month
At 50€/c	27,5	€/day	550	€/month

ROI expenses	
Machine cost	400€
Project cost	6.500€
Others	1.000€
	7.900€

	ROI (only machine)		ROI (all)	
	3%/c			
At 30€/c	2,0	months	39,9	months
At 40€/c	1,5	months	29,9	months
At 50€/c	1,2	months	23,9	months
	4%/c			
At 30€/c	1,5	months	29,9	months
At 40€/c	1,1	months	22,4	months
At 50€/c	0,9	months	18,0	months
	5%/c			
At 30€/c	1,2	months	23,9	months
At 40€/c	0,9	months	18,0	months
At 50€/c	0,7	months	14,4	months

Physiotherapist plan		
Hours	**Without Slax**	**With Slax**
8	Cliente 1	Maquina
815	Cliente 1	Cliente 1
830	Cliente 1	Cliente 1
845	Cliente 1	Cliente 1 / Maquina cl. 2
9	Cliente 2	cl2
915	Cliente 2	cl2
930	Cliente 2	cl2/maq cl.3
945	Cliente 2	cl3
10	cl3	cl3
1015		cl3/maq cl.4
1030		cl4
1045		cl4
11	cl4	cl4/maq cl.5
1115		cl5
1130		cl5
1145		cl5/maq cl.6
12	cl5	cl6
1215		cl6
1230		cl6/maq cl.7
1245		cl7
13	cl6	cl7
1315		cl7/maq cl.8
1330		cl8
1345		cl8
15	cl7	cl8/maq cl.9
1515		cl9
1530		cl9
1545		cl9/maq cl.10
16	cl8	cl10
1615		cl10
1630		cl10/maq cl.11
1645		cl11
17	fin	cl11
1715		cl11/fin

Explorer
Powered by Santander X

Define la esencia que guiará tus decisiones empresariales

Propósito

(Ejemplo: ofrecer una alternativa de consumo local, asequible y responsable)

Ofrecer tratamiento muscular y de patologías o malformaciones de manera constante, asequible y rápida.

Misión

(Ejemplo: producir y distribuir alimentos con precios competitivos a través de cultivos de agricultura ecológica)

Automatizar el proceso de masaje y cuidado del cuerpo creando una máquina o programando un robot que pueda realizar dicho masaje.

Visión

(Ejemplo: la consecución de una sociedad más justa, más sana y más consciente de su papel en el mundo)

El desarrollo de una comunidad feliz y activa que promueve la salud y el cuidado muscular. Longevidad.

Impacto de la organización

- **Social**
  (Ejemplo: mejorar el acceso a la alimentación, fortalecer las redes de cooperación y generar espacios para el intercambio de bienes y servicios)

  Mejorar la calidad de vida de la población activa (no sedentaria), aumentar el nivel de longevidad y reforzar un estilo de vida saludable y bienestar.

- **Económica**
  (Ejemplo: impulsar el tejido productivo vecinal, ofrecer unas condiciones económicas justas a los agricultores e impulsar el desarrollo de la agricultura ecológica)

  Impulsar las clínicas de fisioterapia, los centros de deportes y gimnasios, aumentar productividad general al aumentar el bienestar de la sociedad e impulsar el sector de autocuidado personal

- **Ambiental**
  (Ejemplo: la actividad de la empresa se guiará por los máximos estándares de protección ambiental con el ciclo de vida y la defensa del ecosistema como eje fundamental de su actuación)

  Reuso de maquinaria. Diseños que impliquen el mínimo de fabricación. Suministramiento eléctrico de energías renovables. Seguimiento estricto de las normas de protección al medio ambiente.

- **Reputacional**
  (Ejemplo: empresa comprometida con el medioambiente y las personas, estilo amable y conectado con la naturaleza, pero eficaz y sólido en la producción de bienes)

  Empresa comprometida con el cuidado del cuerpo y mantener una vida saludable y longeva. Promover el deporte y actividad física responsables.

Código de conducta

- **Comportamiento de los empleados**
  (Piensa en cómo debe ser siempre su forma de actuar)

  Abiertos a conocer, enseñar y aprender. Nadie es mejor ni peor que nadie. Curiosos y creativos. Tranquilos pero motivados.

- **Relaciones entre empleados**
  (Identifica qué valores guían el comportamiento interno en cualquier interacción)

  Empatizar. Somos un equipo, tenemos un objetivo en común. Alegres pero honestos. No comparar. Competencia profesional.

- **Actuaciones externas:**
  (Cuál debe ser la actitud de los empleados siempre ante cualquier agente externo)

  Respetuosos y atentos. Honestos. Con orgullo de la empresa y en su defensa. Educados. Establecer mentalidad “somos un equipo”. Empatizar y perdonar pero mantener seriedad.

Cliente Dueño de gimnasio/centro de deportes/rehabilitación o fisioterapeuta	Necesidad	Descubrimiento	Consideración	Compra	Retención	Recomendación
Fases	-Busca innovar su servicio -Añadir más ventajas y beneficios -Atraer más clientes (usuarios) y fidelizar los existentes	-Búsqueda exhaustiva de servicios posibles a añadir por internet, preguntando a socios, destacados en revistas de deportes y salud, identificados en videos virales, noticias, por uso de atletas profesional o promovidos por marcas proveedoras de servicios que ya posee. -Clientes (usuarios) lo piden	-Identifica el ROI -Busca prueba real de eficiencia -Quiere oir opiniones de clientes -Negocia precio asequible -Miedo de hacer una inversion sin retorno seguro	-Oferta de tarifas según uso -Busca inversión -Personaliza su deseo de pago	-Contacto para mantenimiento rápido y sencillo -Necesidad de promover entre sus usuarios -Curiosidad por cómo funciona -Interés en aportar ideas y/o cambios	-Dejar que hablen la opinión verdadera
Puntos contacto	Contacto por todos los medios de posibles clientes.	Redes sociales Pagina web Boca a boca de socios en el sector	Personal y cercano, en persona Remoto por videollamadas Contacto directo con vendedor,	Contacto directo con vendedor	Atencion al cliente cercano. Mantenimiento bi-mensual. Correos regulares sobre mejoras, actualizaciones, en qué trabajamos etc.	Encuesta tras cada proceso. Pedir hacer video promocional. Pedir usar la imagen del cliente junto a la nuestra.
Emociones	Preocupado :S	Interesado y aliviado :]	Inseguro :$	Satisfecho y esperanzador :)	Seguro con su decisión :)	Encantado pero tal vez algo molesto :/
Acciones visibles	Ir puerta a puerta dandonos a conocer	Promoción por todas las plataformas	Ofrecemos prueba temporal sin coste añadido. Contacto cercano y constante	Facilitar trámites. Crear plan de uso personalizado. Instalación immediata.	Cuidado de su negocio a través de nuestro mantenimiento. “Que le vaya bien a nuestro cliente significa que nos irá bien”	Interés en su crecimiento. Realización de videos.
Acciones invisibles	Contacto con proveedores del sector para encontrar clientes potenciales. Investigación de posibles clientes en la zona.	Ser tendencia para que se hable de nuestro producto en el sector	Crear satisfacción en los usuarios.	Demostrar confianza en nuestro servicio para tranquilizar al cliente.	Desarrollo constante del producto/servicio. Inovaciones.	Crear mentalidad de unificar negocios “somos un equipo”
Pains	Presión de mejorar servicio que ofrece.	Esfuerzo de búsqueda y selección de producto a escoger.	Inseguridad del producto/servicio. Miedo a lo desconocido.	Realizar el pago.	Rendimiento bajo. Poco uso por parte de los usuarios.	Modificar o alterar temporalmente su imagen de empresa.

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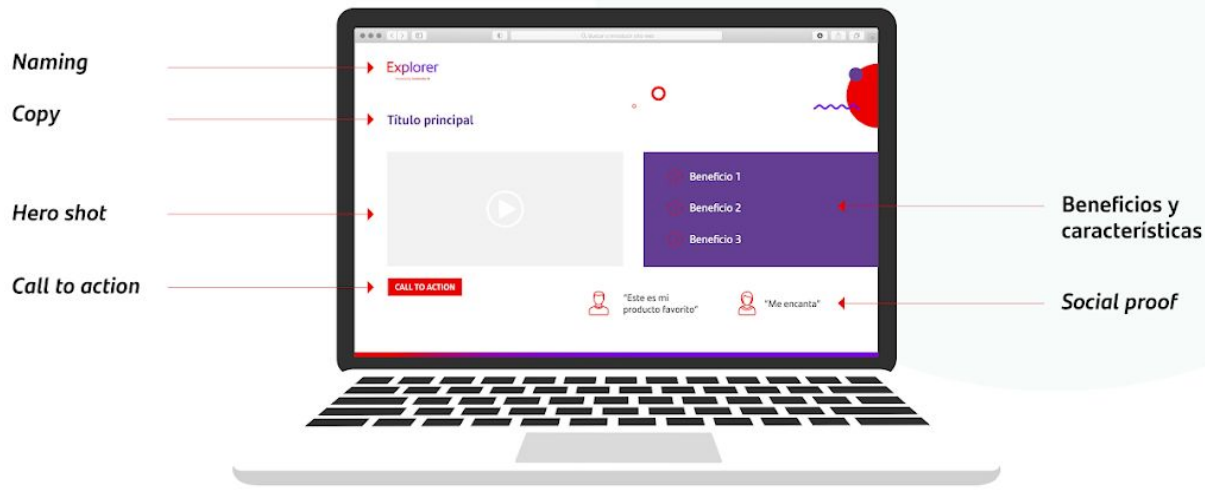
Diseña tu 'landing page'

Si tu *landing page* es nueva, empieza por **detallar los elementos** que aparecen desglosados en la siguiente plantilla. ¡Es el primer paso para poner en valor tu MVP!



1. *Naming*

SLAX

2. Copy

Masajes a demanda, bienestar al alcance de todos

3. *Hero shot*

Imagen de usuario estirado en camilla mostrando el rostro de tranquilidad y con la máquina detrás.

4. *Call to action* (CTA)

Énfasis en relajar, botón: Reclama Relax

5. Beneficios y características

·Sea independiente para relajarse.
·Lay, click, relax & repeat. La ley del mínimo esfuerzo nos gobierna.
·Masajes sin compromiso. Recibe y vuelve a recibir.
·Descarga tus músculos 24/7, que nadie te pare.
·En casa, en el trabajo, en el gimnasio… donde quieras

6. *Social proof*

Audios de gente explicando cómo se sintieron.
Que expliquen un antes y después.

Después de crear tu propia *landing page*, valida el impacto que ha tenido **siguiendo las cuatro grandes métricas**: el número de usuarios, las sesiones, las visitas y la tasa de rebote.

Número de usuarios

Escribe aquí

Sesiones

Escribe aquí

Visitas

Escribe aquí

Tasa de rebote

Escribe aquí

¡Saca conclusiones! Esta información será muy valiosa a la hora de tomar decisiones futuras de mejora.

¿Qué ha salido bien?

Escribe aquí

¿Qué ha fallado?

Falta de organización
Outsourcing

¿Cómo puedes mejorar?

Preparando mejor

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Ruta de validación de hipótesis y MVP

Si lo que quieres es validar tu propuesta inicial de negocio (MVP o Producto Mínimo Viable) **será necesario que compruebes diferentes hipótesis para aprender rápidamente, ser flexible y reaccionar frente a condiciones desconocidas antes de lanzar el producto al mercado.**

Hipótesis básicas	Comienzo	Primera iteración	Segunda iteración	Tercera iteración
Hipótesis del cliente	Ejemplo: el arquetipo de cliente objetivo (*early adopters*)	Fisioterapeutas y/o centros de rehabilitación	Centros de estética	Gimnasios
Hipótesis del problema	Ejemplo: el problema que tiene tu cliente objetivo	Limitación de rentabilidad por jornada laboral. Necesidad de otros profesionales para aumentar el rendimiento.	Falta de productos, tratamientos e innovación. Dificultad de fidelizar al cliente.	Fidelización de miembros. Innovar y captar nuevos clientes.
Hipótesis de la solución	Ejemplo: producto o servicio con el que soluciones el problema de tu cliente objetivo	Máquina automática que trabaja paralelamente al profesional. Incluso fuera de su horario. Máquina que puede usar un/a recepcionista.	Máquina automática trabaja zonas que no afectan a otros servicios. Novedad y placer hacen al usuario volver.	Beneficios de la tecnología en los miembros al realizar ejercicios. Facilidad de uso y novedad captan la atención de clientes.

Ahora, **entra en la zona de experimentos** para corroborar o refutar las hipótesis planteadas anteriormente y, por último, **evalúa los resultados con el mercado real.**

Diseño de experimentos

Hipótesis críticas

La tecnología PMT se usa en fisioterapia/rehabilitación/aumento rendimiento de atletas.

Los fisioterapeutas prefieren comprar el producto, gimnasios hacer un "leasing" y usuarios por subscripciones.

Mejora rentabilidad del negocio al que se aplica.

Hipótesis de mayor riesgo

La tecnología PMT se usa en fisioterapia/rehabilitación/aumento rendimiento de atletas.

Método

(Exploración, *pitch* o conserje)

Exploración

Criterio mínimo de éxito

·3 entrevistas
·50% usan PMT o usarían
·Piden más información o seguimiento del proyecto

Zona de resultados

Hipótesis validadas

Escribe aquí

Hipótesis invalidadas

Escribe aquí

Después de validar que las hipótesis sobre las que se apoya tu MVP son correctas, **¡aterriza el *business case*!**

Segmentos de personas

¿Para quién es este MVP?

Escribe aquí

Propuesta o visión del MVP

¿Cuál es la propuesta de valor de este MVP?

Escribe aquí

Resultado esperado

¿Qué resultado buscas en este MVP?

Escribe aquí

Viajes de usuario

¿Qué punto de contacto del *journey* del cliente será mejorado con este MVP?

Escribe aquí

Funcionalidades

¿Qué acciones se van a optimizar en este MVP?

Escribe aquí

Métricas para la validación

¿Cómo puedes medir los resultados en este MVP?

Escribe aquí

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Propuesta de valor

Nombre de la idea CNC percussive massage machine

Nuestro servicio de máquinas automasajes con tecnología de percusión
Producto/servicio/funcionalidad (ejemplo: asistente digital)

ayudan a fisioterapeutas, centro de rehabilitación, gimnasios, centros de deportes (por ende, sus usuarios)
Segmento del cliente (ejemplo: jóvenes menores de 35 años)

que quiere dedicar más tiempo de calidad a la gestión del negocio, atender usuarios, ofrecer alternativas, innovar su negocio
Jobs/Acciones que realiza (ejemplo: recibir consejos sobre los mejores productos del banco, ofertas y préstamos especiales)

teniendo en cuenta que
Verbo (ejemplo: contando con)

le falta tiempo, no consigue nuevas suscripciones o están en declive
Customer pain (ejemplo: una alternativa a la atención presencial en oficinas)

y obteniendo
Verbo (ejemplo: ganando)

una clientela fiel y constante, aumento de usuarios e incremento de satisfacción
Customer gain (ejemplo: tiempo y facilidad para sacar partido de su cuenta en el banco)

(no como masajeadores manuales (foam rollers), servicios de relajación externos, alternativas más costosas (presión hidráulica, baños termales) **)**
Competidores o sustitutos (ejemplo: canales de la banca tradicional)

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Canvas propuesta de valor

'Gain creators'

(ej: acceso sencillo a la información y reducción del tiempo en las gestiones)

Uso por suscripción aumentará los usuarios.
El cambio en novedades y desarrollo los mantendrá atentos y fieles.
Los usuarios se verán agradecidos con el cliente al haber realizado dicha mejora, reconociendo el buen labor.

'Product & Services'

(ej: asistente digital)

Máquina automasajes

'Pain relievers'

(ej: atención personalizada analizando a través de *big data* el histórico de acciones bancarias de cada cliente)

El usuario recibe un trato mientras el cliente
Atiende sus necesidades, sin dejarlo desatendido.
Máquina de fácil uso "plug and play"
Novedad, innovación y gusto atrae más subscripciones

'Gains'

(ej: información para mejorar las gestiones)

Clientela fiel y constante.
Aumento de usuarios.
Reconocimiento

'Customer jobs'

(ej: pagos con el móvil, uso de la *app* del banco)

Recibir gente activa/deportista
Tratar con problemas musculares
Gestionar citas y miembros

'Pains'

(ej: desplazamiento a oficinas físicas del banco)

Falta de tiempo para atender a usuarios.
Suscripciones en declive o poco constantes.

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los 3 grupos de financiación, elige el que más le conviene a tu proyecto y especifica el nombre de esa financiación que quieres obtener.

upo de anciación: Bootstraping

Tipo de financiación: Propia, pre-seed

ootstrapping, Equity Capital y fórmulas innovadoras)

mpleta la hoja de ruta para obtener esta financiación trazando pequeñas metas todos los meses hasta llegar al sexto mes. Todos estos objetivos deben responder a la pregunta: ¿qué necesito para lograr esa financiación?

MES 1	MES 2	MES 3	MES 4	MES 5	MES 6
¿Qué objetivo te propones cumplir este mes?	¿Qué objetivo te propones cumplir este mes?	¿Qué objetivo te propones cumplir este mes?	¿Qué objetivo te propones cumplir este mes?	¿Qué objetivo te propones cumplir este mes?	¿Qué objetivo te propones cumplir este mes?
Obtener una estima de clientes potenciales y su perfil	Conseguir primer cliente	Conseguir nuevos clientes	Obtener financiación externa	Contratar equipo	Establecer una dinámica de empresa/equipo y valores, desarrollar mejoras o nuevo producto
¿Qué acciones necesitas realizar para alcanzar este objetivo?	¿Qué acciones necesitas realizar para alcanzar este objetivo?	¿Qué acciones necesitas realizar para alcanzar este objetivo?	¿Qué acciones necesitas realizar para alcanzar este objetivo?	¿Qué acciones necesitas realizar para alcanzar este objetivo?	¿Qué acciones necesitas realizar para alcanzar este objetivo?
Cuenta Instagram y landing page	Pitch puerta a puerta y dar pruebas gratuitas	Continuar con difusion por RRSS, Mostrar caso de primer cliente, Continuar pitch puerta a puerta	Agrupar datos otenidos y presentarlos bien, Reaizar plan estratégico a futuro y en qué gastaré la financiacion	conseguir financiacion externa, búsqueda de talento en universidades y por referencias	Ejercicios de acercamiento del personal, establecer objetivo común, usar método scrum para desarrollo.

Elige tu modelo de negocio

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1 De los tipos modelos de negocio explicados previamente en este módulo, selecciona 3 de ellos y completa las preguntas y enunciados para cada opción elegida.

Modelo de negocio 1

Elige un modelo de negocio

Leasing

Marca con una X si cumple con estas características

- [ ] Innovador
- [x] Rentable
- [x] Escalable
- [x] Medible

¿De qué manera le aporta valor a tu cliente?

Permite escalar su negocio o hacerlo más rentable.
Aporta relajación y bienestar.

¿Cuáles son las principales fuentes de ingresos? ¿Cómo haces dinero en este modelo de negocio con tu MVP?

Pago mensual del leasing por la máquina de masajes.
Extras no incluidos en el leasing (nuevos cabezales de masaje, nuevos algoritmos, etc)

¿Cuáles son los principales costes en este modelo de negocio para tu MVP?

Material de máquina, coste de mantenimiento y recambios.

¿Qué precio tendrá tu producto o servicio con este modelo de negocio?

La mitad del coste de la máquina por mes con servicios post venta o mantenimiento incluidos.

Modelo de negocio 2

Elige un modelo de negocio

Suscripción / Freemium

Marca con una X si cumple con estas características

- [x] Innovador
- [x] Rentable
- [x] Escalable
- [x] Medible

¿De qué manera le aporta valor a tu cliente?

Obtiene un masaje en cualquier momento del día (siempre y que disponga de acceso a una máquina). Relajación asequible o gratuita.
Reduce la espera para obtener un masaje.

¿Cuáles son las principales fuentes de ingresos? ¿Cómo haces dinero en este modelo de negocio con tu MVP?

Publicidad de otros servicios al cliente.
Pago para aumentar los minutos de uso.
Compra de subscripción mensual/anual o compra de minutos.

¿Cuáles son los principales costes en este modelo de negocio para tu MVP?

Material de máquina, coste mantenimiento, alquiler local de acceso a máquinas, marketing y difusión.

¿Qué precio tendrá tu producto o servicio con este modelo de negocio?

Gratis limitado a cinco minutos (con publicidad durante el masaje o a cambio de que el cliente realice una actividad ej. CAPTCHA)
Pack de 40 min (sólo sería posible gastar de 15 en 15 min) = mitad precio por hora de un fisioterpeuta ~12€
Subscripción 15 min al día mensual = ⅓ coste de máquina
escalar

Modelo de negocio 3

Elige un modelo de negocio

Venta producto

Marca con una X si cumple con estas características

- [ ] Innovador
- [x] Rentable
- [ ] Escalable
- [x] Medible

¿De qué manera le aporta valor a tu cliente?

Obtiene un producto que puede usar tanto como quiera y que le pertenece. Relajación disponible en cualquier momento. Ahorro en masajes especializados.

¿Cuáles son las principales fuentes de ingresos? ¿Cómo haces dinero en este modelo de negocio con tu MVP?

Compra de la máquina y servicio post venta.
Venta de subproductos o nuevas versiones, mejoras, añadidos a la máquina, etc.

¿Cuáles son los principales costes en este modelo de negocio para tu MVP?

Material de máquina, coste producción, marketing y difusión, ventas.

¿Qué precio tendrá tu producto o servicio con este modelo de negocio?

Precio del coste de la máquina más el 20-30% para beneficios.

2 Lee y compara los 3 modelos de negocio. Una vez hayas analizado cuál encaja más con tu producto o servicio, selecciónalo y escríbelo aquí

Leasing y freemium, una mezcla/unión de ambos donde el cliente haciendo el leasing se encargaría de ofrecer el espacio para los suscriptores del modelo freemium.

Como hacer un 'storytelling'

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Contar una buena historia es un arte. Hay quienes tienen un don natural y otros que pueden aprender a hacerlo. Sin embargo, toda buena historia necesita una estructura y para ello, este ejercicio puede ayudarte. Sigue el modelo de relato clásico para diseñar tu narración.

1 Introducción

Gancho de apertura

Objetivo:

Atraer la atención de forma inmediata.

Puedes usar:

- Una pregunta contundente.
- Un dato potente.
- Un objeto mágico.
- Un acting directo al público.

Plantea tu gancho de apertura:

¿QUIÉN ESTÁ CANSADO?
¿ALGUIEN MÁS ESTÁ CANSADO?
Incluso cuando menos hacemos, sentimos fatiga, nos queremos relajar, descansar…

Hacer enfasi en que este es el problema (por si no queda claro)

2 Nudo

Problema

Objetivo:

Crear consciencia de la existencia de un nicho.

Puedes usar:

- Datos que avalen su existencia.
- Una historia que lo pruebe.
- Una mezcla de los dos.

Describe tu problema:

Os voy a contar el origen de mi proyecto, fue un estado, una sensación. Estaba CANSADO… llevaba todo el día trabajando arriba abajo, etc (contar historia)

Solución

Objetivo:

Explicar el proyecto. Esta es la parte más importante y debe ocupar tres cuartas partes de tu *pitch*.

Puedes usar:

- Presentación del equipo y el proyecto.
- La solución.
- Mercado.
- Competencia.
- Modelo de negocio.
- Tracción (si la hay).

Explica tu solución:

Así que decidí usar mi TFG como principal excusa para gastar tiempo y dinero en intentar hacer una versión más paciente/amable de mi hermano, una maquina masajeadora. Explicar que existen todo tipo de terapias y opciones, incluso las dos startups haciendo algo muy parecido.

3 Desenlace

Cierre

Objetivo:

Involucrar a tu audiencia.

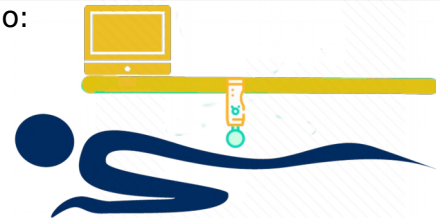
Puedes usar:

- *Call to Action* (qué necesitas y qué ofreces).
- Contacto.
- Conclusión.

Imagina tu cierre:

Ahora os propongo que os pidáis masajes entre vosotros, a ver cuántos acceden, cuantos son buenos y si tardáis menos que venir aquí arriba y estirarse en la esterilla ;)

RESUMEN EJECUTIVO

Logo: 	Descripción de la empresa: En SLAX se pretende trabajar para el bienestar constante y de fácil accesibilidad para todos los niveles económicos. La automacización de los masajes a través de máquinas permite reducir su coste y ofrecerlo a cualquier hora.
Contacto: Alexander José Magnusson Amorós +34 640 698 506 aj.magnussson@gmail.com	Problema que resuelve: A usuarios: Los elevados precios de los masajes tradicionales. La espera que estos implican (tanto por reserva como al profesional). No hay posibilidad de masajes una vez terminada la jornada laboral de los centros. A fisioterapeutas: Número limitado de clientes por día y hora. Bajo rentabilidad. Necesidad de otro fisioterapeuta para aumentar el negocio. Deterioro de las manos, herramienta de uso para aplicar su tratamiento. A gimnasios: Captación de clientes. Satisfacción de clientes. A empresas en general: Satisfacción de empleados. Control indirecto de los descansos. Entorno estresante.
Sector: Salud y bienestar, entretenimiento, deporte.	Solución: Paga menos por un masaje que te relaja y beneficia. No esperes, hay más de una máquina disponible. Accede cuando te plazca. Pon a tus clientes que esperan en la máquina para que empiece la sesión mientras terminas con el anterior y la máquina los dejará listos.

	Uso de las manos reducido al ser la máquina quien hace un 10% de cada sesión. Impacta con una nueva e innovadora máquina que no solo relaja y alivia el dolor muscular, sino que puede ser usado antes de los ejercicios para aumentar el rango de movimiento. Mantén a tus trabajadores contentos con el libre e indefinido acceso a masajes durante sus descansos. Esto los mantiene en la máquina el tiempo que la máquina está programada y puede hacer un seguimiento del tiempo que cada usuario ha hecho uso. Deja al equipo relajado, creando un ambiente tranquilizador en la oficina.
Equipo: Alexander José Magnusson Amorós	Mercado al que te diriges: Centros de rehabilitación, fisioterapeutas, empresas en general, gimnasios, centros de belleza, clubs deportivos, atletas, equipos profesionales deportivos.
Alianzas/partners: ThingiBox (patrocinio en el proyecto y obtengo 20% descuento en compras de material) proveedores.	Competencia: Existen dos empresas que usan robots colaborativos para realizar masajes en todo el cuerpo. Dichos masajes son una emulación de los movimientos de los profesionales. https://massagerobotics.com/ https://capsix-robotics.com/en/elementor-6471/
Inversiones: Inversión inicial: 500€ Inversión a corto plazo: 10.000 - 20.000 €	Ventaja competitiva: Más sencillo y probablemente barato. Puede funcionar 24/7. Fácil montaje y desmontaje.
Uso de los fondos: Creación del prototipo. Adquirir un equipo y producir más versiones y mejorar según críticas.	Modelo de negocio. Tipo de modelo: Leasing + subscripción
Hitos conseguidos y futuros: MVP, landing page, prototipo. Validación de MVP, instalar en un negocio, segunda versión y captación de capital.	

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CERTIFICADO DE FINALIZACIÓN

Alexander José Magnusson Amorós

Ha completado el programa Explorer, promovido por Banco Santander a través de Santander Universidades y dirigido por el Centro Internacional Santander Emprendimiento.

2022 Primera edición

Verified Certificate

This Certificate was Issued by:

Explorer by X - Jóvenes con soluciones

Certificate

Programa Explorer

Name of Recipient

Alexander José Magnusson Amorós

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