An Indoor Mobile Scanning System with Multi-Controller

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***Abstract*—Scanning an indoor environment has become a necessity in the various field of applications in Architecture, Engineering, Construction (AEC) area. However, most of the available scanning systems are stationary, hence making the process of data collection more difficult, especially when dealing with the larger indoor area. Therefore, a mobile scanning system is developed here to handle the above issue. This paper will highlight the process of designing and developing the system. It has been adequately developed, where the design and suitable components were considered in order to make it able to carry a laptop which acts as the communicator with the suitable sensor that will scan the surroundings and a host personal computer (PC). Kinect sensor is used due to its advantages regarding workability and cost. The system is also equipped with an Android-based controller, connected to the platform via Bluetooth, which can be used to manoeuvre the mobile scanner using either auditory/voice or an arrow pad. Based on several experiments and testing conducted, the system can scan and display its surroundings in the 2D image and depth data. These are important in developing a suitable model representing the scanning area in the future. Both auditory and arrow pad controller is also working, where, by utilising an Android-based platform as the controller, the system is having the advantages of more freedom and beneficial compared to the existing mobile system without a similar controller.**

***Index Terms*—AEC; Android-based Controller; Auditory-Based Controller; Bluetooth Module; Kinect; Mobile Scanner.**

I. INTRODUCTION

Building interior reconstruction and modelling has been an interest in Architecture, Engineering, Construction (AEC) area. The model is used for various purposes, including for as-is model (a model/plan representing the condition of a building), which is very important as sometimes it can be different from its as-built (plan before occupation) and is also needed for the building's monitoring and future renovation. Figure 1 shows the stages of a plan that are needed in pre, during and post construction of a building. With the help of current technology of Building Information Modelling (BIM), the same plan that has been used in pre-construction can be utilised in all stages. However, due to this technology that has only been used recently, old and existing buildings are not equipped with the plan. Thus, a proper device that could help to gather the necessary data in developing the plan is needed.

To accomplish this, a Terrestrial Laser Scanner (TLS) can be used. TLS is a stationary laser scanner that can scan its surroundings when it is being placed in a middle of an interior. Its output is in surface or point cloud data, and can be used to model the interior. An example of a TLS and how does it work in scanning building interior is shown in Figure 2.

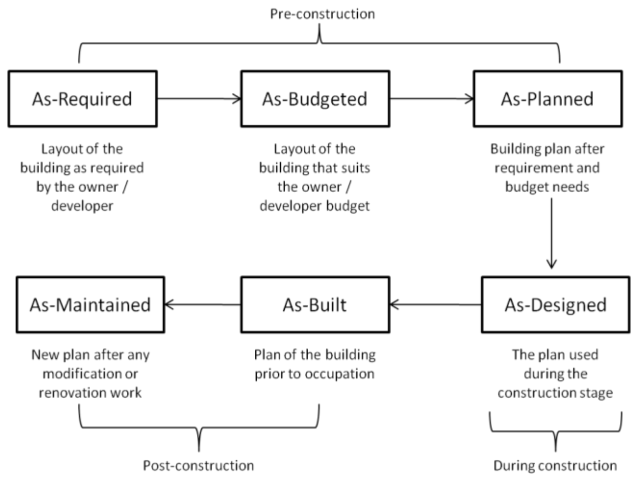


Figure 1: Stages of various planning involves in constructing and maintaining/monitoring a building, where the as-is plan is located between as-built and as-maintained [1]

Figure 2: A TLS scanning an indoor environment [2]

Although it can produce an exact and dense data [2], being stationary equipment, TLS can be very challenging to be used to scan an interior as it needs to be continuously moved around, especially in capturing a large-scale area. Furthermore, a state-of-the-art TLS is costly and can be prohibitive to some [3]. Therefore, it is essential to have a mobile scanning system that can be used to collect internal data for this purpose.

This paper will highlight the design and development of an indoor mobile scanning system. It utilises the usage of Kinect as the scanner to gather the data representing the interior. Kinect is a well-known sensor that has been used towards various applications especially in handling Human-Computer Interfacing (HCI) as it is being developed as a gaming console in the first place. Applications of human-based detection using Kinect include for gesture [4,5] and gait recognition [6].

Kinect has also being used widely to solve for Simultaneous Localization And Mapping (SLAM) of a mobile robot. It is being preferred due to its performance and low cost, but most of the system utilise commercially available robot [7,8]. Although SLAM can be employed to collect and model internal data, the localisation issue is out of scope, and thus, it will not be covered in this work.

The similar platform has been developed by [9-11] for various applications. However, they are not utilising Arduino and Android-based controller, which have been proven to be operated in lesser complexity [12]. In [13], an auditory-based controller has also been integrated by utilising the Kinect's speech recognition, but as this is the only approach that is being adapted, it has a limitation as it will solely depend on this type of controller to move the robot.

Here, the mobile platform is being controlled by the user using an Android-based controller. Equipped with a multi-controller, the user can choose whether to control the platform using auditory/voice command or the arrow pad in the Android application to manoeuvre it to scan its surroundings, which give users more freedom and choices. By integrating both types of controller, the versatility of the platform can be improved and will be beneficial for future work in robot's speech recognition to search and locate people in the future [14]. The controller communicates with the platform via Bluetooth, due to its features which suit for indoor application.

This paper is organised as follows – Section II will cover the methodology, from the hardware to the software, in designing and developing the mobile scanner. Components used will be highlighted, and their justification for their selection is briefly described. Android-based controller development is also included here. Some results and discussion on the performance of the platform in manoeuvring and scanning its indoor surroundings will be covered in Section III and will end with a conclusion and recommendations for future work.

II. METHODOLOGY

The platform was designed and developed with the capability to manoeuvre around an indoor environment, scan and display it is surrounding an image and depth data. Figure 3 shows the block diagram of the system. It can be seen here that a laptop will be used to communicate with the platform via Bluetooth to a host PC. The platform movement is controlled via an Android-based application.

Figure 4 shows the flowchart of the mobile scanning system. Upon initialisation, the scene that the system is scanning will be streamed in RGB / image and depth data on the host computer. At the same time, Bluetooth will start to be connected to control the movement of the platform. To achieve this, the proper methodology has been conducted, which includes the hardware design as well as a selection of appropriate components and software.

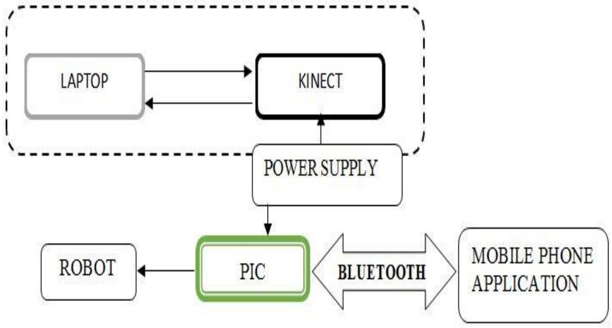


Figure 3: The system block diagram

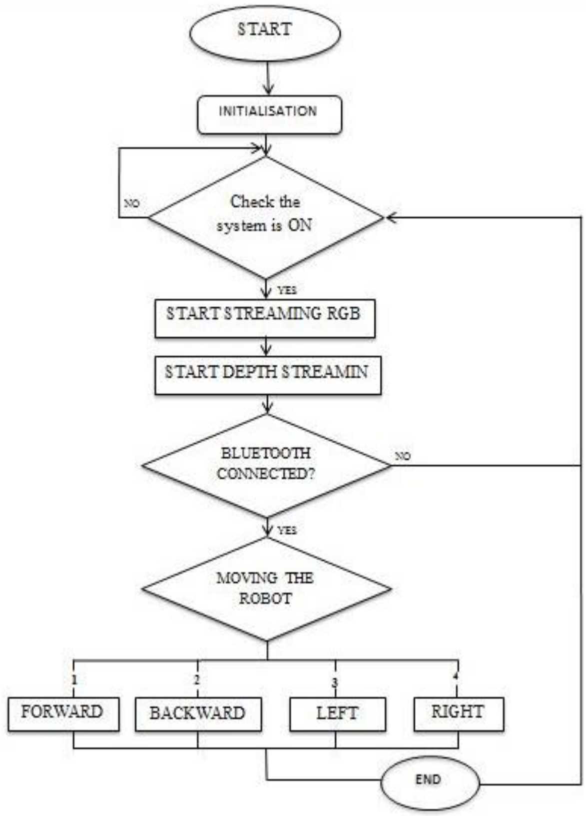
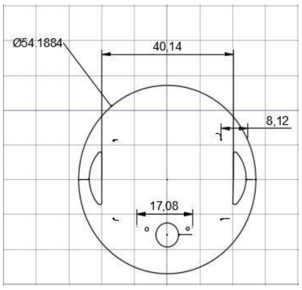


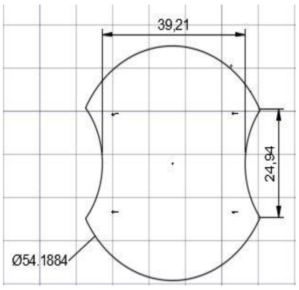
Figure 4: The flowchart of the mobile scanner

A. *Hardware design*

The platform needs to be appropriately designed as it will carry the sensor (Kinect), a laptop as the connector between the Kinect to the host computer, and other components like battery and motor. Therefore, a two-layer platform has been designed, where the upper part will hold the Kinect with the laptop, and the lower part as the base for the accessories. The upper layer is also equipped with two hand holders at the side for easier transportation, and a hole for the wiring and cables. It is circular for easier manoeuvring and control. The drawing has been designed using AutoCAD 2016. Figure 5 shows the design of the platform while Figure 6 shows the 3D drawing using PTC Creo.



(a) Upper layer design



(b) Lower layer design

Figure 5: Drawing of the platform designed using AutoCAD 2016

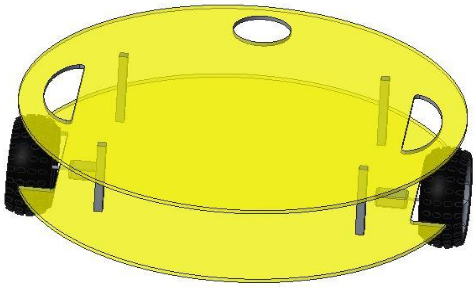


Figure 6: 3D design of the platform using PTC Creo

B. *Selection of Components*

Circular Perspex with 54 cm diameter with 5 mm thickness was chosen to be the two layers due to its durability and cost. Other components of the platform were including a power supply, PIC18 microcontroller, HC-05 Bluetooth model, motor driver, two DC motors of 12 V, 160mA, 22.5 ± 2 rpm and two wheels. As mentioned before, Kinect is used as the scanner to gather information of the platform's surroundings and the data will be displayed in the 2D image (RGB) and depth data. Kinect will communicate with the laptop via USB cable. Table 1 shows the list of selected components and their functions.

Table 1
Components Used and Their Specifications

Component	Specification
PIC18F4580 	Microcontroller to control the mobile robot. Main advantages include low cost, easy to interface, less power visualisation
L298N 	Relays, solenoids, DC and stepping motors are examples of inductive drive loads and accepting the criterion TTL logic levels process
HC-05 Bluetooth 	Connect the phone application with the controller to move the robot remotely within range of ± 900 cm (30 ft)

C. *Software*

PIC18F4580 is utilised as the microcontroller to control the robot. It is programmed using Proteus software. Meanwhile, Kinect is interfaced using MATLAB to scan and display the surroundings. For the Android controller, it is programmed using MIT App Inventor.

III. Results and Discussion

Figure 7 shows the final platform with Kinect and a laptop mounted on it. The laptop will show the surrounding that the Kinect scans in the 2D image and depth data. Kinect has successfully able to scan its surroundings within its range and display the results on the laptop. Similar MATLAB interfacing of image and depth data is also displayed on the host PC. Figure 8 shows some of the surroundings that have been scanned by the system, while Figure 9 shows the same location of where the system is scanning and its respective data in image and depth. From here, it can be seen that the system was able to scan and show the scanning results in image and depth data successfully.

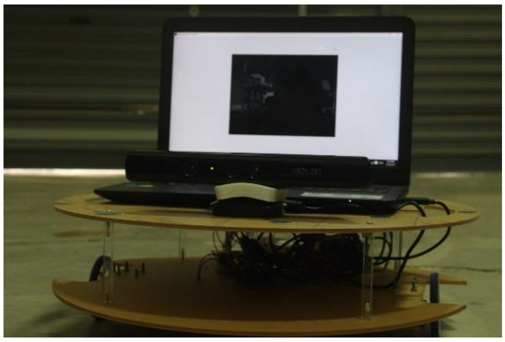
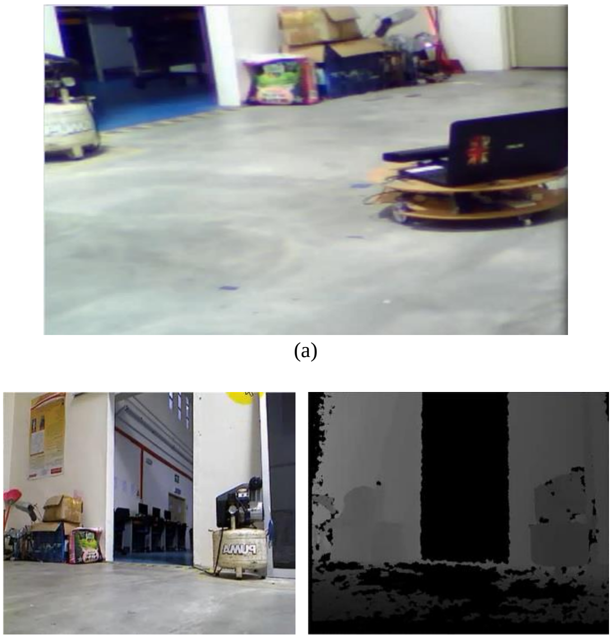


Figure 7: The mobile scanner

(a) Scene 1 image and depth data

(b) Scene 2 image and depth data

Figure 8: The resulting scans taken from the host PC



(a)

(b) (c)

Figure 9: (a) Position of the platform in scanning scene 3; (b) The resulting scan of scene 3 in the image; (c) The resulting scan of scene 3 in-depth data

As the platform is controlled using an Android-based controller, it can be designed as accordingly to the requirement. Figure 10 shows the Android-based controller interfacing. It is equipped with the Bluetooth icon to establish the connection as well as the arrow pad (forward, backward, left, right) to control the movement of the platform. It also comes with a speaker icon to allow the user to record their voice and give a command (front, back, left, right) to drive the platform as part of the auditory-based controller. The controller has successfully able to help the user to manoeuvre the platform as desired.

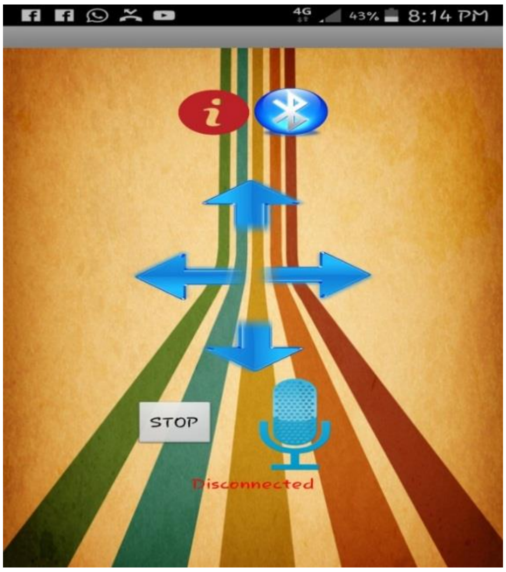


Figure 10: The Android-based controller

IV. CONCLUSION

As a conclusion, this research has successfully designed and developed an indoor mobile scanning system with dual Android-based controller. The system utilises Kinect as the sensor to scan its environment in the 2D image and depth data. Communication of the controller with the platform via Bluetooth has shown sufficient execution. The Android platform has been designed to allow the user to control the movement of the platform either by using the arrow pad or by using his / her voice (auditory). The scanned data can be used to model the interior in developing suitable plans for AEC application. It gives mobility and manoeuvring advantages over a stationary terrestrial laser scanner in collecting internal data. However, it still needs some further work, including a suitable algorithm to scan and map the environment, as current data is still less sufficient to develop a complete model.

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