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.