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Aerial mapping based on visual for search and rescue robot application

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***Abstract*—This research paper aims to develop aerial mapping based on visual using RTAB-MAP for search and rescue robot applications. Mapping these areas is crucial for locating disaster sites that are challenging for humans to reach. Area mapping utilizes a visual RGB-D camera as input and RTAB-Map as a data processing system to represent a 3D map. RVIZ ROS is used for visualizing the map in 3D format. RGB-D images are processed using RTAB-Map to obtain several data points, including odometry, loop closure, timestamp, x, y, z coordinates, and roll, pitch, yaw data from the camera. The test results yielded an optimal area mapping, where the loop closure results in finding corresponding image data quite effectively. As the number of loop closures increases, the area mapping quality improves. In this study, there were a total of 450 loop closure data, which allowed the system to create an optimal 3D map representation. The creation of this map is expected to assist in visualizing hazardous areas to aid in search and rescue efforts during natural disasters.**

***Keywords*—Aerial Mapping; Visual; Robot; RTAB-Map; Rviz-ROS**

I. INTRODUCTION

DANGEROUS areas, such as disaster-stricken regions or environments with challenging conditions, pose significant risks to human lives and infrastructure[1]–[3]. In these unpredictable and potentially hazardous environments, accurate and real-time mapping of impacted areas is crucial for effective response and mitigation efforts. Traditional mapping techniques often prove inadequate in scenarios like these due to limitations in speed, accuracy, and adaptability. Typically, mapping hazardous areas is conducted manually or by utilizing pre-existing mapping data. However, these approaches frequently fall short in addressing unforeseen conditions or emergency situations demanding swift responses. Additionally, most traditional mapping methods cannot offer real-time, accurate, and three-dimensional mapping.

In recent years, the development of real-time 3D mapping technology using visual cameras on aerial platforms has become an increasingly focused area of research. This technology leverages advancements in aerial photography, image processing, and visual computing to rapidly and accurately generate three-dimensional mapping of hazardous areas[4]. Real-time 3D aerial mapping systems based on visual cameras offer several significant advantages. Firstly, aerial platforms allow for the quick and efficient mapping of large areas, surpassing the limitations of ground-based mapping. Secondly, advanced visual camera technology can capture high-resolution images, capturing essential details for accurate mapping. Thirdly, by utilizing sophisticated image processing algorithms, these systems can extract three-dimensional spatial information from visual images, resulting in near-real-time mapping[5].

Real-time 3D aerial mapping based on visual cameras for hazardous environmental conditions has various critical applications. For instance, this mapping can support rescue operations, aid in monitoring environmental changes, and facilitate post-disaster recovery planning. With accurate and real-time mapping, authorities can make informed and effective decisions during emergencies and plan necessary mitigation actions[6].

To address these challenges, the development of real-time 3D mapping systems using visual cameras emerges as a promising solution. By employing visual cameras mounted on aerial platforms, this approach enables high-resolution image capture and real-time extraction of 3D spatial information. Camera-based systems enable the creation of detailed 3D maps of impacted areas[7], [8]. Therefore, research on real-time 3D aerial mapping based on visual cameras for hazardous environmental conditions is crucial. Through the advancement and performance evaluation of such systems, it is anticipated that this mapping approach will bring significant benefits in enhancing responsiveness, safety, and preparedness in hazardous areas. The development of robotics[9]–[12] and automation systems[13]–[15] is a great opportunity for implementing applications in disaster areas.

This paper presents a comprehensive study on the development, implementation, and evaluation of a real-time 3D aerial mapping system based on visual cameras for hazardous environmental conditions. By leveraging the capabilities of visual cameras and image processing algorithms, the proposed system aims to overcome the limitations of traditional mapping methods, enabling accurate and efficient mapping even in rapidly changing hazardous areas. Overall, this research aims to contribute to the advancement of sophisticated mapping technology that can enhance situational awareness, aid disaster response planning, and ultimately improve the safety and resilience of communities facing hazardous conditions.

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II. RELATED WORK

The researchers focused on real-time 3D reconstruction using image data from visual cameras. They developed algorithms and image processing techniques to achieve highly accurate and real-time aerial mapping. This research combined photogrammetry principles and image processing to reconstruct 3D geometry from images captured by visual cameras. The developed algorithms included steps such as feature matching processing, bundle adjustment, and 3D reconstruction based on stereo information. The results of this research demonstrated the capability of the developed method to produce accurate real-time 3D aerial mapping. This method holds potential applications in various fields, including environmental monitoring, disaster management, and urban planning. This research contributes to the advancement of fast and accurate 3D aerial mapping technology based on visual cameras. Its outcomes can serve as the foundation for the development of more sophisticated and efficient aerial mapping systems in the future[16].

The objective of this research was to develop an efficient real-time 3D mapping method using a single camera on an autonomous drone. The method aimed to address hardware limitations and high processing requirements of autonomous drones. The researchers proposed advanced image processing algorithms to reconstruct 3D mapping using image data from a single camera. They integrated visual information with inertial sensor data to accurately estimate the drone's position and orientation. The results of this research showcased that the developed method could achieve accurate real-time 3D mapping using a single camera on an autonomous drone. This method can be applied in various drone applications, such as environmental monitoring, infrastructure inspection, and restricted area surveys. This research contributes to the development of efficient 3D mapping technology using limited resources on autonomous drones. Its outcomes can enhance the mapping and monitoring capabilities of drones in hazardous or hard-to-reach environments[17].

In the researchers proposed an approach that combined visual data from monocular cameras and inertial data from sensors to achieve real-time 3D mapping. They developed advanced image processing algorithms that integrated visual and inertial information to enhance mapping accuracy and speed. The proposed method utilized visual data to extract crucial features from images and used inertial data to estimate the drone's movement and position. By combining these two data sources, they could perform real-time 3D reconstruction with high accuracy. The results of this research indicated that the proposed method successfully achieved real-time 3D aerial mapping with good accuracy. This method has broad potential applications in land surveying, environmental monitoring, and other drone applications. This research contributes to the development of efficient and accurate real-time 3D aerial mapping technology using visual-inertial monocular fusion. Its outcomes can be employed to enhance aerial mapping capabilities, particularly in real-time situations and hazardous or hard-to-reach environments[18].

The researchers focused on developing a real-time 3D mapping method that utilized visual cameras as the main data source. They addressed specific challenges posed by outdoor environments, such as changing lighting conditions, surface texture variations, and UAV movements. The proposed method combined image processing with feature matching techniques to achieve real-time 3D mapping. They used efficient algorithms to extract important features from images, calculate UAV movement, and continuously update the 3D mapping. The results of this research demonstrated that the proposed method could achieve real-time 3D mapping with adequate accuracy in outdoor environments. This method has the potential for various applications in land surveying, environmental monitoring, and other UAV applications in open environments. This research contributes to the development of real-time 3D mapping technology using visual cameras for UAVs in outdoor environments. Its outcomes can enhance aerial mapping capabilities in different environmental conditions and aid in monitoring and mapping in hazardous or hard-to-reach outdoor environments[19].

The challenge lies in effectively and accurately monitoring hazardous areas to identify and understand environmental conditions that can endanger humans or ecosystems. Camera-based mapping methods offer potential solutions, but the challenge is developing a mapping system capable of producing high-precision and efficient real-time 3D maps in hazardous environments. Therefore, this research aims to address this issue by developing and validating a camera-based mapping method that can be used to monitor environmental conditions in hazardous areas in a timely and accurate manner. This research provides a crucial contribution to developing camera-based mapping methods for real-time monitoring of environmental conditions in hazardous areas. With appropriate implementation, this method has the potential to enhance safety and efficiency in disaster management and environmental monitoring.

III. METHOD

In this section, we will discuss the stages involved in the Aerial Mapping process using RTAB-Map. For further clarity, please refer to Fig 1 in the blog for the system diagram.

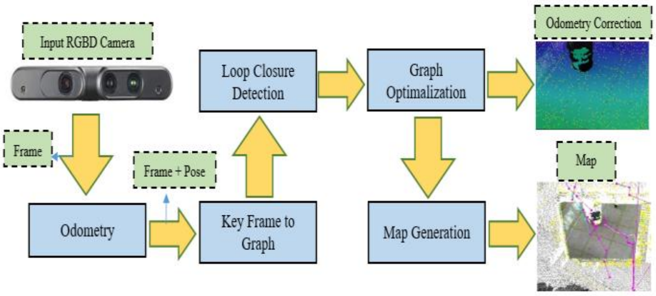

Fig. 1. Propose Blog System

In the blog, the diagram is divided into several sections, including the input, process and output. This section is several steps to achieve the intended purpose of the research.

A. Input Image

RGB-D camera combines an RGB camera with a depth sensor. In the RTAB-Map system (Real-Time Appearance-Based Mapping), the RGB-D camera plays a crucial role in the mapping and localization process. It measures depth, which means it measures the distance to objects within its field of view. This information is essential for understanding the 3D structure of the environment. In RTAB-Map, depth data is used to create a representation of 3D points in the surroundings. Depth information from the RGB-D camera plays a vital role in this process. By comparing depth data with visual (RGB) data, the system can match features and accurately track the camera's movement. In summary, the RGB-D camera in RTAB-Map is an integral component that provides depth information in addition to visual data. This depth data is used for various purposes, including creating 3D maps.

B. *Odometry*

Camera odometry is a crucial component within the RTAB-Map system, used to calculate the movement or change in position of the camera. Camera odometry is employed to estimate changes in the camera's position or movement. When camera odometry produces movement estimates, this information is also utilized in the mapping process. It assists in constructing maps of the environment around the mobile device by updating the relative positions of objects on the map as the device moves. In the developed system, camera odometry is a vital component in supporting accurate real-time mapping and localization processes. It integrates information from the visual camera to calculate and update the mobile device's movement estimates. Therefore, camera odometry aids RTAB-Map in understanding where the mobile device is, how it is moving, and how it relates to its environment in the context of real-time map creation. Consequently, camera odometry contributes to the creation and maintenance of environmental maps within the RTAB-Map system. The odometry equation for a Kinect camera in RTAB-Map can be expressed as follows.

$$\Delta x, \Delta y, \Delta z = Odometry\ Fungtion(depth, visual\ data)$$

- Δx, Δy, Δz are change in position in the global three-dimensional coordinate system (x, y dan z).
- Odometry fungtion is the function that calculates changes in position based on depth data and visual data received from the Kinect camera.

C. *Key Frame to Graph*

Keyframe to graph in RTAB-Map is one of the crucial components involved in the mapping process. In this research, it is used to construct and maintain a graphical representation of the environment recognized by the device during data acquisition. This function serves several purposes and benefits, including being responsible for capturing keyframes, which are points in the mobile device's journey deemed significant in terms of environmental changes. These keyframes contain visual images and sensor data. Keyframe to graph plays a role in creating and updating the environmental map within the RTAB-Map system. By integrating data from keyframes into the graph, the system can understand and record the locations of important objects and features within the environment. In this research, keyframe to graph is used to assist RTAB-Map in building and maintaining the environmental representation, as well as improving and optimizing the mobile device's localization estimates. By leveraging keyframes and the environmental graph, RTAB-Map can create increasingly accurate maps.

D. *Loop Closure Detection*

Loop closure detection is one of the key components in the RTAB-Map system. This function plays a crucial role in understanding the spatial relationships between different locations within the environment recognized by the mobile device. The loop closure detection function is responsible for identifying loop closures, which are situations where the mobile device has returned to a location previously recognized during its journey. This can occur when the device makes a circular trip or returns to its starting point. Correcting Drift: One of the consequences of motion estimation in SLAM is the accumulation of errors or drift over time. When the mobile device performs a loop closure, the system can recognize and understand that this is the same location it has previously recognized. Thus, loop closure detection helps correct the accumulation of drift and update the mobile device's position estimates, maintaining consistency in mapping and localization. Overall, loop closure detection is a critical function in RTAB-Map that aids in detecting, understanding, and addressing situations where the mobile device returns to locations previously recognized during its journey. This helps maintain consistency in mapping and localization, correct drift, improve position estimates, and enhance the efficiency of the mobile device's navigation within the recognized environment.

E. *Graph Optimalization*

Graph optimization in this research is used to enhance the quality of mapping. One of its applications is the optimization of maps, and it is also utilized to optimize the environmental map being constructed. This involves improving the relative positions of objects or features within the map, which helps create a more accurate and consistent map. Map optimization may involve refining the estimates of object locations in the map based on information from various observations and references, such as loop closures. Graph optimization aids in improving the accuracy of mobile device localization. By comparing the current localization estimates with information from previous references in the map, the system can correct and update position estimates more effectively. This helps prevent discrepancies between the current position estimates and well-established data within the map. Graph optimization also assists in optimizing the data processing pipeline. Instead of processing each observation independently, RTAB-Map employs graph optimization to combine information from observations over time.

F. *Map Generation*

The function of map generation in RTAB-Map in this research is responsible for creating and maintaining a representation of the map from the environment recognized by the mobile device during its journey. It creates a map that depicts objects, features, and other structures in the vicinity of the mobile device. These maps are typically in the form of two-dimensional (2D) or three-dimensional (3D) maps, depending on the type of environment being mapped. During the mobile device's journey, map generation combines visual observations to understand the locations of objects and features in the environment. This involves matching visual observations with existing map information to determine the positions of recognized objects. It also serves as a system capable of updating the map. The maps created by RTAB-Map are not static; instead, they are continuously updated during the journey. As the mobile device moves and observes the changing environment, the map is also updated to reflect these changes. This helps maintain the accuracy and consistency of the map over time. In this research, the map generation function is responsible for creating and maintaining a representation of the environment around the mobile device.

G. *ROS Node and Topic*

In RTAB-Map, ROS is used as a vital framework for communication and data management in the development of mapping systems. The functions of ROS nodes and topics are highly relevant in the context of RTAB-Map. ROS nodes in RTAB-Map are responsible for various data processing tasks, such as fetching data from sensors, processing this data for mapping, managing motion estimates, and deciding how to update the map and estimates. Nodes in RTAB-Map communicate with each other through mechanisms provided by ROS. They can send and receive messages containing visual observations and map information. ROS topics are one of the ways in which nodes in ROS communicate with each other. Topics are communication channels that enable nodes to send and receive messages. In this research, ROS topics are used to stream data from the RGB-D camera to the RTAB-Map node. This data is then processed by RTAB-Map for mapping purposes. Nodes in RTAB-Map function as both publishers (sending data to topics) and subscribers (receiving data from topics) as needed. The RTAB-Map node acts as a subscriber, receiving sensor data from the appropriate topic. Overall, ROS nodes and topics enable various nodes to communicate, retrieve data from cameras, and perform data processing for mapping purposes.

IV. EXPERIMENTAL RESULT

In this section, the results of testing the making of 3D maps by utilizing several result, RGB-D, Odometry, Loop Closure, 3D Map, graph view, RTAB-Map and Rviz ROS Visualization view.

A. *RGB-D Image Result*

The results of RGB-D images (color images and depth data) in RTAB-Map are used to understand the environment around the mobile device and build a 3D map of that environment. This information is used in the mapping and localization processes in the RTAB-Map system. Color images are visual representations of the surroundings of the mobile device, providing information about objects, textures, and colors in the environment. Color images are used for visual feature extraction, object identification, and feature matching between different camera frames to track the device's movement. Depth data measures the distance between the camera and objects within the field of view, providing information about the 3D structure of the environment. Depth data is crucial for mapping and localization as it helps understand the depth of objects and the relative positions of objects in 3D space. Figure 2 displays the RGB image result from RTAB-Map.

Fig. 2. RGB Result

Data RGB-D is used to identify and map objects and features in the environment, aiding in the construction of maps that include these objects. RGB-D data is used for feature matching between different camera frames, assisting in tracking the device's movement and detecting loop closures (when the device returns to a previous location). RGB-D data is also used to update the environmental map during the device's journey. This map is continuously updated with new information from RGB-D data to maintain accuracy and consistency in the map over time. Therefore, the results of RGB-D images in RTAB-Map provide information used to build and maintain an environmental map, understand the device's location, and enhance accuracy in mapping and localization within the RTAB-Map system.

B. *Odometry Result*

The results of odometry in RTAB-Map are estimates of the movement or positional changes of the mobile device during its journey. Odometry plays a crucial role in the mapping and localization processes within the RTAB-Map system. Here are the results and their functions. Odometry is used to generate estimates of the mobile device's movement. This includes information about how the device's position changes over time. This information can encompass translation (changes in position in X, Y, and Z coordinates) as well as rotation (changes in orientation or angles). The results of odometry images can be seen in Figure 3.

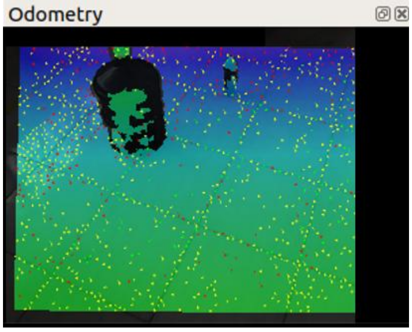

Fig. 3. Odometry Result

Odometry is used to update the device's localization estimates. This helps the RTAB-Map system understand where the mobile device is and how it is moving. Localization estimates are essential information for mapping and understanding the device's position within the environment. Odometry information is used to monitor the device's movement in real-time, allowing the system to track and record the device's movement as it traverses the environment. One issue often encountered in mapping is the accumulation of errors (drift) over time. Odometry can help correct this accumulated drift by periodically updating the device's movement estimates. Odometry information is used to improve the mapping of objects and features within the environment, aiding in creating more accurate maps by updating the relative positions of objects. Therefore, the results of odometry in RTAB-Map consist of estimates of the mobile device's movement and positional changes during its journey. This information is crucial for mapping, localization, navigation, and the maintenance of environmental maps during the journey.

C. *Loop Closure Result*

The results of loop closure in RTAB-Map involve the identification and understanding that the mobile device has returned to a location previously recognized during its journey. Loop closure is a key component of the RTAB-Map system, and its results have significant implications in the mapping and localization processes. Here is a further explanation of the results of loop closure. The primary outcome of loop closure is the detection of situations where the mobile device has revisited a location it had recognized before. This can occur when the device makes a circular journey or returns to its initial starting point in the journey. The results of loop closure can be observed in Figure 4.

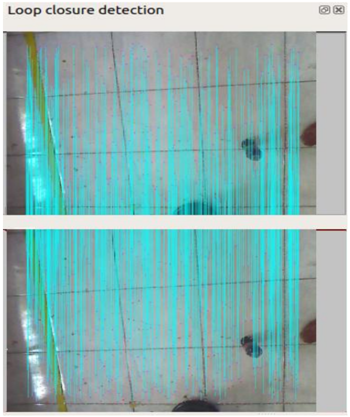

Fig. 4. Loop Closure Result

Identifying loop closure allows the system to update its estimates of the mobile device's position. This helps improve and optimize position estimates, maintaining consistency in mapping and localization. Loop closure ensures consistency in mapping and understanding the device's position within the environment, allowing the system to align new information with existing map data. The results of loop closure can also be used to optimize mapping. The system can leverage information from loop closures to refine the representation of the environment within the map.

Loop closure enhances the efficiency of the mobile device's journey in a known environment. By recognizing previously visited locations, the device can make better navigation decisions. Overall, the results of loop closure in RTAB-Map provide the ability to detect, understand, and address situations where the device returns to locations it had recognized before in its journey. This helps maintain consistency in mapping and localization, correct drift, improve position estimates, and enhance the efficiency of the device's journey in a recognized environment. In this study, the number of loop closures in map creation was 450 data points.

D. *3D Map Result*

The result of the 3D map generated by RTAB-Map is a three-dimensional (3D) representation of the environment recognized by the mobile device during its journey or exploration. This 3D map is the final outcome of the mapping process, which involves the integration of data from various sensors such as RGB-D cameras, odometry, and loop closure detection. The 3D map is a digital representation that depicts objects, features, and the structure of the environment in three dimensions. It includes information about the shape, size, and relative positions of objects within the recognized environment.

The 3D map can be seen as a collection of points in 3D space. Each point on the map represents the 3D position or coordinates of objects or features within the environment. The 3D map also reflects the structure of the environment, including the floor and other detected objects encountered during the mobile device's journey. The 3D map integrates data from various sources, including visual data from RGB-D cameras, odometry data measuring the device's movement, and information from loop closure detection identifying revisited locations. Figure 5 illustrates the result of the 3D map in RTAB-Map.

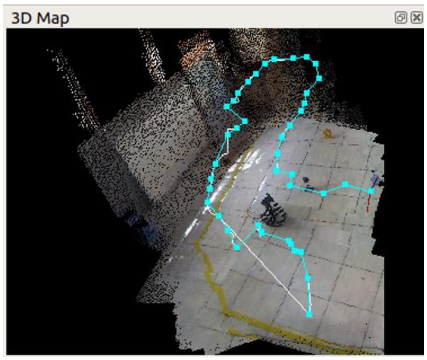

Fig. 5. 3D Map Result using RTAB-Map

The quality and accuracy of the 3D map are crucial. The more accurate the mapping and position estimation of the device, the more accurate the resulting 3D map. The 3D map is not static; it is continuously updated to reflect changes as the device moves and observes the evolving environment. The results of loop closure detection, which identifies revisited locations, assist in maintaining map consistency. This allows the system to align new information with existing map data. Overall, the result of the 3D map in RTAB-Map is a rich three-dimensional representation of the surrounding environment observed by the mobile device.

E. *Graph View*

The Graph View in RTAB-Map is an essential component of this tool that allows us to visualize a graphical representation of the environment recognized by the mobile device during data acquisition. Graph View is useful for understanding the spatial relationships between various elements in the environment, such as object positions, camera locations, and other relations. Graph View visualizes a graphical representation of the device's recognized environment. This graph consists of nodes and edges that depict objects and relationships among them. Each node in the graph represents entities in the environment, such as camera positions (keyframes), object positions, or detected features. Each node has attributes like 3D position, timestamp, and other relevant information. Edges depict relationships between nodes in the graph, which may include information like camera movement between two keyframes or spatial relationships between objects. Graph View allows visualization in a 3D format, making it easier to understand the spatial layout of objects and other nodes within the environment. The result of the Graph View can be seen in Figure 6.

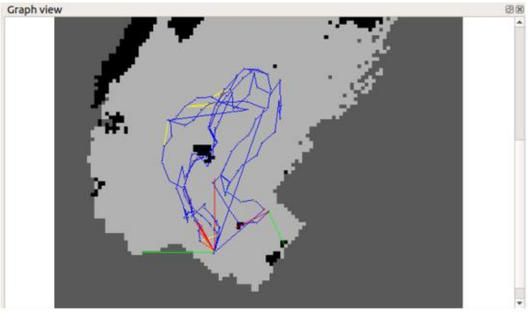

Fig. 6. Graph View RTAB-Map

Graph View assists in visualizing loop closure detection. You can observe how the device has recognized and connected the same locations during its journey. This helps in correcting drift and maintaining mapping consistency. Graph View aids in understanding the spatial relationships within the device's recognized environment. It also aids in troubleshooting and analysis to optimize mapping and localization estimations. We can use the Graph View to inspect the graph and analyze how to optimize mapping and monitoring by improving the positioning estimates of objects and features within the graph. Thus, the Graph View in RTAB-Map is a crucial tool for comprehending the representation of the environment recognized by the mobile device in a 3D graphical format. It facilitates visualization, analysis, and understanding of the relationships among objects, movements, and associations within the environment, thereby supporting the development of better mapping and monitoring systems.

TABLE I

No	X	Y	Z	Roll	Pitch	Yaw
1	0.0021	-0.0026	0.0007	-0.0001	0.00038	0.000714
2	0.0157	0.00168	0.0108	0.04671	0.03227	0.155204
3	0.2328	-0.0567	0.0778	0.02595	0.21370	0.117437
4	0.3325	-0.0580	0.2403	-0.0340	0.27338	0.239126
5	0.3647	-0.0274	0.2341	-0.0674	0.52551	0.127937
6	0.3790	-0.0176	0.2217	-0.0732	0.67197	-0.01806
7	0.4074	-0.0088	0.2722	0.06367	0.89605	0.053323
8	0.4382	-0.0012	0.2681	0.04985	1.00976	-0.14052
9	0.5999	0.16227	0.2584	0.06085	1.05818	-0.08377
10	0.5909	0.15747	0.2570	0.21456	1.00282	0.159766
11	0.6366	0.16498	0.2939	0.30804	1.26219	0.353322
12	0.4623	0.33053	0.3254	0.00221	1.18850	-0.00739
13	0.6058	0.35954	0.3623	0.11472	1.27933	-0.00916
14	0.7146	0.40035	0.4082	0.16096	1.36688	-0.05667
15	0.8773	0.45691	0.4182	0.00265	1.41584	-0.19932

F. *RTAB-Map Result*

In the context of RTAB-Map, mapping and camera movement results can be analyzed based on several key parameters, such as Time Stamp. This is a timestamp indicating when the data was acquired or when the observation was made. Each observation or camera movement comes with a timestamp. The timestamp is used to order the data sequence and understand the sequence of events over time. Due to the length of timestamp data, in this research, timestamp data is replaced with numbers, starting from 1 and so on. Next are X, Y, and Z (Position). These refer to the three-dimensional position of the camera in world coordinates (usually in meters). "X" measures horizontal displacement, "Y" measures vertical displacement, and "Z" measures depth displacement (how far or close an object is). Roll, Pitch, and Yaw (Orientation). These refer to the camera's orientation in three-dimensional space. "Roll" measures rotation around the X-axis, "Pitch" measures rotation around the Y-axis, and "Yaw" measures rotation around the Z-axis. This helps understand the camera's facing direction. Table 1 shows partial results from the created system.

The results of RTAB-Map include the data in Table 1 collected during the 3D map creation journey. This data is used to create and maintain a representation of the surrounding environment and also to estimate the movement of the robot or camera. It should be noted that in real-world usage, RTAB-Map results can be highly complex, including additional data such as point clouds representing objects in the environment. Analyzing this data is crucial for mapping, navigation, and the camera or system's understanding of the environment when using RTAB-Map. For more detailed results of the x, y, z, and roll, pitch, YAW values, where the number of collected data points reaches 450, please refer to Figure 7.

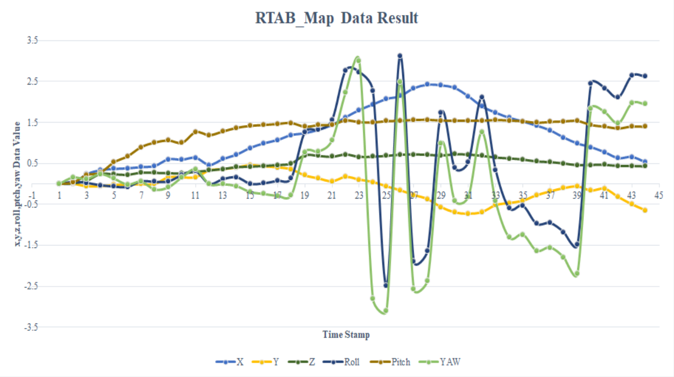

Fig. 7. X, Y, Z, and Roll, Pitch, YAW Data Value from RTAB-Map

G. *Rviz Visualization Result*

Rviz (ROS Visualization) is a visualization tool commonly used in robotic systems running under the ROS (Robot Operating System). Rviz allows us to interactively visualize sensor data, robot models, as well as mapping and monitoring results in a 3D environment. In the context of RTAB-Map, Rviz is used to visualize mapping and monitoring results in a 3D format. Rviz enables us to view 3D mapping interactively. We can see the environment recognized by the mobile device in a

3D format and interact with this visualization. Rviz can visualize points in 3D space representing detected objects and features during the device's journey. This includes visualizing points representing walls, floors, objects, and other structures. Figure 8 shows the 3D map visualization result in Rviz ROS.

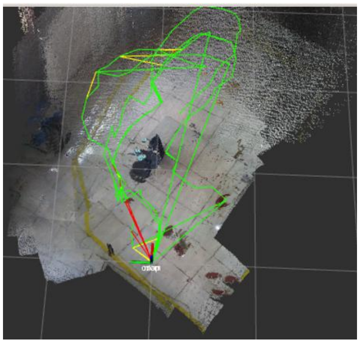

Fig. 8. 3D Map Result Based on Rviz ROS

We can observe the continuously updated 3D map as the device moves in the environment. This includes the structures and objects in the map, as well as updates that occur over time. Rviz can display a visual representation of the camera used by the device, allowing us to see the camera's field of view and how it perceives the environment. We can interact with this visualization, such as changing the viewpoint, zooming in or out, or even highlighting specific objects or points for further analysis. Rviz can also be used to visualize the results of loop closure detection. This helps in understanding how the device recognizes the same locations during its journey. Rviz 3D Visualization Result from RTAB-Map provides a highly useful way to inspect and understand the results of mapping and monitoring in a 3D environment. It's a crucial tool for testing, troubleshooting, and optimizing RTAB-Map-based robotic systems, as well as enhancing the understanding of the surrounding environment.

V. CONCLUSIONS

In this section, the results obtained in the system development are explained, where these results are still at the laboratory scale. From the conducted tests, which utilized an RGB-D camera as input for the creation of a 3D map using RTAB-Map, several key features were employed in map creation, including odometry, loop closure, and graph view. Additionally, Rviz ROS was utilized for 3D map visualization. The results obtained demonstrate that the system developed can successfully create and visualize 3D maps. In the map creation process, a total of 450 loop closures were detected, leading to an improved map quality. This system, developed for mapping areas, can be utilized to visualize hazardous locations that are challenging for humans to access.

VI. ACKNOWLEDGEMENTS

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VII. REFERENCES

[1] K. Peterman and M. Cordes, ‘The Ring of Fire: Volcanoes and Other Natural Forcing’, in *Contextualizing Climate Change: Linking Science and Culture*, vol. 1382, 0 vols, in ACS Symposium Series, no. 1382, vol. 1382. , American Chemical Society, 2021, pp. 27–36. https://doi.org/10.1021/bk-2021-1382.ch004

[2] K. Dubov, *Journey to the Republic of Indonesia: Review & Analysis*. Kalman Dubov, 2021.

[3] ‘Pusat Vulkanologi dan Mitigasi Bencana Geologi - Badan Geologi’. Accessed: Feb. 03, 2022. [Online]. Available: https://vsi.esdm.go.id/index.php/kegiatan-pvmbg/kegiatan-diseminasi-informasi/3888-gempa-bumi-merusak-di-indonesia-tahun-2021

[4] A. Kadambi, A. Bhandari, and R. Raskar, ‘3D Depth Cameras in Vision: Benefits and Limitations of the Hardware’, in *Computer Vision and Machine Learning with RGB-D Sensors*, L. Shao, J. Han, P. Kohli, and Z. Zhang, Eds., in Advances in Computer Vision and Pattern Recognition. , Cham: Springer International Publishing, 2014, pp. 3–26. https://doi.org/10.1007/978-3-319-08651-4_1

[5] F. Nex and F. Remondino, ‘UAV for 3D mapping applications: a review’, *Appl. Geomat.*, vol. 6, no. 1, pp. 1–15, Mar. 2014, https://doi.org/10.1007/s12518-013-0120-x

[6] J. Suh and Y. Choi, ‘Mapping hazardous mining-induced sinkhole subsidence using unmanned aerial vehicle (drone) photogrammetry’, *Environ. Earth Sci.*, vol. 76, no. 4, p. 144, Feb. 2017, https://doi.org/10.1007/s12665-017-6458-3

[7] S. Muharom, T. A. Sardjono, and R. Mardiyanto, ‘Real-Time 3D Modeling and Visualization Based on RGB-D Camera using RTAB-Map through Loop Closure’, in *2023 International Seminar on Intelligent Technology and Its Applications (ISITIA)*, Jul. 2023, pp. 228–233. https://doi.org/10.1109/ISITIA59021.2023.10221078

[8] ‘Local Generating Map System Using Rviz ROS and Kinect Camera for Rescue Robot Application’, *Int. J. Electron. Telecommun.*, Sep. 2023, https://doi.org/10.24425/ijet.2023.146516

[9] S. Muharom, ‘Automatics Detect and Shooter Robot Based on Object Detection Using Camera’, *PRZEGLĄD ELEKTROTECHNICZNY*, vol. 1, no. 1, pp. 52–56, Jan. 2022, https://doi.org/10.15199/48.2022.01.07

[10] S. Muharom, I. Masfufiah, D. Purwanto, R. Mardiyanto, B. Prasetyo, and S. Asnawi, ‘Room Searching Robot Based on Door Detection and Room Number Recognition for Automatic Target Shooter Robot Application’, *Proc. 1st Int. Conf. Electron. Biomed. Eng. Health Inform.*, pp. 43–54, 2021, https://doi.org/10.1007/978-981-33-6926-9_4

[11] S. Muharom, Tukadi, T. Odinanto, S. Fahmiah, and D. P. P. Siwi, ‘Design of Wheelchairs Robot Based on ATmega128 to People with Physical Disability’, *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 462, p. 012016, Jan. 2019, https://doi.org/10.1088/1757-899X/462/1/012016

[12] R. A. Firmansyah, W. S. Pambudi, T. Suheta, E. A. Zuliari, S. Muharom, and M. B. S. Hidayatullah, ‘Implementation of Artificial Neural Networks for Localization System on Rescue Robot’, in *2018 Electrical Power, Electronics, Communications, Controls and Informatics Seminar (EECCIS)*, Oct. 2018, pp. 305–309. https://doi.org/10.1109/EECCIS.2018.8692861

[13] R. A. Firmansyah, I. K. Wicaksono, S. Muharom, Y. A. Prabowo, and A. Fahruzi, ‘Sorting Device Coding Print Quality Machine on Packing Box Prototype Utilizing Optical Character Recognition’, *J. Phys. Conf. Ser.*, vol. 2117, no. 1, p. 012017, Nov. 2021, https://doi.org/10.1088/1742-6596/2117/1/012017

[14] S. Muharom, A. Rizkiawan, I. Masfufiah, R. A. Firmansyah, and Y. A. Prabowo, ‘Detection and Erasing Scribble Blackboard System Based on Hough-Transform Method Using Camera’, *J. Phys. Conf. Ser.*, vol. 2117, no. 1, p. 012010, Nov. 2021, https://doi.org/10.1088/1742-6596/2117/1/012010

[15] E. Alfianto, S. Agustini, S. Muharom, F. Rusydi, and I. Puspitasari, ‘Design Monitoring Electrical Power Consumtion at Computer Cluster’, *J. Phys. Conf. Ser.*, vol. 1445, p. 012027, Jan. 2020, https://doi.org/10.1088/1742-6596/1445/1/012027

[16] H. Rebecq, G. Gallego, E. Mueggler, and D. Scaramuzza, ‘EMVS: Event-Based Multi-View Stereo—3D Reconstruction with an Event Camera in Real-Time’, *Int. J. Comput. Vis.*, vol. 126, no. 12, pp. 1394–1414, Dec. 2018, https://doi.org/10.1007/s11263-017-1050-6

[17] G. R. Rodríguez-Canosa, S. Thomas, J. Del Cerro, A. Barrientos, and B. MacDonald, ‘A Real-Time Method to Detect and Track Moving Objects (DATMO) from Unmanned Aerial Vehicles (UAVs) Using a Single Camera’, *Remote Sens.*, vol. 4, no. 4, pp. 1090–1111, Apr. 2012, https://doi.org/10.3390/rs4041090

[18] M. Zhao, D. Zhou, X. Song, X. Chen, and L. Zhang, 'DiT-SLAM: Real-Time Dense Visual-Inertial SLAM with Implicit Depth Representation and Tightly-Coupled Graph Optimization', *Sensors*, vol. 22, no. 9, p. 3389, Apr. 2022, https://doi.org/10.3390/s22093389

[19] C. Fu, A. Carrio, and P. Campoy, 'Efficient visual odometry and mapping for Unmanned Aerial Vehicle using ARM-based stereo vision pre-processing system', in *2015 International Conference on Unmanned Aircraft Systems (ICUAS)*, Denver, CO, USA: IEEE, Jun. 2015, pp. 957–962. https://doi.org/10.1109/ICUAS.2015.7152384