AIR HOCKEY ROBOT (AHRobot)
BUILD INSTRUCTIONS

Project Blog:
Code Repository & Parts:
Other places of interest:
Licence:
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Contributors:
(*) If you collaborate on the project, add your name to the list

Bill of materials (BOM).

This document is divided in the air hockey table and the robot.

AIR HOCKEY TABLE

- Wood thread screws
  - 50 2.5x16mm
  - 50 3x30mm
  - 20 3x20mm

-Metric thread screws
  - 16 M3x6mm
  - 8 M3x12mm
  - 24 M3 washers
  - 16 M3 nuts
  - 2 M3x20mm
  - 8 M4x12mm
  - 8 M4 nuts

- Wood boards
  - 2 100x60cm x2.5mm MDF (white finish on one side)

- Solid wood slats (*)
  - 2 44x18mm x 1m
  - 3 44x18mmx56.4cm
  - 2 12x18x 90cm (can be 12x12)
  - 4-12x18x 12 cm
  - 4 12x18x 6 cm

(*) if you don´t find the exact dimensions you can easily adapt the whole project ...

- hot glue gun
- EVA foam
- Drill and drill bits 1mm and 1.5mm

- Jigsaw (or marquetry saw) to open fan holes
- 2   90mm fans 12V 0.5A (you can also use 120mm size). This are typical PC fans (Important! 0.5A minimum, 0.6 or 0.8A better). I use old fans from PC power supplies.
- Cable and connectors for fans

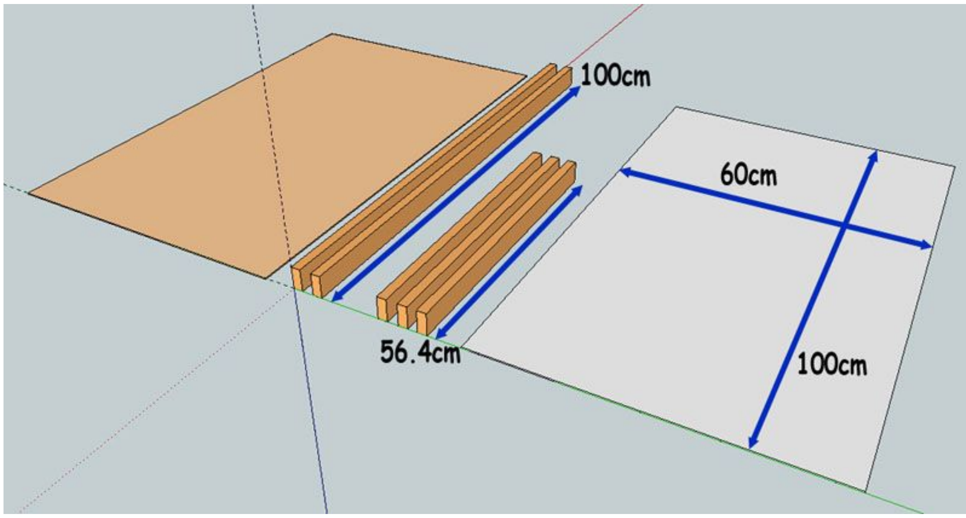
AIR HOCKEY ROBOT

Typical RepRap 3D printer equipment:
- Arduino Mega 2560
- RAMPS 1.4
- 3 A4988 Drivers with heatsinks (or DRV8825)
- 12v fan (Recommended 5-6cm) for electronics cooling
- 3 NEMA17 stepper motors 48N-cm (70oz-inch)
- Motor cable and connectors.
- Five meters of GT2 belt (or T5 belt)
- 2 8mm Stainless Steel rods 46cm (1 meter steel rod and cut)
- 2 8x1mm 65cm carbon tubes (kite tubes, easy to cut)
  (can be replaced by aluminum tube 8x1mm)

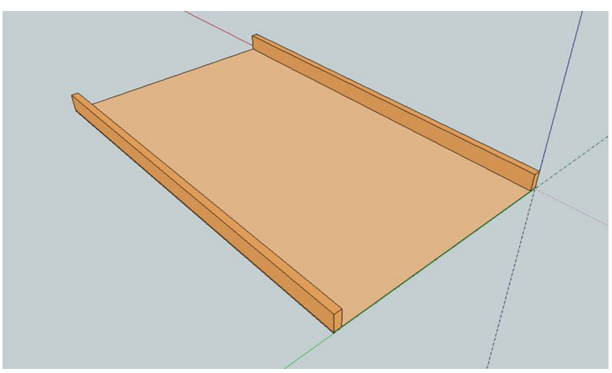
UPDATED: New tube size!
- 1 8x1mm 87.5cm carbon tube (kite tube) for camera
  (can be replaced by aluminum tube 8x1mm)
- 3 608 bearings
- 3(or 4) LM8UU linear bearings
- Small nylon tag fasteners
- Set of 3D printed parts in PLA (repository)
- PS3 EYE Camera
- PC or laptop (i3 processor or higher recommended)
  (In future, PC and PS3 camera will be replaced by a CMUCAM5 camera)
- External 12V power supply (minimum 5A)

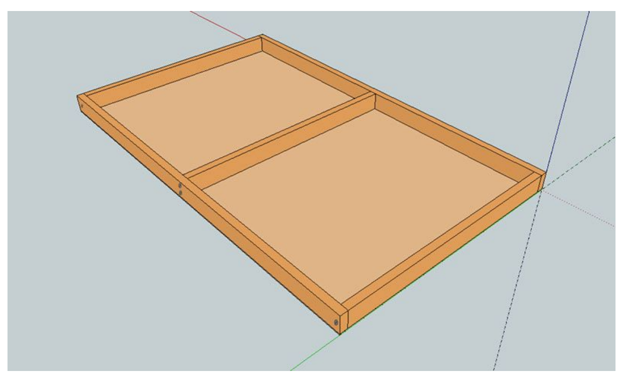
Instructions:

Part I: Building the Air Hockey table

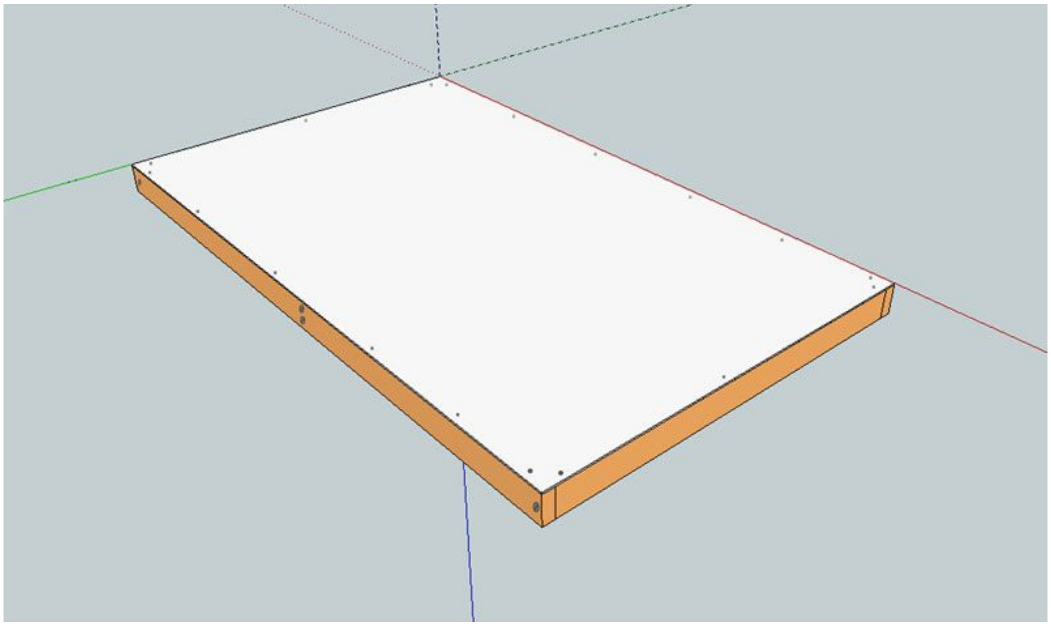


- Assemble the frame with wooden slats as shown in the picture. Use 3x30mm screws to attach the slats, one screw centered at the ends and two screws in the central reinforcement. It is always preferable to mark before with a pencil, then drill with a 1.5mm drillbit (to prevent the wood break) and then insert the screws. Use one of the 100x60cm boards to make sure you assemble it properly aligned. The screw heads must not protrude beyond the wood, we screw them until they are fully embedded in the wood.

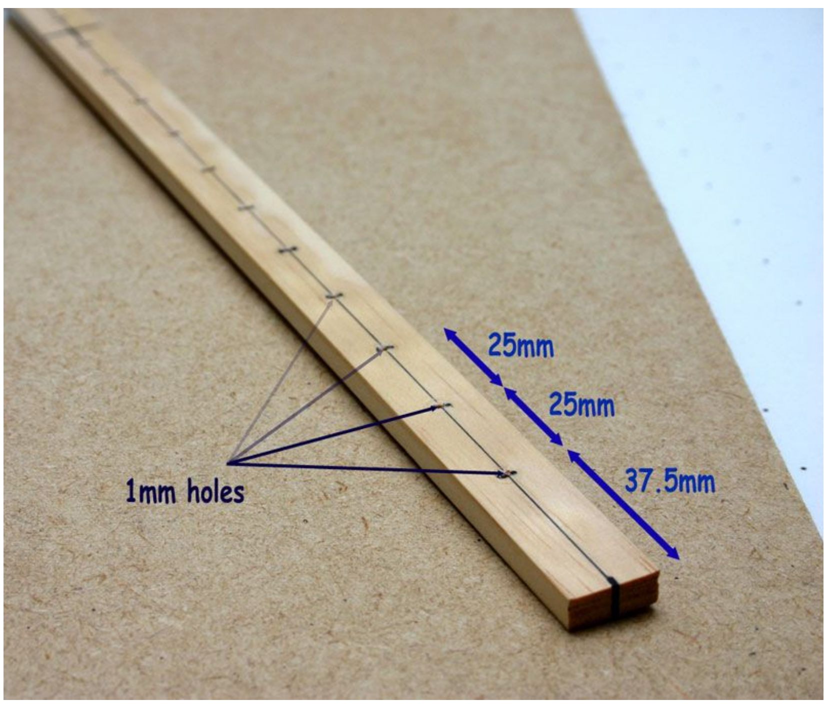




- Screw the 100x60cm board to the frame with some 2.5x16 screws (see photo). Start placing screws around the corner at 3cm from the edge and then approximately at 20cm distance (measure and make marks first, then drill with 1.5mm drillbit and then insert the screws)

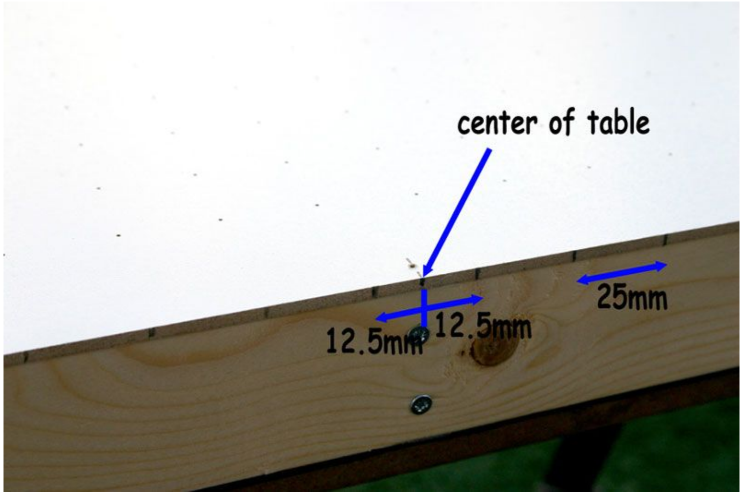


- Now it´s time to open the air holes in the table. We are going to prepare a wood guide. The guide will be a 60x18x5mm wood slat with the holes. First let's mark the position of the holes. Leave a space of 3.75 cm at the edges and then mark every 2.5cm. In total we should have 22 marks. Now we make the holes with 1mm drillbit (Make sure the drill is well leveled)



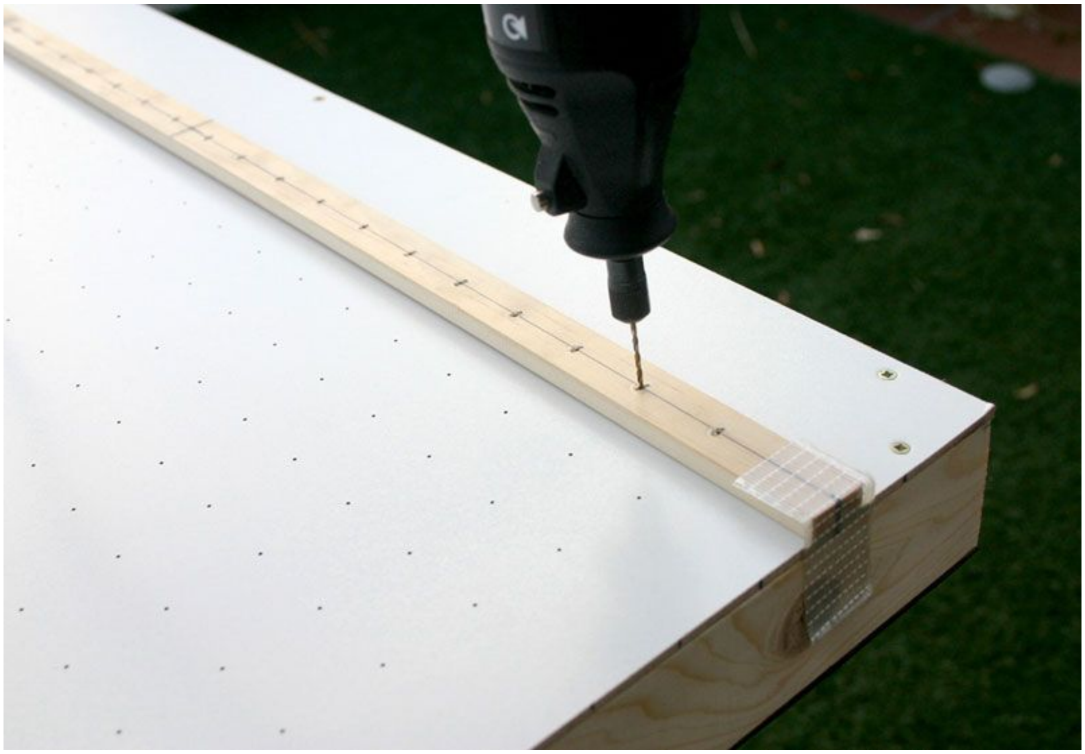
- Now it´s time to make the marks in the board flanges. Important, start from the center of the table (measure it) and make the first mark at 12.5mm on each side of table center. The idea is that in the center we will NOT make holes because we have the center wood slat. Now make marks on the board every

25mm until the edge where we leave a gap of about 6cm. We would have a total of 36 marks in the table (18 on each side of center)



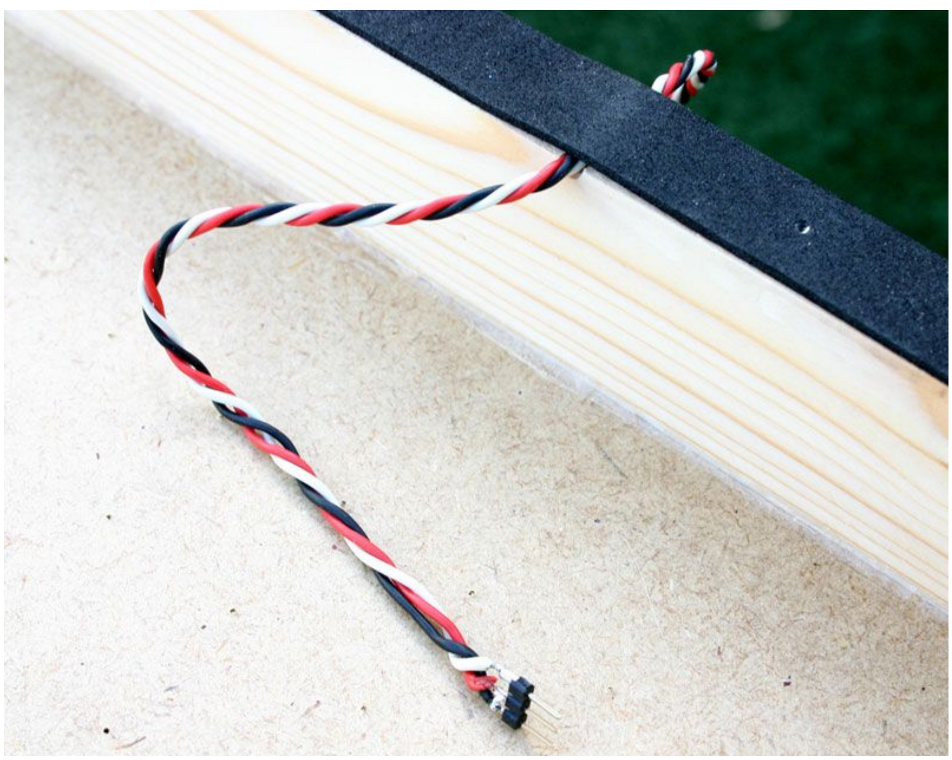
- Place the guide aligned with the marks, secure with tape on each side, press the guide against the table with your hand and started to drill the holes with the 1mm drillbit (22 in each row). We move the guide to the next mark, secure with the tape again and continue making holes ... Looks like a huge work but it´s not so hard (less than 40 minutes)

Tip: Prepare everything to be on a high and comfortable posture.



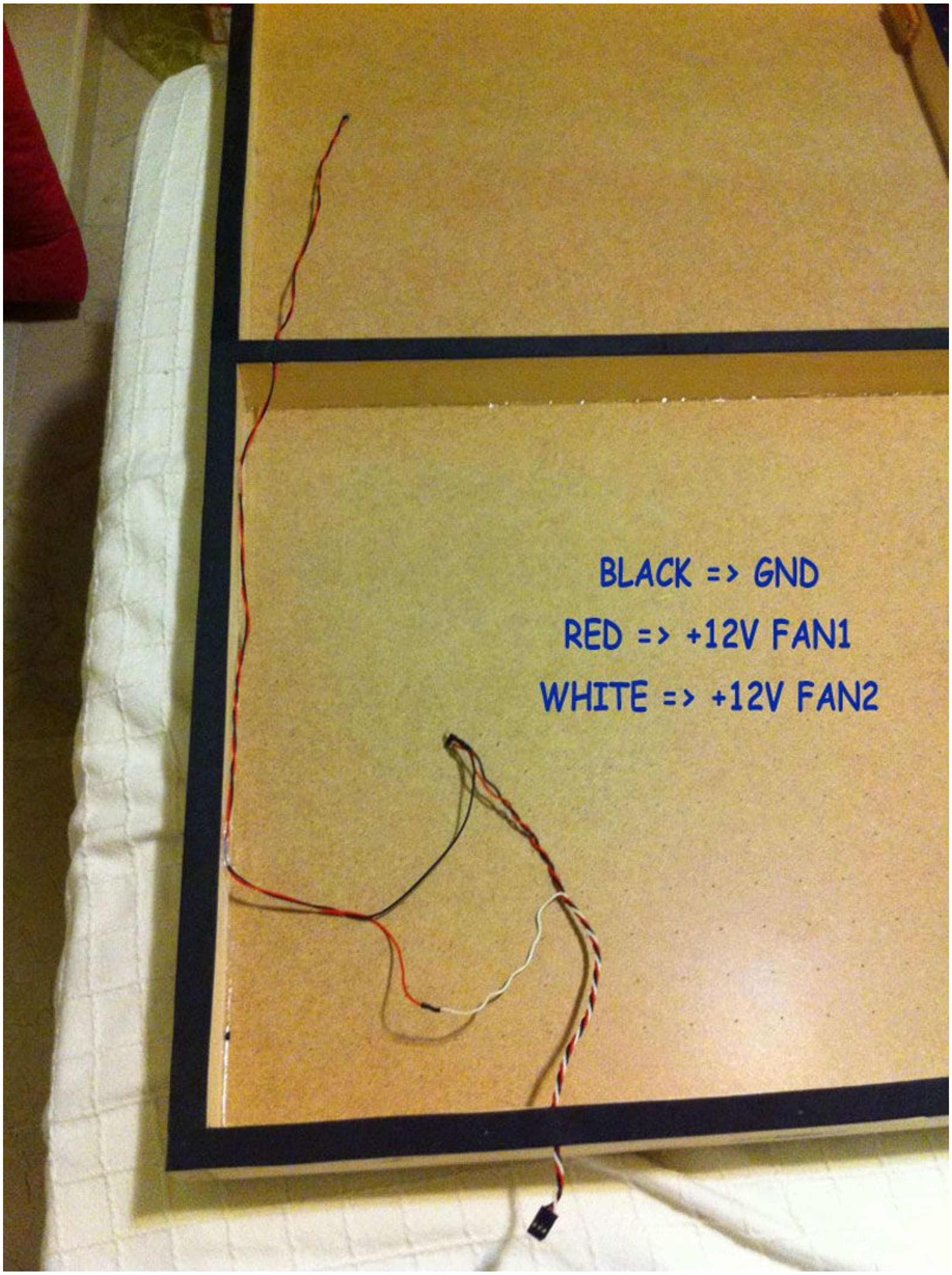
- Once finished the holes in the table, we will cover the slats on the backside of the table with EVA foam (typical craft material), including the center slat. We make this to seal the table (we want that the air could only exit by the top holes). The EVA foam is cutted with the width of the slats and glued with cyanoacrylate

- We prepare the fans connections. (See next step photo to clarify)



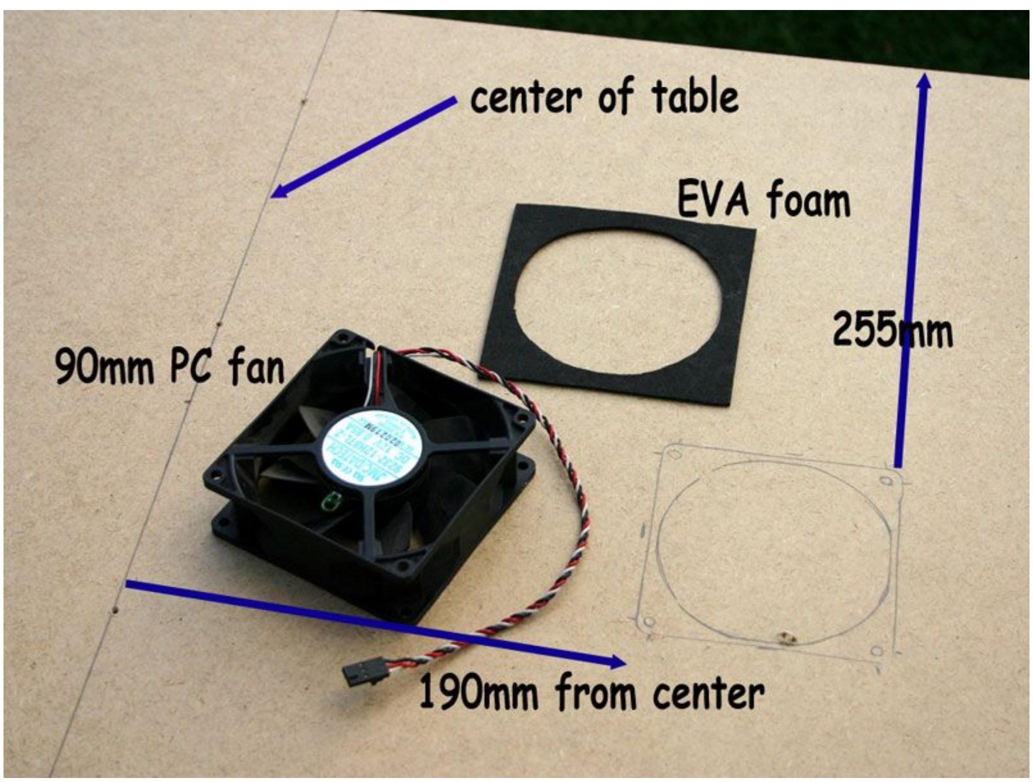
- Fans connector has three wires (black, red and white in the photo). The black is the ground common to the two fans, the red will be positive for one of the fans (+12 V) and white is the positive of the other fan

(+12 V). Note: We only need +12V and gorund connections to the fans (red and black) but some fans have 3 or 4 wires. Sometimes +12V is the yellow cable. Try it first



- we seal the table on the backside with the hot glue gun so the air could not escape.

- On the other 100x60cm board, we will prepare the big holes for the fans. Mark a line on the center of the table. Mark with a pencil the fans in the center of the table. at 19 cm from centerline.



- Drill the holes for the fan M4 screws and also open a hole to insert the blade of the jig saw. With the jigsaw (or marquetry saw) open the center hole of each fan

- Mark and cut the fan shape on the EVA foam with a 2cm extra margin. This will serve to seal the fan assembly

- Screw the fans (M4x12 screws and bolts) ensuring that the EVA foam seal properly and does not touch the blades

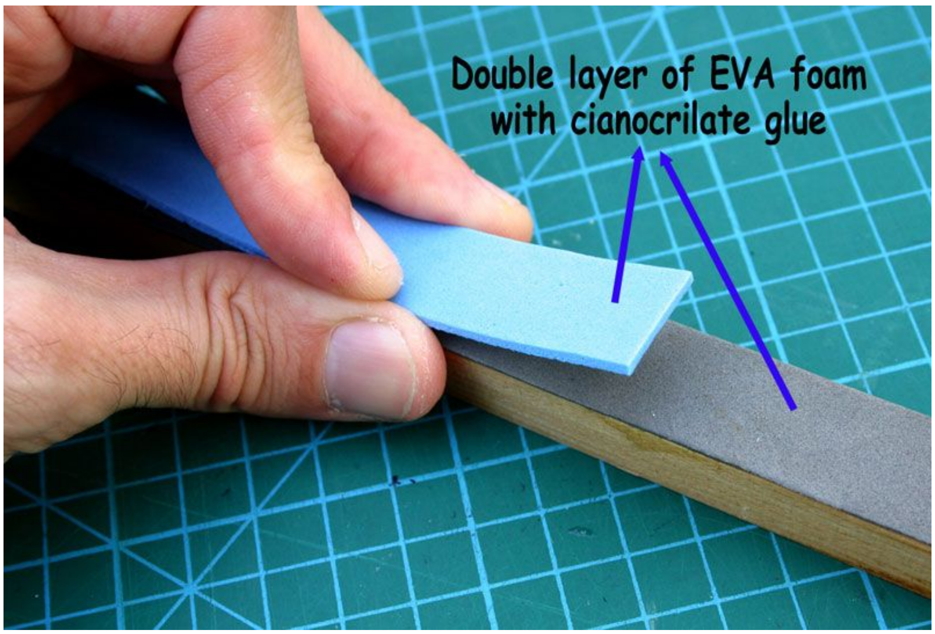
- Close the back board (with the fans) with the 2.5x16mm screws (not overtight the EVA foam, just a good seal). Don´t insert screws exactly in the corners (3cm apart is ok)

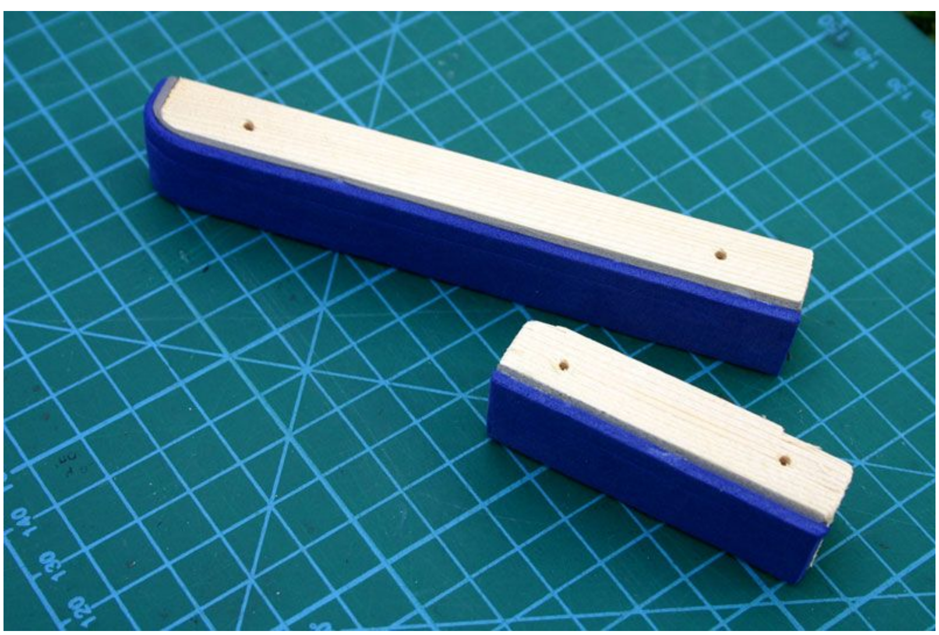
NOTE: Is recommended to add a grid to the fans to prevent childrens to hurt their fingers!.

- Now it's time to prepare the hockey sides To do this we take the 12x18 slats and cut the following measures:

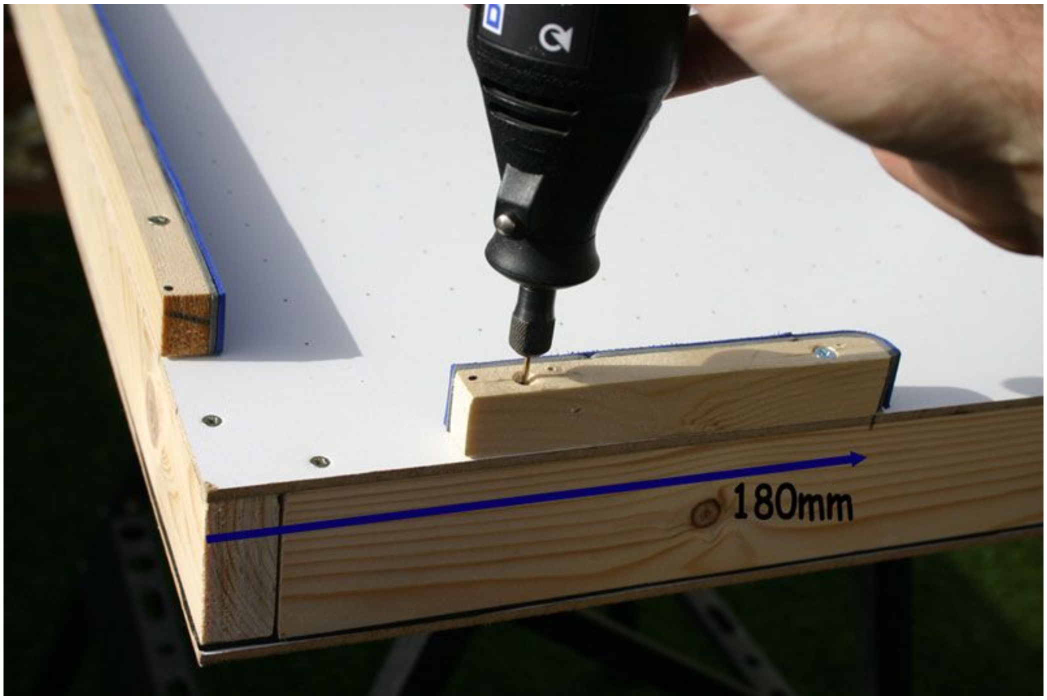
- 2 90cm for sides
- 4 12cm for rear parts, alongside the goals
- 4 6cm for corners

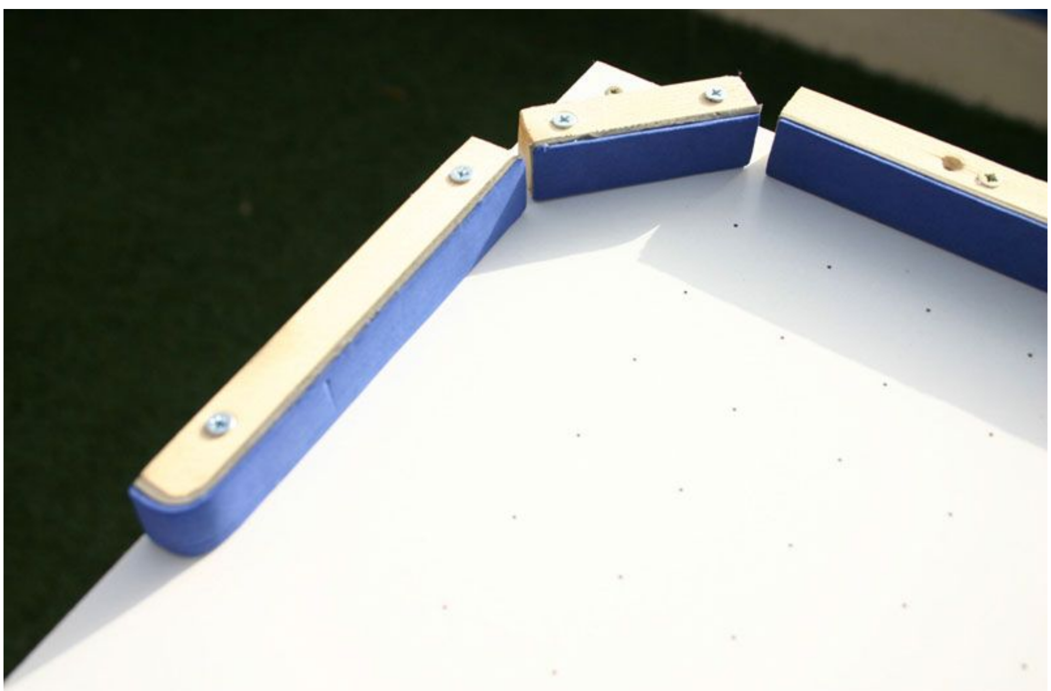
- Now we will cover the slats with 2 layers of EVA foam (glued with cianocrilate). We can use the wood slat to cut the EVA foam with a cutter (on the 18mm side). We need to layers for a good puck bounce. If you want you could round the sides near the goal.





- Now we can screw it into the top of the table. As always first measure, mark, drill a hole and then insert the 3x30 screws. We will begin with the two long sides (90cm), then the back pieces and the corners.


180mm



Well, we have an Air Hockey table ready! Connect a 12V input source 12V (check polarity - +) to the fans.

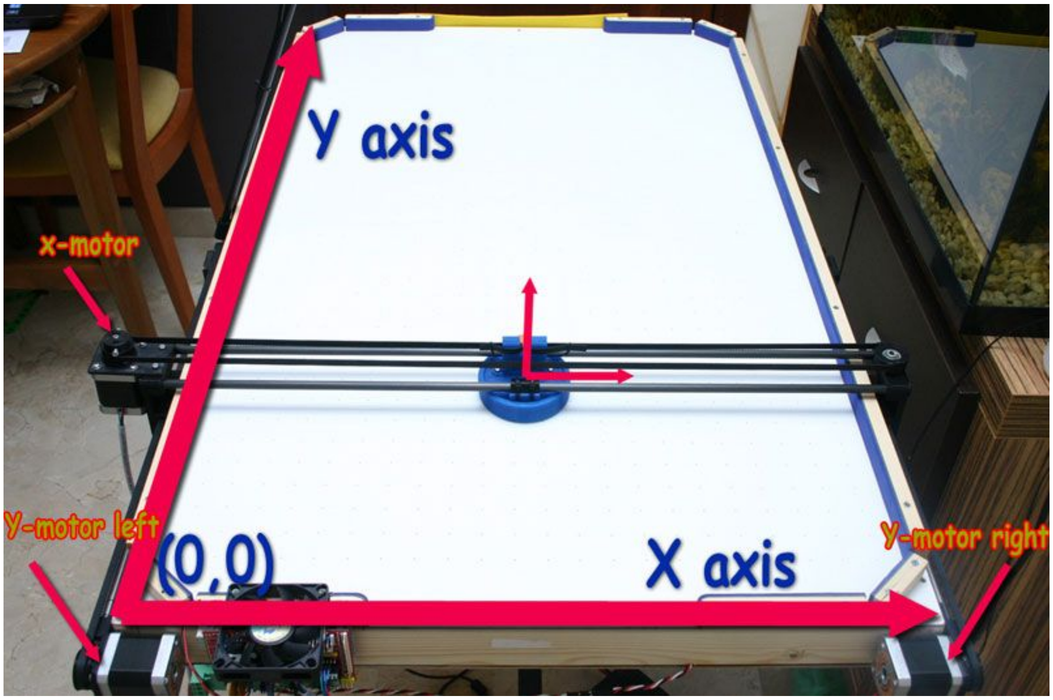
- Now it´s time to 3D print the pusher and the puck (files in repository).
  The puck must be printed with the option of support material because it is hollow inside (cavity for the air in the bottom). Remove the support material and glue a circle of EVA foam in top side (I use green color). It´s recommended to put an adhesive felt on the bottom of the pusher to avoid scratching the table.

Turn on the fans (12V power), and it´s ***time to play and have some fun!!***

Now we will begin construction of the Air Hockey Robot ...

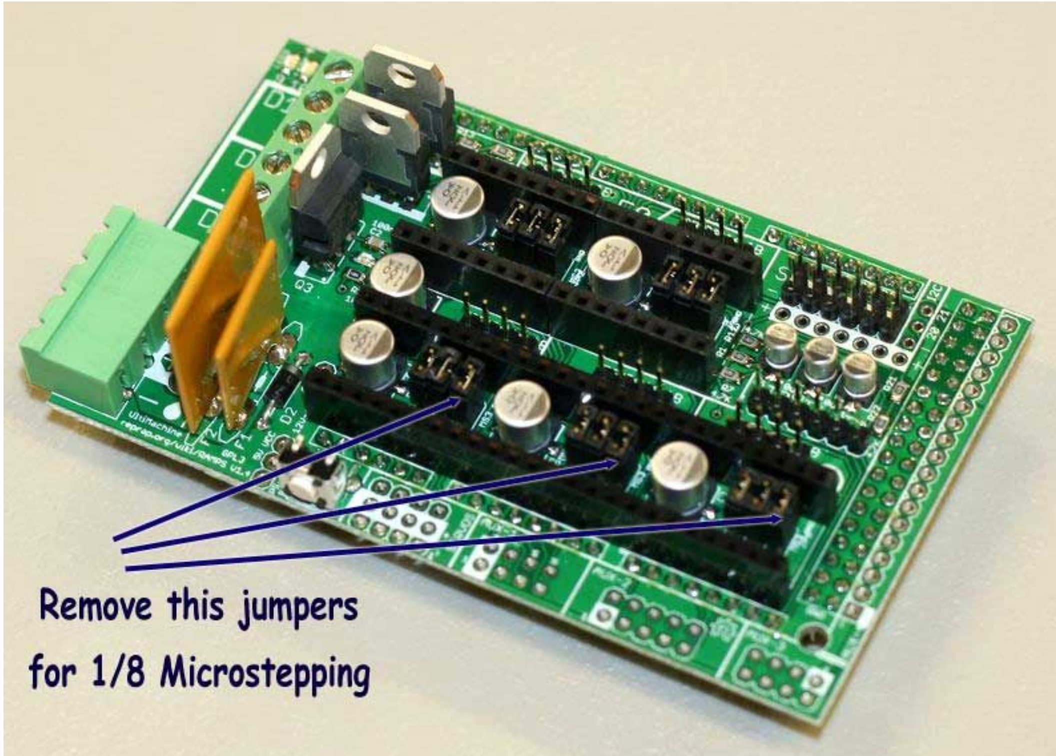
PART II: Construction of Air Hockey Robot

Axes and motors definitios



- Install the RAMPS 1.4 shield into the Arduino Mega

- IMPORTANT: We will modify the RAMPS for use ⅛ Microstepping on drivers. We must remove the JUMPERs shown in the photo. There are boards that do not have jumpers and we need to cut the traces with a cutter (carefully) between these two points. We could check the work with a tester. We repeat this for the drivers of X, Y and Z.



- Insert the stepper drivers with their coolers on the outputs X, Y and Z. The X output will go to the X axis, the Y output will go to the Y axis (left engine, seen from behind the hockey) and the Z output to the right motor.

- Motors. We make a flat part on the output shaft of the motor. The best method to do this is to place the motor on a bench table and use a file.

- Motor cables and conectors. The X motor should have a cable length of around 80cm, left Y-Axis should have a length of 30 cm and the right Y-axis must have a length of 58 cm. To extend the motor cables, solder a new cable with the appropriate connectors. You could buy cables with connectors (typical 3D printer cable set).

- Prepare the 12V power connector on RAMPS. The power supply sholud have 12-15V and a minimun of 5A power. OBSERVE POLARITY: Negative Black, RED positive!. We could also use a 12V battery or a li-poly battery 3S or 4S.

- Connect the Arduino USB cable to the computer. (Should install the appropriate driver if not already). Download the Arduino IDE (recommended 1.0.5 version). Select the Tools-> Arduino Mega 2560 board and tools-> serial port, serial port assigned to the arduino (example COM19).
Upload the sketch: AHR_Motor_Test.ino that is in the Utils / AHR_Motor_Test AHR project folder. (Downloaded from. ZIP project on github). Load into the arduino (Load button). It it´s load succesfully some lights should blink on start.

- Disconnect the USB cable from the Arduino and connect the 3 motor. (blue wire from the motors to the left side). Connect the 12V (RAMPS connector) and check for a few seconds, the motors start to rotate slowly. The X engine should turn in the direction of clockwise, the motor Y (Y-left) should rotate counterclockwise and Z motor (Y-law) should rotate clockwise. If any of the engine does not turn in the right direction we need to modify the code and comment / uncomment lines to reverse the directions of the motors:
 # define INVERT_X_AXIS 1   / / axis Example X
unplug the power reload the program and test again. Later we will perform more tests...
Note: configuration updates that are made in the test application must be transfer to the final code that will be loaded into the robot.

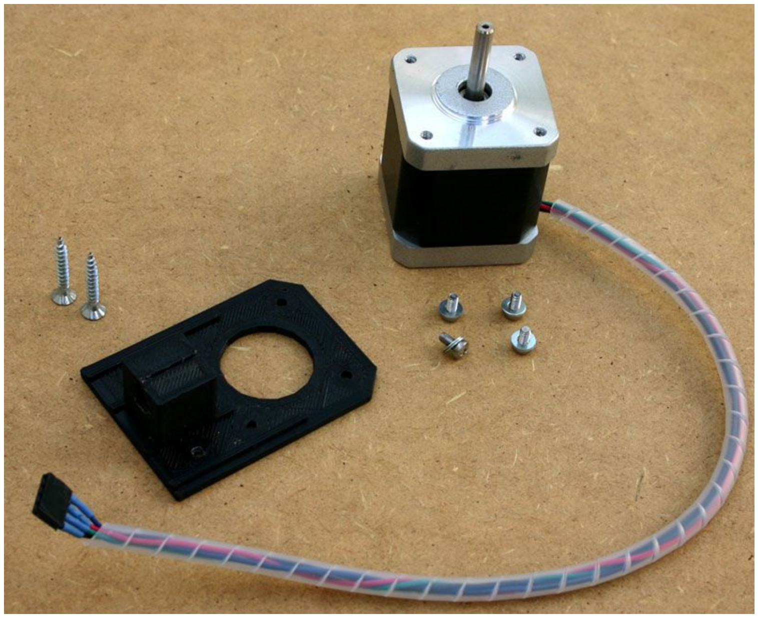
- Setting the motors drivers power. Every motor driver has a small knob to adjust the power (motor current). At this point, if you touch the shaft of each motor with your hand, you should note that it´s quite hard and you are not able to stop it with your fingers easily. If not you should increase the power turning the knob on the driver clockwise slightly.

IMPORTANT: All this part of RAMPS, Arduino Mega + Engines + Drivers + + + drivers setting 12V is the same as 3D printers. If you have problems there are many tutorials and information on this subjects on the net

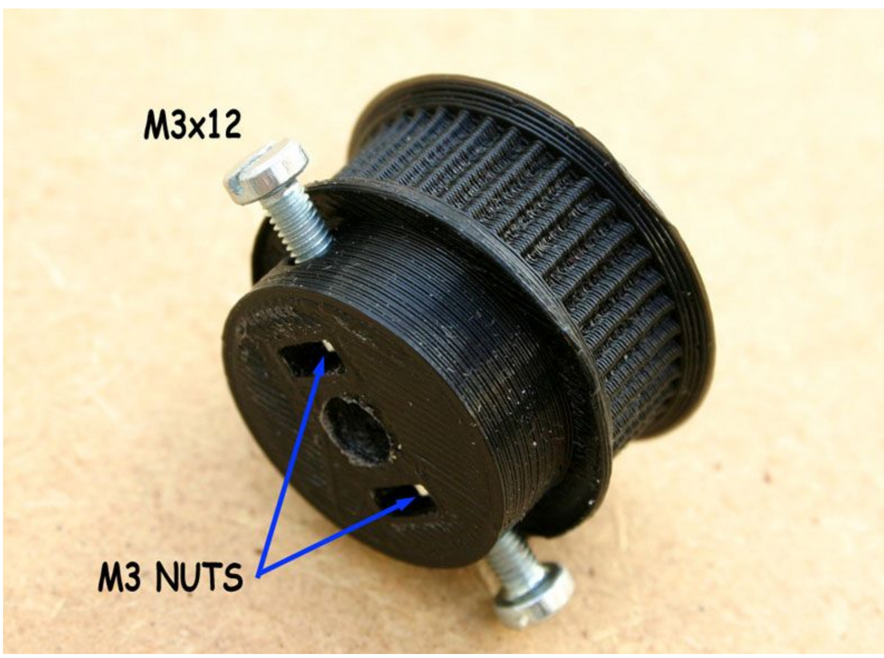
- Print the robot parts from repository. I've printed all in PLA plastic (I think it could work in ABS too). To print the GT2 pulleys you must have your printer very *well calibrated* (and print slowly). If you can not print the GT2 pulleys with enought resolution you have two options: Buy GT2 40 tooth pulleys or change to T5 belts because T5 pulleys are easier to print. In the repository there are al directory for T5 belt parts.

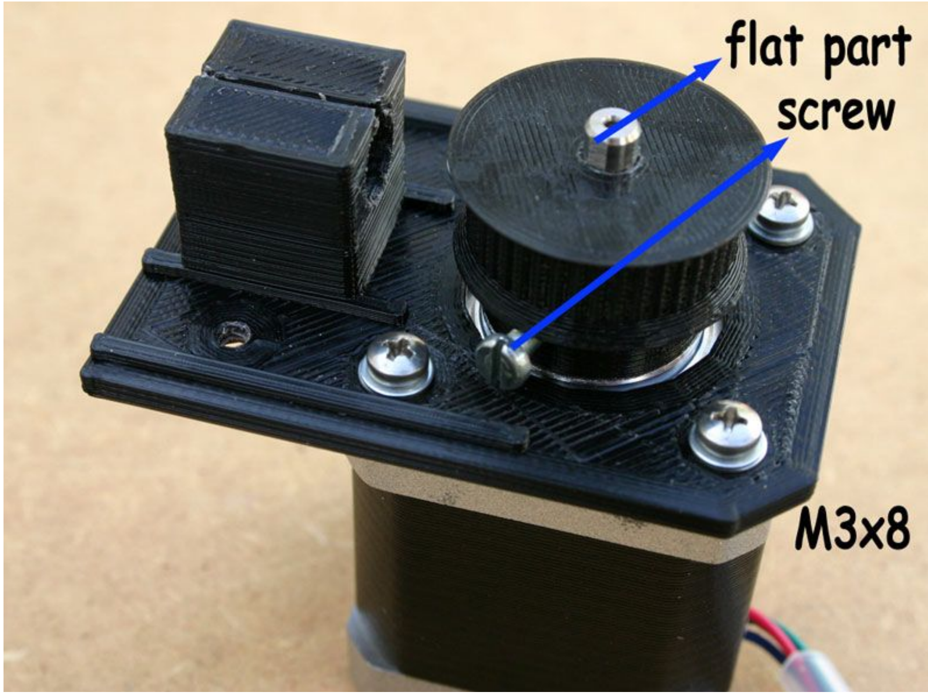
- Usually you need to finish the parts (specially screw and tube holes). Use a round file or even a threaded rod works well as a file. Be sure you have a good fit.

Y axis
We begin with the Y axis. The Y-axis has two sides, the right and the left. Both are fully symmetrical, and use the same parts. We start with the left side mounting the Y axis motor support.

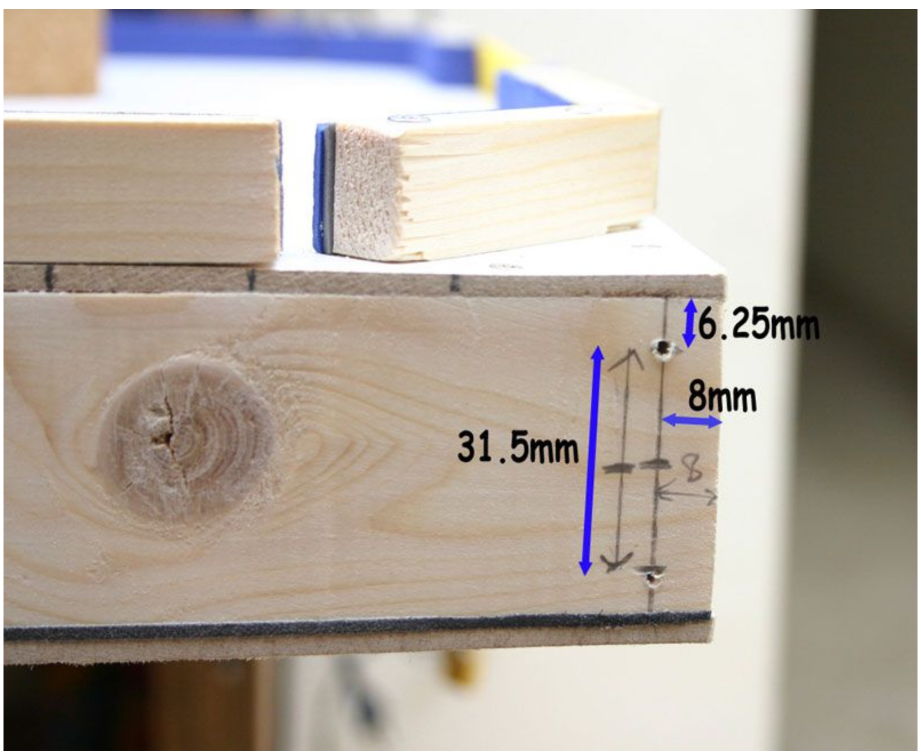


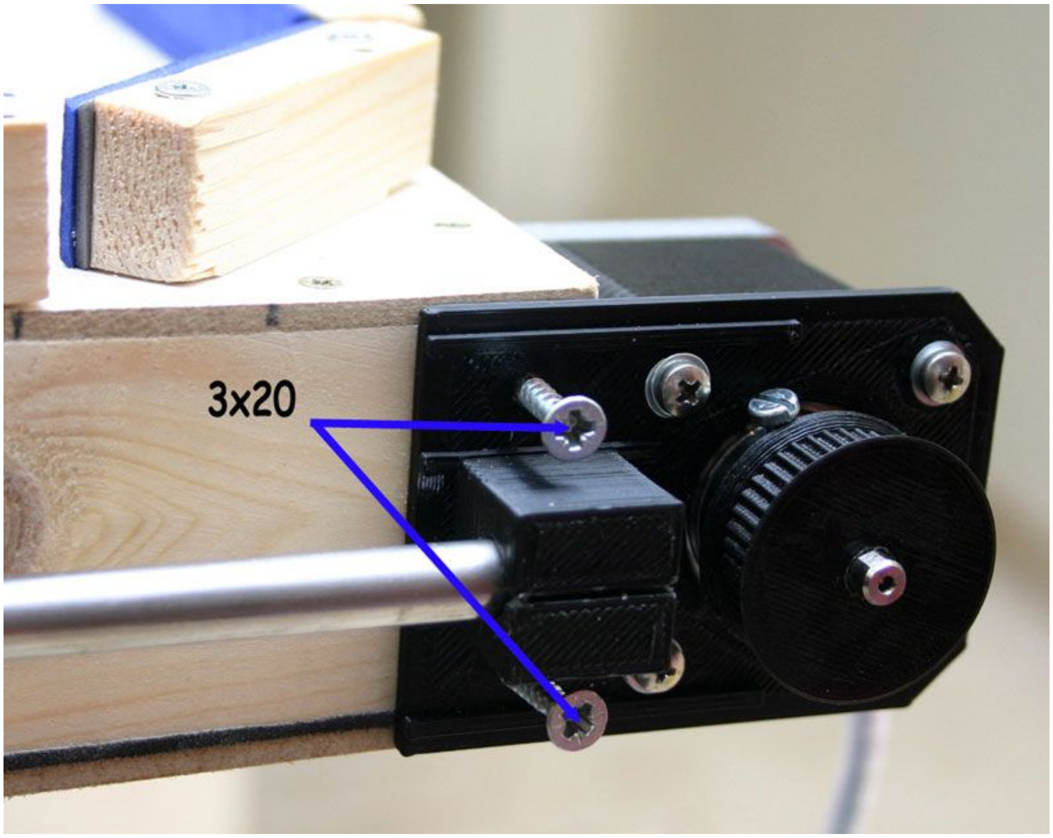
- Now we can screw the motor with M3x6 screws and using one or two washers. Now we can put the 42 teeth GT2 pulley on the motor shaft. The pulley must be mounted with the 2 M3 nuts inserted into their corresponding holes and M3x12 screws. One of the screws should match the flat part of motor shaft to ensure that the pulley does not slip on the shaft.



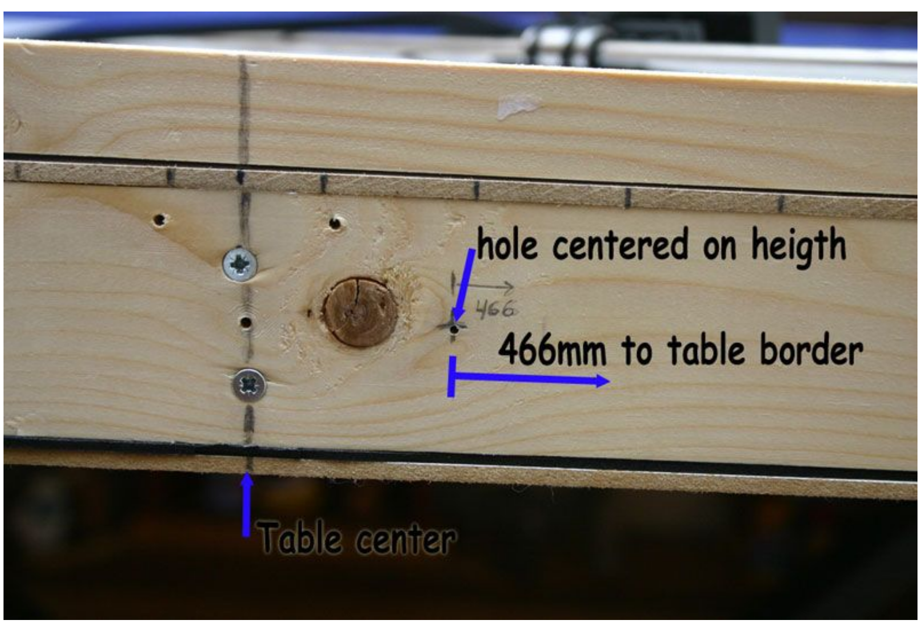


- Now we screw that part to the table. The screws should be at 8mm from the edge, so the motor will be around 2mm from the edge of the table. Use 2 3x30 screws. As always open first the hole with a 1.5mm drillbit to ensure that the wood will not break. This part must be well centered (related to the wood slat) in height.

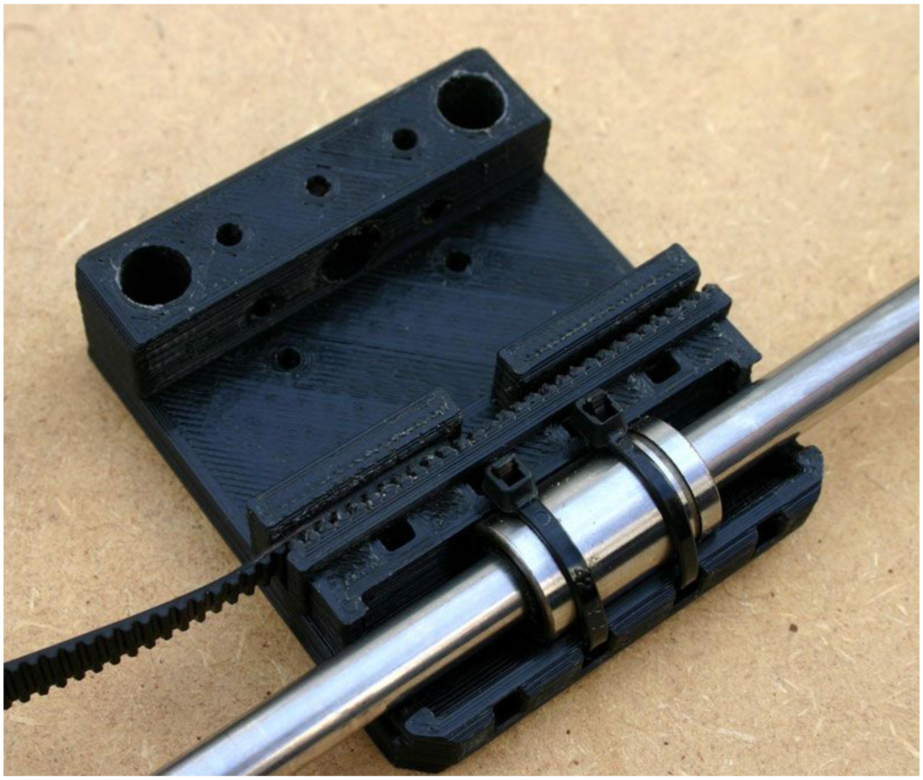




- Make a hole for the Y axis end part at 46.6 cm from the edge of the table and centered on height (related to the wood slat). The idea is that the rod axis must be perfectly centered and aligned with the side of the table.



- Prepare the Y-carriage part inserting an LM8UU ball bearing and fasten with 2 nylon tag fasteners (the piece is ready for mounting one or two bearings but one is enough). I have mounted one bearing on the Y-left side and two bearings on the Y-right side.



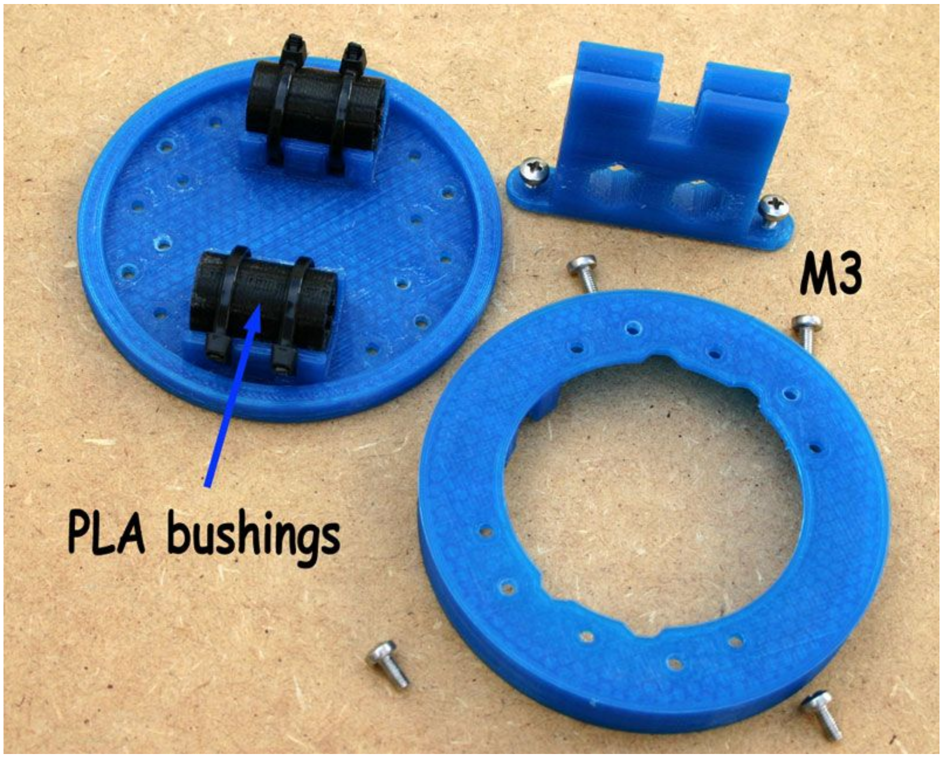
- Insert the Y-carriage into one of the 46cm steel rods. Insert the rod into the motor-mount part and then into the Y-axis end part. Screw the Y-axis end part with one 3x30 screw into the table. Check that the Y-carriage moves properly with little friction along the rail.

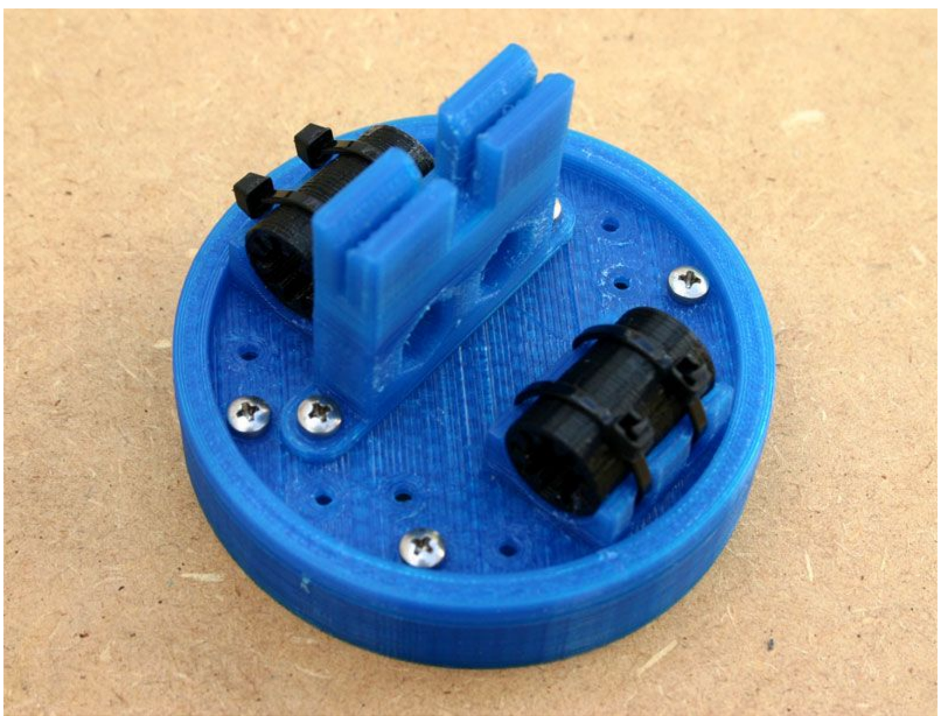
- Now it´s time to mount the other pulley (smooth) at the end part. the pulley is mounted in a 608 bearing with a small 24mm aluminum tube. If there are some clearance between the bearing and the pulley we can glue it together. Now install the pulley on the end part (the belt will prevent it to fall). Now mount the GT2 belt around the two pulleys and fasten to the y-carriage using the belt slots. The belt should be tight enough. Verified that the carriage moves and drag the belt correctly and the motor turns ok but the belt does not slip on the motor pulley. If the belt slips, you need to tighten the belt or maybe your pulley is not printed correctly and the belt slide. Maybe you need to print a higher quality piece or upgrade to T5 belt and pulleys that are easier to print (or buy some metal GT2 40 tooth pulleys).

- Mount the Y axis right side in the same way.

X axis

We start with the X axis carriage parts. Screw top and bottom parts and belt support. I used PLA printed bushings (that work very well with the carbon tubes)(you can use also LM8UU). If the bushings are printed in PLA ensure that tolerances are correct and that slide well in the carbon tube, if not, adjust slightly with a round file.

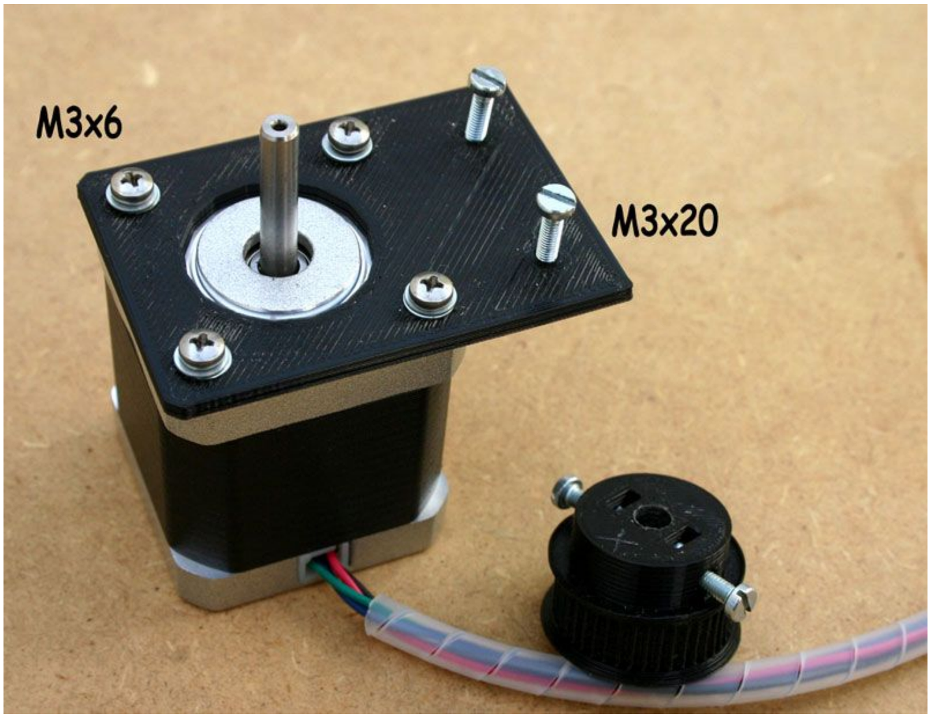




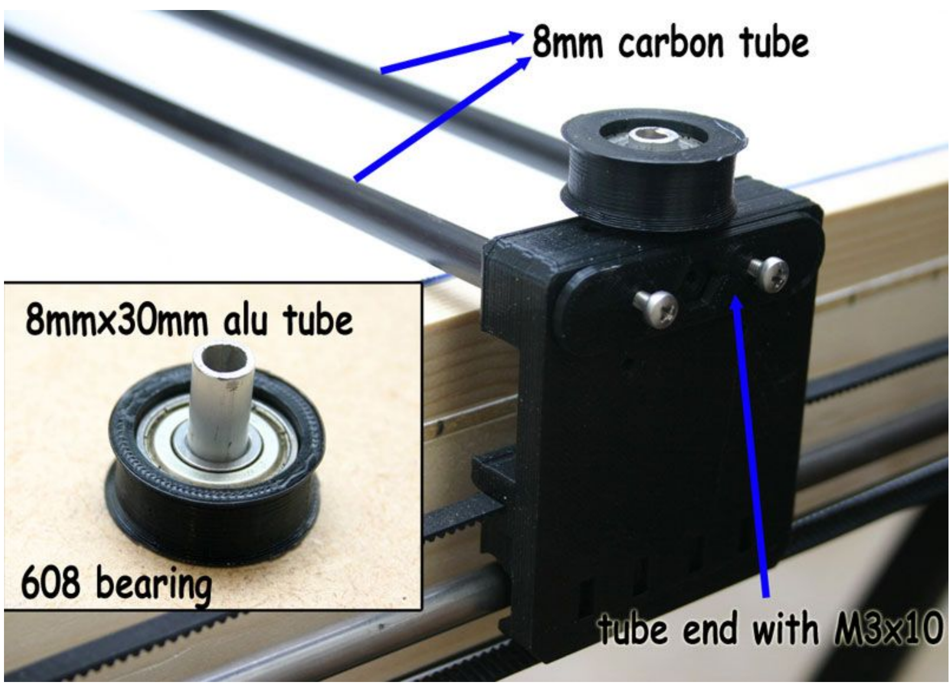
- Mount the two 65cm carbon tubes (or aluminum), through the X-carriage bushings and attach to the Y-carriages holes on both sides. Attach the tubes end part to the Y-carriage using M3 screws.

- Check that the X carriage moves freely in the tubes with low friction and very important: the carriage should hace a clearence with the table of around 2mm all the time. It is very important that the carriage don´t touch the table at any point.
Optionally (recommended) you can glue some EVA foam strips to the front of the car X (which will hit the puck) for a better rebound.

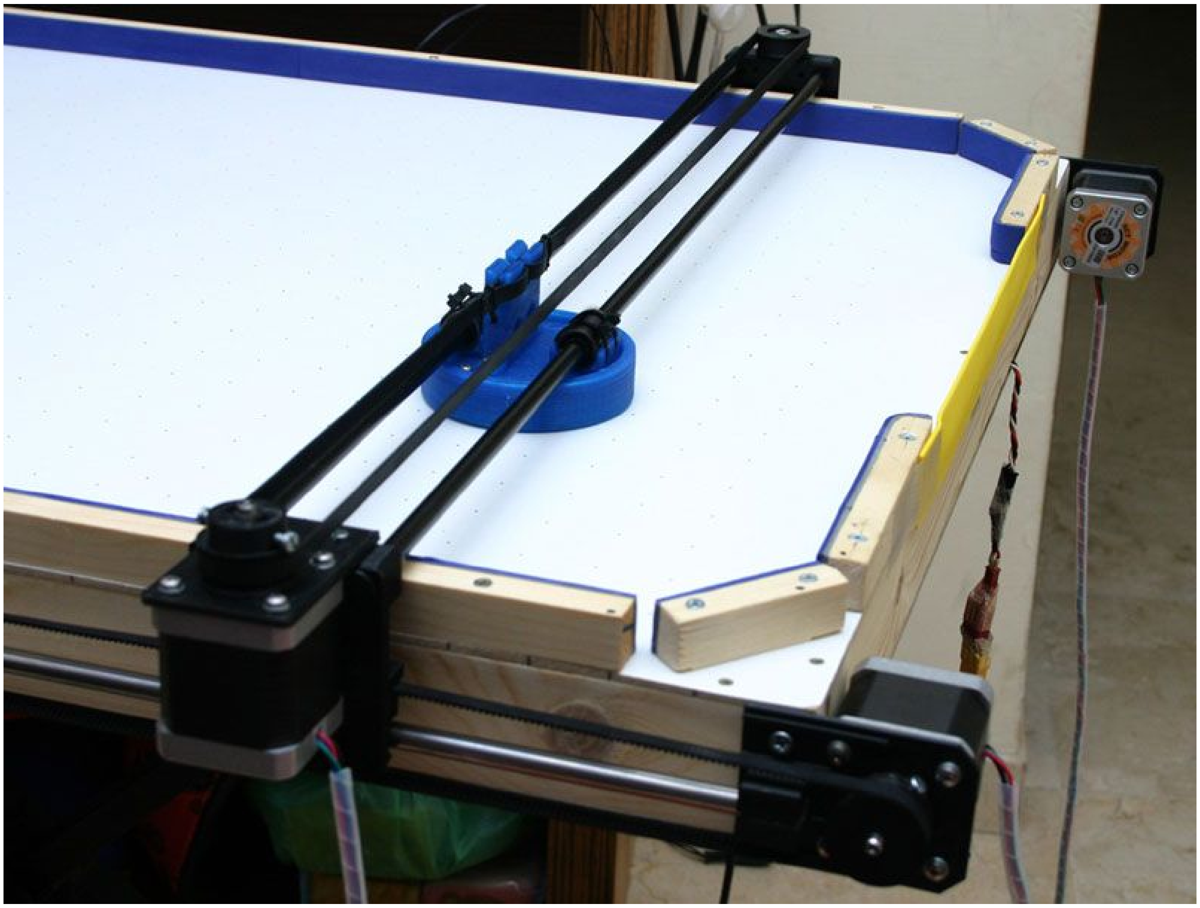
- Mount the X axis motor support and screw it to the Y-left carriage with two M3x20 screws with nuts Place the X motor with M3x6 screws and washers.



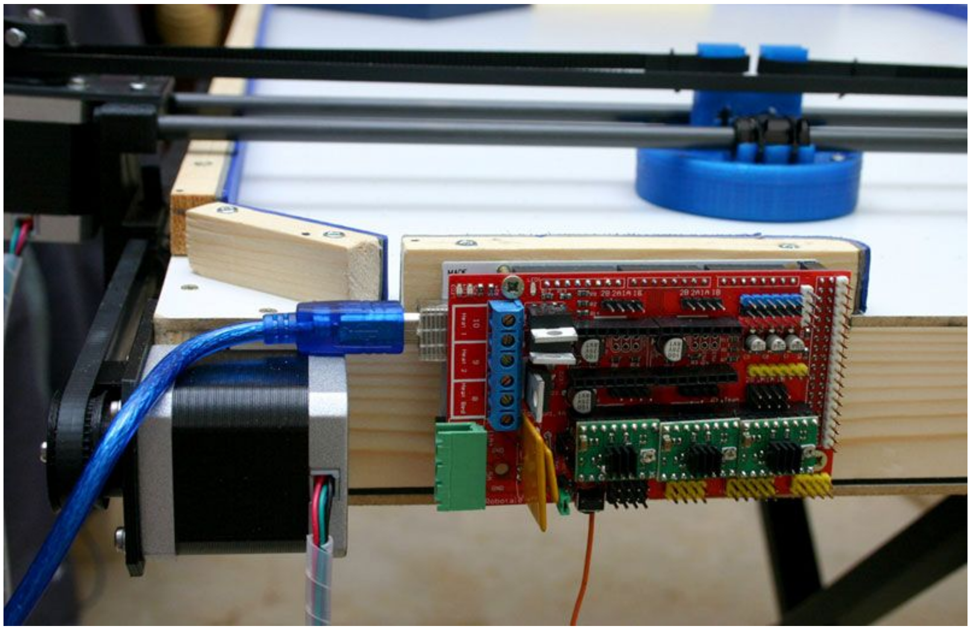
- Insert the 42 tooth GT2 pulley on the motor shaft, as we did with the other motors. At the other end mount the toothless pulley with a 608 bearing and the 30mm aluminum tube inserted into the Y-carriage.



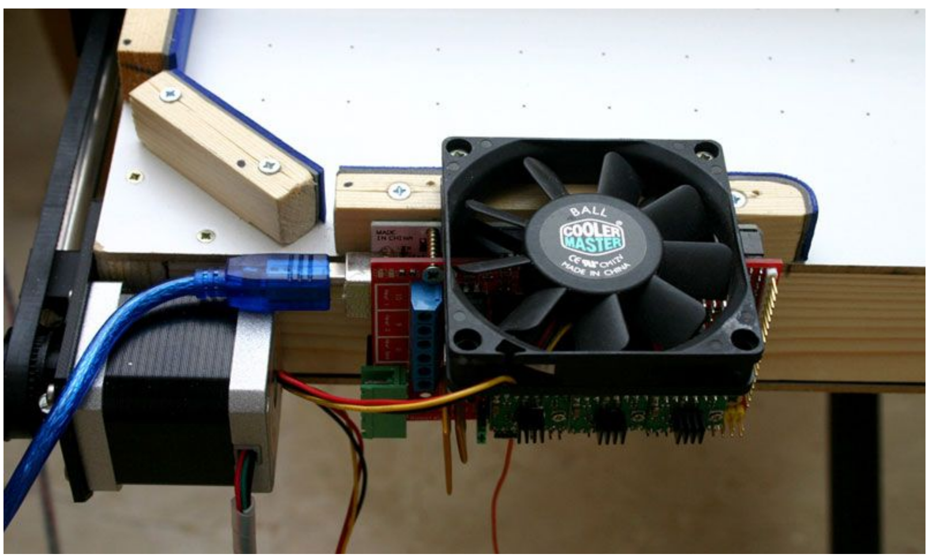
- Mount the X axis belt, hold the belt on the X carriage belt slot and check that is tight enought Try to move the carriage and check that the belt doesn´t slip on the motor pulley.



- Moun the electronics (RAMPS + Arduino Mega) with two 3x30 screws directly into the wood (see photo).

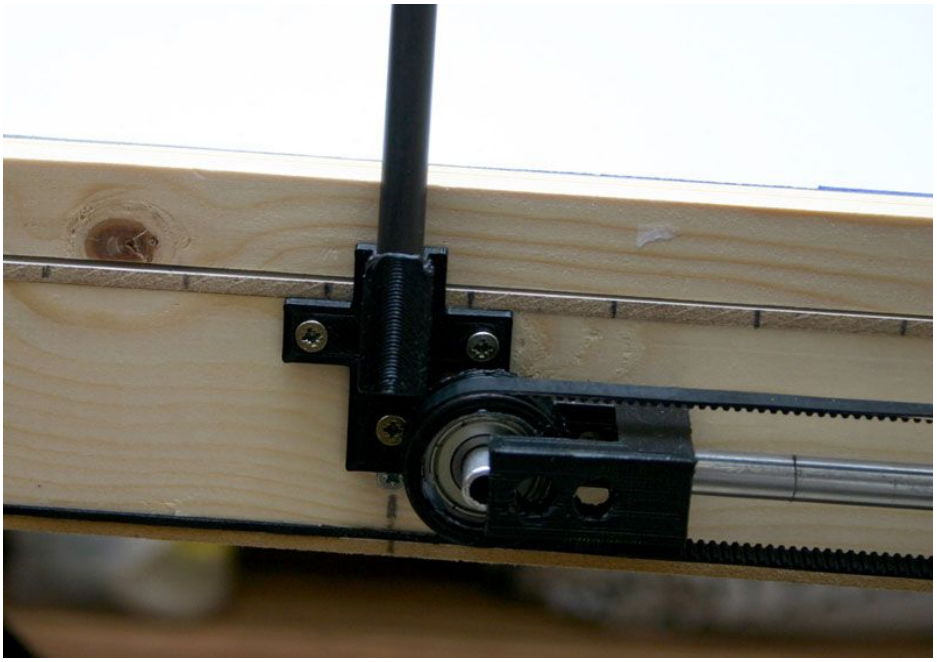


- Mount the small fan for cooling.



- Now it´s time to make the connections. Connect each motor to its driver like we did in the first test. X motor to X axis, left Y motor to Y axis and and right Y motor to Z Axis on RAMPS.
The fan to cool the electronicsis connected to the RAMPS 12V connector (see photo and check polarity, black closer to the edge)
Air Hockey Table fans are connected to the outputs of the FETs as shown in the photo:

- To mount the PS3 Eye camera you will need to print the 2 pieces for mounting the 87.5cm carbon tube (or aluminum). Fix the support to the table with three 3x20 screws. The other piece just fits into the base of the camera. The camera must be completely parallel and aligned to the table and pointing to the center of table.



Tests:

- **Motor test.**
Load the code AHR_Motor_Test.ino (Utils / AHR_Motor_Test folder) into the Arduino.
Before connecting the power supply (12V) to the robot, move the robot manually (by hand) at about the middle of the work area.
Connect the power supply and the robot should begin (after a few seconds) a smooth movement in the X axis toward the positive direction of X axis (to the right). The robot should move exactly 5cm.
If the robot moves in the opposite direction, disconnect power, modify the line in the arduino Configuration.h file:
/ / # define INVERT_X_AXIS 1
and we take the comments to invert the X axis:
 # define INVERT_X_AXIS 1
Check if the robot has moved 5cm (if the pulleys and belts used are the project should be so) Otherwise you would have to modify the line:..
define X_AXIS_STEPS_PER_UNIT 19
If you use 40 tooth GT2 pulleys or 16-tooth T5 pulleys the “19” should be replaced by “20”.
If the robot moved approximately half way (2.5cm) check the microstepping of the drivers.

Within seconds the robot starts a movement in the direction of the positive Y axis (forward)
Again if the robot moves in the opposit direction (Y axis has 2 motors) change the appropiate line:
If the motor that does not move correctly is the Y-left motor then:
define INVERT_Y_AXIS 1
If it´s the Y-right motor:
define INVERT_Z_AXIS 1
Check that the robot moves exactly 5cm again. If not change this:
define Y_AXIS_STEPS_PER_UNIT 19

Remember that any change in the Configuration.h file made in this test must be copied to the final code loaded into the arduino (AHRobot Configurations.h file)

In this test the motors will move very slowly, if still any of the motors lose steps (not able to move and makes a strange noise) you will have to increase the power on the driver of the motor (slightly turning the potentiometer driver in clockwise direction)

- **Motor speed and acceleration test.**
Load the code named AHR_Motor_Test_X.ino this in Utils / AHR_Motor_Test_X folder
Again move the robot to the middle of the workspace.
Turn the power on and the robot within a few seconds shouldl move in the X axis, first slow and then fast.
Check if the robot loose steps (noise and loss of position). To correct start increasing (very slowly) the power of the X motor driver (not too much or it will overheat)
If the robot still loose steps decrease the acceleration on this axis :
define MAX_ACCEL_X 280
decrease by 20 units and try again...

Check also (by removing the motor belt) that the robot is able to move freely and with very little friction along the entire axis and it never toch the table.

Now the same with the Y axis:
Load AHR_Motor_Test_Y.ino code (Utils / AHR_Motor_Test_Y folder)
With power off move the robot manually to the center on X axis and the minimun position (it reaches the stops) on Y axis (totally backward). Power on.
Same as before, if the robot loses steps in one of the two engines of the axis, Power off, increase poweron drivers or decrease acceleration:
define MAX_ACCEL_Y 140
also check that all the robot can move without friction on this axis.

- **Camera install and color calibration**
First install PS3 camera drivers from:
http://.codelaboratories.com / products / eye / driver /
We will make the camera tests with the arduino disconnected.
The zoom of the PS3 camera should be in the blue dot position (wide angle)
The vision system must clearly recognize two different colors, one for the puck (eg green) and one for the robot (for example orange). Use preferably very saturated colors because they that are easy to recognize. We use EVA foam because it´s matte, avoid bright colors.
Load the application (on PC) CHECK_HSV.exe. A screen will appear with some controls to define the ranges of H (color), S (saturation) and V (value) We will properly adjust the values to correctly detect the puck. Then we will adjust to detect the robot color.
Reference values for green EVA foam:
Reference values for orange EVA foam:
The vision system needs light! so be sure you have enough light power on the robot area.
We check that the color is recognized correctly, and we don´t have too much external "noise". We check aso that some slightly variations on lighting conditions, for example, if we put the puck under the shadow of the camera itself, it could recognize the color. If not, play with the controls to get the appropriate values
Get the parameters for puck and robot.

- Final check of the camera
with the previously captured values we will modify the file AHR.bat editing it:
COM19 AHR.exe 70 94 60 150 10 146 5 20 110 200 90 200 60
The first value "COM 19" is the serial port where the Arduino (the same we use to load the code on arduino IDE) The following first 6 values correspond to the range to detect the disk and the other 6 to ranges to detect the robot (which we have selected in the previous step) The last value "60" are the Frames per second of the vision system.
Run AHR.bat and should appear something like the photo
The camera must be aligned and pointing to the center.
The robot should appear on the right side of the picture.
Place the puck in the exact center of the table, we should see that the robot marks the correct position: 300mm in X and 500mm y Y:
Otherwise, move the camera to get something like what is shown in the picture

We should move the puck and the coordinates must be correct (about 1cm error). If not check that the camera is well aligned, the camera tube has the right dimension and if not you could start to play with this parameter in the Configuration.h (read the code comments):
#define CAM_PIX_TO_MM 1.4

And… Let´s play!!
Load the final arduino code: AHRobot.ino (AHRobot folder)
Remember that if we have changed any parameter in the Configuration.h file for robot calibration, verify that these changes are properly copied to the Configuration.h file in this project.
Before power on the robot, we always start the game moving the robot manually to the start position that is: minimun of Y axis and centered on X axis (can be marked in the table.) This will be always the starting position when we reset or boot the arduino!. The code needs to know that the robot is in this position at the beginning.

Power onthe robot (12V), wait a few seconds and the robot will move to the defense position.
On the PC Start the AHR.bat, wait until you see the image ... and start playing!