Mapping for Indoor Walking Path Using Mobile Laser Scanning

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ABSTRACT

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Walkability is one of the keys in developing a sustainable city. These days, many cities have considered enhancing walkability for pedestrian paths to ensure the seamless walking experience for people to reach their destination. Therefore, it is very important to have a good walking environment so people will find walking pleasant. However, there was a lack of studies attempting to include indoor walking environments in their walkability analysis. Most of them only consider outdoor walking paths. This might be due to the difficulties in modelling the indoor walking environment. With the advance technology of laser scanning, it might be possible to develop an indoor walking path by using point clouds collected for a building. The usage of point clouds could make it easier to segment the building elements and obstacles in an indoor environment. In order to produce an indoor map, it is important to reconstruct the building elements such as wall, ceiling, window and door. Therefore, this paper aims to generate the indoor walking path using laser scanning point clouds showing all the options to the pedestrians.

Keywords: *Walkability, indoor mapping, point cloud, laser scanning, mobile laser scanning*

INTRODUCTION

Indoor walking paths can help people nowadays for problem-solving and decision making. This includes the walkability analysis which also should consider indoor walking environments. This is because, according to Lucia (2019), people spend an average of 90% of their time in indoor environments such as houses, office buildings, commercial centers, and transportation facilities. Indoor walking paths can assist disable people, aged people, tourists, and emergency assistants. Indoor walking paths will show the most suitable path between two positions by avoiding the obstacle between them. Meanwhile, the indoor navigation must have dense environmental description to distinguish between free and occupied space. Buildings such as shopping malls require the indoor walking path to help customers feel more comfortable while deciding in the maze and very complex buildings. The indoor walking path map could also be useful for public transport users as most of the shopping malls in Kuala Lumpur these days are connected to the rail transit station such as Berjaya Times Square with Imbi station, KLCC with KLCC station and NU Sentral Mall with KL Sentral. Thus, the public transport user usually will use the route inside the building as it can shorten their time and distance.

The walking path showing the routes from one building to the rail of the transit station and the connection to nearest pedestrian access is important for a high population area to encourage walking behavior among citizens. Hence, the identification of the comfort zone for pedestrians is a main tool to encourage this behavior. Good walking behavior can solve the problem of traffic congestion and environmental pollution. The advanced technology allows users to create an indoor walking path using Indoor Mobile Mapping Systems (IMMS) where the floor plan, walking path, and environment space are extracted from points clouds. In this research paper, GeoSLAM Zeb-Revo with SLAM (Simultaneous Localization and Mapping) algorithm was used where it updates a map of an unknown environment while simultaneously keeping track of user location. The scanner is able to capture about 40,000 points per second and 30m range indoor (Mehdi, 2017). The scanner will capture the indoor environment and translate the environment into millions of point clouds. The final point clouds produced using GeoSLAM Zeb-Revo can be achieved to centimeter accuracy. The scanner is enough to capture the indoor environment such as free and occupied space. Hence, the floor plan and walking path can be extracted from the point clouds. The floor plan usually can be extracted in 2D plans or 3D plans. The objective of this research paper is to create the indoor walking path and their parameters by using the laser scanning point clouds. The created indoor walking path could be useful in studying the walkability of certain areas. The study area is conducted at UiTM Shah Alam in the district of Petaling Jaya, Selangor.

REVIEW OF LITERATURE

Indoor Modelling using Laser Scanning

Nowadays, the high demand for detailed and accurate indoor models has led to the higher focus in BIM and GIS. This collaborative working is used to produce 3D models for the indoor mapping. Indoor mapping aims to visualize the indoor features as a spatial data for one particular built. It is very important to support other solutions including navigation and positioning in an indoor environment. However, it is not easy to model the indoor features, especially in a 3-dimension. Previously, there were many attempts for indoor modelling by using the floor plan and photogrammetry. However, the problems with these two methods lies on the accuracy and the laborious work involved. A long measurement time, measurement error and lower accuracy are the common and the most highlighted issues that are caused by physical manual measurement. Hence, with the new advanced technology helps to provide more reliable and accurate measurement thus it is now a focus on producing 3D mapping for indoor modelling. Nowadays, 3D indoor mapping is developed in various ways. Laser scanning is the reliable measurement method to collect point cloud data. Recently, parallel to the advancement of mobile GIS technology where data capture uses handheld devices, mobile laser scanning is developed to make data acquisition easier.

In recent years, MLS has become such an attractive and more concerned usage due to its flexibility and mobility as compared to TLS (Thomson, et al., 2013). Besides, MLS also has a relevant concept that can be used in different or various related work. Primarily a concept where the instrument or laser scanner was mounted on the vehicles thus capture the information rapidly. Unlike nowadays technology where the instrument now is very portable and small size laser scanners that helps a lot in accessing into narrow and limited size such as corridors and roofs (Fryskowska, et al., 2015). Besides, the development of small size laser scanners is more convenient. However, MLS has a lower accuracy compared to TLS but it gives a lot of benefits on the other side such that it can save cost and increase time saving.

3D point cloud obtained from laser scanning basically will be used for two main applications: quality control of as-built constructions and restoration of existing buildings (Alomari, et al., 2016). The comparison is made between 3D design models from the point clouds that capture the indoor environment through intermediary tools. Thus, all the design will be created and exported from BIM software that has been used in this study which is Autodesk Revit. Additional method inserted in this study is BIM that brings lots of benefits such that it helps in design optimization, clash detection, multi-disciplinary collaboration, time, and cost savings (Eastman, et al., 2011). The integration of laser scanning can help to find the discrepancies between the natural building and corresponding to the design model. Furthermore, the information of 3D design that has been captured from laser scanning helps implement indoor mapping and scene restoration of those existing buildings.

Application of Indoor Mobile Mapping System

A similar work had been done by Diaz (2016) used laser scanning to develop a real-indoor planning methodology based on 3D point clouds. The point clouds were used to detect the obstacles in the route planning and use it for readapting routes according to the real state capture by laser scanning. The point clouds from laser scanning were used to reconstruct the building elements such as floor, ceiling, and walls. The other indoor objects such as furniture were used for obstacle detection. The detection of the building elements is performed using the method of Generalized Hough Transform (GHT) where it creates a binary image from point clouds. The obstacle detection was analyzed from the creation of a buffer which represents a person. The logical network and navigable network were used to define the walking path.

Stegani (2019) used IMMS with SLAM approach to map and survey large sites without the presence of GNSS signal and accurate IMU. This research is performed to evaluate the capability of Mobile Mapping System to provide digital documentation exploitable in facility management applications. The point clouds data was created in Orbit software then exported into shapefile and integrated in ArcGIS and QGIS platforms. The output from the scanning work shows that a large amount of information was obtained from the IMMS that was very useful for facility management.

Staats (2017), had used the IMMS to automatically generate the indoor navigable space for pedestrians. The floors, stairs, walls, and furniture objects were extracted from point clouds to help pedestrians during their indoor navigation. The walking path also was determined based on the trajectory that the IMSS device took during the scanning procedure. The method of voxels model and seed voxels of point clouds was used to create a spatial structure. The trajectory also was analyzed to distinguish between flat and slope surfaces. The combination of trajectory and point clouds was used to identify the surfaces for navigation and final finding of indoor navigability.

METHODOLOGY

The proposed methodology is summarized in Figure 1.

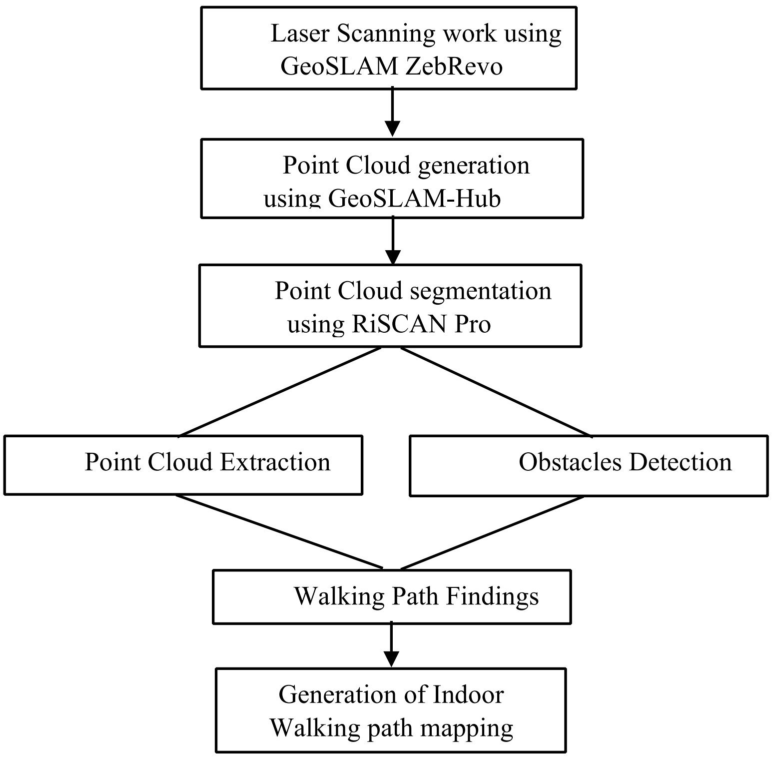

Figure 1. Proposed methodology

Laser scanning work: GeoSLAM Zeb-Revo is the handheld scanner that is easy to operate and only requires an unskilled person to handle. The operator must hold the scanner near the building to be scanned to ensure the complete building structure can be captured. The head of the scanner will rotate to capture the indoor environment. The suggestion ranges from the operator position to the objects scanned is about 30m. However, the near with the objects scanned is better. The operator only needs to walk around the building to be scanned with the normal speed of walking.

Point Cloud Generation: The point cloud is generated using GeoSLAM Hub where it performs automatic registration of the scanned data with their trajectory. The point clouds are exported into .LAS format to be able to use in third-party software.

Point Cloud Segmentation: The critical part is to filter the point clouds to remove the dynamic object or noise that was captured during the data acquisition. The dynamic objects may be people or moving vehicles. The static objects such as furniture will remain as the obstacles in the indoor environment. RiSCAN Pro software will be used to perform this task. The terrain filter used to separate the objects such as vegetation, moving objects such as vehicles and moving people that are present in the point clouds. The first step is to analyse the noise characteristic before applying the filtering function. It is important to know about the maximum object width, the maximum object height, the maximum slope of the terrain of the object to eliminate. Figure 2 shows the difference between the scan data before and after removing the dynamic objects. When the dynamic object or noise has been removed, the point cloud segmentation can be done. It is important to ensure all the noise has been removed to avoid mistakes in point clouds segmentation. According to Diaz (2016), the methodology involved was the segmentation of point clouds to regions classified as building reconstruction and the remaining point clouds were used for obstacle detection and finding the route. In this research, the point clouds segmentation is used to create a region for; 1) Building Reconstruction (Floor Plan, i.e. wall floor, window, and door) and 2) Obstacles.

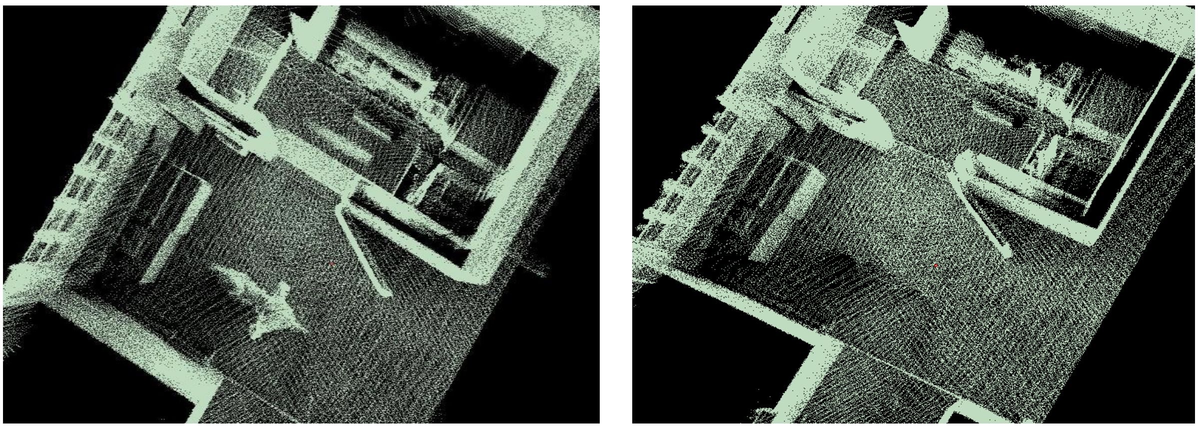

Figure 2. The difference between the scan data before (left) and after (right) remove the dynamic objects

Point Cloud Extraction: The point clouds will be sliced to show the building's floor plan. From the sliced point cloud, it is seen as the wall footprint, window and door as Figure 3. The extraction of the floor plan can be done using the extraction tool on the RiSCAN Pro software. Users must carefully extract the wall footprint, window, and door to show the exact building state. The 3D polyline of floor plan extraction can be exported into CAD format for plan editing and transform to 2D mapping. The 2D floor plan can be overlaid with the final walking path as a 2D map that will elaborate under section 4.

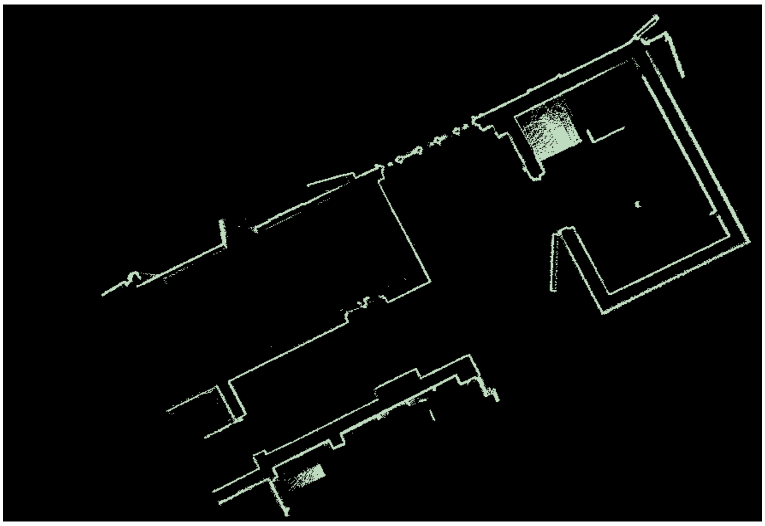

Figure 3. Building footprint sliced from point cloud

Obstacle Detection: The next point cloud segmentation is to define the region for obstacles. The method used for obstacle detection by defining the point clouds that interrupt the trajectory defined by path (Diaz, 2016). In this research, the obstacle is detected by segmenting the static point cloud as the obstacles. The terrain filter used with the setting parameter for static object detection. The building elements such wall, floor, window, door, and ceiling will not be considered as obstacles as it is already segmented into building reconstruction (floor plan). The point cloud other than building elements will be used for obstacles detection and later to be used to analyse the walking path. The point cloud segmentation in this research is define as Connected Components where is separating the ground and non-ground point of point-based classification (Erzhuo, 2019)

Walking Path Findings: The remainder of point clouds from the segmentation stage is used for walking pathfinding. The trajectory from the scanning work using GeoSLAM Zeb-Revo will be used to define the route in an indoor environment. The trajectory will be assumed as a pedestrian that walks in the indoor environment. Buffer tool will be used to create a 0.6m x 0.6m buffer around the trajectory. Normal pedestrians will feel comfortable walking without the obstacles around them. Hence, the 0.6m x 0.6m is suitable to use as the comfort zone to walk. The point clouds that fall in the buffer area will be considered as the obstacles

RESULT AND DISCUSSION

The methodology has been applied using data captured using GeoSLAM Zeb-Revo**.** The point cloud segmentation was carried out to determine the wall, floor, window, door, and ceiling. It can be done automatically using plane-based segmentation where it does the plane local fitting using KNN and calculates fitting residuals for each point (Qingming, 2019). However, in this research, manual extraction is performed to region the building reconstruction elements. This is because the final output of this research is to generate the walking path mapping that can be viewed in 2D plan paper. Hence, this is significant to the pedestrian to use this map while deciding for their walking path. The line path generation was adopted by Vladeta (2018), to extract the vector line path that forms the geometric boundary from the point clouds.

Indoor Walking Path

In order to provide good experience to the people about walkability, several criteria must be included in the study. The factor that affected the walkability to people was listed out by Paula Cambra (2012) that resulted in the 7Cs criteria; connectivity, convenience, comfort, conviviality, conspicuous, coexistence and commitment. One of the criteria is adopted as a framework to produce the indoor walking path from the point cloud. The criteria selected is comfort where the pedestrian is easy, pleasant, protected, relaxed, sheltered and untroubled (Paula, 2012). The route in the indoor environment was generated from the trajectory. The buffer tool under vector analysis was carried out to create a comfort zone for pedestrians. The comfort zone must always be free and protected from the obstacles at any time. This zone must be safe and accessible to provide a sidewalk width or clear route to the pedestrian to travel from one direction to another direction. This concept also applied for an indoor environment where the clearance from the obstacles is always required. The minimum clearance for the comfort zone is summarized below.

Table 1. The suitable pedestrians' zone

No	Comfort Zone/sidewalk width (m)	Condition
1	1.2	Absolute minimum through-route width allowing passage for single wheelchair
2	1.8	Desired minimum path width (1.5m absolute minimum) to allow for two wheelchairs to comfortably pass, widened to 2m near schools and small local shops.
3	1.54	Wide clearance should be maintained between a bus shelter and the kerb, as specified in the Public Transport Bus Stop Layout Guidelines, where insufficient space is available the absolute minimum through route width is 1.2m
4	2.4m	Desirable minimum through-route width (or higher based on demand) for commercial or shopping environments
5	3m-4m	In a busy dining area such as central city, reduced to 2.5m in areas with less pedestrian traffic

Hence, 1.2m of the comfort zone was tested by assuming only one person or single wheelchair will pass through the indoor route at one time. Buffer created around the trajectory (0.6m x 0.6m) assumes the trajectory is the pedestrian. The obstacles that fall around the buffer area is enough to make a pedestrian change their navigation route.

Indoor Walking Mapping

The mapping indoor walking path was produced by combining all the floor plan extraction, obstacles, walking path, and the comfort zone to be used by a pedestrian in an indoor environment (Figure 4). This mapping is generated to provide indoor mapping routes as alternatives for outdoor walking routes. Pedestrians can reduce their time by choosing the indoor route as the connectivity to their destination. In Malaysia, the MRT and LRT station usually link to the shopping mall building. Pedestrians will cross the shopping mall to walk to the nearest transit station. Some pedestrians also may prefer walking indoors as it provides them comfort routes and safety. Hence, the visual map is useful for the pedestrian to enhance the reliability in obtaining the navigation solutions. Besides, to generate the quick route, the representation of the map should be in a 2D model. (Nugroho, 2015).

From the map produced, we can see that some part of the obstacles that fall within the comfort zone. It will cause some inconvenience to the pedestrian. The future proper planning also can be adopted while designing the space and arranging the furniture.

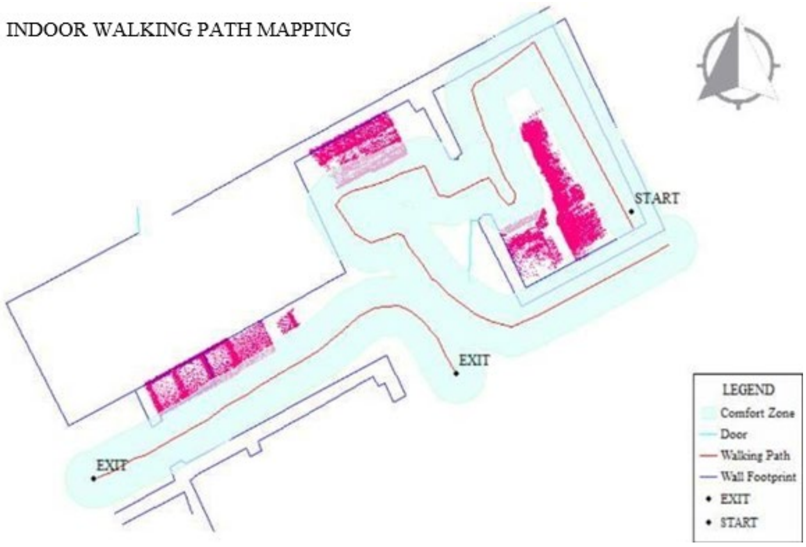

Figure 4. Walking Path Mapping

Accuracy of Point Cloud

The precision and accuracy of the final point clouds depend on the applications and need of the work. The accuracy of the point cloud from the GeoSLAM Zeb-Revo needs to be validated as it is often used in enclosed indoor and mazy spaces. It is also requiring time-consuming performances, manoeuvrability and continuity in surface reconstruction (Giulia, 2018). The point cloud from the scanner needs to be validated to verify the accuracy and informative richness of the point clouds. The quantitative comparison is made by extracting the point cloud into segments and evaluating it based on an analysis of local planar patches. The local planar patches analysis is divided into two; local point density and local standard deviation. From the segmentation of the point clouds, it could show that the scanner provides about 10,776 points for 1meter x 1meter. Meanwhile the local standard deviation is about 17cm. The factor that affects the density is the position of the scanner during the data acquisition. Due to the scanner that keeps moving, scanning at the same place repeatedly is required to increase the scan resolution. Meanwhile, the standard deviation could be influenced by material and acquisition geometry that might be affected by the noise produced. However, for walkability study, the point cloud collected using a mobile laser scanner for walking path finding is sufficient. Plus, due to the need of the study to develop an indoor map for a walking environment in enclosed space, mobile laser scanning is one of the most appropriate techniques.

CONCLUSION

In conclusion, the mapping for the walking path can be done using point clouds from laser scanning. The uses of laser scanning can help to reduce the time and cost for indoor data collection. Indoor Mobile Mapping System (IMMS); GeoSLAM Zeb-Revo is the best handheld laser scanning used to produce the point cloud. The method applies to achieve the objectives are point cloud segmentation where it used to generate the building reconstruction and for obstacles detection. The trajectory from scanning activity is assumed as pedestrian to create a comfort zone. From the summarization of sidewalk condition, the reasonable comfort zone in an indoor environment can be decided. The2D map produced shows the walking path, comfort zone and building elements that are useful for pedestrians to navigate their travel route. In addition, the map is helping in future planning for the indoor environment by analysing the obstacles that fall within the comfort zone. Finally, this paper is an initial test to study the lack of indoor mapping for pedestrian walkability index around Kuala Lumpur Transit Station.

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