MREN 303 Final Report

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***Abstract*— As robotics continues to see a rise in advancements and adaptations, they can present solutions to real-world problems, ranging from basic assistance to disaster rescue. More specifically, there has been a recent growth of rescue style robots, tasked to help humans in disasters and catastrophes. Robots are usually specialized in the rescue operation at hand, incorporating different body styles, drivetrain types, attachments, extendable features, limbs, and so on. However, the market has a lack of solutions when it comes to dinosaur type catastrophes. Here we show a scale model of a robotic solution that can handle and corral dinosaurs, as well as rescue people. We found that our robot was able to retrieve the dinosaur toys, as well as rescue a doll. Our solution can help those in dinosaur catastrophes, where the market may lack solutions. Dino Rescue Bot, the solution we implemented has the main task of retrieving dinosaur toys set around an enclosure and dropping them into a cage, and then to retrieve a ken doll. We implemented a mobile base with a claw arm, enabling it to scoop up the toys and dolls. In all, the robot has good consistency in the rescue operation, and has other features implemented such as differential drive with omni-wheels, and an autonomous mode.**

I. INTRODUCTION (*HEADING 1*)

Rescue operations can often be a tricky challenge for rescue personnel as the environment is often unstable and can result in deaths of many. The need to save individuals as quickly as possible is important to the survival rate, as it decays exponentially with every passing day in a disaster. With this increasing issue, robotic solutions have proven to help drastically with rescue operations, being built for the specific needs of the rescue.

For example, in the leading days after the World Trade Centre collapse in 2001, the first known use of a Urban Search-And-Rescue Robot (USAR) was used in the search efforts, as well as providing a wide range of data collections for later analysis. The USAR had multiple purposes such as searching for victims, finding cleared rubble paths, structural inspection, and hazardous material detection. The robots proved successful at doing such tasks, furthering the rescue effort. The operators were also inherently safe as they operated the USAR remotely.

However, this application is specific to the WTC collapse, and the robot would not be best suited for other scenarios. Our rescue scenario is specialized in corralling dinosaurs and retrieving people, and as such we designed our robot to pertain to that. Taking inspiration from other terrain robots, like the Lynxmotion 4WD robot, we designed and built a mobile base with omni-wheels, with an attached arm & claw limb to reach and grab dinosaurs. It will also include an autonomous mode, where it will navigate to a button to open a door.

There are three main objectives for the robot; complete the autonomous portion, corral all dinosaurs, and rescue the ken doll, all in a timely manner. If the design process of the robot goes smoothly, then all the goals should be achievable, and the robot will have better performance than the other robots in the competition..

II. METHODS

A. Mechanical Design

The mechanical design encompasses all the physical and moving components of the system. From a system overview, this includes the mobile base and claw.

The mobile base serves multiple proposes with the robot design. It holds the electronics, acts as a base for the arm & claw, and moves around on four wheels. Our design went through two main iterations, evolving based on our how our requirements changed. Given this, the design sticks to overall concept of the cardboard prototype, using a square base with front-differentially driven wheels and a claw mechanism. Figure X shows the first iteration of the mobile base, and Figure X is the second iteration.

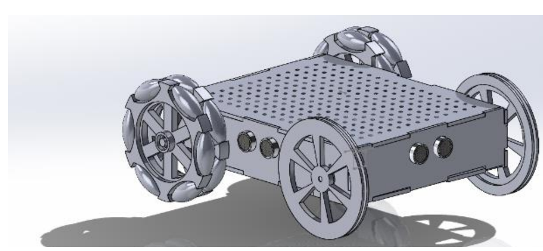

Figure 1: First iteration of 3D modelled base and wheels.

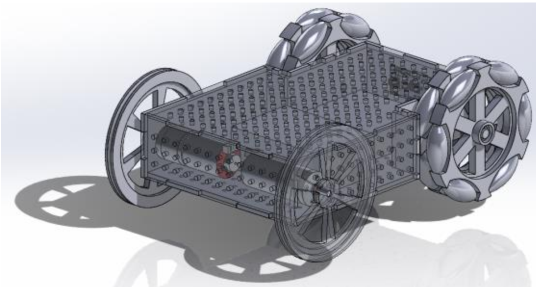

Figure 2: First iteration of 3D modelled base and wheels with internal view.

We listed out what we wanted the robot to achieve, aiming for maximum points in the quickest time possible. For the autonomous portion, we wanted to navigate to the button in a timely manner, hit it with good consistency, and go through the door. For the manual portion we wanted the robot to be agile enough to navigate the course, being stable when carrying objects as well. We saw two main challenges with this; how to rotate freely without needing to drag the back, and a way to improve the centre of balance for good maneuverability. We used the Lynx motion 4WD robot from MREN 203 as inspiration for the general construction of the base. We wanted an enclosed space for the electronics, sensors, and motors, as well as providing secure mounting on top.

The mobile base is made from MDF, which was laser cut into pieces, making the structure of the base. MDF has many advantages as a material, it is relatively cheap, structurally sturdy, and can be easily fabricated. From the CAD sketch of the parts, a DXF file can be exported to the laser cutter to cut out the sketch, creating the final parts. The walls use finger slots and wood glue to hold itself together, resulting in the final structure being level and sturdy.

The first iteration of the mobile base has dimensions of 206x166x46 mm. With the omni-wheels, the overall dimensions are increased 231x227x48 mm, including the wheels. Initially, we did not think the width would be an issue given that the gate is 250 mm wide giving us a margin of error of approximately 10 percent. However, when the robot was partially constructed and tested with only one half of the omni-wheels, this proved to be significantly more difficult, to the point where it was concluded to be impossible. This required the base to be redesigned to be slimmer, as well as accommodate the wider rear from the omni-wheels. In addition, we saw that the side ultrasonic sensors served minimal purpose and were removed for the subsequent design.

The omni-wheels proved to be a challenge to implement as they require two sets of rollers on each wheel, requiring the rear to be recessed 19 mm into the base on each side. Space is left for the ultrasonic sensor, and the battery pack, which sit in the rear portion of the base. This also helps with the center of balance, moving it further back and giving more stability to the robot. The ultrasonic sensors on the side were removed in the second iteration, and the front sensor is instead placed on the back as the autonomous system could be better implemented with this configuration.

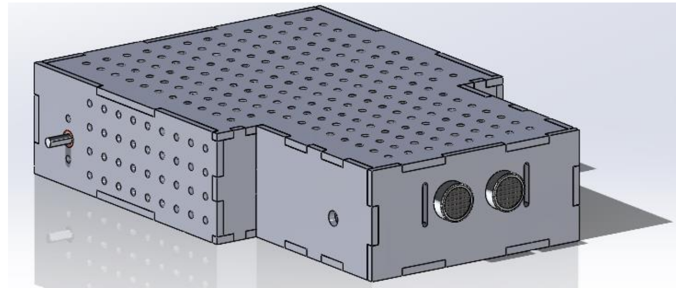

Figure 3: Second iteration of 3D modelled base.

The motors are mounted directly onto the sidewalls, held on by m3x8 mm screws. The base has enough structural rigidity to counter the torque produced and power is delivered to the wheels in a smooth manner.

The omni wheels are a staple piece of robotic design. The current design in shown in Figure X. They enable forward and sideways rotation with minimal friction loss. The omni-wheels were chosen as they provided significant benefit in rotational performance and consistency. This was especially important for the autonomous mode, where the control systems expect a consistent level of performance from the base. The team initially investigated using a ball caster, or even a slide at the back to minimize friction. However, given the material and manufacturing limitations, this proved to be difficult to execute effectively. Although the omni- wheels take more print volume, it is much easier to implement with effective performance.

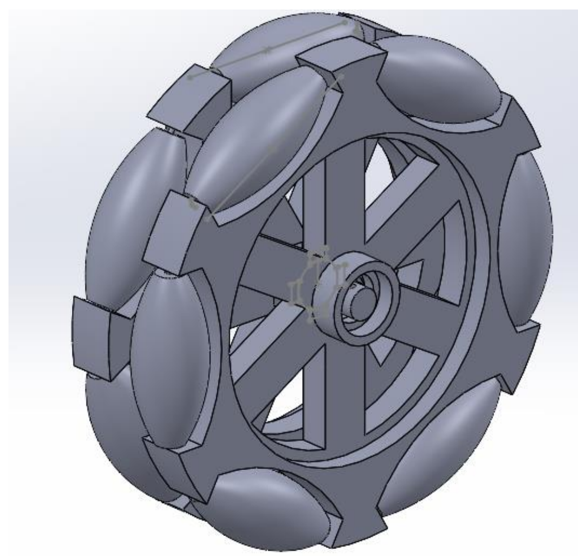

Figure 4: 3D modelled Omni-Directional wheels.

The omni-wheels we designed consist of a two-halve design, allowing a roller to always be in contact with the ground. This means that the robot can switch from forward to rotational motion without dragging the back around with significant friction. Figure X shows the robot moving in a curved path, with the pairs of omni-wheel rollers represented by the blue and green eclipses. As it moves around a curve, the wheel rotates about its axle, and the rollers compensate for the additional velocity component normal to the robot.

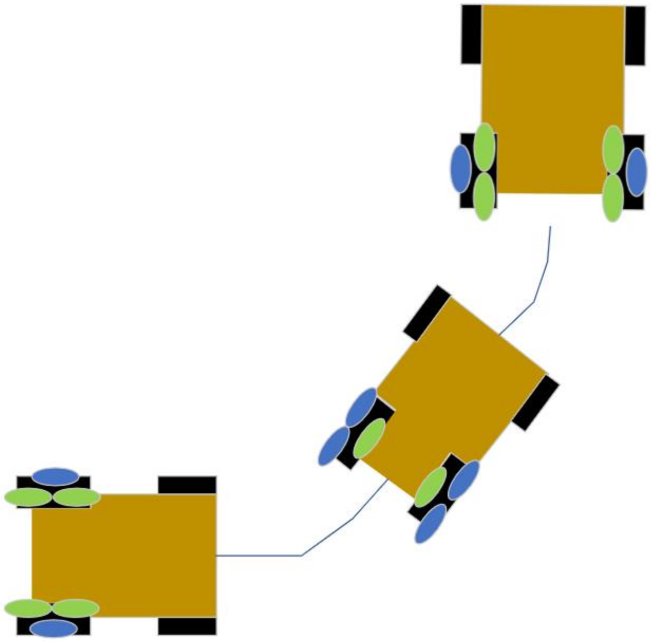

Figure 5: Representation of robot maneuverability with Omni wheels.

The omni-wheels are almost entirely 3D-printed, consisting of wheel, rollers, and spacer, with the exception of paper clips. The wheels also use nylon bearing between the rods to reduce friction. Various tolerances were used throughout various components. No tolerance was used between the wheels and spacers, which results in parts being a squeeze fit. The rollers were given about 2 mm on each side in order to prevent them from getting stuck on the walls of the wheel.

The robotic arm and claw were designed with the intent of being able to pick up Ken while also being able to efficiently corral the dinosaurs into the cage. As it can be seen in the Figure 6 below the claw was specifically designed around Ken's physiology with the two right-most fingers being able to go in between his back and backpack to scoop him up from underneath and the left finger being able to go underneath his thighs, providing stability. The claw is rotated up and down with the use of string that is pulled back and forth by a servo held in place inside the second link of the robotic arm. The second link is comprised of two pieces of MDF and is connected to the claw with a metal rod. The left piece of the second link is connected to the left side of the first link through another metal rod which is firmly held in place with the use of two circular braces that are screwed in place. A second servo is held in place by the right side of the first link and is attached to the right piece of the second link enabling it to lift the entire arm and claw up and down. The third servo is directly attached to the left side of the first link and enables the back-and-forth movement of the entire robotic arm and claw. The right side of the first link rotates on another metal rod which sets it at the same level as its left side counterpart. This rod is held in place by a brace which is screwed on to the base and by a small compartment located in between the left and right sides of the first link. The small compartment is screwed on to the base and holds the third servo in place inside of it. The left and right sides of the first arm are connected together using five metal rods which are slid into small holes located on the upper-rear areas of each member.

Figure 6: Top view of robotic arm and claw.

The wheel and green set of rollers are printed out of PLA, which has suitable material strength properties for the application. The blue rollers are printed from PETG, as we had supply of this on hand. The spacer is 5 mm and printed out of PETG, giving it strong material resistance. The spacer is also designed with an offset of 30 degrees, such that the rollers do not contact each other.

Table X is the final total of the print volume used. In total, we used 13.61 in^3 of filament, under the 15 in^3 limit. This was achieved with a couple of failed prints, totaling to about 3 in^3.

Table 1: 3D-printed parts volume taly.

	3D-Printed Part	#	Material	Volume (in3)
	Drive Wheel	2	PLA	2.16
	Omni-Wheel base	2	PLA	2.14
	Omni-Rollers	24	PLA/PETG	3.18
	Spacer	2	PETG	0.17
	Bumper	1	PLA	2.55
	Claw Spacer	2	PLA	0.41
	Extra/failed prints		PLA/PETG	3.0
Total		33		13.61

Given that two mobile bases were cut out of the MDF, as well as the claw, we used both MDF boards.

B. Electrical Design

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The electrical design encompasses all the actuation and sensing components, as well as the center of the system, the Pico W. We used all the electrical components in our design, with the exception of the line sensing module and two ultrasonic sensors. Figure X shows the electrical schematic of our robot.

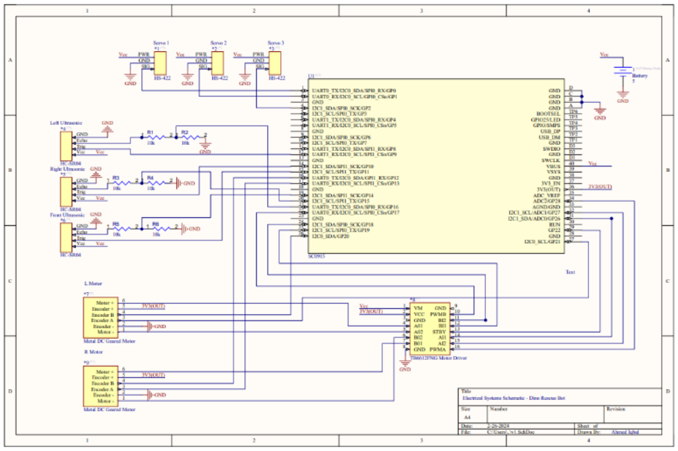

Figure 7: Electrical Schematic.

The power delivery would come from a rechargeable NiMh 4C pack of AA Cells. Table X summarizes the power draw over average and maximum current draw.

Table 2: Total power drawn from all the electrical components in the robot.

Component	Voltage (V)	Avg. Current Draw (A)	Max. Current Draw (A)	Power (W)
DC Motor 1	5	0.25	1.2	1.25 (6 with max current draw)
DC Motor 2	5	0.25	1.2	1.25 (6 with max current draw)
Ultrasonic Sensor 1	5	0.015	0.015	0.075
Ultrasonic Sensor 2	5	0.015	0.015	0.075
Ultrasonic Sensor 3	5	0.015	0.015	0.075
Servo-Motor 1	5	0.28	0.8	1.4 (4 with max current draw)
Servo-Motor 2	5	0.28	0.8	1.4 (4 with max current draw)
Servo-Motor 3	5	0.28	0.8	1.4 (4 with max current draw)
Raspberry Pi Pico W	5	0.05	0.15	0.25 (0.75 with max current draw)
Motor Driver	5	1.2	1.2	6
Total		2.6	6.2	13.2 (35 with max current draw)

The internal wiring of the robot was done on the smaller breadboard, in such a way that the wire runs would be as short and optimal as possible, shown in Figure X. By placing the Pico in the centre of the base, this puts all the wires within reach of the pinouts. The left and right motors are also wired accordingly.

C. Software Design

Two scripts were written to control this robot. The first script, "MREN 303 Pico W Wifi Gamepad Input" was written by Dr. Wu in Python. The script reads the inputs from the gamepad, establishes a network connection with the Raspberry Pico W, and sends the input information to the Pico. The second script "PicoUDPGamePadReadGameModes" was written by Dr. Wu in Arduino. The script reads connect to the MREN 303 Wi-Fi enabling the Pico to read the inputs sent from the Python script. The team added to this script assigning various commands from the controller to actions performed by the DC motors and servo motors. The team also incorporated three modes in the robot software, idle mode, manual mode, and autonomous mode. Idle mode is triggered by pressing the start button. Once idle mode is active, the robot is not able to move in any way. Once the start button is pressed again the robot is turned back to manual mode. In manual mode, the DC motors and servos can be controlled freely. If the "A" button is pressed, the robot enters autonomous mode, in which the user can no longer control the robot. Once autonomous mode starts, the robot follows a series of steps which get it to maneuver around the starting course, press the red button, and go through the gate. Autonomous mode stops either when the robot goes through the gate or after 30 seconds has elapsed, however, in case the robot fails autonomous mode it can be brought back into manual mode by pressing the "B" button on the gamepad. Autonomous mode uses a combination of the encoders and the distance sensor. Once it starts, the robot drives forward until the distance sensor reads about 40 centimeters, this ends the first step. For the following steps, the robot relies solely on the encoders and drives towards a desired position for each step. The position of the robot is calculated using P control and the team learned how to read the encoders from "CurioRes".

III. Results

Overall, the robot showed promising outcomes in completing the tasks. With the new design implementation, the robot was able to corral the dinosaurs. However, we found that the performance of the robot would vary significantly at times. Section A. will highlight the results from the claw. Section B will summarize the results of the mobile base, omni-wheels, and autonomous system.

A. Robot Arm & Claw

The robotic arm and claw were constructed almost only out of MDF since a large portion of the available 3D printed material was already being used for the front and back wheels. One major limitation of the robotic arm was its strength. When it was first constructed it was not able to pick up Ken and could barely lift any dinosaurs. This was because the team severely underestimated the weight of the robotic arm. To try and reduce the load on the servo's, some elastic bands were added to the arm. The two first bands were connected between the top of the first link and the end of the second link, reducing the amount of torque that the second servo needed to lift the second link and claw. The addition of the first two elastic bands drastically improved the strength of the robot, enabling it to lift the dinosaurs with ease. However, the arm was still not strong enough to pick up Ken. Two more bands were connected between the first link and the base, reducing the amount of torque required by the first servo to rotate the first link backwards. The addition of these last two bands enabled the robot to keep Ken levitating while driving, however, the arm was still not able to lift him from the hole. The team was not able to further improve the arm by adding more elastics since they prioritized getting the autonomous mode to work. Even though the team's first goal (picking up Ken) wasn't achieved, the team managed to achieve the second goal, which was corralling the dinosaurs over towards the cage and lifting them inside. This was facilitated due to the wide reach of the claw.

B. *Mobility and Autonmous Mode*

The mobility of the robot was shown to be inconsistent at times. We found that paper clips holding the rollers would often flex in place, not allowing the roller to rotate freely. This caused the rollers to drag, reducing the mobility of the robot. This was especially apparent in the autonomous mode, as it is sensitive to the rotation speed.

IV. Conclusion

In conclusion, the robot performed with varying levels of success, being able achieve its goals with some difficulty. With further iterations to the design, we can see better performance from the robot.

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