# EN2533 - Robot Design and Competition
# Sensor Selection and Justification

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## 1 Chosen sensors for each specific sub-tasks

| Task | Task Description | Sensor |
|---|---|---|
| Task 1 | Crossing lines of varying widths and reading the barcode | TCS34725 Dual Mount Colour Sensor x5, Quadrature Encoders |
| Task 2 | Grabs a virtual box and moves it to a specific checkpoint | TCS34725 Dual Mount Colour Sensor x5, Quadrature Encoders, VL530L0x(TOF) |
| Task 3 | Following a path marked with a specific colour | TCS34725 Dual Mount Colour Sensor x5 |
| Task 4 | Following a path marked with dotted lines | TCS34725 Dual Mount Colour Sensor x5 |
| Task 5 | Navigation through a door-like portal | VL530L0x(TOF) |
| Task 6 | Rearranging the boxes of different heights into a specific order | VL530L0x(TOF) |
| Task 7 | Grabs a small box and inserts it into a larger box's hole | Quadrature Encoder Readings |
| Task 8 | Navigation through uneven terrain and placing a coin on a magnetized spot | GY-271 (HMC5883L) Magnetometer, VL530L0x ToF x3 |

Table 1: Task Descriptions and Associated Sensors

# 2 Reasons for selecting above sensors

## 2.1 TCS34725 Colour Sensor

When selecting a sensor for the line-following task of this challenge, we evaluated and tested out several options, including the TCRT5000 IR emitter and phototransistor, standalone IR emitters and receivers available in the local market (without specific model names), and the TCS34725 color sensor.

When choosing the sensor for this main sub task, we had 3 concerns.

1. Capability of providing a distinguishable reading for White, Black, Red and Blue lines.
2. Capability of taking accurate readings while having enough ground clearance as we have to navigate through the rough terrain presented in the last sub-task.
3. Reducing the cost and capability of rapid prototyping.

If we are to use IR sensors, then the the IR sensors we are choosing must be capable of distinguishing at least 3 colours using different IR analog read values. When testing the TCRT5000 IR emitter and receiver, we found that it wasn't capable of differentiating colors, even the white and black, if the sensor's ground clearance exceeded about 2mm. The standalone IR emitter LED and phototransistor showed slight improvements in detecting color variations, but their performance was significantly impacted by ambient light conditions and surface characteristics. Additionally, they failed to detect lines when the ground clearance was more than a few millimeters.

In contrast, the TCS34725 color sensor demonstrated better performance, accurately identifying colors even at a distance of 15mm, after precise calibration. This provided the necessary ground clearance for the front of the robot. Only downside it has was, the sensor's default sample integration time is 50ms introducing significant delay to the robot's control loop. But we found out that it can be adjusted to 2.4ms, 24ms, 101ms, or 154ms, allowing for a trade-off between speed and accuracy. Given that our primary goal in this challenge is to complete all tasks rather than achieve the highest speed, the TCS34725 offers an excellent balance between speed and accuracy, making it the good choice for our application.

Also, we allowed the fact that better IR receivers and emitters from foreign reputed brands might be able to offer the performance we required, the cost of them would be higher than that of 5 colour sensors combined and we have to develop a sensor array circuit using them eliminating the capability of rapid prototyping unlike the plug and use capability of colour modules as they are using I2C for communication. (When making a colour sensor array these modules needed to address with an I2C multiplexer as this sensor does not come with a XSHUT pin)

As a side note, we opted against implementing a sensor array lifting mechanism in the final subtask, which would have eliminated the need for sufficient ground clearance in the front of the robot. We made this decision to avoid adding unnecessary mechanical complexity to our robot's design.

## 2.2 VL530L0X ToF sensor

For wall detection, gate detection, and box height measurement, we selected the VL53L0X ToF sensor mounted on an SG90 servo motor. As it has a range of 3cm to 200cm, this sensor comfortably meets our requirements.

We decided against using ultrasonic sensors due to their lower accuracy compared to ToF sensors, larger size, and greater fluctuation in readings. While ToF sensors also exhibit some fluctuations, we successfully mitigated this issue by applying a moving average filter and threshold filtering, achieving highly accurate readings with an error margin of just $\pm 3mm$. This level of precision is more than sufficient for our goals.

Additionally, we opted not to use IR sensors for wall detection because, unlike ToF sensors, they depend solely on the intensity of the reflected IR light. This makes them susceptible to variations in surface color, condition, and ambient light, potentially leading to less reliable readings.

Also as this sensor have a XSHUT pin, we can integrate this into the I2C bus without needing to interfere with a multiplexer, reducing the complexity.

## 2.3 GY-271 (HMC5883L) 3 axis Magnetometer

After entering the rough terrain section, we will rely on this magnetometer sensor and wall detection from the 3 ToF sensors for navigation, as encoder readings may be unreliable due to potential slipping. The magnetometer can measure magnetic field intensities across different ranges, minimum range being ±1.3G while the maximum range being ±8.1G. Initially, we will use the lower range to maintain a constant heading based on the Earth's magnetic field. If the readings exceeds the lower range due to the magnetic field present in the arena, the robot has the capability of switching to higher measuring range and follow the path where the magnetic readings get even higher and higher.

We did not explore alternative solutions, as this was the only viable option we found. We have tested the magnetometer for maintaining a constant heading on the XY plane using the Earth's magnetic field. However, we still need to study how the readings are affected by an external magnetic field.

### 2.4 Side Note

Since all of these sensors support I2C communication, we can utilize a single I2C bus on the MCU, which simplifies wiring and reduce the number of pins required for the sensors.

Additionally, we are considering integrating an accelerometer and gyroscope, such as the BMI160 or LSM6DS3, depending on the accuracy of turn detection with encoder readings in the rough terrain.