UNIVERSIDAD DE VALLADOLID

ESCUELA DE INGENIERIAS INDUSTRIALES

Grado en Ingeniería en Electrónica Industrial y Automática

IMPLEMENTATION OF A CONTROL SYSTEM FOR MOROBOT AND ITS APPLICATION IN PLAYING TIC-TAC-TOE

Autor:

Martínez Cueto, Óscar

Responsable de Intercambio en la Uva:

Fernando Martínez Rodrigo

Universidad de destino:

University of Applied Sciences Technikum Wien

Valladolid, septiembre 2021.

TFG REALIZADO EN PROGRAMA DE INTERCAMBIO

TÍTULO: Implementation of a control system for morobot and its application in playing tic-tac-toe

ALUMNO: Óscar Martínez Cueto

FECHA: 25 de junio de 2021

CENTRO: Main Campus at Höchstädtplatz

UNIVERSIDAD: University of Applied Sciences Technikum Wien

TUTOR: Johannes Rauer

Resumen

Aprender a través del juego es muy beneficioso para un grato aprendizaje y una mayor motivación del estudiante. Si además se realiza empleando la robótica en el juego, se consigue introducir a una temprana edad el pensamiento de programación de una manera creativa y atractiva para el alumno. Por ello en este trabajo se emplea un miniaturizado, e impreso en 3D, robot industrial (morobot) para el cual se programa y se construye un entorno de forma que se pueda jugar al 3 en raya con él. De esta forma finalmente se consigue un sistema barato y fácilmente reproducible para poder enseñar programación o diseño 3D de forma amena. Puede ser utilizado por los estudiantes para desarrollar ciertas partes propias para el sistema y hacerle modificaciones de forma creative

Palabras clave: Robots, aprendizaje mediante juego, Morobot, Arduino, 3 en raya.

Abstract

Learning through play is very beneficial for enjoyable learning and increased student motivation. If it is also done by using robotics in the game, it is possible to introduce programming thinking at an early age in a creative and attractive way for the student. For this reason, this work uses a miniaturised, 3D printed, industrial robot (morobot) for which an environment is programmed and built in such a way that it can be used to play tic-tac-toe. In this way, an inexpensive and easily reproducible system for teaching programming or 3D design in an entertaining way is finally achieved. It can be used by students to develop certain parts for the system of their own and make modifications creatively.

Keywords: Robots, learning through play, Morobot, Arduino, Tic-tac-toe.

BACHELOR PAPER

Term paper submitted in partial fulfillment of the requirements for the degree of Bachelor of Science in Engineering at the University of Applied Sciences Technikum Wien - Degree Program Mechatronik/Robotik

Implementation of a control system for morobot and its application in playing tic-tac-toe

By: Óscar Martínez Cueto
Student Number: 2000330002

Supervisor 1: Johannes Rauer

Vienna, 25.06.2021

Declaration of Authenticity

“As author and creator of this work to hand, I confirm with my signature knowledge of the relevant copyright regulations governed by higher education acts (see Urheberrechtsgesetz/ Austrian copyright law as amended as well as the Statute on Studies Act Provisions / Examination Regulations of the UAS Technikum Wien as amended).

I hereby declare that I completed the present work independently and that any ideas, whether written by others or by myself, have been fully sourced and referenced. I am aware of any consequences I may face on the part of the degree program director if there should be evidence of missing autonomy and independence or evidence of any intent to fraudulently achieve a pass mark for this work (see Statute on Studies Act Provisions / Examination Regulations of the UAS Technikum Wien as amended).

I further declare that up to this date I have not published the work to hand nor have I presented it to another examination board in the same or similar form. I affirm that the version submitted matches the version in the upload tool.”

Vienna, 25.06.2021

Place, Date

Signature

Abstract

Learning through play is very beneficial for enjoyable learning and increased student motivation. If it is also done by using robotics in the game, it is possible to introduce programming thinking at an early age in a creative and attractive way for the student. For this reason, this work uses a miniaturised, 3D printed, industrial robot (morobot) for which an environment is programmed and built in such a way that it can be used to play tic-tac-toe. In this way, an inexpensive and easily reproducible system for teaching programming or 3D design in an entertaining way is finally achieved. It can be used by students to develop certain parts for the system of their own and make modifications creatively.

Keywords: Robots, learning through play, Morobot, Arduino, Tic-tac-toe.

Resumen

Aprender a través del juego es muy beneficioso para un grato aprendizaje y una mayor motivación del estudiante. Si además se realiza empleando la robótica en el juego, se consigue introducir a una temprana edad el pensamiento de programación de una manera creativa y atractiva para el alumno. Por ello en este trabajo se emplea un miniaturizado, e impreso en 3D, robot industrial (morobot) para el cual se programa y se construye un entorno de forma que se pueda jugar al 3 en raya con él. De esta forma finalmente se cosnigue un sistema barato y fácilmente reproducible para poder enseñar programación o diseño 3D de forma amena. Puede ser utilizado por los estudiantes para desarrollar ciertas partes propias para el sistema y hacerle modificaciones de forma creativa

Palabras clave: Robots, aprendizaje mediante juego, Morobot, Arduino, 3 en raya.

Acknowledgements

I would like to kindly thank my supervisor Johannes Rauer for guiding me through the work jams and resolving certain doubts. Radu Curcean for his help as lab manager. And my family and my Erasmus friends for their support and encouragement along the process.

Table of Contents

1 Introduction

It is well known that industrial robots improve our productivity, producing faster and with less costs than humans and that is why they are so used. In a similar way, using miniature-robots to learn how to program and control them instead of using industrial robots directly is cheaper, easier to transport, easier to build and much less dangerous in case of failures or mistakes learning. In this manner, learning about industrial robots can reach more people, including children, much more easily [1, 2].

In addition, if to this it is added that children (or anyone) can learn something very useful while they are playing, learning will be much easier, productive and entertaining [2, 3, 4]. So why not take advantage of our natural interest in games and learn useful things as we play?

At the Competence Center Digital Manufacturing, Automation and Robotics of the UAS Technikum Wien they are specialized in mechatronics and robotics in industrial environments. They are currently developing and launching the miniature-robot platform “morobot” which consists of different miniaturized and 3D-printed industrial robots which can easily be programmed with different microcontrollers [5].

For these reasons, this works it is done to contribute and advance in this attractive way of learning.

1.1 Goals of this work

In this work a system to control some cheap mini-robots is implemented. The motivation of the work is to get easily control a robot that resembles how it would be to work with an industrial robot.

The benefits of learning through play are to be exploited, so a system for playing tic-tac-toe is implemented. The program designed for Arduino guides the game and depending on the buttons that the players press, the Morobot performs the corresponding movements to pick up and move the pieces of the game.

The robot has been provided by UAS Technikum Wien. The robot has been provided by UAS Technikum Wien but with the addition of a 3D printed gripper. And the pieces used to assemble the game are cut with a laser cutting machine. With all this assembled plus the Arduino program, several games have been tested.

1.2 State of the art

First, about miniaturized robots. The use of this type of robots for learning is nothing new. Because manufacturers know that it is almost always easier to create small robots than industrial robots themselves, so most of the brands have their robots in small size.

But most of these robots are still not very cheap. Therefore, for an institution dedicated to teaching these matters, like the UAS Technikum Wien, it is a very good practice to develop this kind of robots.

Four different types of morobots are being developed at UAS Technikum Wien as shown at Fig. 1 [6]. They could be five because one of them (morobot-s) can work as a rrr robot or a rrp robot. In addition, two grippers have been developed to work with morobots (one angular gripper and one parallel gripper) and can be modified easily for specific applications using 3D design. They can also use suction cups instead of grippers in order to pick up pieces.

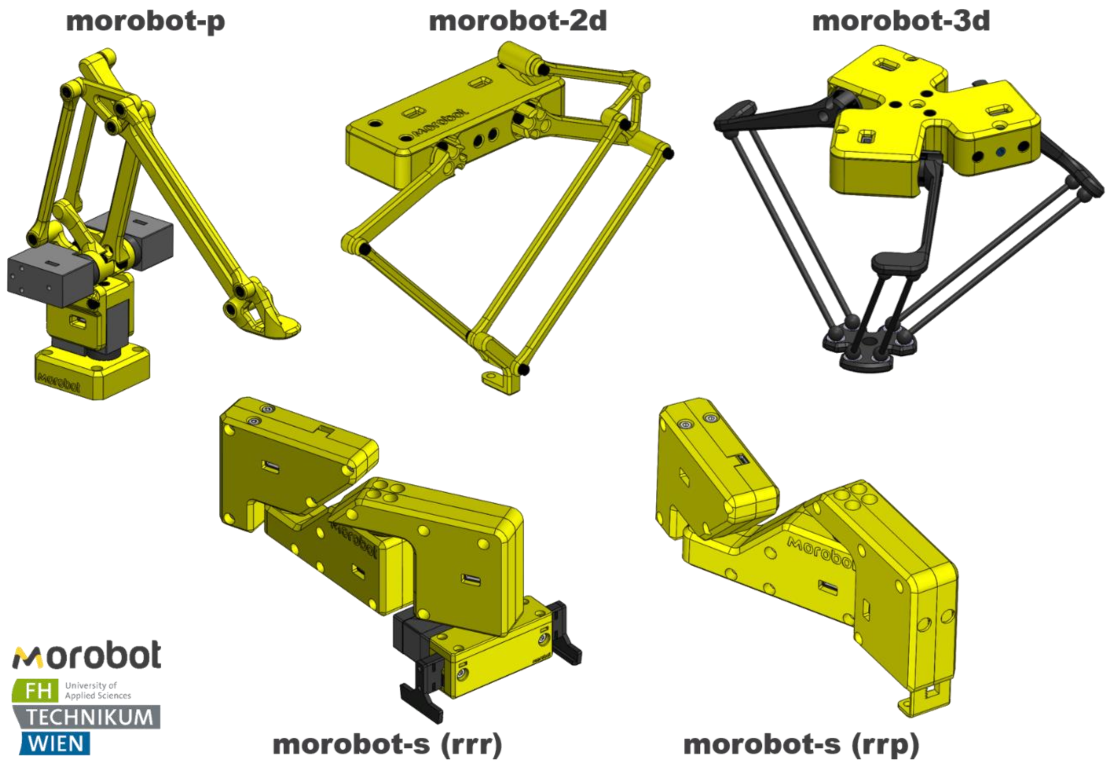


Figure 1. Different types of morobot [6].

The price varies depending on the model but a morobot costs around 100€ while other small robots cost thousands of euros (data collected from [7, 8, 9, 10, 11]).

As can be seen in Table 1, there is a loss of performance using morobot compared to other companies' robots, but for students morobot has enough to learn for a much lower price.

Brand	Model	Price (buying one unit)	Max. Reach	Axes
KUKA	KR 3 AGILUS	29351$ ≈ 24000€	541 mm	6
ABB	IRB 120	13000$ ≈ 10630€	580 mm	6
NIRYO	NIRYO NED	2999$ ≈ 2450€	440 mm	6
Morobot (FHTW)	Morobot-p + gripper	~100€	306 mm	4

Table 1. Comparison of miniaturised industrial robots.

The use of robotics in children's education can be very beneficial. Learning through robotics increases children's engagement in manipulative-based activities, the development of motor skills, hand-eye coordination and a way of understanding abstract ideas. In addition, robot-based activities provide an appropriate context for cooperative behavior and teamwork. Valuable results are achieved in technology-based education programmes (translated from Spanish, [12]):

- Competence in intellectual effort, computer literacy and technological fluency.
- Self-confidence in handling technical concepts and problems.
- Collaboration and cooperation skills.
- Use of technology to establish contacts with peers and adults by creating face-to-face relationships or in virtual communities.
- Sense of presence and physical reality in increasingly digitised or mediated environments.
- Awareness of their personal values and respect for others, responsible use of technology.
- New ideas for applying technology to improve our environment (school, community, society).

In addition, computer science has certainly lost its appeal lately although it is employed in virtually all spheres of life [13]. And one way in which there are already many initiatives is the use of robotics as they are doing in the Institute for Personal Robots in Education (IPRE) [14]. They apply and evaluate robots as a context for computer science education.

There are also other examples of use of robots at an early age such as Lego Mindstorms [15]. You can get different kits with a lot of parts and build your own robot with several sensors and leaving free to your imagination how you want to create your own robot and using a very simple and intuitive block programming for children.

They also organise a tournament for different age groups in many countries every year called First Lego League (FLL) [16] where a set of missions are set on a certain board and each team can build and program the robot as they wish to complete as many missions as possible in a given time. In this way, this stimulates creativity while introducing them to the world of programming, robotics and problem solving through a great game.

Figure 2. lego mindstorms kit on the left [17], and examples of robots built with it on the right [18, 19].

Learning through playing has been shown to be beneficial for learning and personal development. “*Learning through play happens through joyful, actively engaging, meaningful, iterative, and socially interactive experiences. Our goal is to develop creative, engaged, lifelong learners who thrive in a 21st century world*” [20]. Still many people are reluctant to use this teaching method. However, It is a teaching system to combat school dropouts and depression in students, that has a long road to advance [4].

As Dr. Alicia fernández oliveras affirms it is possible to learn without having fun but not have fun without learning (translated from Spanish, [21). For this reason, using games to teach something in particular that we want someone to learn it, it requires great creativity and a lot of work behind but the benefits for students are much broader.

Bringing together these two ideas of using mini-robots and learning through play, this work seeks to make a small contribution to the growth of these learning possibilities.

2 Development of the system

The morobot is controlled for this work by an Arduino Mega board but could be implemented in a similar way with another microcontroller (such as an ESP32).

Programming is done in Arduino (based on C/C++) but could be done in other programming languages. And to realise the program we rely on the library already implemented by the UAS Technikum Wien called morobot.h.

The different motors of the morobot are easily connected to each other: from the Arduino board to the first motor, from the first motor to the second motor, from the second motor to the third motor, and finally from the third motor to the fourth motor which is the one for the gripper.

In addition to the morobot, a button matrix is connected to the Arduino board (see Fig.3). With these buttons we can choose different movements for the robot or select different program options depending on what is shown on the screen. This whole system is set up with the aim of having an environment in which to play tic-tac-toe.

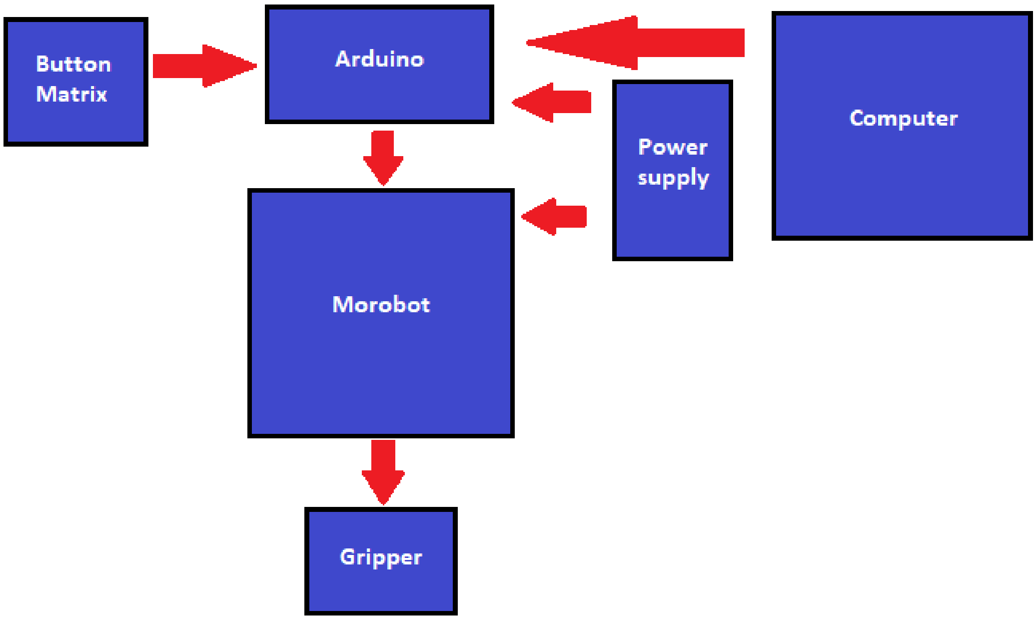


Figure 3. System diagram.

The system must also be supplied with 12 volts to power the motors of the morobot. So, we connect it by means of a transformer to the power supply (from 220 to 12V).

In the following sections, everything about the control of the morobot and its system is shown in more detail.

2.1 Mechanical part

The system used in this work consists of several elements.To begin, the main element is the morobot-p provided by the university (it can be seen in Fig. 1 on page 7) to which a parallel gripper is added.

To develop the right gripper for my system I started from the part designs provided by the university and I made some modifications to obtain a gripper with a design suitable for the operation of my system. I have 3D printed these parts (Fig. 2 and 3) and I have mounted them, attached them to a smart-servo and assembled it to the end of the morobot-p.

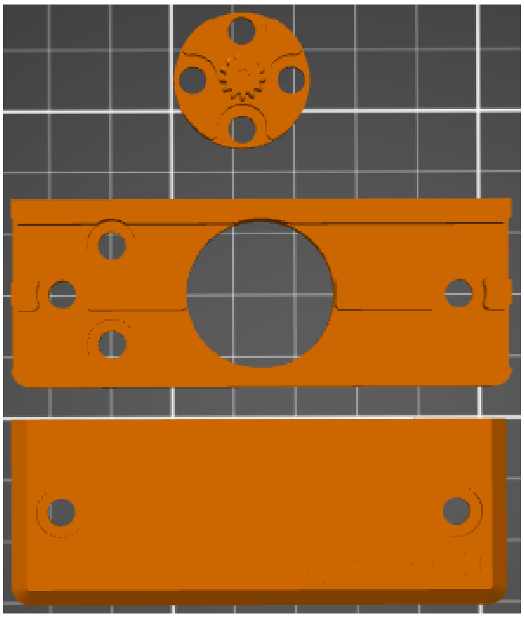


Figure 4. Unmodified parts of the gripper.

The modifications made to the gripper are (see Fig. 3): in the top piece, to make a single hole in the centre instead of four, as the end of the morobot-p has only one hole to connect the end-effector.

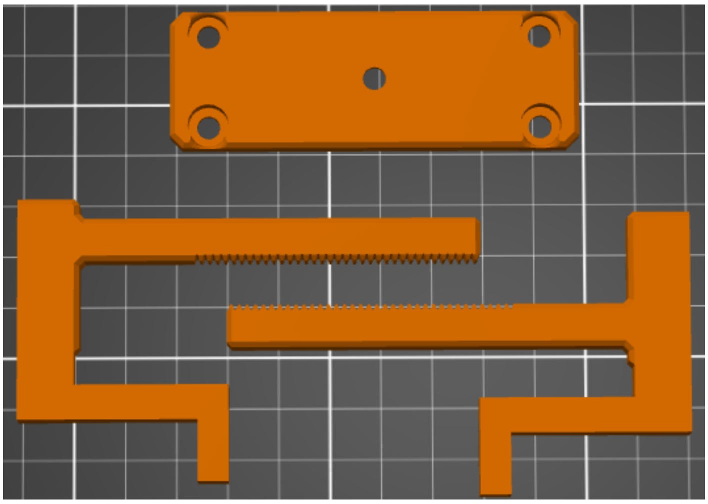


Figure 5. Modified parts of the gripper.

And the other two pieces have been modified to be able to have the gripper for the desired size of the pieces of the set and to extend downwards to be able to access them from above. Once we have a suitable gripper mounted on the morobot-p, we can pick up and drop off parts.

To play tic-tac-toe some designs in CAD are made to laser cut them in 4mm methacrylate sheets and then assemble them:

- A grid to play and its walls and floor for a more robust design (Fig. 5).
- Other grids where the pieces are stored and their corresponding walls and floor (Fig. 6).
- The pieces to play with, which will be cubes with X or O (Fig. 7).
- A base for the morobot to stand on (Fig. 8).
- And a large board on which to place all the elements.

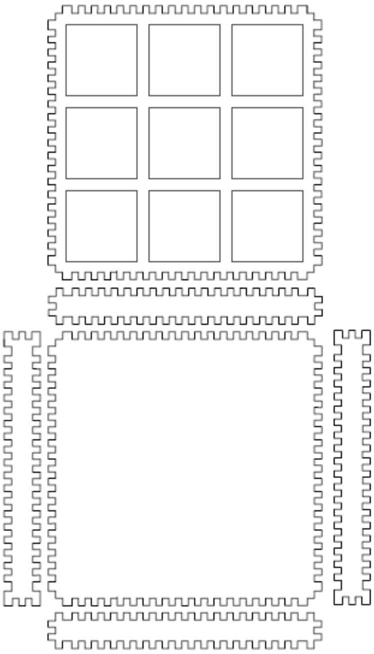


Figure 6. Parts for the tic-tac-toe grid.

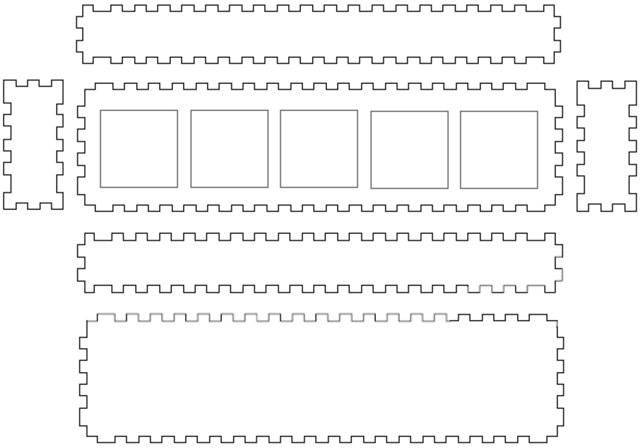


Figure 7. Parts for the grid to store pieces.

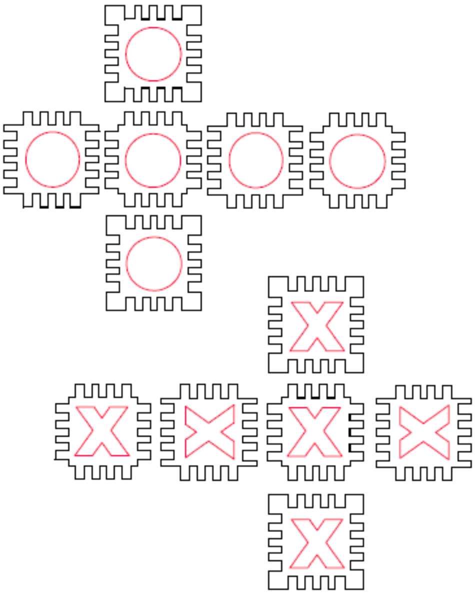


Figure 8. Parts for the X and O pieces.

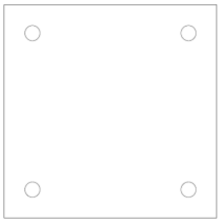


Figure 9. Base for the morobot.

All these parts have been conveniently glued together in order to get the robot's workspace suitable for working and playing tic-tac-toe (see results in section 3).

2.2 Electrical part

The connection of the morobot motors as mentioned above is as follows (see Fig. 10): motor one connects its inputs to 12v (red wire), to GND (black wire), to pins D18 and D19 of the Arduino Mega board (yellow and white wires, respectively). And its four outputs are connected to the corresponding inputs on the second engine. In the same way the outputs of the second motor are connected to the inputs of the third motor and the outputs of the third motor to the inputs of the fourth motor (gripper).

The Arduino Mega board is also conected to ground (GND pin) and 12 volts (Vin pin) to have a proper power supply.

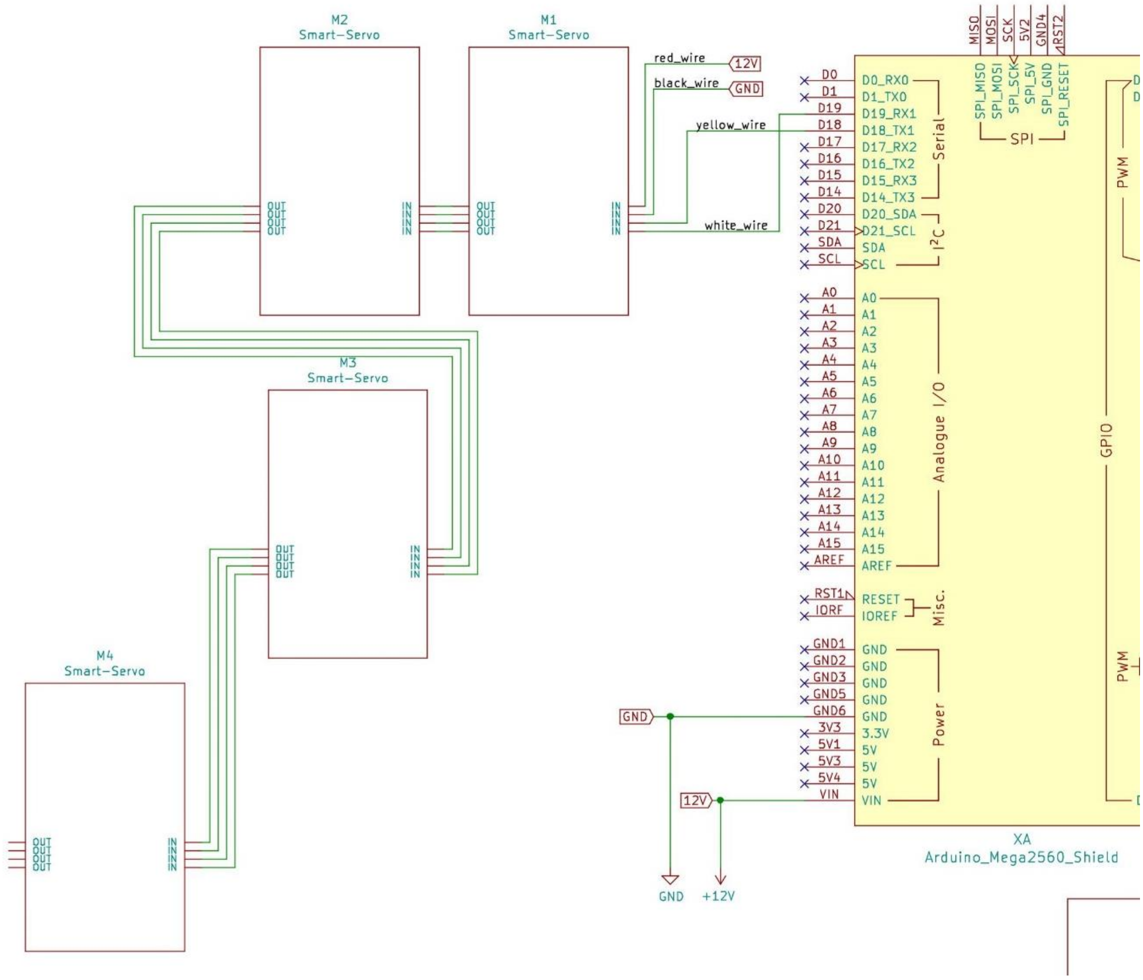


Figure 10. Electrical circuit A.

Moreover, it is also conected to the button array 4x4 as follows (see Fig. 11): pin O4 of the button array to pin D10 of Arduino mega board, pin O3 to pin D11, pin O2 to pin D12, pin O1 to pin D13, pin R1 to pin D6, pin R2 to pin D7, pin R3 to pin D8 and pin R4 to pin D9.

With these connections the Arduino board is now able to detect all the button presses and use them in the program properly.

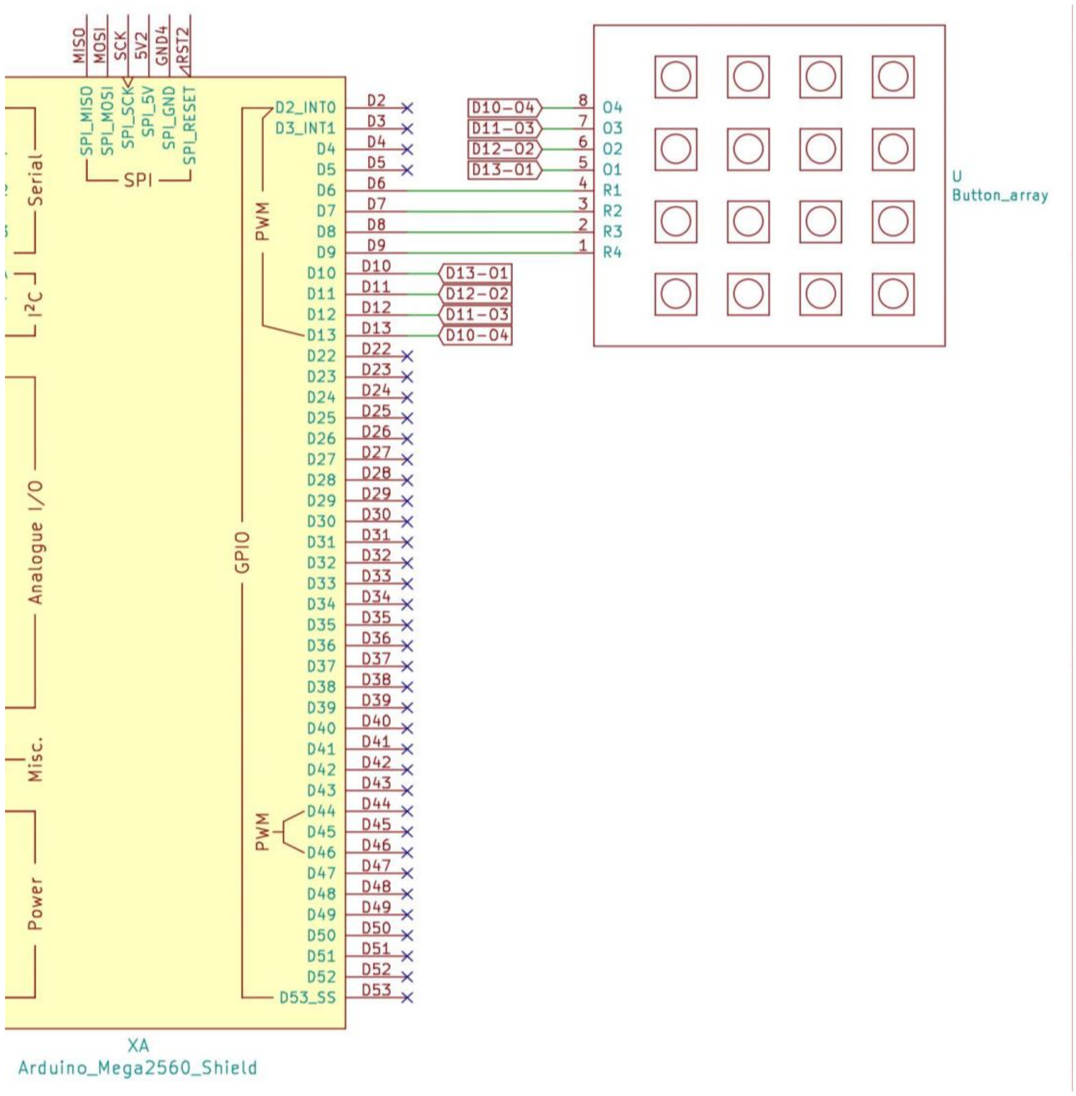


Figure 11. Electrical circuit B.

For the complete electrical circuit see appendix.

2.3 Programming part

To control the system, a program has been created in Arduino language (resembling C++). But it is presented in the form of flowcharts so that it can be exportable to other programming languages.

First, the general functioning of the program is (see Fig. 12) starting in a menu, depending on which button is pressed, one of the following options is carried out: S1 to play a new game, S2 to see the rules and an explanation of how the game works on the screen (and then go back to the menu) and S3 to exit the program.

When the game starts (button S1 pressed) the morobot moves to pick up O pieces (each time one) and returns to the starting position where it waits for a button to be pressed depending on where the player chooses to place their piece.

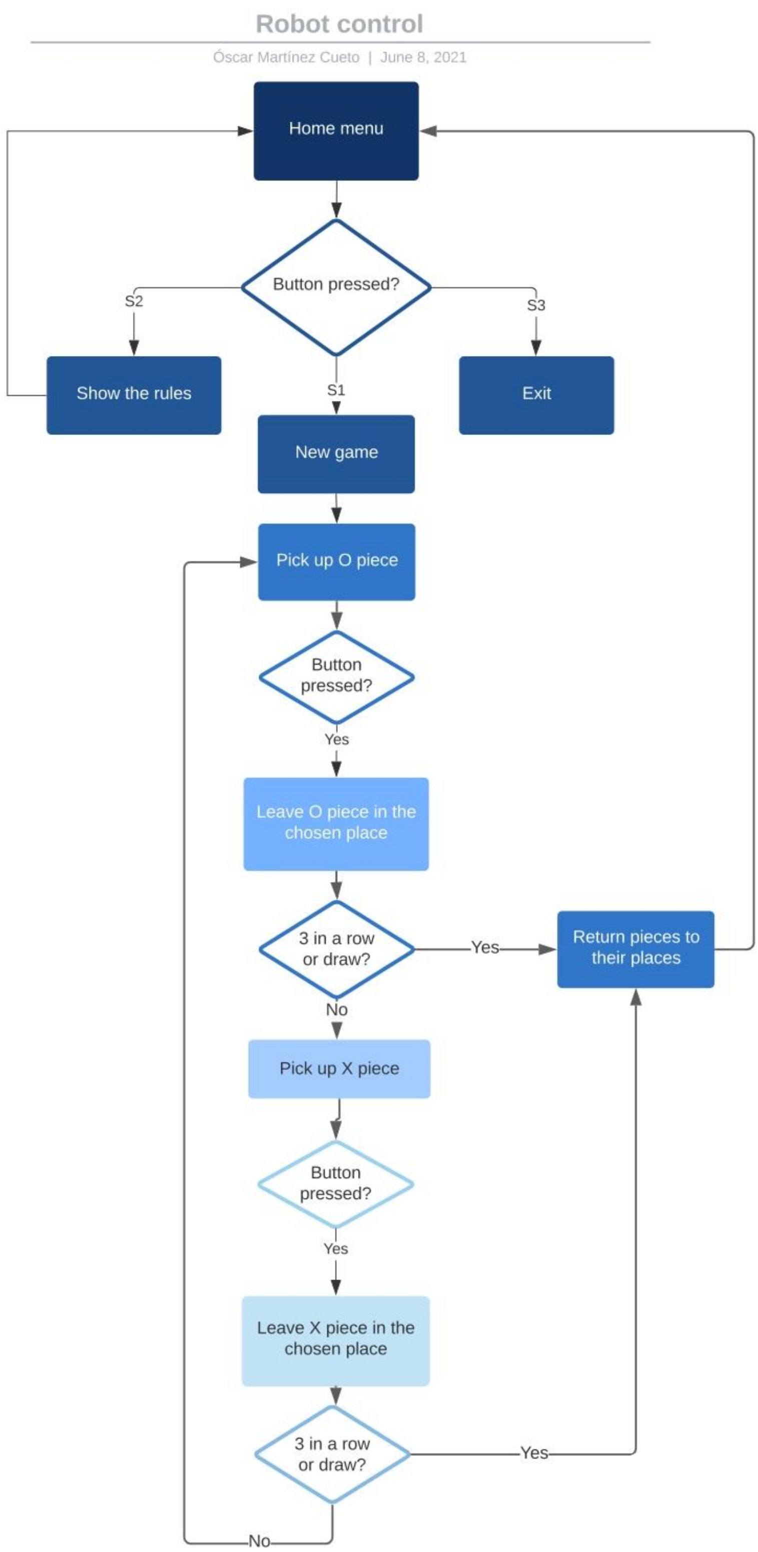


Figure 12. General flowchart.

Once the player presses the button the morobot moves to this position to release the piece, it checks if the player has won the game or if the game is a draw and if it is neither, moves directly to take an X piece (each time a different one). And in the same way as before, the morobot stays in the initial position waiting for the player to press the corresponding button for the position where they want to leave their piece.

Now, it checks if the second player has won or there is a draw and if it is neither, return to the O pieces and stays in this loop until someone wins or there is a draw and when the game is over, it congratulates the winner on the screen, put the pieces back in place and it returns to the start menu.

2.3.1 Pick up pieces

More specifically what the program does in "pick up O pieces" is (see Fig. 13): is to move from the home position (with the end effector forward where the tic-tac-toe board is located and at a comfortable height) to its right side where the O pieces are located and depending on which turn number it is, it is directed towards one piece or the other. Then the morobot closes the gripper and moves upwards and back to its home position.

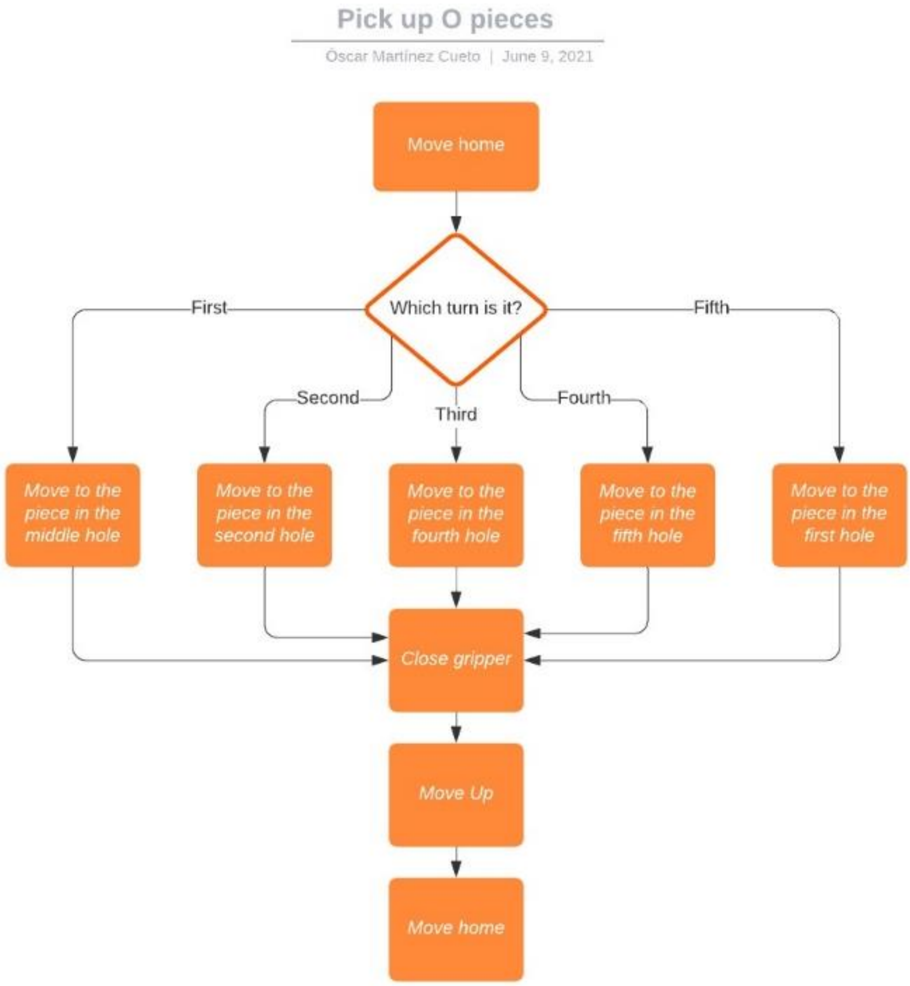


Figure 13. "Pick up O pieces" flowchart.

To take the X pieces, the procedure is similar except that you will only take 4 pieces because as the second player, you never get to use 5 pieces. And that morobot will turn to its left side instead of its right, where the X pieces are located.

To do all these movements I use functions from the morobot.h library that has been developed. This allows you to easily perform movements with the different motors and obtain a desired position.

To make possible these movements. to reach the piece in question and carefully remove it from its box, a series of small movements of each motor are made until the right position is reached.

2.3.2 Leave pieces

Another function to be explained in more detail: leave pieces in the chosen place (Fig. 14).

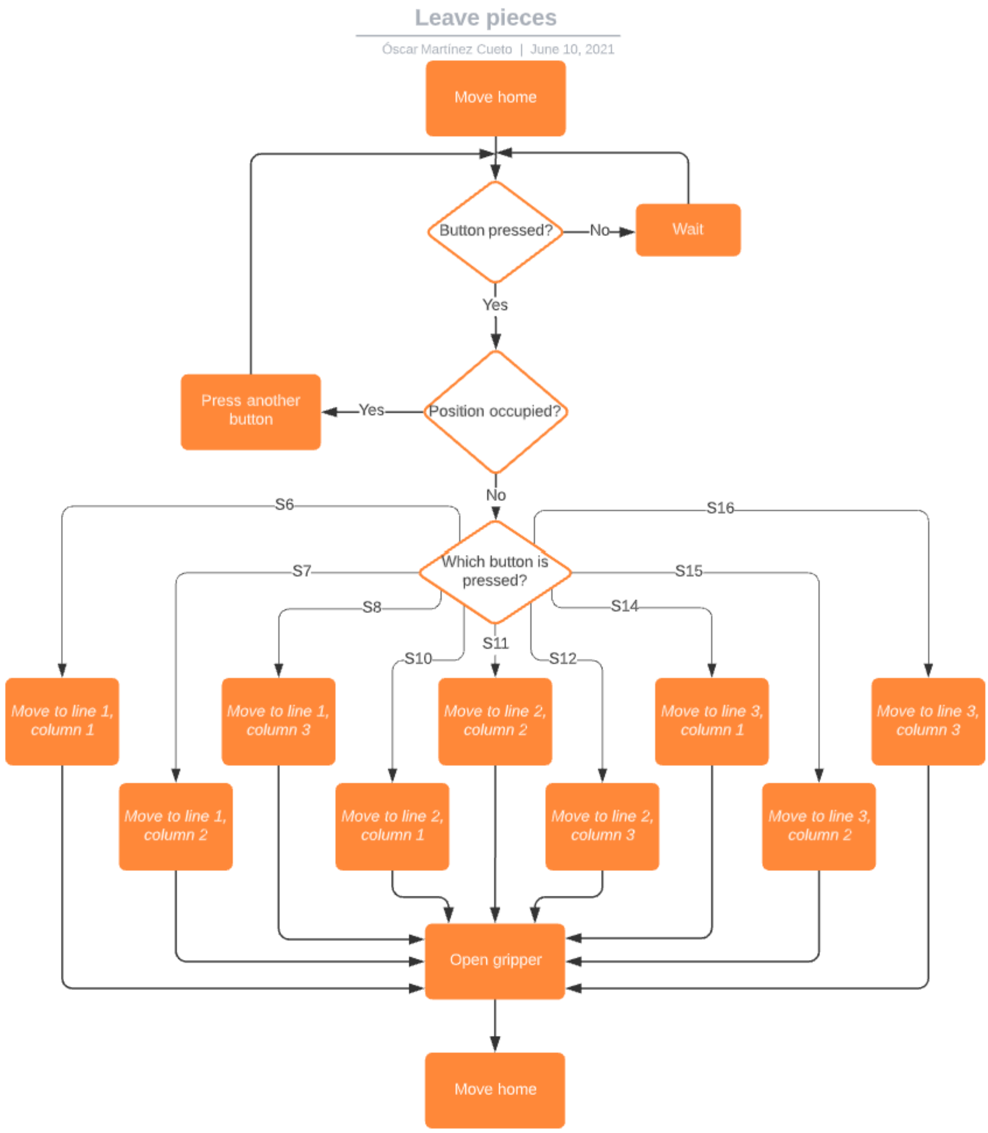


Figure 14. "Leave pieces" flowchart.

In the home position the morobot remains waiting for the player in question to press the appropriate button depending on where they want to place their piece. The position corresponding to each button can be seen graphically in Fig.15.

The system remembers which places are already occupied and If the button pressed is one that corresponds to a place that is already occupied, it sends a warning message to the user to press another button because that position is occupied.

The morobot carefully positions the end effector in the chosen position using the button, opens the gripper a little so that the piece falls down but without hitting other possible pieces on the sides and slowly returns to the home position.

The procedure for programming the movements is the same as for picking up the pieces. It involves making a series of small movements with the different motors until it reaches the right position so that it reaches its position without colliding with other pieces and improving the precision of the final position.

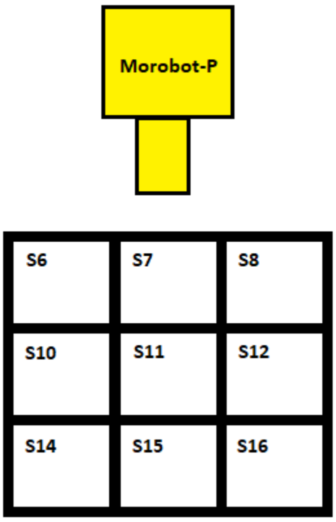


Figure 15. Positions on the board for each button.

Finally, to return the pieces to their places, the procedure is very similar to putting the parts down and picking them up from their original place, but in reverse.

Saving in different variables the positions that have been occupied in order to be able to return the pieces correctly. Careful movements to pick up the pieces from the board and lift them, then it moves to the home position and carry them to its right position and carefully put them back in place.

3 Results and Discussion

This chapter deals with all the results obtained throughout the work and some discussion of them.

3.1 Physical assembly

The parts in figures 3 and 4 were printed and assembled with the motor included, resulting in the shape shown in Fig. 16.

The end gripper meets expectations and is the right size and shape to pick up the game pieces.

Figure 16. Gripper mounted.

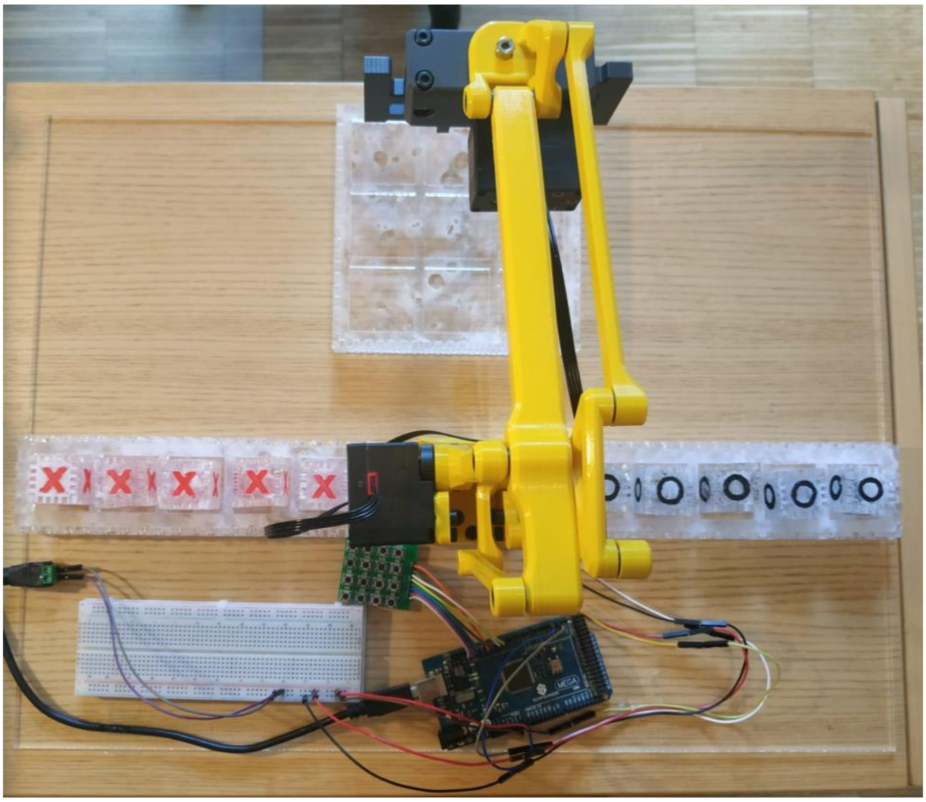


Figure 17. Workspace placed.

Fig. 17 shows both the gripper assembled to the morobot and the complete system already in place. The pieces of Fig. 5-9 already glued and placed in their places. And the Arduino board, the button array and all its electrical circuit can also be seen already in place.

The system is properly positioned so that the system runs smoothly, and the morobot-p can pick up the pieces and move them without bumping into each other.

3.2 System in action

With the whole system set up and the program developed, we proceed to test and observe the results obtained.

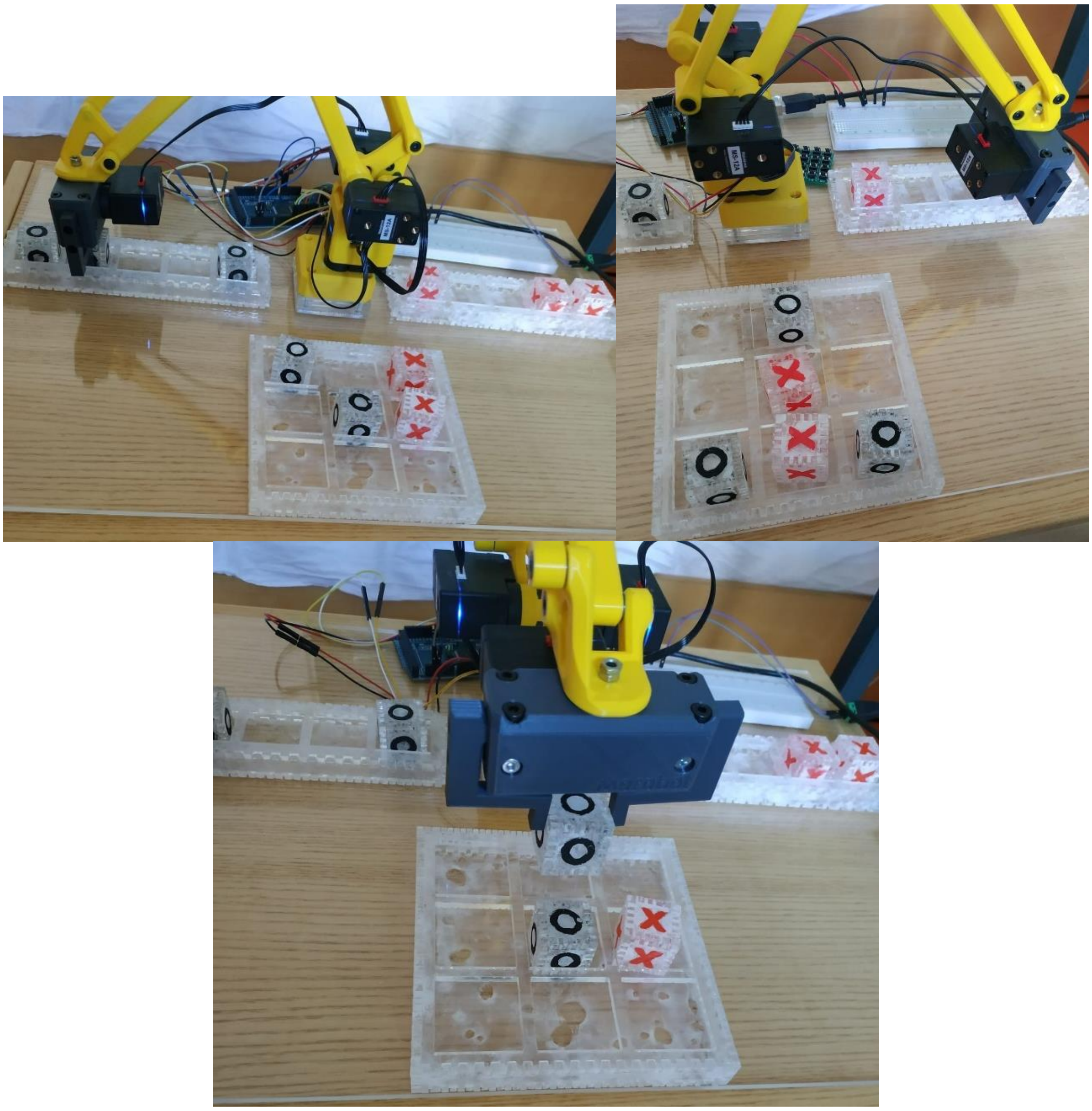


Figure 18. System in action.

It can be seen in Figure 18 the morobot playing in various positions and the pieces being moved in different games. As it can be seen the system is working correctly and can continue to pick up and drop off pieces.

In the meantime, players are shown on the screen the action to be taken so that the game can be played properly.

In the following images we can see different situations that occur in the games and how they are displayed on the screen. For example, Fig. 19 shows how when a position already occupied is selected, a warning message is displayed on the screen.

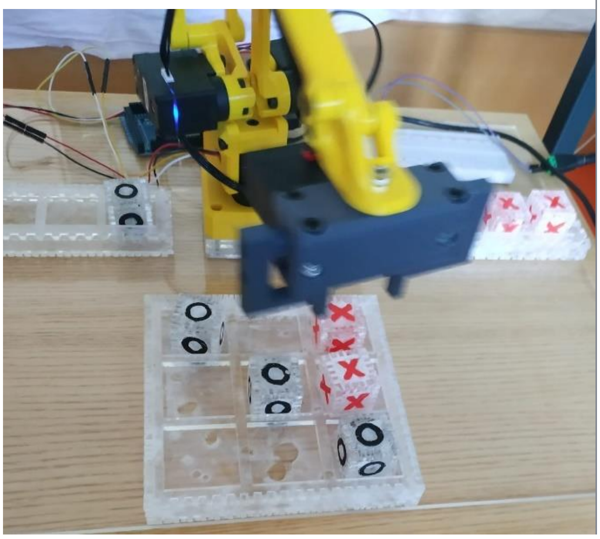
```
S11
Place in line 2, column 2
Taking X piece

Choose where you want to place your piece
L1C1. Press S6 for line 1, column 1
L1C2. Press S7 for line 1, column 2
L1C3. Press S8 for line 1, column 3
L2C1. Press S10 for line 2, column 1
L2C2. Press S11 for line 2, column 2
L2C3. Press S12 for line 2, column 3
L3C1. Press S14 for line 3, column 1
L3C2. Press S15 for line 3, column 2
L3C3. Press S16 for line 3, column 3

S11
Position occupied, choose another position
```

Figure 19. Screenshot of position occupied.

And then it would be asked again to choose where it wants to place the piece.



```
Taking O piece

Choose where you want to place your piece
L1C1. Press S6 for line 1, column 1
L1C2. Press S7 for line 1, column 2
L1C3. Press S8 for line 1, column 3
L2C1. Press S10 for line 2, column 1
L2C2. Press S11 for line 2, column 2
L2C3. Press S12 for line 2, column 3
L3C1. Press S14 for line 3, column 1
L3C2. Press S15 for line 3, column 2
L3C3. Press S16 for line 3, column 3

S16
Place in line 3, column 3

*******************************************
Player 1 has won!!
Congratulations!!
*******************************************

Returning pieces
```

Figure 20. Player 1 winning.

Another case is shown in Fig. 20, player 1 doing 3-in-a-row. On the left you can see how the board looks and the robot starting to move to pick up the pieces again. On the right you can see what appears on the screen when it finishes, how it congratulates the winner and prepares to return the pieces to their place.

The next case shown is when all nine squares of the board are occupied without any of the players having made 3-in-a-row, i.e., a draw (Fig. 21).

Similar to the previous one, on the left it can be seen the fully occupied board and on the right, what is shown on the screen when this situation is reached in the game.


```
Choose where you want to place your piece
L1C1. Press S6 for line 1, column 1
L1C2. Press S7 for line 1, column 2
L1C3. Press S8 for line 1, column 3
L2C1. Press S10 for line 2, column 1
L2C2. Press S11 for line 2, column 2
L2C3. Press S12 for line 2, column 3
L3C1. Press S14 for line 3, column 1
L3C2. Press S15 for line 3, column 2
L3C3. Press S16 for line 3, column 3

S10
Place in line 2, column 1

*******************************************
The game is now a draw.
Nice game!
*******************************************
```

Figure 21. Draw.

In the latter case it is also shown how at the start you can choose the option to view the rules before you start playing (see Fig. 22).

```
Welcome to play tic-tac-toe!

Menu:
1. Press S1 to play a new game
2. Press S2 to see the rules
3. Press S3 to exit

S2

See the rules

RULES TIC-TAC-TOE
It is a  two-player game.
The first player will move the O-cubes and the second, the X-cubes.
Following the instructions that will appear on the screen you will be able to move your cubes pressing the buttons.
The objective of the game is to line up three of your cubes before your opponent does. They can be aligned in a column, in a row or on a diagonal
If you manage to align 3 of your cubes you have won. If your opponent does it, you have lost. And if none of you does it, it is a draw.


Menu:
1. Press S1 to play a new game
2. Press S2 to see the rules
3. Press S3 to exit
```

Figure 22. Show the rules.

The rules are displayed and the program return to the home menu in case you want to play a game, exit the programme or view the rules again.

3.3 Discussion

The target system has been successfully implemented. The morobot-p is able, through the designed and assembled gripper, to pick up the created parts. In addition, the program works correctly and it is possible to play 3-in-a-row with it.

As a complication, I have found that the gripper cannot rotate, so the squares in which to position the pieces must be slightly larger than the pieces are, otherwise it would not hit the square. Furthermore, the robot's precision decreases considerably with the addition of the weight of the gripper (mainly its motor) and it is necessary to be very careful, and when it picks up a piece, this weight also makes its behaviour somewhat worse.

4 Conclusions and future lines

A miniaturised robot (morobot) control system has been successfully implemented, resembling the movements of industrial robots but applying it to the tic-tac-toe game.

This system can be used to introduce children to programming by giving them everything done except some parts of the program so that they are motivated by being able to play tic-tac-toe and at the same time become familiar with the movements and the way an industrial robot works without them really being aware of them or bored.

In the same way it can also introduce students to CAD design and 3D printing, giving them the programming already done, creating the different pieces to play with. Will be another motivating and entertaining yet useful way of learning.

As possible future lines of research and work, this system could be augmented by adding artificial intelligence to the robot so that it can play against the machine. Or even one robot could play against another robot. This would make the system more difficult but also more attractive.

This work could also be continued by implementing a similar system but for other different morobot types, making certain modifications to the workspace and the morobot's fastenings so that they could work correctly according to their forms of movement. This enables the teaching of different types of robots and their movements.

This system is cheap and easily replicable in other places so that it can reach many people. This form of learning will be reassuring, attractive and beneficial for the learners.

5 Bibliography

[1] Miller, D. P. & Nourbakhsh, I. (2016) Robotics for Education. In: Siciliano B., Khatib O. (eds) Springer Handbook of Robotics. Springer Handbooks. Springer, Cham.

[2] Curto, B. & Moreno, V. (2015). EXPERIENCIAS CONSTRUCCIONISTAS CON ROBÓTICA EDUCATIVA EN EL CENTRO INTERNACIONAL DE TECNOLOGÍAS AVANZADAS. Ediciones Universidad de Salamanca (Spain).

[3] Johnson, J. (2003). Children, robotics, and education. *Artificial Life And Robotics*, 7(1-2), 16-21. doi: 10.1007/bf02480880

[4] Alimisis, D. (2009). *Teacher education on robotics*. Athens: School of Pedagogical and Technological Education.

[5] UAS Technikum Wien. Engine – Engineering goes International [online]. Available: https://engine.ie.technikum-wien.at/webpage/en/ at Online Laboratories – Morobot [Accessed: 27/05/2021].

[6] UAS Technikum Wien – my.sharepoint [online]. https://fhtw-my.sharepoint.com/:f:/g/personal/rauer_technikum-wien_at/EqCmgnG48F5DhoUqymyPeDsBle8L1-g1K1zmv48mNSwo6Q

[7] Digikey – KR 3 Agilus. https://www.digikey.com/es/products/detail/kuka-robotics-corporation/KR-3-R540/10239959

[8] Alibaba Manufacturer Directory - Suppliers, Manufacturers, Exporters & Importers. IRB 120 https://spanish.alibaba.com/g/abb-irb-120.html

[9] IRB 120 data - Industrial Robots (Robotics). https://new.abb.com/products/robotics/industrial-robots/irb-120/irb-120-data

[10] Digikey – Niryo Ned https://www.digikey.com/en/products/detail/niryo/NIRYO-NED/13682292

[11] Robotshop – makeblock smartservo ms 12a https://www.robotshop.com/en/makeblock-smart-servo-ms-12a.html

[12] Universitat Politècnica de Catalunya - Usos Y Beneficios De La Robótica En Las Aulas https://www.upc.edu/latevaupc/usos-y-beneficios-robotica-las-aulas/

[13] Blank, D., Robots make computer science personal. *Commun*. ACM, 49(12):25–27, 2006.

[14] Institute for Personal Robots in Education http://www.roboteducation.org/

[15] MINDSTORMS® | Themes | Official LEGO® Shop US https://www.lego.com/en-us/themes/mindstorms

[16] Home Page | FIRST LEGO League https://www.firstlegoleague.org/

[17] Set de lego mindstorms ev3. (2021). Retrieved 12 June 2021, from https://www.levelthreevip.top/products.aspx?cid=62&cname=set+de+lego+mindstorms+ev3

[18] Bauanleitungen für Roboter aus dem LEGO MINDSTORMS Education Basis-Set – NanoGiants Academy e.V. (2021). Retrieved 12 June 2021, from https://nano-giants.net/bots/

[19] LEGO Mindstrorms EV3 Robot Base Chassis 5 - The Big One. (2021). Retrieved 12 June 2021, from https://www.fllcasts.com/materials/59-lego-mindstrorms-ev3-robot-base-chassis-5-the-big-one

[20] Zosh, J. (2017). *Learning through play*. Billund: LEGO Fonden.

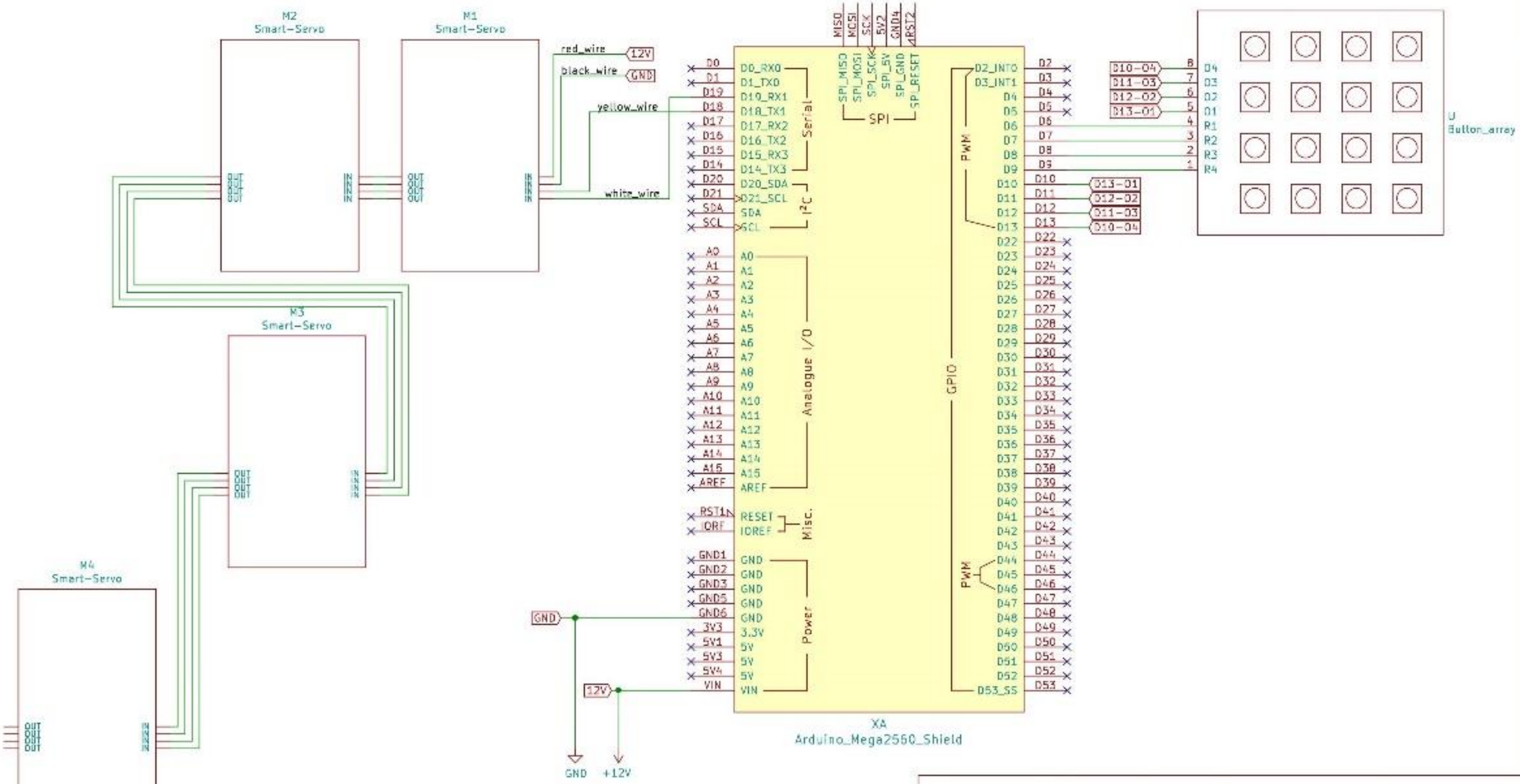
[21] Fernández Oliveras, A. (2019). Aprender jugando y la cultura del esfuerzo. *Granadahoy*.

6 List of figures

7 List of Tables

Appendix

- Electrical circuit



Sheet: /
File: electrical_circuit.sch

Title: Morobot control electrical circuit

Size: A4 | Date: 01/06/2021 | Rev:
KiCad E.D.A. kicad (5.1.9)-1 | Id: 1/1