Cave Surveying Robot

Defining the Problem:

Cave surveying involves taking measurements of a cave in order to form a map. This is crucially important for any caver, as many caves involve dead ends, blind corridors and twisting passages – it is easy to get lost (Hunt, 2019). In a general survey, typically only distance, angle, and incline are measured with a digital device, while sketching, and data collection is done by hand (CavingUK, n.d.). This means measurements are precise, but it takes a very long time – typically about 60 – 150 meters of measurement per day (Beard, 2022). Caves can be kilometers long, and in this case traditional surveying techniques can take too long for complete maps (White, 2021).

A robot could replace the measuring, data collection and sketching of the cave. Autonomous movement of this robot would be useful for preventing the dangers of caving, however if a caver is carrying and operating the device, terrain can be avoided more efficiently.

Design Requirements:

- Must generate a map that can be followed.
- Must use the robotics materials available in school
- Must be faster than traditional surveying.
- Must be functional when surveying dark environments.
- Must be usable in a range of different cave widths.
- Must be an embedded system.
- Must be not drain a power source in a day of surveyal.

Design Solutions:

Ultrasonic wave emission and detection can measure distances based on the time it takes for the wave to reflect, and return. This is because it is assumed the waves travel at a constant speed of sound, and therefore time can be converted to distance (Burnett, 2020). As sound is being used, ultrasonic sensors can measure distances in the dark (Gillespie, 2019).

Using a small ultrasonic device to automatically detect and map the surrounding cave walls would create a fast low-detail map of the cave. With this there is no need to create survey points and sketches, and there is no need to measure inclinations and distances. Additionally, this map could be constructed in the dark, so there is no need to light up the area of surveyal. Although it may not be high-detail, it could create enough detail for cavers to safely navigate through the cave – something is better than nothing.

Computer stereo vision is a much more complex algorithm, but is much more precise and accurate in measurements (Hassain, Hassan, Saad, Win, 2017). Due to the need for cameras, stereo vision needs a lit up area for surveyal, but a light source can be included (ClearView Imaging, n.d.). Additionally, the two cameras, light and computational complexity mean a high power consumption.

The below table is used to compare the design solutions.

Categories:	Computer Stereo Vision	Ultrasonic Sensor
Dark functionality	0	1

Range	1	0
Accuracy	1	0
Speed of measurement	1	1
Power usage	0	1
Small Form Factor	0	1
Total:	3	4

This table shows that the ultrasonic sensor is a better design solution, and hence the robot will follow this.

Additional design considerations:

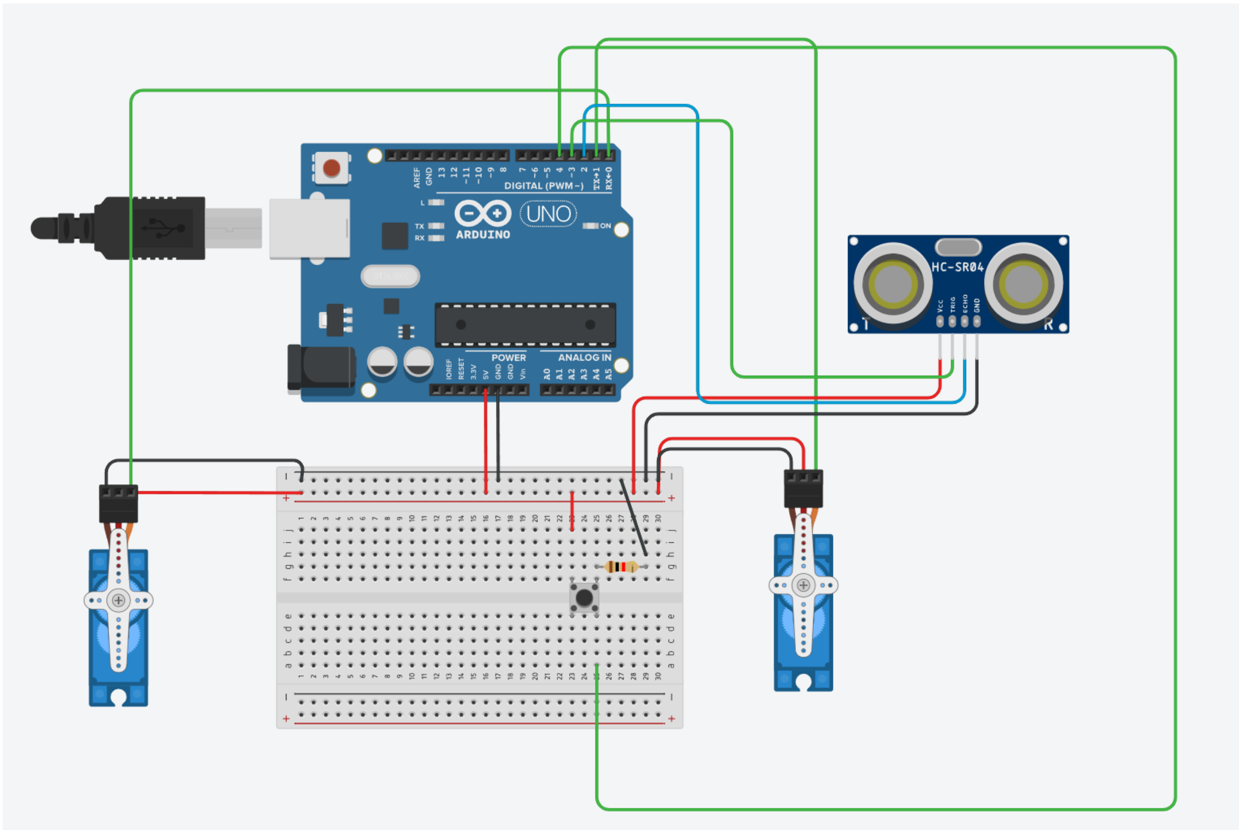
For an ultrasonic sensor to map the walls of a cave, it needs to be able to see all surrounding walls. As the ultrasonic sensor does not have a 360° view, it has to be rotated somehow. This could be done by hand, but the position relative to the walls could be changed. A motorized rotation would work in this situation, however the position of the motor would have to be addressable, so one full rotation can be made. There are DC motors and servo motors available at school, which each have their flaws.

The DC motors cannot be ran of the PWM supply as they use too much current. This means an additional driver or controller is required. DC motor drivers can only provide speed control, and act as a on/off switch, meaning a controller would have to be used. A DC motor controller can provide position inputs, however they are not available at school. This leaves servo motors.

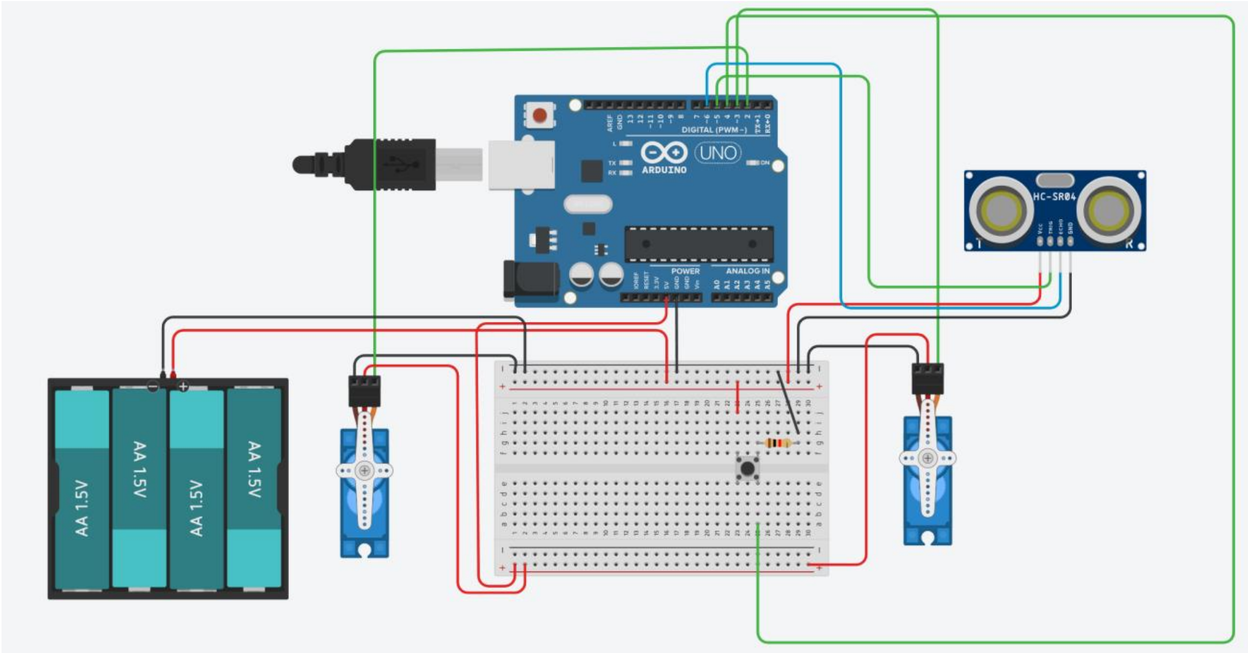
Servo motors offer full positional control, which is perfect. The available servo motors do not have full rotational control, stopping at 180°. Due to all other options being lost, some improvisation must be made. Two 180° servo motors can be used to rotate a full 360°.

Planning:

My first model of the circuit can be found below.

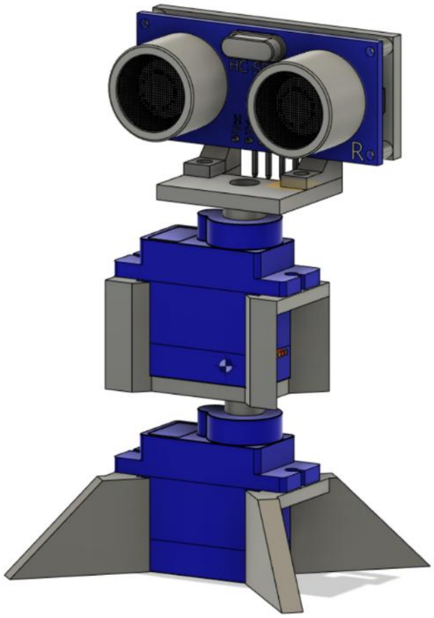


This circuit has a few issues that I found during later research. The Arduino does not have enough current to drive both servos, the ultrasonic sensor and serial input, so an external power supply has to be used. The 0 and 1 pins are used for serial connection on the Arduino uno, so the attached servos will behave weirdly when serial is being used, so the pins have to be moved.



This iteration fixes these issues.

Due to the need for two servo motors, a robot body is required to fix the parts together. The center of rotation must line up across both servos, so the ultrasonic sensor is not displaced much, and can achieve an accurate reading. Additionally, the body must have wide legs to balance the robot in it's rotation, especially considering the robots high center of gravity. I created the design, as there was nothing already available that suited the needs of this body. My design is below – the servo and ultrasonic sensor models are not my creation, but are free use.



The robot body can then be 3d-printed and assembled.

References

Beard, J. (2022). *Mapping Caves.* https://www.spgcavers.org/?page_id=667

Burnett, R. (2020). *Understanding How Ultrasonic Sensors Work.* https://www.maxbotix.com/articles/how-ultrasonic-sensors-work.htm

CavingUK (n.d.). *Cave surveying and B.C.R.A. survey grades.* https://www.cavinguk.co.uk/info/Surveygrade.htm

ClearView Imaging (n.d.). *Stereo Vision for 3D Machine Vision Applications.* https://www.clearview-imaging.com/en/blog/stereo-vision-for-3d-machine-vision-applications

Gillespie, K. (2019). *Ultrasonic Sensors: Advantages and Limitations.* https://www.maxbotix.com/articles/advantages-limitations-ultrasonic-sensors.htm

Hassan, M. & Hussain, A. & Saad, M. & Win, K. (2017). 3D Distance Measurement Accuracy On Low-Cost Stereo Camera. *Scientific International.* 29(3), 599-605.

Hunt, W. (2019). *Getting Lost Makes the Brain Go Haywire.* https://www.theatlantic.com/science/archive/2019/02/getting-lost-cave-labyrinth-brain/582865/

White, W. (2021). *Cave.* https://www.britannica.com/science/cave