Robotics Autonomous Surveillance Algorithms for Assessing Construction Automation and Completion Progress

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Abstract –

Exact development progress estimation has been demonstrated to be basic to the accomplishment of a structure venture. The techniques for robotized development progress estimation proposed in past examinations have certain constraints in light of fragmented informational collections. The principle target of this research was to create a precise, basically completely mechanized strategy for development progress estimation utilizing a 360□ cameras and 3D information with LiDAR technology to detect site plan by remote-detecting innovation. The cameras at that point select the parameter settings that best fulfill the relegated contending solicitations to give high goals perspectives on the stage accomplishments. We propose using robotic scanning with AI analytics to tackle the plaster stage and the camera parameter determination issues continuously. The adequacy of the proposed framework is approved in both reproduction and physical test. The consequences of the proposed progress estimation technique can be utilized as contribution for development progress representation and enhance the inspections timeframe.

Keywords –
Construction Robotics; Inspections Enhancements; AI Detection; Internal Mapping; Autonomous Inspection

1 Introduction

Robots and mobile platforms have recently begun to solve many of the goals for remote sensing. Mobile laser scanning devices have enabled the identification and classification of roadside objects [1].

Human-mounted solutions, like backpacks equipped with laser scanners, allow for human-in-the-loop navigation of indoor spaces [2]. These mobile solutions afford operators access to previously inaccessible regions that stationary systems cannot sense.

Autonomous and semi-autonomous mobile remote sensing platforms, including robots, further improve the flexibility that mobile sensing offers. Robotic agents can operate without the need of constant human presence and input [3][4]. Therefore, environments can be remotely sensed without involving or endangering humans, making surveying safer and more efficient. Many robotic platforms outperform their human counterparts in similar sensing and mapping tasks as well [5], which increases the reliability and accuracy of produced geospatial intelligence. This process of simultaneously localizing a robot in its surroundings and mapping these surroundings is known as Simultaneous Localization and Mapping (SLAM). The fine level details and autonomy afforded by SLAM robots have contributed to the ubiquity of these platforms as mobile and adaptable exploration solutions.

One result of the increased use in robotic remote sensing platforms is a greater portfolio of environments and spaces that can be explored. Urban and subterranean environments pose a unique challenge because they typically feature tight spaces and are often poorly lit. Additionally, underground caves are often rocky and difficult to traverse. Nonetheless, robots have been produced to explore these spaces. Urban-focused robots use three-dimensional (3-D) lidar to scan areas due to the high failure rate of visible-light dependent cameras [6][7]. As a result, robots can produce highly detailed maps for the precise environments for which they are selected, including deep mines and archaeological sites [8].

The goal is to provide the warfighter a cost-effective solution that provides situational awareness, in near real-time, of building interiors and Subterranean (SubT) environments. In order to address the gaps listed above, merging a mapping technology with a robotics platform that has limited computational and power resources will need be done successfully.

However, most commercially available LIDAR systems are designed for use outdoors, specifically for high-resolution aerial imaging and mapping applications. As a result, they tend to be large, heavy, power-hungry, data bandwidth intensive, and expensive and not suitable for integration on a robotics platform. Also, the amount of data collected is quite large (gigabits) and requires post-processing (days). In the last few years, the automotive industry's push for autonomy has resulted in a number of industries producing SWaP-C sensors that should be suitable for a robotics platform and still be capable of surveying and mapping underground structures and the interior of buildings.

This capability would provide the warfighter with data intelligence to develop situational understanding and support troop maneuverability. Utilizing these commercial off the shelf (COTS) low-power sensors to provide a near real-time solution has yet to be implemented, and the benefits provided when compared to their larger, expensive, and power-hungry counterparts are unrealized.

In regards to the robotics platform, the Maneuver Center of Excellence (MCoE) SubT equipment list has a variety of robot platforms, including the Firstlook and Packbot 510. Both of these robots are equipped with cameras, but neither system generates point clouds of the environment. In addition to the cost of the robotics platform, additional revenue is also required for mapping sensors (i.e., GeoSLAM ZEB-REVO or Carnegie Robotics Multisense). However, these sensors merely sit atop the robotics platform and do not leverage the robot's on-board sensors for enhanced positioning and localization. The robotics platform that is being leveraged for this report is the Army Ground Vehicle Robot (GVR-BOT) Gen 1.1 platform. This platform is the reference design standard for Project Manager (PdM) Unmanned Ground Vehicle. By combining the robot's localization and positioning sensors with the mapping solution, highly accurate data can be generated.

2 Literature Review

2.1 Robotics Surveillance

The construction industry is known to be a major economic sector. However, it is also dealt with different types of inefficiencies as well as low productivity. Robotics autonomous surveillance is a solution that has the potential to address such types of shortcomings. Delgado stated that robotics and subsequent automated systems can revolutionize and also provide several advantages to the overall construction industry [9]. Construction is considered to be a labour-intensive sector. Nonetheless, it can also be stated that the Robotic System automation can help to become very effective in other sectors as well for labour cost reduction and at the same time, look for productivity and quality improvement.

2.2 Robotics Automation

Different types of Construction Robotics exist in the construction industry. These can be group into 4 general categories. This include off-site prefabrication systems, on-site automated and robotic systems, drones and autonomous vehicles, and exoskeletons. The adoption of such robotic mechanisms can be largely attributed to the successful use of robots in the automotive manufacturing industry of Japan. Construction works need to be completed soon as significant financial matters are involved. However, this process can be automated as Artificial Intelligence (AI) can consider proper measures that will improve the situation related to robotics involvement in construction [9].

2.3 Factors of Robotics Automations

This is evident that there is a cost for the client for robotics adoption in their whole process. Governments are considered to be the major clients of all the construction and infrastructure companies. Furthermore, the public spending amount in the infrastructure can have a big influence as well in terms of adopting new technologies. The construction companies operate in a highly competitive market. If we consider that price is the only criteria for selection, then the construction companies can significantly consider reducing the overall profit margins in an aggressive manner. This type of manner will increase confrontational behaviour as well as restrict those people from alternative thinking [10].

2.4 Technical Factors

There is also case where different practical factors can limit the overall robotics related implementation. These factors can be attributed to the technical limitations that reside within the current technologies and also some other work-related factors.

The challenge in this case is the high complexity that remains within the construction tasks which also have effects on the usability and effective of the robotic automated solutions [9]. Construction robotics, with the help of AI detection and internal mapping, can consider construction automation and inform about completion. This type of autonomous inspection will bring results within a short period of time. To improve the quality of such inspections, it is preferred to have inspections enhancements in place [9].

A construction work consists of many stages. With AI detection and other latest technologies, it is possible to know about construction automation and completion period. The progress will help the stakeholders to make relevant decisions that will have an impact at the direct workflow.

2.5 Adaptation Process

There is a certain level of complexity in the overall construction process and hence, sufficient preparation is necessary for adaptability. All the participants who work in the construction process needs to be considered in the overall adaptation process. The autonomous inspection will help time and cost for the companies and help them focus on the core issues. The adaptation process of the robotic automation can take place through step by step process [11].

2.6 Robotics in Construction Automation

The robotic technology performance is on the rise rapidly and therefore, this can complement the construction process's automation and completion progress monitoring. Nonetheless, to conduct the operations flawlessly, workers need to have mechatronic and robotic training as well as qualifications [9]. The stakeholders and the decision makers can think about automation and integration of different advanced technologies in the construction field. This can be done when the guidelines are properly followed and considered into the thinking process.

Robotics can work in different forms and it has also been considered for augment abilities. There are working exoskeleton available which will not only help to enhance the wearer's mobility but also make them much stronger. This will make those people less prone towards any type of work-related injuries. These wearables eliminate major stress as well as damage that can result from being involved in physical labor too often [11].

Robotics and automation play a crucial role in the construction sector. It is also to be noted that there should be high technology of Research & Development to be used because of the dynamic and unstructured nature of the overall construction environment. There are several robotics automations which are used in the construction area and they include- fireproofing spray robot, wall finishing robot, steel beam positioning manipulator, spray coating robot, and ceiling panel positioning robot. In terms of the civil work, there are also the use of different types of robot, such as- semi autonomous robot, concrete crusher, demolition robot, robot for all jobs etc. Each of these robots have different purposes that they serve [12].

2.7 Robotics in Construction

The primary role of automated techniques in the construction sector is to develop a multidimensional as well as a comprehensive costs and benefits analysis which is related to some certain robotic application. The success in this regard can be analysed through the process of technical as well as economic feasibility. The technical feasibility is an ergonomic evaluation of the steps that help to complete the given work task. It also considers the analysis related to the robot control and process monitoring requirements [9].

Through the process of Robotics and Automation, we have also seen an increase in the overall occupational safety issue. Using robotics and its automation help especially in the case of dangerous zones. There are several automated systems which may help in working for the dangerous zones for the humans. This type of automation helps to reduce the labour related injuries and also keep company cost at a minimum. There is an increase in quality that is evident as well because of the robotics autonomous surveillance algorithms. These operations are carried out with less variability in comparison to the human workers [13].

The automation system possesses a greater control towards the whole production process. We are able to detect the problems easily and for different stage as well. Through this process, it gets easier to understand if there is a correct functioning of the system happening or not. The robotics automation gives greater control towards the final result and this can be controlled in an efficient way by look at the steps of the overall process individually.

3 Research Methodology

3.1 Lidar Automation

The method of simultaneous localization and mapping (SLAM) using a light detection and ranging (LiDAR) sensor is commonly adopted for robot navigation. However, consumer robots are price sensitive and often have to use low-cost sensors. Due to the poor performance of a low-cost LiDAR, error accumulates rapidly while SLAM, and it may cause a huge error for building a larger map. To cope with this problem, this paper proposes a new graph optimization-based SLAM framework through the combination of low-cost LiDAR sensor and vision sensor. In the SLAM framework, a new cost-function considering both scan and image data is proposed, and the Bag of Words (BoW) model with visual features is applied for loop close detection. A 2D map presenting both obstacles and vision features is also proposed, as well as a fast relocation method with the map.

Experiments were taken on a service robot equipped with a low-cost LiDAR and a front-view RGB-D camera in the real indoor scene. The results show that the proposed method has better performance than using LiDAR or camera only, while the relocation speed with our 2D map is much faster than with traditional grid map.

Localization and navigation are the key technologies of autonomous mobile service robots, and simultaneous localization and mapping (SLAM) is considered as an essential basis for this. The main principle of SLAM is to detect the surrounding environment through sensors on the robot, and to construct the map of the environment while estimating the pose (including both location and orientation) of the robot.

3.2 SLAM Detection

LiDAR can detect the distance of the obstacles, and it is the best sensor to construct a grid map, which represents the structure and obstacles on the robot running plane. The early SLAM research often used LiDAR as the main sensor. Figure 1 shows the obstacles near the robot, marked in red dots. SLAM has the ability to detect moving objects as well. Table 1 shows the angle and distance from the obstacle shown in figure 1.

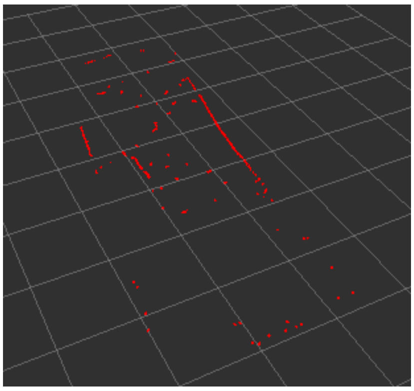

Figure 1. Obstacles Detection

Table 1. Angle and Obstacles

Angle	Distance
-179	2.691
-143	2.124
-107	0.901
-71	0,655
-35	2.679
1	1.872
36	0.963
72	0.643
108	0.703
144	1.344
180	0.729

Extended Kalman filter (EKF) was applied to estimate the pose and of the robot, but the performance was not ideal. For some strong nonlinear systems, this method will bring more truncation errors, which may lead to inaccurate positioning and mapping. Particle filter approaches were introduced because they can effectively avoid the nonlinear problem, but it also leads to the problem of increasing the amount of calculation with the increase of particle number. In 2007, Grisetti proposed a milestone of LiDAR-SLAM method called Gapping based on improved Rao-Blackwellized particle filter (RBPF), it improves the positioning accuracy and reduces the computational complexity by improving the proposed distribution and adaptive re-sampling technique.

As an effective alternative to probabilistic approaches, optimization-based methods are popular in recent years. In 2010, Kurt Konolige proposed such a representative method called Karto-SLAM, which uses sparse pose adjustment to solve the problem of matrix direct solution in nonlinear optimization. Hector SLAM proposed in 2011 uses the Gauss-Newton method to solve the problem of scanning matching, this method does not need odometer information, but high precision LiDAR is required. In 2016, Google put forward a notable method called Cartographer by applying the laser loop closing to both sub-maps and global map, the accumulative error is reduced. Figure 2 shows the map generated using hector slam. This map is saved and then used in navigation to avoid the walls. The dark black boxes shown in figure 2 shows the room boundaries.

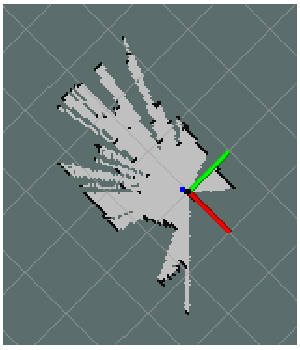

Figure 2. Map generated using Hector SLAM

3.3 Traditional Grid Map

Occupy grid map is wildly used in LiDAR-SLAM, it is a simple kind of 2D map that represents the obstacles on the LiDAR plane:

$$Mgrid = \{mg(x, y)\},$$

where mg(x, y) denotes the possibility if the grid (x, y) is occupied. Generally, the value of mg(x, y) can be 1 (the grid (x, y) is occupied) or 0 (the grid (x, y) is not occupied).

Feature map is another kind map generated by most feature-based Visual-SLAM approaches; it can be represented as:

$$Mfeature = \{f(x,y,z)\},$$

where f(x,y,z) denotes that on the world position (x,y,z), there is a feature f(x,y,z), for real applications, f (x, y, z) could be a descriptor to the feature in a dictionary like BoW.

As a result, a feature map is a sparse map which only has value on the position which has features. This makes a feature map is reliable for localization, but not good for navigation and path-planning.

3.4 360 degree Cameras

In photography, a 360-degree camera is a camera with a visual field of the entire sphere or simply a camera with the ability to capture a 360-degree field of view in the horizontal plane. Such cameras are a highly appreciated in instances when large visual field coverage is desired, such as in robotics or panoramic photography.

Most cameras have a field of view that ranges from a few degrees to almost 180 degrees or sometimes slightly larger than this. It implies that such cameras have the ability to capture the light falling onto their focal points through a sphere. On the contrary, a 360-degree camera covers a full sphere and has the ability to capture light falling from all directions onto the focal point. In actual application, however, most 360 degrees cameras can cover almost a full sphere along the equator, but with the exclusion of the bottom and top of the sphere. Should they cover the full sphere, including the top and the bottom, the rays will not meet at a single focal point.

3.5 Robotic Computer Vision

360-degree cameras are used in robotics to solve simultaneous localization and mapping as well as for visual odometry. With the ability to capture a 360-degree field of view, the 360-degree cameras lead to better optical flow, feature matching and feature selection in robotics.

The 360-degree camera would be used to take pictures of the rooms constructed. That will be used later on to determine the stage the wall is in. It can take the picture of the whole room in one go, and then the program can differentiate different walls in the room.

Figure 3. 3 stages of construction

After taking the picture, the program will use AI to determine the stage the wall is on and then evaluate the progress of the construction. Figure 4 shows the three stages of construction that are Blocks, Plaster and Primer. After determining the stage of all walls in the house, the program can evaluate the progress of house completion.

4 Results & Findings

For each classified scene, a confusion matrix was generated, used to examine commission and omission errors, the accuracy of the producer, and the classification in general. In turn, the K was calculated, which computes the agreement between the classified image and the observed reality due solely to the accuracy of the classification, deleting the agreement that would fit simply wait by chance. How much is K close to 100% how much is the classification accuracy good.

Table 1 below provides a detailed information from the used images in the training and testing with each results classification accuracy.

Table 2. Learning Model Classifications Accuracy

Dataset	Amount	Confusion Matrices	Classifier Behaviour Testing
Training	Class plaster 540	Class one-one 99%	Class with plaster 98%
		Class one-two 1%	Class without plaster 99%
	Class without plaster 540	Class two-two 100%	
Testing	Class plaster108	Class one-one 100%	Class with plaster 100%
		Class one-two 100%	
	Class without plaster 108	Class two-two 0%	Class without plaster 100%

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