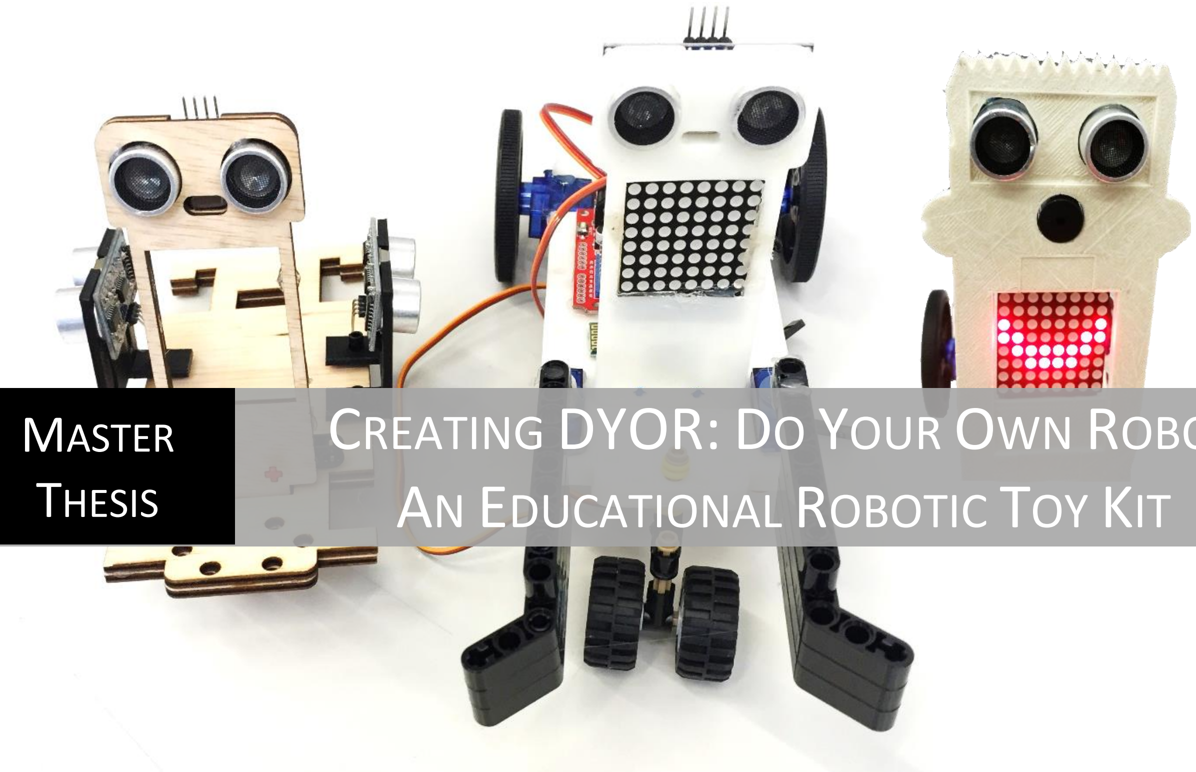
MASTER THESIS

CREATING DYOR: DO YOUR OWN ROBOT
AN EDUCATIONAL ROBOTIC TOY KIT



Escuela Técnica Superior de Ingeniería del Diseño

Presented by | Harshika Singh

Escuela Técnica Superior de Ingeniería del Diseño

Creating DYOR: Do Your Own Robot
An Educational Robotic Toy Kit

A Thesis Presented

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Date, Dean of the Graduate School

The undersigned have examined the thesis entitled '**Creating DYOR: Do Your Own Robot- An Educational Robotic Toy Kit**' presented by **HARSHIKA SINGH**, a candidate for the degree of **Master's in Design Engineering** and hereby certify that it is worthy of acceptance.

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ABSTRACT

Experimental verification on the educational value of robotics as an educational device in the elementary, middle and high schools gave rise to the upcoming research perspectives regarding educational robotics. Another fact revealed during the analysis of the survey conducted among the school students and teachers was the absence of the low cost robots in education (90% of studies use Lego). The study aims at developing an alternative robotic kit "DYOR: Do Your Own Robot", as the name indicates is an Educational Robotic Toy Kit especially for high school students which comes with the complete package. The kit not only includes basic robot building electronics and frames but also guidelines, materials, moulds etc. to build your own robot from the scratch. The paper describes the various processes involved in creating DYOR which could contribute to the formation of learner's independence, developing their leadership skills, promotes a positive educational process. This project presents DYOR: an educational robotic toy kit how it helps the school students to get better understanding of the aspects of engineering before they get ready to choose their career. It provides an ideal platform enabling school students understand various elements like science, manufacturing technology, mathematics, design and apply their knowledge in these areas effectively with additional inputs like programming, logical analysis to create solutions for the given task. This paper also describes the various designing steps and manufacturing process involved in creating DYOR.

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“Health is the greatest gift; Contentment is the greatest wealth; A trusted friend is the best relative; Liberated mind is the greatest bliss” – Buddha

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CHAPTER 1

Introduction

Nowadays, a need to improve the educational process and the modernization of existing syllabi is essential for scientific creativity of the students. Because of the current trends that demand highly trained professionals that are capable of implementing latest achievements of science and technology in industry. Therefore, mass attraction of the young generation to the engineering and design professions is necessary. A lot of high schools in many different countries have introduced subjects like robotics in their curriculum. This not only helps the students to develop interests towards engineering and design but this younger generation to enhance their analytical thinking and technical creativity. They develop a better quest of achieving their goals and an ability to take up challenges in the competition.

Considering all these factors and the educational effectiveness of robotics as an educational tool in schools, MAS CAMARENA a centre for education in Valencia- Spain introduced it in their curriculum. The school is well known in Valencia for its innovative and new teaching methodologies, like recently this school introduced scuba diving in their sports curriculum. The school was using the LEGO Mindstorms NXT robots as a training platform for their high school students. The students participated in various robotic competitions like robot soccer and line following. The school wanted an alternative educational robotic kit and it was in August, 2015 when they came to Dr Leopoldo Armesto, a professor at Universitat Politecnica de Valencia. This came as an opportunity to create DYOR: Do Your Own Robot, an educational robotic toy kit where these kids can create their own robots from the scratch.

The kit contains all the tools necessary to build a simple robot. It also contains instructions for building the standard simple robot. The DYOR kit comes with the electronic components, Lego pieces (as parts are compatible with the standard technic Lego pieces) and the manufacturing guide. The manufacturing guide explains each method (3D printing, Laser Cut or moulded) with their respective designs. The project also explains the methodology for developing each design and its fabrication method. As the school also showed interest in introducing simple 3D modelling to their high school students, the designs were simplified. There were 100-150 school students plus 50 university undergraduates of UPV, thus an efficient production method is important. DYOR was developed mainly for these reasons: price, ease of use, different programming options, and the variety of sensors that came with the basic kit.

1.1 Problem Statement

There are many robotic kits available in the market on the basis of the educational courses. Festo Didactic, Lego Mindstorms, Bioloid, Mechatronics Control Kit Parallax and etc. About 90% of the schools use Lego Mindstorms. The major issues currently faced by Mas Camarena were:

- High cost of the existing robotic kits makes it inconvenient for the school as a large number of students are showing interest in the course (150 to 200 students). The cost of one Lego Mindstorms kit cost $320-$350.
- LEGO Mindstorms NXT robots not that easy to configure and use.
- Also being multipurpose and motivational for the students, is difficult to achieve in on single device.
- The commercial kits are limited to specific approaches.
- Limited sensors and movements.
- The programming language is an issue.

1.2 Objective of the work

LEGO has attracted many people, as a toy, as a hobby, even as an educational tool for all generations all over the world. However, the design and construction of large scale LEGO models is not easy for beginners. The main objective of the work was to develop a complete educative robotic toy kit, which not only provides basic robotic knowledge but also design and construction of its parts. Children might want to print out construction kit pieces and use in conjunction with existing commercial construction kits or with the help of teachers/parents they could enjoy moulding or their cutting their pieces. Simple design, trouble free fabrication and materials were kept in mind. The work aimed to make learning fun and interesting for children. This project work also provides training sessions to create DYOR to the high school students, university undergrads and teachers.

1.3 Flow of work

The approach adopted to accomplish the present work is described below:

- The work starts with identifying the problem faced by the school and their additional needs by conducting a survey.
- Background study, market and on desk research followed by analysis of the results obtained and identifying their demands.
- The next few chapters are devoted to design phases which include concept development and system level design.
- Detail design for different manufacturing technique, prototyping and various manufacturing methods like 3D printing, laser cutting and moulding are explained in the next few chapters.

- Testing and redesign followed by steady state manufacturing technique and approval.
- Fitting of electronic components and Arduino programming comes next.
- Novel design is created taking into account the various best features and attributes that are obtained, keeping in mind the skills, knowledge and facilities available at the school. In the last chapter results and benefits of having this new educational kit are discussed along with conclusion and the summary of the entire project.

1.3.1 Work Breakdown Structure

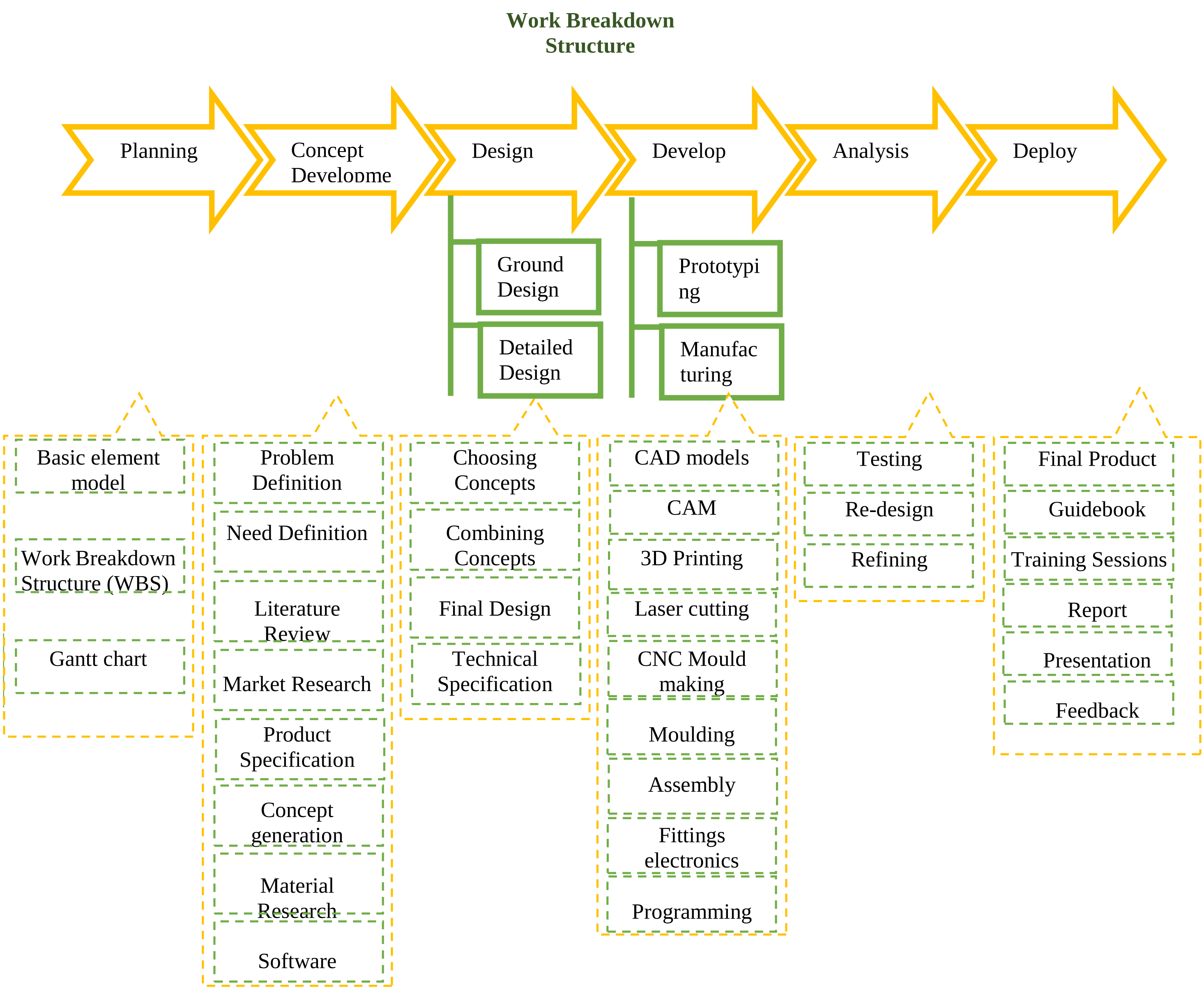


Figure 1 Work Breakdown Structure (WBS)

1.3.2 Basic Element Model

The basic element model was used to make a structured approach for the different parts of the project. The project was divided into task, interested parties, environment and resources. Bellow follows a short description of each part and it can also be seen in **Figure 2.**

Task: The task of the project is to design a product that can be used to build robots in an educational and/or entertaining purpose.

Interested parties: Interested parties were divided into positive interested parties and negative interested parties. The positive interested parties found were people interested in electronics, educational institutions, NGO or low budget associations. The negative interested parties that were found were profit companies with similar products.

Resources: There are many resources in the project which can be used. The main resources are the knowledge of the members of the team, already existing projects, access to 3D-printers, laser cutters, CNC, and other resources from the University Polytechnic of Valencia, ability to conduct surveys and possibilities to contact schools. The resources also include access to Arduino and sensors as well.

Environment: The project is carried out in a non-profit and open source environment

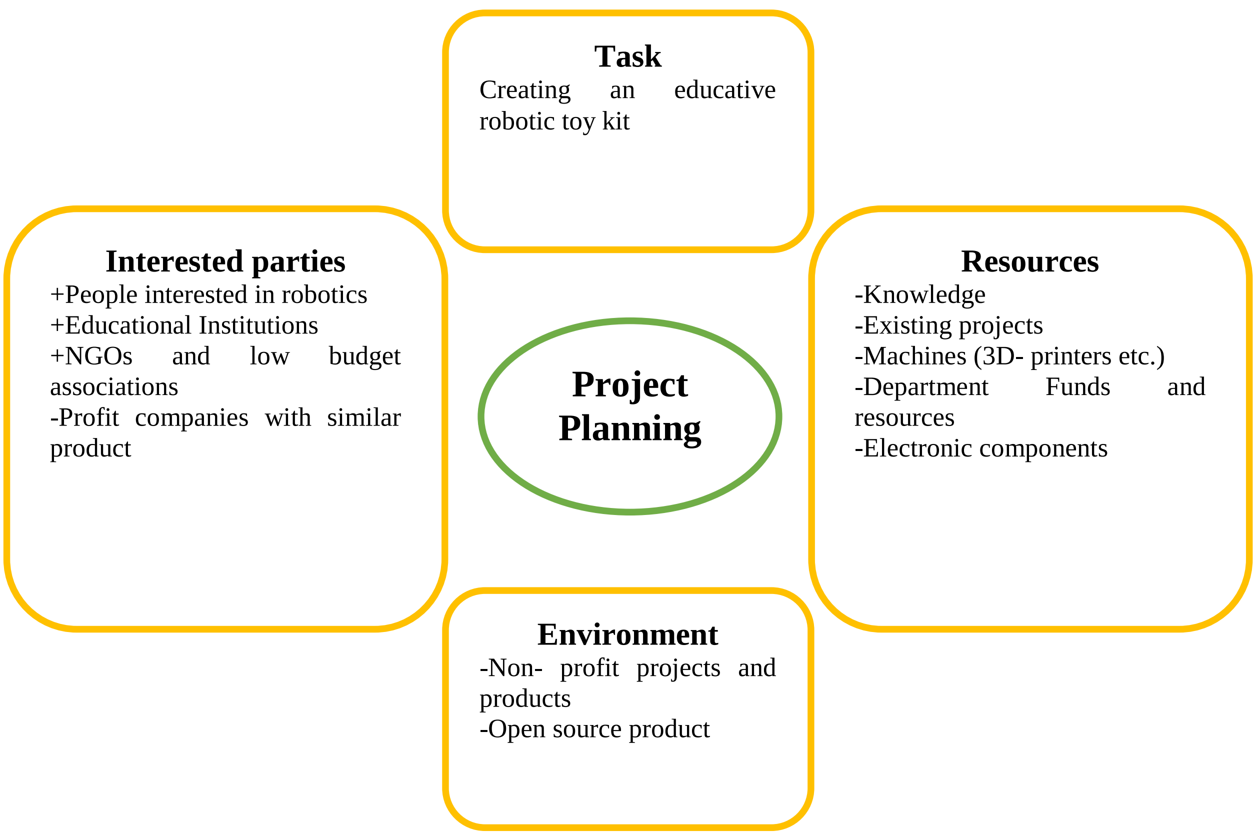


Figure 2 Basic Element Model

1.3.3 Gantt chart

The Gantt chart shows the main activities, subtasks, and the time they should be carried out. The Gantt chart was used as a guideline and it shows which activities have to be finished before the next one starts. However, many of the tasks were carried out simultaneously and unexpected happenings such as delivery times and complications made some of the activities slower/faster than expected. But the deadlines were still fixed and the expected results were delivered on time. In order to finish in time Gantt chart was made and is shown in Appendix A.

CHAPTER 2

Background

The gap in the market for a cheap product with LEGO compatible modules and already existing kits was wide enough to place DYOR. Creating DYOR was a continuation of the previous similar project called LEDURA (Lego educational Arduino robot) which aimed to integrate Lego with Arduino thus creating a product which had a lot of potential. DYOR was later created when the school wanted to implement LEDURA in their curriculum from September 2016. They also wanted their students to learn simple 3D modelling (creating shapes like cube, holes etc.) and build it from the very scratch. Thus, various factors needed to be modified as they wanted this kit for around 100 children. Now production and the design became very crucial and hence Creating DYOR!

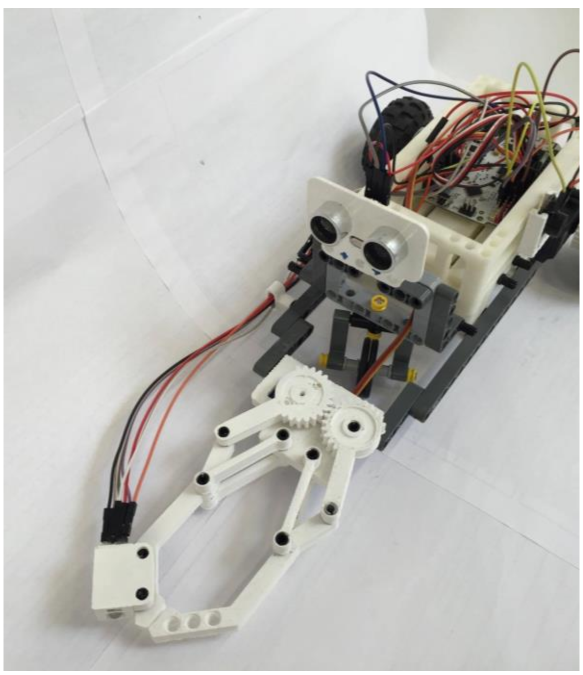


Figure 3 LEDURA without cover and with all its components

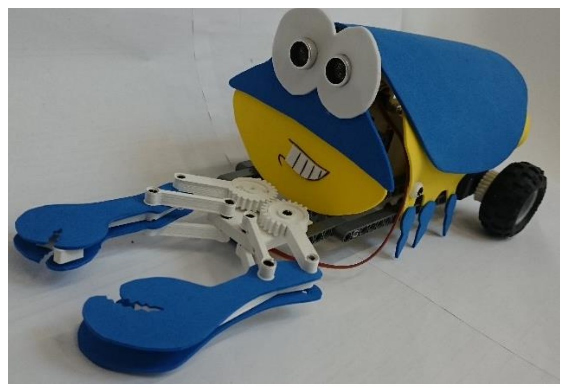


Figure 4 Crab shaped cover

Figure 5 Lion shaped cover

The main characteristics in LEDURA which were changed in DYOR were:

- The open box main case was changed to 2.5 D shaped.
- Instead of separate case for each sensor, design with sockets for fitting sensors into it was chosen.
- Foam paper cover was replaced by a firm "face".
- Eliminating complex design and programming, simple design of two components.
- Other manufacturing methods were taken into account as they would be more economic.

2.1 Literature Review

Improving the educational process and the modernization of existing curricula is necessary to create conditions for scientific creativity of students (Bazyleva, Marguna, Zimenkoa, & Kremleva, 2014). These trends pose high requirements to level of training of professionals that have to be capable to implement the latest achievements of science and technology in industry. Therefore, mass attraction of the young generation to the engineering and design professions is necessary. Studies show that engaging children in construction-based robotics activities (children as young as four can play to learn a range of concepts) and demonstrates that kindergartners were both interested in and able to learn many aspects of robotics, programming, and computational thinking (Bers, Flannery, Kazakoff, & Sullivan, 2014) (Ospennikova , Ershov, & Iljin, 2015). The article (Benitti, 2012) reviewed suggest that educational robotics usually acts as an element that enhances learning, identifying the potential contribution of robotics as an educational tool, in the context of elementary, middle and high schools, summarizing relevant empirical findings and indicating future research perspective. Also (Karp, et al., 2010) writes in their paper, the key success factors for the implementation and development of a LEGO robotics as a program for elementary school students in West Texas

Significant efforts have been made in the past by researchers to provide the product designers with effective guidelines towards providing an efficient toy kit. LEGO has attracted many people, as a toy, as a hobby, even as an educational tool for all generations all over the world like (Kozaki, Tedenuma, & Maekawa, 2016) where even beginners were able to build realistic complex LEGO models as they introduced a system to reconstruct large scale LEGO models from multiple two dimensional images of objects taken from different views. Lego and technic Lego have drawn attention of researchers as much as they attract kids. The work done by (Cruz-Martín, et al., 2012) deals with the already existing alternative of using the LEGO Mindstorms NXT robots as a training platform. The article by (Fiorini & Paolo, 2005) describes how LEGO kits can be used to successfully teach robotic design and kinematic analysis and the article provides the results of the innovative use of the LEGO kits in robotics.

Computer assisted LEGO construction was also used in our project to generate clear instructions. The efficacy of LEGO bricks has attracted engineers to develop tools for virtually assembling LEGO bricks using a computer (Luo, et al.), such as LDraw (Jessiman, 1995) and its variants (Clague, Agullo, & Hassing, 2002), the LEGO digital designer (The Lego Group, 2016), and a web-based LEGO design service (The Lego Group, 2016).

Fabrication for children as described in the article by (Eisenberg, 2013) , creating tools that enable children to build their own scientific instruments, kinetic artwork, model railroad settings, doll furniture, tops, and many other objects. The generation and rationalization of 3D models for fabrication has recently become a topic of great interest in the computer graphics community. Design for additive manufacturing (DfAM) is an emerging field in engineering design and one of its benefits include unlimited geometric (Gao, et al., 2015). However, most fabrication methods still require the user to have expensive equipment such as laser cutters or 3D printers. The paper by (Berman, Zarb, & Frank, 2012) examines the characteristics and applications of 3-D printing and compares it with mass customization and other manufacturing processes. Since 3-D printing does not require expensive tooling, forms, or punches, it is particularly cost effective for very small production runs. The generic cost model presented (Alexander, Allen, & Dutta, 1998) (Baumers , Dickens, Tuck, & Hague, 2016)shows how the cost of additive manufactured product is calculated and affected. Whereas plastic moulding used for toys and domestic products provides efficient and economical way for medium scale production as plastic parts of different shapes and sizes of the same plastic material can be produced in “one product mould” (Chan Ivan, Pinfold, Kwong, & Szeto, 2014). Building arbitrary 3D models out of LEGO manually often involves significant trial-and-error as stated by (Testuz , Schwartzburg, & Pauly, 2013). Moulding concepts were also generated, the models made by rapid prototyping were later used in casting processes as in (Sirinterlikei & Mativo, 2005).

Robot toys are an ideal platform to investigate the potential and limitations of human–robot social interactions like Robota (Billard, 2003). In the paper presented by (Balaji, Balaji, Chandrasekaran, Ahamed khan, & Elamvazuthi, 2015), describes Indian robotic trainer FASTBot (FASTBot , n.d.)as the tool to create awareness on engineering in the minds of school students before they get ready to choose their career and an ideal platform for enabling school students to understand various elements like science, technology, mathematics and apply their knowledge in these areas effectively with additional inputs like programming, logical analysis to create solutions for the given task. In the research done on socially interactive robots by (Fong, Nourbakhsh, & Dautenhahn, 2003), it was seen that educational robots also acts as tools and therapeutic aids.

2.2 Qualitative Research

2.2.1 Market

There is not a robotic product on the market that easily combines Technic LEGO and a control centre except LEGO Mindstorms EV3. This product has been on the market for a long time and have had the biggest market share and therefore they can choose the benchmark price on the market. The problem faced by those using LEGO Mindstorms EV3 was its cost and had some limited functions. Schools who want to offer robotics in their curriculum do not have a good alternative.

The research part was carried out to get more information about the products that are already in market and the costumer's requirement. By doing a market research information and knowledge about the market was gathered, which helped in taking better decisions. Both desk research and field research were used. The project was to make a modular robot kit that is controlled by Arduino that could be used for educational purposes and it was important to know how well it fits into the market. The project covered, robotic market and a segment that should be for hobby usage and/or educational purposes.

The aim of this market research was to explore the existing market and the competitors that were providing robotics for home usage or for educational purposes. There was an expected gap between simple but limited robots and more advanced robots. The gaps could be filled with an innovative product that was designed during this project. The goal was to compare prices of the existing products in the market and see if DYOR would be an inexpensive alternative for people interested in robotics kits. The products that were compared were modular, programmable and easy to use. It was kept in mind that DYOR should be compatible with LEGO bricks and Technic LEGO.

Exploration of the market, customers and competitors:

The consumer robotics market has achieved significant recognition in the past few years as the popularity of robotic automation has grown. The consumer robots are usually made to mimic human tasks like cleaning and talking. The key components that are used in consumer robotics include processors, software, microcontrollers, sensors, actuators, cameras, displays, manipulators, power supplies, communication technologies, mobile platforms and legs among others.

The market for robotics is growing rapidly and new market segments are created all the time, so to find the segment that best suits the project. The latest market reports available have to be read to determine the segment. In the robotics market segments differ in multiple ways but according to Robotics Tomorrow the market can be segmented based on end-use, components and industry verticals number of different ways. Based on industry verticals, the consumer robotics segments are telepresence robots, educational robotics kits, UAVs, healthcare robotics and industrial robotics.

The one that best suited the project was the educational robotics kit segment. After finding the correct segment, information about the consumers and competitors were gathered and analysed.
The consumers that the project focused, were schools that would use it in the education of programming, electronics, designing, fabrication and robotics. The product could be used at home for people who have robotics as a hobby, this would be an attractive alternative to the existing robotic kits. This robot kit would be very versatile with different components and build options. This makes it easy and relatively cheap for customers to expand their designs and be creative. When objectives for the market research has been established, questions can be made that has to be answered with the research. These questions have to be asked so relevant information about the market, customers and competitors are gathered. The questions should be made with the objectives in mind.
The market

- What kind of segments are there on the market?
- Is there a gap in the market?
- How will our entrance affect the market/customers?
- What are the market trends?

The customers

- Who are the target customers and what do they want?
- Where are they located?
- What is the profile of an ideal customer for the product?

The competitors

- What is the profile of a typical competitor for our business?
- What are the competitors' main strengths?
- What are the competitors' main weaknesses?

2.2.2 Users

To find the consumer needs survey was conducted. During this survey the target group was divided into students, teachers and engineers. The questions were made so that strengths and weaknesses of the LEGO Mindstorms EV3 could be found.
Survey questionnaire were sent to the school Mas Camarena and some university undergraduate students of UPV, the responses of the survey are presented below. The survey was given to the teachers **Table 1** who are going to teaching robotics. The other data from the questionnaires is attached in Appendix B

Summary of the answers from questionnaire – teachers

1	**What is the strengths of LEGO Mindstorms as an educational tool?**	
		Lego is useful as an introduction to robotics and/or programming
		It is a very attractive resource for students of any age and for programming it is pretty intuitive
		The children like it a lot, and they have already played with it since they were younger. And the program for programming is very intuitive and easy.
		Plain and simple. You can feel the students' attraction for LEGO.
2	**Are there problems with LEGO Mindstorms?**	
	Yes	First of all, it is too expensive. For the second the NXT programming tool isn't that accurate
	No	It is usable for advanced levels of robotics and/or programming
	Yes	It is very expensive and there is no flexibility with other components.
	Yes	The programming is very limited and sometimes there are programming "block" that doesn't function correctly. Also it is an expensive tool for the classroom.
3	**If you have used Arduino, what did you think about it?**	
		Very useful and economical
		I have not used it yet but it is an alternative for students with less resources
4	**If you have used both LEGO Mindstorms and Arduino, which is the better system and why?**	

		I can't have an opinion; it is my first year of using Ardublock
		We are I the beginning of Ardublock
		The LEGO blocks are very visual and is it easy for younger to understand. With Ardublock you learn more about the concept of programming and it's useful for older students
		Both are useful
5	**Which functions do you miss in LEGO Mindstorms?**	
		To have components that is not so expensive that students can work them individually, it is impossible today with LEGO, that already is too expensive
		To integrate more components with electronics
		To have an open source system that you easily can improve
		Power programs with less limits and more sensors than those only sold by LEGO.

Table 1 Response from the teachers

This questionnaire was sent out to the students of the Mas Camarena School as during the interview of the teachers from the school they suggested that they wanted the students to give their opinion on the matter **Table 2**. The other data collected from questionnaire is in Appendix B.

Summary of the answers from questionnaire – students

1	**Write the things you think are missing from the LEGO Mindstorms**	
		More precision of movement, that and the wheels.
		The ability to make a radio command. Pistons (although you can do with a gear system). Lasers, all improve with lasers, and are able to burn things better.
		More utility
		Some more features

2	**Write the good things about LEGO Mindstorms**	
		Ability to work in teams
		There are many but the main one is that it encourages creativity and learning programming, which probably will need in the future.
		I don't know...
		It is pretty creative
3	**What would like the robot to be able to do?**	
		The chores. To sing. Have a conversation. Teach. Create any and anytime
		My duties My bed Play to Play (like Nintendo ROB but better) Construct me a light saber Build Other robots Follow The three laws of robotics Asimov
		Planning to tell me when I say it
		More control for me and more advanced, like having information and thoughts
		You can take pictures when you order it while the music plays you in the mobile robot.
		The chores
		to identify people

Table 2 Response from the high school students

The last questionnaire was sent out to engineers. The opinion of the more experienced people who want/currently use robot and their opinion about the LEGO Mindstorm were taken into account. The questionnaire for had different questions as seen below in charts.

Summary of the answers from questionnaire – engineers

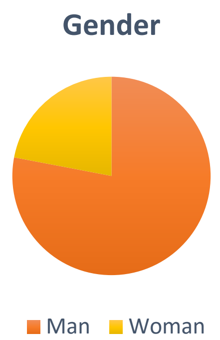


Figure 6 Gender: Engineering students

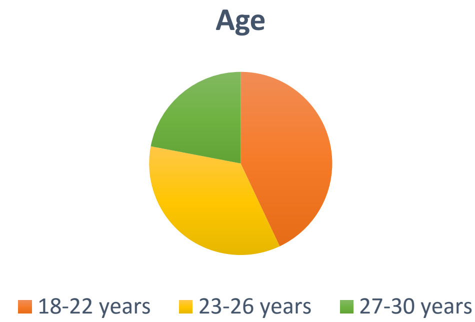


Figure 7 Age: engineering students

Figure 8 Used Lego Mindstorm?

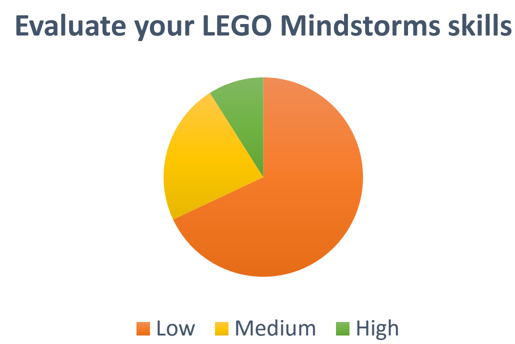


Figure 9 Evaluate Lego mindstorm skills

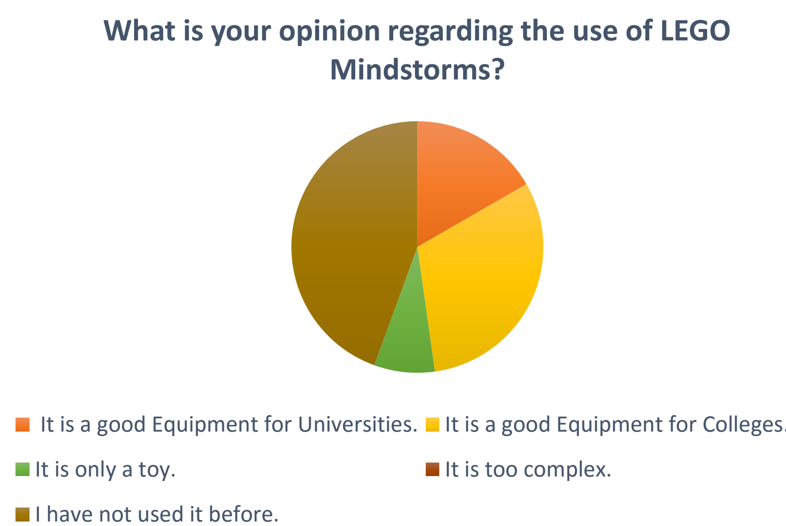


Figure 10 Opinion about Lego mindstorm

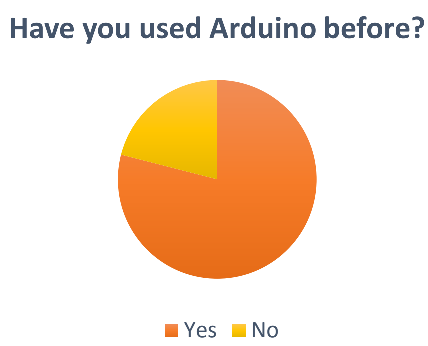


Figure 11 Used Arduino before?

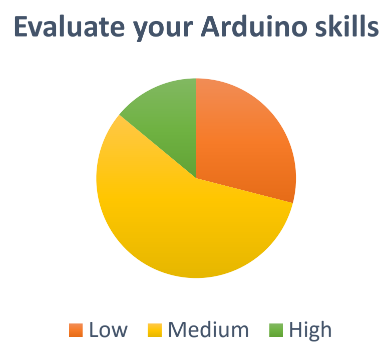


Figure 12 Arduino skills

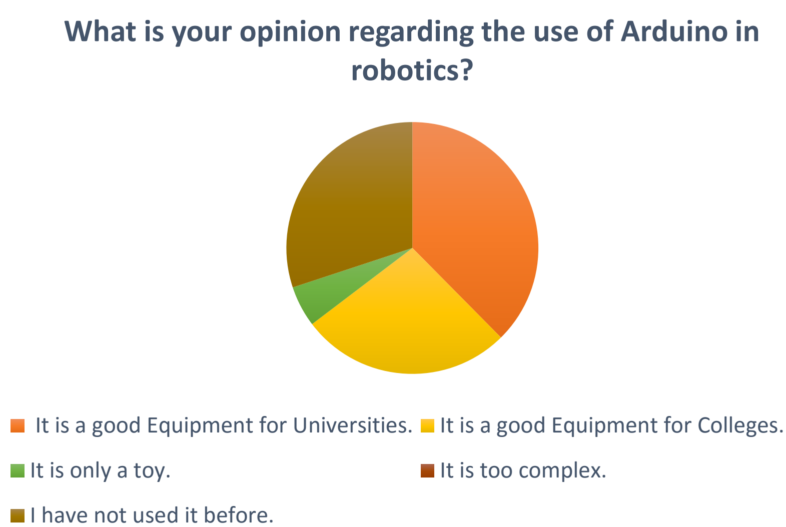
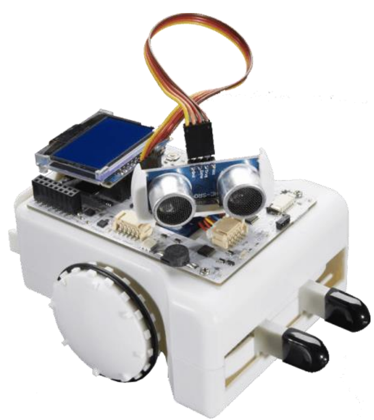


Figure 13 Opinion of Arduino in robotics

2.2.3 Competitors

Information was gathered about the different companies and the products they manufacture. At the end of the thesis a comparison of their products and this product shown. A comparison table showing price, number of sensors included in the kits and what type of software and hardware they use are given in **Table 3** and **Table 4**.

	The Lego Group was founded in 1932 in Billund, Denmark by Ole Kirk Christiansen. The latest version is the Lego Mindstorms EV3. Created by the LEGO Company it is a versatile building system that uses the EV3 P-brick as its control centre and power station. LEGO offers educational tools for students ranging from preschool to middle school. (The Lego Group, 2016)
	Modular Robotics is a small start-up company from USA that makes a different kind of educational robotic kit. Modular robotics uses a different kind of modules for the robot that are connected by magnets. Modular Robotics aims to be a provider of educational tools to elementary school and secondary school. (Modular Robotics Moss, n.d.)
	Arcbotics is a small start-up company from USA that is creating affordable, open-source, programming and electronics. and has since then released 2 educational robot kits, Sparki and Hexy the Hexapod . The robots use Arduino as their control center. Sparki, is aimed for educational purposes in late elementary school. It has a lot of features and is relatively low priced. (Arcbotics:products:sparki, n.d.)
	Makeblock have a robot kit called mBot that consists of aluminum beams, mechanical components, electronic modules, and features an Arduino-compatible controller and standard sensors. Mbot is an educational robot for kids, which offers a Scratch-like programming environment to control an Arduino-compatible robot. (Makeblock mBot, n.d.)

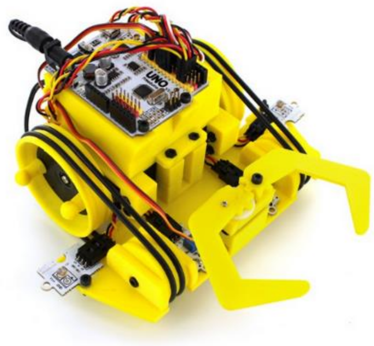
	Barcelona based company called BQ that manufactures BQ Printbot. For programming the BQ Printbot a block program have been developed based on Ardublock but is now more attractive in case of appearance. (bq Printbot-evolution, n.d.)

Table 3 Competitors and their products

Product	LEGO Mindstorms EV3	Moss Zombonitron 1600	Arcbotics Sparki	Mbot	DYOR	BQ Printbot
Price	349,90 €	199,95 €	149,00 €	74,99 €	38,36€ - 65,86€ *	99,90€
Programmable brain	EV3 Brick	MOSS Double brain block	Arduino	Arduino	Arduino & BQ ZUM Core	BQ Zum board
Programming program	LEGO Mindstorms software	MOSS Scratch & MOSS Flash	SparkiDuino & Minibloq	mBlock & Arduino IDE	Ardublock & Arduino IDE	Bitbloq
Hardware	Technic LEGO	Plastic cubes connected by magnets	Plastic structure	Aluminum structure	Plastic structure	Plastic structure
Motors	3	2	2	2	3	3
Sonar sensor	X	1	1	1	1	1
Light sensor	X	X	3	1	X	2
IR sensor	X	X	X	X	X	2
LED	X	X	1	X	X	X
Color sensor	1	1	5	X	1	X
Touch sensor	1	X	X	X	X	X
IR beacon	1	X	1	1	X	X
IR remote control	X	X	1	1	X	X

Speaker	Built into EV3 Brick	X	X	X	X	X
Bluetooth link	X	Built into MOSS Double brain block	X	X	1	Built into Zum board
Accelerometer	X	X	1	X	If mobile phone is mounted on the robot	X
Magnetometer	X	X	1	X	X	X
Display	Built in EV3 Brick	X	1	X	X	X
Buzzer	X	X	1	X	1	1
Compatible with LEGO	Yes	Yes (only LEGO bricks)	No	Yes	Yes	No

Table 4 Comparison between the competitors

2.2.4 Analysis

From the information gathered on the existing market it was seen that there was already a wide range of different segments. The most of the developers aim to go into one market segment. In case of DYOR, the users of the product could use it in any way and in a different segment than planned. The classification of the product as an educational robot kit makes it easier to find the right segment.

From the answers collected from the teachers, the need for a cheaper alternative to the LEGO Mindstorms EV3 kit was clearly indicated. The answers show that LEGO Mindstorms have good qualities, like “The programming is very intuitive and easy to learn” and “that the teachers can feel the students' attraction for building with LEGO”. But the biggest problem with it seems to be the price. For schools that have to get 50-100 kits, it was very expensive deal.

The answers from the students where a good mix between boys and girls. The age was 13-15 years for all the (30-40) students. Over half the students had used LEGO Mindstorms before and answered rest of the related questions. The majority liked LEGO Mindstorms and none of them thought that it is too simple. Everyone thought that there was something missing from the LEGO Mindstorms. This was the area where DYOR lies. Some features like lasers were not incorporated as this would not be either safe or practical.

While working these projects, the students develop the ability to work in teams when constructing the robot. It also encourages creative learning, programming and overall creativity.
From the answers it was seen that 86% wanted to try a new robotic kit which further encouraged this the project. Majority of the students wanted to implement mobile phones with the robot, which was later implemented in DYOR as an additional feature. When asked what they wanted the robot to do the general answer was to do house chores, like cleaning, play football, hold objects etc.

The answers from the engineers show that it was common to use LEGO Mindstorms, 57% have used it before and 68% thought their LEGO Mindstorms skills were low. The engineers thought that LEGO Mindstorms was better suited for upper secondary school/college than for universities which means that it was too simple for more advanced use. The engineers were more familiar with Arduino, 79% have used it before. Which means that Arduino was more suitable and simple for basic technical uses.

2.3 Material

Furthermore, some research was done to find out the various production method which could be used to manufacture the product on a big scale. 3D-priniting works well on prototyping but when producing on a big scale injection moulding or laser printing would be the better choice. Material research was done to find the best material for each production method. The characteristics that were required were:

- Good strength
- Stability
- Nontoxic
- Preferably low costs
- Ease of manufacture

More details of the material used in each manufacturing process are given in their respective sections.

2.4 Electronic Components

The electronics were a big part of the project. Sockets for electronic sensors and actors were designed to put together. The goal was to provide multiple possibilities to the user. To achieve this goal, it was important to offer a wide range of sensors which could be fitted in the sockets provided in the base or face. By means of attaching additional technic Lego beams to the holes provided, more sensors could be attached. Considering the short amount of time allowed for the project, skills of the teachers and high schools students as well as the aim to attract them towards engineering, not discouraging them by introducing complicated electronics. The job was to choose the most important sensors and actors which were simple to program and understand, given below are the short description of the most important sensors and actuators which they might use in creating DYOR or in various school level robotic competitions. If wanted more sensors or actuators could be added. During the work built in sensors have been preferred to make it easier to build for someone less experienced in the field. How these sensors are fitted, is further explained in 3.3.2 Model 1 and 3.3.3 Model 2.

Before fitting them in the models, note that the components are calibrated and functioning properly.

1. **Echo sensor**

The simplest way to detect obstacles was to use an echo sensor. It works like a conventional sonar. It sends an ultrasound (ping) then listen for echoes. If echoes are received, it calculates the time the ping took to come back and then gives the related distance to the Arduino. An illustration of how the echo works can be seen in **Figure 14** Sonar sensor working (The Five Senses of Sensors - Sound, n.d.)

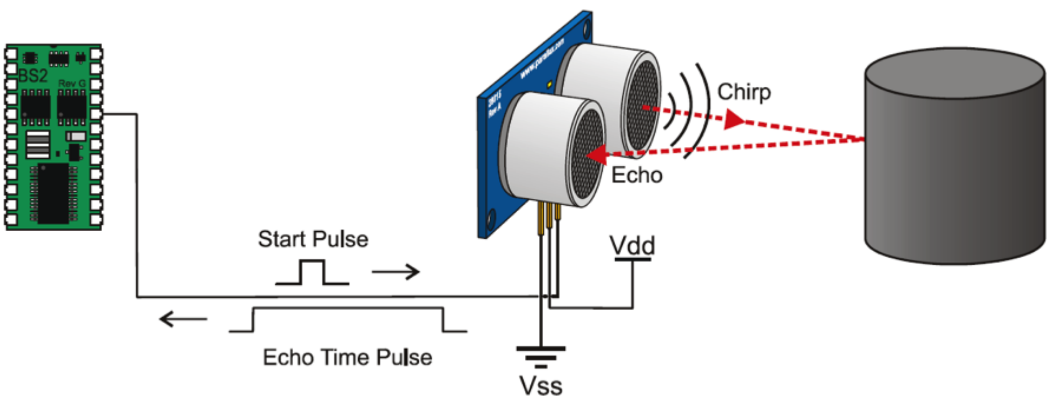


Figure 14 Sonar sensor working

This kind of sensor was very simple to use as it only requires a VCC, GND and a Signal pin. The pin connections for the sonar sensor is given in 3.3.4 Schematics.

2. **Line sensor**

Although this built-in sensor called "line sensor" is optimized for the purpose of following lines, it is basically only an optical reflected sensor. It gathers an infrared LED and a phototransistor pointing on the same direction, opposite of the optical coding wheel sensor, see **Figure 15**. In this way, every change of colour or material will be followed by a change of light reflection and will then be detected.

Figure 15 Line Sensor Module – TCRT5000L

3. LED Matrix

This includes an 8x8 LED matrix (red colour), a MAX7219 chip to control the LEDs, header PINs and sockets, one 10KOhm resistor, a 100nF capacitor, a 10uF electronic capacitor and a PCB where everything is connected together.

The LED matrix has a common cathode. This module does not work with common anode matrixes.

Figure 16 LED matrix

4. Servo motors

The servo motor is more than a simple motor. It is a square plastic box containing a DC electric motor, gears, a potentiometer and a piloting board that allows the motors to be controlled in position. The Input are 3 cables, 2 for the electric alimentation and one for the signal. This way of work makes the servo motor very convenient to use since it does not require any external power operating circuit. A picture of the servo motor can be seen in **Figure 17** and **Figure 18**. In this case two *9g micro servo* motors were used to control the arms of the robot and *continuous rotation servos* which were attached to the wheels.

Figure 17 Micro servo for the arm

Figure 18 Continuous rotation servo for the wheels

5. Arduino Nano

The Arduino Nano is a small, complete, and breadboard-friendly board based on the ATmega328 (Arduino Nano 3.x) or ATmega168 (Arduino Nano 2.x). It has more or less the same functionality of the Arduino Duemilanove, but in a different package. The Arduino Nano can be programmed with the Arduino software and the new code could be uploaded to it without the use of an external hardware programmer (Arduino Nano, n.d.) .

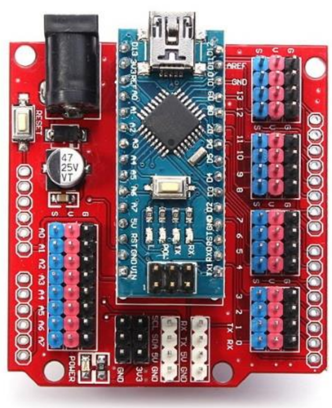


Figure 19 Arduino nano on its extension board


Figure 20 Bluetooth

6. Bluetooth

To be able to connect the smartphone to the robot, a Bluetooth link was required. In order to establish this link, a Bluetooth module was required. These Bluetooth modules for Arduino are called Bluetooth shield and were relatively cheap. The Bluetooth compatible shield can be seen in **Figure 20**

CHAPTER 3

Methodology

In addition to the detailed methods described in this section, the basic approach to this project includes finding the problem and the customer needs by interviews and survey. A concept can be defined as both an “approximate description of the technology, working principles, and form of the product” as well as a “concise description of how the product will satisfy customer needs". After concept generation, a set of customer needs and target specifications were kept in mind. The results in an array of product concept design alternatives from which a final design was selected. After determining the problem in this project, an attempt to design and build a robot to solve the problem of self-fabrication was focussed. Some time was taken to study a number of different situations and a lot of designs and prototypes were generated. The concepts which were satisfying the requirements were chosen for further evaluation. Different parts from the different alternatives were combined to find the most attractive solution. The designs were then 3D modelled and fabricated.
Verification of the models and redesigning took place continuously. Some of the technical specifications/task that DYOR should do were:
The discussions from the concept generation led to a set of technical principles that the robot should fulfil.

1. Moving (on ground), turning (programmed movement)
2. Detecting obstacles (automatic movement, location)
3. Finding objects (locating objects, sorting)
4. Pickup object
5. Playing (football or robot wrestling)
6. Line following
7. Optional features (mobile controlling, making sound, camera)

3.1 Design

The most suited manufacturing methods were chosen and the design of the parts of the robot were modified depending on the type of method.
While designing three major things were kept in mind:

- The purpose of construction
- Specific requirements
- Simple design and manufacturing methods

The gathered information from the surveys conducted were analysed and kept in mind during the design part. The ideas generated were narrowed down based on their ability to provide possible and alternative solutions.
*The purpose of construction: T*he target group, need and the objective of the project were important to any product as they form the base. In this case the *target group* were the high

school students of Mas Camarena in particular and other users who might use his kit as their hobby or entertainment. Since the product is not limited to any particular age group (as the level of complexity is defined by the user), university students and even teachers/parents could actively participate in creating DYOR. The need of developing this product was to provide them with an alternate cheaper educational robotic kit. The main objective of the project was to create a kit to make learning fun to the high school students and have clear idea about their engineering career.

Specific requirements: the modularity, the technique and the available resources. One example of modularity applied to the first proposed model and the final model is shown below:

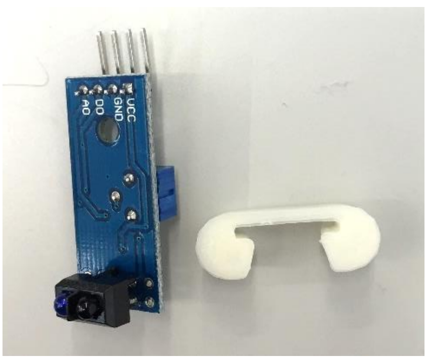


Figure 21 Test socket design for IR sensor in DYOR

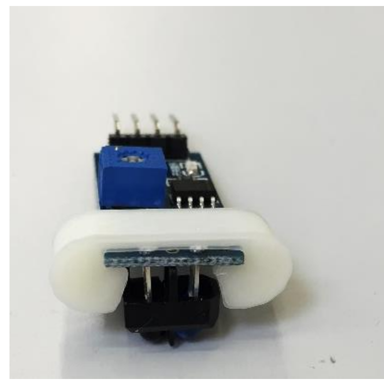


Figure 22 IR sensor fitting in its socket

- *The physical configuration:* used was one of the proposed by LEGO (Astolfo, Ferrari, & Ferrari, June 2007) in the kit building guide i.e. Modularity. Three sensors were connected: ultrasonic (facing out on top of the face), sound (optional) and light (at the bottom). Two motors were connected, both of them situated symmetrically at each side of the robot; a turning wheel (mounted on the rear side). These could be removed or added depending on the type to robot.

- *The choice of this language has been supported by several benefits:* it runs on the Arduino IDE using Arduino Nano. The school may use the same code provided while the university students may modify or change to language to, C. It was important to have programming language in real-time embedded systems and which also shares the basic syntax constructions of many other languages.

- *The construction according to the student's point of view*: The product is compatible with technic Lego; the design is not limited to the one proposed in the guide. Other beams and sensors could be added according to the user. The idea was to have a main body or the "brain" consisting of controlling unit i.e. Arduino. The other parts were attached to the main body. Several designs of the robots could be created depending on the arrangement of these parts to the main body.

- *Simple design and manufacturing methods:* in terms of user, cost, robustness and versatility. The main element of creating DYOR was that it also provides various fabrication methods. The students/teachers of the school have liberty to choose the method like 3D printing (with the design provided or their own), Laser cutting (from 2D sketches which are simple to do) or moulding (the moulds provided).

3.1.1 CAD

The generation and rationalization of 3D models for fabrication was the next step. 3D-modelling is the process of developing a mathematical representation of any three-dimensional surface of an object via specialized software in this case CATIA V5 and Solid Works were used. Making Lego compatible parts were the main consideration besides simple construction of "block and holes" (which a high school student can build) were also kept in mind. To clarify what is meant by beam, peg, axle etcetera and explanation can be seen below **Figure 23**.

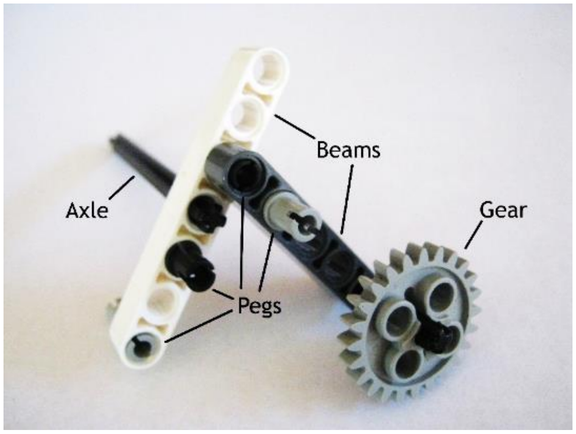


Figure 23 Nomenclature of various technic Lego parts

Dimensions

The dimensions that are used by LEGO were also used on as a starting reference for the designs of the base and the face **Figure 24**. Since 3D printed parts were also used as the master mould for creating silicon moulds, several test samples were made to see how precise the 3D-printer was. The hole and axle dimensions were changed because the hole/axles in 3D printed models were tighter and smaller. So the final dimensions for the round holes are radius 2.55-2.6 mm. The cross hole has a radius of 2.7 mm and the cross has a width of 2.3 mm and a height of 1.29 mm **Figure 25**. There is also an extruded part at the round holes which makes the LEGO pegs fit better with the beams. All the blocks were made LEGO compatible and used LEGO units in most cases, one LEGO unit equals to 8 mm according to the measurements.

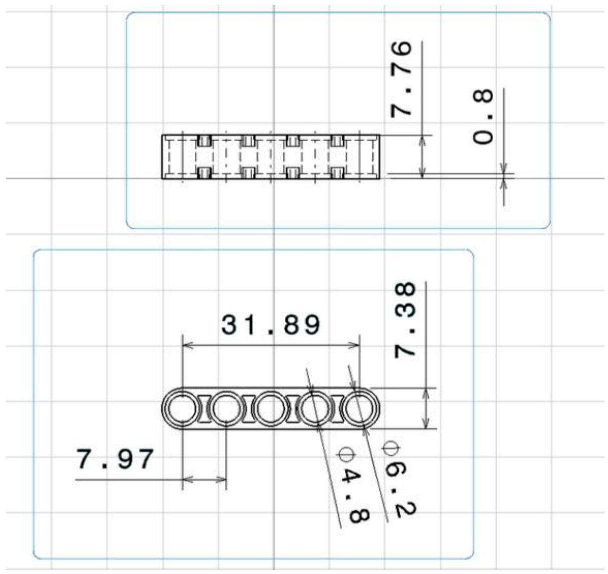


Figure 24 Dimensions for Technic LEGO (Lego Answers beta, n.d.)

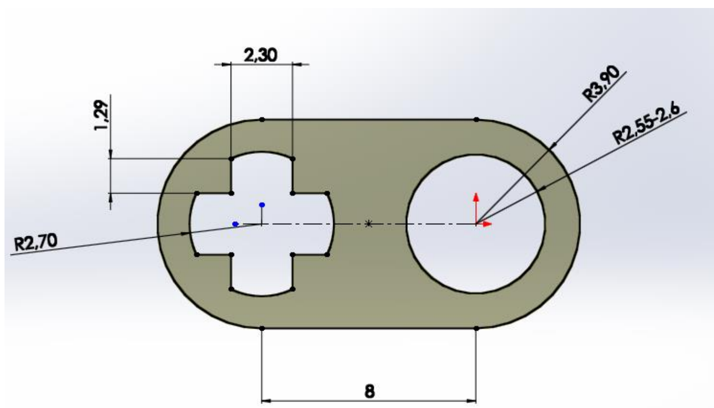


Figure 25 Test model with larger dimensions

For subtractive manufacturing i.e. Laser cutting, the dimensions of the holes and crosses were taken same as technic Lego dimensions. All the dimensions of the final concepts are given in Appendix C.

3.1.2 Preliminary solution

The base or the main body which consists of the "brain" of the robot. Several components could be attached to it by means of Lego pins and holes provided in the design. The first few concept designs consists of an open box with openings for cables and attachment of battery as seen in **Figure 26** and **Figure 27**. The main body consisted of two parts, case and battery holder **Figure 28**.

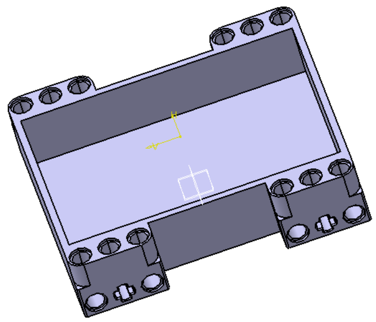


Figure 26 Battery case for the first final prototype

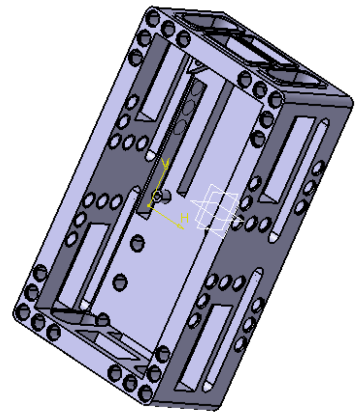


Figure 27 CAD main case for the first prototype

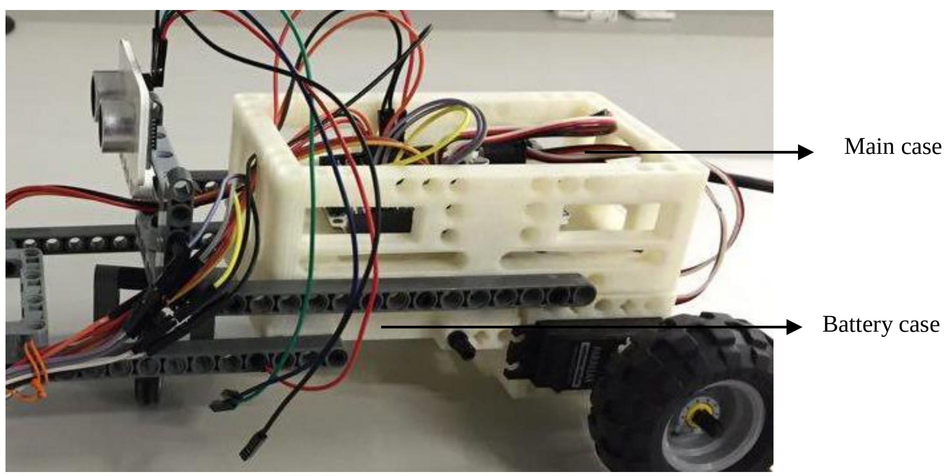


Figure 28 Main case with the battery case combined in LEDURA

The main body had holes of Lego dimensions so that various beams could be attached. Modularity was one of the key factor. Each sensor or a component had a 3D printed case as seen in **Figure 29**, **Figure 31**and **Figure 33**. These cases had holes or crosses for Lego pins and axles to be inserted and attached to the main body or beams. The colour sensor (RGB LED and photoresister) was placed in a case which was attached to the gripper's arm as seen in **Figure 34**. The arms/gripper was 3D printed along with its gears which was then fitted to one micro servo motor as in **Figure 30**. Continuous rotation servos were enclosed in a 3D printed as in **Figure 33**. Mobile case was also provided as an option to place a cellular phone on top the main body, which could have served as a screen. Buzzer was also used along with the colour sensor to distinguish between colours i.e. red, green, blue and yellow. Later when the school approved of the idea and also proposed the concept of self-manufacturing, some major design changes had to be made.

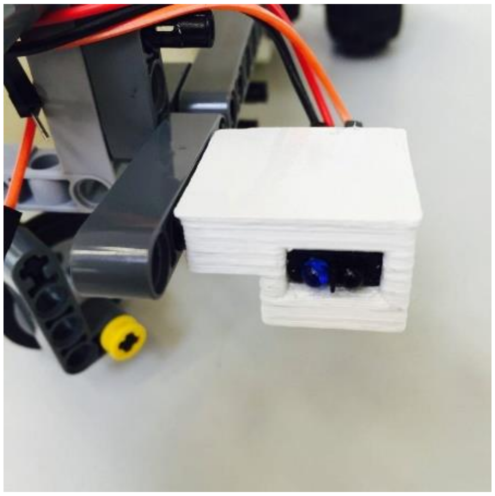


Figure 29 IR sensor in its 3D printed case

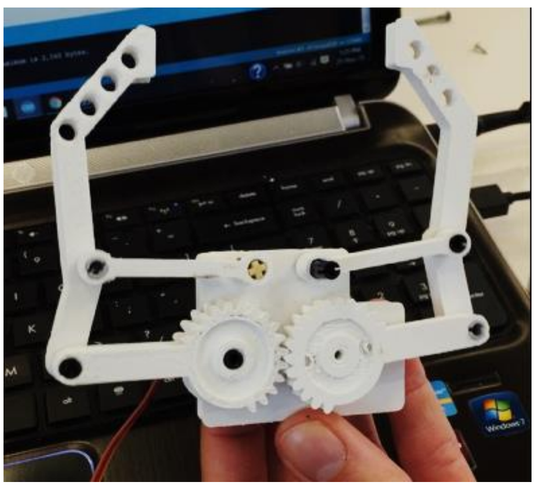


Figure 30 3D printed gripper

Figure 31 Sonar sensor in its case

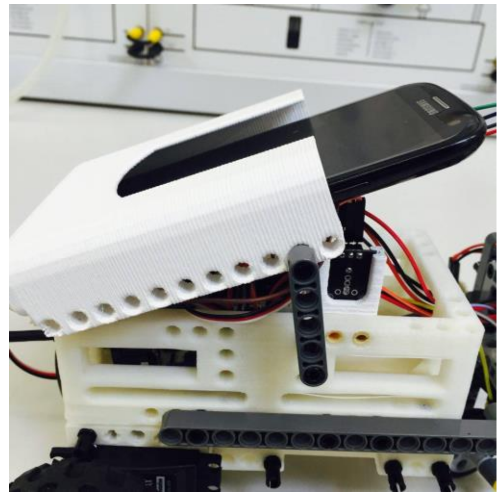


Figure 32 Cellular phone case attacjed to the main body

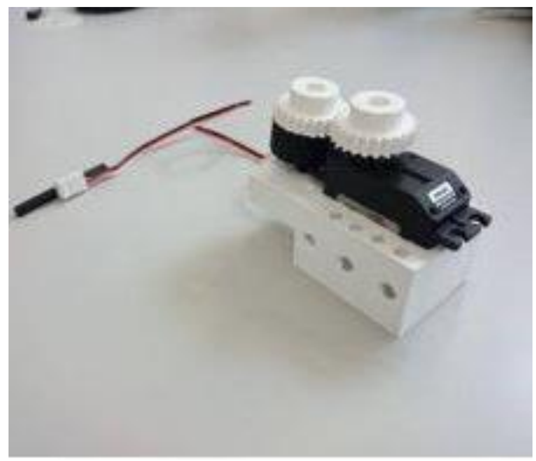


Figure 33 Continuous roatation servo in its case

Figure 34 Colour sensor attached to the gripper

Initially, the robot had no "face" as such, just the echo sensor case and grippers. Although a soft sponge like paper was given a shape of a lion and crab to cover the cables and make it more attractive. The covers are made by measuring the body of the robot. They were first made in illustrator and then printed. The same figures were then cut out of foam paper which was used for the body parts as **Figure 38** and **Figure 37**. The parts were cut out and attached to the robot. To attach the cover to the robot, holes were made in the cover which fits the pins on the robot. There were special 3D parts printed to stick on the pins and keep the cover in his place. Some parts of the covers were glued to other parts.

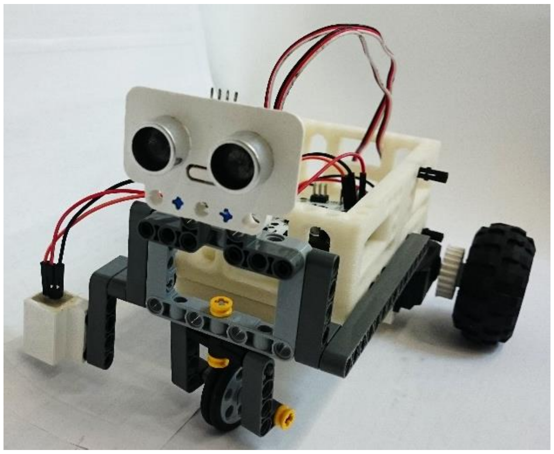


Figure 35 LEDURA without cover

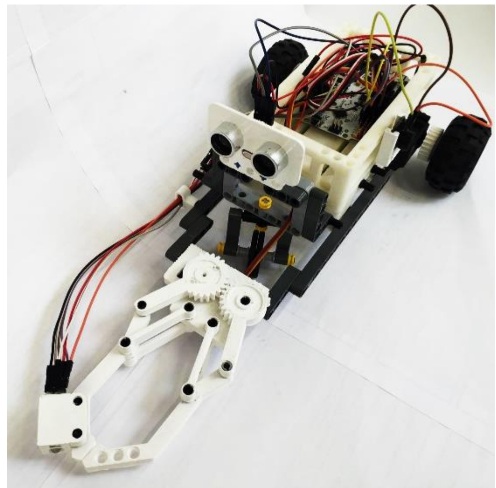


Figure 36 LEDURA with all its components

Figure 38 Lion cover (drawn in Illustrator)

Figure 37 Crab cover (drawn in Illustrator)

The lion cover prototype includes the functions of line following and avoiding obstacles. To this prototype the echo sensor, line following sensor and the servo motors for the wheels were included as seen in **Figure 35** and the lion cover prototype could be seen in **Figure 40**.The crab cover prototype could be used for gripper objects. The prototype includes echo

sensor, the colour sensor, the buzzer, the gripper and the servo motors. It includes a cover illustrating a crab as in **Figure 39** and the crab prototype without cover can be seen in **Figure 36**

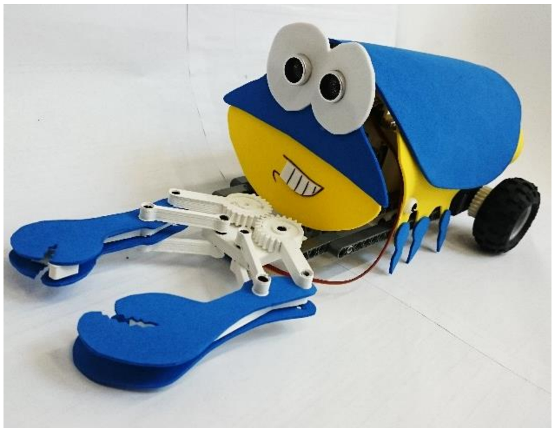


Figure 39 LEDURA: crab cover

Figure 40 LEDURA: lion cover

3.1.3 Adapted solution

The first prototype of LEDURA was built and presented before the professors and school teachers/instructors, discussion of feasibility issues took place. The realization of the important factors such as scale, material selection, cost, and other physical restraints such as facilities available for medium to large scale production and time were major issues which needed further attention. Thus second prototype "DYOR" came into picture and the following changes and new concepts were incorporated. A prototype is an early sample, model, or release of a product built to test a concept or process or to act as a thing to be replicated or learned from. The Rapid prototyping method to quickly fabricate a scale model of a physical part or assembly using three-dimensional computer aided design (CAD). The construction of the part or assembly was done using 3D printing (additive layer manufacturing technology). The prototype was designed to test and try a new design to enhance precision by system analysts and users. The prototypes served to provide specifications for a real, working system rather than a theoretical one.

A) Base

The common *new design* concept **Figure 41**, Figure **42** and **Figure 43** of the base had the following characteristics:

1. Open box concept was discarded as it required complex injection moulding or more 3D printing material.

2. 2.5 D design was taken into consideration for easy and multiple manufacturing techniques.
3. Not having multiple modular components like servo motor case, buzzer case, echo sensor case etc., the new design had sockets.
4. More or less same design for all the fabrication techniques.
5. All in same plane.
6. Instead of having outer hole (diameter 6.2mm) and inner hole (diameter 4.8mm), only hole of 4.8mm diameter were made to avoid complications during moulding.

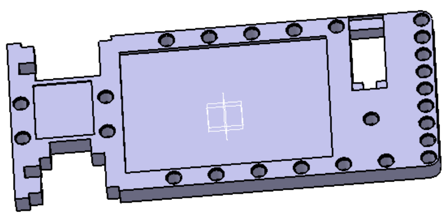


Figure 41 First adapted base design concept

Figure 41 shows the first concept of the base of DYOR with a shallow pocket to place Arduino board and Bluetooth. Sockets for one servo for geared gripper and two sockets for continuous rotation servos for the wheels were provided. This was further modified as too many double holes could create defects in moulding.

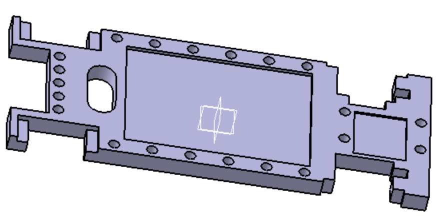


Figure 42 Second adapted base design concept

Replacing geared arms with two servo motors directly attached to the arms and providing a socket to fit in the face were the changes seen in **Figure 42.** This was modified as the face was colliding with the front turning wheels

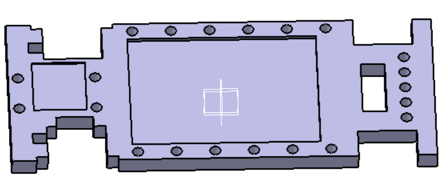


Figure 43 Third adapted base design concept

A separate pocket to insert the face in the base was provided in this concept as seen in **Figure 43**. This was simplified to less holes and no shallow pockets for the components.

B) Face

The general *new design* concepts for the *Face* in **Figure 44** and **Figure 45**. The new concept developed after the first model was presented to the school teachers. Some of the features incorporated in the Face were:

1. Single parts with pockets for sensors like echo, LED matrix, and IR sensor.
2. Eliminating several separate cases for sensors as they would be not feasible with different manufacturing techniques.
3. Simple construction of blocks and holes.
4. Replacing gears of the grippers/arm with Lego beams directly attached to the servo motors.
5. Echo sensor as eyes and Led matrix as mouth which could convey many emotions (happy, sad etc.) through its LEDs, were found to be more attractive than a paper cover. It could be manufactured in many ways and could firmly be attached to the base of the robot.

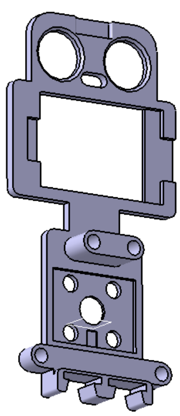


Figure 44 First adapted face design concept

The concept of the face shown in **Figure 44** has sockets for the echo sensor, LED matrix, colour sensor and two IR sensors. The two extruded holes were for attaching it to the base **Figure 41**. The design well suited but the school teachers found colour sensor too complex for high school students, thus the design needed to be modified. Also this was feasible for 3D printing and no other fabrication method.

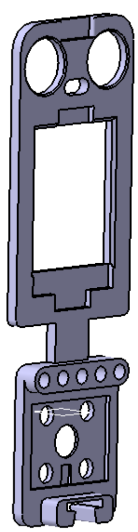


Figure 45 Second adapted face design concept

The other concept was similar to the first one, having sockets for fitting sonar sensor, LED matrix, colour sensor and IR sensor as in the **Figure 45**. The only difference was that it had only one IR sensor and LED matrix to be placed vertical. This made the design a bit larger in length and narrower. The concept was changed to another one when the use of the colour sensor was discarded in the face. The colour sensor was kept optional and could be added if the user desires.

C) Final Designs

Several designs were made and tested. The analysis took place on the basis of the simplicity of the design, number of components, manufacturing methods, amount of material used and material available. Many prototypes were made and small changes in the dimensions were included each time for better fitting. Some of the final design which were chosen for the base and the face are shown below.

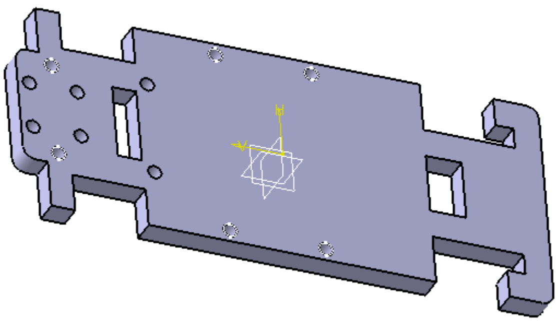


Figure 46 Final base design 1

The final design shown in the **Figure 46** is for the base, both 3D printed and laser cutting. It could also be used as a master piece for moulding. The design was simple only made use of holes and block which made it possible for children to construct in any 3D software. Also one common design for all the manufacturing methods

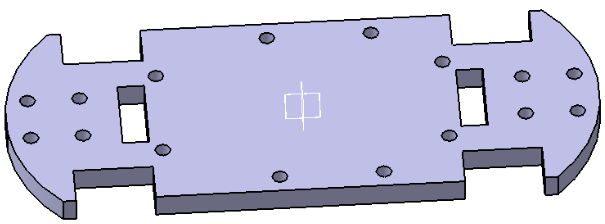


Figure 47 Final base design 2

The final design of the base also included the one shown in **Figure 47**. This was for the base whose mould was made by machining. Due to the tool limitation, the design was slightly changed and was made symmetric. As the design was symmetric it also gives the possibility of using omi wheels to the user.

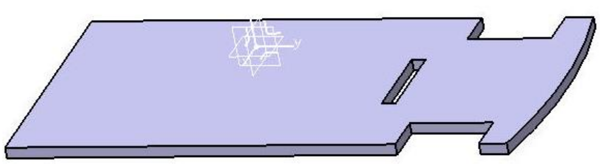


Figure 48 Final base design 3

This design in **Figure 48** was considered as it was thinner (4mm) and was the simplest. It had no holes and very few sockets. It could be drawn using simple 3D softwares (Tinkercad) using holes and blocks. It was tested and a ten-year-old kid could easily make using Tinkercad.

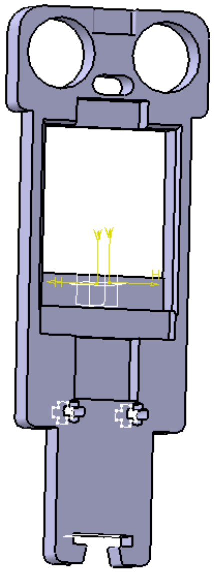


Figure 49 Final face design 1

The final design of the face is shown in **Figure 49**. The design has sockets for fitting sonar sensor, LED matrix and one IR sensor. The crosses provide attachments to the base if needed. Simple and common design of the base for all the manufacturing methods. The lower portion is narrower as to be inserted in the pocket provided in the base.

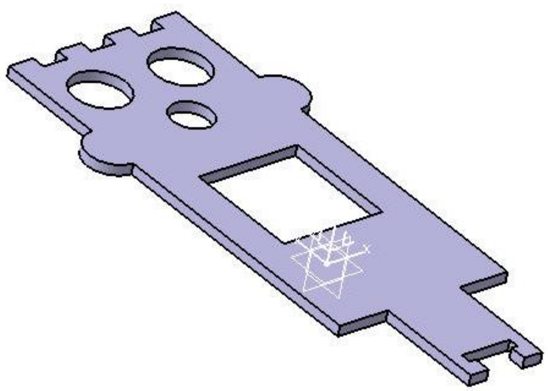


Figure 50 Final face design 2

The final design of the face shown in **Figure 50** has sockets for fitting sonar sensor, LED matrix, buzzer and one IR sensor. It has no crosses for attachments to the base. The design is 4 mm thick and could be drawn using and simple 3D software, in this case Tinkercad. The lower portion is narrower as to be inserted in the pocket provided in the base. It forms the shape of the face of a very famous cartoon character in "The Simpsons" called Bart Simpsons.

3.2 Manufacturing

In this section, a variety of potentially fertile areas for innovative design in 3D printing, laser cutting and plastic moulding for children are explored. Additive and Subtractive manufacturing techniques were used in the project, **Figure 52**. Additive manufacturing where the 3D objects are constructed by deposition of material in layer that it become the predesigned shape whereas in subtractive manufacturing 3D objects are created by successively removing the material from a solid block. The areas examined were:

- Expanding the range of physical media available for manufacturing
- Incorporating ideas new ideas to generate simple product into manufacturing
- Exploring methods for creating portable and ubiquitous manufactured product
- Creating techniques for specifying, altering, and combining 3D elements in the context of their fabrication.

- Making necessary changes in the design according to the method of fabrication.

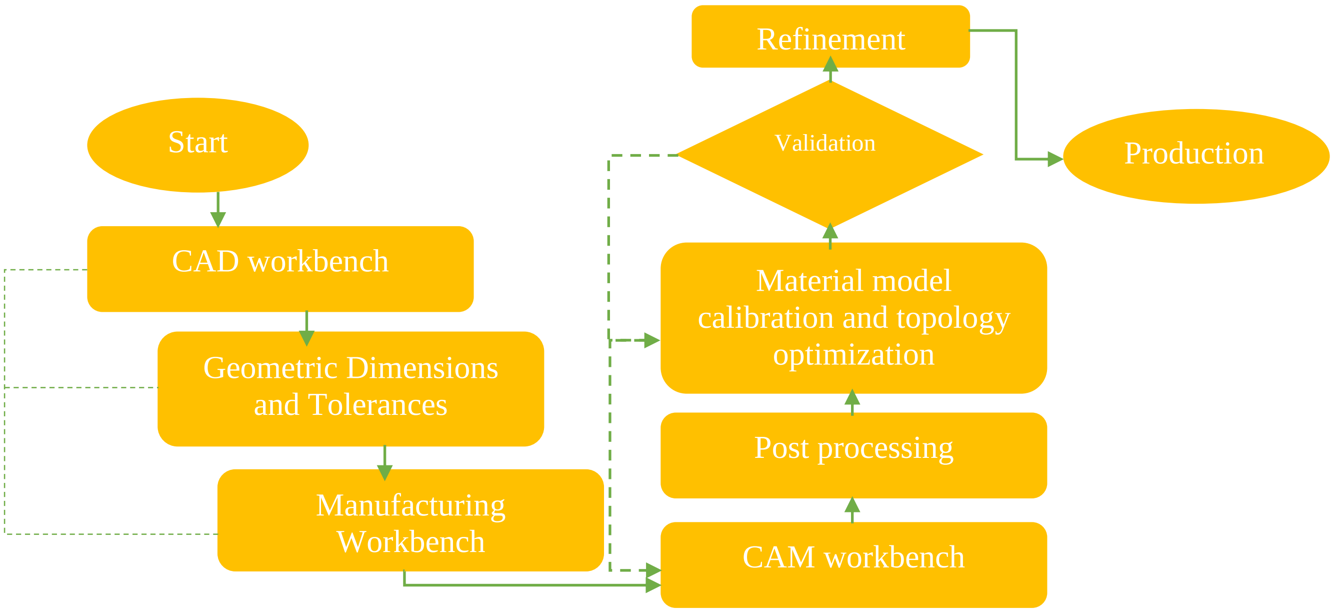


Figure 51 Manufacturing Flow diagram

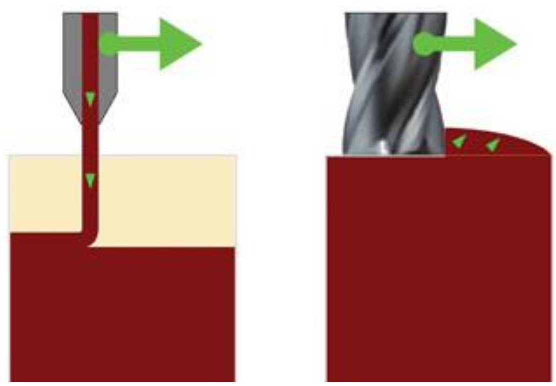


Figure 52 Additive manufacturing (left) Subtractive manufacturing (right)

3.2.1 CAM

CAM (computed aided manufacturing), in this case CATIA V5 (advanced machining) and NX manufacturing work bench were used. Tool path, tools, and various machining techniques like pocketing, contouring, sweeping, facing and drilling were checked before machining the part in CNC. NC codes were generated for different machines and their postprocessors.

The CNC machining process took place in Instituto de Diseño y Fabricación at Universitat Politecnica de Valencia.

The CNC machine used was Fagor 8050 and the tools were limited to 8mm, 6mm, and 3mm diameter both conical and end mill. Thus the design of the base was slightly changed (made symmetric) which gave the possibility of using *Omni wheels.*

The aluminium CNC mould manufacturing for the base and the face are shown below:

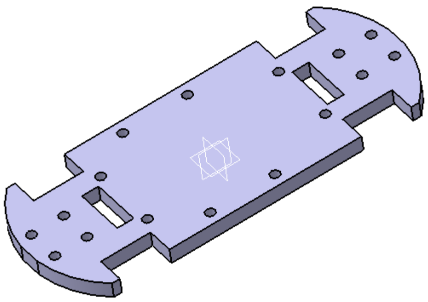


Figure 53 Master piece for moulding

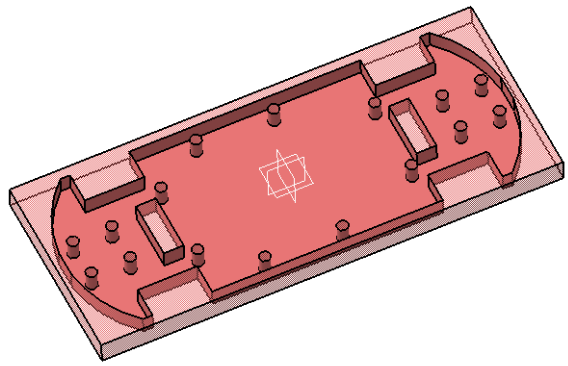


Figure 54 Mould design created in CAD

The CAD design was created and its negative (for the mould) was made by using Boolean remove operation in CATIA V5 as seen in **Figure 54**.The stock material[1] was created and all the machining processes were done virtually. The tools were selected as of those available in the laboratory and tool path was generated. When all the tool path and the contour mill processes were computed, the NC code was generated for particular postprocessor. The code was manually verified before actually feeding it in the CNC machine.

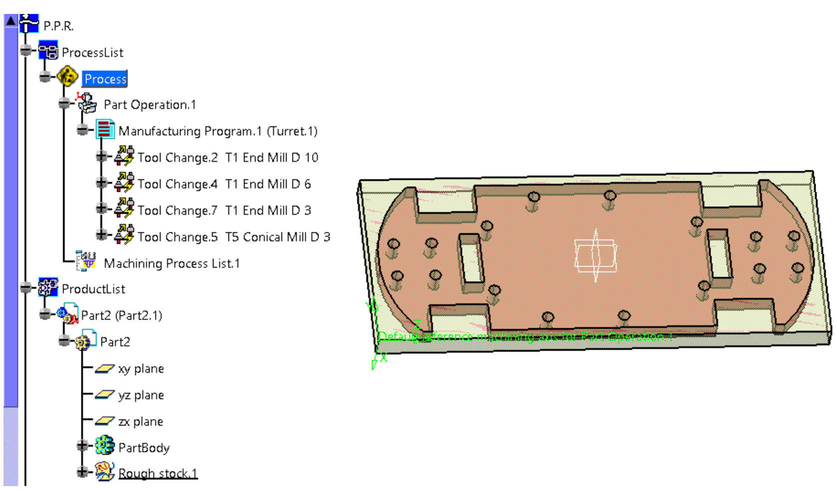


Figure 55 CAM: Base with stock material

[1] Stock material: Bulk material from which the material is removed as in subtractive manufacturing to give it a final shape.

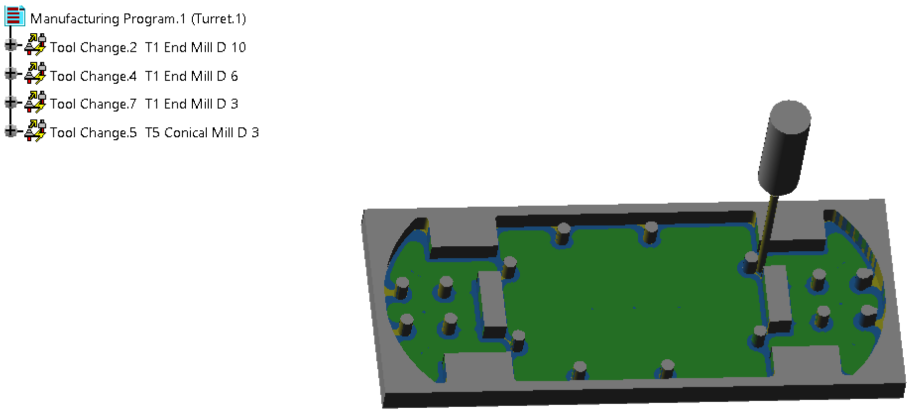


Figure 56 CAM: Base after final machining

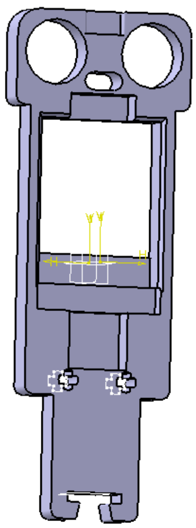


Figure 57 Face master piece

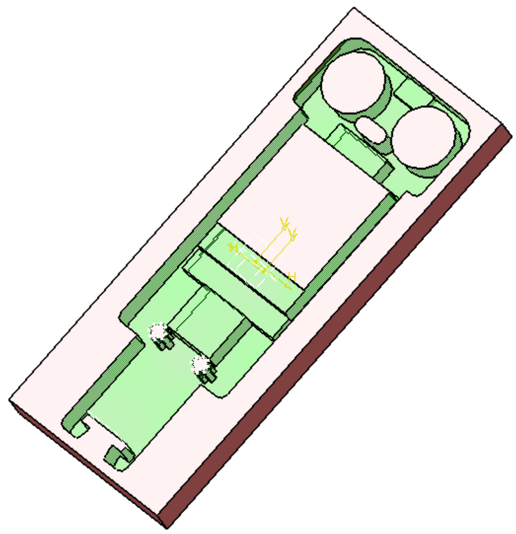


Figure 58 Face mould created in CAD

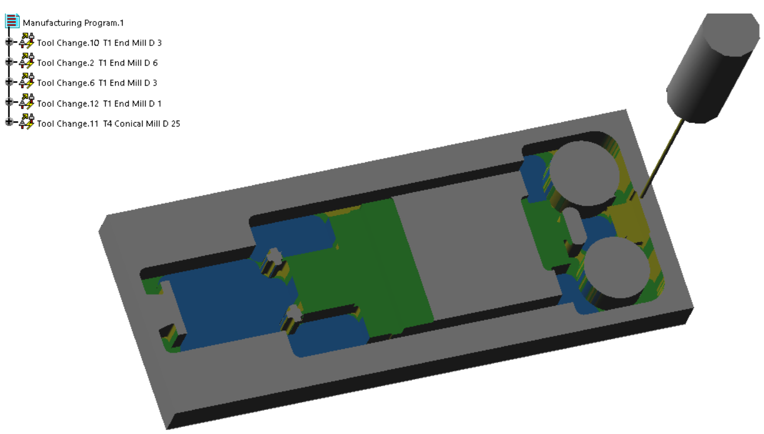


Figure 59 CAM: Face after final machining

3.2.2 3-D Printing

3-D printing uses an additive manufacturing process where the products are built on a layer-by layer basis, through a series of cross-sectional slices. In this case 3-D printing was chosen as one the production method as it enables small quantities of customized goods to be produced at relatively low costs. While currently used primarily to manufacture prototypes and mock-ups, a number of promising applications exist in the production. Many consumer versions of rapid prototyping machines that are relatively low-cost and easy to use are available. As the school was showing a great interest in building their own models, this could have been the most feasible method for them if the production was small.

Besides low cost of the 3D printers, their integration with computer-assisted design (CAD) software makes 3-D printing more efficient. At the end of the product design process, the work was saved as STL (an industry standard stereo-lithography format) or similar file. Transferred to the system connected to the 3D printer, opened in a software provided by the 3D printer company (XYZ printing in this case), and simply printed.

The final product could be seen below **Figure 62**. It consisted of base and the face with holes for attaching additional components. The pockets for the motors and sensors could be seen.

Further images show the step by step construction of the full model.

This method was necessary as the school wanted to introduce simple 3D modelling in their curriculum and they also owned a 3D printer.

Designing for children leads to think about aesthetics (can we make 3D printed objects more colourful?), about understand ability (can we make the task of 3D modelling easier?), about safety (can we create new non-toxic coatings for 3D printed items?), and about cultural issues (can we create software interfaces through which children can, remix, and combine 3D-printed forms?) (Eisenberg, 2013). There are number of 3D modelling software available and one such is Tinkercad (Tinkercad, n.d.) which is a simple, online 3D design and 3d printing tool for the masses. A designer, hobbyist, teacher, or kid, can use Tinkercad to make toys, prototypes, home decor, models, etc. Other tools for creating simple designs from scratch and also modifying the existing design are available for free online.

There are still some limitations other than the cost of software to make 3D fabrication and printers. One recurring issue in high-end 3D printing involves the need for ‘‘support’’ materials in the printing process, to allow for the creation of complex shapes.

Material

The material used was ABS plastic which is a copolymer with different amount of acrylonitrile, butadiene and styrene monomer. It is commonly used in everyday products such as household appliances. ABS is resistant to acids, alkaline solutions, alcohol, oil, grease, salt solutions, and saturated hydrocarbons.

Prototypes

A number of prototypes were made and tested based on the printing material and techniques. The ones providing maximum precision and closest to the specification list, were selected as the final prototype

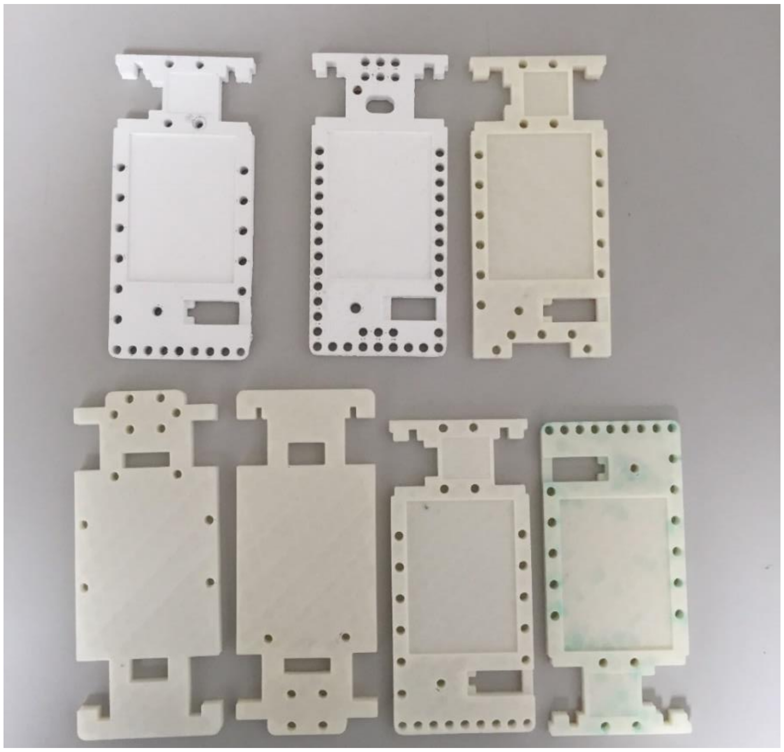


Figure 60 Prototypes of the base 3D printed

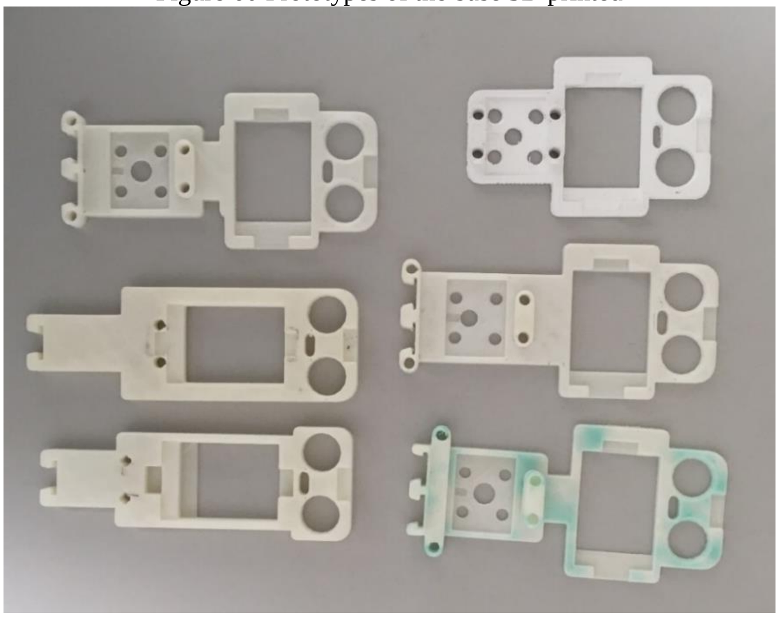


Figure 61 Prototypes of the face 3D printed

Main features of the final prototypes were:

1. Changing design to 2.5 D.
2. Instead of making cases for all the sensors, sockets were provided in the base and the face.
3. Giving options for multiple fabrication as 3D printing for medium scale production was not economic.
4. Reducing the body to two parts, base and face.
5. Reducing the number of holes for connections to provide robustness.
6. Making single diameter holes to easy moulding.
7. More to less keeping the same design for all the manufacturing techniques.
8. Removing a separate battery case. Instead providing with battery holders.

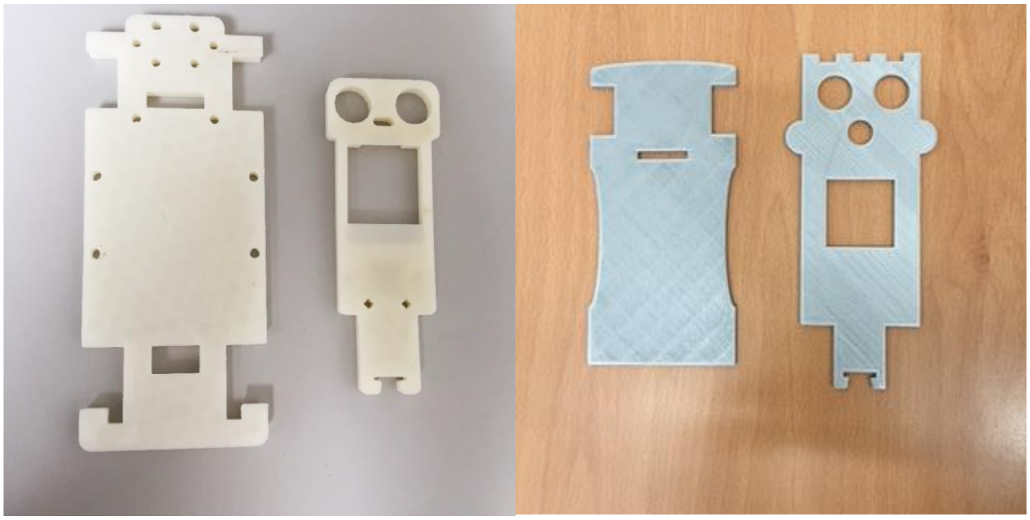


Figure 62 Final bases and faces 3D printed

3.2.3 Laser Cutting

Laser[2] cutting is a manufacturing process which uses an industrial laser to cut materials. One of the primary considerations is laser size. This depends on the materials to be cut, and their thickness. Basically, the thicker the material, the higher the KW rating needed for a laser to achieve a satisfactory cutting rate. The most common cutting gases include oxygen, nitrogen, air, and argon, although others are also used. The selection of the best cutting gas is a function of the material to be cut. The process of laser cutting is shown in **Figure 63**.

CAM which stands for Computer Aided Manufacturing could be used to make tool paths. The pattern to be cut is programmed into the laser to produce the final profile required. Drawing Interchange Format (DXF) files or Drawing eXchange or DWG format ease the

[2] Laser: Light Amplification by Stimulated Emission of Radiation

transferring of files between AutoCAD and other software systems, DXF has become a industry standard. Most CAD, drawing, mapping and GIS software packages have some ability to import DXF files.

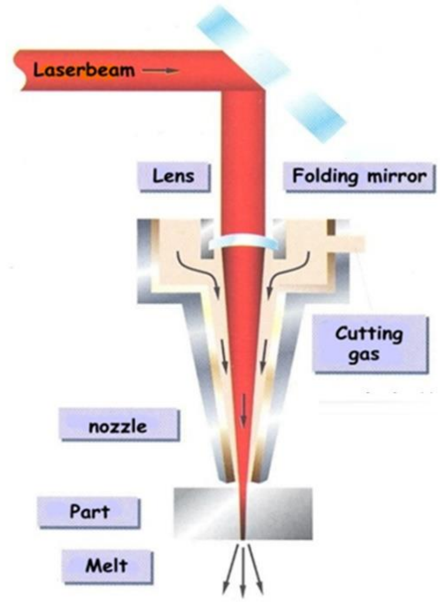


Figure 63 Laser cutting process

The initial testing process was done at Instituto de Diseño y Fabricación at Universitat Politecnica de Valencia under the guidance of Professor Juan A. García.

Some of the benefits included:

- Fast and smooth production process
- Options of having large number of materials (plastic, wood, metal etc)
- Large numbers of vendors and laser cutting shops available in Valencia- Spain, which means that the school could easily get the large number of parts easily.
- 2D designs were used for laser cutting, JPEG or PDF file could also be imported.
- Children could easily draw their robot shapes in 2D even by using paint in windows and get them cut.
- Very economic for medium to large scale production.

Material

The material used for the initial testing was 3mm plywood. Plywood being nontoxic and eco-friendly. Three 2D designs of a base were cut on a plywood in order to obtain approximate 9 mm thickness (by gluing them one on top of the order). The later samples include testing with 4mm plywood with slightly different shapes. Two of the 2D design were cut then glued to obtain 8mm thickness.

Prototypes

The first prototypes of the laser cut were done in IDF centre at UPV. The designs were transfers to a software used to transfer .dxf files to laser cut machine. The cutting process is shown in the **Figure 64** .The entire process take less than 10 mins. The cut pieces were carefully taken out of the plywood.

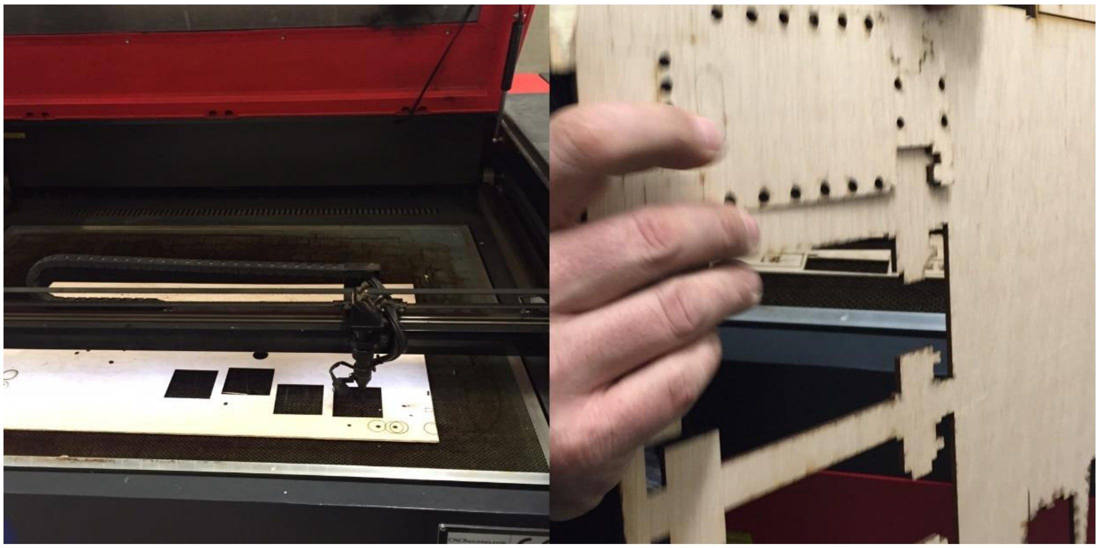


Figure 64 Plywood getting cut in the laser cutting machine (left) Cut base parts taken out of plywood(right)

More than two prototypes were made as described in 3.1.3 Adapted solution. Three or two pieces of the base, depending on the thickness of the plywood (3mm or 4mm) were cut and then glued together to get the desired thickness as in **Figure 65** and **Figure 66**. The pockets and the holes were kept similar as described before though the holes in the first prototype were found to be 0.1 mm larger than the given size. Care was taken for the second prototype so that the pins and face fit tightly, **Figure 68** and **Figure 69**

Figure 65 3mm 3 base parts laser cut

Figure 66 Base parts glued together

Figure 67 2 laser cut base prototypes

Figure 68 Final Base and face 1 (laser cut)

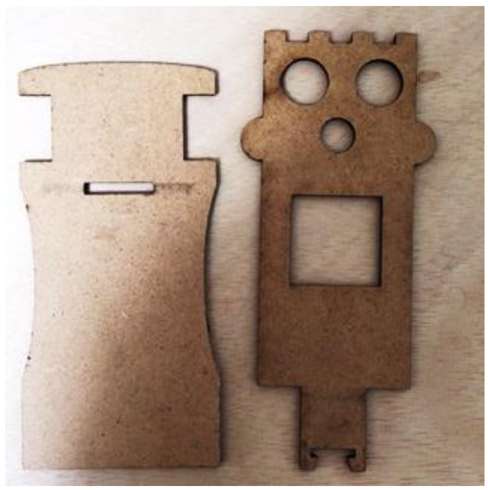


Figure 69 Final Base and face 2 (laser cut without holes & single layer)

3.2.4 Moulding

In this method, students are exposed to various plastics resins and mould building materials (CNC built aluminium mould provided or their own silicon mould). **Figure 70** and **Figure 71** illustrates 3-D models generated. The students move forward to the mould design and fabrication stage. It captures and maintain student interest within fun and creative team design environments. Show below are the CAD generated master pieces and their negatives (mould).

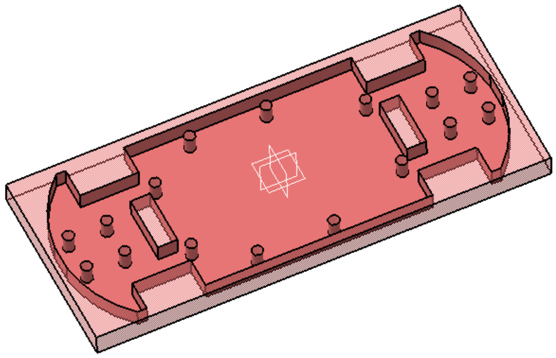


Figure 70 CAD model of the base mould

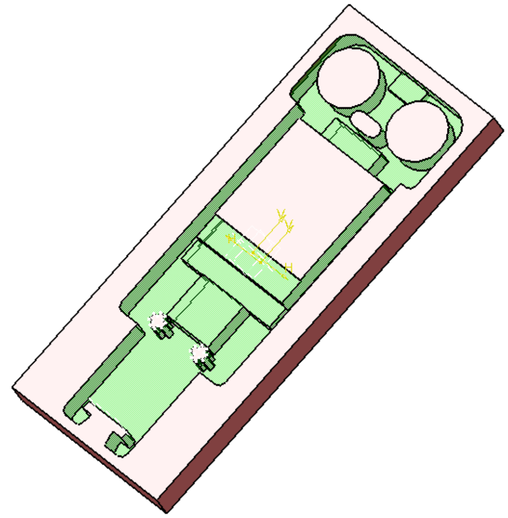


Figure 71 CAD model of the face mould

Prototypes

Some experiments were carried out using different materials and mould and mould designs. Silicon mould and Aluminium mould were the main ones and the designs were simplified to avoid complications. The designs proposed in 3.1.3 Adapted solution were taken for initial material testing. For CNC mould the design of the base was modified due to tool limitations.

Experiment 1

The first experiment was with the initial prototype of the base of the robot. The steps were as follows:

1. The material to build silicon moulds (A and B), 50% for both the material (A and B) weighed according to the volume of the 3D printed base for moulding.
2. For example, the rough volume of the base was104cm^{3,} taking into account the volume of the moulding container (i.e. slightly more than the base), and the moulding material was weighed. In that case was 56grams (28 grams of each).
3. The base was fixed to the container and the properly mixed silicon was poured.
4. Care was taken that no air bubbles were created.
5. After 24 hours, the mould was ready for casting.
6. Some trimming and removing of silicon was done to clean the mould.
7. Acrylic resin (2/3) and its solvent (1/3) were taken enough to fill the mould.
8. More than 24hrs were taken for it to dry and then it was taken out of the mould.

Figure 72 A & B silicon mould material


Figure 73 Mixing of A & B


Figure 74 Pouring mounding material over master piece


Figure 75 Air bubbles were eliminated

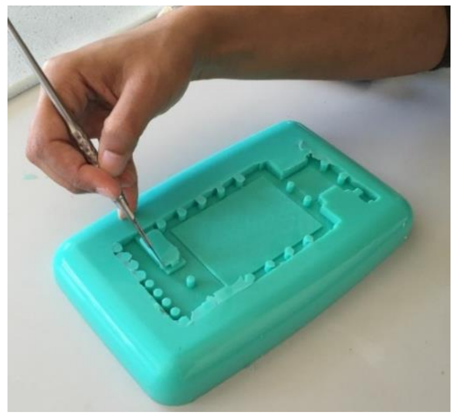


Figure 76 Cleaning of silicon mould

Figure 77 Weighing acrylic resin for the mould

Figure 78 Pouring acrylic resin

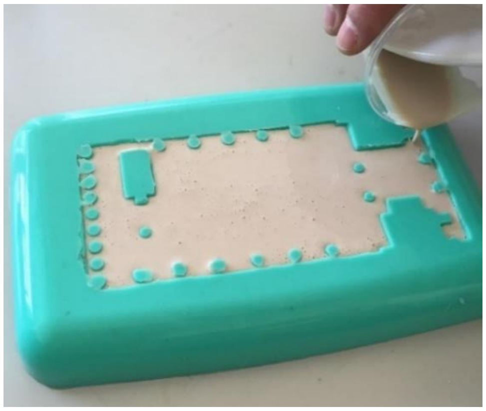


Figure 79 Setting acrylic resin

Results:

The results of the first experiment with the acrylic resin were not satisfying. Despite being nontoxic resin, the dried based lacked plastic properties. It result was brittle and heavy as seen in **Figure 81**. The narrow part of the base was not able to come out of mould. The base was porous and insertion of Lego pins was not feasible.

Figure 80 Moulded base out of mould

Figure 81 Acrylic resin base with broken edges

Experiment 2

The construction of the silicon mould was done in the same manner as in experiment 1 for the face.

1. The face was place on a plain surface and an open box was constructed using transparent plastic material.
2. The silicon mould material (A and B) was poured and after a day it was ready for moulding.
3. This time epoxy resin was used and poured into the silicon mould.
4. The resin dried within 15 minutes.

5. Carefully the moulded face was taken out and finished into a clean using sandpaper and file.

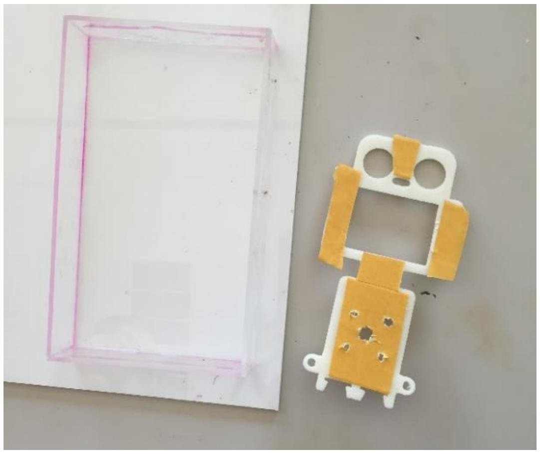


Figure 82 Master piece : face


Figure 83 Pouring silicon

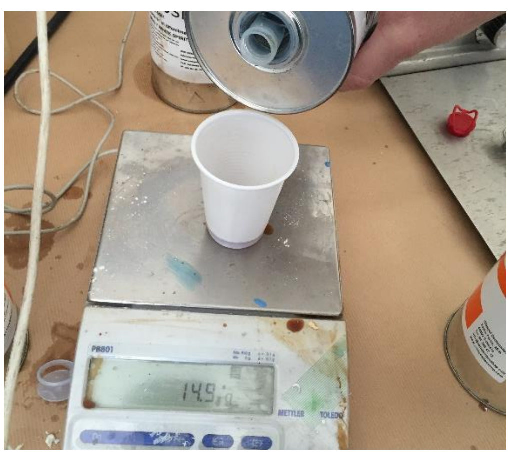


Figure 84 Weighung epoxy resin

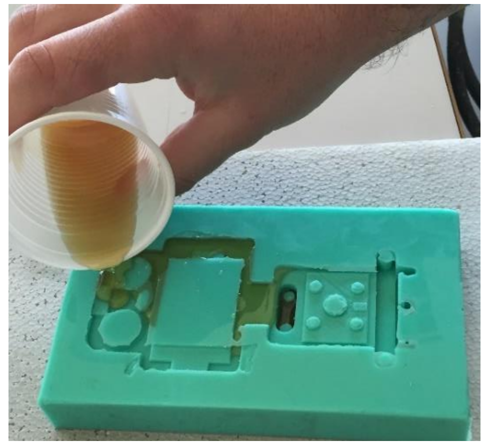


Figure 85 Pouring epoxy resin

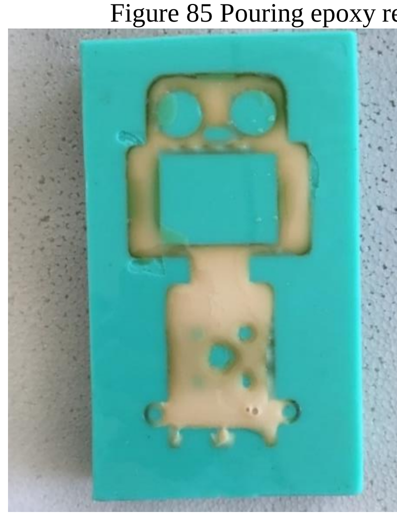


Figure 86 Mould setting

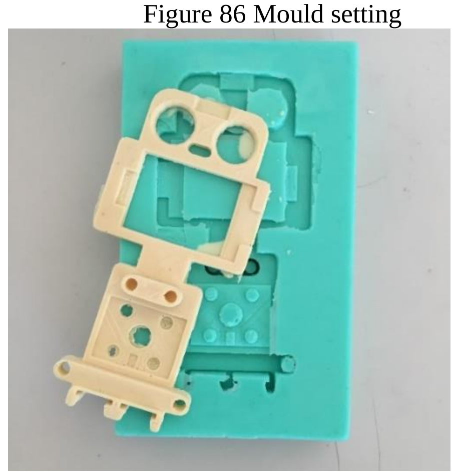


Figure 87 Epoxy resin dried

Results

The final product was exactly same as the master part. It was easy to take the face out of mould. The process was quick and the final product had all the plastic properties as required. The only drawback was that the resin was toxic. The all other properties of the resin were desirable. **Figure 89** shows the final design build with epoxy resin. These parts were thinner and were had all the details. Sanding these parts further made the edges smooth.

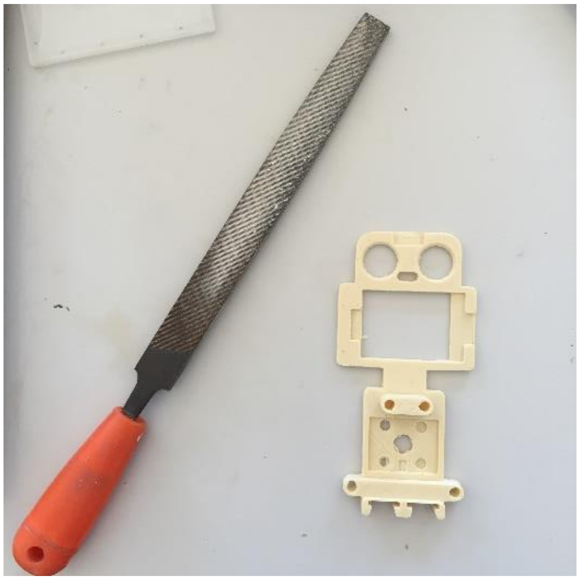


Figure 88 After sanding epoxy resin part

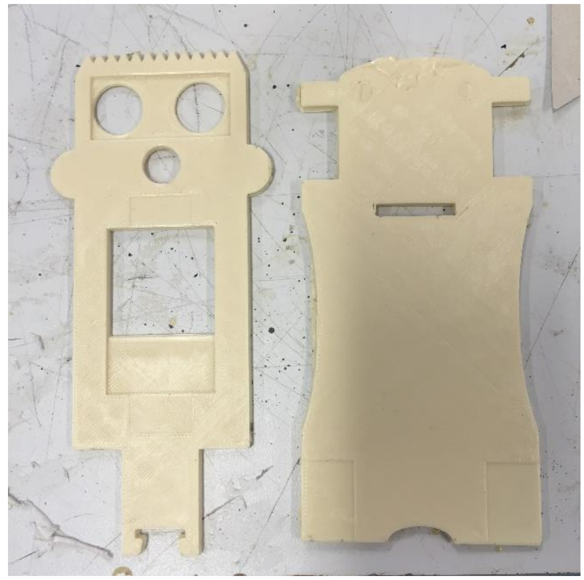


Figure 89 Final design (epoxy moulding)

Experiment 3

The construction of the silicon mould was done in the same manner as in experiment 1 and 2 but face and base mould was prepared in one. Doing this saved a lot of time as well as material. The steps are given below:

1. The silicon mould containing the negatives of both the parts was made in one.
2. The acrylic resin, both the powder and liquid in ratio 3:1 was taken.
3. Semi solid dough was prepared.
4. Hands were used to spread the mixture to avoid air bubbles.
5. This time glass fibre mat was used to enhance strength and to make the pieces less brittle as before in experiment 2.
6. The parts took 24 hours to cure and ready for sanding.
7. Glass fibre mixed in the dough gave cleaner appearance than the glass fibre mat spread on the acrylic mixture.
8. The additional acrylic mixture was poured during moulding on top of the mat.

Figure 90 Silicon mould with both the parts

Figure 92 Glass fibre mat on the base

Figure 91 Acrylic dough spread evenly

Figure 93 Acrylic resin with glass fibre mat

Results

The final moulded parts were of the desired thickness and shape **Figure 94**. Due to glass fibre mat introduced this time, made it less brittle. Acrylic resin because it is nontoxic even though it was not very plastic. The fibres made the appearance messy and the surface uneven. In the end, using acrylic resin in the form of dough mixed with glass fibre mat would provide school children a fun course.

Figure 94 Cured parts before sanding

3.3 Assembly

DYOR was made compatible with Lego pieces, pins, axles, cross beams could be attached to the main body for adding other technic Lego parts like front wheels or supporting wheels and arms which could be used as kickers as well as grippers. These could/were then attached to the front base holes and to the mini servo motors respectively. The following section shows the steps to build these parts.

The main two components and the sockets where the other electronics and Lego parts are to be fitted is shown in **Figure 95**

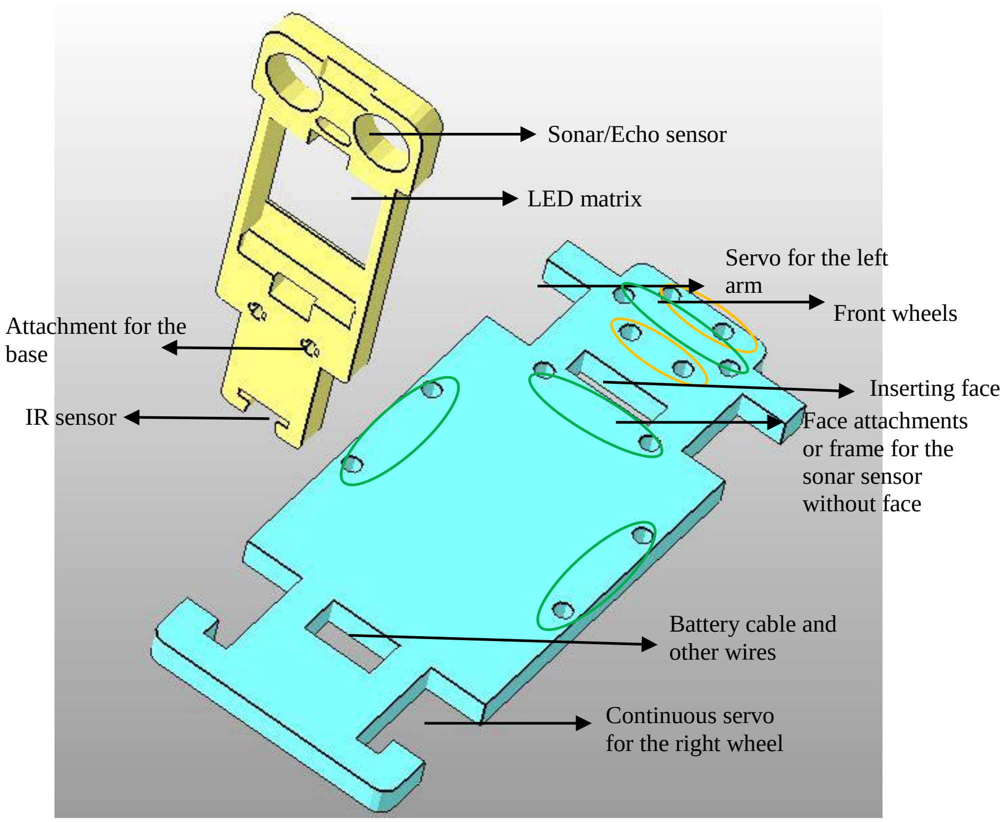


Figure 95 Main parts and their functions

3.3.1 Lego parts

A) Front Wheels

In Lego Mindstorms kit the caster wheels provided is often lousy and could hardly respond to the robot's movements and skids as they cause friction, slowing the robot down and affecting the measurements. The solution to this problem was a smooth Lego caster wheel, made of two tires that rotate freely to give ultimate movement control. The Lego Digital Designer (LDD) (LEGO Digital Designer build your dream model, n.d.) was used to for virtual construction and later used for generating building Instructions.
The components needed to build this are given in **Table 5**

The steps for building front/supporting wheels from the technic Lego parts are shown below **Figure 96**.

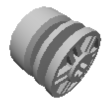
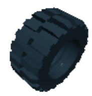
Brick	Name	Picture	Part	Color code	Quantity
4490127	RIM WIDE 18x14 W. CROSS Ø4.8		55982194 - Medium Stone Grey		2
4140670	TYRE NORMAL WIDE Ø30,4 X 14		3039126 - Black		2
4239601	1/2 BUSH		3212324 - Bright Yellow		4
4206482	CONN.BUSH W.FRIC./CROSSALE		4309323 - Bright Blue		2
4211086	CROSSAXLE 3M WITH KNOB		6587199 - Dark Stone Grey		4
4107085	ANGLE ELEMENT, 0 DEGREES [1]		3201326 - Black		2
4121667	DOUBLE CROSS BLOCK		3218426 - Black		2
Total:					18

Table 5 Lego parts for the wheels

Figure 96 Steps to build front wheel arrangement 1

The second options to attach wheels was to the single centre hole, this allows freer movement. The steps are shown below **Figure 97**.

Figure 97 Steps to build front wheel arrangement 2

B) Arms

This is very versatile and the simplest part of DYOR. The arms could be used as kickers (as during robot football) by placing the 3m part of the beam outwards or as grippers (it can grab onto an object) by placing those inwards. Using Technic Lego pieces as given in the **Table 6**. It was mounted onto a base, directly gluing them to the servo motor, can control the grabber's movements. The size of the jaws can be altered by using different bent Lego Technic Liftarms. The Lego Digital Designer (LDD) (LEGO Digital Designer build your dream model, n.d.) was used to for virtual construction and later used for generating building Instructions. The steps for building arms from the technic Lego parts are shown below. Repeat it for the other arm (**Figure 98**).

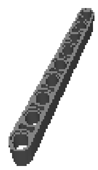
Brick	Name	Picture	Part	Color code	Quantity
4210757	TECHNIC 9M BEAM		40490199 - Dark Stone Grey		2
4140327	TECHNIC ANGULAR BEAM 3X7		3227126 - Black		6
4121715	CONNECTOR PEG W. FRICTION		278026 - Black		12
Total:					20

Table 6 Lego parts for arms

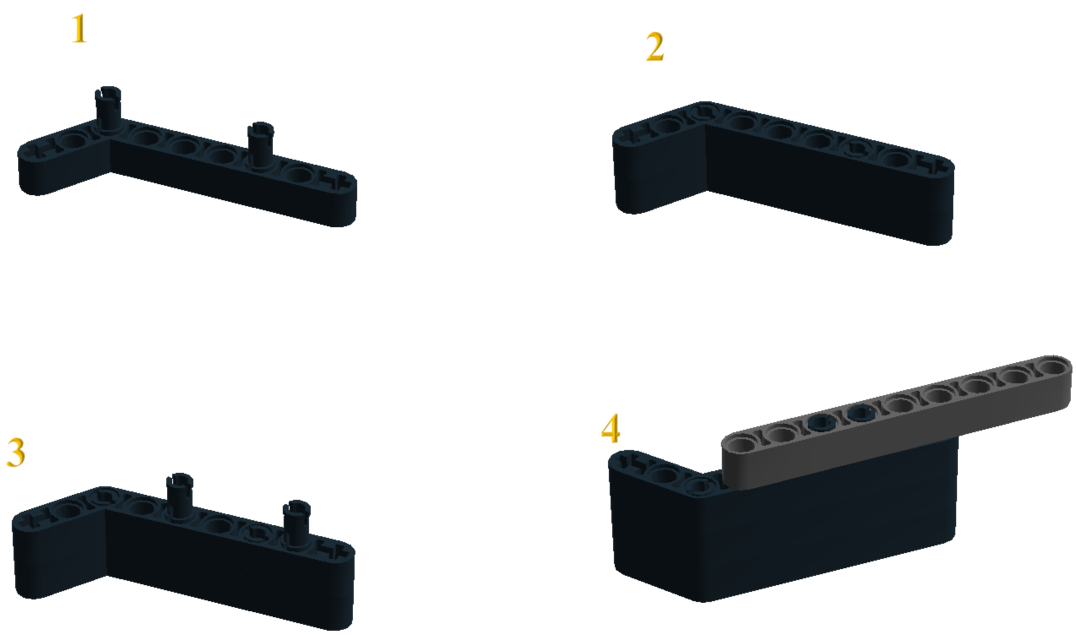


Figure 98 Steps to build DYOR arms

3.3.2 Model 1

DYOR could be done in many different ways where user's imagination is the limit. The kit of two sample or examples of "how to build your robot" and where to place its components. For model 1 things needed were:

- Base and Face
- Lego parts: Arms, wheels and front wheels
- Electronics: Arduino Nano with the extension board, sonar sensor, IR sensor, LED matrix, servos (2 9g servos and 2 continuous rotation servos), connecting wires and batteries.

The steps of build are explained through pictures below.

Note: The components shown in the pictures are CAD models and not actual components. They might differ from the real shape but they would give an approximate idea about fitting the components.

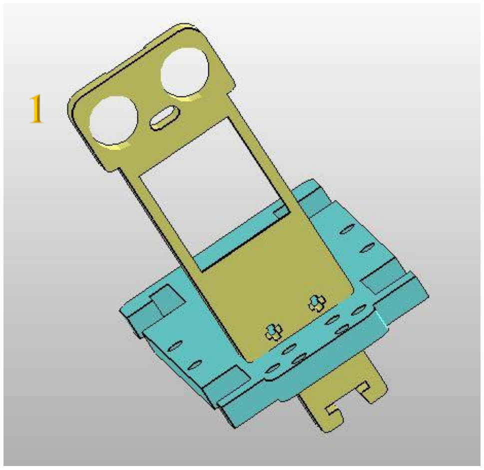


Figure 99 Base with the face inserted

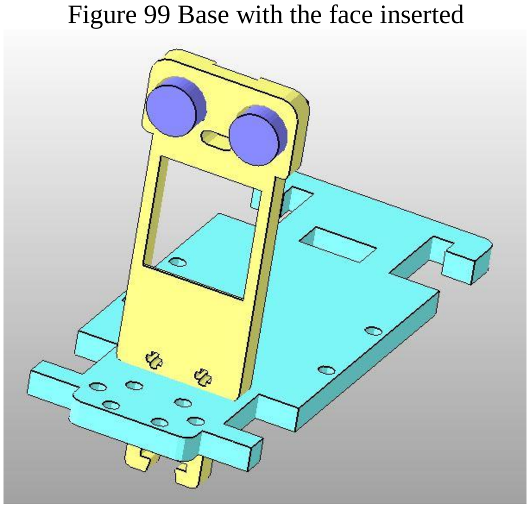


Figure 100 Face with the sonar sensor

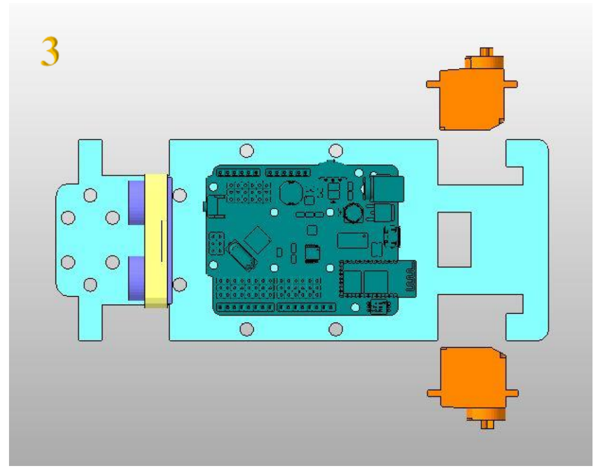


Figure 101 Motors for the wheels-in this socket

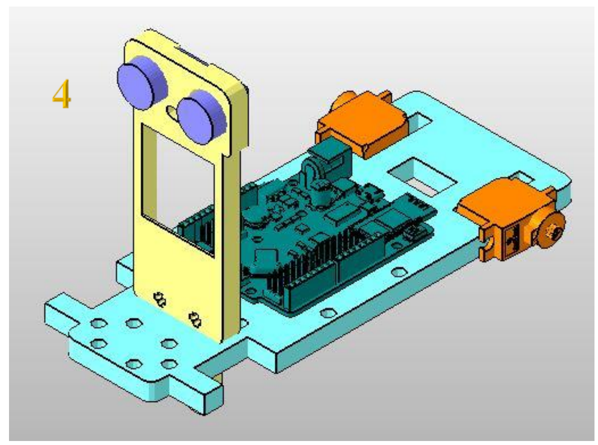


Figure 102 Base with the servo motors

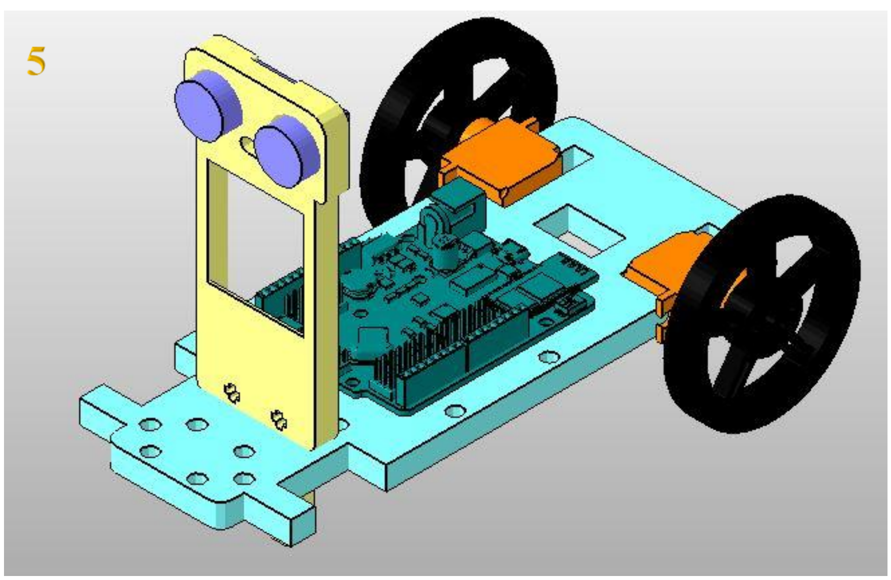


Figure 103 Wheels attached to the continuous rotation servos

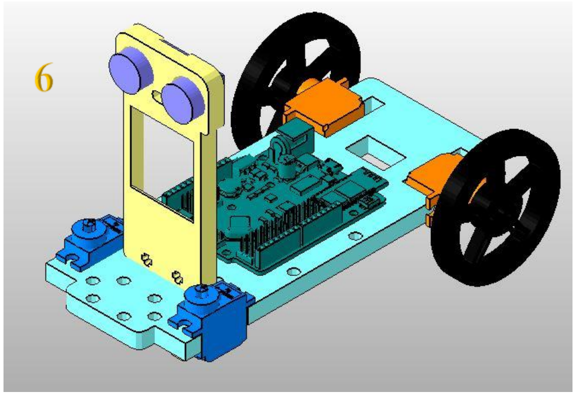


Figure 104 Servos for the arms in their sockets

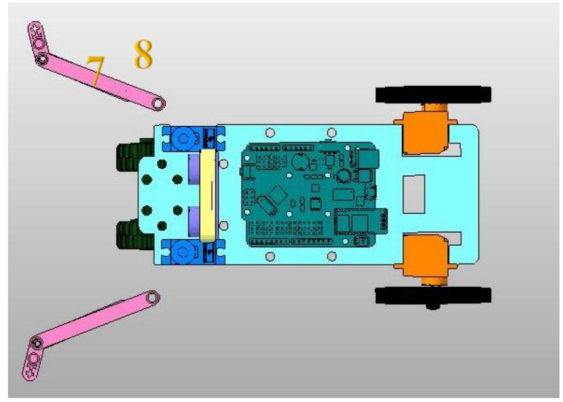


Figure 106 Lego arms attached to the servos

9

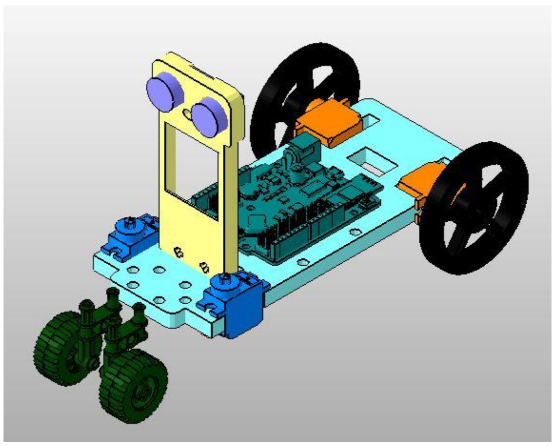


Figure 105 Front wheels to the base

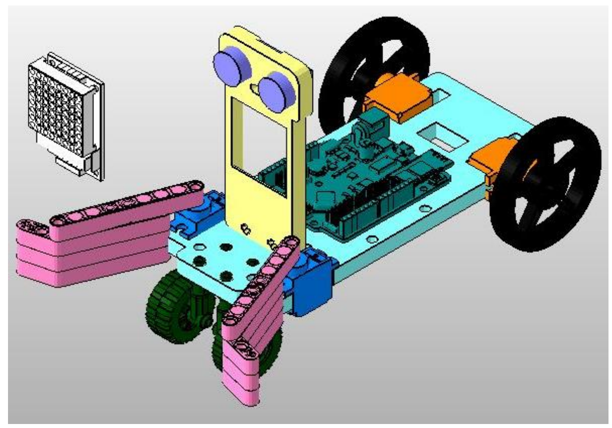


Figure 107 LED matrix in the face socket

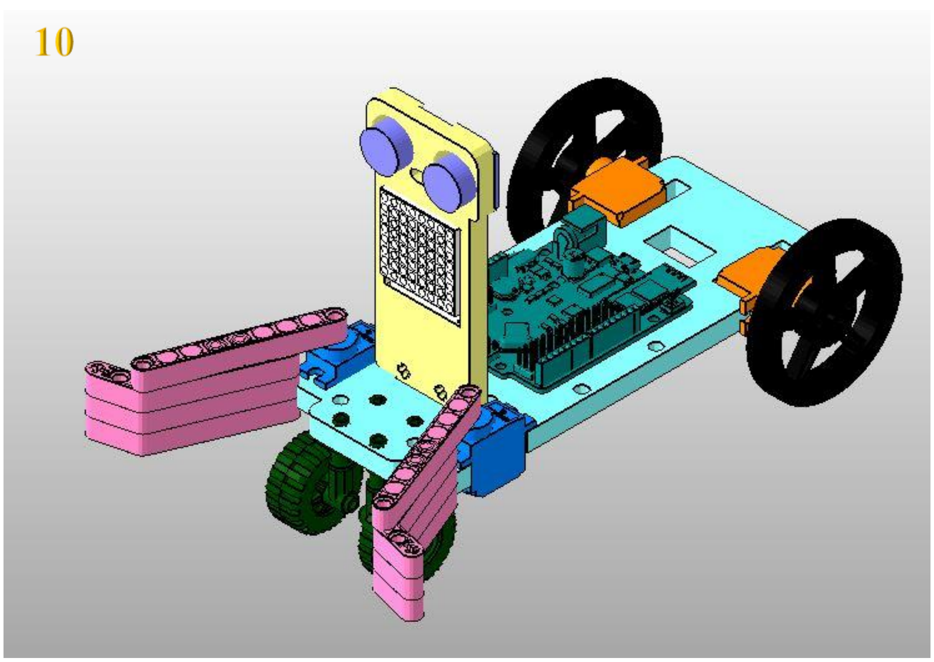


Figure 108 Model after fitting the above components

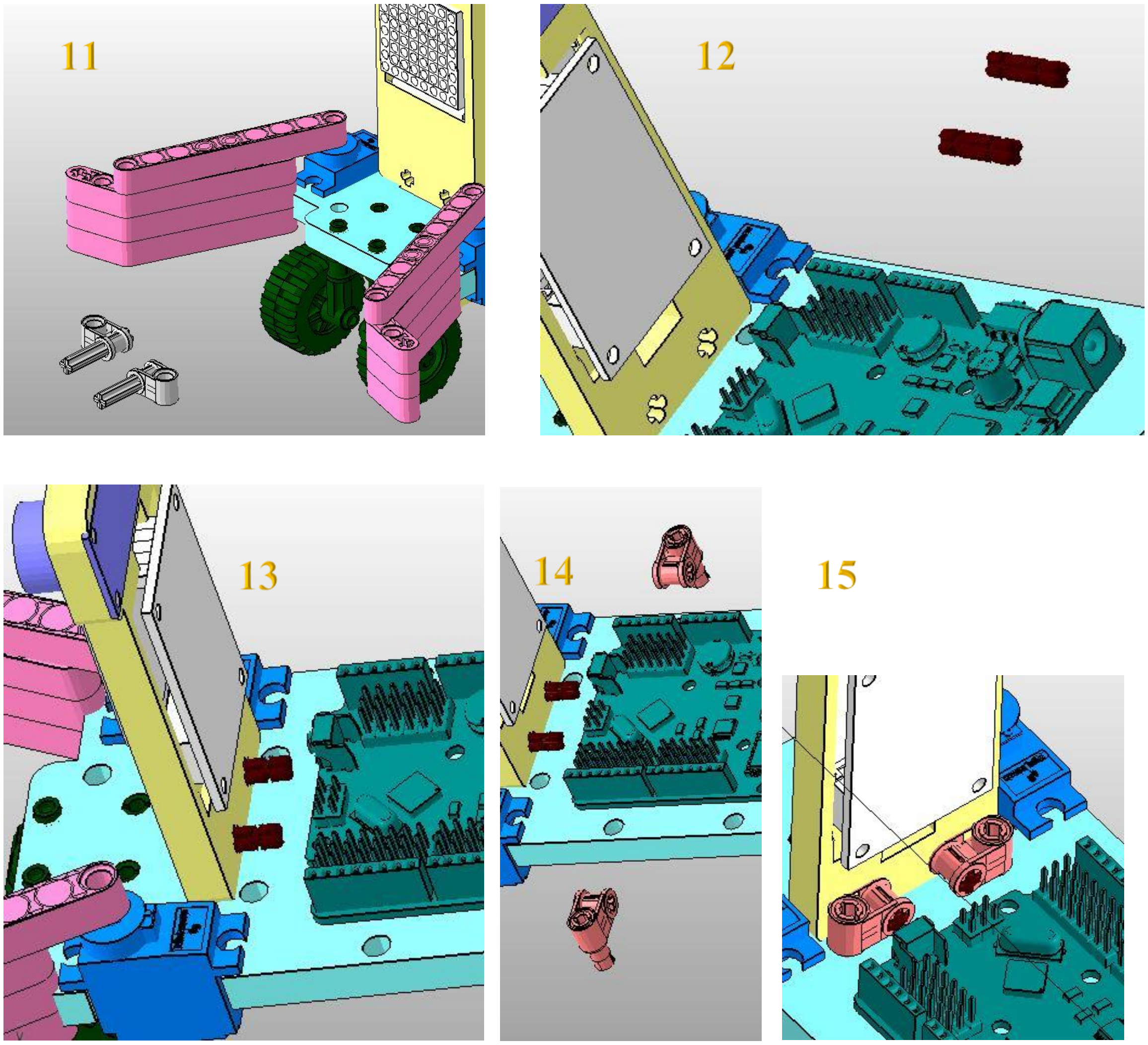


Figure 109 (11-15)Steps to attach face to the base by means of Lego pins and connectors

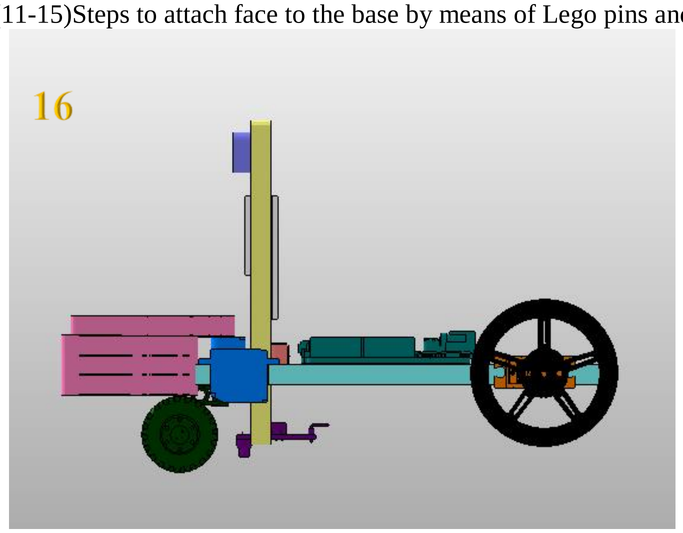


Figure 110 IR sensor in the cut in the face (facing downwards)

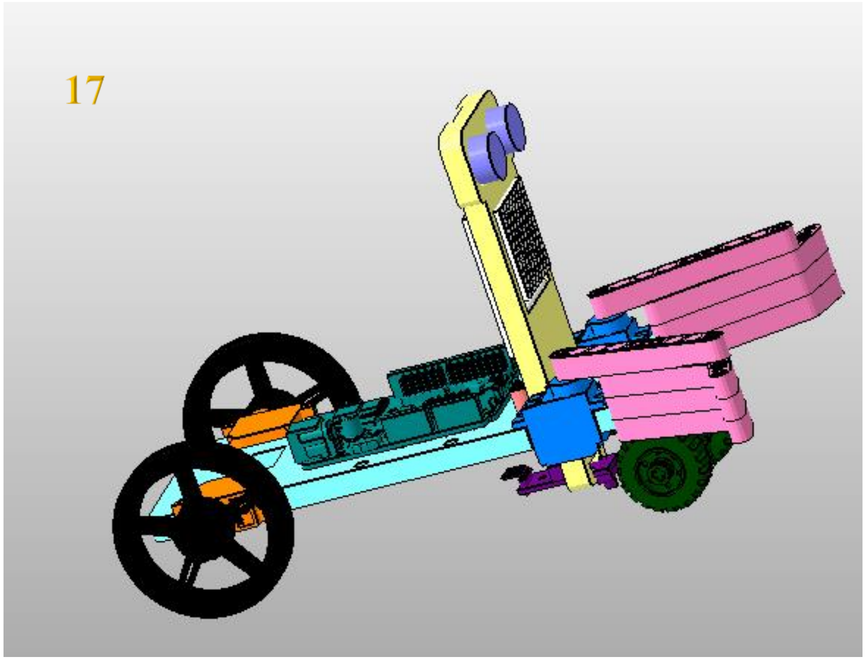


Figure 111 Model 1 with all the components

3.3.3 Model 2

Model 2 was another example to build DYOR using less components. It was simpler to build as it requires only the sonar sensor case to hold the sonar. It could be placed in the front by means of two holes (40mm apart) provided on the base. The base also has additional two sets of holes on the sides, if the user wants to mount three sensors.
The steps are shown below through CAD images.

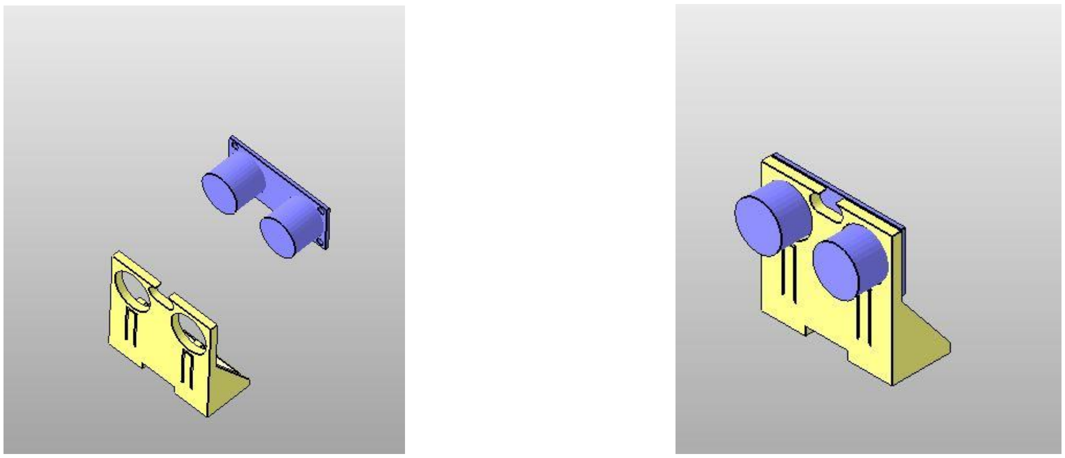


Figure 112 (Left) Sonar sensor and the holder(Right) sonar sensor in its case

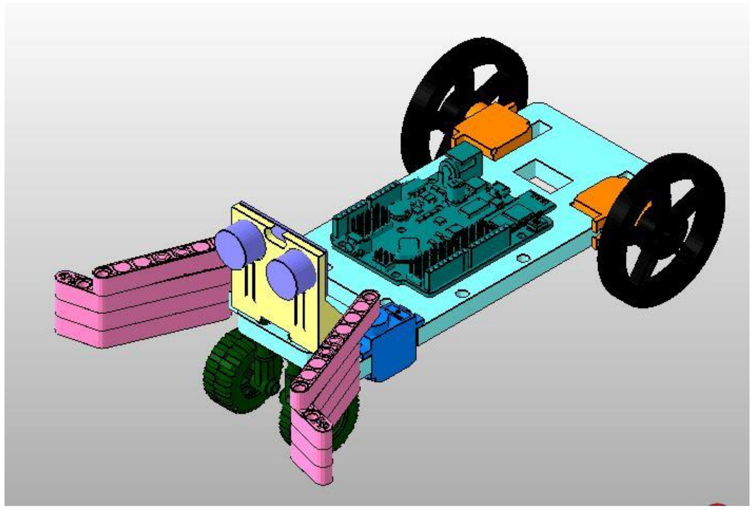


Figure 113 One echo sensor in model 2

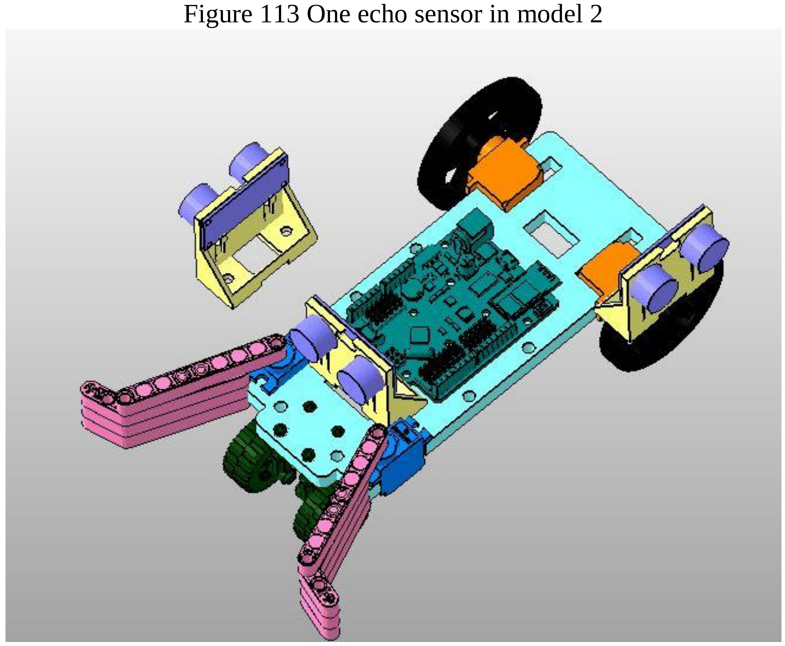


Figure 114 Three echo sensor in model 2

3.3.4 Schematics

The schematics of the electronic components were done using Fritzing. Shown in **Figure 115** is for the model 1 which uses arms, LED matrix and one sonar sensor. Bluetooth and IR sensor were also used. Using these components and their code, the robot could detect obstacles, use arms, move, and turn, follow a line (Black and white) and could connect the robot to their phones using Bluetooth. The use of these components are not mandatory, the user could add or remove according to his/her need.

- LED matrix: Displaying messages or emotions.
- Sonar sensor: Detecting obstacles
- IR sensor: Following a line (detecting black and white)
- Bluetooth: Connecting to the cellular phone

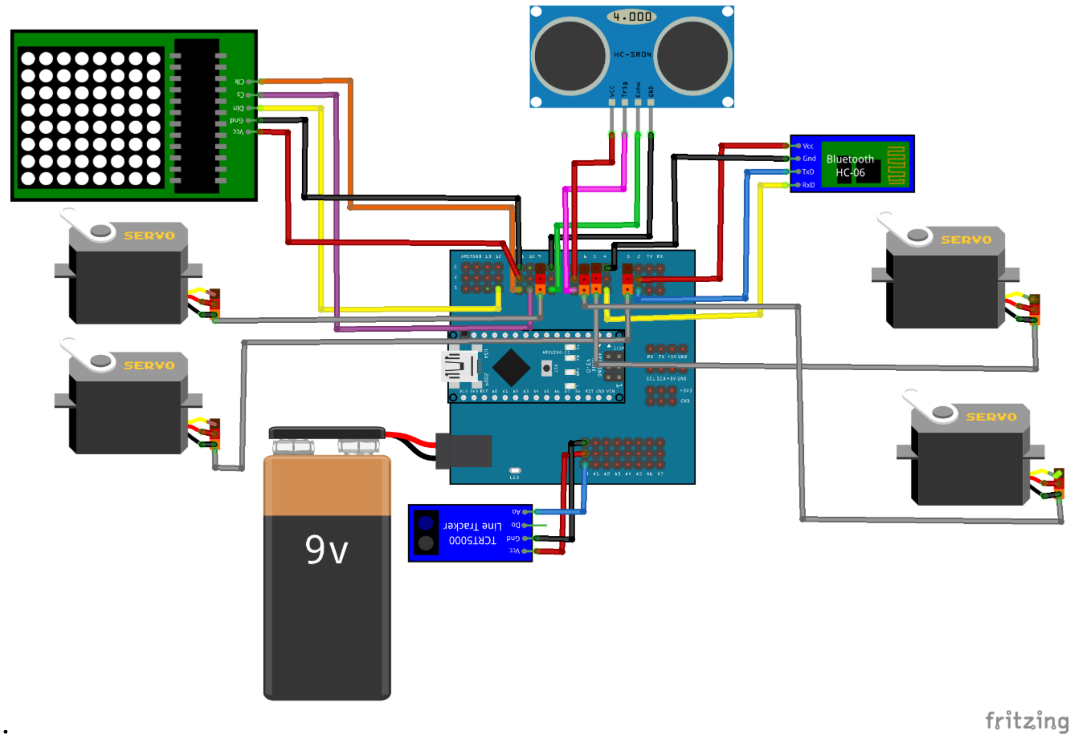


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Figure 115 Schematics for model 1

The other shown in **Figure 116** is for model 2 where DYOR uses one or more sonar sensors. Three sonar sensors provide better defection and obstacles could be avoided from the front, left and right of the robot. It also provides the possibility to connect the robot to the user's mobile phone using Bluetooth.

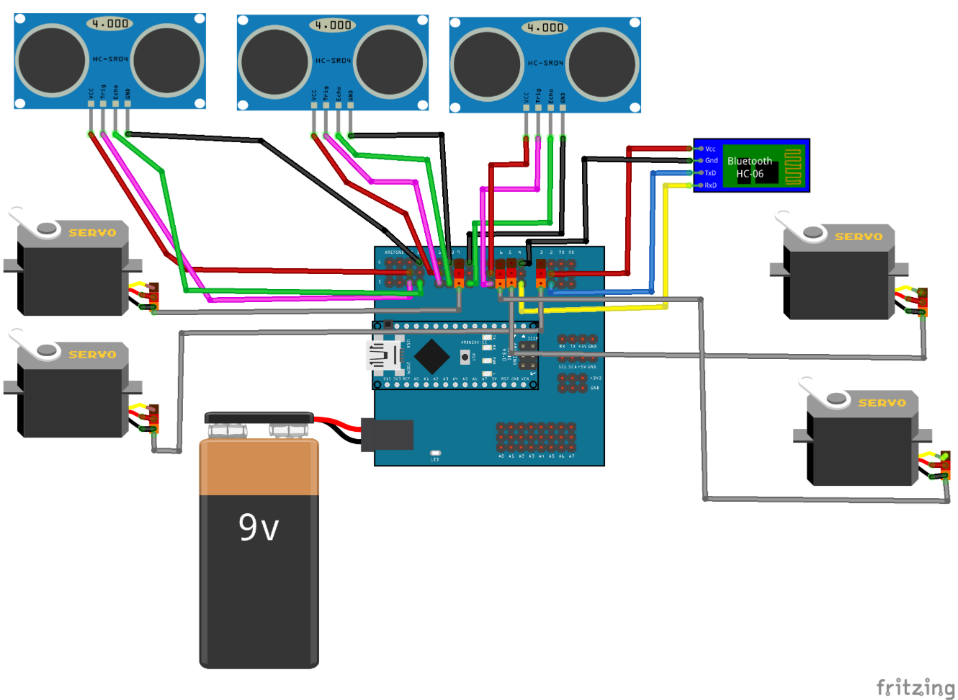

Figure 116 Schematics for model 2

3.4 Programming

In the absolute, programming was not a part of the project. Indeed, the programming part is meant to be done by the user. The aim of the project was only to provide the user the physical parts - required for his project. But, as the parts designed are meant to be used to build robots, it was valuable for the project to provide a robotic kit with come codes for the sensors used and also to test and demonstrate the viability of the final product.

The specifications were simple:

- The robot has to move on its own
- The robot has to detect obstacles and avoid them
- The robot has to be able to grab or kick an object using its arms.
- The robot could follow a line.
- The robot could display emotions.
- Optional: the robot has to be linked to a smartphone via Bluetooth, detect colours or buzzer

The software used for programming was Arduino for Arduino Nano.

3.4.1 Moving on its own

This first step consisted in learning about servo motors. They are the actors used to move the robot. A servo motor has a particular way to work. It uses frequency to code the position it has to reach. Arduino offers a simple library to control servo. This made the programming work for this part a lot easier. In this part the motors were calibrated to work at the same speed. For code used for this purpose see. The speed for both servos were set to 90 and the screw on the bottom of the motors were chanced until both motors were standing still. Thereafter was the speed set so the motors were supposed to move at the same speed and the calibration screw was changed again until it has moved as wanted? By increasing the speed of one and decreasing the speed of the other servo by same factor, the robot could turn in desired direction.

3.4.2 Detecting and avoiding obstacles

The detection of obstacles and the movement of the robot were programmed together. This way the robot would avoid the obstacles when it is moving or it could be programmed to knock objects over as in robo- wrestling.

The programming of the detection of obstacle using a sonar was also simplified by the use of the Arduino Sonar Library. This library allows a simple use of the echo, providing short function exiting directly the distance from the obstacle. This part was divided into two parts, first making a program working for one sensor and thereafter include another two or more sensors to get more accuracy.

A) One echo sensor

The code for the detecting and avoiding obstacles with one sensor can be seen in. The model 1 as described above makes use of one echo sensor but the user could use two or more. The code consists of three different parts. In the first part the Arduino Sonar Library NewPing was included, the pins for the sonar were defined and some declarations are made. Thereafter follows the setup and last was the main loop.

The main loop work in the following way. The motors were set in a start speed. Since one motor was turning clockwise and the other counter clockwise for same value, they were here set to 85 and 95. This made the robot move forward. Then the robot started to sense for obstacles. By constantly sending out sounds with the sonar a distance to an object could be calculated. This was made in a loop. Every time the sonar sense an object closer than 15 cm it started counting and if it did not feel anything close the counter was set to zero again. If something was detected closer than 15 cm three times in a row, the looping stopped and the speed of both motors were set to 90, which means standing still.

The speed of the motors was the set to rotate with the same speed, which made one wheel spins forward and one spin backward and the robot was turning. It would keep turning as long as it could sense one thing in the closest 15 cm during three out of five measurements. When nothing was detected in front the robot would start moving forward again.
This program was tested on an early prototype without 3D-printed parts with good result. But since there is a problem to detect objects that are not placed immediately in front of the sensor there was sometimes problem that it did not sense an object good enough. To be able to make better predictions another two echo sensors were included.

B) Three echo sensors

The basics of the program using three echo sensors come from the previous program with three sensors. The model 2 gives the possibility to use one or three sonar sensor as well. The code can be seen in. The main difference was that the robot could detect objects in a wider angle and is therefore less likely to bump into objects. The start of the program was the same as above and starts by setting speed to the motors and sensing with the sensor placed in the middle. When an abject is detected by the centre sonar three times in a row the motors will stop.

Thereafter will the two sensors on the sides, sonarLeft and sonarRight start sense for objects. They will make 10 readings and calculate the mean value. If the right sensor detects an object closer than 20 cm the zone is set to zone 3 and if the left sensor detects something the zone is set to zone 2. If none of the sensors feel the object, the zone is set to zone 1.

Then the robot will start to turn, but this time it takes into account if there in an object detected in zone 2 or zone 3 as well. If an object is found in zone 3, the robot will turn to the left and otherwise it will turn to the right. See **Figure 117** for definition of zones.

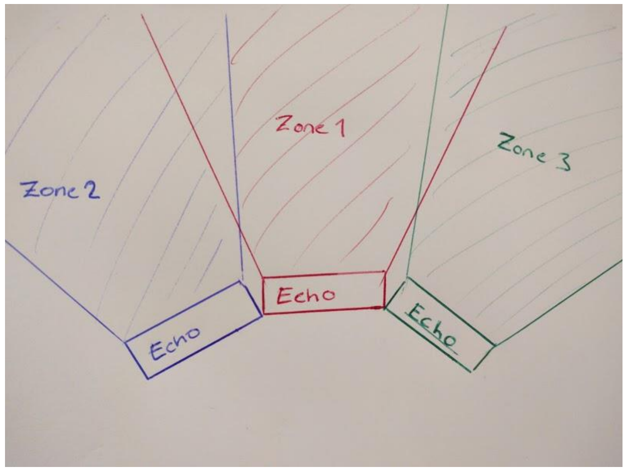

Figure 117 Range diagram for model 2

3.4.3 Follow a line

This feature was implemented even though it was not in the initial plan. Following is an explication of the code. Before starting readings of reference values for black and white colour were made. During perfect conditions white reading should give a value of 0 and black 1023, but the readings of the actual surface used gave the value of white to around 600 and for black around 865.

In the beginning a standard speed is set, normally so that the robot should move straight forward. Here the speed for left is called sL and for right sR. Thereafter the value of the black and white senor is read. Then the error is calculated as in Equation 1 given below.

$$error = value - \frac{black + white}{2}$$

This means that if the sensor is placed straight on the black and white line the error should be zero, while if it is placed more on white than black the error will be negative and if it on the black side it should be positive.

In order to follow the line the speed of each wheel will be given by $(sL - k \cdot error)$ respectively $(sR - k \cdot error)$, where k is a constant fitted to correct the turning. In this example k was given to 0,010. This means that if the robot is placed more on white than black it will turn to the right, and if it is placed more on the black than the white it will turn to the left and trough this stay on top of the black and white line.

3.4.4 Display Emotions

The LED matrix provides an excellent platform to display messages but setting the LEDs to high and low voltages. By setting certain LEDs to high and others to low, forming a shape equivalent to “happy; or “sad” mouth. The Arduino library could be used for reference.

3.4.5 Grab and kick objects with arms

The gripper was designed during the project and is driven by a DC motor. This motor however works a bit different from the motors driving the wheels. This motor is given a position that it goes to, this position goes from 15 to 105. The arms were implemented in an application where it is working together with the echo sensor which then decides whether it should be opened or closed.

3.4.6 Bluetooth Setup

When designing started a copy of the already existing application were downloaded. The app was made by a former UPV student. To use the MIT App inventor, as the high students do not have to have lot of app designing experience.

There was a user interface selection list on the left where different features were added either on the interface window or as a background feature. The buttons that were used is simply placed on the screen and with spacers in between the right position. The application had already an interface with some buttons but these were changed from text buttons to picture buttons (emoticons) to give a simpler look to it. The buttons connected the device to the Arduino/BQ – board for example blue is for connecting and red is for disconnecting. In the upper right corner is the close application button, it is made as a simple x. On the bottom two buttons controlling the arms were placed. There were two background features, one for the accelerometer sensor and one was for the Bluetooth client. The accelerometer is a non-visible component that can detect shaking and measure acceleration approximately in three dimensions. These sensors send information about the movement of the phone which is it interprets to movement.

The applications name was DYOR and could be downloaded from the app inventor using a QR-code. The coding of the Arduino is necessary to be able to communicate with the smartphone. Smartphone and Arduino use a specific 'protocol' to communicate. The protocol defines the way both sides understand each other when communicating. It allows the user to change the application, for example adding buttons or functions, without having to change anything on the Arduino program. For every action on the smartphone, a line of characters was sent. The line start with an opening character. Then follow groups of 2 bytes, first one containing a number corresponding to the Arduino pin linked to the action, for example if 'go forward' then the two servos located pin 9 and 11 will be activated. The first byte will be 9) and the second one corresponding to the 'amount of power' put into the pin (analogWrtite between 0 and 255). Finally, when all the actions have been translated into groups of two bytes, a closing character is sent. This protocol is also conceived to ask data to the Arduino. If the user wants to receive data from its robot such as temperature, speed, battery level etcetera, it can ask the Arduino using the command '00' or '03' followed by the numbers of pin and finally by the pins requested. The Arduino will then read the value of these pins (analog or digital) and send it to the Android application using the same protocol. Details of the Arduino/Android communication/ sending instructions such as emoticons (to Led matrix to display them) or music (to buzzer) are seen in **Figure 118** .

Figure 118 Example of exchange of instructions from mobile to DYOR

In the android application side, the accelerometer is used to sense the tilt of the smartphone and translate it into orders for the Arduino. An illustration of the connection is shown in **Figure 119**.

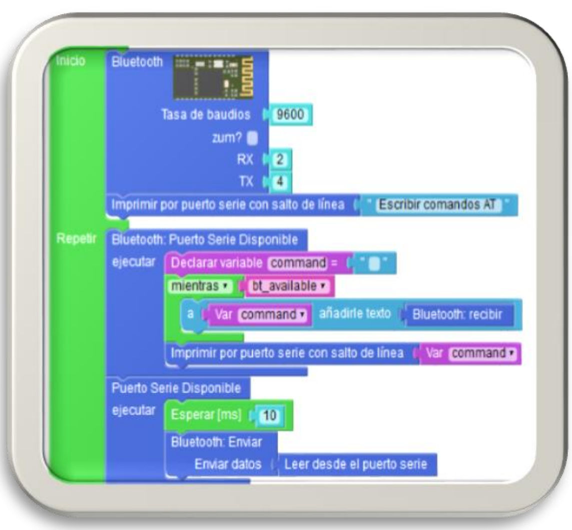

Figure 119 App inventor for conveying order to DYOR via Bluetooth

There was also a button designed to move the arms. Those orders will then be translated to fit in the protocol and then send to the Arduino.

CHAPTER 4

Results

The price of the product is significantly lower than of the competitors and still provides the same amount of sensors and actuators. This product has from the start been aimed not to be mass produced or be a money earning product. But to be a tool for schools or hobbyists to develop their programming, problem solving and creativity skills. In the future an open source library with blueprints of the modules, examples of coding and tutorials could be provided for the users. This is the reason why no big effort will be put on to make a marketing plan for the product. The school that we have been cooperating with had a problem that the current product was too expensive so the goal was to meet the need in that aspect. The product can be used with not only Arduino boards but also similar products based on the original Arduino. The product also gives the possibility of using multiple arrangements or types of front/turning wheels as seen in **Figure 120**, **Figure 121** and **Figure 122**.

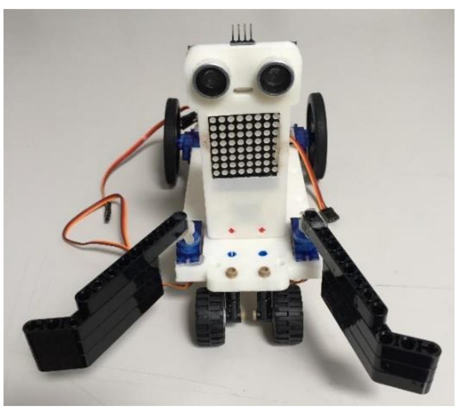

Figure 120 Double hole front wheels

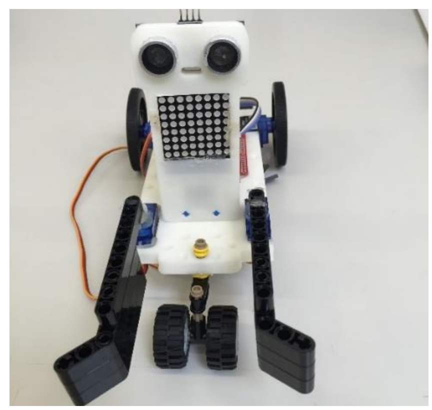

Figure 121 Single hole front wheels

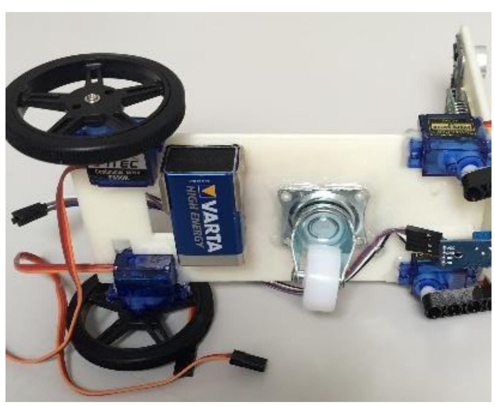

Figure 122 Castor wheel

DYOR could be made of various materials: acrylic, wood, epoxy or ABS material. Some of the results of the project using different materials and techniques are shown in **Figure 123**, **Figure 124** and **Figure 125**. The product was tested during the annual educative fair in Valencia on 14 May,2016, where a lot of kids (8 years and above) were present. The activity of creating DYOR attracted not only the kids but their parents as well. Some build the silicon mould while others poured the resin. They were so interested in building their own robot from the very beginning that they were ready to come the next day as well. There was also a long queue to fit electronics into the body as seen in **Figure 126**. The final outcome of DYOR moving, singing and displaying symbols was appreciated by the mayor of the city, parents, teachers and kids (**Figure 127**). The poster of the event could be found on Appendix D.

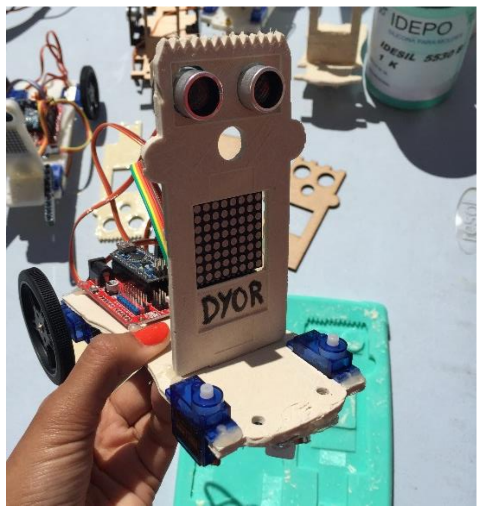

Figure 123 DYOR: acrylic resin (Moulding)

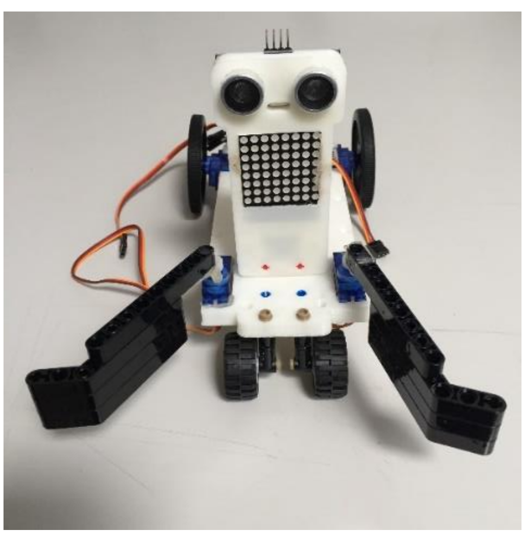

Figure 124 DYOR: ABS material (3D printing)

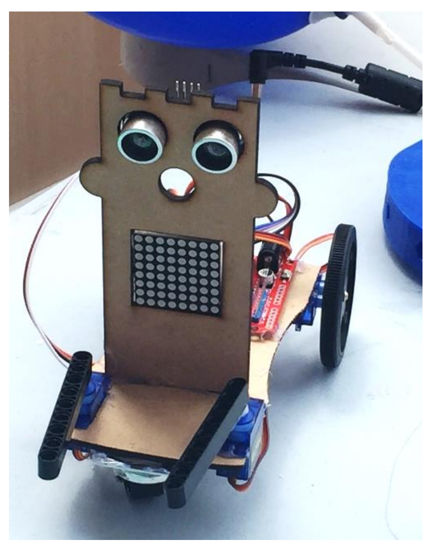

Figure 125 DYOR: Plywood (Laser cutting)

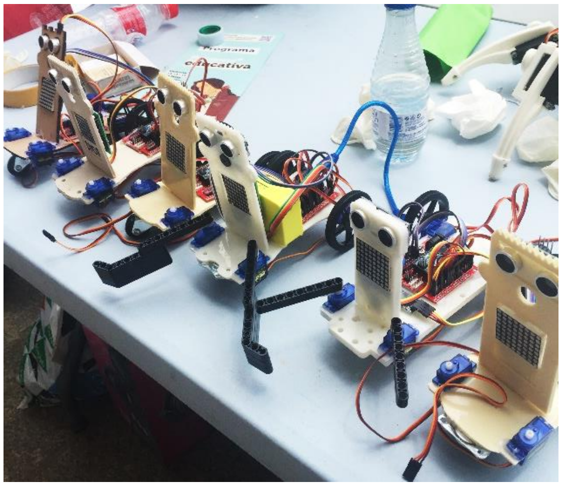

Figure 126 DYOR made by kids at Primavera Educativa

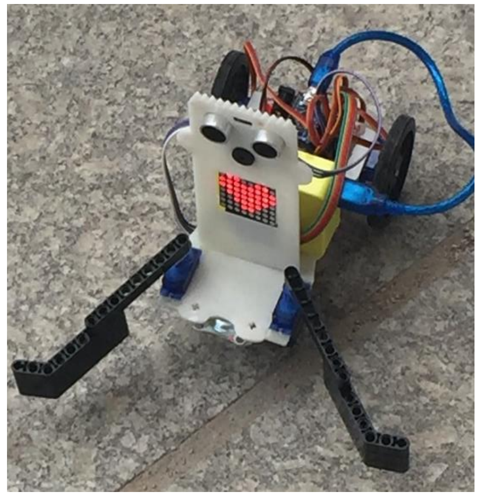

Figure 127 DYOR moving and displaying symbols

4.1 Cost Analysis

Here the cost this project was put together and analysed for a price of manufacturing. One important fact, this analysis assumes that the buyer has an access to a 3D printer. The price was a manufacturing price for the user and not a potential selling price that a company who is devoted to profit it would have. There was zero profit for us with this price. The analysis shows that the difference between the robots in the project compared to the robots on the market are notable and quite significant. The difference also shows that the robots in the market could have tougher competition and that would lead to reduced prices. Important reminder that the flexibility, ease of manufacturing and functions were also taken into consideration.

For this analyse the research was done with the internet, as desk research. Different websites were researched for the robot to get the best price without reducing the quality of the product. To analyse the costs it was within interest to not only look for one solution on the robot because the robot may contain different hardware and functions. The different costs and sources for the information will be provided for readers potentially interested. In this study the total cost has been divided to two different options for the robot. These vary in the functions and part they require and use. The cost analysis for:

- **Preliminary Solution**
- **Adapted Solution**: Model 1 and Model 2 with
    - 3D printing
    - Laser Cutting
    - Moulding

4.1.1 Cost of the preliminary solution

The analysis was divided in four different categories to show the possibility and flexibility on this project.

1. "Bq zum core" was the simplest of them even if it is not the cheapest one. This one contains all the necessary components for the robot to be able to move forward (Bq board, two servos, cables, AA batteries). In addition to that it is also equipped with sonar, color sensor, photocell, ohm resistor IR emitter, and Photo transmitter and cover material.
2. "Bq zum core + gripper" contains all the above and then the necessary parts for the gripper (cables, small servo).
3. "Arduino" this option was added to reduce price for the people interested. With this option the price includes all the basics except that an Arduino and Bluetooth sensor is replacing the Bq board.
4. "Arduino + gripper" is the more advanced option with equipped with gripper and all the parts needed for it to work and Arduino as base.

The electrical components needed to make the robots were commonly used and could be ordered online or bought in a local electronics store, see **Table 7**. The prices may vary from website to website but in this cost analyse the prices were seen as the lowest possible at that moment. If ordered in bigger numbers, the prices might be reduced.

Component	**Price per unit**
BQ Zum core	34,90 €
Arduino Nano V3.0 + Expansion shield	7,40 €
Bluetooth link	5,28 €
sonar sensor	1,95 €
Big servo motor	6,18 €
Color sensor - RGB LED	1,52 €
Color sesor - photocell LDR	1,50 €
Color sensor - 330 ohm resistor	1,00 €
IR emitter & Photo transmitter	0,60 €
Buzzer	0,97 €
AA battery	0,61 €
Cable	0,07 €

Table 7 Electrical components for the robot

Other things to be added to the robot were LEGO parts and printed parts. The LEGO parts were necessary for the frame of the robot and also to attach different functions. The parts needed for the prototypes are found in the calculus sheet and provided with prices, seen in the tables below. The idea was that the basic robot (as required my school) needed at least these parts but of course the user can design a robot with the same functions with other LEGO parts or with more or less parts. On the website (Looking for a replacement part?, n.d.) more or less all LEGO parts could be found and ordered as needed. This was a cheaper choice than to buy big LEGO kits that may not include everything needed.

Printed parts were needed for the main body and the cases for all the sensors. Blueprints is planned to be available online in a library.
Material needed for the printed parts is calculated in **Table 8**. In the calculus table with prices and amount of plastic separated for each part. The time taken to print a specific part was also measured.

Block	Units	Amount of plastic / m	Price for printing material	Print time / min
Main body block	1	24,49	2,60 €	315
Servo block	2	6,80	0,72 €	93
Battery block	1	9,49	1,01 €	118
Echo sensor block	1	1,56	0,17 €	22
BW case	1	1,47	0,16 €	27
Colour	1	1,38	0,15 €	23
Phone case	1	13,19	1,40 €	187
Gripper	1	9,71	1,03 €	138
Small sensor	1	1,01	0,11 €	17
Total	**10**	**69,10**	**7,33 €**	**940**

Table 8 Printed parts

The cost was calculated with the price of on cartridge used in a 3D-printer which contain 240m of ABS plastic string, this costs **25,45€**. The prices were found online (Catalog:filament, n.d.).
In this cost analysis the workload to develop this product was not taken into consideration because it was a project for educational purposes for the developers and the profit/wages were not a priority in this project. The final prices for the four different robots include a programmable brain and all the parts needed to build it. Underneath is a list of the parts, prices and how many units of each is needed, see **Table 9**. The total price for the robots is shown at the bottom of the table.

Line following robot			**Line following robot**		
With BQ Zum core			with Arduino Nano V3.0		
Part	**units**	**Price**	**Part**	**units**	**Price**

BQ Zum core	1	34,90 €	Arduino Nano V3.0 + Expansion shield	1	7,40 €
Sonar sensor	1	1,95 €	Bluetooth link	1	5,28 €
Big servo motor	2	6,18 €	Sonar sensor	1	1,95 €
small servo motor	0	2,62 €	Big servo motor	2	6,18 €
Colour sensor - RGB LED	0	0,00 €	small servo motor	0	2,62 €
Colour sensor - photocell LDR	0	0,00 €	Colour sensor - RGB LED	0	0,00 €
Colour sensor - 330 ohm resistor	0	0,00 €	Colour sensor - photocell LDR	0	0,00 €
IR emitter & Photo transmitter	1	0,60 €	Colour sensor - 330 ohm resistor	0	0,00 €
Buzzer	0	0,97 €	IR emitter & Photo transmitter	1	0,60 €
AA battery	4	0,61 €	Buzzer	0	0,97 €
Cover material	1	1,00 €	AA battery	4	0,61 €
Cable	7	0,07 €	Cover material	1	1,00 €
Main body block	1	2,60 €	Cable	7	0,07 €
Servo block	2	1,44 €	Main body block	1	2,60 €
Battery block	1	1,01 €	Servo block	2	1,44 €
Echo sensor block	1	0,17 €	Battery block	1	1,01 €
LEGO Wheel Rim Ø30 x 20	2	0,02 €	Echo sensor block	1	0,17 €
LEGO Black Tyre Balloon Wide Ø56 X 26	2	1,00 €	LEGO Wheel Rim Ø30 x 20	2	0,02 €
LEGO Tyre for Wedge	1	0,09 €	LEGO Black Tyre Balloon Wide Ø56 X 26	2	1,00 €
LEGO Wedge Belt Wheel	1	0,06 €	LEGO Tyre for Wedge	1	0,09 €
LEGO Long Pin with Friction	4	0,04 €	LEGO Wedge Belt Wheel	1	0,06 €
LEGO Bushing	3	0,03 €	LEGO Long Pin with Friction	4	0,04 €
LEGO Half Bushing	3	0,03 €	LEGO Bushing	3	0,03 €
LEGO Axle to Pin connector	5	0,05 €	LEGO Half Bushing	3	0,03 €
LEGO Beam Bent 90 degrees, 3 and 5 Holes	4	0,12 €	LEGO Axle to Pin connector	5	0,05 €

LEGO Beam 2 x 4 Bent 90 Degrees	2	0,06 €	LEGO Beam Bent 90 degrees, 3 and 5 Holes	4	0,12 €
LEGO Beam Frame 5 x 7	1	0,94 €	LEGO Beam 2 x 4 Bent 90 Degrees	2	0,06 €
LEGO Technic Pin	28	0,28 €	LEGO Beam Frame 5 x 7	1	0,94 €
LEGO Axle 6	2	0,02 €	LEGO Technic Pin	28	0,28 €
LEGO Axle 4	3	0,03 €	LEGO Axle 6	2	0,02 €
LEGO Axle 2	2	0,02 €	LEGO Axle 4	3	0,03 €
LEGO Beam 15	2	0,36 €	LEGO Axle 2	2	0,02 €
LEGO Black angle Connector	1	0,02 €	LEGO Beam 15	2	0,36 €
LEGO Beam 7	1	0,04 €	LEGO Black angle Connector	1	0,02 €
LEGO beam 5	0	0,00 €	LEGO Beam 7	1	0,04 €
		57,33 €	LEGO beam 5	0	0,00 €
					35,11 €

Table 9 Parts list and total price for lion prototype

Underneath shows the prices and parts for the robot including the gripper, see **Table 10** This means more LEGO parts and some more electrical components.

Gripper robot with colour sensor			**Gripper robot with colour sensor**		
With BQ Zum core			With Arduino Nano V3.0		
Part	**Units**		**Part**	**Units**	**Price**
BQ Zum core	1	34,90 €	Arduino Nano V3.0 + Expansion shield	1	7,40 €
Sonar sensor	1	1,95 €	Sonar sensor	1	1,95 €
Big servo motor	2	6,18 €	Big servo motor	2	6,18 €
small servo motor	1	2,62 €	small servo motor	1	2,62 €
Colour sensor - RGB LED	1	1,52 €	Colour sensor - RGB LED	1	1,52 €
Colour sensor - photocell LDR	1	1,50 €	Colour sensor - photocell LDR	1	1,50 €
Colour sensor - 330 ohm resistor	3	3,00 €	Colour sensor - 330 ohm resistor	3	3,00 €
IR emitter & Photo transmitter	1	0,60 €	IR emitter & Photo transmitter	1	0,60 €
Buzzer	1	0,97 €	Buzzer	1	0,97 €
AA battery	4	0,61 €	AA battery	4	0,61 €

Cover material	1	1,00 €	Cover material	1	1,00 €
Cable	14	0,07 €	Cable	14	0,07 €
Main body block	1	2,60 €	Main body block	1	2,60 €
Servo block	2	0,72 €	Servo block	2	0,72 €
Battery block	1	1,01 €	Battery block	1	1,01 €
Echo sensor block	1	0,17 €	Echo sensor block	1	0,17 €
Colour	1	0,16 €	Colour	1	0,16 €
Phone case	1	1,40 €	Phone case	1	1,40 €
Gripper	1	1,03 €	Gripper	1	1,03 €
Small sensor	1	0,11 €	Small sensor	1	0,11 €
LEGO Wheel Rim Ø30 x 20	2	0,02 €	LEGO Wheel Rim Ø30 x 20	2	0,02 €
LEGO Black Tyre Balloon Wide Ø56 X 26	2	1,00 €	LEGO Black Tyre Balloon Wide Ø56 X 26	2	1,00 €
LEGO Tyre for Wedge	1	0,09 €	LEGO Tyre for Wedge	1	0,09 €
LEGO Wedge Belt Wheel	1	0,06 €	LEGO Wedge Belt Wheel	1	0,06 €
LEGO Long Pin with Friction	6	0,06 €	LEGO Long Pin with Friction	6	0,06 €
LEGO Bushing	3	0,03 €	LEGO Bushing	3	0,03 €
LEGO Half Bushing	3	0,03 €	LEGO Half Bushing	3	0,03 €
LEGO Axle to Pin connector	4	0,04 €	LEGO Axle to Pin connector	4	0,04 €
LEGO Beam Bent 90 degrees, 3 and 5 Holes	4	0,12 €	LEGO Beam Bent 90 degrees, 3 and 5 Holes	4	0,12 €
LEGO Beam 2 x 4 Bent 90 Degrees	2	0,06 €	LEGO Beam 2 x 4 Bent 90 Degrees	2	0,06 €
LEGO Beam Frame 5 x 7	1	0,94 €	LEGO Beam Frame 5 x 7	1	0,94 €
LEGO Technic Pin	40	0,40 €	LEGO Technic Pin	40	0,40 €
LEGO Axle 6	2	0,02 €	LEGO Axle 6	2	0,02 €
LEGO Axle 4	3	0,03 €	LEGO Axle 4	3	0,03 €
LEGO Axle 2	2	0,02 €	LEGO Axle 2	2	0,02 €
LEGO Beam 15	4	0,72 €	LEGO Beam 15	4	0,72 €

LEGO Black angle Connector	1	0,02 €	LEGO Black angle Connector	1	0,02 €
LEGO Beam 7	1	0,04 €	LEGO Beam 7	1	0,04 €
LEGO beam 5	2	0,06 €	LEGO beam 5	2	0,06 €
		65,86 €			**38,36 €**

Table 10 Parts list and total price for crab prototype

4.1.2 Cost of the adapted solution

One of the main reason to build DYOR from the first prototype of LEDURA was that the new model should be cost effective for medium to large scale production. The use number of electronic sensors and Lego parts were not limited to the ones shown below. The user may add or remove them. Given in Table 11 and **Table 12** are the cost of Lego parts used in the two models shown in the previous chapter.

Name	Quantity per model	Cost per piece	Final price
Technic 9m beam	2	0.14 €	0.28 €
Technic angular beam 3x7	6	0.04 €	0.24 €
Connector peg w. Friction	12	0.003 €	0.036 €
Total	20		**0.556 €**

Table 11 Adapted solution: Cost of the Lego parts used(arms)

Name	Quantity per model	Cost per piece	Final price
RIM WIDE 18x14 W. CROSS Ø4.8	2	0.02 €	0.04 €
Tyre normal wide ø30,4 x 14	2	0.02 €	0.04 €
1/2 bush	4	0.01 €	0.04 €
Conn.bush w.fric./crossale	2	1.40 €	2.80 €
Crossaxle 3m with knob	4	0.02 €	0.08 €
Angle element, 0 degrees [1]	2	0.07 €	0.14 €
Double cross block	2	0.11 €	0.22 €
Total	18		**3.36€**

Table 12 Adapted solution: Cost of the Lego parts used(wheels)

The castor wheel used in one of the solutions provided could be even more economic. The cost of castor wheel is **1.65 €,** which would provide an alternative option to the Lego wheels. Also it was simpler and just needed to glue to the base whereas the Lego front wheels were attached by means of connector pins.

The basic electronics used are given in **Table 13** (shipping cost were not included). The cost of electronics used in model 1 was 48.85 € and in model 2 was 40 €. As stated before the user could add or remove them depending on the complexity of the robot. The cost of electronics may vary from store to store and the quantity ordered.

Name	Quantity per model	Cost per piece	Final price
HC-SR04	1	1.50 €	1.50 €
Buzzer	1	2.48 €	1.75 €
Servo FS90R	2	6.26 €	12.52 €
Servo 9G SG90	2	3.50 €	7.00 €
Wheels	2	4.28 €	8.56 €
Line follower sensor	1	1.24 €	1.24 €
Arduino Nano V3.0 + Expansion shield	1	7.40 €	7.40 €
Bluetooth link	1	5.28 €	5.28 €
LED matrix	1	4.89 €	3.60 €
Total	15		**48.85 €**

Table 13 Adapted solution: Cost of electronics used

A) 3-D Printing

This method was widely used as there is no set up charge. The school also had a personal 3D printer. The CAD software and designs used simple and easy to replicate. 3D printing proves very helpful while prototyping and for small production. The cost of 240 m of ABS material filament is 25.45 € (the prices may vary from store to store). The cost of one unit of base and face is given in **Table 14**.

Part name	Material used (m)	Cost of a part	Time (min)
Base	13.43	1.44 €	175
Face	8.62	0.92 €	50
Total	22.05	**2.36 €**	**225**

Table 14 Cost of 1 unit 3D printed parts

For 240m of ABS filament approximately 9-10 pieces i.e. 5 bases and 5 faces could be made. Thus for 50 pieces each 5 roles of ABS material were needed which means 254.50€. In this method the cost as well the time needed to print increased with the number of units.
* The maintenance cost and the amortization was not considered, keeping them in mind the price of one piece may rise up to 5-6 €.

B) Laser Cutting

The cost of one laser cut piece of base and face was very low provided the laser cut machine facility is available. For the prototypes the laser cut machine in the IDF laboratory of UPV was used. The time taken was very less.

Part name	Material used (mm)	Cost of plywood(500x400mm)	Cost of a part	Time (min)
Base	144x72	1.40 €	0.073 €	3
Face	152x56	1.40 €	0.06 €	5
Total			**0.14 €**	

Table 15 Cost of 1 unit laser cut parts (not outsourced)

In case of 8mm thickness the parts are double and then glued i.e. a total of **0.28 €**. For minimum waste plywood of larger dimension was taken which further lowers the cost and time. For 500x400x4 mm plywood, 9-10 pieces could be cut. 1x1 metre of 4 mm thickness for 50 pieces each was needed. The cost would be around 20 € if the laser cut machine was available. The fact that the school had no such personal laser cut machine, outsourcing would be the option for them. The outsourcing costs 1.24 € for two pieces (base and face) at Laser Art, Valencia. In this case the cost of 50 units of each is given in **Table 16**. The additional amount of 15 € setup fee irrespective of the quantity and then 1.24 € for one base and face were charged. Thus one piece (if outsourced) would have costed 16.24 €.

Part Name	No. of Units	Cost of 50 cut parts
Base	50	50X 0.76 €
Face	50	50X 0.48 €
Total of the pieces	100	**62 €**

Table 16 Cost of 50 laser cut pieces, outsourced (Laser Art, Valencia)

C) Moulding

This method of moulding turns out to be very cost effective for medium to large scale production. Though the initial cost of mould making material and resin very high and not suitable for one prototype. The cost of 2000grams of Ecros silicon moulding material was 61.30€ and the cost of 3000grams of Ecros acrylic resin material was 30 €. They were brought from Idepo store in Valencia. The cost may vary from store to store and brand to brand (the shipping cost were not included).

Part name	Mould material used (grams)	Cost of master part mould
Base and face	500	15.4 €
Total		**15.4 €**

Table 17 Cost of one mould

The curing time for both the mould and the moulded part was one day. Once the silicon mould was made, it could be used for around 200 pieces. Thus eliminating the cost of mould with each unit.

Part name	Acrylic resin used (grams)	Cost of moulded part
Base	60	0.6 €
Face	50	0.5 €
Total		**1.1 €**

Table 18 Cost of 1 unit of base and face (acrylic)

6000 grams of acrylic resin for 50 units of each was needed. Thus the cost of it if further lowered to 48.50 €. Now each unit (base and face) cost 0.9 €.

Part name	No of units	Cost of moulded parts
Base and face	50	45 €
Mould	1	15.4 €
Total		**60.4 €**

Table 19 Cost of 50 moulded units

As discussed later in detail in the next section of Comparison, the method of moulding was the very economically effectual in the medium to large scale production. Since there was no setup cost or machines needed (only if the mould is made from metal, CNC), it could easily be done by students.

4.2 Comparison

The manufacturing price for the different robots vary a lot but the biggest factor was the difference in what programmable brain was used. The BQ Zum core was good cause it includes the Bluetooth sensor but it is 27.50€ more expensive than Arduino V3.0 and it expansion shield. The shipping cost for any of the ordered parts was not included.

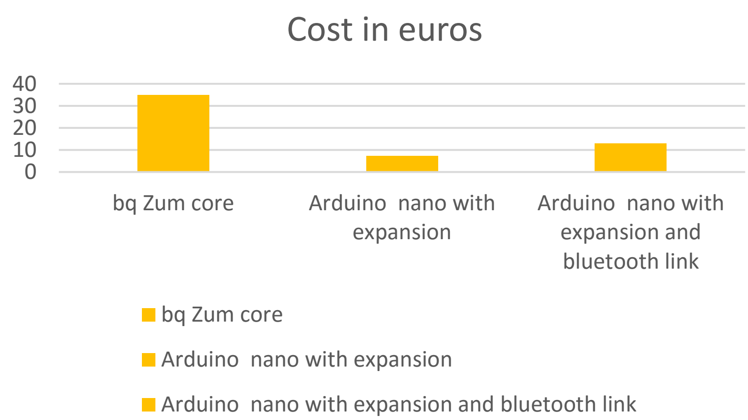

Figure 128 Graph of cost (programmable brains)

In contrast to the moulding processes that require costly moulds, 3-D printing entails relatively low fixed costs. Since 3-D printing does not require expensive tooling, forms, or punches, it is particularly cost effective for very small production runs. This enables the school to profitably use 3-D printing as it economically fills custom designs.
In contrast to moulding and laser cutting, in 3-D printing, the variable costs per part do not decrease with large production runs. 3-D printing technologies were used to produce initial product prototypes. It was more quick than injection moulding and laser cutting (outsourcing) operations since no set-up time is required. Further, considerable time savings were incurred when producing revised designs and minute changes like reducing holes.
In comparison to laser cutting (subtractive technology), which use multi-axis cutting machines to carve wood to the desired shape, there was less waste material with 3-D printing. No scrap, milling, or sanding were required. The school already has the 3D printer and assuming that they had the ABS filament, the cost for very small production (<3 units) as seen in **Figure 129**. 3D printing suits the best as in the other techniques, the cost of mould and setup cost were high. Laser cutting was not economically suitable because due to outsourcing, a minimum set up charge of 15 € was charged. It was done as the school had no laser cutting machine.

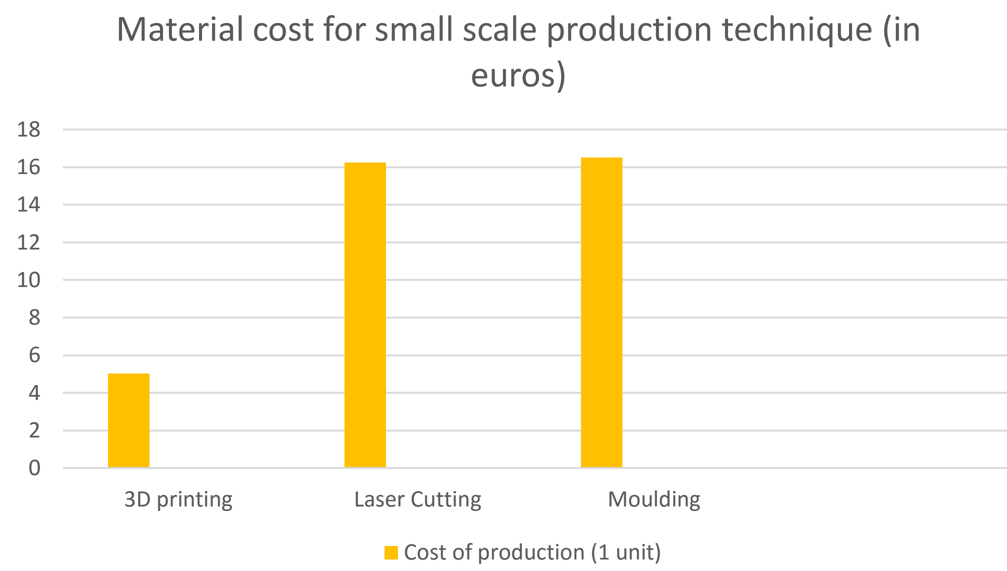

Figure 129 Cost of manufacturing (one unit) based on school's facilities

The graph shown below in **Figure 130**, compares the manufacturing techniques for different types of production. For the small scale production (in this case 8-10 units) moulding became most efficient as the cost of making the mould was not present each time. 3D- printing lies the second (not considering the electricity and setup charges). Laser cutting was most expensive as the school had to depend on outsourcing. They didn't have the machine and the outsourcing charges minimum amount as set up charge (of 15 €), no matter how many pieces were present.

For medium and large scale production 3D printing was the most expensive one. It also took maximum time. The most proficient was moulding, as one mould could be used for 200 pieces, thus only the cost of acrylic resin was taken into account. Laser cutting was the second most effective method as the set up cost was fixed, only the price per piece was considered. The transportation/shipping cost was not considered.

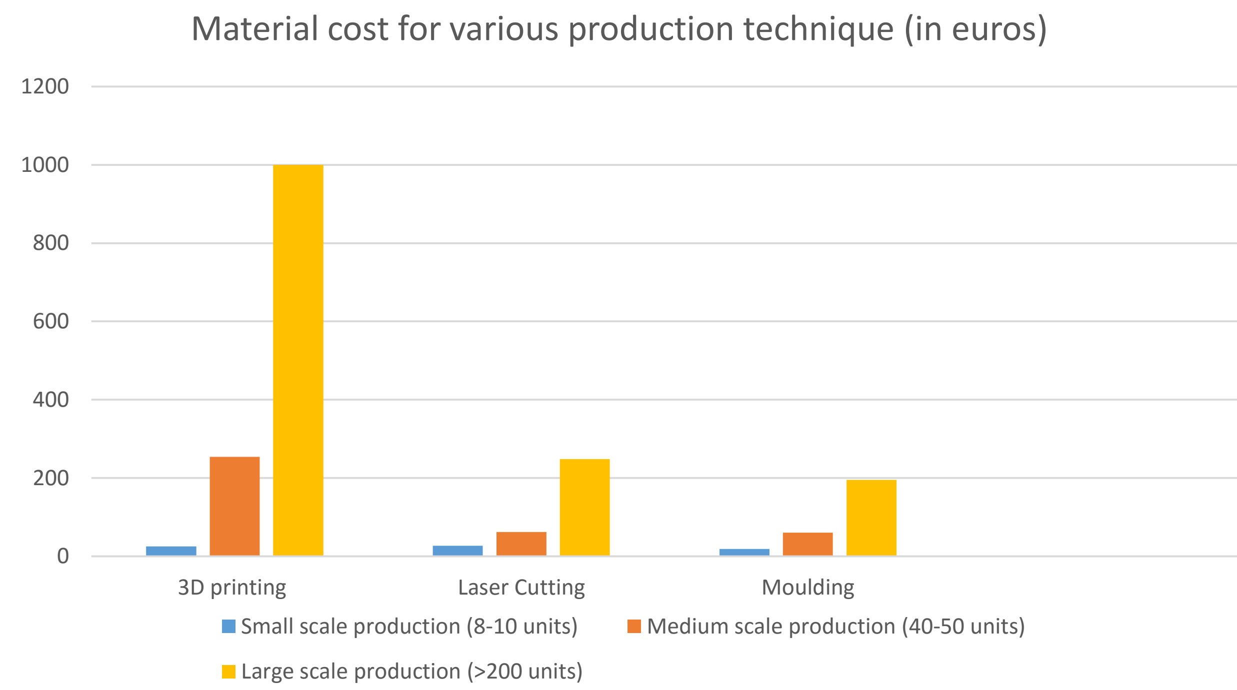

Figure 130 Manufacturing material graph(cost)

In this paragraph the comparison of this product to its competitors is given. When looking at the components and parts that the price includes there was no difference in quality or quality. With the idea of an open source solution to the educational robot market the prices were reduced. The objective for the project was to make an inexpensive alternative for schools to use in their robotics classes. With cost analysis it is shown that it was possible to create such successful product called DYOR, whose cost is almost 7 times less that the widely used Lego Mindstorms kits.

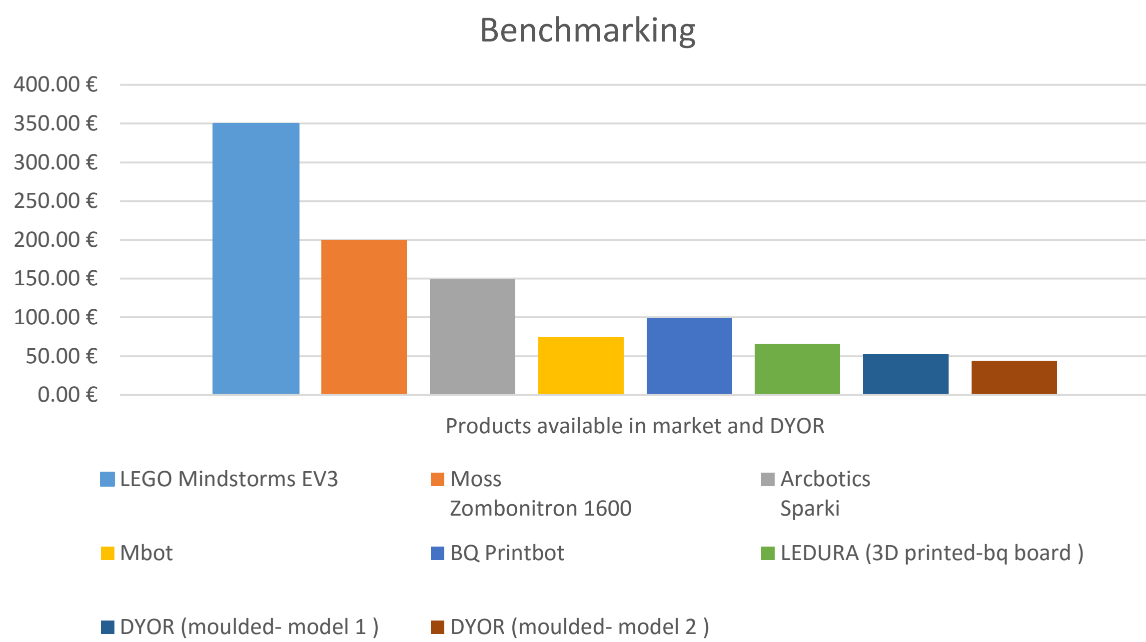

Figure 131 Graph showing cost comparison among competitors and DYOR

As already mentioned this robot was not for profitable companies, it was for learning. A reduced price for educational purposes are very important, because at this moment the biggest concerns in the robotic class in schools were the prices and simplicity. To be clear, this robot also has the possibilities to additional functions beyond the ones in the calculus. Not to forget that it was also possible to make an even more basic robot, with that in mind also the price would be reduced significantly.

CHAPTER 5

Conclusion

The entire project work consisted of the following product design, project management and teamwork. Concept development, artistic and industrial design, material and manufacturing process selection forms the second part of the project. Mechanism design and assembly, actuators, sensors, controls and programming was the last part. The seminars and workshop at ETSID at UPV were introduced to build various aspects of project management and team-based environments where basic understanding of management of resources, scheduling, and control of activities were taught. The team dynamics, leadership, communications, conflict resolution, and other interpersonal skills were also developed. The first prototype of LEDURA was built in a team of five international students where brainstorming prospective project ideas, followed by the concept development took place. Once the first design was completed and presented before the professors and school teachers/instructors, discussion of feasibility issues took place. The realization of the important factors such as scale, material selection, cost, and other physical restraints such as facilities available for medium to large scale production and time were major issues which needed further attention. Thus second Final Prototype “DYOR” came into picture which took a form of a thesis.

A guide to construct and program was also provided. Training sessions on how to use the kit in the school was held by Professor Leopoldo Armesto.

This educational robotics kit was less complex as compared to the others available in the market. Plus, special instructional guide of materials, manufacturing and construction were also incorporated in the kit. The introduction of elements of engineering knowledge into the educational program and forming of the initial mastering experience in students of creating something from the very beginning does not contradict education objectives. The efficiency of its use in teaching has already been proven. It has been demonstrated that the efficiency of learning increases when implementing the interdisciplinary links of "Technology” in educational area. Mas Camarena school curriculum was comprised of the following content in the following sequence: introduction basic product design (3D modelling), teamwork, manufacturing (either by out sourcing for Laser Cutting or self-manufacturing by 3D printer or moulding), assembly, actuators, sensors, controls and programming. Following is a short discussion and suggestions on future work. But to summarize the outcome of the project: a fully functioning prototype has been made and there are many possibilities for improvements.

The project developed design briefs, including marketing, targets groups in the case of the robotic toy development process. The need was analysed and several designs were proposed. A set of materials and feasible manufacturing techniques were prepared within the various experiment conducted during the project. The final designs and their blueprints as seen in Appendix C were suggested.

Figure 132 Kids making DYOR at Primavera Educativa

Future Work

During the first few months of the project a lot of time and effort has been put on making a physical prototype and less work on exactly how this could be implemented at schools. Towards the last 3-4 months a lot of work and meeting were done to implement DYOR. The schools wanted to introduce this project from September 2016 in their curriculum. Thus proper training of the teachers and students was needed. The prototype has several functions working, but there could be improvements. During the prototyping the aim for using it in schools has been primary and some of the programs, designs and functions could have been made easier to suit the target group better.

There are also improvements to do in the market research, for example extend the amount of people answering to the questionnaires could be increased to get better result and to get a product that suit the needs of different schools.

The prototype could be extended with further functions such as locate objects in a more effective way, colour detection, buzzer, microphone or to lift up the object after grabbing it. All files and different programs could be collected and it would be profitable if the programming could be used by choosing and combing parts of code to a full program. To do this the code used could be broken down in parts concerning each sensor or actuator which thereafter could be inserted into a main program prepared for as many different combinations as possible. It could also be an idea to implement block coding. There could also be an extension of easy code, for example to make a LED-light blinking or to use echo sensor to move forward between two walls. The instructions could be divided between simple, for example using a buzzer or a LED-light, to more advanced combinations where several sensors and actuators are cooperating. The instructions could contain a suggestion of how to put the blocks together, how to connect the Arduino and how to write the program, and access to the code.

The material for moulding could be changed depending on its nature and need. Need for mare economic and nontoxic material for moulding is still pending. The possibility to use Omni wheels with the designs provided is still open.

In order to make it possible for schools to use the stl-files as well as blueprints, all parts were saved in a library so it was easier to find. This would make it possible for the school to choose which parts to print. By doing this the school could decide which properties that are more desirable and most suitable for the students. An instructions manual was provided for step by step building for the two models and coding. The project still lacks the feedback data from the school after implementing Creating DYOR in their curriculum as the thesis was to be submitted in July 2016. Depending on the feedback data collected further changes could be made according to the user. The idea of implementing of this project in other (local/global) High schools still needs to be done.

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Appendix A

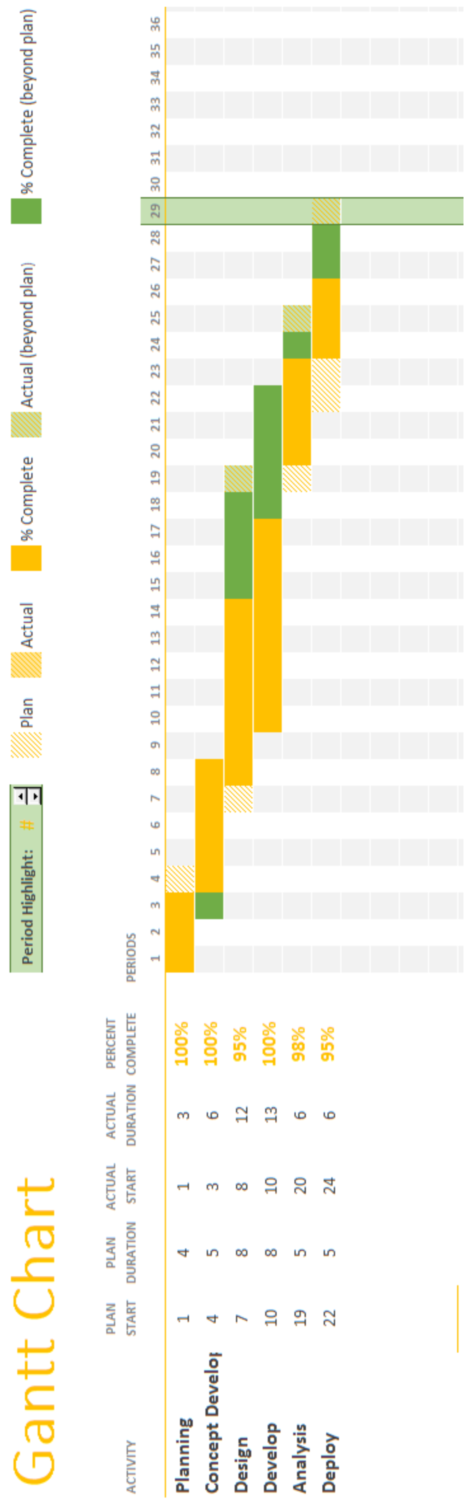
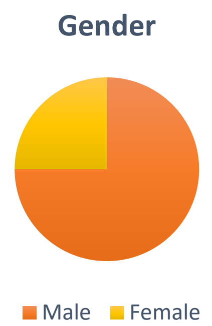
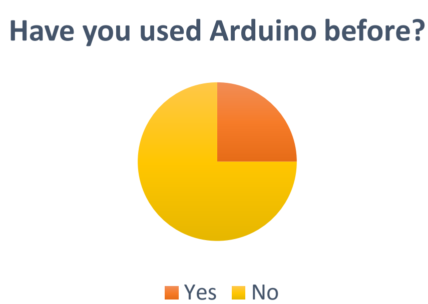


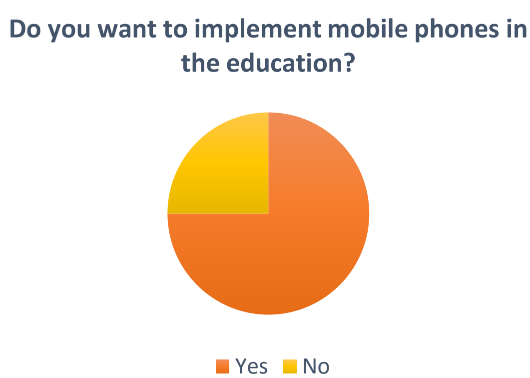
Figure 133 Gantt chart

Appendix B

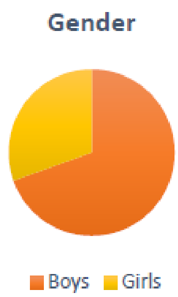
Data from the questionnaire – teachers

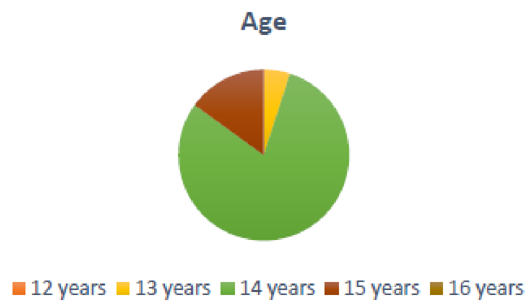


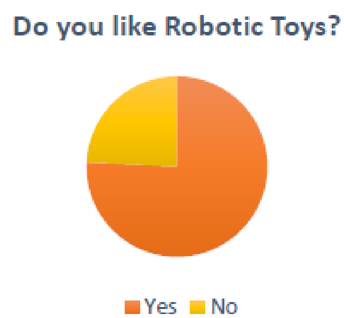


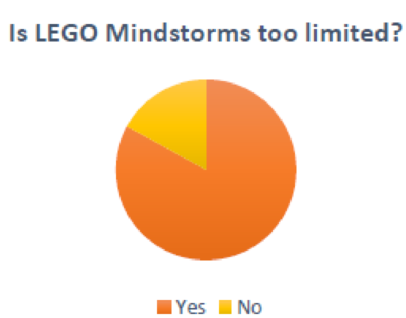


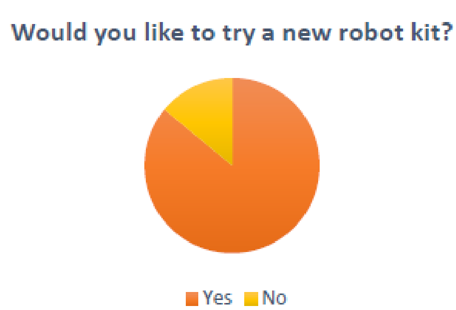
Data Collected from the questionnaire- High school students











Appendix C

Dimensions of the final designs

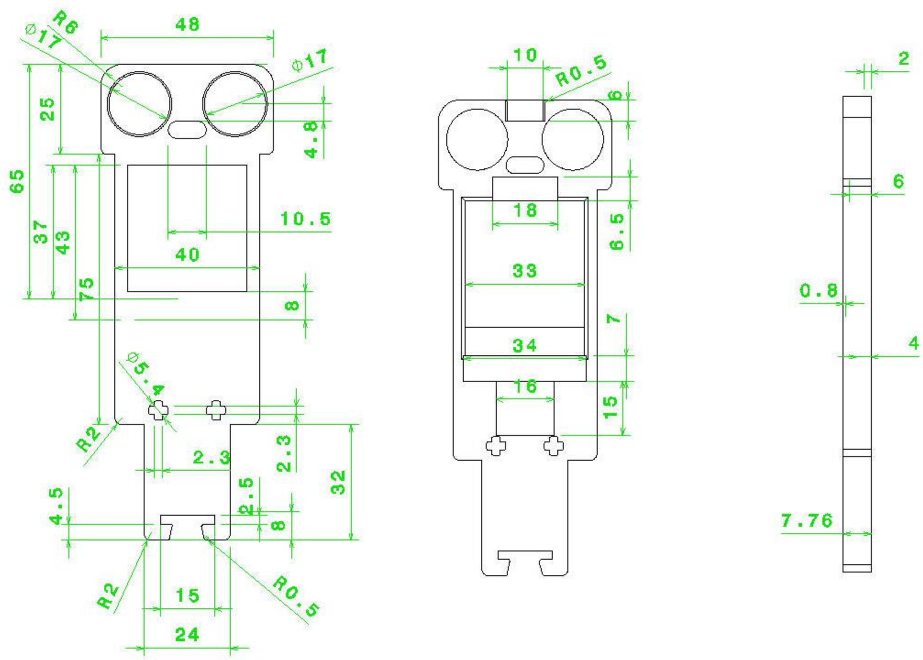


Figure 134 Dimensions: front, back and side view of the face1

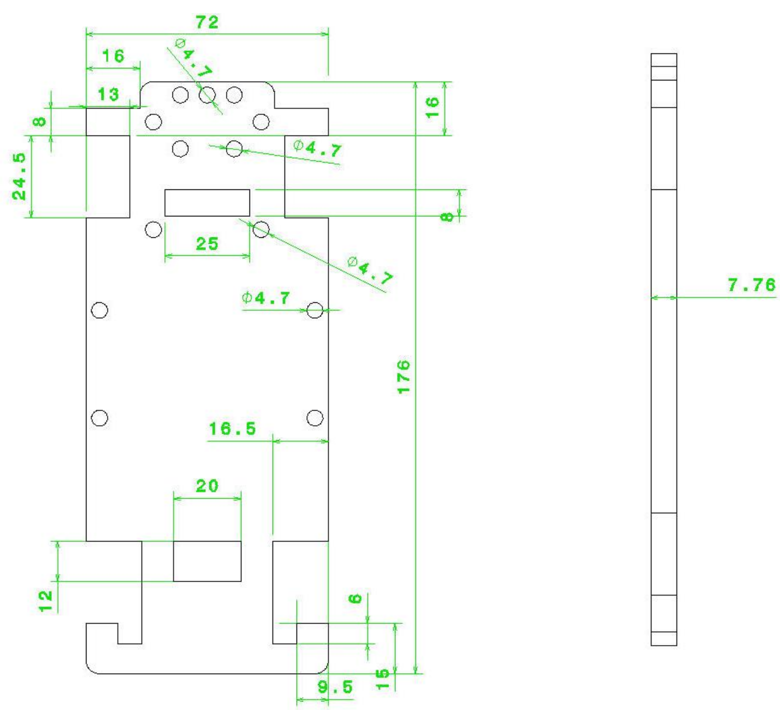


Figure 135 Dimensions: Front and side view of the base1

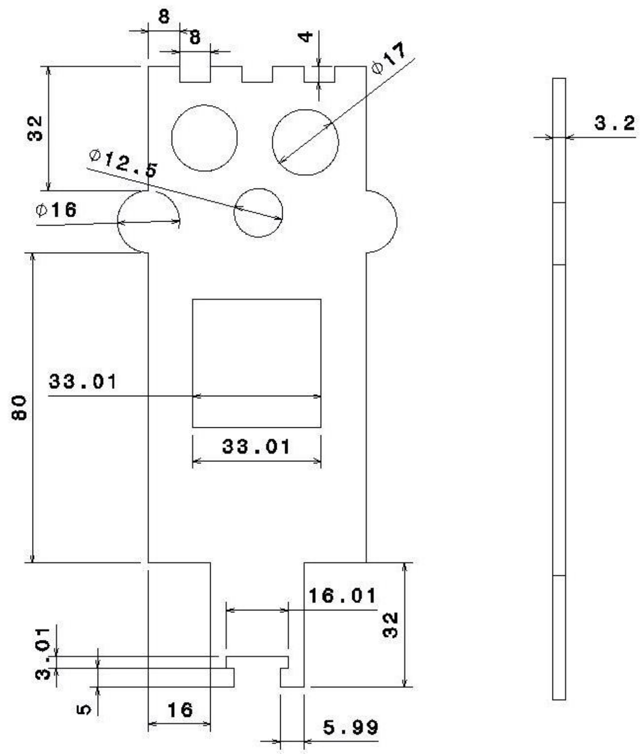


Figure 136 Dimensions of face 2

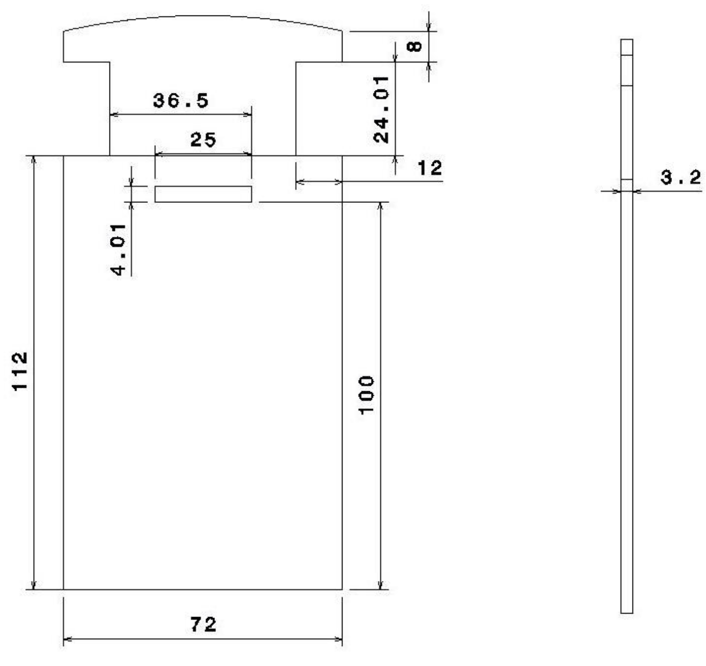


Figure 137 Dimensions of base2

Appendix D

Proyectos Educativos en Robótica
Talleres de Robótica e Impresión 3D
Harshika Singh, Rubén Esteve
Andrés Conejero, Leopoldo Armesto
Universitat Politècnica de València
INSTITUTO DE DISEÑO Y FABRICACIÓN
DYOR: Do Your Own Robot
¿Qué es DYOR?
Un paquete educativo orientado a la Educación Secundaria con el propósito de iniciarlos a aquellos aspectos básicos de la ingeniería. Se puede integrar en los contenidos educativos de diversas asignaturas multidisciplinares.
NO es otro kit de robótica
Los alumnos de Secundaria aprenden a diseñar un robot (CAD), fabricarlo utilizando diferentes procesos y tecnologías, montan y programan la electrónica y desarrollan una App de móvil para jugar a fútbol. Es mucho más que un kit de robótica!
Matemáticas y Dibujo Técnico
Diseño CAD
Geometría
Cálculo
Arte y Música
Personalizaciones con goma EVA y pintura
Composición de Partituras sencillas
Ciencias y Tecnología
Impresión 3D
Fabricación de moldes y corte por láser
Electrónica Arduino
Informática
Programación de Arduino
Programación Apps de Android
Innovación
Proyecto STEM con materiales de bajo coste reutilizables que integra asignaturas de Matemáticas, Dibujo (CAD), Ciencias y Tecnología (fabricación y electrónica), Informática (programación Arduino y Apps de móvil) y Arte y Música (personalizaciones).
Formación a Profesorado
DISEÑO DE ROBOTS EDUCATIVOS CON HERRAMIENTAS CAD, ARDUINO, IMPRESIÓN 3D Y APPS MÓVILES
Centro de Formación de Posgrado
Universitat Politècnica de València
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