Bachelor's Degree Final Project

Degree in Industrial Engineering

Random Light and Sensor Station for Karate Training

PROJECT REPORT

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1 Summary

This paper describes the process of designing and building a training device aimed at helping young athletes in the practice of Karate. This training station will be used to practice different striking techniques with the aid of glowing parts which will guide the user around the structure to enable them to exercise different training drills. Both the structural and electronical aspects will be analyzed and discussed with the help of SolidWorks for the design and OrCAD for the electronical simulations.

The result is a functional training device which interacts accordingly with the user.

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2 Glossary:

Dojo: Place where you practice the Path

FSR: Force Sensitive Resistance

Karate-Do: The path of the empty hand

Kata: Form

Kumite: Combat

Makiwara: Karate training tool, initially used in Japan

Sensei: Teacher or master

Seiken: Two first knuckles of fist corresponding to the index and middle finger

3 Preface

3.1 Origin of the Project

The main idea of this project comes from the need every sport has for specialized training equipment. Taekwondo, judo and boxing are all Olympic sports and you will find a large variety of specialized equipment dedicated to improving technique. Karate on the other hand is not an Olympic sport yet and there is a limited amount of equipment specifically designed for karate training. This is why I thought of a project based on an ancient tool called "*makiwara*". A *makiwara* is used in a similar way a boxer would use a punching bag. Originally it consisted in a wooden plank which is driven into the ground and bound with straw rope on the upper striking surface. It is used to toughen all areas of the hands by striking with different techniques. The main objective of this project is to create a makiwara to improve the practice of punches, kicks, and other strikes by incorporating a lighting and sensor system which illuminates different parts of the striking surface, guiding the student to execute different strikes.

3.2 Motivations

I've been a karate instructor for the past 8 years, teaching both the sport and its values to children between the ages of 6 and 12 years old. I competed in karate tournaments for many years and have always worked on improving my karate technique. So, I understand the value of designing a better karate training device

Two current events also pushed me to develop a better *makiwara*.

- Karate will be an exhibition sport in the Tokyo Olympics of 2021.
- The television series "Cobra Kai", a sequel of the well-known "Karate Kid" movie, was launched in 2021.

These two highly publicized media events have significantly raised children's interest in karate and made me see a need and an opportunity for making karate training accessible and fun for the kids.

3.3 Previous Requirements

In order to program the electronics behind the random light and sensor system, I will need to acquire some previous knowledge on Arduino. This is why one of the first steps in this project is to familiarize myself with both the language and the components I will be using. Learning by doing will be very important during this project and the main reason I choose to take it on.

4 Introduction

As mentioned in the Preface, the objective of this project is to design a wooden structure which can be used in the practice of karate as a punching and kicking training device and which differs from the typical boxing punching bags. In order to make it more useful and modern, this project also aims to incorporate a light and sensor system, with Arduino, which will guide the athlete to strike different designated areas in order to train different attack techniques. The idea of using wood is to resemble ancient tools and equipment which were used in Japan when karate started in Okinawa, giving it a traditional value.

5 Project Goals

This project has two main goals. The first is to design and elaborate the structure used for striking, and the second is to program and implement the random light and sensor device using Arduino. The following structure will be used in order to thoroughly analyze different aspects related to both the design and posterior implementation of the different components that will configure the final product.

5.1 Structure:

- SolidWorks Designs
- SolidWorks Simulation
- Wood Cutting
- Construction and Padding
- Decoration
- Budget

5.2 Random Light and Sensor:

- Arduino Previous Knowledge
- Simple Code and Schematics
- Sensor Information
- Actuator Information
- Pressure Sensors and Final Lights Implementation
- Final Program Elaboration
- Sensor and Actuator Mounting
- Trials

Chapter I: The Structure.

The goal of this chapter is to define and verify a structure which allows different striking techniques. As mentioned in the introduction, the design the structure will follow is based on a *makiwara.* Before going into detail on the specific structure for the project, it is important to understand how and why *makiwara's* were used in ancient Japan.

6 History of Karate and Makiwara

Karate as a martial arts started in Japan, in the island of Okinawa*. Sensei Gichin Funakoshi* and his son *Yoshitaka Funakoshi* are known for being the promoters of what is known as Shotokan Karate, the first style of Japanese Karate-Do. The direct translation of Karate-Do is "The path of the empty hand", "Karate" meaning empty handed, and "Do" being the path. So it comes as no surprise that Karate isn't a martial art which uses any kind of weapons, thus the importance of training and toughening of the extremities such as hands and feet, which are the striking tools used in this combat sport. In order to fully understand the importance of *makiwaras,* the following statement made by *Sensei Gichin Funakoshi* , in his book "Karate-Do My Way of Life" is a perfect description of why it was used:

"Many people are under the erroneous impression that karate weapons consist only of the hands (clenched or unclenched) and the arms, the feet and the legs. It is no exaggeration, however, to say that every part of the body, from the top of the head to the tips of the toes, may be used as a weapon. For example, from the wrist down there are at least ten potential weapons: the *seiken* (regular fist), the *uraken* (the back fist), the *shuken* (the hand-fist), the *ippon-ken* (the single-point fist), the *chükõken* (another single-point fist), the *tettsui* (the hammer-fist), the shutõ (the sword hand), the nukite (the spear hand), the ippon nukite (the one-finger spear hand) and the *nihon nukite* (the two-finger spear hand). And from the ankle down: the *koshi* (the ball of the foot), the *shusoku* (the hand-foot), the *sokutõ* (the sword foot), the *tsumasaki* (the tip of the toe), the *enju* (the heel) and the *sokkõ* (the top of the foot). Other areas of the arms and legs used as weapons are the wrists, the elbows and the knees. There is almost no part of the body that may not be used as a weapon." […]

"When the *seiken* is used correctly, the knuckle of the middle finger strikes the opponent in one straight blow, with all the force of the arm behind it. The *seiken* may properly be called the heart of karate and should be practiced every day and with the utmost thoroughness. Unless it is completely effective, all kata and kumite become worthless. The most popular way of training with the *seiken* is to make use of a *Makiwara*, a stick post covered with rice straw. The *Makiwara* also, incidentally, may be used in strengthening the sword hand (*shutõ*), the elbows and the knees. I think I am in no way exaggerating when I say that practice with the *Makiwara* is the keystone in the creation of strong weapons." (1)

In Figure 1 a traditional makiwara can be seen used by *Sensei Gichin Funakoshi* .

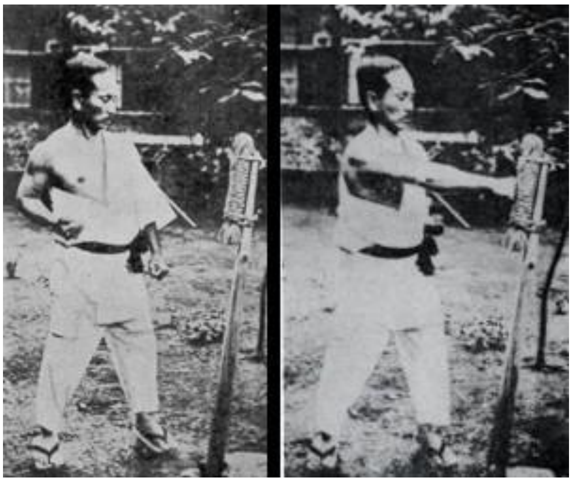


Figure 1: Sensei Gichin Funakoshi training with a makiwara (1)

Nowadays, karate has become a sport practiced worldwide, meaning that some traditional values and ways of training have evolved into more modern ways. Every *dojo* used to have a *makiwara,* nowadays, that isn't always true. Personally, I think this is due to practitioners and modern sensei's not wanting to have their younger students endure such extreme physical training. This is why this project is aimed to give karate students the opportunity to train with a *makiwara* in a different way.

7 Design

This chapter is aimed at showing the different elements that will define the final structure. It will also describe the different structural and ergonomic parameters taken into account when deciding how the final structure can best ensure the user an effective and fun training experience.

7.1 Main Structure

The structure will be divided into two main striking zones: one for leg kicks and one for fist punches. As mentioned before, the design will aim at giving the user the same experience a traditional *makiwara* does, with the difference of providing a separate area designated for the leg kicks. The frontal part will be a wooden board, as it was traditionally done, with the padded area incorporated. Pine wood, specifically insignis pine, was chosen for the different structural elements for two main reasons: First, because insignis pine's mechanical properties (see Table 1) fit well with the makiwara's function (numerous martial arts brands already commercialize makiwaras made of pine). Secondly, because insignis pine is widely available, versatile and easy to work with. The properties of insignis pine were later simulated with SolidWorks simulation program.

Density	500kg/m3 at 12% humidity
Compressive Resistance	434 kg/cm^2
Static Flexing Resistance	874 kg/cm^2
Elastic Module	90.000 kg/cm^2
Poisson coefficient	0.4

Table 1: Insignis pine mechanical properties

7.2 The Kick Striking Zone

This striking zone was the one which had to undergo some brainstorming in order to incorporate this additional part to the traditional *makiwara*. After various designs were sketched the following proposal was put forward.

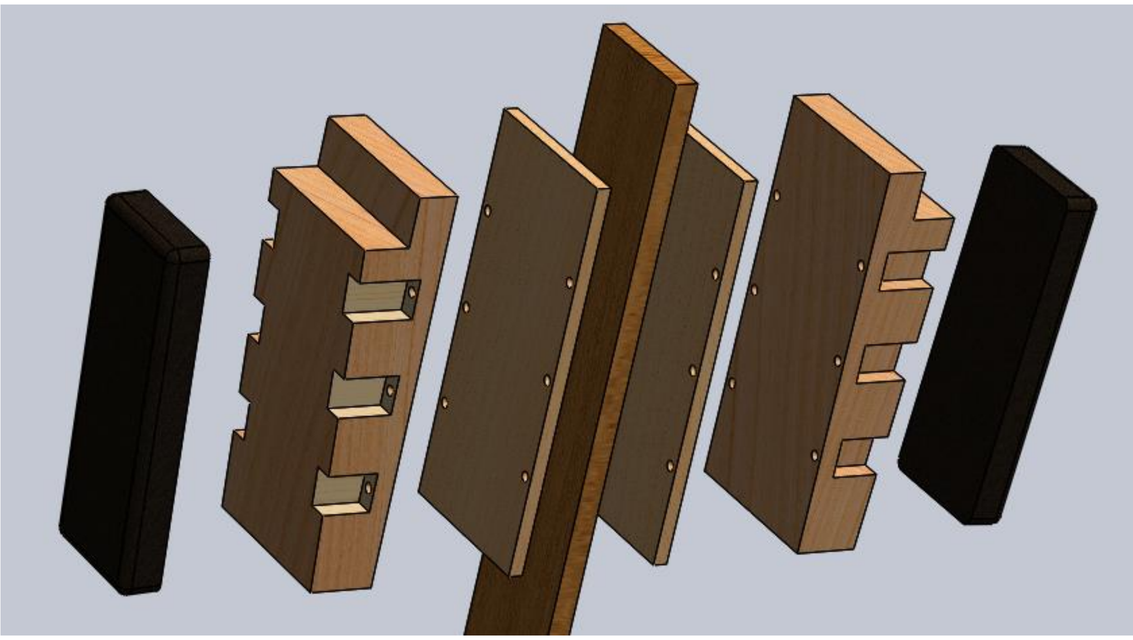


Figure 2: Kick striking zone design

The best solution seemed to be to incorporate a second board aligned perpendicularly to the punching board. This second board would serve to later mount the padding areas designated for the kicks and would also serve to locate the elements used protect the electronics and illumination device. One important aspect taken into account when designing was that it was important for these striking zones to be removable in order to protect the electronics inside the padded hit area in case of adverse weather. This is why these two striking areas will be connected by a bolt which will allow the user to dismount these from the board. The wooden parts which serve as a base for the padding (represented with the black elements) also allow these to stand out at a slight angle from the punching board. This will enable the user to strike this area without the risk of hitting other elements. As can also be seen in Figure 2, there is a space to mount the electronic case where the LEDs will light up on top of the wooden piece where the padding is directly mounted.

7.3 Electronical cases

Another designing aspect which had to be introduced was the incorporation of the electronical devices into the structure. These cases had to fit the electronic PCB boards and if possible intensify in some way the light emitted from the LEDs from the illumination system which is explained in chapter II. In order to accomplish these specifications the following designs were printed with a 3D printer using transparent PLA.

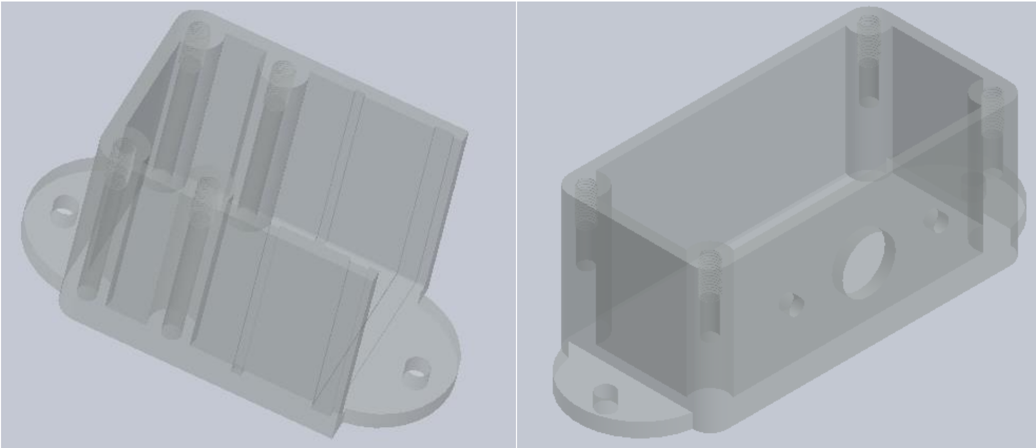


Figure 3: Electronical cases to mount the lighting system

The reason for using transparent material was to illuminate to whole electronical case when the LEDs turned on, giving the user a clearer signal to react to. Two different designs were elaborated, one for the central punching area (figure on the right) and one for each kicking area (figure on the left). As can be seen in the previous figures, these are designed to fit perfectly in their designated areas. The kick case will be mounted on the wooden base mentioned previously and the punching case will be mounted on top of the padded area of the punching zone. These have a groove where a transparent piece of methacrylate will close these cases protecting the electronic elements placed inside, which are also designed to slide into these cases and fit perfectly in order to avoid the different parts moving inside the case.

For a better visual experience and for decoration purposes the cover to the kicking cases was printed with a black belt logo. This can be seen in the following figure.

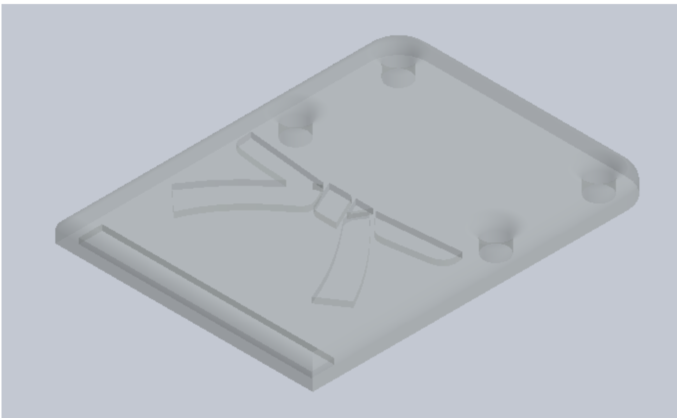
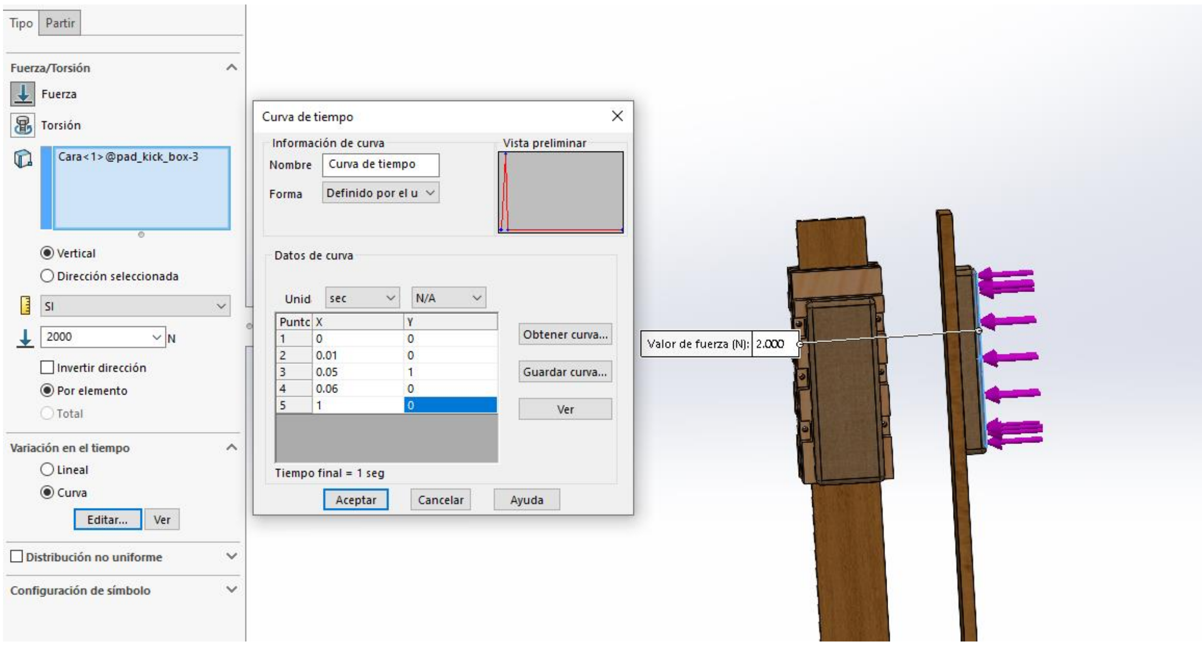


Figure 4: Cover to the electronical cases

7.4 Mechanical simulations

Simulating wood with SolidWorks is challenging due to the anisotropic nature of wood which can introduce wide variability between simulation and actual physical results. This being said, the properties from Table 1 were introduced into the system in order to have an estimate of what deformations would occur and especially important was to ensure that the front board didn't make contact with the kicking board.

To correctly simulate the effect a punch would have on the boards, the following considerations were taken into account. First, a nonlinear curve had to be defined simulating an impulse of force for a short period of time. This definition can be seen in Figure 5 where a nonlinear curve was defined to represent this short instance of impact.



Punto	X	Y
1	0	0
2	0.01	0
3	0.05	1
4	0.06	0
5	1	0

Figure 5: Definition of the nonlinear force on the makiwara

The results to this simulation showed that the *makiwara* board didn't suffer any deformations which would break it and the maximum displacements occurred on the top of the board and didn't surpass 4 cm, indicating that the 10 cm distance between both boards was sufficient.

SolidWorks simulation was followed by prototype testing. Results showed that these maximum displacements were actually smaller than the simulation showed, reaffirming the fact that the distance between boards was correct.

7.5 Anchorage

There are many ways these two boards can be anchored to the ground; the most important aspect was for these boards to be completely anchored and placed accordingly respect each other, respecting the distance and the perpendicularity between them. There are many mounting elements in the market designed to secure boards to the ground but for the purpose of this project, we propose the following solution which can be seen in Figure 6.

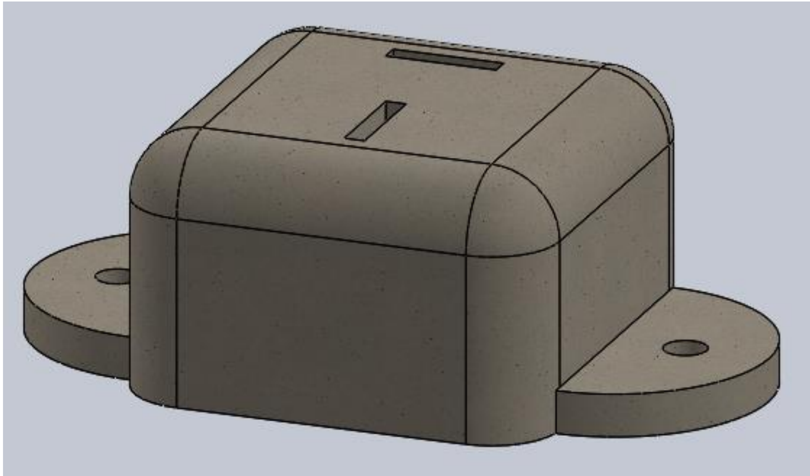


Figure 6: Anchorage design

This anchoring system would consist of a concrete base, mixed with metal elements to ensure shear strength. This base can be constructed through a formwork and can be anchored to the ground with spikes or bolts through the lateral flaps. This base enables the user to easily remove both boards in case of adverse weather if this structure is installed outdoors, an important aspect taken into account throughout this project.

8 Full Assembly

The following figures represent the final product assembly where the previous elements described can be seen in their final configuration.

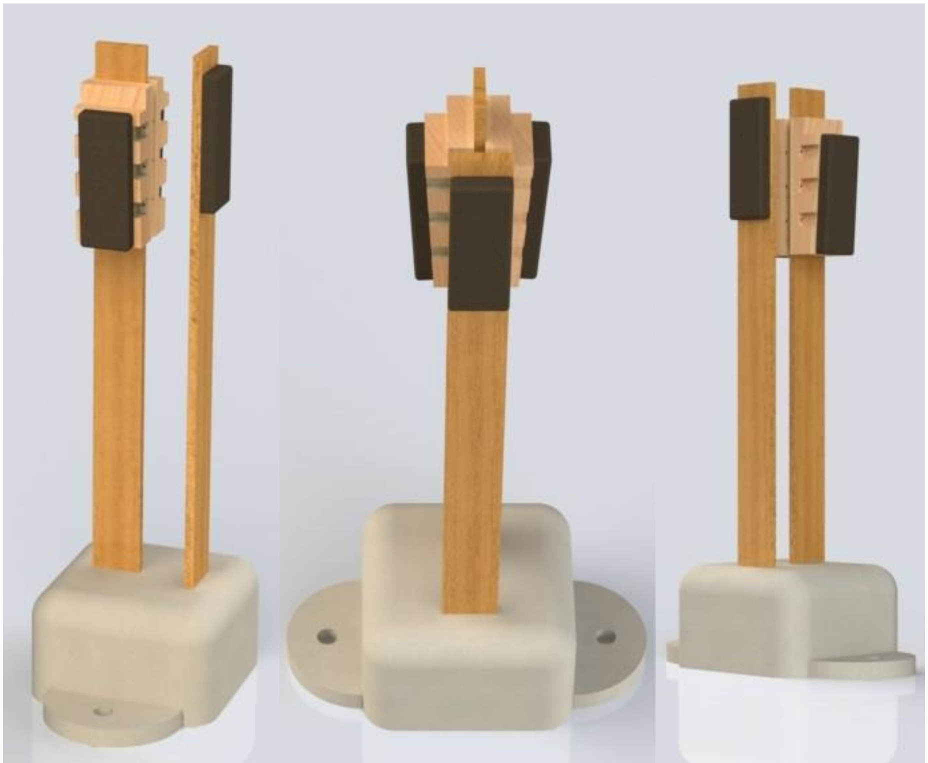


Figure 7: Final full assembly design

9 Structure Budget

This budget presents the costs of all the structural material used. The 3D printing material component is an estimate taking into account the material and the printing time. This was done because this material was available in my workshop.

Structure Budget:		
Component	**Amount**	**Price [€]**
Pine wood boards	4	29,98
Concrete 25kg bags	2	15,3
Padding material	1	12,98
Leather roll	1	13,32
3D printing	-	30
Total		101,58

Table 2: Structure budget

10 Structure Conclusions

The final result presented is a functional station that allows the user to train different striking techniques as a result of thorough designing. This structure design also takes into account the users safety preventing them from hitting any undesired areas or bolts.

One of the objectives was to present a product which could safely be used outdoors. The unique anchorage design along with the removable pads makes this product the perfect and ideal training station for exterior workout and a posterior easy process of packing away and storage.

As mentioned in the introduction, esthetics was also important in order to resemble traditional Okinawa equipment. The result is a wooden structure with a faithful resemblance to traditional *makiwaras* with some modern touches added, like the cases printed with the 3D printer.

Chapter II: Random Light and Sensor Device.

This chapter describes the program which will enable the different components in the structure to work as reflex training equipment, and the implementation of the circuit design which will consist of both sensors and actuators.

11 Previous Steps:

In order to program and implement, it was important to choose the right equipment. For the testing and programing, the electronic board that was used is an ARDUINO UNO and a sixty line Protoboard. There are two main controllers which were compared, the Raspberry Pi and Arduino. One of the main differences between them is that an Arduino is a microcontroller and Raspberry Pi is a functional computer. For the necessities of this project, Arduino seemed like the better option because of it being simpler, more economical, and complied with the specifications of the number of digital and analog pins. The large community created in Arduino with open source code which helped in the bettering of the final code was also an important reason for choosing Arduino UNO

Before getting into using more elaborate equipment like pressure sensors or specific illumination, a previous circuit was made using the Protoboard , the Arduino, Pushbuttons, LED's and resistors. This was some of the material which came in one of Arduino's starter packs.

11.1 First project code:

The first code written is a simple version of the final code. The objective of this code is to test the functionality of the random lights and implement the interaction between the different elements on the Protoboard and the Arduino processing board. In Figure 8 the schematics for this first version can be seen.

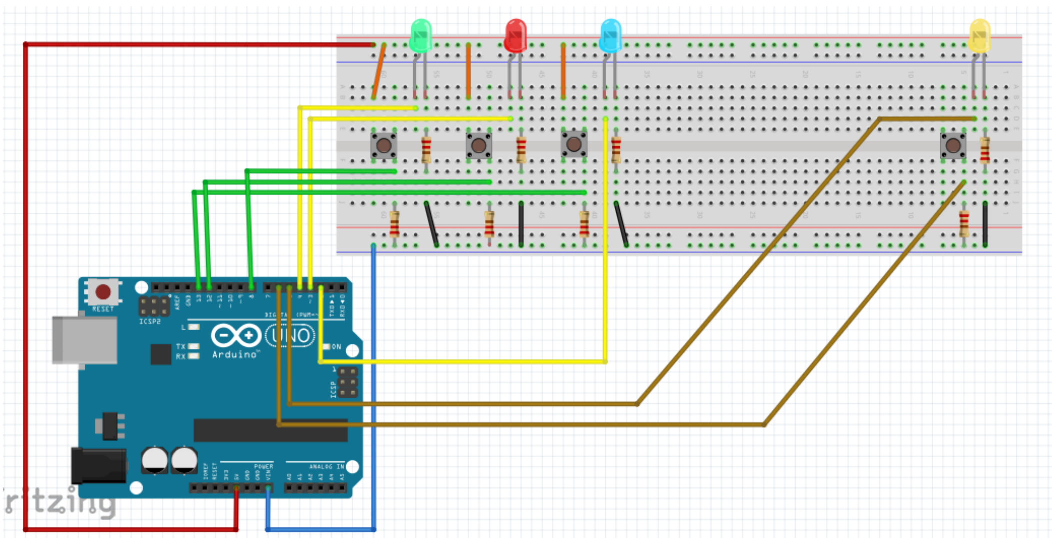


Figure 8: Schematics for simple version

This first simulation consists of 4 pushbuttons; the 3 pushbuttons located on the left side of the Protoboard represent the pressure sensors which will later be substituted. The right pushbutton represents the On/Off button. The resistors used are 220Ω and the lights used are simple 2 pin LED's. The final configuration will consist of 3 or 4 LED's to ensure the user a better visual experience.

Once the connections have been defined, the code can be found in Annex 1 with relevant comments for further understanding. The code can be separated into four different blocks in order to fully understand its performance:

11.1.1 Definition of Variables:

The first step is to define the different parameters which are going to be used to control and interact with the Arduino board. As can be seen in the code, this consists of the 4 LED's and 3 pushbuttons. The time parameter is defined by *inGame*, which tracks how long the program is running. A restriction which is necessary is how long the users have between the light signal turning on and hitting the force sensor. Two new parameters are defined with this objective; *timeOutHit* that will count how long it takes the user during this period of time and *timeHit,* a constant value which defines this time mentioned above. Finally two more variables are defined; *randomLed* and *numberHits* which, respectively, will store the random LED pin to turn on and how many hits are detected through the push buttons.

Once all the code was defined, due to the delays implemented in the code, a scale had to be established in order to relate the time defined in the code and the real time it took the Arduino board to process. After various trials it was determined that if the *inGame* parameter was limited to 10000 units, the running time was one minute. It was also determined that every ten hits, the running time added 5 seconds to the clock. With a medium value of 40 to 50 hits per game, this gave the user an estimated time of training of 90 seconds. This seemed a reasonable amount of time per game and is the reason for the 10000 units limiting the *inGame* parameter.

11.1.2 Void Setup

This subsection is dedicated simply to define which of the above parameters are going to be processed as inputs and which ones as outputs. In this case the LED's are defined as outputs and the push buttons as inputs.

11.1.3 Light Sequence

The light sequence is an important part in the code, as it will be responsible for randomly selecting a LED to turn on, and later detecting whether a pushbutton is hit. The process followed in order to think out this part of the code is the following; The Arduino board is constantly running, so once the light sequence is triggered one random light will turn on. Once this light is on, the user will have a defined amount of time to hit the designated zone before another randomly selected light is turned on. The next step is detecting what push button is hit and only changing to another light if the correct area is hit, this is to say the zone designated for that specific LED. If these conditions are met the variables used for counting how many hits and tacking track of the clock are modified and a new random LED is chosen to repeat the same light sequence.

11.1.4 Loop

As mentioned in the previous subsection, the Arduino board is constantly reading data, so, in order to start the light sequence the starting push button must be pressed. This is where the *inGame* variable is important as it will be responsible for the clock and ending the loop once the time is up. Due to this loop, it is possible to keep track of how many of these are done during the execution of the light sequence, thus being able to calculate the time we want to define to train. The times explained above take into account the 5ms, which is every how long the Arduino board is processing, and the delays in the code.

12 Implementation of the Force Sensitive Resistors (FSR)

Once the main code, introduced in the previous chapter, interacted accordingly with the users external inputs, the Force Sensitive Resistor's were incorporated in the place of the pushbuttons. FSR's were chosen for this project for two main reasons. First, these sensors are mostly used for detecting slight changes in pressure, but not necessarily with big precision. These sensors act like a variable resistor, varying from 1MΩ when no pressure is applied to practically 0 when maximum pressure is applied. The resistance change is inversely proportional to the applied force. This variation in the resistance implies a change in voltage which can be measured with the analog pins in the Arduino chip. These sensors are therefore not a great instrument of precision but are very useful for our project as it will be possible to detect this difference in potential and interpret this information with the Arduino as a hit to one of the different striking zones of the makiwara. Secondly and most important, these sensors can easily be found in the market in different shapes, force ranges and operating capabilities; they are very thin and flexible, making them ideal to incorporate in the striking zones without the risk of them breaking.

13 OrCad Simulations

Once all these elements have been defined, it is important for the project to validate and ensure all these electronic components will work accordingly and function in optimal conditions taking into account the Arduino will be powered with a 9V battery. The following table shows the specifications which have to be considered. This information has been obtained from the datasheets of the different components that can be found in Annex 2. Testing was done with a multimeter to obtain and ensure the FSR resistance values. The most critical conditions which have to be evaluated is whether the 5V,which is the maximum tension the Arduino board can deliver, can power the whole configuration and also see if the LEDs illuminate correctly or on the other hand receive too much intensity and burn out. Taking into account that there will be 4 or 5 LED's, depending on the simulation results, a buffer will have to be added to ensure these LED's receive enough intensity.

Component	Max Forward Current [mA]	Max Reverse Voltage [mA]	Peak Forward Current [mA]
Blue LED	20	5	75
Red LED	30	5	75
Green LED	20	5	75
Yellow LED	30	5	75

	Max Resistance	Min Resistance	-
FSR	1MΩ	0.1Ω	-

Table 3: Electronical component specifications

Visual inspection was also done during the first trials. This is why the green LED was not used due to dim light. Blue LEDs are the brightest and will be used in the light sequence. Even though red LEDs are not as bright and clear as blue, they were also put to test in order to have two different colors, if that were to be the final decision.

13.1 Schematics

With the help of OrCAD schematics a simplified circuit is sketched. The student license doesn't have the Arduino One schematic, so the following sketch was drawn in order to analyze the different intensities that ran through the circuit to ensure the components worked correctly. This specific sketch represents an instance in which no sensor is being pressed, being the FSR represented with a 1MΩ resistor.

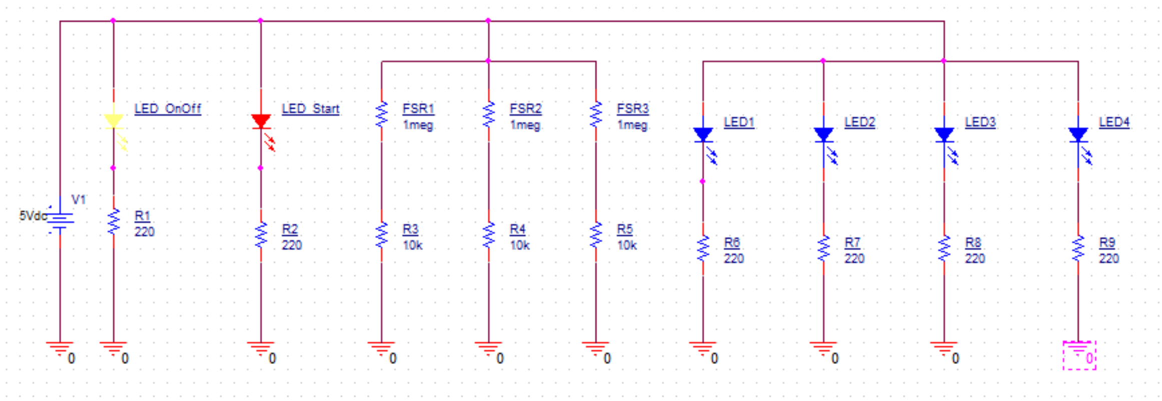


Figure 9: OrCad schematics for general configuration

As can be seen, from left to right, there is the 5V battery which powers the whole circuit. Then two LED's in series with a 220Ω resistance to avoid exceeding the 20mA limit. The three FSR, have a 10kΩ resistor in series. The goal of this is to ensure the intensity that runs through the LED's does not suffer any sudden peak values and that it's sufficient to light these up. This is the reason a 10kΩ resistor is incorporated, which is significantly higher than the 220Ω, in series with the FSR to ensure minimum intensity runs through them even when their variable resistance is near 0 Ω. The simulations that will later be mentioned will take into account various situations. Finally on the right side are the 4 LED's which turn on when the Arduino selects the random output.

13.2 Simulations

The following simulations intend to make sure the configuration which has been proposed is possible with these components, given different circumstances provided by the users. These results will later be compared to the readings obtained from the multimeter on the protoboard and will be discussed in the following conclusions.

1. First configuration: Represents the initial configuration when the user has to hit the pushbutton to start with the light sequence.

Component	**LED ONOFF**	**LED START**	**FSR1**	**FSR2**	**FSR3**	**LED1**	**LED2**	**LED3**	**LED4**
Configuration	ON	ON	1MΩ	1MΩ	1MΩ	OFF	OFF	OFF	OFF

Table 4: Configuration 1 for OrCad simulation

The schematic and the graphical results to this configuration can be found in Annex 3.

2. Second configuration: Represents the instance between the user seeing the light turn on and hitting one of the sensors, meaning one group of LEDs are turned on and the linked FSR is still at 1MΩ.

Component	**LED ONOFF**	**LED START**	**FSR1**	**FSR2**	**FSR3**	**LED1**	**LED2**	**LED3**	**LED4**
Configuration	ON	ON	1M Ω	1MΩ	1MΩ	ON	ON	ON	ON

Table 5: Configuration 2 for OrCad simulation

The schematic and the graphical results to this configuration can be found in Annex 3.

3. Third configuration 3: Represents another simulation where a fifth LED was introduced into the system. This was done to see how much it changed the visual effect and how it affected the rest of components.

Component	**LED ONOFF**	**LED START**	**FSR1**	**FSR2**	**FSR3**	**LED1**	**LED2**	**LED3**	**LED4**	**LED5**
Configuration	ON	ON	1MΩ	1MΩ	1MΩ	ON	ON	ON	ON	ON

Table 6: Configuration 3 for OrCad simulation

The schematic and the graphical results to this configuration can be found in Annex 3.

It is also important to have an estimate regarding the durability of the battery. In order to have a wider variety of options, calculations were done for the use of a portable rechargeable battery, specifically a 5V and 26800mAh battery, and a standard 9V and 580mAh battery. The following considerations were taken into account when doing the calculations.

The consumption of the LEDs is considered to be of 13,8mA which is what the OrCAD simulations presented. Also taken into account was the number of LEDs that were simultaneously on, in this case 6LEDs, 4 representing the striking zones and the other 2 the on/off LED and the start LED. The following times were determined for the different batteries mentioned:

$t_{9V} = \frac{580mAh*9V}{5V*13,8mA*6} = 12,17h$ $\quad\quad$ $t_{5V} = \frac{26800mAh*5V}{5V*13,8mA*6} = 323,67h$

14 Simulation Conclusions

The following tables sum up the OrCAD simulations compared to the experimental results in order to properly discuss the results.

Forward Current[mA]				
Configuration 1	LED OnOff(Red)	LED Start(Green)	LED Red	LED Blue
OrCAD Results	13,8	13,8	13,8	13,8
Multimeter results	13,62	13,5	/	/
Configuration 2	LED OnOff(Red)	LED Start(Green)	LED Red	LED Blue
OrCAD Results	13,8	13,8	13,8	13,8
Multimeter results	13,62	13,5	13,57	13,58
Configuration 3	LED OnOff(Red)	LED Start(Green)	LED Red	LED Blue
OrCAD Results	13,8	13,8	13,8	13,8
Multimeter results	13,62	13,53	13,62	13,58

Table 7: Forward current comparison

Forward Voltage[V]				
Configuration 1	LED OnOff(Red)	LED Start(Green)	LED Red	LED Blue
OrCAD Results	1,96	1,96	1,96	1,96
Multimeter results	1,97	1,57	/	/
Configuration 2	LED OnOff(Red)	LED Start(Green)	LED Red	LED Blue
OrCAD Results	1,96	1,96	1,96	1,96
Multimeter results	1,96	2,07	1,88	2,47
Configuration 3	LED OnOff(Red)	LED Start(Green)	LED Red	LED Blue
OrCAD Results	1,96	1,96	1,96	1,96
Multimeter results	1,96	2,07	1,88	2,47

Table 8: Forward voltage comparison

As can be seen from these results, the experimental values obtained and the different simulations that have been run display similar results.

One of the objectives of these simulations was to establish whether it was necessary to incorporate a buffer, like a ULN2003A, which could amplify our current up to 500 mA. After visual inspection and measurements were done, it was decided it was not necessary as the LEDs light up perfectly and the current going through them was sufficient and in accordance with the parameters from the datasheets.

The specifications from the datasheets for the forward current and forward voltage are also accomplished and therefore it is safe to say that these configurations defined work in optimal conditions.

Regarding the batteries, it is clear that the rechargeable battery allows a longer autonomy, but at the same time these batteries are much bigger, more expensive and occupy more space. The 9V standard battery has an autonomy of around 12h which is sufficient to carry out 12 training sessions of 1h each. This is the reason it is up to the user to decide how to feed the Arduino UNO, either through the USB connector the Arduino already has installed or through the V_{in} pin on the board.

15 Final Configuration and Code

After all the different simulations and testing, the final code, which can be found in Annex 4, was defined. The final configuration can be seen in Figure 10. The decision was taken to use 4 LEDs as it didn't make a big visual difference to have 5 LEDs and on the other hand would affect the battery life.

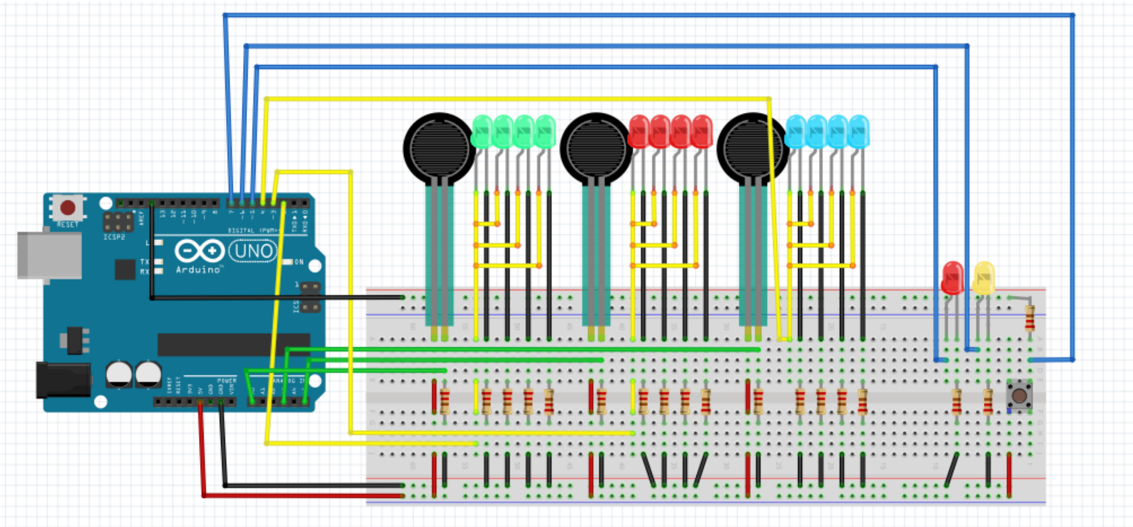


Figure 10: Final configuration setup on protoboard

For the construction of the prototype, a PCB board was assembled. Due to the high price of producing a PCB on demand, a prototype plate was used to reproduce this final configuration. These types of PCB plates are very convenient to solder the different components because the holes where the components are inserted are pre-tinned in order to solder easily, making it ideal to build the prototype.

The following table aims to be a summary of the different components used in the assembly of the electronic device.

Component	Amount	Type
Arduino UNO	1	-
Protoboard	1	60 lines
FSR	3	FSR 402 13mm Circle x 56mm
Resistance	12	220Ω
Resistance	3	1kΩ
LED	12	Blue
LED	1	Green
LED	1	Red
Double Sided PCB board	1	Elegoo

Table 9: Electronical components

16 Electronics Budget

This budget took into account all the material used during the process of elaborating both the first project code and the final project code taking considering all the electronic components.

Electronics budget:		
Component	**Amount**	**Price [€]**
Arduino UNO Starter Pack(Resistances, LEDs, Pushbuttons, wire, Arduino UNO)	1	79,9
Force Sensitive Resistors	3	19,65
Switch	1	1,84
Shipping Charges	/	18
PCB boards	10	19,99
Total		139,38

Table 10: Electronic budget

17 Environmental Impact

This project has elements which have an impact on the environment and as with all engineering projects these need to be analyzed.

Using wood was a way of conserving the traditional way a makiwara was built, but also an alternative to using plastic or other polymeric materials. The use of pine wood requires the cutting of trees and therefore has an impact on the environment. This being said, with the correct treatment, these boards will last for generations. The ease with which this structure can be dismantled promotes the recycling of its components, again reducing the environmental impact.

The 3D printing process and the subsequent PLA plastic design for the case are the components of this project which have the largest environmental impact. PLA is a growing problem due to the difficulty of recycling this polymer through conventional recycling plants where it can contaminate other polymers such as PET of which most plastic bottles are made. Nowadays, there are several more sustainable options in the market using recycled PLA. This material was not used in the construction of this specific prototype but should be an important consideration when this product is introduced into the market and produced at a larger scale.

Batteries are a well-known environmental contaminant and that is why rechargeable batteries were used during the process of assembly. The environmental impact of battery production cannot be avoided, but an alternative option to explore would be to integrate a small photovoltaic plate in the makiwara to charge the batteries, thus reducing the environmental impact generated by recharging off the grid.

18 Overall Conclusions

The overall result of this project has numerous positive aspects. I have been able to put into practice knowledge obtained from different engineering views, from structural designing to implementation of electronic equipment. The objectives related to the structure and the electronics were properly met and successfully assembled into one final functioning product.

This first prototype is a good starting point for a final product which could, with proper financing and further development, end up being equipment used in martial arts schools. This further development should be focused on cheapening the cost of construction and finding better and more powerful ways of illuminating the different striking zones. Another aspect which would better this project would be to incorporate a LCD (Liquid Crystal Display) in order to give the user some feedback. The reason this wasn't done in this project was the lack of digital inputs available.

The versatility of the code is another strong aspect of this project. This code can be easily modified or amplified in order to offer different training modes that would focus on strengthening different aspects of the athlete's technique.

As mentioned at the beginning of this project, the aim was to encourage young athletes to practice with this important traditional karate training device and continue with the martial arts legacy. This structure, is an example of an ancient tool transformed into a modern one which will be more appealing for the younger generations

This project is a turning point in my career as it requires the application of a wide range of the skills one acquires in the process of becoming an engineer. It also shows how important it is to incorporate knowledge from other areas of learning, such as karate, into product design.

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