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# DEVELOPMENT OF LOW-COST 3D MAPPING SYSTEM OF INTERIOR SPACES WITH 360° LIDAR

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**ABSTRACT:** This research develops a three-dimensional (3D) scanning system based on a 2D LiDAR sensor, namely RPLiDAR A2, which is modified into a 3D system using servo motors and Arduino Nano. This system is designed as a low-cost solution for interior 3D design mapping, the method used is HW/SW co-design, which integrates hardware and software into one unit. The communication flow utilizes data conversion from polar to cartesian coordinates and PointCloud2 representation within the Robot Operating System (ROS) environment. The 3D model reconstruction process was performed using the Alpha Shapes algorithm from the Open3D library, generating a surface mesh from the point cloud data. Visual results show that the system is able to capture the general geometry of the object with a success rate of 65-75%, although there are still some limitations such as point density, normal estimation, and lack of color information. This research reinforces previous theories and findings regarding the effectiveness of LiDAR technology in 3D mapping and demonstrates that the innovative transformation of 2D to 3D LiDAR functions can produce an economical and reasonably accurate mapping system. The prototype 3D scanning system can be applied in various fields such as building interior mapping which is useful in renovation planning or room layout planning. The limitations found open up further development opportunities, particularly on improving the quality of point cloud data and the efficiency of the meshing process for practical applications and more realistic visualization.

**Keywords** - LiDAR, ROS, 3D, Point Clouds, Low-Cost Mapping

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## 1. INTRODUCTION

The world is currently facing an unprecedented wave of urbanization in history, with more than half of the global population now living in both large and small cities. This rapid urban growth, coupled with the limited availability of land in urban areas, compels societies to make optimal use of space (Mulyana and Pratiwi, 2024) [1]. The need for optimal space utilization is increasingly pressing, both for redecorating and rearranging furniture, and for creating space amidst land constraints (Parent et al., 2021) [2]. Room mapping is the process of creating a two-dimensional or three-dimensional graphical representation of a room, which provides detailed information about its size, shape, and the elements within it (Chan et al., 2021) [3]. In this room mapping, manual measurements are still often performed. Visual data acquisition of a building has evolved towards utilizing technology through 3D scanning, one example being the use of LiDAR sensors for capturing existing building data for documentation purposes. The importance of data or information about existing buildings is now no longer limited to a two-dimensional (2D) format. The demand for information in three-dimensional (3D) form is increasing to make it easier for users to understand the physical condition of a space, the changes that occur, and to enable more realistic interaction with the designed space. Three-dimensional documentation techniques can record objects more comprehensively and objectively compared to 2D mapping methods. However, to date, the process of scanning physical space information in 3D is still considered complex and requires special expertise, thus the associated costs are relatively high (Dewi & Putra, 2023) [4].

The RPLiDAR sensor is a two-dimensional (2D) device that utilizes laser technology to detect surrounding objects. This system design adopts ROS (Robot Operating System) as a framework for inter-process communication. Structurally, the system is divided into several main modules: mapping, localization, path planning, navigation, and obstacle avoidance. To achieve simultaneous mapping and localization, the SLAM (Simultaneous Localization and Mapping) algorithm is implemented. The mapping module is responsible for recording the characteristics of the robot's surrounding environment and archiving this laser detection data in a digital map representation (Louise et al., 2023) [5]. In its utilization, RP LiDAR is used as a two-dimensional device, while in this research, the reading or mapping is changed from two dimensions to three dimensions (3D). In particular, the 3D point cloud acquisition method that combines two-dimensional (2D) LiDAR with a pan-tilt unit and the approach of integrating a monocular camera for low-cost indoor color map construction has gradually gained attention as a prominent research field. These methods mainly extend 2D LiDAR data into 3D point clouds through mechanical motion driven by a stepper motor or through a multi-sensor fusion strategy, thereby effectively reducing the cost of data acquisition. In this approach, the LiDAR is rotated or tilted along an axis perpendicular to the scanning direction to achieve continuous rotation of the scanning plane, effectively covering the entire 3D space.

Comparison between previous products and this innovation shows significant differences in the technology used, data accuracy, cost, mapping efficiency, and ease of use. Previous products still rely on manual methods and 3D scanning-based mapping technology with LiDAR sensors to document buildings. Although 3D documentation provides more accurate results than 2D, the process is still complicated, requires special expertise, and is quite expensive. In addition, manual mapping requires more time and effort in the process of measuring and mapping space. As an innovation, the new system uses a 2D RPLiDAR sensor with a 3D point cloud acquisition method developed through the SLAM approach and monocular camera integration. This technology enables simultaneous mapping and localization at a lower cost than conventional methods. With a 2D LiDAR-based approach enhanced to 3D through mechanical movement using a stepper motor and a multi-sensor fusion strategy, this system can expand the scanning coverage more effectively.

This study aims to develop a 3D mapping system based on 2D LiDAR sensors with a point cloud approach to produce a more accurate and comprehensive representation of space. In addition, this study integrates the SLAM method to improve the efficiency of room mapping, optimizes the cost of 3D data acquisition through the use of stepper motor-based pan-tilt units, and develops a ROS-based system so that communication between processes in LiDAR sensor data processing becomes more efficient. Finally, this study will also analyze the differences in mapping results between conventional methods and the proposed innovation in terms of accuracy, time efficiency, and implementation costs. With this innovation, it is expected that 3D spatial mapping can be done more easily, quickly, and at a lower cost compared to the previous conventional scanning method.

## 2. RESEARCH OBJECTIVES

2.1 Develop capabilities in research and development of 3D mapping technology with a focus on cost efficiency and accuracy.

2.2 Assist industry partners in utilizing more affordable 3D mapping technology for various commercial and operational applications.

2.3 Provide 3D mapping solutions that are more accessible and applicable to various sectors, including education and small businesses.

## 3. LITERATURE REVIEW

**Table 1.** Latest Research Related to LiDAR Use

| Author | Year | Definition |
|---|---|---|
| Staffas et al. [6] | 2022 | 3D LiDAR, or Light Detection and Ranging, is an advanced imaging technique that uses laser pulses to create a three-dimensiona representation of an environment, achieving high precision through the use of superconducting nanowire single-photon detectors (SNSPD) fo enhanced detection capabilities. |
| Chan et al. [3] | 2021 | The LiDAR odometry and mapping (LOAM) method is one of the firs LiDAR-based 3D SLAM methods to achieve the best results in real time. |
| Lu et al. [7] | 2025 | 3D-UMamba is a U-Net-based deep learning model with a Selective State Space Model (Mamba) for multi-source LiDAR data semanti segmentation, offering higher efficiency than its transform. This mode was tested on Multispectral LiDAR (MS-LiDAR) for vegetation mapping Aerial LiDAR (DALES) for urban mapping, and Vehicle-mounted LiDAI (Toronto-3D) for road mapping. Although accurate and efficient, 3D UMamba still has limitations in tokenisation, small object detection, an complex environments. |
| Mulyana & Pratiwi [1] | 2024 | The use of LiDAR sensors in this study proved to produce highly accurat data, with a measurement difference of only about 0.2% compared to th actual size. This shows that LiDAR is a reliable tool for room mapping especially in environments that require high precision. |

3D LiDAR, or Light Detection and Ranging, is an advanced imaging technique that uses laser pulses to create a three-dimensional representation of an environment, achieving high precision through the use of single-photon detectors made of superconducting nanowires (SNSPD) for enhanced detection capabilities (Staffas et al., 2022) [6]. Additionally, the LiDAR odometry and mapping (LOAM) method is one of the first LiDAR-based 3D SLAM methods to achieve the best results in real-time (Chan et al., 2021) [3]. Furthermore, 3D-UMamba is a deep learning model based on U-Net with a Selective State Space Model (Mamba) for semantic segmentation of multi-source LiDAR data, offering higher efficiency compared to its transformer. This model was tested on Multispectral LiDAR (MS-LiDAR) for vegetation mapping, Aerial LiDAR (DALES) for urban mapping, and Vehicle-mounted LiDAR (Toronto-3D) for road mapping. Although accurate and efficient, 3D-UMamba still has limitations in tokenisation, small object detection, and complex environments (Lu et al., 2025) [7].

The use of LiDAR sensors in research by (Mulyana & Pratiwi, 2024) [1] has been proven to produce highly accurate data, with measurement differences of only around 0.2% compared to actual measurements. This demonstrates that LiDAR is a reliable tool for room mapping, especially in environments that require high precision. Overall, this research makes a significant contribution to the understanding and development of indoor mapping technology using LiDAR. These findings not only confirm LiDAR's advantages in terms of accuracy and efficiency but also pave the way for further innovation in integrating LiDAR technology with other smart systems.

**Table 2.** Latest Research Related to the Drivers Used

| Author | Year | Definition |
|---|---|---|
| Winardi et al. [8] | 2022 | Arduino Nano is a small microcontroller capable of controlling various types of sensors and motors, making it ideal for controlling the movement of servo motors in a 360-degree scanning process. With servo motors, we can accurately control the position of the LiDAR sensor, enabling more comprehensive data collection across the entire area. |
| Krsmanović et al. [9] | 2022 | The Arduino Nano acts as a control unit, regulating the servo motor that rotates the LiDAR, enabling room scanning. |
| Yan et al. [10] | 2023 | The rotating servo motor mechanism enables 360-degree scanning, improving efficiency and accuracy in data collection. |
| Chan et al. [3] | 2021 | Jetson modules, such as NVIDIA Jetson Nano, have become essential in processing the large amounts of data generated by LiDAR sensors. These modules offer excellent computing power in a small, energy-efficient form factor, making them ideal for real-time 3D mapping applications. In one study, Jetson modules were used to process point cloud data and perform localisation and mapping simultaneously indoors. |
| Li et al. [11] | 2024 | The use of the Jetson platform enables real-time processing and mapping, as demonstrated by the system that utilises iterative nearest-neighbour algorithms and particle filters to optimise global positioning. |

The development of room scanning systems, particularly those involving LiDAR technology, demonstrates the integration of various components to achieve optimal functionality. One important component is a microcontroller such as the Arduino Nano, which functions to control various types of sensors and motors. The Arduino Nano is well suited for controlling the movement of servo motors in the 360-degree scanning process (Winardi et al., 2022) [8]. The role of the Arduino Nano as a control unit is also emphasised by (Krsmanović et al., 2022) [9], who state that the Arduino Nano controls the servo motor to rotate the LiDAR, thereby enabling scanning of the surrounding environment. This rotating servo motor mechanism enables 360-degree scanning, which in turn improves the efficiency and accuracy of data collection (Yan et al., 2023) [10].

The increasing demand for more advanced data processing has made computing modules such as the NVIDIA Jetson Nano increasingly essential**.** The Jetson modules have become crucial in handling the vast amounts of data generated by LiDAR sensors (Chan et al., 2021) [3]. These modules offer excellent computational capabilities in a compact and energy-efficient form, making them ideal for real-time 3D mapping applications. In one study, a Jetson module was employed to process point cloud data and perform simultaneous localization and mapping (SLAM) in indoor environments (Chan et al., 2021) [3]. Further utilization of the Jetson platform enables real-time processing and mapping, as demonstrated by systems that incorporate iterative closest point (ICP) algorithms and particle filters to optimize global positioning (Li et al., 2024) [11].

**Table 3.** Recent Research on the Software Utilized

| Author | Year | Definition |
|---|---|---|
| Mulyana & Pratiwi [1] | 2024 | 3D room data visualization has been implemented by an Apple-developed tool called RoomPlan, which can be developed intc applications for the iPad and iPhone, making it compatible with iOS users. |
| Mulyanto *et al.* [12] | 2020 | The Robot Operating System (ROS) provides a flexible framework foı developing robot software. ROS enables the design of modular anc parallelized systems, supporting scalable and efficient development The resulting data can be visualized using RViz. |
| Basavanna & Shivakumaı [13] | 2020 | RViz is a visualization tool for ROS applications. It receives data fron laser scanners and renders the incoming information in visual form In this study, RViz is used to display the environmental map. |
| Li *et al*. [11] | 2024 | Python is used as the primary programming tool for creating, testing and comparing point cloud registration in indoor 3D mapping experiments. |
| Dalaney *et al.* [14] | 2022 | Autodesk Fusion 360 has been developed to support product desigr and engineering with a focus on sustainability. |
| Li *et al.* [11] | 2024 | Open3D is used to efficiently execute and compare point clouc alignment methods in Python. It enables testing and visualization of 3D data necessary for map construction. |

The processing and visualization of 3D room modeling data from LiDAR has been carried out using one tool available to iOS users, namely Apple RoomPlan. *Apple RoomPlan* is a framework based on ARKit developed by Apple for automatic room modeling. When combined with LiDAR sensors on iOS-based devices, such as the iPad Pro, it delivers accurate 3D visualizations in real time. *RoomPlan* is capable of capturing spatial room details quickly. However, the limitation of *RoomPlan* is that it is only available to iOS users and its scanning performance depends heavily on good lighting conditions (Mulyana & Pratiwi, 2024) [1].

The Robot Operating System (ROS) can serve as a highly adaptable system for developing robotic software. ROS enables the planning of modular and parallelized system architectures. It is useful for managing the synchronization of data between cameras and 2D LiDAR sensors for object detection and distance measurement. The data is then processed in parallel through separate nodes within ROS, producing data fusion that can be visualized in RViz to facilitate real-time system monitoring and validation (Mulyanto *et al.*, 2020) [12].

RViz is a visualization tool for ROS applications. It receives information from laser scanners and renders the incoming data in a graphical format. In this study, RViz is used to display the resulting environmental map. Visualization through RViz allows users to view scan data from 2D LiDAR sensors in graphical form. SLAM (Simultaneous Localization and Mapping) processes can be verified, ensuring accurate environmental mapping by the sensor through RViz (Basavanna & Shivakumar, 2020) [13].

Python and C++ programming languages are used to handle tasks requiring high performance and real-time processing, such as point cloud data processing, sensor control, and integration with ROS (using C++). Python is particularly useful for rapid prototyping, scripting, and integration with various visualization and data processing libraries (e.g., Open3D). This combination of languages provides an efficient balance between data acquisition accuracy and development convenience. In this study, the researchers constructed a colored 3D indoor map by merging multiple scan points to produce a map that is accurate, detailed, and applicable to various domains such as robot navigation and facility management.

Python is employed as the primary programming language to develop, test, and compare point cloud registration methods in indoor 3D mapping experiments. Open3D is utilized to efficiently run and evaluate point cloud alignment methods within Python. It supports the testing and visualization of 3D data necessary for map generation (Li et al., 2024) [11].

Autodesk Fusion 360 has been developed to assist in product and engineering design with a sustainability-oriented approach. Its collaborative capabilities are considered to accelerate design iteration processes with reduced digital and physical waste. Compared to conventional tools, Autodesk Fusion 360 offers enhanced efficiency in functional integration, decision-making, and sustainability-driven, data-based workflows (Dalaney et al., 2022) [14].

## 4. METHOD

The methodology employed in this project for developing a low-cost, interior 3D mapping system with a 360° LiDAR is a Hardware/Software (HW/SW) co-design approach. This embedded systems engineering strategy involves the simultaneous development of both hardware and software components to achieve optimal system functionality.

### 4.1 Time and Place of Research

The research on the development of a low-cost 3D mapping system for interior spaces using a LiDAR A2 360° was conducted from February to June 2025 at the Electronics and Instrumentation Physics Laboratory of Sebelas Maret University and CV. Enuma Technology.

### 4.2 Research Equipment and Materials

The hardware configuration for this low-cost 3D mapping system comprises several core and ancillary components. A digital servo, governed by an Arduino Nano, dictates the vertical articulation of the RPLiDAR A2 sensor. The Jetson Nano serves as the central processing unit, tasked with managing the influx of sensor data, executing the mapping algorithms, and interfacing with the Arduino. Ancillary components are in place to ensure system integrity; these include a 12V fan for the thermal regulation of the Jetson, as well as the necessary jumper wires (male-to-male, female-to-female, and male-to-female) to facilitate device integration. Furthermore, the system is powered by an external adapter, and the components are housed within a custom enclosure fabricated from 3D printing filament.

## 4.3 Research Procedure

### 4.3.1. Hw sw co design

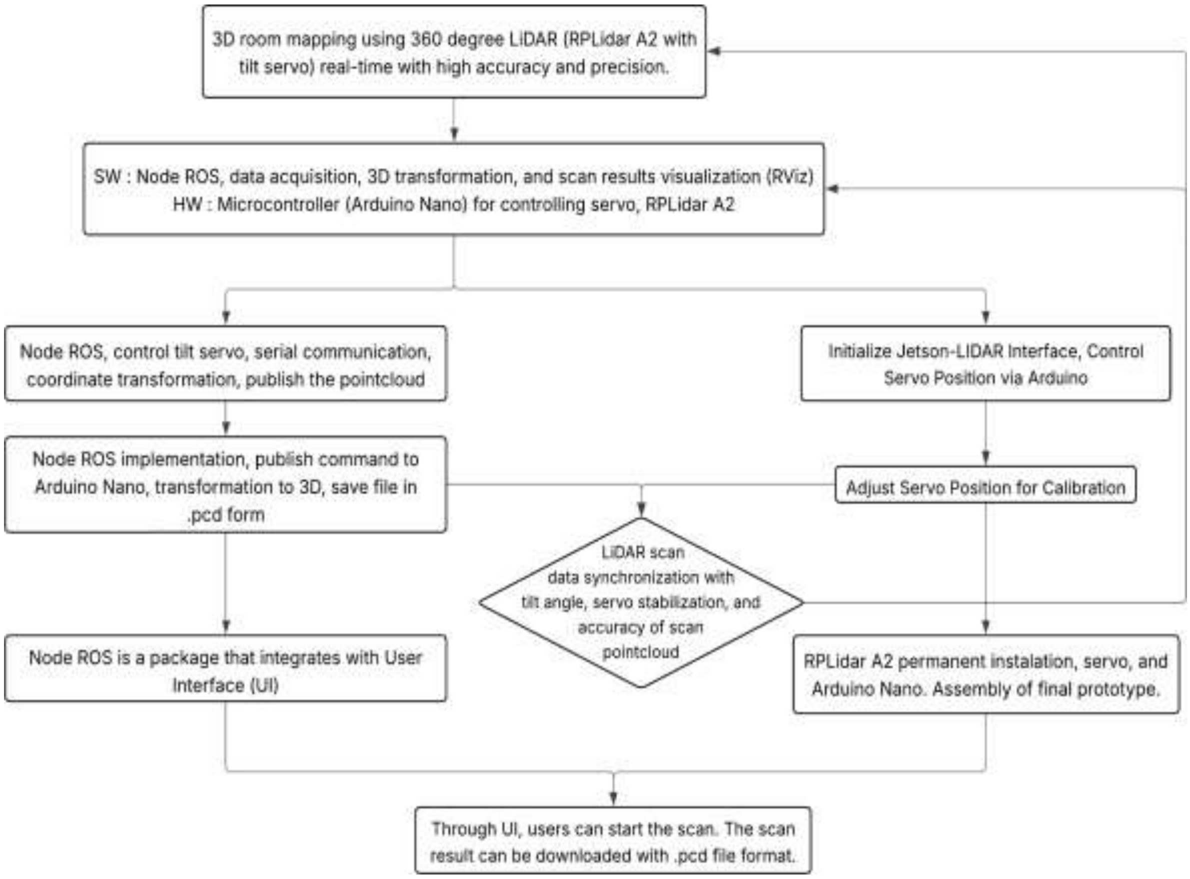



Fig. 1 HW/SW Co diagram

This system is based on a Hardware/Software Codesign approach to construct a 3D Scanner by augmenting the capabilities of the Slamtec RPLiDAR A2 2D LiDAR sensor. To overcome the limitation of scanning on a single horizontal plane, the sensor is integrated with a vertical motion mechanism controlled by a precision servo motor, enabling it to perform scans at various tilt angles. The entire system management, from hardware orchestration to data processing, is implemented within the Robot Operating System (ROS) framework. The workflow is initiated by a main ROS node that first sends a target vertical tilt angle command to an Arduino microcontroller via serial communication. Once the Arduino confirms that the servo motor has reached the desired position, the main node immediately captures a complete **/LaserScan** dataset from the **/scan** topic, which is continuously published by the RPLiDAR driver. This confirmation-based synchronization mechanism ensures that each acquired 2D data "slice" is precisely associated with its corresponding vertical tilt angle. Subsequently, the node performs a real-time geometric transformation, wherein each 2D scan point is projected into 3D coordinate space by integrating the known tilt angle information. This newly formed set of 3D points is then aggregated and published as a **/PointCloud2** message to the **/lidar_points** topic. This iterative process continues until the entire vertical angular range has been covered, at which point the combined 3D point cloud representing the complete room geometry is permanently saved to a **.pcd** file for further analysis, while real-time visualization can be performed using RViz.

4.3.2. ROS System Workflow

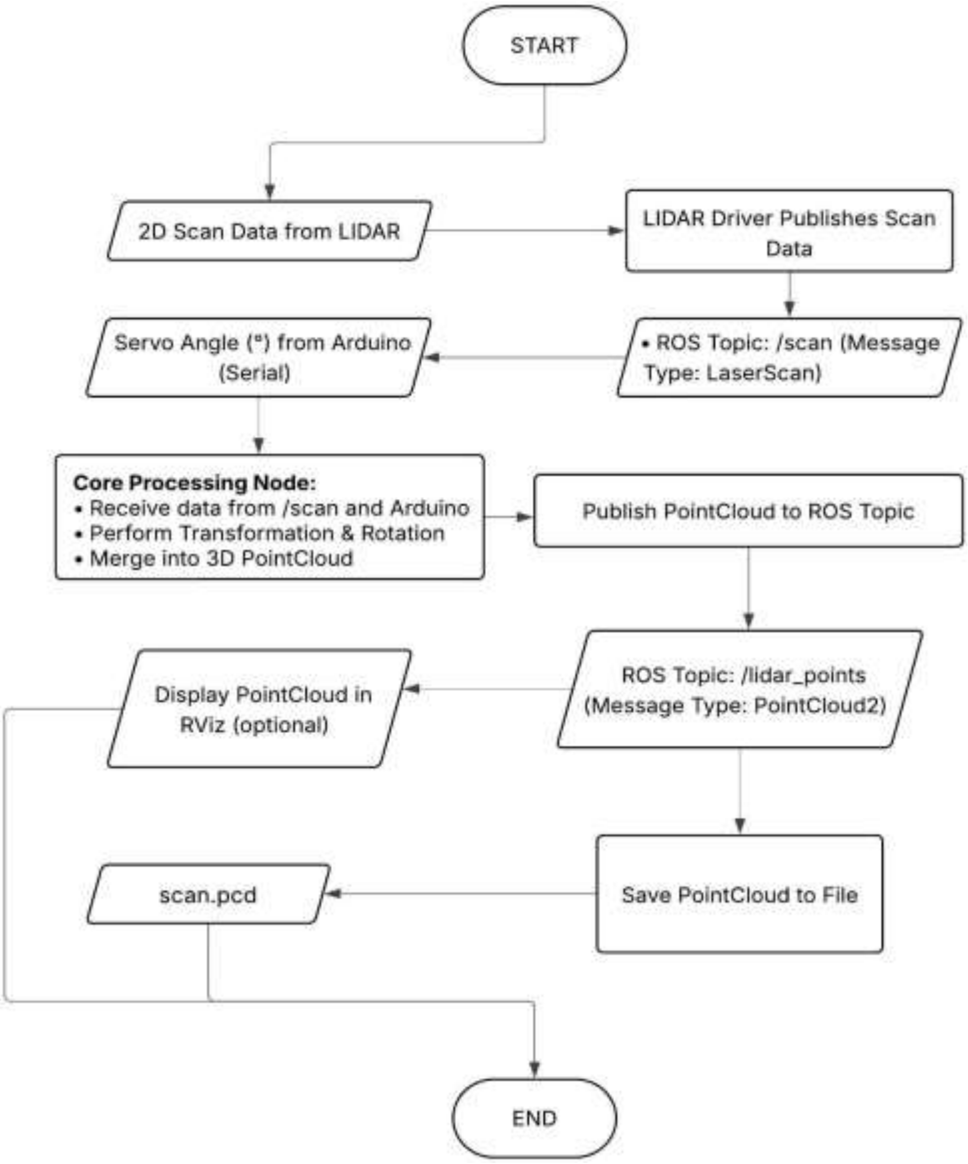



Fig. 2 ROS System Diagram

The data processing pipeline within the Robot Operating System (ROS) framework commences with data acquisition from the LiDAR sensor. This sensor performs continuous horizontal scans of the environment and publishes the raw data to a designated ROS topic, **/scan**. This data is encapsulated within the standard **/LaserScan** message format, which contains range information for each angular increment in a single scanning plane. Subsequently, a dedicated processing node serves as the core of this workflow. The node subscribes to the **/scan** topic to receive the real-time stream of **/LaserScan** data. Within this node, each 2D scan dataset undergoes a geometric transformation. This transformation integrates the 2D range data from the LiDAR with the corresponding vertical tilt angle, which is obtained from the servo motor control unit. Through this process, each 2D scan point is projected into a 3D coordinate space. The result of this transformation is aggregated into a point cloud and published to a new topic, **/lidar_points**, using the **/PointCloud2** message type. For the purpose of data monitoring and validation, a visualisation tool such as RViz can be employed by subscribing to the **/lidar_points** topic to render the 3D point cloud as it is being constructed. Once the entire scanning sequence across all predefined tilt angles is complete, the final 3D point cloud data is persistently stored in the Point Cloud Data **.PCD** file format. This file can then be utilized for post-processing applications, such as object analysis, metrology, or 3D reconstruction.

4.3.3. Communication Flow

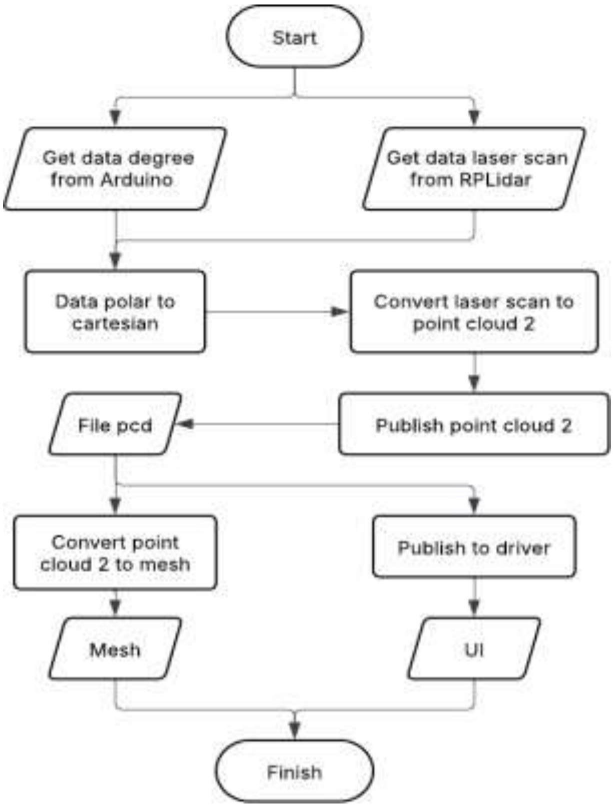



Fig. 3 System Data Flow Diagram

The system is fundamentally designed to generate a 3D map of an environment by utilizing a 2D laser sensor, such as the RPLiDAR, mounted on a servo motor that is controlled by an Arduino. To produce the 3D representation, the servo adjusts the sensor's tilt angle. A Python program serves as the central controller for this entire process, initially communicating with the Arduino to ascertain the LiDAR's current tilt angle while simultaneously acquiring distance scan data from the RPLiDAR. The raw 2D data from the LiDAR, consisting of angle and distance measurements, is converted into Cartesian x and y coordinates. This tilt angle information from the Arduino is then used to incorporate the z-dimension, thereby transforming each 2D laser scan into a set of 3D points known as a PointCloud2. This point cloud is published to the **/lidar_points** ROS topic, making it accessible for other applications like real-time visualization. The Python program actuates the servo for a predefined number of sweeps (**max_sweeps**) to collect data across a comprehensive range of tilt angles. All 3D points gathered from these sweeps are aggregated and saved as a single **.pcd** file, a standard format for 3D point cloud data. In essence, the program acquires angular data from the Arduino and 2D laser data, integrates them to create 3D data, and stores the complete 3D map as one file. Subsequent processing steps may include converting the PointCloud2 data into a surface model (mesh) or rendering it within a user interface (UI).

## 5. DISCUSSION

### 5.1 Interpretation of research results

The 3D scanning system in this study was developed by utilizing a 2D LiDAR sensor (RPLiDAR A2) combined with a digital servo to generate rotational motion that enables three-dimensional data acquisition. The data acquisition process begins by retrieving raw data from the topic/laserscan provided by RPLiDAR. This data, which inherently contains distance and angle information (polar coordinates) of the sensor's surroundings, is then converted into a representation of Cartesian points. This set of points is further converted into the PointCloud2 format for further processing. To ensure sufficient object coverage, the sensor performed a scan with an angular coverage of 180 degrees that was repeated five times. After these five scanning cycles are completed, the collected PointCloud2 data is automatically saved into a directory. The result of this stage is a pointcloud2 representation of the scanned object, as visualized in Fig. 4.

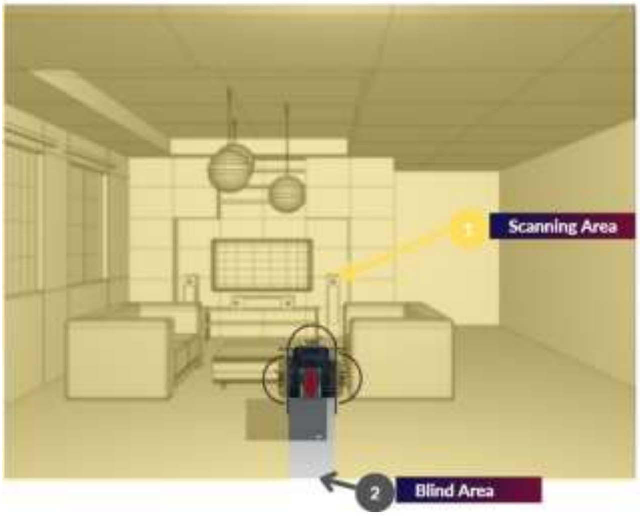



Fig. 4 Scanning Area and Blind Area

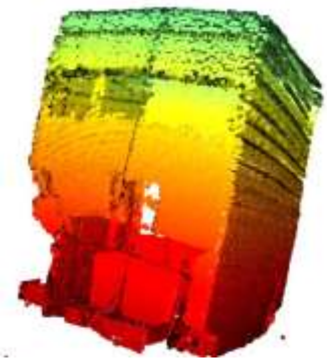


Fig. 5 Scan result PointCloud2

Fig. 6 Scan result Mesh

The next step is the reconstruction of the 3D surface from the stored pointcloud2 data. A Python script was used to process this PointCloud2 data. In the script, the Alpha Shapes algorithm, implemented using the Open3D library, was applied to generate a mesh model from the pointcloud. The Alpha Shapes method was chosen for its ability to reconstruct a surface from an unstructured set of points by identifying the underlying geometric shape. The result of this meshing process is a 3D model of the object's surface, as shown in Fig.5. Based on the visual analysis of Fig.5 (pointcloud2) and Fig.6 (mesh), the scanning system shows moderate success in capturing the general geometry of the scanned object. It is estimated that the success rate in capturing object surface data is in the range of 65-75%. Fig.4 shows that most of the main surface of the object was successfully captured, although there are some areas with lower point density and discontinuities, especially in parts that may be obstructed or at the limit of the effective range of the LiDAR sweep. Consequently, as shown in Fig.6, the mesh model generated using the Alpha Shapes method displays some artifacts in the form of holes and less smooth surfaces. This indicates that the density and completeness of the input pointcloud2 data are crucial factors that affect the final quality of the reconstructed mesh model. Nonetheless, the overall shape of the object can still be recognized quite well.

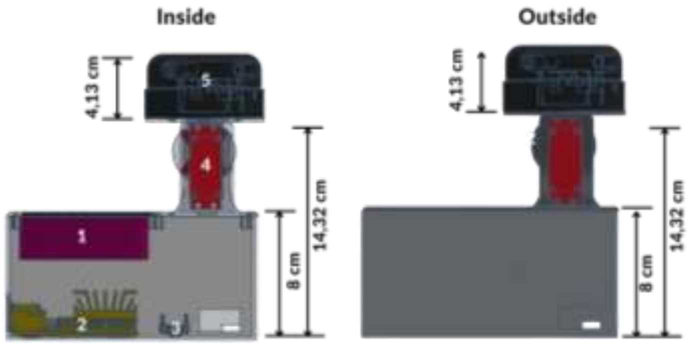
5.2 Connecting findings with previous research and existing theories.

The results of this research is a prototype of the A2 LiDAR-based 3D mapping system that able to accurately map interiors at low-cost, also this result aligns with the theory of previous research regarding the effectiveness of LiDAR technology in three-dimensional mapping. As explained by Staffas et al. (2022) [6], LiDAR is a high-precision imaging technology that utilizes laser pulses to produce a 3D representation of an environment. In this context, the developed prototype shows consistency with the detection capability and accuracy promised by LiDAR technology. LiDAR Odometry and Mapping (LOAM) method, known as one of the best 3D SLAM methods in real-time (Chan et al., 2021) [3], is the theoretical basis for processing and visualizing point cloud data in this system. The integration of data processing methods in the ROS (Robot Operating System) and the transformation of data into point clouds with PointCloud2 and .pcd formats support the efficiency of the mapping process. This research also of Mulyana & Pratiwi (2024) [1] which shows that the utilization of LiDAR sensors can produce room mapping data with minimal deviation to real size, which is around 0.2%. This shows that although the system is designed for cost efficiency, accuracy can still be maintained through precise mechanical design and optimized data processing.

In terms of device integration, Arduino Nano is use as a servo motor controller for vertical rotation according to the 360° scanning mechanism has been supported in the literature by Winardi et al. (2022) [8] and Krsmanović et al. (2022) [9]. These implementations have proven to be effective in producing a comprehensive scan, while strengthening efficiency in data acquisition. This mechanism plays an important role in forming a more complete and dense point cloud data, thus improving the quality of the 3D mesh formed through reconstruction algorithms such as BPA and Poisson.

In addition, this research is in line with the utilization of computing modules such as Jetson Nano in real-time data processing that has been shown in research by Chan et al. (2021) [3] and Li et al. (2024) [11]. Thus, the results of this study not only prove the reliability of the low-cost system in interior 3D mapping, but also make a practical contribution to the development of portable and efficient LiDAR systems for the education sector, small businesses, and industrial partners who need mapping solutions that are easy to access and implement. The system also opens up opportunities for further integration with AI processing technologies and semantic segmentation while keeping in mind the challenges of segmenting small objects and complex environments.

The main advantage of this research is that the prototype 3D mapping system developed an innovation of the LiDAR A2 sensor, which is basically only capable of producing two-dimensional (2D) mapping. Through the integration of servo motors and vertical control by Arduino Nano, as well as data conversion from polar to cartesian coordinates and advanced processing using ROS and mesh reconstruction algorithms, the system successfully transforms the function of the LiDAR A2 into a three-dimensional (3D) mapping device. This innovation makes the system an economical solution for 3D mapping needs, without the need for specialized 3D LiDAR devices, which generally have high prices. Thus, this research not only proves the reliability of the low-cost system in interior 3D mapping, but also makes an innovative contribution by transforming the function of the LiDAR A2 from 2D to 3D. This system has potential applications in various sectors, and provides a foundation for further integration with artificial intelligence and semantic segmentation such as the 3D-UMamba model (Lu et al., 2025) [7], while taking into account challenges such as small object detection and complex environments.




Number Representation:
1 : Fan
2 : Jetson
3 : Arduino Nano
4 : Servo
5 : RPLiDAR A2

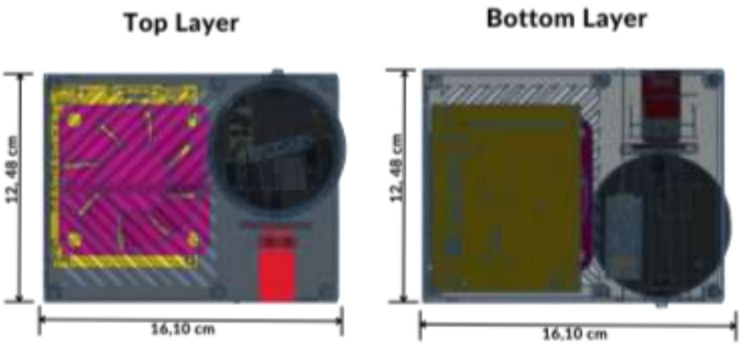



Fig. 7 Final product

5.3 Implication of the findings

The results obtained from this study are three-dimensional interior space mapping using a low-cost LiDAR sensor-based system that still provides representative results. This study contributes to the development of mapping technology and SLAM systems and can serve as a reference for further research. Practically, the developed system can be applied across various sectors, such as building mapping, indoor monitoring, and robot navigation systems. The implementation of this system is also relevant for supporting the development of smart buildings and smart homes, particularly in real-time data-based space management. Since it uses affordable devices, the development of this system is suitable for educational institutions or industries requiring room mapping solutions. The design and development process of LiDAR is closely related to fostering innovation and creative problem solving. For example, the ability to adjust sensors and scanning parameters enables the development of optimal tools for tasks such as small-scale environmental monitoring that may be overlooked by commercial systems. However, it must be acknowledged that LiDAR development also faces several challenges, particularly related to accuracy, calibration, and data standardization. Achieving precision levels comparable to commercial systems requires a deep understanding of error sources and meticulous calibration methodologies. These challenges also represent a broad area of research. Collaboration through open-source platforms and the potential integration with artificial intelligence for data processing offer avenues to address some of these limitations and continue advancing LiDAR system development.

Overall, the development of 3D LiDAR scanning tools such as this has great significance, not only as an engineering achievement but also as a contribution to more inclusive innovation. Such projects build local technical capacity and promote hands-on learning in the field of Science, Technology, Engineering, and Mathematics (STEM).

Success in designing and implementing 3D LiDAR devices can inspire more similar initiatives, accelerate the development of 3D scanning technology, and support various research efforts and practical applications that benefit the broader community.

5.4 Research limitations and suggestions for future research

This study faced some major limitations related to the data quality and modeling process. Firstly, the quality and completeness of the point clouds produced still need to be improved. The point cloud obtained is sparse, which reduces the level of detail and accuracy of the final model. Furthermore, the point cloud is not equipped with normal vector information at each point. In fact, normal information is crucial for accurately reconstructing surfaces, calculating lighting effects, and performing advanced operations such as curve-based segmentation. In addition, the absence of color (RGB) data at each point limits the ability to reconstruct realistic visual appearance (texture) and hinders applications based on material analysis. This limitation is thought to be due to a combination of factors such as the short scanning time, the limitation of the primary sensor (possibly using only a distance-measuring LiDAR without an integrated RGB camera), and the preprocessing algorithm that does not yet result in normal estimation or color extraction. Secondly, the process of converting the point cloud into a print- or simulation-ready mesh (STL) format is problematic. Point clouds cannot be converted directly to STL. Computational mesh generation efforts are also constrained by hardware specifications that are inadequate to run 3D processing software efficiently, causing the process to run very slowly or even fail.

## 6. CONCLUSION

6.1 This research successfully designed and realized a prototype 2D LiDAR-based 3D scanning system (RPLiDAR A2) modified into a 3D system through integration with servo motors and Arduino Nano controller. This prototype utilizes a low-cost approach while still maintaining decent scanning accuracy.

6.2 The developed system shows great potential to be adopted by small to medium-sized industry partners with limited budgets. By reducing production costs and using open-source components, this system can be utilized in interior mapping applications, asset monitoring, object documentation, and other operational needs. The results of this research show that LiDAR technology does not have to be expensive to be functionally applied in a real-world context.

6.3 The prototype was designed with ease of replication and flexibility of use in mind, making it highly relevant to the education and community sectors. Educational institutions and small businesses now have the option to utilize 3D mapping technology without having to rely on expensive commercial devices.

## 7. REFERENCES


1. Mulyana, D. I. & Pratiwi, T. A. 2024. Optimasi pengukuran dinamis dari visualisasi model ruangan 3d menggunakan sensor lidar dan framework room plan. *Jurnal Indonesia: Manajemen Informatika dan Komunikasi (JIMIK)*. 5(3): 2623-2633.
2. Parent, J. R., Witharana, C., & Bradley, M. 2021. Mapping building interiors with LiDAR: Classifying the point cloud with ArcGIS. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 44, 133-137.
3. Chan, T. H., Hesse, H., & Ho, S. G. (2021, April). Lidar-based 3d slam for indoor mapping. In2021 7th international conference on control, automation and robotics (ICCAR)(pp. 285-289). IEEE.DOI: 10.1109/ICCAR52225.2021.9463503.
4. Dewi, N. I. K., & Putra, W. B. (2022). Pemindaian Ruang pada Bangunan dengan Mobile LiDAR Camera. *Jurnal Arsitektur TERRACOTTA*, *4*(1), 80–91. https://doi.org/10.26760/terracotta.v4i1.8146.
5. Louise, Susanthi, Y., & Muliady. (2023). Mapping dan Navigasi untuk Robot Pengantar Makanan di Restoran Berbasis ROS. *Techné : Jurnal Ilmiah Elektroteknika*, *22*(1), 111–128. https://doi.org/10.31358/techne.v22i1.348.
6. Staffas, T., Brunzell, M., Gyger, S., Schweickert, L., Steinhauer, S., & Zwiller, V. (2022). 3D scanning quantum LIDAR. Conference on Lasers and Electro-Optics, 1–2.

7. Lu, D., Xu, L., Zhou, J., Gao, K., Gong, Z., & Zhang, D. (2025). 3D-UMamba: 3D U-Net with state space model for semantic segmentation of multi-source LiDAR point clouds. *International Journal of Applied Earth Observation and Geoinformation*, *136*(December 2024), 104401. https://doi.org/10.1016/j.jag.2025.104401.
8. Winardi, S., Kristiyono, A. E., Herlambang, S. M., & Budijanto, A. (2022). Rancang Bangun Radar 360 Derajat Berbasis Arduino. *Jurnal Teknologi Dan Ilmu Komputer Prima (Jutikomp)*, *5*(2), 74–79. https://doi.org/10.34012/jutikomp.v5i2.2992.
9. Krsmanović, V., Barjaktarović, M., & Gavrovska, A. (2022). System for 3D Mapping using Affordable LIDAR. *Telfor Journal*, *14*(2), 67–72. https://doi.org/10.5937/telfor2202067K.
10. Yan, L., Dai, J., Zhao, Y., & Chen, C. (2023). Real-Time 3D Mapping in Complex Environments Using a Spinning Actuated LiDAR System. *Remote Sensing*, *15*(4), 1–17. https://doi.org/10.3390/rs15040963.
11. Li, X., Li, X., Hu, G., Niu, Q., & Xu, L. (2024). A Low-Cost 3D Mapping System for Indoor Scenes Based on 2D LiDAR and Monocular Cameras. *Remote Sensing*, *16*(24), 1–30. https://doi.org/10.3390/rs16244712.
12. Mulyanto, A., Borman, R. I., Prasetyawana, P., & Sumarudin, A. 2020. 2D Lidar and Camera Fusion for Object Detection and Object Distance Measurement of ADAS Using Robotic Operating System (ROS). *JOIV: INTERNATIONAL JOURNAL ON INFORMATICS VISUALIZATION*. 4(4): 231-236.
13. Basavanna, M. & Shivakumar, Dr. M. 2020. Mapping of an Unknown indoor environment using 2D- Lidar and ROS for mobile robot navigation. *International Journal of Advanced Science and Technology*. 29(5):14338-14345.
14. Delaney, E., Liu, W., Zhu, Z., Xu, Y., & Dai1, J. S. 2022. The investigation of environmental sustainability within product design. *Design Science*. 8(15): 1-45.

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