DEVELOMPENT OF A MODULAR AXIS STRUCTURE FOR THE PURPOSE OF ATTAINING SEVERAL ROBOTIC ARCHITECTURES

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This paper has the objective to present the benefits of developing and implementing a series of translation axes into various robotic architectures, as well as to present the prototype that was built in order to study and research the performances it is capable of reaching outside virtual simulations. Further on, the process designing and manufacturing the series of axes is listed, which are then assembled together to achieve the structure of a 3-DoF Tripteron Cartesian parallel robot, one the configurations that these axes can be installed in.

Keywords*:* Prototype, translation axis, modularity, educational, Tripteron.

1. Introduction

Industrial robots, although versatile, a limit is set to the range of operations they are capable of doing by their very construction. Therefore, a robot that can change its structure is bound to have an increased number of applications that it can do efficiently, when compared to the usual industrial robots available on the market.

For the purpose of developing such a robot, a compact structure of modular translation axis proved to be the most efficient way when considering a price-performance ratio, on top of having relatively less complex kinematics. In order to achieve such a goal, it was essential to produce a prototype in order to predict the behaviour of future, improved versions of this modular axis, that could be assembled to create the previously mentioned versatile robot.

2. Designing the axis

The first aspect to consider when thinking about the design of the axis is how it is going to be assembled together with other axes in various positions, considering this is the fundamental quality of the axis, but also how it is going to be as compact as possible.

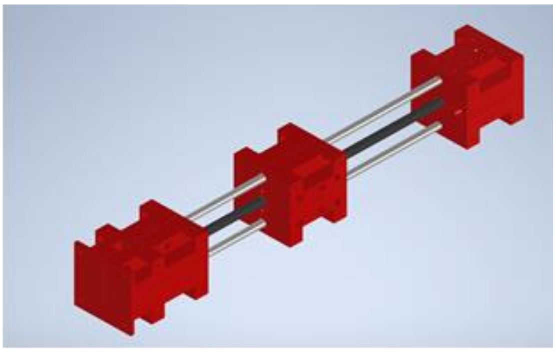

Fig. 1. 3D of the exterior of the axis prototype

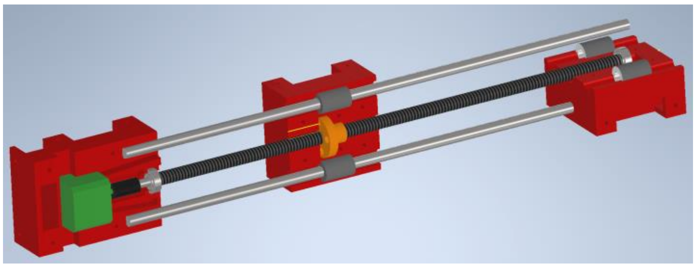

Fig.2. 3D of the interior of the axis prototype

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Another aspect that has to be mulled over is about anticipating exactly how many architectures the combined axis is able to be integrated in. The conclusion we came to this far is that the axis is able to be the implemented the following robots: Tripteron, Reversed Delta robots with 3,4 or 6 axes, Simple and Double gantry robots. Stewart platform, XY-Theta parallel robot, column robot.

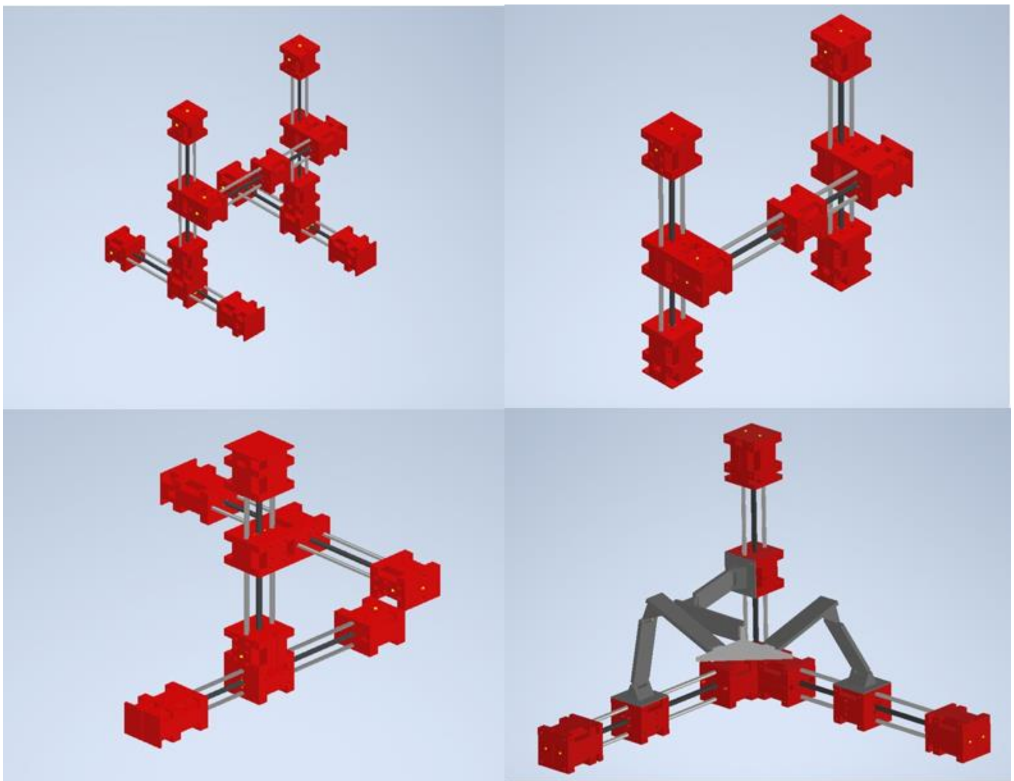

Fig.3. Some of the possible configurations that can be obtained (top left – double gantry robot, top right – simple gantry robot, bottom left – Column, bottom right – Tripteron)

For the design part of the axis and the robots, the software used was Inventor Profession from Autodesk, used for the design, animation and finite element analysis (possible due to Autodesk's partnership with Ansys, from which they developed a patch).

3. Tripteron

Tripteron is a unique robot configuration, a three or four axis parallel cartesian robot with position command, with applicability in numerous domains, such as 3D printing, pick and place operations, cinematography etc. For the first prototype we built, we chose this architecture.

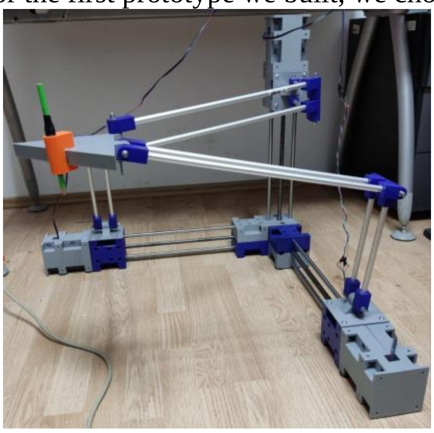

Fig.4. The built tripteron prototype

4. Manufacturing

As far as the process of manufacturing the cases goes, what we used was a 3D printer from Creality (CR-V 10S) and PLA as the filament. In order to obtain the least number of waste pieces, the CAD stage included a part of tolerances analysis. Due to the usage of a 3D printer however, the corresponding tolerances could not be obtained, so that the main aspect taken into consideration was the precision of the printed layer. Therefore, after several tests, the most optimal solution was to have an increase of 0.2 mm for every functional dimension, in order to make up for the errors of the printer. The parts that were meant to be assembled into the cases were fitted with a press-fit type of fastening, Although the procedure of calculating the tolerances could be considered vague, the results turned out to be more than promising, obtaining the respective lot of housings with the least possible amount of waste parts.

The specific settings for the process of 3D printing with PLA were the nozzle temperature of between 190 and 220 degrees Celsius, the bed temperature between 40 and 50 degrees Celsius, according to the specific characteristics provided by the manufacturer. For the infill amount of 20% Gyroid-type, due to its excellent strength-quantity ratio.

Fig.5. Resulted 3D printed parts with components slotted in

5. Computer Aided Engineering

For the finite element analysis we studied the axis behaviour under torsion, compression and bending stress with an equivalent force of 1000N and a torque of 10000Nm, obtaining maximum stress values of 2192,38 MPa (developed on the XX axis at bending) and maximum displacement values in module of 1,809 mm (obtained on the X axis at bending).

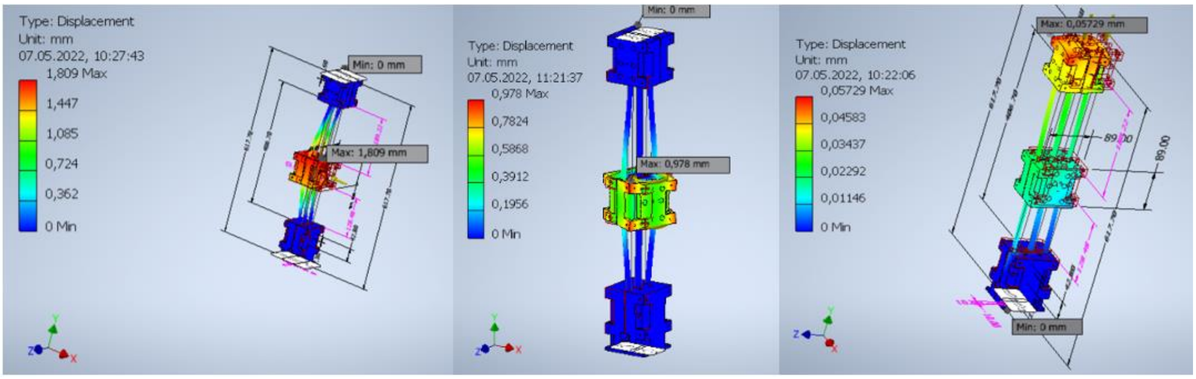

Fig.6. Finite element analysis results for displacement extracted from the report (left – bending, middle – torsion, right – compression)

6. Electronical command and control

As far as the electronical and command side of things is concerned, we used an Arduino UNO R3 development board, and since we used a NEMA 17HS4401 stepper motor, we also paired it with a A4988 stepper motor driver. The driver is connected to a 12V source which is more than enough to power the stepper motor.

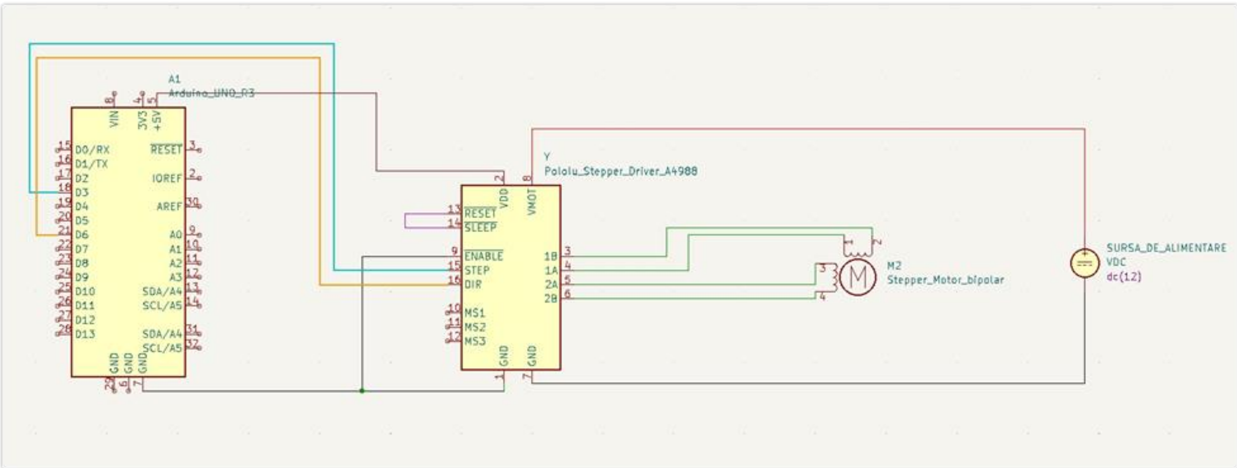

Fig.7. Electrical diagram for one axis

For the tripteron, the firmware on the Arduino we used GRBL, on top of which we used Universal G-code Sender (UGS) that acts as a Graphical User Interface (GUI) but also sends the G-code necessary to drive the mechanism.

7. Conclusions and future work

In this paper are presented the results of our analysis on reasons as to why we developed modular translation axis which can be assembled to form various architectures of robots. These results proved to be fruitful, as we think this subject is worth to be researched further. As a consequence, we decided to design and manufacture a prototype that can be studied upon.

Therefore, the benefit of constructing a prototype comes in the form of discovering issues that occurred due to several reasons, including the ones that appeared as a result of the fabrication process used for the housings, in our case, due to the 3D printing. This, in turn helps us gather information that is necessary to optimize the said fabrication process. In the future, we plan on changing the materials used for the construction of the axis, from PLA (which is comparably cheaper, but possesses lower qualities) to ones with better qualities, suited for industrial use, as well as switching to fabrication processes other than 3D printing. Improvements can be also made by replacing the current motors with ones that have greater torque, to not only extend the range of applications that the robot is capable of doing, but also improve their quality, by also adding a closed-loop control system. Another aspect that can be polished up on is the modularity of the axes, as to allow future such improvements to be easier to implement and raise the degree of universality of the axis. Further improvements must be considered in more detail, in order to satisfy the condition of having a relatively low cost but high performance.

In the future, the prototype can also be used in education. In this way, students to study the discrepancies between a 3D model and the real, physical version of such a mechanism as well as to learn about the different types of architectures that it can achieve, and more. Going further, this can be a good method of collecting functional feedback on simulating processes similar to the ones in the industry, as we plan on further testing its capabilities. In this way, we can further discover the limitations of such a design and improve on it with the feedback that we received.

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