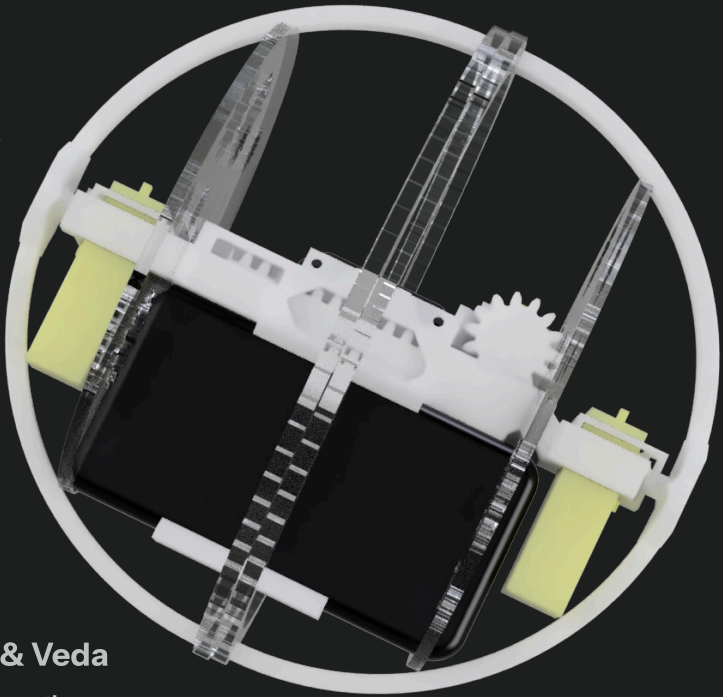
Doppy.

Using sound to follow a moving object.



Group 46

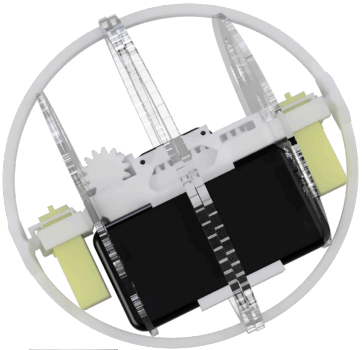
DE2

Hamish & Veda

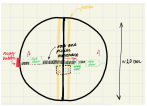
Physical Computing

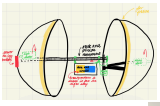
Introduction

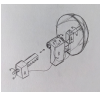
Doppy is a companion droid designed to keep the user company as they walk around. This project was made with the use of audio, mechanical and circuit engineering, with the purpose of making it interactive and entertaining.



Initial ideas and brainstorming







We immediately thought to make a robot that would open, close and follow you around, so we started experimenting and drawing how we envisioned it would look like.





The idea was to be as "resourceful" as possible, so using the least amount of material was a way we thought we could fulfil the brief.

Before opening a CAD drawing, we did sketch exploration of how the snap-fit mechanism would work, and how the spokes and rack would fit into the design.

We wanted to use snap-fits so that we would easily be able to put the compponents together and take them apart.





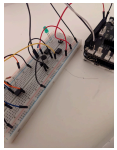
After printing and testing for tolerances, we got one that fit together perfectly.





As we wanted the Bela to be screwed on, it took us a few attempts to get the screw holes in the right area

Circuit practice



Testing out adhesives



Rack + snap-fit prototypes





We tested different gear sizes for the rack and pinion to compare.



Female snap-fit prototypes

Prototyping phase

Components

The large, circular panels, laser-cut from acrylic, function as **stabilisers for the external shell**. Their inclusion prevents beam bending in the spokes and keeps the wheels aligned, enabling the robot to stand straight and **avoid veering from its path**.

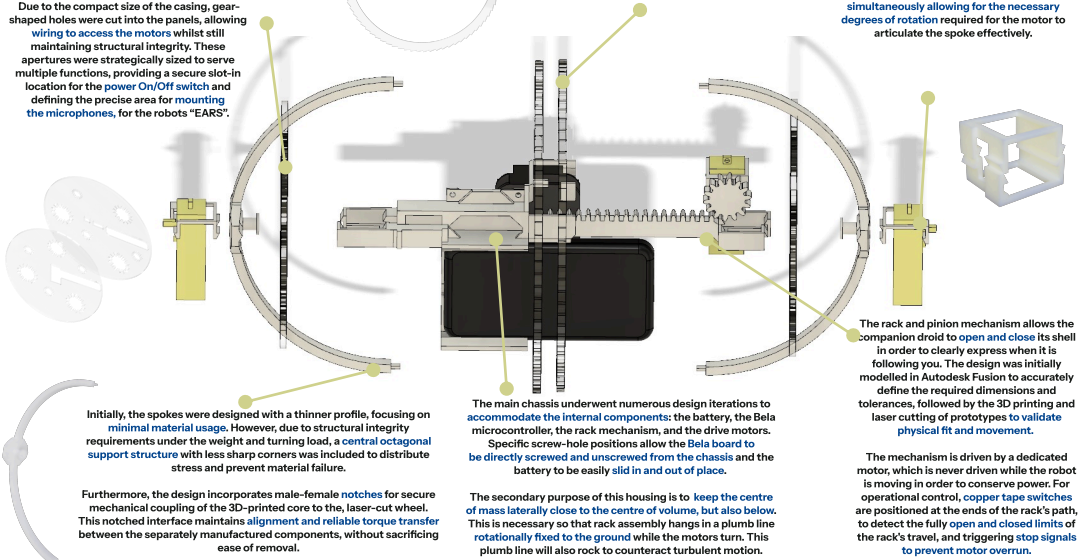
Due to the compact size of the casing, gear-shaped holes were cut into the panels, allowing **wiring to access the motors** whilst still maintaining structural integrity. These apertures were strategically sized to serve multiple functions, providing a secure slot-in location for the **power On/Off switch** and defining the precise area for **mounting the microphones**, for the robots "EARS".

These laser-cut wheels underwent **several design iterations** for stability and durability. Their thickness was increased after it **cracked under the load of the rig**, and the spoke interface notches were moved centrally over the initial top-edge placement to **reduce slack and bending** of the rack assembly .

To affordably add surface friction, the wheels feature **grooves with beads of hot glue**.

The two external yellow servo motors directly drive the rotation of the spoke assembly, turning the shell into wheels. Each motor connects **immediately to the central spoke structure via a female connector pin**, which **transfers rotational force to the wheels**.

For ease of placement and removal, the body of the servo motor is secured to the rack assembly using a **male-female snap-fit mechanism**. This attachment is designed to hold the **motor firmly in place**, while **simultaneously allowing for the necessary degrees of rotation** required for the motor to articulate the spoke effectively.



Initially, the spokes were designed with a thinner profile, focusing on **minimal material usage**. However, due to structural integrity requirements under the weight and turning load, a **central octagonal support structure** with less sharp corners was included to distribute stress and prevent material failure.

Furthermore, the design incorporates male-female **notches** for secure mechanical coupling of the 3D-printed core to the, laser-cut wheel. This notched interface maintains **alignment and reliable torque transfer** between the separately manufactured components, without sacrificing ease of removal.

The main chassis underwent numerous design iterations to **accommodate the internal components**: the battery, the Bela microcontroller, the rack mechanism, and the drive motors. Specific screw-hole positions allow the **Bela board to be directly screwed and unscrewed from the chassis** and the battery to be easily **slid in and out of place**.

The secondary purpose of this housing is to **keep the centre of mass laterally close to the centre of volume, but also below**. This is necessary so that rack assembly hangs in a plumb line **rotationally fixed to the ground** while the motors turn. This plumb line will also rock to counteract turbulent motion.

The rack and pinion mechanism allows the companion droid to **open and close** its shell in order to clearly express when it is following you. The design was initially modelled in Autodesk Fusion to accurately define the required dimensions and tolerances, followed by the 3D printing and laser cutting of prototypes **to validate physical fit and movement**.

The mechanism is driven by a dedicated motor, which is never driven while the robot is moving in order to conserve power. For operational control, **copper tape switches** are positioned at the ends of the rack's path, to detect the fully **open and closed limits** of the rack's travel, and triggering **stop signals to prevent motor overrun**.

How it works

All the electronics and actuators used:

3x DC motors:
- 2 DC motors used for the rotation of the wheels
- 1 DC motor used for the rack and pinion mechanism to expand and contract the robot

1x Speaker with Power Amp:
- They were used for the output of Doppy's speech: the R2D2 noises

2x Electret Microphones:
- These were used as the EARS to detect where the phone pulse signal was coming from

1x Tactile switch:
- This was used to turn the robot ON/OFF

2x Dual-H-Bridge Motor Drivers:
- These were used to drive the motors forwards and backwards.

1x Bela board:
- A Bela board was used to run all the code

1x 5-Volt battery pack:
- This was used to power all the actuators and the Bela board

Copper tape switch:
- Stuck to rack to measure open/closed states

The user presses the power button on doppy

↓

Doppy turns on, and the motor powered rack and pinion expands to open up the ball whilst it makes a waking up R2-D2 noise

↓

Using its ears (the two microphones) it listens for a high frequency audio pulse that the user would be playing from an app on their phone

→

Doppy listens for the pulses and hears a different volume in each ear, which it uses to approximate the angle of origin of the sound.

↑

The angle signal is smoothed out and PWM signals are sent to the motor, with different speeds in order to turn.

↑

The PWM signals are split so that the motors take turn moving in order to stay low-power. Doppy is nonw 'following' the sound

→

If the user presses "wait" on the app, Doppy stops moving and pauses. They can press "follow" again if they want it to start following them again, using the same process

↓

This goes on until the user presses the on/off switch on Doppy, where after he is pressed, he contracts again and goes to "sleep"

The software

We began with a feasibility test for sound localisation as we were advice this was most difficult, and that Bluetooth and. WiFi signals would be too inaccurate at our scale of distances.

After applying an envelope and a signal threshold for 2 std. dev. above block-mean, we were able to detect a signal and rule out both speed-of-sound calculations and the Doppler effect. Using a rolling Laplace transform approximation instead of block-mean yielded insignificant improvement.

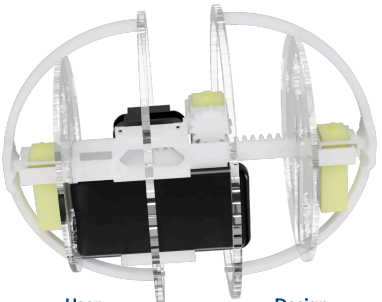
We discovered that amplitude differences could be separated from the noise with a sufficient sound barrier between the microphones. We tried block-averages, convolution and weighted moving average (WMA), opting for WMA to smooth the signal.

We created a motor class to handle PWM. signals, rapidly alternating between motors to save power. The duty time was a. linear function of the amplitude differennce, giving us basic PID behaviour where displacement decays towards the origin of the sound.

We also used the speaker distances from the ears to correct for microphone sensitivities in the calibration.

We then made an android app for sending the 'follow' signal, using Android Studio and a Gemini Agent (LLM).

Evaluation and future possibilities



Future possibilities

- The temporary hot glue should be replaced with press-fits and mechanical fasteners such as bolts or sliding sleeves.
- The electronics should be hidden and the volume dial on the amplifier should be placed in a hatch to tidy up the outward appearance.
- Explore consolidating the motor and rack assembly into a single, self-contained linear actuator module to reduce wiring and simplify maintenance.
- Upgrade the copper wire limit detection to optical or magnetic end-stop sensors for greater precision and reliable motor cut-off.
- Increase power supply to H-bridges to ensure Doppy can handle more load and friction when moving around.
- Use speaker to communicate with the user, such as a distress during motor-stalling, excitement when close or exasperation if the user moves away too fast.

User Complaints

The highly visible wires and exposed yellow servo motors detract from the overall clean look of the structure. The numerous visible components (motors, gearing, wires) break the minimalism and simple design style, making the robot appear less like a final product and more like a high-fidelity prototype.

The second significant piece of user feedback concerns the extensive use of hybrid materials and external reinforcements for stability, particularly the thicker acrylic rings and the hot glue on the wheels. Users expressed concerns about long-term reliability as it creates a perception of a fragile or high-maintenance product.

Design Oppurtunities

The project still has great design potential to make the central drive components built-in or subtly encased without affecting the mechanical transmission or the critical thermal management of the motors. This would significantly improve the aesthetics toward a commercial-ready product.

A possible solution is to integrate a dedicated, friction material (e.g., a custom rubber O-ring groove) in the wheel design to replace the hot glue, and refining the central chassis to be made of a single, stronger material (like aluminium) that centralises the mass more effectively, thereby reducing the dependency on the acrylic circles for more support. However, this would increase manufacturing cost and complexity.

The exposed motors and gearing should be integrated into a streamlined cover, maintaining the minimalist style while allowing for critical access and heat dissipation.

Replace the hybrid acrylic structure with a single, stronger enclosure material (e.g., carbon fiber composite or lightweight aluminum) to reduce bulk and increase intrinsic durability.

