MSE 2202B Introduction to Mechatronic Design

Final Design Project
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Executive Summary:

This year's MSE 2202b design project was to construct an autonomous, mechatronic tesseract-seeking device. The robot had to operate in perform two tasks. For task one the robot had to drive around in a 8’ by 3.5’ rectangle searching for magnetic tesseracts. It then had to deposit them between two black tapes lines on a wall by the home gate. For task two the robot started on the outside of the wall. The robot needed to pick up the tesseracts, drive under a gate and deposit them on the gate’s ceiling. In order to accomplish such a task, the group designed and prototyped an autonomous solution. The robot that was designed contained several unique features that aided in this task. The first feature was an infrared light curtain that was designed to detect both good and bad tesseracts. The second was the turntable arm which used two motors, one to turn the turntable and the other to raise the arm. On this arm was another servo to raise and lower the end effector, acting as a wrist. The end effector had a servo controlling the height of an enclosed magnet, as well as a hall effect sensor and a line tracker sensor. The robot's frame was composed of an upper and lower flat plate, spaced apart by several standoffs. The microcontrollers, battery, wheel motors, wheels, ultrasonic distance sensors, and infrared sensors were located between the plates. The front and the sides of the robot had ultrasonic sensors to detect walls and robots. All of these components were effective in their purpose, their only downfall was the implementation of the code. In the future, if there ever exists another tesseract crisis and the company is in disarray, group 12 will be there to resolve the issue.

Introduction:

Earlier this year, the Southwestern Ontario Tesseract Co. discovered that they had a problem. The issue was that some of their finished and unfinished tesseracts were appearing in random locations across the factory floor. Due to this issue, the company required the development of a fully autonomous mechatronic device that could collect the magnetic tesseracts, while avoiding the “bad” tesseracts, and place them. The tesseracts must then be taken from the holding area and placed on a raised platform. They asked that these task be separated in two modes. The company asked for a device that could fit within an MSE locker without being disassembled. It must be robust enough to function on any factory floor. They had also asked for a device that would be safe and not interfere with any other systems or devices. This report will cover the design process of the device including, design concepts, tests, experiments, adjustments and recommendations regarding the final product.

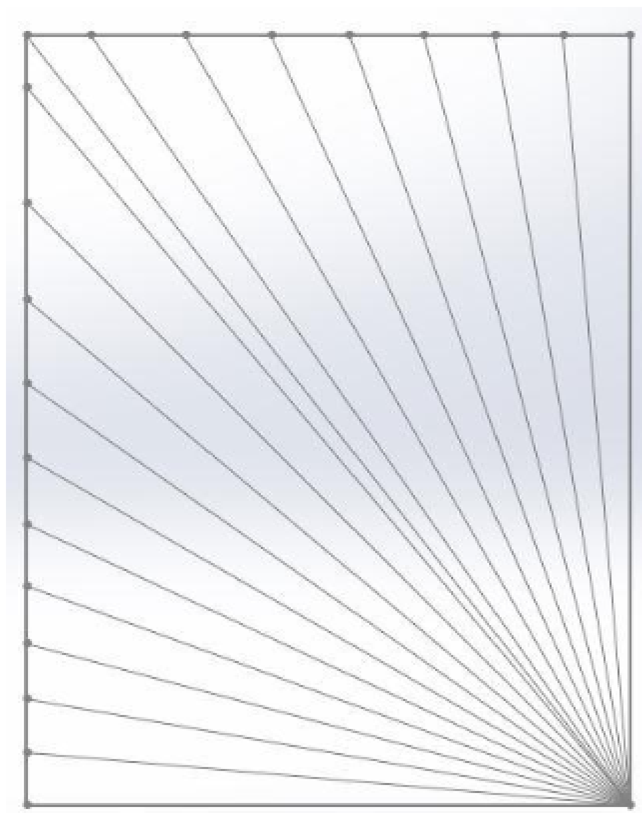
Discussion:

The design process began with identifying the different steps that the device must take in both modes. In mode one, the device needs to be able to leave from its home base, find “good” tesseracts, and return them to a polarized base and deposit them between black lines all while avoiding other tesseracts as well as the other device and its territory. In mode two, the device must be able to take the tesseracts from the drop-off position and drive under a gate and deposit them on an elevated landing. After the two modes had been clearly identified, the group proceeded to brainstorm different methods and components that could be used to accomplish each task for each mode. The first things that was agreed on was that the device would utilize a round frame, have two wheels and have an arm with an end effector. The two group's biggest design challenges were trying to find a way to detect the blocks without actually touching them and constructing the end effector.

Originally the group decided to construct a horizontal light curtain towards the front of the round base to detect the light curtain however there were doubts that it would effectively detect the blocks without the drive base bumping the tesseracts into one another or into the magnetic walls. In order to better detect the blocks, the group decided to use an array of thirteen line tracking sensors that form a half circle at the front of the frame. They would all be connected to an Arduino Mega 2560 and calibrated to detect the tesseracts. If any of these line trackers read true then it will send a low signal to pin thirteen which is plugged into the main arduino board. By the end design, the device had ten line trackers attached to the Arduino Mega searching for the tesseracts.

The end effector was also a challenge because of the way the robot was designed. The group needed to effectively fit a magnet, a mini-servo, a line tracker and a hall effect sensor at the tip of the end effector. There were two original concepts to accomplish this challenge, magnet and servo combination. The first was to use a corkscrew mechanism, in order to raise or lower the magnet which would be housed in a closed cylinder. By using a mini-servo, the corkscrew could be turned which would raise or lower the magnet. The other concept was to attach the mini-servo directly to the magnet using a thin rod in order to directly raise and lower the magnet. After constructing prototypes for both concepts, the group decided to merge the two concepts into one. This was done by using the servo and the thin rod to raise the magnet in the cylinder. From there, the group attached a hall effect sensor and line tracker to the end which. This would allow the end effector to detect the black lines and the tesseracts magnetic field as well as the unique polls at each homebase.

The group had also agreed that the device should have its base low to the ground and should have a top layer three inches above. This volume would leave room for the wheel motors, the arduino boards and all of the wires. Another big decision was where to add the ultrasonic sensors, for the collision avoidance system. Through experimentation, it was determined that the best positions for the sensors would be parallel and perpendicular to the wheels. This is due to the way the ultrasonic waves reflect off angle surfaces which would sometimes cause the sensors to read larger distances than they were in reality. By mounting the sensors in these positions, this matter could be avoided. In addition, the group decided that mounting two sensors on the left and right sides would make it easier to program in a drive straight function. The final ultrasonic sensor was added to the very front in order to aid the collision avoidance system.



1. This diagram represents the various angles that the ultrasonic sensors were tested at to compare their measured distance from their real distance.

The housing for the electrical components, such as the Arduino boards and the battery, were added between the device's two platforms in order to reduce clutter on the upper surface.

This was done by mounting the Arduino Mega to the ceiling of the top base and mounting the main arduino above the wheel motors. The last main components were the turntable and the arm. The turntable was screwed into the centre of the top layer which had a U-channel screwed in place. From there an encoder motor was added on the outside of the U-channel and utilized gears to rotate the arm. The turntable itself was controlled by a motor that was attached on top of the turntable and used a small gear to move the turntable. The main arm itself was attached to another small arm that had the end effector attached to its tip. The end effector arm was controlled by a servo to make it an arm of three degrees of freedom.

Conclusions:

The results at the showcase made the group realize certain shortcomings. The first of which being the implementation of the Hall Effect sensor. The Hall Effect sensor proved to be mostly effective during testing with a variable sensitivity of around ten to twenty, however during the showcase run, the hall effect sensor would blatantly ignore a magnetic tesseract that it would have otherwise detected during testing even if it was half a centimeter way. This severely compromised the group's capability of detecting tesseracts during the run. This issue could have been addressed by implementing more hall effect sensors to get a wider range of magnetic readings. In addition the navigation code the group implemented wasn't robust enough for the objective of the course. The group found the robot turning on itself 25% of the time due to some logical coding issues. These problems could have easily been resolved had the group allocated more time to collaborative programming. When the hall effect sensor did detect a tesseract, there were issues when trying to retrieve it due to the play in the arm’s gears. This was caused by tiny spaces between the gears. The group tried to solve the issue by implementing PID control however, there was not enough experience in the group to effectively implement such algorithms into the program. Another issue the group found was staying parallel to walls at short distances. This could have been greatly improved by using line trackers or infrared sensors in parallel with the existing ultrasonic sensors. The reason to implement such a system would be have a more accurate short proximity reading in order to keep the device parallel to the wall at short distances.

Recommendations:

Throughout the design of this device, the group realize that there were certain components that could have greatly been improved. To begin, stepper motors would have proven to be much more effective than the encoder motors for specific motion. The group also found that the version control software, Github, used for the duration of the project was complicated. This resulted in coding complications including duplicated variables and functions. In addition it was found that using one Hall Effect sensor was not completely ideal for detecting tesseracts.

The problem is caused by the nature of the magnetic field having a north and south pole. This causes the Hall Effect sensor to read certain dead zones where it won't detect the magnet. A solution would be to add multiple hall effect sensor to the end effector in order to have a better chance of detecting the magnetic field. Another asset to this device would have been the implementation of PID control system. This would have accounted for the substantial play in arm gears and drive motors. The material used for the base of the device and the arm would also be a lighter more sturdy material such as acrylic due to the fact that it looks cleaner. The end effector would also be one piece made out of plastic, to not interfere with the magnetic field that the magnet gives off. The infrared sensors used in the infrared crown would also be replaced with an array of TCRT5000L infrared sensors due to their smaller size and better accuracy.

See Product Development File for Appendices Equivalent