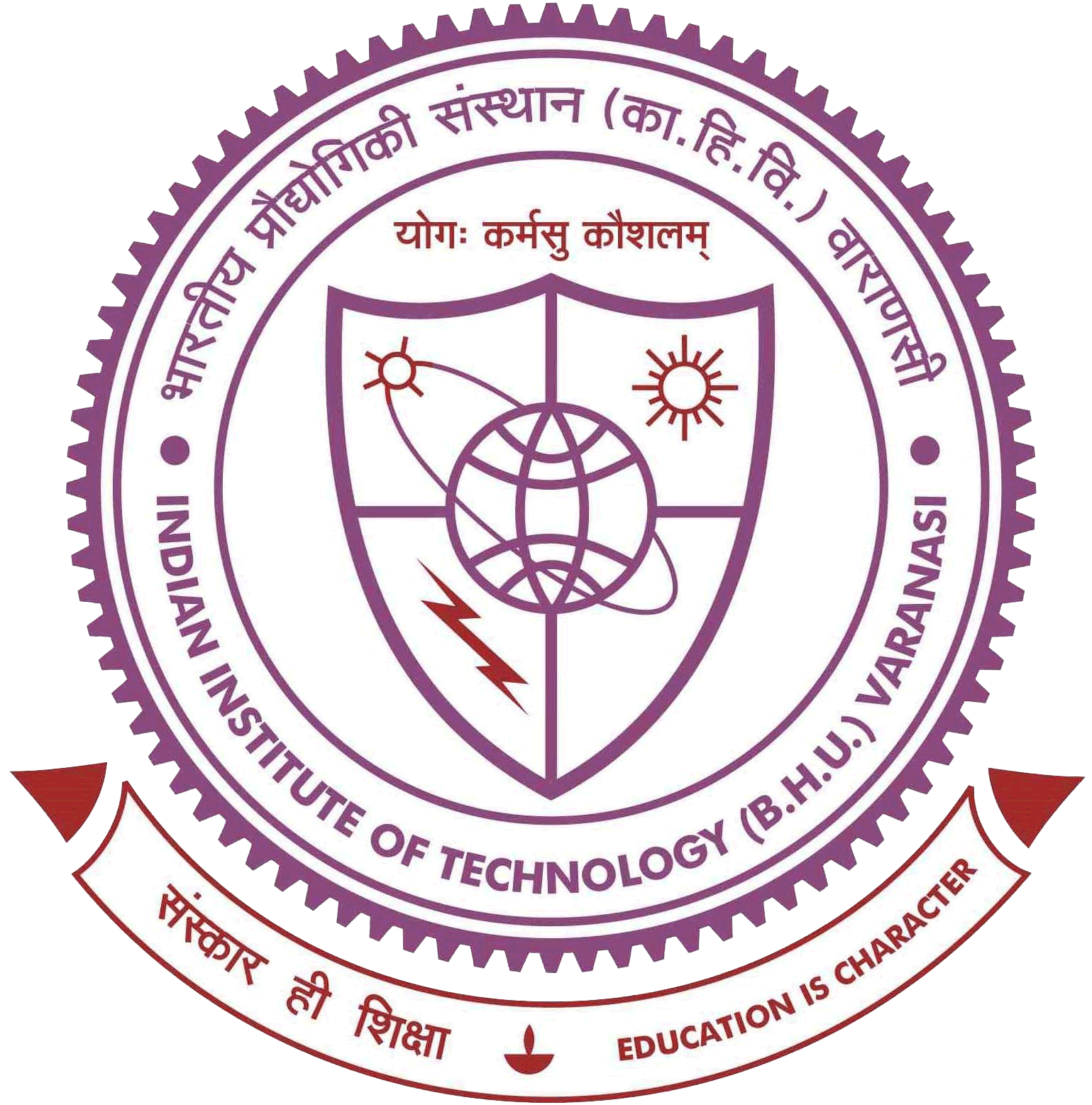
****

**EXPLORATORY PROJECT REPORT**

**Aim:** Use of LiDAR technology for determination of volume and dimensions of the cuboidal object

**Under the supervision of -**

**Dr. Kishor P. Sarawadekar**

(Department Of Electronics Engineering)

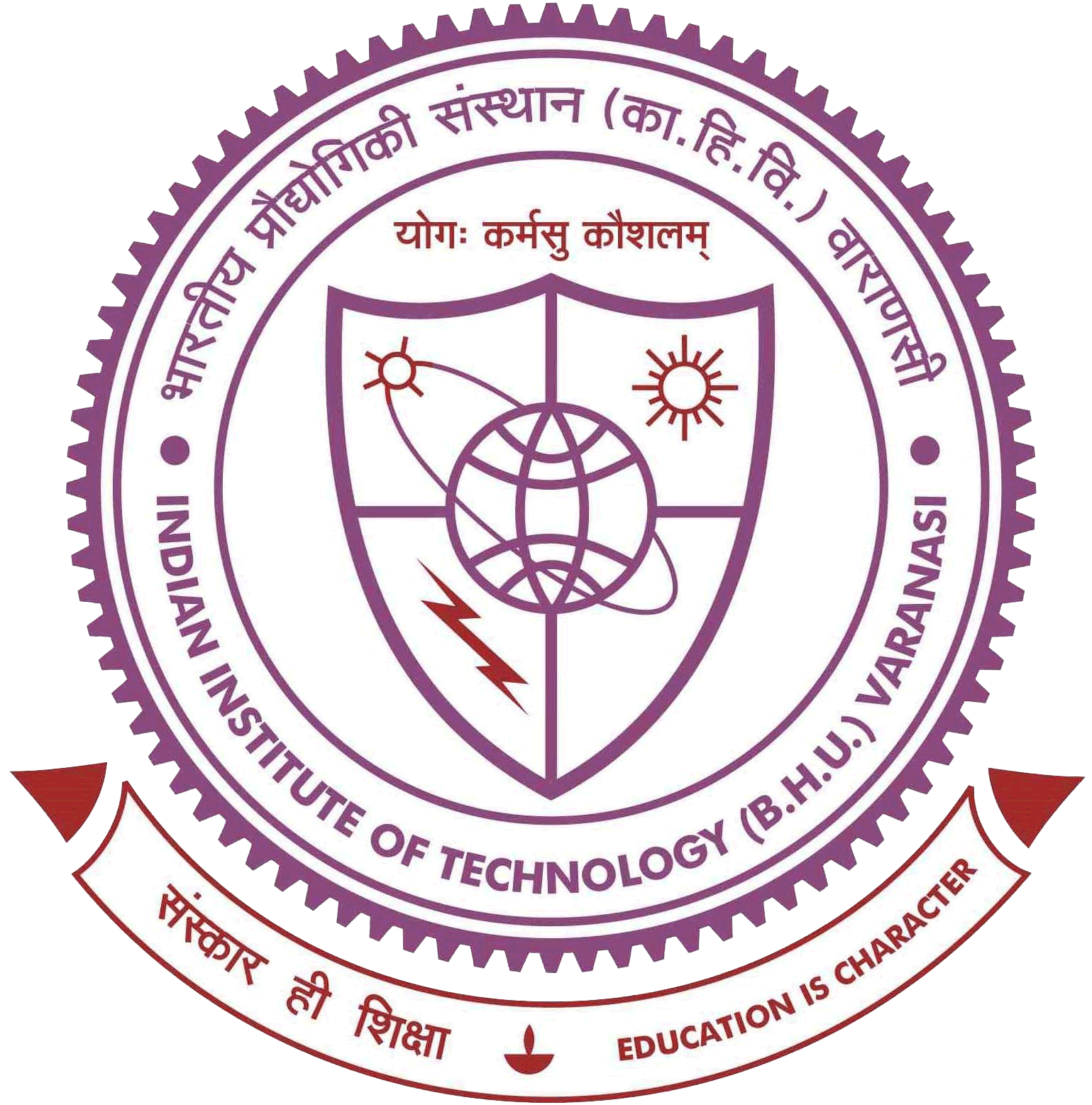
Submitted by :-

Aadarsh Kumar (21095142)

Vaatsalya Sinha (21095123)

Harsh Kumar (21095047)

Sangle Nilesh Ganesh (21095104)

****

Department of Electronics Engineering

IIT (BHU) Varanasi

# CERTIFICATE

This is to certify that this project report ‘Use of LiDAR Technology for Determination of Volume and Dimensions of the Cuboidal Object’ is submitted by Aadarsh Kumar Singh, Harsh Kumar, Vaatsalya Sinha, Sangle Nilesh Ganesh and the Project was carried under the guidance of **Dr. K.P Sarawadekar.** We approve this project for submission of the Exploratory Project IIT (BHU) Varanasi.

**Signature Of Supervisior:**

Dr. K.P. Sarawadekar

Department Of Electronics Engineering

IIT (BHU) Varanasi

# Acknowledgement

I would like to express my sincere gratitude towards all those who have helped me in completing this project successfully. Firstly, I would like to thank my project guide, ***Dr. Kishor P. Sarawadekar***, for providing me with valuable guidance and support throughout the duration of this project. Without his constant support and encouragement, this project would not have been possible.

I would also like to express my gratitude towards the faculty and staff of Electronics Engineering Department for providing me with a conducive environment for learning and for giving me the opportunity to work on this project.

**DATE : 03-05-2023**

Students:

1. Vaatsalya Sinha
2. Aadarsh Kumar
3. Harsh Kumar
4. Sangle Nilesh Ganesh

# INDEX

[**CERTIFICATE 2**](#_l6to72fvln1b)

[**Acknowledgement 3**](#_e719rgv5t15x)

[**INDEX 4**](#_l04gj8ajlmxk)

[**Abstract 5**](#_zhzhlhwz2lc)

[**Problem Statement 6**](#_21eca54iwgv0)

[**Introduction 7**](#_csoyjvwq6q9m)

[**Description of the Problem Statement 8**](#_lk3gjxp49gsd)

[**RP LiDAR 10**](#_wzag779qdo2s)

[**METHODOLOGY 12**](#_xq9oj8mp1z2x)

[**USABLE APPROACHES 13**](#_76a0zjfylyaw)

[**APPROACH 1 14**](#_eijrttlxb0va)

[**APPROACH 2 17**](#_zqq3b8rhtrl)

[**APPROACH 3 21**](#_ik33zbomlcp6)

[**APPROACH 4 24**](#_35kdrnsvbx3r)

[**APPROACH 5 27**](#_fnn1vir11tgo)

[**RESULTS AND ANALYSIS 30**](#_6g9kh5phric7)

[**CONCLUSION 33**](#_y9n2r5foxwjg)

[**REFERENCES 34**](#_l5l51zzt4lu)

**Use of LiDAR technology for determination of volume and dimensions of the cuboid objects**

# Abstract

In this fast-paced world, it is inevitable that the manual labor employed in industries will be replaced by their automated counterparts. There are a number of existing solutions which deal with object dimensions estimation but only a few of them are suitable for deployment in the industry. The reason being the trade-off between the cost, time for processing, accuracy and system complexity. The proposed system aims to automate the mentioned tasks with the help of a 2 D RPLiDAR. The minimal use of equipment makes the system simple, power and time efficient. The proposed system has an average error of around 3% in the dimension estimation.

# 

# Problem Statement

In the logistics systems of Industry 4.0, robots are often used in tandem to transport goods and materials throughout the supply chain. These robots can be programmed to pick up and place objects onto conveyor belts, which then transport them to their destination. However, in order to ensure efficient and safe transportation of objects, it is necessary to measure their dimensions and volume.

Measuring the dimensions and volume of objects is necessary for several reasons. Firstly, it ensures that the objects are loaded correctly and do not get stuck or damaged during transport. Secondly, it helps to optimize the use of space on the conveyor belt and in the warehouse, reducing the number of trips required to move the objects. Lastly, it can help to identify any irregularities or inconsistencies in the shape and size of the objects, which could be indicative of defects or damage.

However, measuring the dimensions and volume of objects can be a challenging task. The key challenge is the need to accurately measure the dimensions and volume of objects in real-time. This requires the use of high-speed sensors and advanced algorithms to process the data in real-time. Addressing these challenges is crucial in ensuring the smooth and efficient operation of logistics systems in Industry 4.0.

# Introduction

Logistics systems are an integral part of the supply chain that ensure timely and efficient delivery of goods from manufacturers to consumers. As global trade continues to grow, there is an ever-increasing need to improve the efficiency of logistics systems. One of the ways this is achieved is through the adoption of new technologies that can streamline processes, reduce costs and improve accuracy.

One such technology is LiDAR. Light Detection and Ranging (LiDAR) technology works by emitting laser beams and measuring the time it takes for the light to bounce back after hitting an object. It has become increasingly popular in recent years due to its ability to accurately measure distances and create 3D maps. LiDAR is primarily used in autonomous vehicles, drones, and mapping applications, but its potential extends beyond these areas.

LiDAR technology has numerous applications in Industry 4.0, the latest phase of industrial revolution which aims to bring automation and data exchange to manufacturing processes and logistics systems. In robotic automation, LiDAR sensors can be used to detect objects, measure their dimensions, and help robots navigate and manipulate objects in their surroundings. LiDAR can also be used in quality control by scanning manufactured parts and detecting any defects.

# Description of the Problem Statement

Efficient warehouse management is critical for an effective supply chain in the world where e-shopping is getting popular. A lot of warehouses even systems today employ manual labor for monotonous jobs like measuring dimensions of objects, scanning codes, etc. These systems are not only slow, but also not as cost effective as their automated counterparts. Also, in a post-Covid world, contact-less delivery will play a major role in warehouse systems, ensuring the safety of the customers. Many E-Commerce and E-Grocer Companies have their sales increased by 100% due to Covid19. There has been a drastic increase in the sales of packed foods, sanitizers and other household things. According to a report an E-Grocer company received 30,000 orders per day due to high requirement. Thus, as the demand rises, compromise in the services takes place. This may include wrong delivery of a product, delay in the shipment. Thus, a system is required that is faster, is contact less and involves fewer manual efforts. 3D reconstruction of objects using 2D images have been a great advancement in the field of computer vision. This can be done to analyze the object without any physical intervention in the process which makes it suitable for fragile objects. 3D reconstruction of objects also makes it easier for computational analysis and extracting the attributes of the object. There are several solutions to solve the mentioned problem of estimating the dimensions of boxes. Each method employs a different set of hardware and different algorithmic process to achieve the same. Some focus extensively on the accuracy of the measurement while some focus on the operational speed and computational time. The power consumption varies based on the hardware employed. Height of a 3-D object can be measured with the help of a RPLiDAR and a camera. This is done with the help of communication channel. Since, there is no estimation of the length and breadth of the objects, this model is not well suited for industrial applications where all the three dimensions of the object are required. The system that we are designing will consist of a single RPLiDAR and a camera module. This system focuses on utilizing as low power as possible because of a smaller number of components and high speed of operation which would be favorable for most of the industrial applications. The trade-off between the accuracy and the speed of operation is well suited for industrial needs.

# RP LiDAR

* RPLIDAR is a laser range scanner that measures distances to objects using a rotating laser and a sensor
* It is produced by RoboPeak and is lightweight, low-cost, and easy to integrate into robotic systems
* RPLIDAR sensors generate 2D point cloud data to create maps of environments or localize robots within a space
* They have a scanning range of up to 18 meters and a sampling rate of up to 10,000 samples per second
* RPLIDAR is used in various robotic applications, such as UAVs, autonomous vehicles, and mobile robots, as well as in industrial automation and smart city projects
* RPLIDAR is compatible with different programming languages and platforms, including ROS, Arduino, Python, and C++.

Fig1. Image Of RPLiDAR - A1

**Properties of 2D RPLiDAR :**

Min Distance: 12cm

Max Distance: Up to 12 meters

760 data points in 360 degrees

Angular Resolution: 0.0082 (1 data point in 0.0082 radians)

Scanning Frequency: 5.5 Hz

Scanning Range: 360 degrees

Motor Speed: 6000 RPM

Height as low as 1mm can be measured but the dimension of the box should be greater than 4cm (the accuracy can be adjusted depending on the overall height of the box)

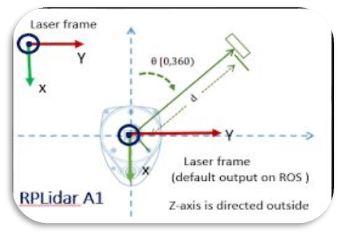


Fig2. Working Of RPLiDAR - A1

# METHODOLOGY

The goal of this project is to develop a system that can accurately measure the volume of a box using RPLiDAR. The system should be able to detect the dimensions of the box using the RPLiDAR sensor and use this information to calculate the volume of the box. The accuracy of the system is crucial, as even small errors in measurement could result in significant discrepancies in the calculated volume. Additionally, the system should be user-friendly and provide easy-to-understand output to the user. The success of this project would provide an efficient and reliable method for determining the volume of boxes in various applications, including inventory management and shipping.

* Here our main concern will be cube/cuboidal shaped objects (of course it can be further extended to a few different regular shapes).
* First we will find the dimensions of the object using just one Lidar.
* Then we will calculate the volume of that object

# USABLE APPROACHES

1.Using two RPLiDAR oriented perpendicular to each other (Stationary and Moving Object)

2. Using one RPLiDAR and a web camera (Stationary and Moving Object)

3.Using one RPLiDAR and a Conveyor belt (Moving Object)

4. Using one RPLiDAR and a Stepper Motor (Stationary and Moving Object)

5. Using one RPLiDAR and a Servo Motor (Stationary and Moving Object)

# APPROACH 1

**Using two RPLiDAR oriented perpendicular to each other**

Here we will use two RPLiDAR which are perpendicularly oriented with each other. One LiDAR oriented in the plane of breadth will give us an array of points from which we can easily calculate two dimensions ie. breadth and height. Other LiDAR oriented in the plane of length will also give us an array of points from which we can easily calculate two dimensions ie. length and height.

Now we have all three dimensions of the object (cuboidal) from which we can easily calculate its volume using the formula of volume of cuboid.

Volume of cuboid = l \* b\* h

**PROCEDURE : --**

1. Position the box where both lidars can see it.
2. Mount one lidar facing one side of the box and the other lidar facing a perpendicular side.
3. Generate 2D point clouds for each lidar, then combine them to create a 3D point cloud of the box's surface.
4. Use a surface reconstruction algorithm to create a 3D model of the box's surface.
5. Calculate the volume of the box using the 3D model.
6. Repeat the process from different angles to ensure accuracy and completeness.

**Advantages of this model :-**

1. Improved accuracy: By using two RPLIDAR, we can capture more data from different angles and directions, resulting in more accurate measurements of the box's dimensions.
2. Faster scanning: Since two RPLIDAR are used simultaneously, the time it takes to scan the entire box is reduced, resulting in faster measurements.
3. Better coverage: With two RPLIDAR, we can cover more area of the box and capture more data, resulting in a more comprehensive and detailed 3D model of the box.
4. Redundancy: In case one RPLIDAR fails or provides inaccurate measurements, the other RPLIDAR can provide a backup, ensuring that the measurements are still reliable and accurate.
5. Flexibility: Using two RPLIDAR provides more flexibility in terms of placement and orientation, allowing for a more customizable setup depending on the specific requirements of the measurement scenario.
6. It can be used for moving as well as stationary objects.

**Disadvantages of this model :-**

1. Cost: Using two RPLIDARs increases the cost of the setup, as an additional RPLIDAR needs to be purchased.
2. Complexity: The setup of two RPLIDARs requires additional hardware and software configuration, which increases the complexity of the system.
3. Calibration: The calibration of two RPLIDARs placed perpendicularly can be challenging, as it requires precise alignment of the two devices to ensure accurate measurements.
4. Limited application: The setup of two RPLIDARs may not be suitable for all volume estimation scenarios, such as measuring irregularly shaped objects, as the placement and orientation of the two devices may not be optimal.
5. Maintenance: Using two RPLIDARs may require additional maintenance compared to using a single device, as both devices need to be kept in good working condition and aligned properly to ensure accurate measurements.

# APPROACH 2

**Using one RPLiDAR and a web camera**

🡺WEB CAMERA :

A webcam is a [video camera](https://en.wikipedia.org/wiki/Video_camera) which is designed to record or stream to a [computer](https://en.wikipedia.org/wiki/Computer) or [computer network](https://en.wikipedia.org/wiki/Computer_network). They are primarily used in [video telephony](https://en.wikipedia.org/wiki/Video_telephony), [live streaming](https://en.wikipedia.org/wiki/Live_streaming) and [social media](https://en.wikipedia.org/wiki/Social_media), and [security](https://en.wikipedia.org/wiki/Closed-circuit_television). Webcams can be built-in computer hardware or [peripheral devices](https://en.wikipedia.org/wiki/Peripheral), and are commonly connected 

*Fig3. web camera*

to a device using [USB](https://en.wikipedia.org/wiki/USB) or [wireless protocols](https://en.wikipedia.org/wiki/Internet_protocol_suite). Web cameras generally give data points in terms of pixels.

Here we will use one RPLiDAR and a web camera. One LiDAR oriented in the plane of breadth will give us an array of points from which we can easily calculate two dimensions i.e. breadth and height. Web camera will give the area of top surface in pixels which later will be converted into meter squared by taking reference with breadth calculated by LiDAR. Some constant k can be defined as

k= (breadth in meter calculated by camera)/(breadth in pixels by LiDAR).

Where K is a pixel to meter ratio

Which will be used to determine the top surface area of the cuboid.

A = (area of top surface(in pixels square))\*k\*k

Now we have all three dimensions of the object (cuboidal) from which we can easily calculate its volume using the formula of volume of cuboid.

Volume of cuboid = A\* h

**PROCEDURE : --**

1. Position the box in the range of camera and LiDAR.
2. Mount LiDAR and camera facing top side of the box.
3. Generate 2D point clouds for lidar and image by camera, then combine them to create a 3D point cloud of the box's surface.
4. Calculate the volume of the box using the taken data.
5. Repeat the process from different angles to ensure accuracy and completeness.

**Advantages of this model :-**

1. Cost: Using one RPLIDAR and one camera relatively decreases the cost of the setup
2. Calibration: The calibration of a RPLIDAR and camera placed facing the top is simple, as it does not require much precise alignment of the two devices to ensure accurate measurements.
3. Wide application: The setup of a RPLIDAR and camera may be suitable for all volume estimation scenarios, such as measuring irregularly shaped objects, as the placement and orientation of the two devices is optimal. But, it will require a good programme to recognize all the shapes.
4. Flexibility: Using a RPLIDAR and camera provides more flexibility in terms of placement and orientation, allowing for a more customisable setup depending on the specific requirements of the measurement scenario.

**Disadvantages of this model :-**

1. Slower scanning: Since one RPLIDAR and one camera are used, the time it takes to scan change the units increments, resulting in slower measurements.
2. Complexity: The setup of one RPLIDAR and camera requires additional hardware and software configuration, which increases the complexity of the system.
3. Redundancy: In case RPLIDAR fails or provides inaccurate measurements, the other measurement provided by camera can not be reliable, Which will make more error.
4. It can be used for stationary objects only.
5. Maintenance: Using a RPLIDAR and camera may require additional maintenance compared to using a single device, as both devices need to be kept in good working condition and aligned properly to ensure accurate measurements.

# APPROACH 3

**Using one RPLiDAR and a Conveyor belt**

Here we will use one RPLiDAR and conveyor belt. One LiDAR oriented in the plane of breadth will give us an array of points from which we can easily calculate two dimensions i.e. breadth and height. The conveyor belt will move at a constant speed and we will find the object's length .

l = (speed of conveyor belt) \* (time taken to transverse the length).

Speed of the conveyor belt is kept constant which is known to us.

Time can be determined with the help of RPLiDAR array points .We will start time when we have an array of varying length and stop it when array points become constant.

Now we have all three dimensions of the object (cuboidal) from which we can easily calculate its volume using the formula of volume of cuboid.

Volume of cuboid = l \* b\* h

**PROCEDURE : --**

1.Position the box in the range of LiDAR.

2.Mount LiDAR facing the top side of the box.

3.Generate 2D point clouds for lidar, then find the length using constant l and real time program.

4.Calculate the volume of the box using the taken data.

**Advantages of this model :-**

1. Cost: Using one RPLIDAR relatively decreases the cost of the setup.
2. It can be efficiently used in industries where conveyor belt are used.
3. It is most suited for transportation ,shipping and warehouses.
4. It will increase the accuracy of volume determination.

**Disadvantages of this model :-**

1. Decreased accuracy: By using one RPLiDAR, we will have less data, resulting in less accurate measurements of the box's dimensions.
2. Slower scanning: Since one RPLIDAR and a conveyor belt are used, the time it takes to scan is equal to (length of object)/(speed of the conveyor belt), resulting in slower measurements.
3. Limited application: The setup of two RPLIDARs may not be suitable for all volume estimation scenarios, such as measuring irregularly shaped objects, as the placement and orientation of the two devices may not be optimal
4. Complexity: The setup of a RPLIDAR and conveyor belt requires additional hardware and software configuration, which increases the complexity of the system.
5. Redundancy: In case RPLIDAR fails or provides inaccurate measurements, which will make more error.
6. It can be used for moving objects only.
7. Maintenance : Using a RPLIDAR and conveyor belt may require additional maintenance compared to using a single device, as both devices need to be kept in good working condition and aligned properly to ensure accurate measurements.

# APPROACH 4

**Using one RPLiDAR and a stepper motor**

Here we will use one RPLiDAR and stepper motor. One LiDAR oriented in the plane of breadth will give us an array of points from which we can easily calculate two dimensions ie. breadth and height. The stepper motor will move at a constant speed and we will find the object's length .

l = (speed of stepper motor) \* (time taken to transverse the length).

Speed of the stepper motor is kept constant which is known to us.

Time can be determined with the help of RPLiDAR array points. We will start time when we have an array of varying length and stop it when array points become constant.

Now we have all three dimensions of the object (cuboidal) from which we can easily calculate its volume using the formula of volume of cuboid.

Volume of cuboid = l \* b\* h

**PROCEDURE : --**

1. Position the box in the range of LiDAR.
2. Mount LiDAR facing the top side of the box.
3. Generate 2D point clouds for LiDAR
4. Then find the length by moving the LiDAR with the help time and motors constant velocity
5. Calculate the volume of the box using the taken data.

**Advantages of this model :-**

1.This method can accurately estimate the volume of both moving and stationary objects, as it simulates real-time measurement by moving the Lidar along the entire length of the object.

2. It simulates getting the volume in real-time.

**Disadvantages of this model :-**

1. This method works for stationary objects only.
2. The cost increases as a stepper motor is needed to move the Lidar along the length of the object.
3. Height of the Lidar needs to be fixed, limiting accuracy to smaller boxes or larger boxes with potential accuracy loss.
4. Constantly moving parts can be prone to corrosion and friction, making maintenance difficult in industrial settings.
5. Slower scanning: Since one RPLIDAR and a stepper motor is used, the time it takes to scan is equal to (length of object)/(speed of the stepper motor), resulting in slower measurements.
6. Complexity: The setup of a RPLIDAR and stepper motor requires additional hardware and software configuration, which increases the complexity of the system.
7. Maintenance: Using a RPLIDAR and stepper motor may require additional maintenance compared to using a single device, as both devices need to be kept in good working condition and aligned properly to ensure accurate measurements.

# APPROACH 5

**Using one RPLiDAR and a Servo Motor**

By rotating the Lidar, we can achieve a similar result as having two perpendicularly oriented Lidars. Additionally, the system will have a height adjustment mechanism using stepper motors, allowing us to adjust the accuracy for different sizes of boxes by moving the Lidar along the height instead of the length.

This method requires scanning the object twice as we need to get data points in two planes by rotating the lidar by 90 degrees.

However This method also gives us the flexibility of rotating the lidar in a complete 180 degree, thus enabling us to get the data points in many different orientations which can be used in future for detecting the dimensions of irregular objects.

**SERVO MOTOR :**

A **servo motor** is a type of motor that can rotate with great precision. Normally this type of motor consists of a control circuit that provides feedback on the current position of the motor shaft, this feedback allows the servo motors to rotate with great precision. If you want to rotate an object at some specific angles or distance, then you use a servo motor. It is just made up of a simple motor which runs through a **servo mechanism**. For this tutorial, we will be discussing only about the **DC servo motor working**. Apart from these major classifications, there are many other types of servo motors based on the type of gear arrangement and operating characteristics. A servo motor usually comes with a gear arrangement that allows us to get a very high torque servo motor in small and lightweight packages. Due to these features, they are being used in many applications like toy car, RC helicopters and planes, Robotics, etc.



Fig3 : Servo Motor

**Volume of cuboid = l \* b\* h**

**Advantages of This Model :**

* We can measure the volume of object in almost real time.
* We can adjust the resolution of the lidar and its accuracy.
* Less moving parts, less wear and tear in the moving parts.
* Has the potential to calculate the volume of irregular shapes with further optimization.

**Disadvantages of This Model:**

* Lidar is rotating so there are some moving parts.
* Few extra sensors, motors etc. increases the cost.
* Using a Lidar along with a lot of motors and sensors becomes a bit more complex and resource intensive
* Rotating Lidar by exactly 90 degrees is a challenging task failure which will cause errors.

# RESULTS AND ANALYSIS

**A. Existing Methodologies**

Some of the existing methodologies are compared with ours to analyze the pros and cons of each one. There are some methodologies that employ multiple lasers and cameras or cameras with depth sensors, etc. Some measure the length of the objects based on how fast they are moving. Some of them only calculate a single dimension of the objects. Comments on existing methodology,

1) This methodology uses laser triangulation and deep learning methods for dimension estimation. Two cam- eras and four lasers are required for the process. It produces very accurate results but the processing is very costly, leading to slower operations.

2) This methodology measures only the height of the object. The shape of the deflected laser is considered so it can be used for curved surfaces as well. The camera error is not accounted for. This methodology uses only one camera and laser.

3) This method uses the laser triangulation principle for height estimation. Only height of the object is calculated using this method. Camera error is not accounted for which leads to higher error. This methodology uses only one camera and laser.

4) To measure the height of the object, a camera with depth sensor is used. As the objects move over a conveyor belt (with known speed), the time that an object takes to cross the depth sensor is used to measure the length of the object. The error in the measurements is low. The error will depend upon the speed of the conveyor belt and the speed of the camera.

**B. Results of the Proposed Methodology**

After whole analysis of all five approaches to calculate the all the three dimensions of a cuboidal objects we conclude that the **APPROACH 5** was best. This is because it can be used to calculate the dimensions of a stationary as well as moving object (like conveyor belt).

**Possible Improvement:** Further the accuracy can be adjusted based on the object dimension with a stepper motor.

**Stepper Motor :**

* The stepper motor converts a pulsing electrical current, controlled by a stepper motor drive, into precise one-step movements of this gear-like toothed component around a central shaft.  It has high inner hole accuracy, stable and accurate speed in the working process without losing step. The motor has high overall stability, even speed and low noise.



Fig4. Stepper Motor

In this approach first RPLiDAR is placed in the plane of breadth which will give us an array of points from which we can easily abstract the two dimension height and breadth. Now to get the third dimension we will rotate the plane of LiDAR by 90 degrees using a servo motor. In this orientation we will get an array of points from which we can abstract two dimension height and length. Combining data from both the datasets, we will get all the three dimensions of the cuboid from which we can get the volume by using the volume formula of the cuboid.

The proposed methodology was tested to calculate the dimensions of cuboidal boxes.

# CONCLUSION

The proposed system can be used to estimate the dimensions of the objects very swiftly and with minimal components as compared to other methods. The precision and speed of this methodology are well suited for industrial needs. To minimize the errors that happen due to lighting conditions, the system can be enclosed in a casing with internal lighting. This system can also be integrated with an IOT based system to create a real time object tracking system. It can be easily integrated with any other automation system that makes use of object dimensions for efficient stacking of objects. Since the process of calculating the dimensions is contact-less it can be used to calculate the dimensions of fragile objects. This system will have high importance even in the post-covid world where contact-less operations are of key importance.

TEAM MEMBER 1 :\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

TEAM MEMBER 2 :\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

TEAM MEMBER 3 :\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

TEAM MEMBER 4 :\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Under The Supervision of

***Dr. K.P Sarawadekar :***\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

# REFERENCES

* http://wiki.ros.org/rplidar
* https://en.m.wikipedia.org/wiki/Stepper\_motor
* https://www.slamtec.ai/home/rplidar\_a2/?gclid=CjwKCAjwjMiiBhA4EiwAZe6jQxricsqxXxFlrHnC5NIMfLhEKFfau3ZYW3U0MpwgV6VRH6HRFMf\_hhoCPJUQAvD\_BwE
* https://circuitdigest.com/article/servo-motor-working-and-basics
* https://en.m.wikipedia.org/wiki/Webcam
* LiDAR: Range-Resolved Optical Remote Sensing of the Atmosphere" by Claus Weitkamp
* "LiDAR Remote Sensing and Applications" by Pinliang Dong and Qi Chen
* Warehouse Management: A Complete Guide to Improving Efficiency and Minimizing Costs in the Modern Warehouse (3e) By Gwynne Richards
* http://wiki.ros.org/Motor%20Controller%20Drivers
* http://wiki.ros.org/usb\_cam
* http://wiki.ros.org/video\_stream\_opencv
* https://en.wikipedia.org/wiki/Robot\_Operating\_System
* https://www.slamtec.ai/home/rplidar\_a1
* http://wiki.ros.org/Documentation
* http://wiki.ros.org/noetic/Ubuntu