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Indoor localization Using SLAM

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Abstract. Simultaneous Localization and Mapping (SLAM) is one of the main and well researched topics to robotics, namely, in the field of autonomous and environment aware robots. SLAM is used in many applications such as self-driving cars, and robotic indoor localization. This paper investigates the current methods and approaches used in mapping. It also studies the feasibility of designing an affordable mapping device using off the shelf components and open-source software. The paper includes a case study for designing a hand-help mapping device. Portable laser rangefinders (LIDAR) are the sensor used for creating the maps. AI aided computer vision is suggested for use. A full design is described including top-level, finite state machine, schematics, raw data logging, and an in-door mapping algorithm. Every aspect is tested using simulation and real data. The paper also tests an open-source operating system as an implementation environment. Also, the paper introduces an alternative approach for mapping, namely, autonomous mapping using a small, wheeled robot. Finally, all results are discussed and analyzed, also, possible future work and improvements are highlighted.

Keywords: SLAM, robotics, computer vision, indoor localization.

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1. Introduction

Building floor plans are a useful asset in a variety of applications. Typically, Computer aided design (CAD) is used in producing these maps. Sometimes, manual surveys also needed to be combined with it to collect multi-layered plans. The manual surveys usually conducted a human labour equipped with laser tape measures. These two methods are widely used in building management tasks, however, the production of such floor plans can be labour intensive and can be slow, and subject to human errors, due to the lack of accuracy.

Therefore using SLAM can be used in surveys, which can swiftly and accurately mitigate errors and mistakes that are caused by the complexity of building structure. One possible downfall of using SLAM is that it requires a significant amount of computational power. There are a number of research areas dedicated to reducing the computational complexity requirement as in [1-5].

The main aim of this paper is to investigate the feasibility of designing a hand-held device that can be used in building surveying using off the shelf components combined with open source code and software. This paper also investigates the current methods and approaches used in mapping using SLAM.

Portable laser range-finders (LIDAR) sensors and AI aided cameras are used to create the indoor maps. A full design is described in the report including: top level, finite state machine, schematics, raw data logging, and an in-door mapping algorithm.

The prototype is tested using an online simulation tool. The paper also tests an open-source operating system as an implementation environment. Also, the paper introduces an alternative approach for mapping, namely, autonomous mapping using a small wheeled robot.

Finally, all results are discussed and analysed, also, possible future work and improvements are highlighted.

2. Mapping and ranging in literature

Authors in [6] shows the importance of portable laser rangefinders which also known as LIDAR in SLAM research. SLAM is used to visualise and generate floor plans using real-time data. Acquiring data in real time helps building surveys assessing the quality of the captured data. The authors also highlight the necessity of building portable mapping device. The also stated the importance of limiting the computational recourses of such a capturing device. In their papers the authors present a method that facilitate a backpack to work as a mapping platform. The approach used in their paper achieves a real-time mapping with 5 cm resolution. Branch and bound technique is used to compute the scan-to-subman matches as contains for the real-time data. Further details and all the empirical data and finding can be found in [7]

2.1. Mathematical representation

SLAM often formulated as a combinatorial optimisation problem. Such approach is presented in [6]. The authors used a novel Bayesian estimation method for pedestrian's localisation and simultaneous mapping. The suggested method uses odometry with inertial measuring unit (IMU) mounted on their footwear.

They described the methodology with great details, however, to summarise, when pedestrians roam within a certain area such as indoor spaces, the odometry data collected from IMU can provide some of the area characteristics such as doors, walls, and turns. The authors where capably of extracting this information even when the data suffers oddities such as noise and drift prone. The authors were able to construct whole maps out of those readings. The called their novel approach FootSLAM. The authors claim that the IMU enabled them to achieve a very stable relative positioning with 1-to-2-meter accuracy [8].

2.2. SLAM Types

Without losing generality, SLAM can rely on different type of sensors. In this section four SLAM sensing technique are listed.

2.2.1. Acoustic SLAM

Direction of Arrival (DoA) is often used to estimate and locate a sounds source position in 3D space. This expanded the SLAM techniques to the acoustic domain. In this approach the 3D position of the sound sources works as anker points in mapped environment. To deploy this method the mapping device should be equipped with microphone arrays so the DoA can be estimated adequately [9]. This type of SLAM laid the foundation to expand these type studies and research in acoustic scene mapping.

2.2.2. Audio-Visual SLAM

The main purpose of this technique used to be the interaction between robots and humans. It provides a platform and common framework. The idea is to fuse the data from both audio and video sources to construct surrounding awareness.

The SLAM algorithms designed for Human-centred robots try to mimic the human environmental perception. The robot tend to interactive with acoustic as well as visual modalities and stimulus.

This method is used in drones service robots and other mobile robotic applications. The use of lightweight and low power components like microelectronic microphone arrays and monocular cameras and is empirical [10].

Audio-Visual SLAM has the capability to enable complimentary function of these type of sensors, by compensating the narrow field of view, optical degradations

2.2.3. Collaborative SLAM

Collaborative SLAM combines Data and visual inputs obtained from multiple robots or users to construct maps [11].

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3. Implementation

The Robot Operating System or what is sometimes referred to as ROS is defined to be an open source flexible framework for writing, developing and running robot software. The operating system consists of a collection of programming libraries, simulation tools, and conventions that aim to simplify the task of creating complex and robust robot behavior across a large range of robotic platforms.

Fig. 1. Four Wheeled SLAM Robot

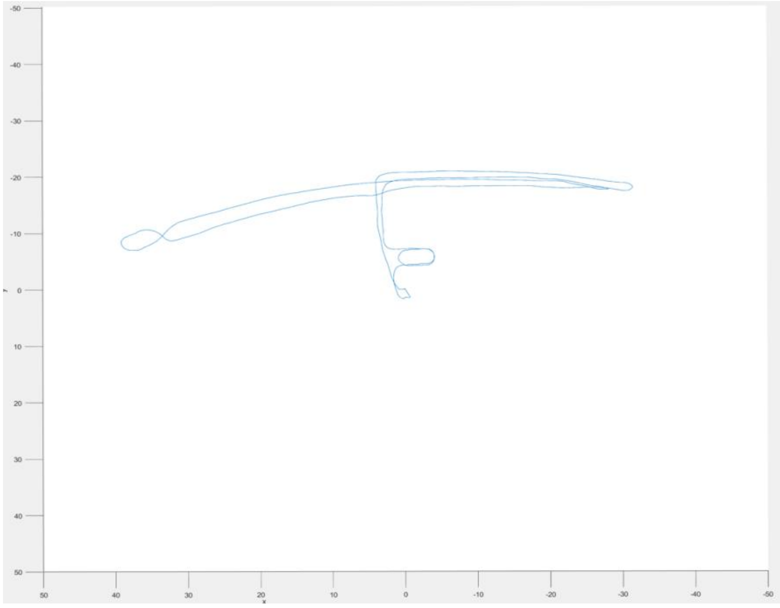

Fig. 2. Angelsea Building Route Map (Top view)

One of the well-known examples of simulation platforms is ROS studio. ROS studio is a powerful simulation tool used in robotic mapping algorithm proof of concept. It enables the implementation of the code algorithm and then monitors the analysis performance. The monitoring mechanism can be both visual representation and

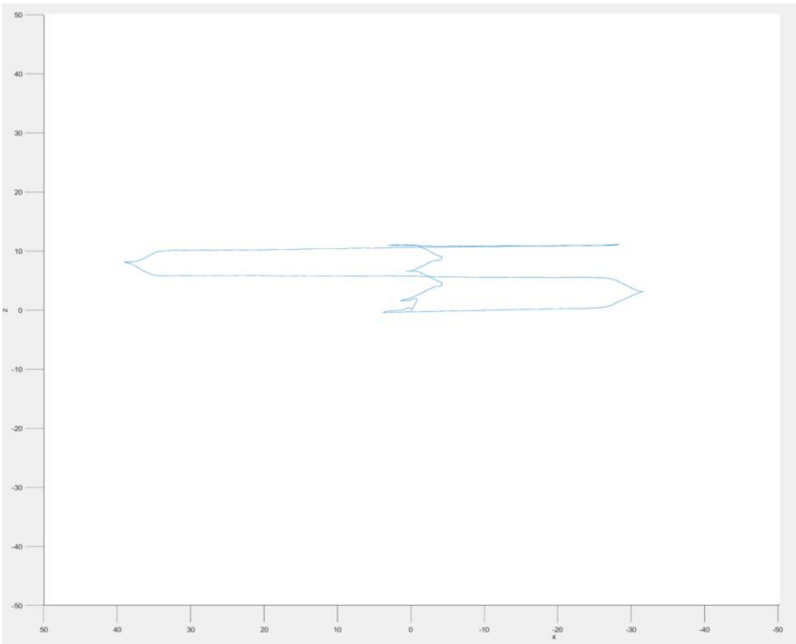

Fig. 3. Anglesea Building Route Map (side view)

3.1. Simulation

Ros Studio provides an online simulation tool that can work as a testbench for the code. The IDE also provides a visualisation tool when RIV software can be run on one window while terminals can be added to control the hardware. The environment is very versatile. The general user interface can be seen in the picture below.

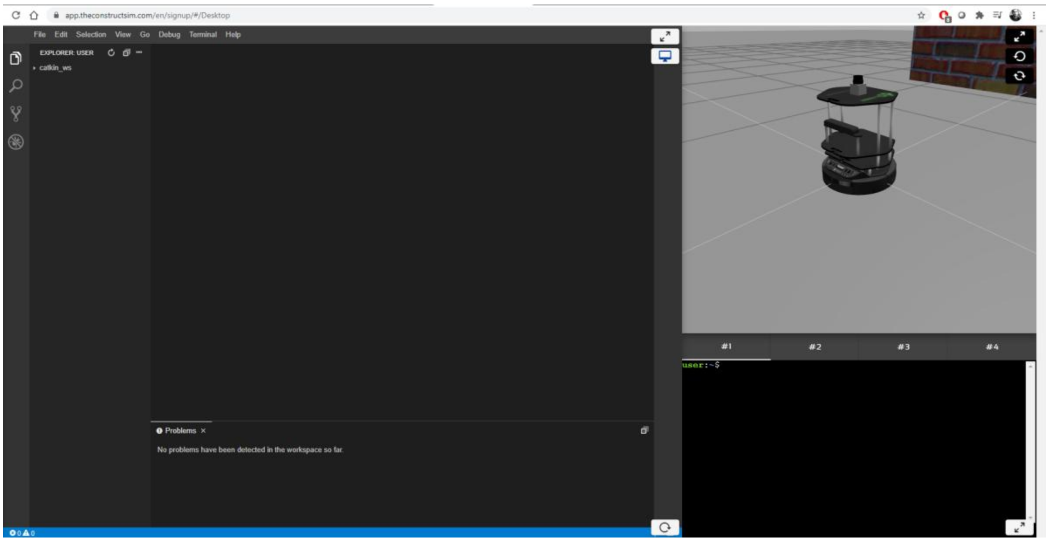

Fig. 4. Simulation Environment

As it can be observed in the figure above, the environment consists of adjustable windows that can provide different levels of simulated interface with the ROS. These windows can be adjusted as required. For example in the following figure. The IDE was configured to have two terminals, simulation environment, RISv software and testing environment.

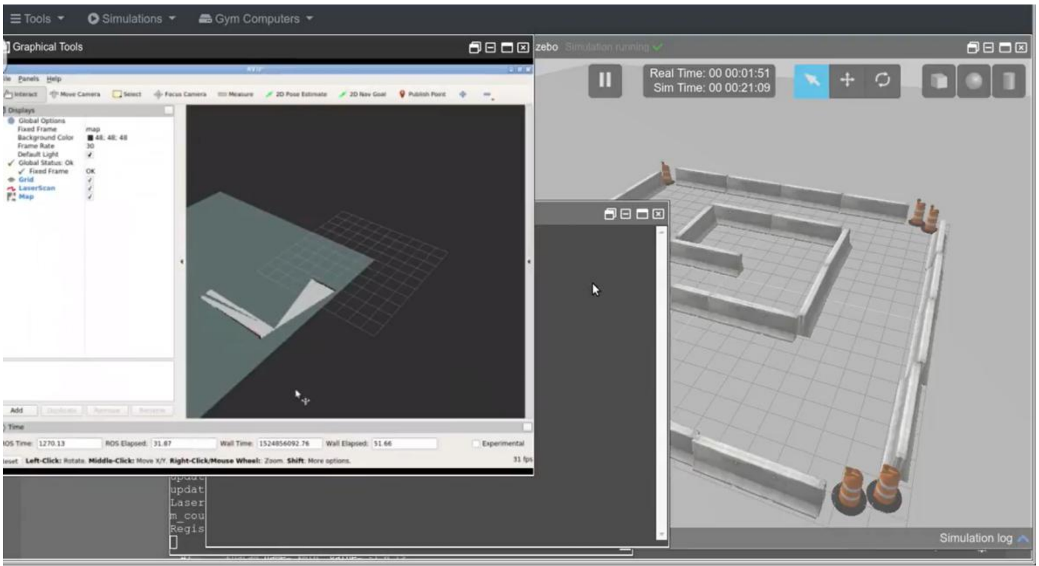

Fig. 5. Map Simulation

The ROS Studio can also work as a Linux based machine that can accept git and other Linux commands, which enables adding repositories. This enables fast testing and deployment of open source software and code.

All the code that has been used was first tested using the simulation environment to validate the proof of concept.

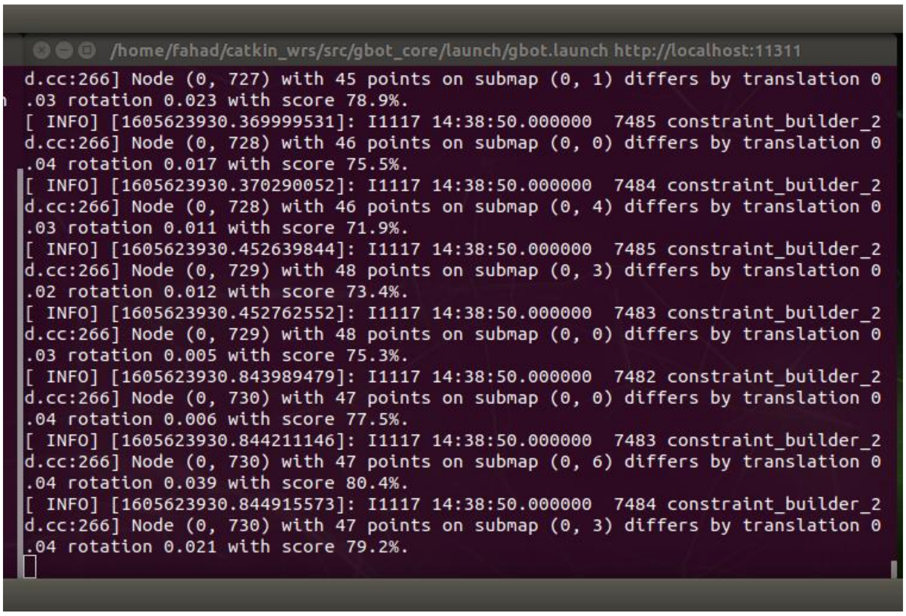

Fig. 6. Lidar Raw Data

3.2. Visualisation

This section will address the visualization procedure of the mapping. There should be two terminals used. The first one is to start the LIDAR data acquisition routine. The second one is to link the data with the Rviz software to construct and update the map. As shown in the figure below.

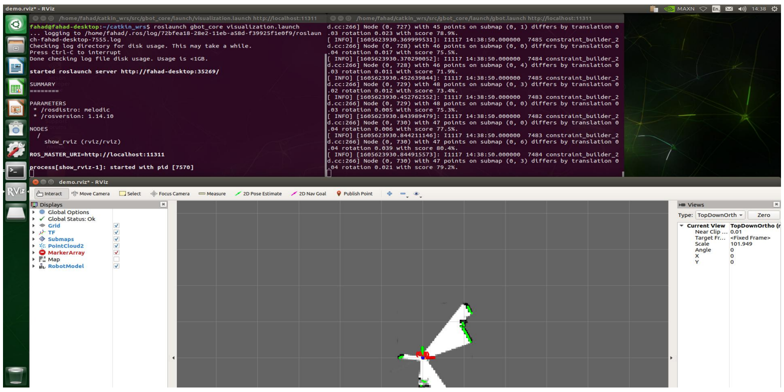

Fig. 7. Live Data Streaming

4. Result Analysis and Conclusion

The original aim of the paper was to create a hand-held indoor mapping device. This was achieved, moreover, further enhancement is suggested and deployed. There are five main outcomes, namely, indoor mapping, indoor localisation, indoor navigation, and finally AI based object recognition. Indoor mapping is done in two stages. The first stage is to collect live data from the LIDAR sensor. The second stage is to construct a map from the collected data. The map is created simultaneously while the sensor data is obtained.

Indoor localisation was achieved by two-dimensional fusing of live data streams collected from sensors with previously constructed maps of the location. One advantage of using the mapping algorithm suggested in this paper was the ability of updating the indoor map well as the indoor localisation. This is done by using a two-layered decision tree. The first layer depends on the probabilistic method suggested in the previous chapter. The second layer is map update. Once the device achieves an above certainty threshold score; it would address any differences in the map then update them accordingly.

During the development, four design cycles were achieved. The first cycle was conducted with simulation. The second cycle was the hardware implementation. This cycle highlighted a few issues which simulation did not reveal, namely, data jitter as it will be explained in later sections. The mitigation of the jitter was proposed and tested in the third cycle by introducing few sensors. During the last cycle a four-wheels chassis was added, with all the relevant motor motion control circuitry.

Design process and result evaluation. The first stage was the raw data collection and logging. This was achieved purely by the LIDAR data without any historical references as shown in the presentation video and figure below.

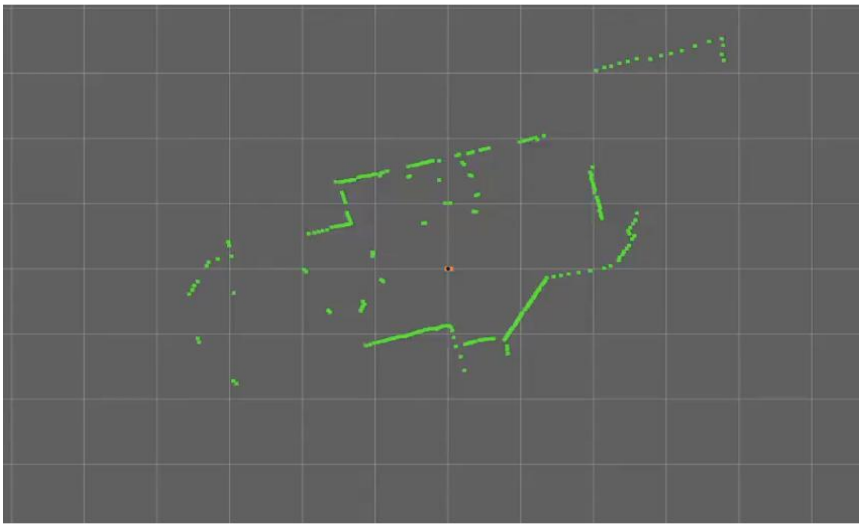

Fig. 8. Raw data

In the figure above every point is an independent LIDAR reading. It can be seen clearly from that there are outer edges with missing gaps due to the presence of some obstacles. The second stage was to construct a map using the data, however, the produced map ended up being jittery with a lot of fade, which led to the second cycle of the development stage. The mitigation of the jitter was achieved by data fusing. IMU sensor was used to provide a calibration for the data, while providing extra depth with the 3-axis tracking of the device.

Rvis is a very powerful tool that can be a suitable environment for such a task. After fusing data with IMU and historical LIDAR data; a much better maps were produced which had better resolution, updated in real-time, and more accurate. The figure below shows an example of the constructed maps. More details are also available in the attached videos.

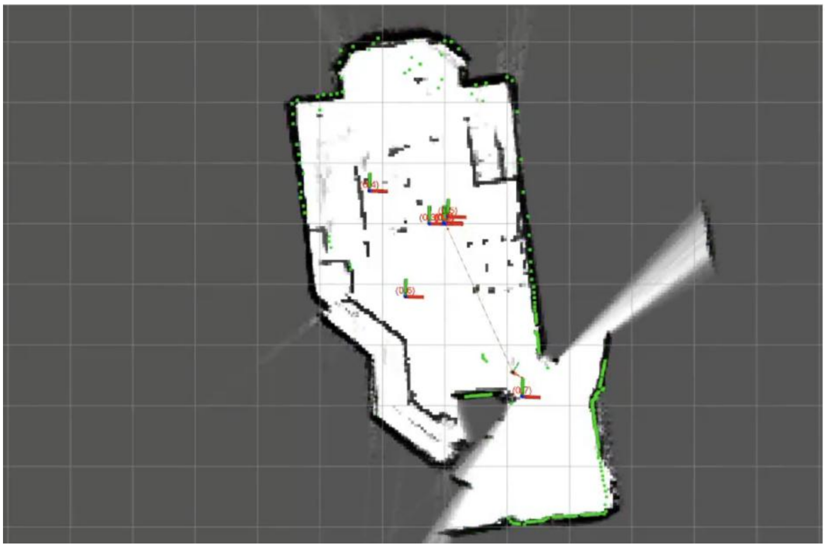

Fig. 9. Map constructions

As it can be seen from the figure. The black lines are constructed from historical data, whilst the green data are the live data stream obtained from the LIDAR. Adding the IMU sensor added new depth to the device as it enabled the path tracking along three dimensions as well as data calibration.

The following picture shows the path tracking. The blue lines show the track that the device was on. Further examples are available in the attached video. The IMU also enabled 3-axis positioning and tracking, as shown in chapter three with AnFgelsea building example.

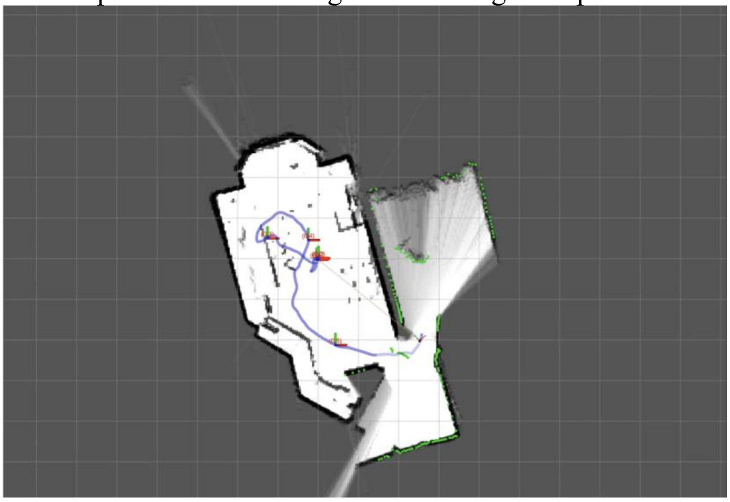

Fig. 10. Path tracking with IMU stabilisation

The final map shown in the figure above in fact is a multi-layered image consisting of number images fused and projected on top of each other. The layers are as follows: Live Data, historical data, stored map, path tracking, and finally IMU 3-axis. Positioning.

The final stage was the addition of the chassis. That expanded the objective. The original plan was to design a hand-held device. The added capability can also take advantage of some of the RVIS tools. It is possible to control the vehicle using the same software and also by planning robot routes using reference points.

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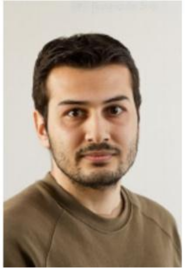

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مجلة كلية العراق الجامعة للهندسة والعلوم التطبيقية

الية التمركز الداخلي بأستخدام تقنية SLAM

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الملخص . التمركز المتزامن ورسم الخرائط (SLAM) هو أحد الموضوعات الرئيسية التي تم بحثها جيدًا في مجال الروبوتات ,وتحديدا في مجال الروبوتات المستقلة والمدركة للبيئة. يتم استخدام SLAM في العديد من التطبيقات التي تعتمد على انشاء الخرائط الانيه مثل ما هوا معمول به في العجلات ذاتية القيادة والتمركز الآلي في الأماكن المغلقة .تبحث هذه الدراسة في الأساليب والطرق الحالية المستخدمة في رسم الخرائط. كما يدرس جدوى تصميم جهاز رسم خرائط ميسور التكلفة باستخدام مكونات جاهزة وبرامج مفتوحة المصدر .يتضمن هذا البحث دراسة حالة لتصميم جهاز رسم خرائط يدوي. أجهزة تحديد المدى بالليزر المحمولة (LIDAR) هي المستشعر المستخدم لإنشاء الخرائط. يُقترح استخدام الرؤية الحاسوبية بمساعدة الذكاء الاصطناعي. يتم وصف التصميم الكامل بما في ذلك المستوى الأعلى ، وآلة الحالة المحدودة ، والخطط ، وتسجيل البيانات الأولية ، وخوارزمية رسم الخرائط الداخلية. في البحث سيتم اختبار كل جوانب التصميم الاولي باستخدام المحاكاة بالاضافه الى البيانات الحقيقية .تختبر هذه الدراسة أيضًا نظام تشغيل مفتوح المصدر كبيئة تنفيذ للتصميم. بالاضافه الو ذلك تقدم الدراسة أيضًا طريقة بديلة لرسم الخرائط، وتحديدا رسم الخرائط المستقلة باستخدام روبوت صغير رباعي العجلات وفي النهاية ،تتم مناقشة جميع النتائج وتحليلها ، ويسلط الضوء على الأعمال والتحسينات المستقبلية المحتملة.