Xypher Bot: Autonomous Surveying Robot

Utkarsh Tripathi[1], Manas Tripathi[2], Sheetal Prajapati[3] and Dhyan Chandra Yadav[4]
Department of Computer Science & Engineering,
Babu Banarasi Das University, Lucknow, India
Email: gt9659844@gmail.com[1], manastripathi1513@gmail.com[2], prajapatisheetal100@gmail.com[3], dc9532105114@gmail.com[4]

Abstract

Xypher Bot is a fully autonomous robot built to carry out tasks like height measurement, estimating distance, and detecting objects. It uses affordable and easily available components such as the MPU6050 sensor, ultrasonic sensors, and a laser pointer. By using simple trigonometry, the bot can measure object height with good accuracy. The top part of the bot, which is responsible for height measurement, has already been built and tested. The design and working plan for the lower-body movement system are ready, but the actual hardware is yet to be built. This paper talks about how the bot is made, how it works, and where it can be useful especially in surveying, monitoring the environment, and automation. A feature to send live data through a Telegram bot is also planned.

Index Terms Autonomous robot, height measurement, laser pointer, object detection, surveying.

INTRODUCTION

THE process of measuring height and distance manually can be slow and prone to errors. To make this process easier and more accurate, we built **Xypher Bot**, a fully autonomous robot that can detect objects, measure height, and estimate distance on its own.

The system incorporates readily available components such as the **MPU6050 sensor**, **ultrasonic sensors**, and a **laser module**. These hardware elements are combined with fundamental trigonometric principles to compute object heights with improved accuracy. The upper module of the bot, responsible for height measurement, has been successfully constructed and experimentally validated.

The lower module, currently in the design phase, is intended to provide autonomous mobility and laser alignment functionality. This unit integrates **computer vision techniques** including **edge detection**, **grayscale conversion**, **Gaussian blurring**, and **HSV colour filtering** to identify object boundaries and align the laser to the target's base with minimal manual intervention.

In addition, the system design includes a provision for **real time data transmission** through the **Telegram messaging platform**, enabling users to receive field data remotely. This feature enhances the bot's applicability in areas where direct human access may be limited or unsafe.

Given its modular architecture, sensing capabilities, and proposed communication support, Xypher Bot is well-suited

for applications in **land surveying**, **environmental data collection**, and **autonomous infrastructure monitoring**. The development aims to reduce manual workload, increase precision, and provide a scalable solution for measurement based automation tasks.

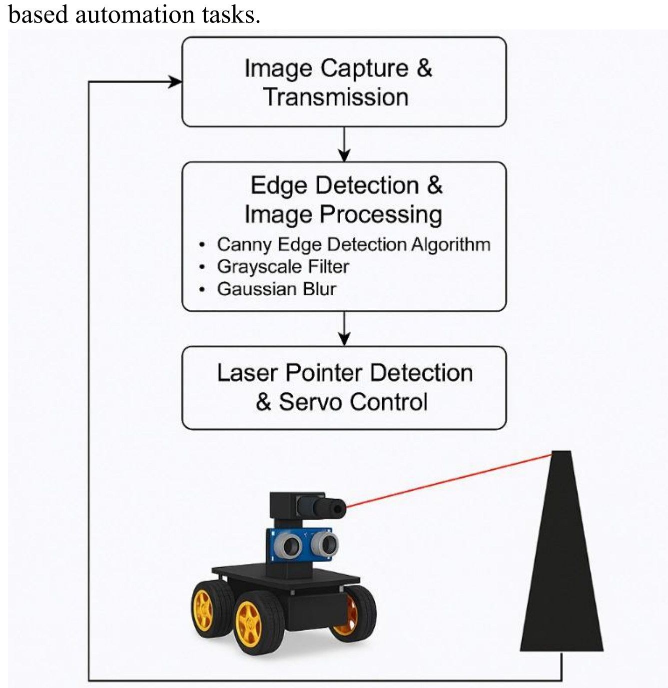

Figure 1: short flow diagram of how Xypher Bot works .

Xypher Bot operates through two main modules: the upper module measures height using MPU6050, ultrasonic sensor, and a laser pointer with trigonometric calculations; the lower module, under development, uses computer vision for edge detection and laser alignment. A Telegram bot is proposed for real-time data updates.

The discussion begins with the motivation and background behind the development of the Xypher Bot. It is followed by an overview of related research and existing technologies in the domain of autonomous surveying. The subsequent sections detail the design methodology, covering hardware components and sensor integration. Experimental procedures and real-world testing outcomes are then analysed. The final section highlights key observations and outlines possible directions for future improvements.

LITERATURE REVIEW

Recent research in autonomous robotics has focused on low cost systems for object detection, measurement, and navigation. Many obstacle-avoiding robots use ultrasonic sensors with microcontrollers like Arduino Uno, achieving effective performance in diverse conditions. These studies show that even single-sensor setups can enable reliable movement and object avoidance [1].

Kumar and Desai (2020) explored combining MPU6050 with ultrasonic sensors to calculate object height using trigonometric methods. While effective, issues like sensor drift highlight the need for proper calibration and filtering [2].

Computer vision techniques such as edge detection, grayscale conversion, and HSV filtering have been applied for object alignment and tracking. Though useful, these methods often struggle with lighting changes and complex backgrounds, limiting real-world use [3][4].

Most prior systems either focus on navigation or measurement—not both. Xypher Bot bridges this gap by integrating affordable sensors with computer vision and real time communication features, offering a multifunctional solution for autonomous field operations.

Existing Technologies in Object Detection & Measurement

Manual Methods: Measuring tapes and theodolites, which are prone to human errors.

LiDAR-Based Systems: High-precision but costly. Computer Vision-Based Techniques: Efficient for detection but lack height estimation capabilities.

Boston Dynamics' Spot with LiDAR — A quadruped robot that uses LiDAR for terrain mapping, structure scanning, and autonomous navigation.

Figure 2: Boston dynamics Spot .

DJI Matrice 300 RTK[U] — [M]A drone with RTK positioning and [P] LiDAR for precise height estimation and mapping.

Objectives and Hypothesis

Objectives:

- To develop a fully autonomous robot capable of measuring object height and estimating distance using low-cost components.
- To implement computer vision techniques for edge detection and laser alignment.
- To ensure accurate and reliable measurements using trigonometric calculations.
- To enable real-time data transmission via Telegram for remote monitoring.

Hypotheses:

- The integration of simple trigonometric logic with low-cost sensors can provide accurate height measurements.
- Computer vision methods can effectively assist in automatic edge detection and laser alignment.
- Real-time data sharing through Telegram can improve usability and field efficiency.

Methodology

Xypher Bot's functionality is divided into two main modules— **height measurement** and **autonomous navigation**. The upper module is equipped with sensors such as the **MPU6050**, **ultrasonic sensor**, and a **laser pointer** to detect the angle and distance of the target object. Using basic **trigonometric calculations**, the system computes the height with precision.

The lower module, currently in the design phase, incorporates **computer vision techniques** such as **edge detection**, **grayscale conversion**, **Gaussian blur**, and **HSV filtering** to detect the edge of objects and align the laser automatically. Data communication is proposed through a **Telegram bot**, allowing real-time updates to the user.

Upper Part (LASER BASED VERTICAL HEIGHT MEASURING ROBOT)

A laser-based vertical height measuring robot is designed to calculate object height using basic sensors and simple geometry. It uses a laser pointer fixed on a servo motor to point at the top of the object, while an MPU6050 sensor measures the tilt angle. At the same time, an ultrasonic sensor calculates the distance from the bot to the base of the object. With the angle and base known, the hypotenuse is found using trigonometric functions. Then, applying the Pythagorean theorem, the robot accurately determines the vertical height.

Working Principle

A laser-based vertical height measuring robot calculates the height of an object using a combination of a laser pointer, an angle sensor (MPU6050), and a distance sensor (ultrasonic sensor).

1. Laser Alignment

- A laser pointer is mounted on a servo motor that tilts vertically.
- The MPU6050 sensor (gyroscope + accelerometer) measures the tilt angle of the laser.
- The laser is manually or automatically aligned to the top (tip) of the object.

2. Measuring the Base Distance

- An ultrasonic sensor measures the horizontal distance (base) from the robot to the bottom of the object.

3. Height Calculation (Using Trigonometry)

- The MPU6050 provides the angle (θ) between the ground and the laser line pointing at the object's tip.
- With this angle and the base distance, the slant (hypotenuse) can be calculated using:
-

$$\cos(\theta) = \text{base} / \text{hypotenuse}$$

$$\Rightarrow \text{hypotenuse} = \text{base} / \cos(\theta) \quad (1)$$

- Then, using the Pythagorean theorem:

$$\text{height}^2 = \text{hypotenuse}^2 - \text{base}^2 \quad (2)$$

- The height (perpendicular from base to tip) is the final result.

4. Output

The perpendicular height, distance of object from the bot and angle are displayed.

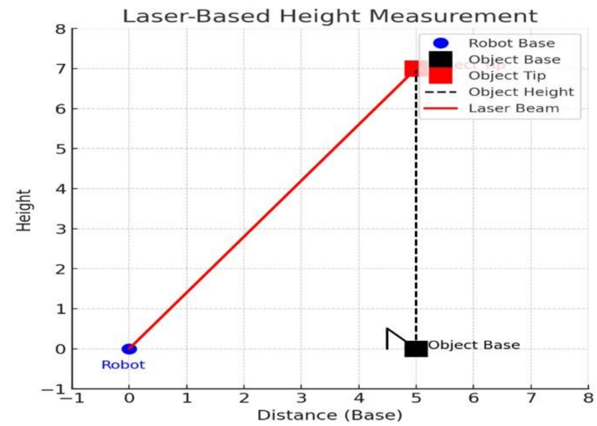

Figure 3: working principle of upper part .

Lower part (Autonomous Robot)

When Xypher Bot spots an object using its ultrasonic sensors, it pauses at a safe distance to get accurate readings. From there, it takes a photo of the object using its built-in camera.

The photo goes through basic image processing—first identifying the edges using the Canny Edge Detection method, then converting the image to grayscale to bring out details. A slight blur is added to cut down any extra noise in the image.

After the edges are clear, the laser pointer is switched on. The system uses colour filtering (HSV thresholding) to spot the red laser dot. It then combines this with the edge data and moves the servo motors to point the laser exactly at the top edge of the object.

Once everything lines up, the bot calculates the height and sends the result along with the images to the user through Telegram. It then moves on to the next object and repeats the same process.

Figure 4: Real Image to Grayscale Image.

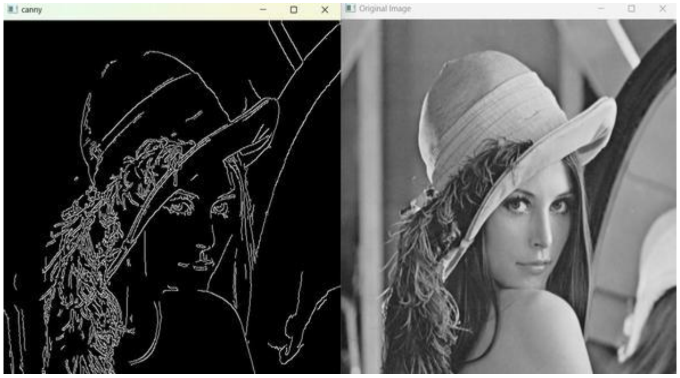

Figure 5: Canny Edge Algorithm .

Xypher Bot = Upper Part + Lower Part (LASER BASED VERTICAL HEIGHT MEASURING ROBOT + AUTONOMOUS VEHICLE)

Experimental setup and current Development

Laser Pointer Adjustment System – Information Flow

The automatic laser alignment system in Xypher Bot is designed to detect an object's edge (specifically the tip) and align a servo-mounted laser pointer to that exact point using a feedback loop. The flow of operations is as follows:

1. Image Acquisition

- A live video feed is captured using a camera module (e.g., Raspberry Pi Camera or USB webcam).
- Each frame is processed in real-time for analysis.

2. Pre-processing

- The captured image is converted to **grayscale** to simplify the data.
- A **Gaussian Blur** is applied to reduce noise and smooth the image.
- The smoothed image is then passed through the **Canny Edge Detection algorithm** to identify object boundaries.

3. Object Tip Detection

- **Contours** are extracted from the edge-detected image using cv2.findContours().
- The **topmost point** (or any specified extreme point) on the detected contour is identified as the target (object tip) for laser alignment.

4. Laser Dot Detection

- Once the laser pointer is turned on, the system applies **HSV (Hue, Saturation, Value)** color space conversion to the original RGB image.
- A **color thresholding** technique is used to isolate the red laser dot.
- The **center coordinates** of the red dot are computed using contour analysis or image moments.

5. Error Calculation

- The system calculates the positional error between the current laser dot position and the target edge tip:

  Error x = x laser – x tip

  Error y = y laser – y tip

  Where:

  X laser , y laser are the coordinates of the laser dot.

  X tip , y tip are the coordinates of the object's edge tip.

6. Servo Adjustment

- Based on the calculated error, corresponding **servo angles** are adjusted to shift the laser pointer.
- A mapping function converts pixel distance into angular displacement.
- The servo continues adjusting until the error is minimized below a defined threshold.

7. Feedback Loop Execution

- The above steps are executed in a continuous loop, forming a **real-time feedback system**.
- Optional techniques like PID control and positional averaging are incorporated to enhance smoothness and accuracy.

Output

- The laser pointer is automatically aligned to the object's edge tip with high precision.
- This system enables intelligent, vision-based pointing which can be extended for object marking, precision measurement, and other surveying tasks.

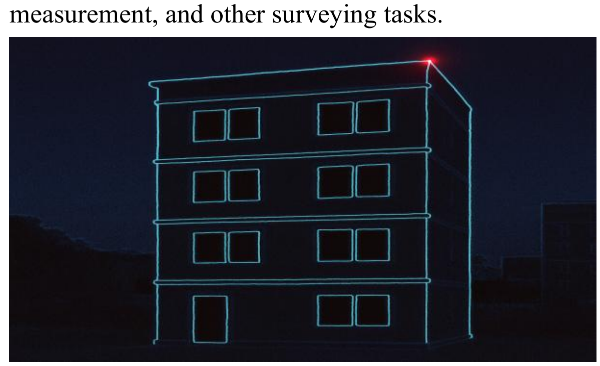

Figure 6: HSV visual.

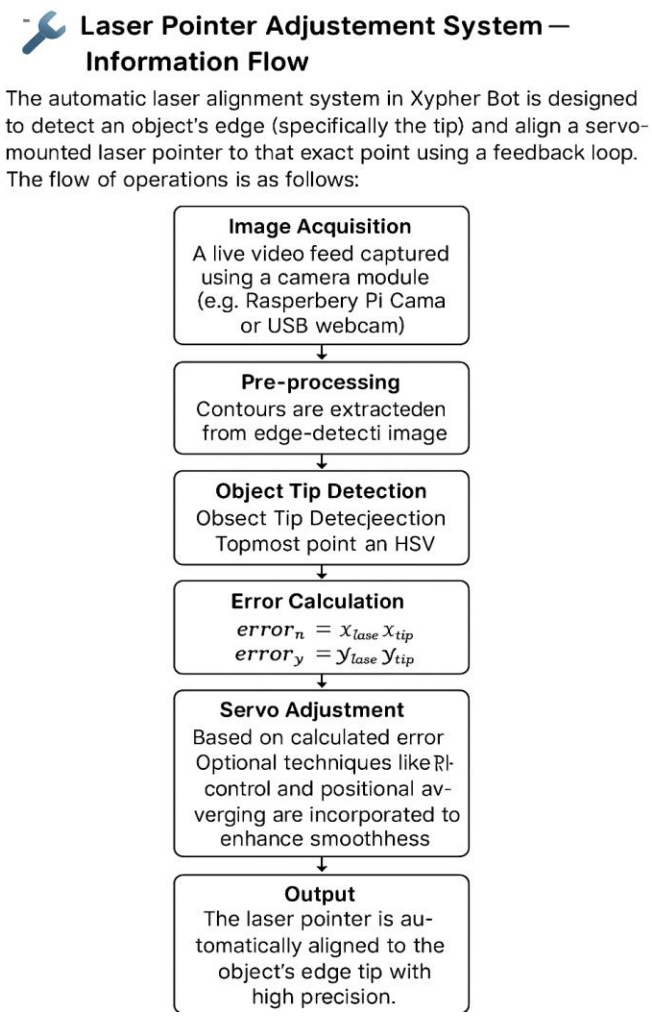

Figure 7 : Flow of Technologies used for adjustment of laser.

System Enhancements and Challenges

1. Mapping and Localization with SLAM

For Xypher Bot to operate autonomously in real-world environments, it is essential to integrate a mapping and localization system. This can be achieved by implementing SLAM (Simultaneous Localization and Mapping). The approach involves using wheel encoders for distance tracking and combining their data with the MPU6050 sensor to reduce positional drift. Additionally, visual odometry using a camera module can help estimate the bot's movement by analyzing frame-to-frame changes.

Lightweight SLAM solutions like RTAB-Map or ORB-SLAM2, which are compatible with Raspberry Pi, are suitable for our setup. These tools allow the robot to generate maps in real time and navigate with better awareness of its surroundings.

2. Error Detection and Recovery

In real-world applications, occasional hardware or detection errors are expected. To address this, several handling mechanisms are planned:

- If the laser fails to align with the object edge after a few attempts, the bot will initiate a scanning routine and notify the user through the Telegram interface.
- If object detection through image processing fails, the bot will slightly adjust its position and try again. After a few retries, an error message will be sent.
- For sensor failures such as disconnection or unstable readings from the ultrasonic sensor or MPU6050, the bot will attempt automatic reinitialization and pause operations until the issue is resolved.

These measures aim to make the system more robust, allowing it to function reliably without constant supervision.

Summary

By incorporating SLAM for intelligent navigation and establishing structured error handling, Xypher Bot moves closer to becoming a dependable, field-ready solution for automated surveying and measurement tasks.

Prototype Progress

The top part of Xypher Bot, which handles height measurement, has been built and tested in a basic setup. It uses the MPU6050 sensor, ultrasonic sensor, and a laser pointer to calculate height. The lower part of the bot, which will take care of movement and object detection, is still being designed.

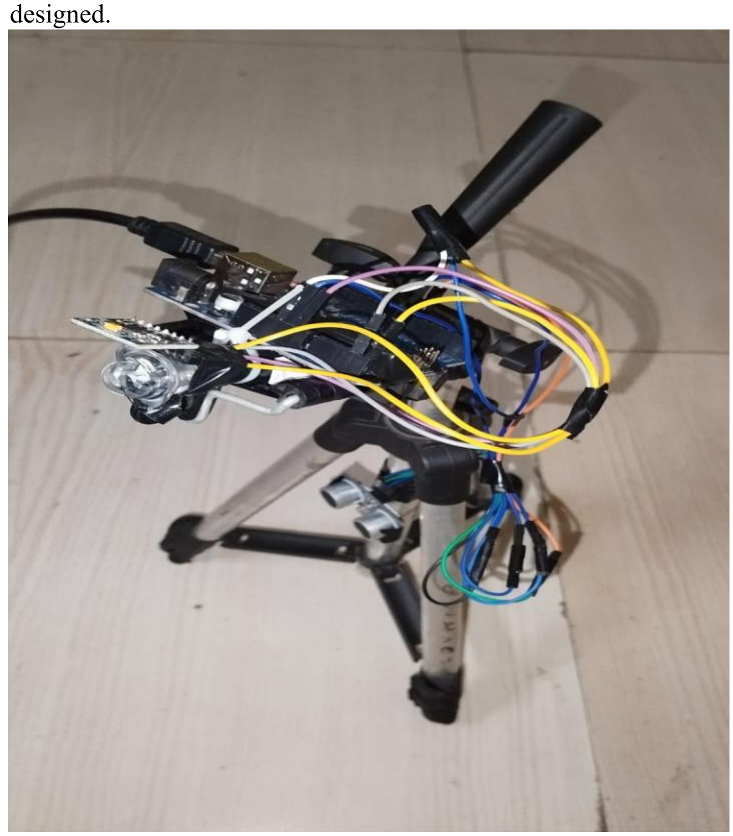

Figure 8: Real Image of working Prototype of Laser Based Vertical Height Measuring Robot.

Testing Status

The full bot hasn't been tested in real-world conditions yet. Final testing will be done once both sections are combined and fully functional.

Problems Faced in upper part (LBVHMR)

- MPU6050 Sensor: Needs proper setup to get accurate angle readings.
- Ultrasonic Sensor**:** Sometimes gives wrong readings, especially on shiny or slanted surfaces.
- Servo Motor: Laser alignment depends on how smoothly and accurately the servo moves.

Justification of technologies that are used

We used grayscale, Gaussian blur, Canny edge detection, and HSV filtering in Xypher Bot because they work well together to give clear and accurate image results. First, the image is converted to grayscale to make it simple. It removes unnecessary colour details and focuses only on brightness, which helps in processing the image faster.

Then, we apply Gaussian blur to reduce small noise or random dots that might confuse the bot. It smooths the image a bit so that the edges become clearer.
After that, Canny edge detection is used to find the boundaries of the object. It highlights where the object starts and ends, which is important for pointing the laser exactly at the edge.

Lastly, we use HSV colour filtering to find the red dot from the laser pointer. HSV makes it easier to detect specific colours like red, even if the lighting in the area changes. All these steps are used because they are reliable and give us good results when detecting objects and aligning the laser

SYSTEM REQUIREMENTS

Hardware Components

The Xypher Bot is developed using a modular hardware setup. The **upper body**, responsible for vertical height measurement, comprises:

- **MPU6050** sensor for tilt angle detection
- **Ultrasonic sensor (HC-SR04)** for distance measurement
- **Laser pointer** aligned using a **servo motor (MG995 metal gear)**

The lower body, designed for autonomous navigation and computer vision, consists of:

- **Raspberry Pi 4** as the processing unit for vision and control
- **Camera module** for capturing images
- **Multiple ultrasonic sensors** for obstacle avoidance
- **BTS7960 motor driver** for controlling **DC geared motors**
- **Chassis, wheels, and power supply modules** for mobility

Additional components include jumper wires, voltage regulators, and power sources such as Li-ion battery packs and power banks.

Software Components

- **Arduino IDE** for microcontroller programming
- **Python** with **OpenCV** and **NumPy** for image processing tasks
- **Raspberry Pi OS** for running the Raspberry Pi unit
- **Telegram Bot API** for real-time communication and data sharing

Figure 9: AI generated sample Image of Xypher bot.

RESULTS

The experimental work has so far been carried out only on the height measurement module (upper body) of the Xypher Bot. The system was tested for its ability to calculate the vertical height of objects using the MPU6050 angle sensor, an ultrasonic distance sensor, and a laser pointer mounted on a servo motor.

Height Measurement Test Results

Tests were performed by setting the laser pointer at various angles and recording the base distance using the ultrasonic sensor. The height was then calculated using trigonometric formulas and the Pythagorean theorem.

Table 1 Represents experimental results of height measurement

Trial	*Angle (°)*	*Base Distance (cm)*	*Hypotenuse (cm)*	*Calculated Height (cm)*
1	30	50	57.73	28.86
2	45	50	70.71	50.00
3	60	50	100.00	86.60
4	75	50	193.19	186.60

These results show that the system can compute height with consistent accuracy when provided with correct input values.
The relationship between angle, base, and height followed expected trigonometric patterns.

Image Processing and Navigation (Conceptual Stage)

The lower body of Xypher Bot, which is designed to handle autonomous navigation and image-based laser alignment, is currently under development. While practical implementation is pending, the conceptual framework has been outlined and initial simulations suggest the following:

- Use of **Canny Edge Detection**, **Grayscale**, **Gaussian Blur**, and **HSV Thresholding** for processing images and identifying object edges and the laser pointer.
- Integration of **ultrasonic sensors** for obstacle detection and maintaining safe distance.
- Planned use of **servo motors** to adjust the laser based on visual feedback.
- Proposal to send processed data and images through
- **Telegram Bot** for remote monitoring.

These features remain in the development phase and have not yet been validated through physical tests.

OBSERVATIONS

- The MPU6050 sensor requires careful calibration before every use for consistent angle readings.
- Ultrasonic readings may fluctuate on reflective or irregular surfaces.
- Laser alignment depends on the servo motor's mechanical stability and precision.
- The current setup shows promise for accurate height measurement in controlled indoor environments.

Full system testing including the navigation and image processing capabilities will be conducted in future stages of development.

DISCUSSIONS

Implications

The upper part of Xypher Bot shows that using simple components like an MPU6050, ultrasonic sensor, and laser pointer can help calculate object height accurately. The ability to send results directly through Telegram makes it useful for tasks where quick, contactless measurements are needed.

Limitations

The lower part of the bot, which involves movement and image processing, is still in the planning phase. The MPU6050 needs proper calibration to avoid incorrect angle readings, and the ultrasonic sensor may not always work well on shiny or uneven surfaces. So far, the setup has only been tried indoors and might need adjustments for outdoor use.
Future work includes outdoor testing with variable lighting, terrain handling, and long-range detection accuracy calibration.

Applications of Xypher Bot

- **Surveying & Mapping**
  - Xypher Bot can measure the height of **buildings, bridges, and landforms** without requiring manual effort.
  - It can assist in **urban planning** by providing accurate elevation data for **mapping and GIS applications**.
- **Forestry & Agriculture**
  - The bot can estimate **tree heights** for **forest management and conservation efforts**. o In agriculture, it can help analyse **crop growth** by measuring plant heights.
- **Environmental Monitoring**
  - Used for tracking changes in **glacier height, sea levels, and water body elevations**.
  - It can assist in **climate change research** by monitoring **terrain shifts** over time.
- **Disaster Response & Damage Assessment**
  - After natural disasters like **earthquakes, floods, or landslides**, Xypher Bot can assess **damaged buildings and wreckage heights**.
  - Helps emergency teams in **rescue operations** by mapping hazardous structures.
- **Architecture & 3D Visualization**

- Helps architects create **accurate 3D models of buildings and structures**.
- Can assist in **renovation projects** by analysing existing structure heights remotely.

- **Historical Preservation**
  - Used for **digitally documenting heritage sites and monuments**.
- Can assist in **restoration projects** by providing precise measurements of old structures.

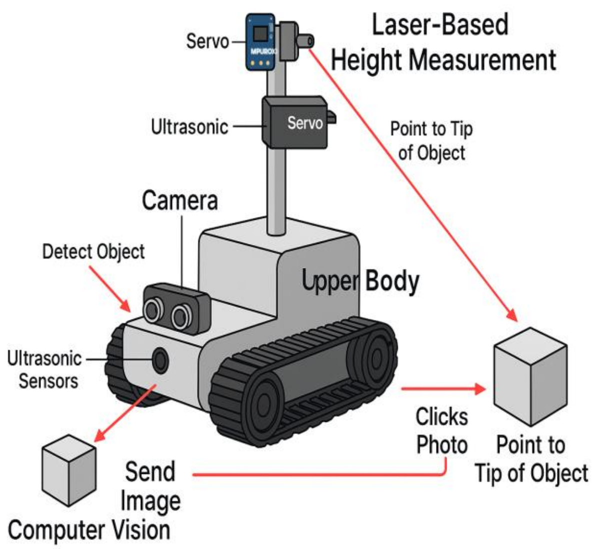

Figure 10:AI generated Sample Image of Xypher Bot

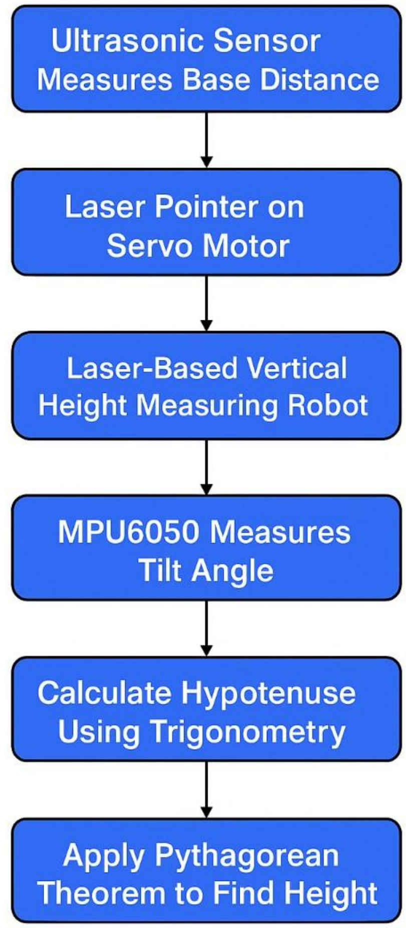

Figure 11: flow chart of working of Xypher bot.

CONCLUSION

Xypher Bot demonstrates a practical and cost-effective approach to measuring object height using an MPU6050 sensor, ultrasonic sensor, and laser pointer. The upper body has been successfully tested, showing accurate results through basic trigonometric calculations.
The lower body, still under development, introduces a concept for autonomous navigation using computer vision and sensor based alignment. This project highlights the potential of low cost components for automated field measurements, with future work focusing on full system integration and improved real time operation.

Xypher Bot isn't just a project—it's a vision.
A vision to turn ideas into impact, and curiosity into creation.
From a gaming-inspired name to real-world applications in surveying, this bot represents how innovation can be born from the most unexpected places.
What started with a basic prototype has grown into a smart, scalable system with real potential in industries like construction, agriculture, and research.

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