**Why we choose HC-SR04 Ultrasonic Sensors and not VL53L0X TOF Sensors?**

**1. TECHNOLOGY DIFFERENCES**

**HC-SR04 (Ultrasonic)**

* Uses **sound waves** at 40kHz frequency
* Measures time-of-flight of acoustic pulses
* Wavelength: ~8.5mm (much larger than surface irregularities)
* Detection cone: 15-30° typical

**VL53L0X (TOF)**

* Uses **infrared laser** at 940nm wavelength
* Measures time-of-flight of light pulses
* Wavelength: ~0.94μm (microscopic)
* Detection cone: 25° typical (but effective spot is smaller)

**2. PERFORMANCE WITH BLACK SURFACES**

**HC-SR04 Advantages:**

* **Acoustic waves are color-blind** - sound reflects equally from black, white, or any colored surface
* Surface absorption affects amplitude, not time measurement
* Black surfaces reflect ultrasound just as effectively as white surfaces
* No dependency on optical properties of the target

**VL53L0X Disadvantages:**

* **Black surfaces absorb ~90-95% of IR light**
* Dramatically reduced signal-to-noise ratio
* May fail to detect black walls entirely at longer distances
* Requires significantly more power to compensate for absorption
* False readings or "no detection" errors are common

**3. ANGLED SURFACE BEHAVIOR**

**HC-SR04 with Angled Surfaces:**

* **Wide beam pattern** (15-30°) captures reflections even from angled surfaces
* Sound waves create multiple reflection paths
* Can detect walls at angles up to 45° reliably
* Diffuse reflection pattern helps maintain detection

**VL53L0X with Angled Surfaces:**

* **Specular reflection** - laser beam reflects away from sensor
* Narrow effective beam requires perpendicular surfaces
* Angles >15° often result in no return signal
* Mirror-like reflection on smooth surfaces causes complete signal loss

**4. NAVIGATION SPECIFIC ADVANTAGES**

**Wall Following Capability:**

HC-SR04: Reliable detection at various angles

- Can detect walls while turning

- Maintains readings during diagonal approaches

- Effective for corner detection

VL53L0X: Loses signal during turns

- Requires perpendicular alignment

- Misses angled walls

- Poor corner detection

**Opening Detection:**

The HC-SR04's wider beam pattern actually helps in detecting openings:

* Gradual distance increase as approaching an opening
* Natural averaging effect reduces noise
* Clear threshold detection for 70cm+ openings

**5. TECHNICAL COMPARISON FOR BLACK MAZE WALLS**

|  |  |  |
| --- | --- | --- |
| Parameter | HC-SR04 | VL53L0X |
| Black Surface Range | 2-400cm | 5-50cm (unreliable) |
| Angled Surface (30°) | 90% detection | <20% detection |
| Response Time | 20-30ms | 20-30ms |
| Power Consumption | 15mA | 20mA average |
| Reliability in Maze | Excellent | Poor |

**CONCLUSION**

The VL53L0X's advantages (precision, size, speed) are negated by its fundamental inability to reliably detect black surfaces at angles - a critical requirement for maze navigation. The HC-SR04's "inferior" technology actually becomes superior for this specific application where robust detection matters more than precision.