Design of a 3D Puzzle for Building a Robot

John Roberts, Jonathan Oros, Dayana Jimenez Estrada
Northern Illinois University
College of Engineering, Mechanical Engineering
Dekalb, Illinois

Dr. Sachit Butail
Northern Illinois University
Department of Engineering, Mechanical Engineering
Dekalb Illinois
sbutail@niu.ed

***Abstract*— Creating a method for teaching robotics to younger students will be beneficial for individuals with interest in pursuing robotics. The students should be able to learn different aspects of robotics from the kit that would be provided. Through the assembly process, they will be able to learn by seeing how the linkages of the leg work together to create motion, and how the components should be fastened together. The electronic components should be able to teach these students about the wiring that is needed to connect all the components together as well as the programming needed to allow these components to work together to allow the walker to function correctly.**

I. Introduction

As the need for automation increases in business, robotics become more and more common. As this need for robotics and automation increases, the importance of the younger generations getting an early introduction to robotics will increase as well. Providing an easier and more affordable way to teach students that show interest in robotics at a younger age will be able to provide a head start on their education.

The challenge is to create a robotics kit that will not be overly priced to manufacture or sell. The robot should be like a puzzle, where the user will get instructions, a workbook, and an unassembled robot that they will have to assemble themselves. The workbook will have the wiring schematics of the electrical components, as well as information and lessons on programming all the components to work together. The robot should be quick to assemble.

II. Walker design

The robot that was designed was a walker design. This design required both a mechanical design aspect for the legs and base, and an electrical design for electronic components and the wiring schematics. Press fit binding posts are to be used for fastening all the components together to minimize the time for assembly.

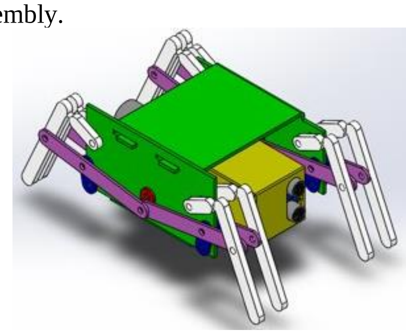


Figure 1: Fully Assembled Model

A. *Mechanical*

To minimize the number of components needed to build the robot, the idea of incorporating living hinges in the design was considered. A living hinge is a thin flexible hinge that is made from the same material as the two pieces that it connects, these living hinges are used in many different products and require the material to be flexible enough to bend, but strong enough to not break or buckle under loading. For this reason, Polypropylene was chosen as the material that will be used in all components that would use hinges of any kind.

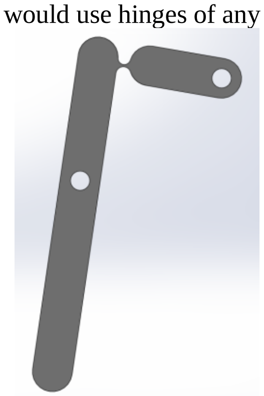
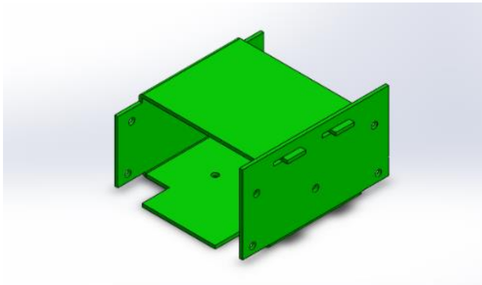


Figure 2: Living Hinge Leg Design

The walker design was created modeling its legs after the Klann Linkage design, one reason being that it had the smallest range of angles that each link would rotate through. The largest angle of rotation that would be replaced by a living hinge would be only 25 degrees. By changing some of these connections between links from pin joints to living hinges it would minimize the amount of components needed to construct the legs, and by creating the geometry of the hinge to be a certain shape and thickness, the hinge will allow more than the required angle of rotation.

To create the robot, a sturdy base would be needed, which would have a platform to mount the electronics, as well as two walls to mount legs on either side. Instead of having multiple pieces being fastened together to create this base, the idea was to create this out of one single flat sheet. With the idea of living hinges, a similar concept could be applied to allow a flat sheet to fold in certain locations by cutting a 90° v-cut across that section of the sheet where it should fold. With these folds, the material can be bent in a way that the two ends of the sheet will meet and two hook shaped cutouts could be inserted into the opposite side and create a locking mechanism to create a sturdy base structure for all the other components to be mounted onto.



.

Figure 3: Folded Base

Testing was done to determine the lifespan of the living hinges and the folds in the base. A fixture was designed and created where a motor would be mounted, and an arm would be attached to the motor. When power was sent to the motor, the arm rotated and pushed material of the living hinge. The hinge was then rotated by the arm and underwent over 10,000 cycles without failure.

Another form of testing that was planned, and unfortunately cancelled, was to have kits sent out to middle school age students to have them assemble the robot. They would have been timed and would have given feedback on how easy they thought it was. There would have been a survey with this data, and it would have given us insight on whether the main purpose of teaching students was successful.

B. *Electrical*

The goal was to design a robot that had the capability to avoid collisions. To do this an ultrasonic distance sensor was used to detect the distance between the robot and an obstacle. A motor driver was used to power the DC (Direct Current) motor and an Arduino Nano was used as the microcontroller. In addition to simply avoiding obstacles, a second control program and circuit was made that would allow for the study of the dynamics of the robot. It will still maintain all the components and functionality of the obstacle avoidance system; however, a 6-axis accelerometer will be added to study both the linear and rotational acceleration about each axis. This data, as well as data from the ultrasonic distance sensor will then be saved to an SD card so it can be imported into a computer program and studied.

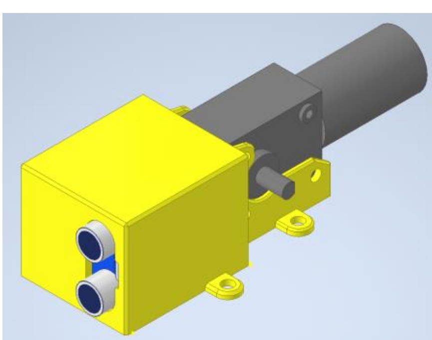


Figure 4: Electrical Housing

III. Manufacturing

A. *Waterjet*

The leg links with living hinges were cut with a waterjet out of a 1/4-inch thick polypropylene sheet. This allows for multiple of these linkages to be cut out of a single sheet. The material at the location of the living hinge was very thin measuring at 0.05" thick. This manufacturing process was utilized due to the thin material condition and the complex geometry that was required for the living hinge.

The outline of the base was cut out of a 1/8-inch thick polypropylene sheet using the waterjet. The hole locations where the electronics case and the legs were mounted were also cut out with the waterjet in the same operation.

B. *Mill*

The 90° V-cut grooves that were cut into the Polypropylene base were cut using a 90° drill bit. The material at the center of the V-cut had thin material conditions measuring at 0.05" thick to allow for bending and folding of the material.

C. *3D Printing*

The components for the housing that hold all the electrical components and the motor were 3D printed, due to complex geometries. This cuts down on manufacturing time and material waste. Extensions for the drive shaft of the motor were also 3D printed for ease of manufacturing.

D. *Laser Cutting*

All links for the leg design that did not incorporate living hinges were laser cut out of a 1/8-inch thick acrylic sheet. This allowed multiple links to be cut out of one sheet in a short amount of time.

IV. Youth STEM Education

This robot can also serve as a great teaching tool to get young students interested in STEM, by allowing them to get hands on and assemble a walking robot. Students would be given the components needed to build the robot, along with instructions on how to fold the body into shape and lock it into place. As well as how to mount the legs and the electronic housing to the body.

Acknowledgements

We would like to thank Dr. Sachit Butail and Matthew Kleszynski for their assistance and all the guidance they provided throughout the year

References

Sebastian Linß, Stefan Henning and Lena Zentner (April 3rd 2019). "Modeling and Design of Flexure Hinge-Based Compliant Mechanisms, Kinematics - Analysis and Applications."

Prashanth, N, et al. "Influence of Link Lengths and Input on the Foot Locus Trajectory of Klann Mechanism."