ACS6502 Group Project (GP) Final Report

The Direct Approach Variable Item to Destination (DAVID) robot

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1. DEVELOPED SYSTEM OVERVIEW

The mechatronic system is designed to perform a pick and place operation along a path with and without an obstacle. It is equipped with a soft-gripping mechanism that uses 2 degrees of freedom. The program instructs the robot to move forwards, continuously reading the value from the hall sensor. On detecting the magnet in the cube, the gripper is closed and the cube is lifted. In task 1, the robot moves in a straight line, until the IR reflectance sensor reaches the black strip, which is used to mark the destination point. The robot is triggered to lower the cube and release it on the target mark, and then move backwards. In task 2, the robot picks up the cube as earlier, but then it follows a fixed motion to avoid the obstacle that is 1 metre away.

2 COMPONENT LIST & PURCHASED ITEMS

Table 1 gives the list of components used in the robot.

3 OUTSOURCED DESIGN/LIBRARY/SOFTWARE MATERIALS

We did not use any outsourced materials.

4 MECHANICAL DESIGN, MATERIALS, AND FABRICATION METHOD

The system shown in Fig 1 is the designed robot. The four-wheel design was chosen as it gives better stability compared to two-wheeled systems. The arm uses a soft gripper to grab the box. A dual gripper design was used for its higher durability [1]. The material used for the gripper was rubber. A strip of rubber was wound in a U-shape. The base of the U-shape was fixed to the body of an SG90 servo motor. A string was attached to both ends of the gripper and connected to the shaft of the servo motor. When the servo shaft rotates, it pulls the string, causing the gripper to close. Rotation of the servo shaft in the opposite direction causes the string to lose its tension and the gripper returns to its original open position. The gripper servo was mounted onto the 3D printed holder provided in the mechatronics kit. The gripper assembly was attached to another SG90 servo motor located at the top of the robot body through a wooden linkage. This servo motor was attached to the body using custom-made acrylic supports and L-brackets. The second servo enables the gripper to rotate on an axis parallel to the top surface of the robot. Thus, the gripper arm assembly has a total of two degrees of freedom. During testing, the gripper was able to lift weights as high as 50g.

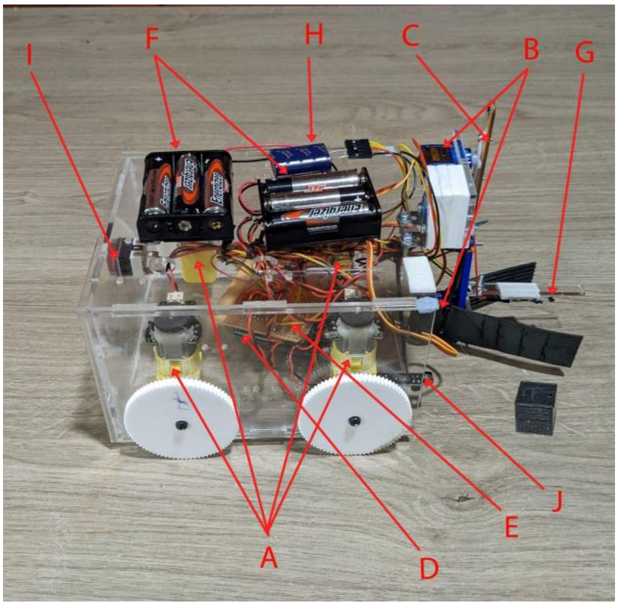

Fig. 1. Labelled image of 'DAVID' along with the cube. Components listed in Appendix Table 1.

The design of the main chassis of the robot was made using Fusion 360. The dimensions of the chassis were 166mm x 152mm x 96mm. T-slots were incorporated in the design because of their ease of assembly. The chassis was made using a 3mm clear acrylic sheet. Acrylic was chosen because of its easy machinability, high durability, and relatively lower costs. It also adds to the aesthetics. The acrylic sheet was cut using a laserscript laser cutter machine. This is a water-cooled CO2 type laser cutter with a precision of 0.01mm and a bed size of 600mm x 900mm. It uses a stepper motor for driving the laser head and can cut acrylic up to 10mm in thickness. All the faces except the top face were glued together using adhesive for improved rigidity. Appropriate slots and holes were made in the faces of the chassis to facilitate the fixing of components and to allow the connection wires to pass through. Most of the mass was concentrated in the centre towards the front of the robot because of the presence of the gripper arm. To compensate for this, the Arduino, protoboard, and battery holders were placed towards the back of the robot. Even though initially wheels were brought from an outside source, they were not used in the design since the delivery got delayed. Therefore, wheels with a diameter of 60mm were custom fabricated using a 5mm white acrylic sheet and by laser cutting. The wheels were designed using Fusion 360 software.

The robot was able to move in a two-dimensional space in any direction. During testing, the robot was also able to climb a slightly inclined path without slipping. At first, there was a slight deviation from straight-line motion. But this was corrected to a great extent by redistributing the weights of various components. The average straight-line speed of the robot was about 20cm/s. The average time to pick up or drop the object was 1.5 seconds.

The 2cm x 2cm x 2cm cube was designed using fusion 360. It was made in two halves with two slots incorporated inside them to provide space for mounting two magnets. The cube was fabricated using the 'Ultimaker 2+' 3D printer. It uses the Fused Filament Fabrication (FFF) method for printing. It has a nozzle diameter of 0.4mm and a layer height of 0.2 to 0.3mm and a maximum build speed of 24mm^3/s. PLA was used as printing material with a 20% in-fill.

5 ELECTRONICS DESIGN

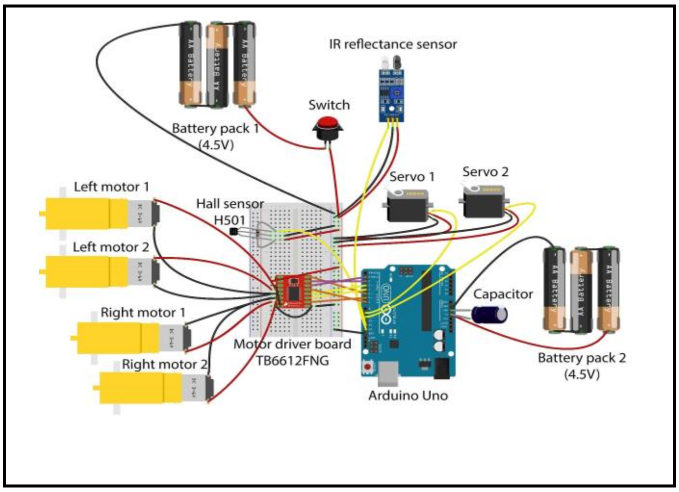

Fig. 2 Schematic representation of the electronic components in the system.

As shown in Fig 2, four DC motors were used for locomotion. Two motors on the left and right work in tandem using a single motor driver thus eliminating the need for a second motor driver. Since the motor driver provided in the kit (TB6612FNG Motor Driver Board) can handle an average current of 1.2 amperes on a single channel, it is sufficient to run two motors on a single channel. Power to these motors was supplied from 3 AA batteries connected in series. Also, the servo motors and sensors were powered by the same battery pack. A push-type switch was connected in series to this battery pack for the easy switching ON and OFF of the power supply to the circuit.

An Arduino Uno board was used for it had the appropriate number of pins, and it was readily available whereas ordering a different board would have added to the budget unnecessarily. When the Arduino was also connected to the same battery pack, it was observed that when the direction of motors was reversed or when servos were in operation the current draw increased at that instant causing the sudden voltage to drop in the circuit. At this instance, the voltage to the Arduino dropped below the minimum required voltage which triggered a reset in the ATmega328P microcontroller. To eliminate this, another similar battery pack was used to power the Arduino. Also, a capacitor was connected between 5V and GND pins for power conditioning by keeping the voltage stable. This isolated the digital electronics circuit from the analogue circuit. Also, this power setup made the circuit safe from various types of hazards as the operating voltage never went above 5V. Another advantage of this power setup was that it made the operation more efficient. Only 6 non-rechargeable AA batteries were used during the whole project phase, which includes all test runs and actual videos. Fig 3 shows the protoboard mounted on the Arduino to reduce the number of jumper wires used by soldering together connections to and from the motor driver.

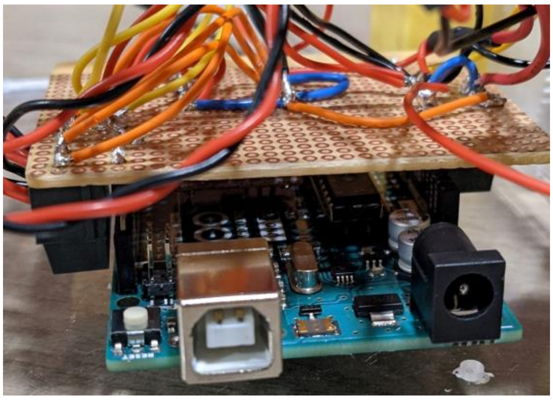

Fig. 3 Protoboard mounted on Arduino UNO.

For detecting the cube, a hall effect sensor was implemented. The distance sensors provided in the kit were not usable at proximity less than 10cm. Since a hall effect sensor can detect changes in magnetic flux due to a permanent magnet, it would aid in pinpointing the location of the cube containing the magnet [2]. It was placed on a platform extending from the gripper. To release the block at the target 2 metres away, a reflectance sensor was used. A black line was taped near the target mark. When the robot reaches the target point, the reflectance sensor would measure no reflected values from the black strip, signaling the target.

6 BEHAVIOUR (MOTION) DESIGN

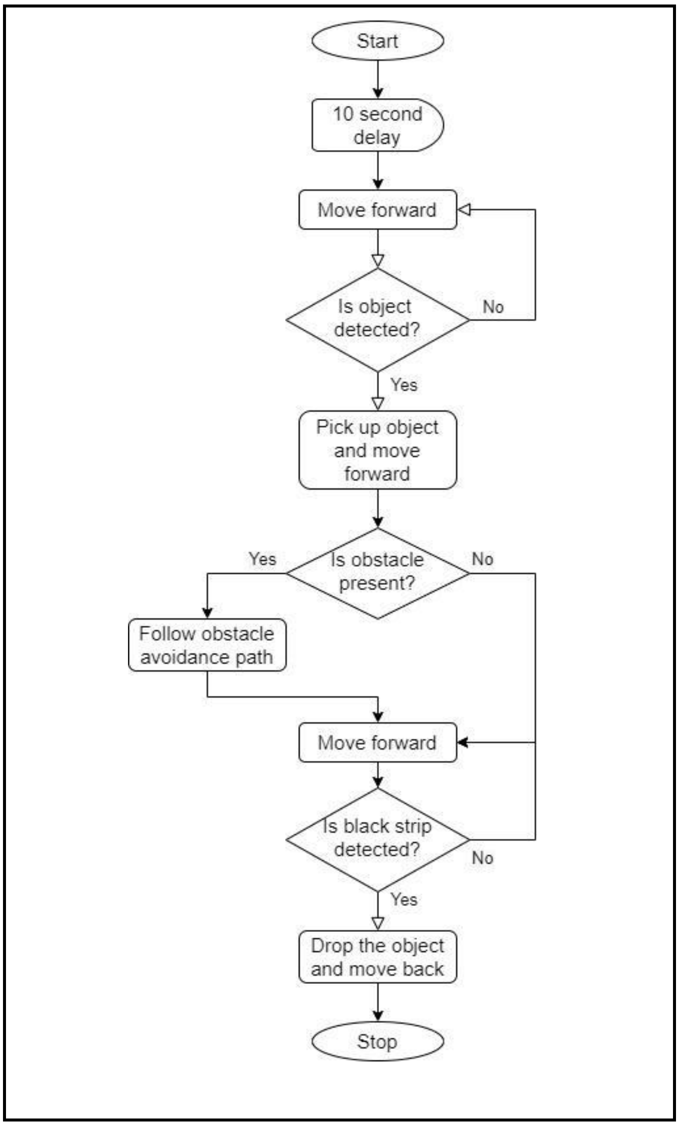

Fig. 4. Flowchart of the operation logic

Fig 4 describes the algorithm in a flowchart for its ease of understanding. The robot was programmed to start with an initial delay of 10 seconds, to give enough time for all human operators to step outside the robotic workspace for safety reasons. Then the program instructs the robot to move forwards, continuously reading the value from the hall sensor. On detecting the magnet in the cube, the gripper is closed, and the cube is lifted. The tasks are designed as described in the assignment brief provided for the project [3]. In task 1, the robot moves in a straight line, until the IR reflectance sensor reaches the black strip, which is used to mark the destination point. The robot is triggered to lower the cube and release it on the target mark, and then move backwards. In task 2, the robot picks up the cube as earlier, but then it follows a fixed motion to avoid the obstacle at the 1 metre point.

7. TASK 1 Performance Result

The robot was successful in accomplishing task 1. As demonstrated in the video, the robot could detect the block, pick it up, and drop it as desired. The gripping mechanism was suitable for the task and allowed high precision. The cube always landed within a centimeter of the centre of the destination X marking. The robot functioned at a good speed and finished the task in about 16 seconds.

8. TASK 2 Performance Result

Similar to task 1, the robot performed task 2 well too. The obstacle provided little cause for concern since the bot was programmed for a path along which it maneuvered satisfactorily. Two paths were defined for the robot to follow. First, the robot uses a rectangular path where it traces the boundary of the obstacle to go around it. The speed was impressive, finishing the journey from starting motion and picking up the cube to dropping it off and moving backwards within 30 seconds. The drop-off was made 3 cm away from the centre of the X marking. The second path followed for the same task was a triangular one, where it moved diagonally and out of the periphery of the obstruction, turned by approximately 90 degrees, and rejoined its original straight-line path to the destination. This was a faster path, completing the operation in 22 seconds, and the cube was placed almost 6 cm away from the centre of the X, in perfect horizontal alignment.

9. DISCUSSIONS AND PROJECT REFLECTIONS

The advantages of having a four-wheeled system include a higher maximum possible speed, greater stability, which in turn amounts to higher accuracy. The gripper provided an enhanced ability to grip the cube without damaging it. It could also be expanded to other irregularly shaped objects, since a soft gripper is compatible with a variety of shapes and sizes, as illustrated in the demonstration video. The protoboard used to solder together some connections reduced the mesh of jumper wires. The wires that were used to connect the components without soldering them were tied together with zip-ties for neatness and to prevent entanglement. The robot moved fast with a good success rate of pick-up and drop of the cube.

However, there were a few limitations that needed to be considered. The initial alignment of the robot affected the way it approached the cube, and that sometimes led to the cube not being detected. Having four motors drew in a lot of power to compensate for which double the power supply was required, along with a capacitor to sustain the charge and prevent the Arduino from resetting. The weight of the batteries had to be aligned towards the centre of mass of the robot to ensure that the robot moved in a straight line.

The components ordered arrived too late, leading us to use alternatives (such as acrylic wheels), and the path had to be redesigned (from line follower to a predetermined set of motions). The t-slot system for building the body of the bot gave enough access to the circuit in case it needed rechecking or any changes had to be made to it.

In hindsight, maybe with a higher budget or with LiPo or NiMH batteries, we could incorporate IR distance sensors in multiple directions, replacing the UNO with a Mega for the number of pins (or use multiplexers on a UNO board) in order to detect the obstacle and make calculated changes in the path to reach the destination. Other aesthetic additions like RGB LEDs could be made too. As an experience, the project helped us to divide the work to suit our strengths, and we understood the importance of having the presence of mind to make changes to the design due to the last-minute crisis of not receiving the components on time. Overall, project DAVID completed all the required tasks to our satisfaction.

APPENDIX

Table 1: Mechanical and electronic components and material list

component name/model	count	weight	current/power consumption	total price excl. VAT	link	Labels in Fig.1
DF robot micro DC motor with encoder	4	49g	upto 2.8A	(included in the kit)		A
SG90 servo motor	2	9g	upto 250mA	(included in the kit)		B
3mm acrylic sheet - clear 600mm x 600mm	1	-	N/A	£10.00 (iforge)		not labelled
5mm acrylic sheet - white	-	-	N/A	(iforge stock)		not labelled
Wooden linkage	1	ignorable	N/A	(included in the kit)		C
Arduino UNO	1	38g	15mA	(included in the kit)		D
Protoboard	1	ignorable	N/A	(iforge stock)		E
AA battery holder (3 battery)	2	ignorable	N/A	(included in the kit)		F
Dry cell AA battery (max discharge current 1.5A)	6	23g	N/A	(personal stock)		not labelled
H501 hall sensor	1	ignorable	20mA	£1.49	link	G
5F Capacitor	1	7.5g	N/A	(iforge stock)		H
10k resistor	1	ignorable	N/A	(included in the kit)		not labelled
Toggle switch	1	ignorable	N/A	(iforge stock)		I
TB6612FNG motor driver	1	ignorable	N/A	(included in the kit)		not labelled
IR reflectance sensor	1	ignorable	10mA	£1.88	link	J
Plastic printed holder for SG90 servo motor	1	ignorable	N/A	(included in the kit)		not labelled
Rubber strip 25mm x 200mm	1	ignorable	N/A	(iforge stock)		not labelled
Solid core connecting wires	-	ignorable	N/A	(included in the kit)		not labelled
Cable tie 100mm	1	ignorable	N/A	(included in the kit)		not labelled
Male header pins	-	ignorable	N/A	(iforge stock)		not labelled
Bolts/nuts/screws/washers/L-brackets/adhesives	-	ignorable	N/A	(included in the kit)		not labelled
	Total	1120g	Upto 3A (excl. batteries)	£13.37		

Table 2: Outsourced design/library/software materials

material name	description	link
Nil	Nil	

REFERENCES

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2. Administrator, “How to use Hall effect sensor with Arduino? - working, Hook-up guide and relay control,” *Electronics Hub*, 06-Oct-2019. [Online]. Available: https://www.electronicshub.org/hall-effect-sensor-with-arduino/. [Accessed: 17-Nov-2021].
3. S. Miyashita, D. Damian, and B. Taylor, “Assignment Brief ACS6502 Group Project (GP).” University of Sheffield, Sheffield, Oct-2021.

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