DOI: https://doi.org/10.33103/uot.ijccce.21.3.1

Asus Xtion Pro Camera Performance in Constructing a 2D Map Using Hector SLAM Method

Heba Hakim[1], Zaineb M. Alhakeem[2], Ali Fadhil[3]

[1]*Computer Engineering Dept., Basra University, Basra, Iraq.*

[2]*Communication Engineering Dept., Iraq University College, Basra, Iraq.*

[3]*Electrical Engineering Dept., Basra University, Basra, Iraq.*

[1]*hiba.abdulzahrah@uobasrah.edu.iq*, [2]*zaineb.alhakeem@iuc.edu.iq*, [3]*ali.marhon@uobasrah.edu.iq*

Abstract*— Simultaneously and location mapping (SLAM) is an important technique for achieving a full autonomous navigation system by constructing a 2D map of the surrounding environment. A performance of two popular distance sensor (Asus Xtion Pro Camera and 2D LiDAR) in building a map of the indoor environment using Hector SLAM is presented in this paper. Navigation system using 2D LiDAR can only detect object on a certain level of plane. This leads to miss the obstacles that are below and/or above the level of laser scan. So the generated map will be inaccurate that causes collision during autonomous navigation. Asus Xtion Pro sensor can be a low cost alternative for a laser distance sensor in addition to its ability to provide 3D data. Using data of depth image, the entire obstacle will be detected to prevent collision. Many experiments in real time scenarios in indoor environment have been conducted to evaluate the performance of the RGB-D sensor vs. 2D LiDAR in constructing a 2D map. Furthermore, the results also indicate that some modifications on the parameters of Hector SLAM method are able to enhance the accuracy of map which is constructed by Asus Xtion Pro camera. Therefore, Asus Xtion Pro offers a good alternative to build a 2D map using Hector SLAM. This work is implemented in ROS on Raspberry Pi 3 B+.*

Index Terms*— 2D SLAM, Asus xtion pro camera, 2D LiDAR, Navigation system, ROS.*

I. INTRODUCTION

The navigation system can be developed by using simultaneously and location mapping (SLAM). SLAM is a mobile robot approach that can be used to construct a 2D/3D map of unknown environment depending on the acquired data from the sensor and computes the sensor location within a map at the same time [1-4]. The quality of map is important to success the process of navigation therefore the constructed map must include enough obstacles to ensure the collision avoidance.

Many sensors are used in SLAM methods including laser scanners, sonar sensors and cameras [5-10]. Over the past years, the laser distance sensors have generally been utilized in SLAM methods for robotics applications because of its high speed and accuracy. Although it has these features, its view is limited to a plane where it is mounted. Due to the high cost of these laser sensors, LiDAR called Neato xv-11 that has a low cost is utilized in this work to gather data as a 2D plane from an indoor environment. The algorithms of 3D SLAM is essentially based on 3D sensing device to construct a 3D map and estimate the pose. In the last 10 years, the development of SLAM algorithms based on computer-vision (such as using RGB-D camera) has actively begun [11-14]. The main disadvantage of these algorithms is the huge computations that consume the processing unit (CPU). While, 2D SLAM based on laser scanner is fast, simple, and not demanded a large amount of memory. Thus,

Received 6/4/2021; Accepted 28/6/2021

DOI: https://doi.org/10.33103/uot.ijccce.21.3.1

2D-SLAM approachs are commonly utilized and preferred in constructing of indoor environment mobile robot map [15-17].

So, RGB-D camera (Asus Xtion Pro) is used in this work instead of 2D laser scanners in 2D SLAM method (Hector SLAM) to solve the drawback of 2D laser scanners in detecting objects with variable sizes and shapes.

II. SYSTEM OVERVIEW

To compare the performance of Asus Xtion Pro camera in generating 2D map using 2D SLAM method (Hector SLAM) with respect to the performance of 2D LiDAR, the navigation system with Asus Xtion Pro camera has been proposed to replace 2D LiDAR sensor. There are 2 systems in this work: (1) Navigation system with 2D LiDAR, and (2) Navigation system with Asus Xtion Pro camera. In both systems, Raspberry Pi B+ 3 with stretch operating system is utilized as a powerful low cost micro-computer, since the aim of this work to get the navigation system with low cost (such as an assistive device for visually impaired people). The Hector SLAM method [17] is carried out using Robot Operating System. ROS is a framework to develop the applications of robot which contains a set of tools and libraries [18].

A. Navigation system with 2D LiDAR

This navigation system includes a Neato XV-11 LiDAR that is attached to a white cane as shown in *Fig.* 1 [19].

LiDAR is a very useful sensor in robotics platforms. It is used for navigation and localization. The problem is its high cost. In last years, the robots of vacuum cleaner are developed a lot in using advanced sensors. Lately, the low cost LiDAR sensor is available as a part of Neato robotic vacuum. Neato xv-11 LiDAR is 2-D laser scanner from robotic vacuum with a full 360° view of the environment that measures data with the 5Hz scanning frequency and distance range 0.15m-6m. It establishes the serial-communication with a Baud rate at 115200 bps.

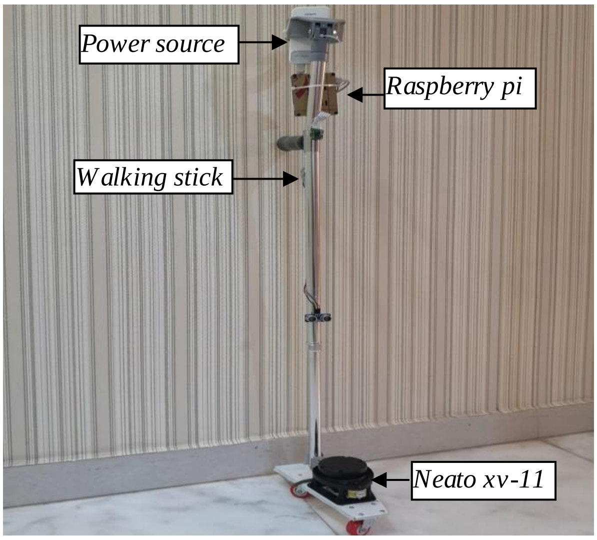


FIG. 1. NAVIGATION SYSTEM WITH LIDAR

Unlike the more expensive LiDAR that measures the distance based on time of flight technology, Neato xv-11 LiDAR is based on triangulation principle by using laser and CMOS imager with a small baseline between them. To measure the distance to object, an infra-red laser signal is emitted by laser transmitter from LiDAR with a determined angle to the object. To connect Neato xv-11 LiDAR to Raspberry Pi, the xv-11 controller v.2 is used. The xv-11 LiDAR controller is an interface board

Received 6/4/2021; Accepted 28l6l2021

 ISSN (Print) 1811-9212 ***ISSN (Online) 2617-3352***

DOI: https://doi.org/10.33103/uot.ijccce.21.3.1

connects the LiDAR, starts/stops it, and transfers the LiDAR serial data to a Raspberry Pi through the USB connection as well as control the speed of rotation (between 200-300 RPMs). The USB cable is used for communication and power. The USB port of Raspberry Pi powers the LiDAR by 5V and the motor is driven 3V to spin through a voltage regulator.

The data format of LiDAR is represented by packet with the length of 22 bytes. For a full revolution, 90 packets will be sent. Each packet contains four consecutive readings. So the total reading is 360 (at 1 degree increments) at 5 Hz.

2D sensors (such as 2D LiDAR) that used in navigation and mapping system have a main problem to detect obstacle with small size and various shape. The scenarios describing this problem are shown in *Fig*. 2.

The first scenario shows that a sensor mounted at a specific height cannot see the obstacle that is appeared under its visible range. Another scenarios show that it may not interpret the location of obstacle correctly if the obstacle has a non-uniform shape (like L-shape). To solve this limitation, RGB-D camera (Asus Xtion Pro) was used in this work.

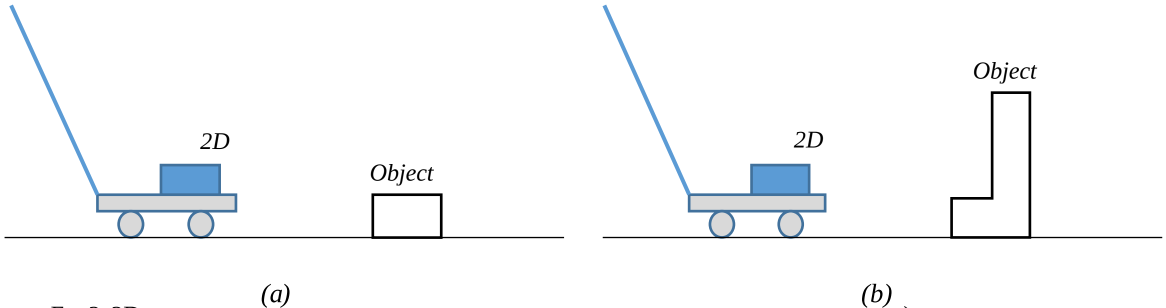


FIG 2. 2D SENSOR SCENARIO UNABLE TO DETERMINE THE CORRECT LOCATION OF OBJECT: (A) OBJECT UNDER THE VISIBLE RANGE OF LIDAR (B) OBJECT WITH UNIFORM SHAPE

B. Navigation system with RGB-D camera

This system contains Asus Xtion Pro camera as shown in *Fig*.3 [20] to be used rather than 2D LiDAR to solve the detection problem of obstacles with different shapes and sizes.

Asus Xtion Pro camera is one of the most common active 3D sensors. It is introduced by PrimeSense and Asus Companies in 2012 . This type of sensors is a structured light sensor where the triangulation principle has been used to determine the depth (distance) for each pixel.

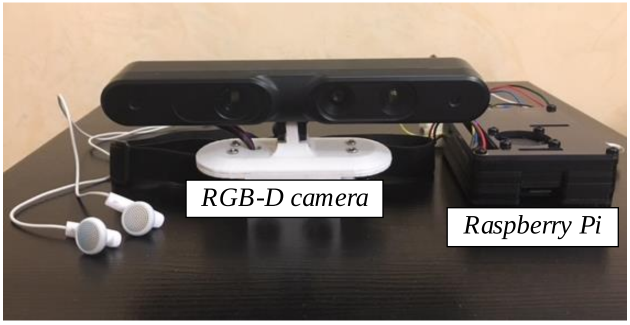


FIG 3. NAVIGATION SYSTEM WITH RGB-D CAMERA

Asus Xtion Pro contains (1) a VGA camera to gather RGB image, (2) depth sensor determines the distance of object from the camera to acquire a depth image, and (3) two microphones. RGB image as well as raw depth map are provided with resolution of 640 × 480 pixels at 30 fps. It has an angular field of view of 58° horizontally and 45° in vertical axis. It is held on a stand to allow manually tilt which may be up to 70°. The accurate working distance range of the depth camera is from 0.8 m to 3.5 m. With this camera, it is possible to gather a 3 channels color image (Red, Green, and Blue), each one of these channels has 8 bits, and also depth information has 11 bits per pixel in

Received 6/4/2021; Accepted 28l6l2021

DOI: https://doi.org/10.33103/uot.ijccce.21.3.1

visual image which has been expressed in mm (millimeters). The zero depth indicates that there is no information of depth at that particular pixel. IR laser source and an CMOS sensor (IR camera) are used to compute the depth information. IR light is emitted from the IR laser source in the form of a known speckles pattern by the diffraction grating on the view in front of the camera. these reflected spackles are read by IR camera. After that, the processor of depth camera receives the speckle dot and computes the value of depth by correlating the captured pattern with a stored reference pattern which is located on the plane with a known depth to the sensor. The output of this processing is depth map [21, 22]. *Fig*. 4 shows the depth measurment process.

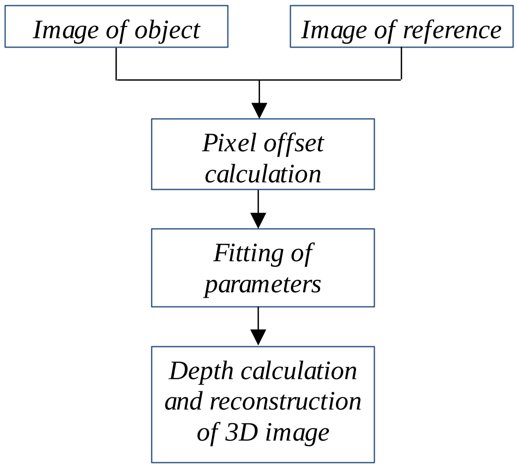


FIG 4. DEPTH MEASUREMENT PROCESS

Asus Xtion Pro live sensor in our system works mostly indoor environment, as sunlight produces high intensity IR interference that leads to saturation in the depth acquisition. In fact, this camera is not totally unused in outdoor environments but it can be used for a cloudy day or a night scene. Also, it is supplied a power from Raspberry pi board through USB 2.0. Asus Xtion Pro live is adopted in this work as a good alternative to laser scanners due to its compact design, low cost, USB powered, and low power usage.

III. THE METHODS

To construct an indoor environment map and estimate the location of a sensor within this map, a 2D SLAM method called hector SLAM [17] has been used. When the sensor is moving, the map is updated by using the sensor data. In order to utilize Asus Xtion pro camera as a 2D sensor for Hector SLAM approach , the depth data (3D) is transformed to 2D laser data [23].

A. Hector SLAM

Mapping and localization is implemented using Hector SLAM method [17]. Hector SLAM is the most common methods of 2D SLAM intended for the laser distance sensor. It is utilized in various applications of mobile robot to construct a final 2D map of the surrounding environment and at the same time the user position is estimated within a resultant map.

By the comparisom with other most 2D SLAM approaches, Hector SLAM does not need IMU (Inertial Measurement Unit) sensor or odometer information in order to work and localize well. Also, this method consumes low computational resources and has low error estimation [17, 24]. The 2D pose estimation in hector SLAM is only based on the powerful process of scan matching. The scan matching process is based on the Gaussian-Newton method, which optimally aligns endpoints of a laser scan with the constructed map. The laser scan end points are projected within a map and the probabilities of occupancy are estimated. The Gauss-Newton method is used to predict the next

Received 6/4/2021; Accepted 28l6l2021

DOI: https://doi.org/10.33103/uot.ijccce.21.3.1

position without need for search of a data association between the beam endpoints. The algorithm seeks to determine the best laser scan alignment within the map by finding the rigid transformation $\xi = (p_x, p_y, \psi)^T$ which can be expressed in (1):

$$\xi^* = \operatorname{argmin}_{\xi} \sum_{i=1}^{n} [1 - M(S_i(\xi))]^2 \qquad (1)$$

where the map value is returned by the function M(Si(ξ)) at Si(ξ) which are the world coordinates of scan end points $s_i = (s_{i,x}, s_{i,y})^T$. To start estimate ξ, Δξ which optimizes the error measure can be estimated according to (2):

$$\sum_{i=1}^{n} [1 - M(S_i(\xi + \Delta\xi))]^2 \rightarrow 0 \qquad (2)$$

When an IMU is utilized, Hector SLAM is also depended on 3D navigation method by Extended Kalman Filter (EKF)

In this work, IMU sensor was not used and Hector SLAM was applied by 2 different laser scan data. Since Hector SLAM in ROS depends on the use of LiDAR to build a map, the Neato XV-11 LiDAR has been used to provide the information of laser scan to the nodes in ROS. ROS provides driver for Neato xv-11 LiDAR which reads raw sensor data and convert it to laser scan format as ROS messages. This message contains an array of distance values in 2D plane that is used in building a map in SLAM.

When Hector SLAM is applied by Asus Xtion Pro camera, the laser scan data has been computed from the depth image obtained with Asus sensor. This approach will be discussed in section 3.2.

B. Depth image to 2D laser scan

The method described in [23] is adopted to convert depth information (3D) into 2D laser data. Firstly, the depth information is acquired from Asus Xtion Pro live camera (as an array of 640 ×480 pixels) that represented Z-coordinate. After that, The X-coordinate and Y-coordinate corresponding to each pixel in Z-coordinate (i.e. depth pixel) are stored in 2 separated array of size 640 × 480 pixels). That means, the algorithm has 3 arrays representing X, Y, Z coordinate with size 640 × 480 pixels for each one. Next, from every column of Z-array, the minimum element was chosen such that

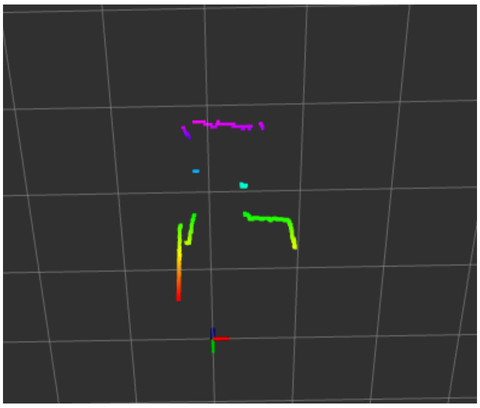
$$Z'_j = \min(Z_{0,j}, Z_{1,j}, Z_{2,j} \ldots \ldots Z_{479,j}) \qquad (3)$$

The X-coordinate for the minimum Z-element was chosen, resulting an array of 640×1 while the algorithm ignored the Y-coordinate as the movement will only be in direction of X and Z. These arrays represent the X and Z coordinates of the closest obstacle (i.e. the location of the closest obstacle without need for the vertical location).

By this method, RGB-D camera was utilized rather than the laser distance sensor to gather a 2D laser data to construct a 2D map by Hector SLAM. *Fig*. 5 shows the laser scan data acquired from Asus sensor in ROS where red color indicate to the object that is close to a camera while purple color is far from it. This observation was done in visualization tool in ROS called Rviz which has many tools to allow the visualization of the data of different sensors such as laser scan data, depth data, ... etc.. Furthermore, it has a tool to view an occupancy grid map in real time resulting from the process of mapping and localization.

Received 6/4/2021; Accepted 28l6l2021

DOI: https://doi.org/10.33103/uot.ijccce.21.3.1

(a) *(b)*

FIG 5. (A) A REAL SCENE OVERLAPPED WITH LASER SCAN, (B) LASER SCAN DATA

RESULTS AND DISCUSSION

The following subsections describe experiments in real time scenarios to evaluate Asus Xtion Pro sensor vs. 2D LiDAR in constructing a 2D map. Furthermore, the effect of changing Hector SLAM parameters has been studied. This proposed system is implemented in ROS.

A. RGB-D Camera vs. 2D LiDAR

To validate the mapping process with Asus sensor, Neato xv-11 was used to generate map and compare it with the one that was constructed using Asus sensor.

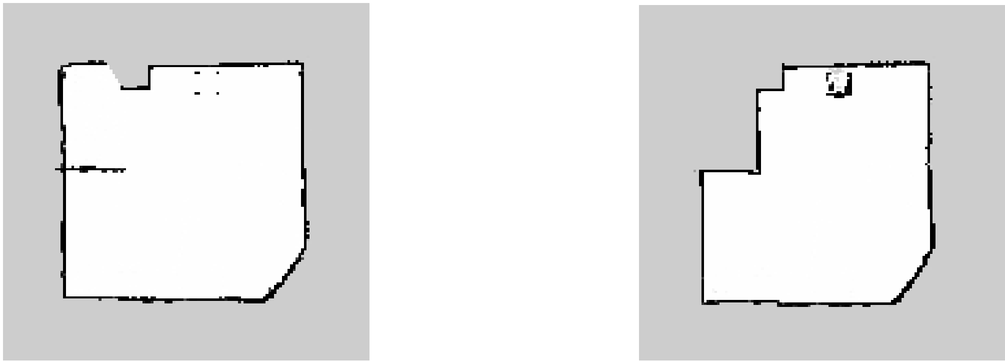
Hector SLAM method for both sensors is running with the same parameters except: (1) the minimum and maximum laser distance which are different because of the range of Asus Xtion Pro live camera differs from Neato xv-11 LiDAR; (2) the thresholds of map update which will be illustrated in subsection 4.2. Both techniques of laser scan were successfully able to build a 2D grid map. Each 2D map cell has a being occupied probability: (i) a free cell has white color; (ii) an occupied cell has black color; (iii) a cell that was not scanned has dark grey color. *Fig*. 6 (b) and *Fig*. 6 (c) show the obtained map using both techniques. As observed from *Fig*. 6 (b), some obstacles didn't appear in the map such as the surface of chair and bed. Only the legs of chair and bed are shown in a map because LiDAR will just see a part of the obstacle instead of whole shape. While the map that is constructed by using Asus sensor in *Fig*. 6 (c) shows the chair seat and bed which didn't appear in *Fig*. 6 (b). Also, the whole table in a 2D map from *Fig*. 7 (b) was not detected but only its legs appear because it is taller than the visible range of laser scan.

(a)

FIG 6. (A) REAL IMAGE.

Received 6/4/2021; Accepted 28l6l2021

DOI: https://doi.org/10.33103/uot.ijccce.21.3.1



(b) *(c)*

FIG 6. (B) 2D MAP USING NEATO XV-11, (C) 2D MAP USING ASUS XTION PRO LIVE.

(a)

(b) *(c)*

FIG 7. (A) REAL IMAGE, (B) 2D MAP USING NEATO XV-11, AND (C) 2D MAP USING ASUS XTION PRO LIVE.

B. Performance of Hector SLAM with changing the parameters using Asus Xtion Pro Live camera

There are many parameters of hector_mapping node. These parameters can be divided into:

- Map parameters: These parameters are used to adjust the properties of map such as the origin location, size, period of map publish, ... etc.. The most important one is the Thresolds of map update (map_update _angle_thresh and map_update_distance_ thresh). Both parameters are changed to study their effect on the performance of map updates by using laser scan data generated from Asus camera.

Received 6/4/2021; Accepted 28l6l2021

DOI: https://doi.org/10.33103/uot.ijccce.21.3.1

- Tf prameters: These parameters are used to set tf frames. tf is a package for transformation that allows computations in a coordinate frame and then converting them to other one in time at any desired point.
- Laser parameters: These parameters are used to adjust the thresholds of laser scanner. The default values of these parameters are for sensor of type Hokuyo UTM-30LX. So, they should be changed to match Asus camera which is used instead of this sensor.

In this section, the Hector SLAM performance has been studied on 2 types of environment (i.e. corridor with no feature and Room with some features). The some parameters was modified to study how the SLAM performance with Asus sensor changes. The real-time data used in this testing was recorded using the tool of ROS called ROSbag. This tool was used to allow analysis of offline Hector SLAM with various values of parameters.

As mentioned before, Asus camera range differs from the range of laser sensor, so the laser parameters in hector_mapping node were adjusted as:

- Laser_min_dist = 0.8 [m]
- Laser_max_dist = 3.5 [m]

In addition, the map size and resolution were changed to:

- Map_size = 512 [pixel]
- Map_resolution = 0.05 [m/pixel]

Since odom frame is not used, odom_frame has been set to:

- Odom_frame = base_link

Now, in both experiments, all other parameters were kept constant with the default values except the values of map_update_distance_thresh and map_update_angle_thresh were changed.

Since Asus Xtion camera has a limited field of view and range , the Hector SLAM was run with lower update threshold value. With this setting, the algorithm may be allowed to provide update of a map at a faster rate that leads to perform better position estimation and scan matching. *Fig*. 8 (b) shows the resultant maps on image of a real-time scenario in *Fig*. 8 (a) when changing distance threshold of map update from 0.1 [m] to 0.8 [m] and angle threshold of map update from 0.1 [rad] to 0.8 [rad] simultaneously. As seen from maps, there is no effect on the final map when a parameter of angle threshold was modified while keeping the parameter of distance threshold constant. On the other hand, these final maps improved when the parameter of distance threshold was decreased. So, it can be observed that Hector SLAM provides an accurate 2D grid map at lower value of distance threshold of map update 0.1 [m]. In our hector_mapping node, this parameter was adjusted to 0.2 [m]. With these setting, the environment has been mapped accurately and the quality of maps are noticed to outperform the map building using the default value of parameters.

(a)

(Continue)

Received 6/4/2021; Accepted 28l6l2021

Iraqi Journal of Computers, Communications, Control & Systems Engineering (IJCCCE), Vol. 21, No. 3, Sep 2021

DOI: https://doi.org/10.33103/uot.ijccce.21.3.1

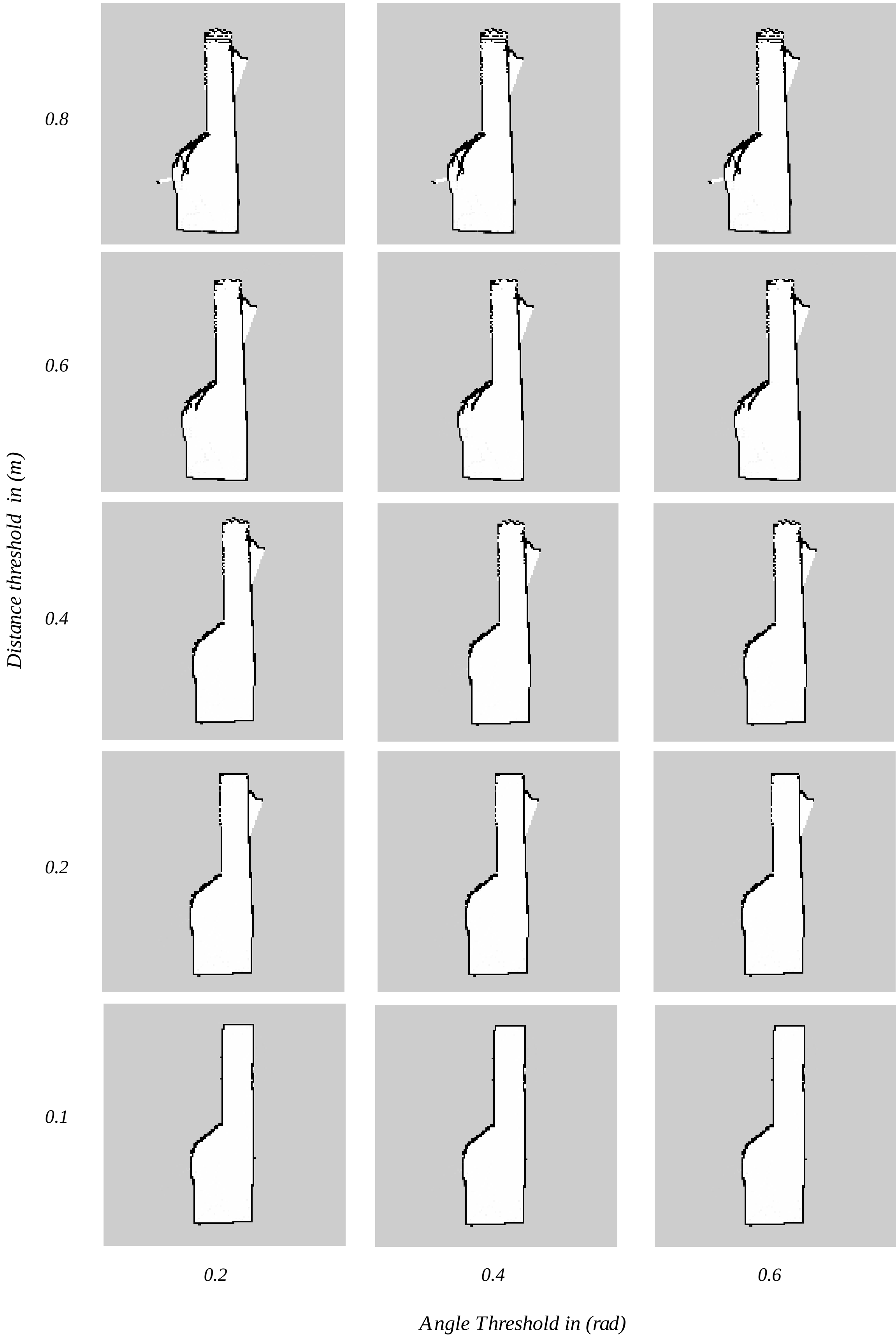


FIG 8. (A) IMAGE OF A REAL-TIME SCENARIO, (B) HECTOR SLAM WITH VARIOUS ANGLE AND DISTANCE THRESHOLD

Received 6/4/2021; Accepted 28l6l2021

DOI: https://doi.org/10.33103/uot.ijccce.21.3.1

CONCUSION

The comparison between two modern sensors (RGB-D camera and LiDAR) in construction a 2D map has been illustrated in this paper. That leads to utilize Asus Xtion Pro camera as a low cost sensor rather than 2D laser scanners to solve the detection problem of obstacles with variable shapes and sizes. Moreover, the suitable setting of Hector SLAM parameter values has been adjusted to construct a high-quality map of unknown surrounding environment with Asus Xtion Pro camera. Hector SLAM has been chosen among all other methods of 2D SLAM because of its accurate constructed map, the pose estimation, which is determined by the process of scan matching without requiring the information of odometry and a lower computational complexity because the Gauss-Newton algorithm, is used. Also, 2D SLAM approaches are faster than 3D SLAM and these approaches do not need high performances platform. In addition, this work shows the ability of a low cost hardware platform (Rasberry Pi 3 B+) to run real-time Hector SLAM operation. The specific aim of this work is to adopt this approach to achieve a low cost navigation system. In a future work, Hector SLAM based on Asus Xtion Pro camera will be adopted in an assistive navigation system to aid a visually impaired person who has low income and can't afford the cost of the expensive assistive devices to navigate safely in an unknown environment.

REFERENCES

[1] H. Durrant-Whyte and T. Bailey, "Simultaneous Localization and Mapping (SLAM): Part I The Essential Algorithms", IEEE Robotics and Automation Magazine, Vol. 13, No. 2, pp. 99-110, 2006.

[2] T. Bailey and H. Durrant-Whyte. “Simultaneous Localization and Mapping (SLAM): Part II”, IEEE Robotics and Autonomous Systems (RAS) Magazine, Vol. 13, No. 3, pp. 108–117, 2006

[3] C. Cadena, et al., “Past, Present, and Future of Simultaneous Localization and Mapping: Towards the Robust-Perception Age”, IEEE Transactions on Robotics, Vol. 32, No. 6, pp. 1309-1332, 2016.

[4] M. Dissanayake, et al., "A Solution to the Simultaneous Localization and Map Building (SLAM) Problem", IEEE Transactions on Robotics and Automation, Vol. 17, No. 3, pp. 229–241, 2001.

[5] G. Chaudhari, et al, "Robotic Assistant for visually impaired using sensor fusion", In: Proc. of International Conf. IEEE on (SmartWorld/ SCALCOM/ UIC/ ATC/ CBDCom/ IOP/ SCI). pp. 1-4, 2014.

[6] J. Bai, et al., "Wearable travel aid for environment perception and navigation of visually impaired people", Sensors, Vol. 8, No. 2, pp. 1-27, 2019.

[7] Y. Endo, et al., "Indoor positioning and obstacle detection for visually impaired navigation system based on LSD-SLAM", In: Proc. of International Conf. IEEE on Biometrics and Kansei Engineering (ICBAKE), pp. 158-162, 2017.

[8] K. Ramesh, et al., "Real-time localization and navigation in an indoor environment using monocular camera for visually impaired", In: Proc. of International Conf. IEEE on Industrial Engineering and Applications (ICIEA), pp.122-128, 2018.

[9] H. Hussain and E. K. Hamza," Indoor Localization System using Wireless Sensor Network", Iraqi Journal of Computers, Communications, Control and Systems Engineering, Vol.18, Issue 1, pp. 29-38, 2018.

[10] N. J. Jihad and S. M. Abdul Satar, "Optical Camera Communication performance evaluation: Review", Iraqi Journal of Computers, Communications, Control and Systems Engineering, Volume 20, Issue 3, Pages 42-49, 2020

[11] M. Labbe, and F. Michaud, "RTAB-Map As an Open-source Lidar and Visual Simultaneous Localization and Mapping Library for Large-scale and Long-term Online Operation”. Journal of Field Robotics, Vol. 36, No. 2, pp. 416–446, 2018.

[12] F. Endres, et al., "3D mapping with an RGB-D camera", IEEE Transactions on Robotics, Vol. 30, No. 1, pp. 1-11, 2014.

[13] R. Mur-Artal, et al., "ORB-SLAM: A Versatile and Accurate Monocular SLAM System", IEEE Transactions on Robotics, Vol. 31, No. 5, pp. 1147–1163, 2015.

[14] M. Raul, and J. Tardos, "ORB-SLAM2: an open-Source SLAM system for monocular, stereo, and RGB-D cameras", IEEE Transactions on Robotics, Vol. 33, No. 5, pp. 1255–1262, 2017.

[15] G. Grisetti, et al., "Improved techniques for grid mapping with Rao-Blackwellized particle filters", IEEE Transactions on Robotics, Vol. 23, No. 1, pp.43-46, 2007.

Received 6/4/2021; Accepted 28l6l2021

DOI: https://doi.org/10.33103/uot.ijccce.21.3.1

[16] B. Steux and O. Hamzaoui, "tinySLAM: a SLAM algorithm in less than 200 lines C-language program", In: Proc. of International Conf. IEEE on Control Automation Robotics & Vision, pp. 1975-1979, 2010.

[17] S. Kohlbrecher, et al., "A flexible and scalable SLAM system with full 3D motion estimation", In: Proc. of International Conf. IEEE on Safety, Security, and Rescue Robotics, pp. 155-160, 2011.

[18] J. O'Kane, "A Gentle Introduction to ROS", ISBN: 978-14-92143-23-9, 2018.

[19] H. Hakim and A. Fadhil, "Indoor low cost Assistive device using 2D SLAM based on LiDAR for Visually Impaired People", Iraqi Journal of Electrical and Electronic Engineering, Vol. 15, No. 2, pp. 115-121, 2019.

[20] H. Hakim and A. Fadil, "Navigation system for visually impaired people based on RGB-D camera and ultrasonic sensor", ACM International Conference on Information and Communication Technology, pp. 172-177, 2019.

[21] T. Jia, Z. Zhou, and H. Gao, "Depth Measurement Based on Infrared Coded Structured Light", Hindawi , Journal of Sensors, Vol. 2014, pp. 1-9, 2014.

[22] H. Hakim, Z.Alhakeem, and S. Al-Darraji, "Goal Location Prediction based on Deep Learning using RGB-D Camera", Bulletin of Electrical Engineering and Informatics Journal, Vol. 10, No. 5, pp. 2811-2820, 2021.

[23] K. Kamarud, et al., "Method to convert kinect's 3D depth data to a 2D map for indoor SLAM", In: Proc. of International Conf. on Signal Processing and its Applications (CSPA), pp. 247-251, 2013.

[24] H. Hakim and A. Fadil, "Indoor Wearable Navigation System Using 2D SLAM Based on RGB-D Camera for Visually Impaired People", Springer, Advances in Intelligent Systems and Computing, Vol. 1292, pp. 661-672, 2021.

Received 6/4/2021; Accepted 28l6l2021