A Navigation System For Visually Impaired Based On The Microsoft Kinect Sensor In Universiti Tunku Abdul Rahman Kampar Campus (Block G,H,I And N)

BY

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Finally, I must say thanks to my parents and my family for their love, support and continuous encouragement throughout the course.

ABSTRACTS

This project is design to help visually impaired persons. Since the technology is getting advanced day by day, it is our belief that recent advances in technologies could help and facilitate in the day-to-day operations of visually impaired and disabled people. Device kinect was released by Microsoft which is a low-cost and short-range 3D scanner that is able to acquire 640 x 480 range map of the scene at the pace of 30 times per second and work in range between 0.5 to 4 meters. It make us believe that it have the abilities to tracking and identifying obstacle in and along the path during walking. so, the kinect sensor will be use in this project as camera and depth sensor because its output provides sufficient data for the task of analyzing and detecting obstacles. The system will be develop by using openCV engine to process captured video frames. Voice output will be sent to user if obstacle detected in and along the path during walking.

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LIST OF ABBREVIATIONS

WHO	World Health Organization
3D	Three Dimensional
VGA	Video Graphic Array
FPS	Frames Per Second
CMOS	Complementary Metal-Oxide-Semiconductor
RFID	Radio Frequency Identification
GPS	Global Positioning System
USD	United States Dollars
WLAN	Wireless Local Area Network
2D	Two Dimensional
RSS	Received Signal Strength
PDA	Personal Digital Assistant

Chapter 1 : Introduction

1.1 Motivation and Problem Statement

According to WHO, 285 million people are visually impaired worldwide, 39 million are blind and 246 million have low vision. About 90% of the world's visually impaired live in developing countries. They need the help of others to go to an unfamiliar place but sometimes they still have to rely on their own ability to solve problems when the assistant is no there. It is our belief that recent advances in technologies could help and facilitate in the day-to-day operations of visually impaired and disabled people. Our goal is to develop a system to help visually impaired persons experience by providing enough information to make them feel comfortable on a walk from one location to another.

Project that design a navigation system for visually impaired based on the microsoft kinect sensor has been proposed. **K**inect sensor was released by Microsoft. It is a low-cost and short-range 3D scanner that work in range between 0.5 to 4 meters and able to capture 640 x 480 range map of the scene at 30 FPS (frames per second) .The data provides by kinect sensor is suitable for the task of obstacle tracking and identification.

1.2 Project Scopes

This project focused on navigation aid for the visually impaired and blind people which involves three key questions: where am I, where am I going and how do I get there. Proposed system should be able to help the visually impaired and blind people to navigate in their surroundings just like people with normal sight. System must be able to identifying the obstacle in and along the path during walking and prompt user with voice output when the obstacle is detected. However, due to time constraint, this system will only work for indoor environment and tactile feedback and navigation for outdoor environment will not be implemented.

1.3 Objective

- Look into current development of the related system and implementation of navigation aid system for visually impaired.

- The end system of this project will be able to guide the user navigate in the indoor environment of block G,H,I and N at Universiti Tunku Abdul Rahman Kampar Campus.

- The outcome and methodology from this project must be able to extend to other type of building structures.

1.4 Contribution

- Selecting the proper methods and technologies for visually impaired navigation aids system.

- Design a wearable assistive human computer interface that can aid the visually impaired person walks walk around in a building.

- Increase the function of existing visually impaired navigation aids system.

1.5 Background Information

1.5.1 The Kinect Sensor For Windows

There's some hardware working together with the Kinect sensor:

- RGB video camera - This is a detection hardware that help Kinect sensor to detecting surrounding features by using three color components which are red, green and blue.
- Depth sensor - This hardware contains the functionality to capture video frame from a dark room by using infrared and monochrome CMOS technology.
- Multi-array microphone - This hardware helps to reduce down the environments noise and concentrate on the players voice to allow them to use voice controls.

Kinect sensor was released by Microsoft. The video cameras and depth sensor of kinect have a 640 x 480-pixel resolution at 30 FPS (frames per second) and works in a range between 0.5 to 4 meters. The quality data it provides is sufficient for the task of obstacle tracking and identification.

Chapter 2 : Literature Review

Over the recent years, color acquisition devices and computing hardware getting advanced day by day. With the help of technologies and hardware, a lot of solutions can be provided to assist blind people in indoor navigation. Some technologies have been applied to assist them: RFID, ultrasonic systems, GPS, radar, sensor networks, infrared positioning system and compass system.

2.1 Global Positioning System

One of the type of visually impaired navigator has been developed is GPS-based navigation device with audio guidance. GPS receiver pick up the digital code signal from GPS satellites. The device calculate the distance between the satellite and the receiver by reading the time that taken by signal to reach the devices. Devices can provides latitude, longitude and height information by getting the distance between three or more satellites. The devices can navigate user to destination by using the information collected from GPS receiver.

The advantages of this device are inexpensive hardware and friendly user interface. The navigation program determine the best route using the list of waypoints stored in the program. GPS navigation program can be used in most of the places as long as the maps is stored in the program and GPS receiver can receive the digital code signal from GPS satellites.

However, GPS devices unable to tell the user which way was facing during initialize state, it only can calculate the direction after user started moving. Future more, the signals from satellites used in GPS technology are not suitable for indoor environment.

2.2 Radio Frequency Identification (RFID)

The radio frequency identification (RFID) is a technology that can storing and retrieving data from radio frequency compatible integrated circuit using electromagnetic transmission. RFID positioning systems are suitable to used for indoor positioning and navigation in complex environments such as exhibition halls , airport hall, hospitals, offices and etc. It is a inexpensive and flexible wireless technology to use in the navigation devices.

RFID(Radio Frequency Identification) based navigation system for visually impaired. (Ceipodor, Medaglia, Rizzo, Serbanati n.d)

The system is composed by four actors which is:-

- The tag grid
- The handheld and Bluetooth headset
- The RIFD reader cane
- The navigation data server

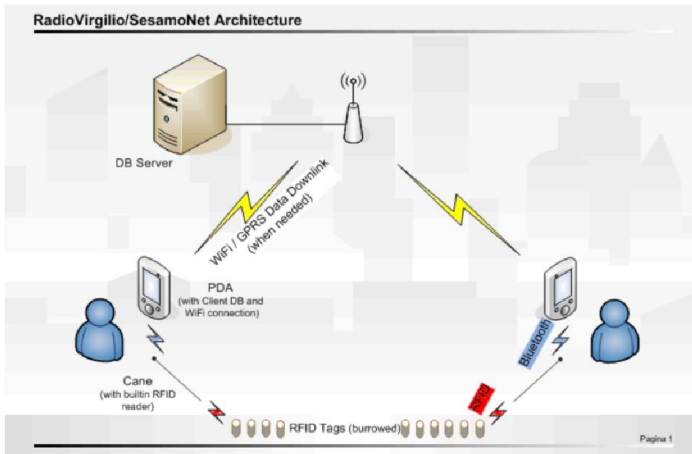

Fig. 1. RadioVirgilio/SesamoNet Architecture

As shown in figure 1, first, the cane reader reads the tag's ID with RFID technology. Then the PDA device will receive the information from cane reader and process. After that, the voice output will be send to user Bluetooth headsets. The PDA will stores all the tag's information data that used to reference and process those information that read by RFID cane reader. When a internet connection is available, user can choose to update the navigation data from server. The mobile device will navigate user based on the tag ID information that read by RFID cane reader during walking.

The advantages of RFID system are user friendly interface and can be use at indoor and outdoor environments as long as the tags is installed. The modular structure design also make it easy to maintain.

However this system only working in the environment that RFID tags is installed. There is also an issue on read range and metal objects interference.

2.3 RADAR

Microsoft research group proposed a RADAR system for indoor positioning and tracking. By using the existing WLAN technology, RADAR system also used triangulation location technique calculate the signal strength and signal-to-noise ratio to determine the location of a user. The RADAR system can provide accurate and consistent positioning information in 2D. It also enable location-based applications for users.

The advantages of RADAR system is easy to be set up by reused the existing indoor WLAN infrastructures and only need few base stations to perform location sensing.

However, the limitation is that the RADAR navigation aids system rely on WLAN technology and it is difficult for some low battery capacity devices to keep WIFI turning on for a long time.

There is also a privacy issue with the design of RADAR system, the location of user may be traced without their acknowledgement. Moreover, the overall performance of the RADAR system depends on the strength of the received signal.

2.4 Sensor Networks

Sensors are devices that generate outputs by exposed to a physical or environmental condition including sound, light, temperature and others. There are two types of sensor which is active sensors and passive sensors. Active sensors can probe and interact with the environment such as sonar and radars, however passive sensors only receive information from surrounding. "The sensor-based positioning systems consist of a large number of sensors fixed in predefined locations." (Michel & Christmann & Fiegert & Gulden & Vossiek September 2006) The location of the users can be located by calculating the collected measurements information from sensors.

The price and the small size of sensors for Sensor-based positioning systems provides a low cost and convenient way of indoor positioning and navigation.

However, there are some limitations in using sensor technology for indoor navigation which is less accuracy and battery life for low battery capacity devices in case of real-time tracking. The sensors will needed to install in predefined locations before using or else the system will failed to locate the person or device.

2.5 Infrared Positioning Systems

"Infrared positioning systems offers absolute position estimations, it needs line-of-sight communication between transmitters and receivers without interference from strong light sources" (Fernando & Krishnan & Sun & Kazemi-Moud 2003).

2.5.1 Active Badge

"The Active Badge system uses diffuse infrared technology to realize location sensing." (Fernando & Krishnan & Sun & Kazemi-Moud 2003). The position of an active badge can be specified by the information from the sensors that are fixed in predefined locations, sensors that connected with wires will forwards the location information to the user devices from a central server. The Active Badge system can locate users by estimating the location of the active badges taken along with the users in the coverage area. Based on the location information, some location-based applications can be designed.

The advantages of Active Badge Infrared Positioning System is the wearable active badges are small and lightweight and long battery of active badge.

However, The coverage range of infrared signal is only about several meters. Thus, the system provides only small area accuracy such as room size and needs more sensor to cover a bigger area. The infrared signal is influenced by sunlight and fluorescent light.

2.6 Ultrasound Positioning Systems

2.6.1 Active Bat

Active Bat positioning system is designed by researchers at AT&T Cambridge, it has the ability to provides 3D position and orientation information for the tracked tags. The Active Bat System can located the users location by measure the distance of the wearable tag with triangulation location technique. "The tag keep broadcasts a short pulse of ultrasound in a period time and received by a matrix of ceiling mounted receivers as shown in Figure 2. The distances between the tag and the receivers can be measured by the ultrasonic waves and a minimum of three receivers is needed to calculate the 3-D position ."(Active Bat 2008)

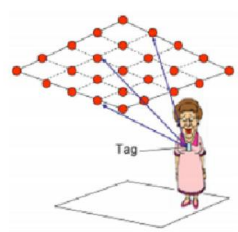

Fig. 2. Active Bat System

However, Active Bat positioning system is influenced by the reflection and obstacles between tags and receivers, which reduce the accuracy. Complex and costly installation for a large number of sensors on the ceiling is also an issue.

2.7 COMPASS

COMPASS system uses the existing WLAN technology infrastructures and digital compasses to enable location based applications for users. "The COMPASS system uses a probabilistic positioning algorithm to determine the location of a user. "(King & Kopf & Haenselmann & Lubberger & Effelsberg September 2006) Position can be estimated by calculate the distance of signal strength from different access points.

Digital compass is integrated into a chip and its small size, low power consumption and low cost component. It makes the COMPASS system takes advantages to provide low cost and accurate positioning services to locate a user carrying a WLAN-enabled device such as smart phone, tablet, PDA and etc. (King & Kopf & Haenselmann & Lubberger & Effelsberg September 2006)

2.8 Conclusion

Universiti Tunku Abdul Rahman Kampar Campus Block G,H,I And N comes with Wireless Infrastructure. Since the WLAN infrastructure is already there, Compass and Radar indoor positioning method is suitable to use in the proposed system. Compass and Radar can reused the existing indoor WLAN infrastructures perform positioning and navigation function. WLAN technology is commonly used and integrated in most of the wireless devices such as laptops, mobile phones and etc. Therefore, The systems may reuse these wireless devices as target to locate users.

Chapter 3 : Methodology and Tools

3.1 General Work Procedures

The Proposed System will use a kinect sensor to capture scene environment and divide it into color image and 3D depth image. OpenNI will be use to retrieve color image and depth image and then pass it to OpenCV engine to process. OpenCV engine will be use to processing depth image. In image processing stage, depth image slicing process will "slice" the image into the parts that used for blobs tracking and produce a high-contrast image. The result will sent to next process which is obstacle tracking and identification process. Obstacle tracking and identification process will taking charge and a certain portion of captured image will be taken into consideration as the path. Only the objects in and along the path will identify as obstacle. The result will sent to path finding process. Path finding process is use to detect the path where is no obstacle and tell the user which direction is clear to go. Finally, Voice output will send to user headphones to navigate them.

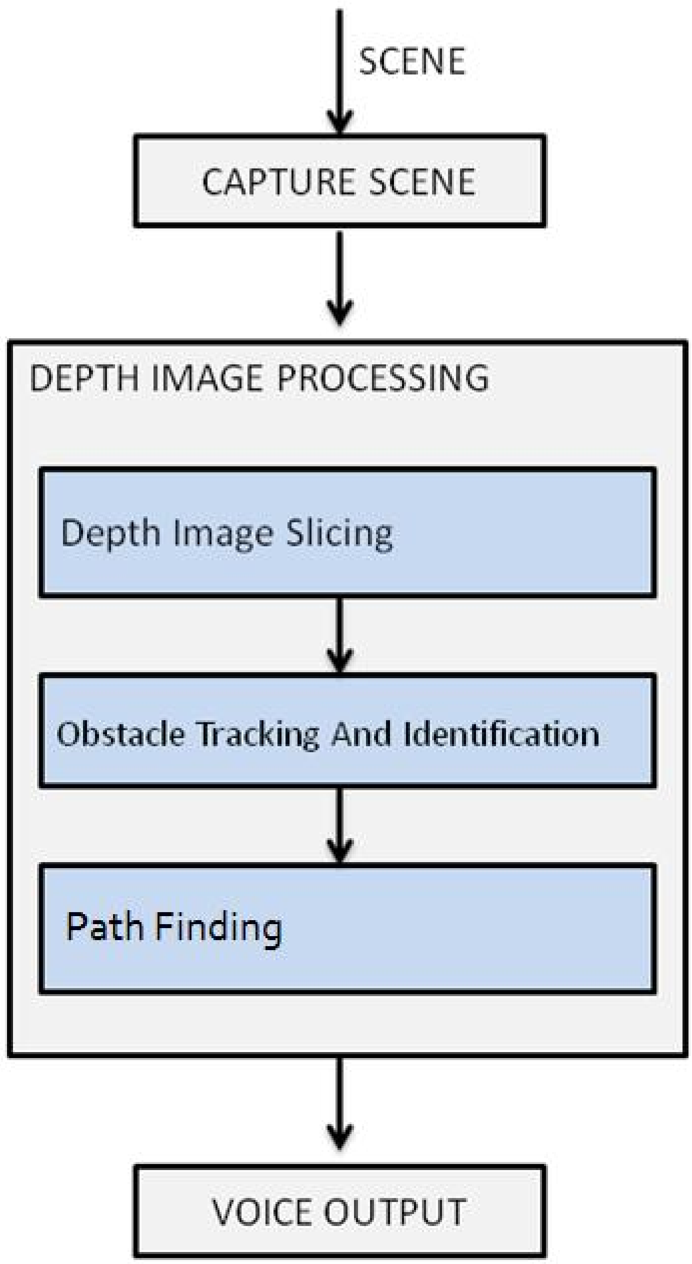

Fig.3. Methodology

3.1.1 Depth Image Slicing

In order to perform blobs tracking, there has to be high contrast between the object and the background. In other words, the object needs to be isolated and ignore everything else that out of the defined depth range. OpenCV vision library does a reliable job of finding the blobs.

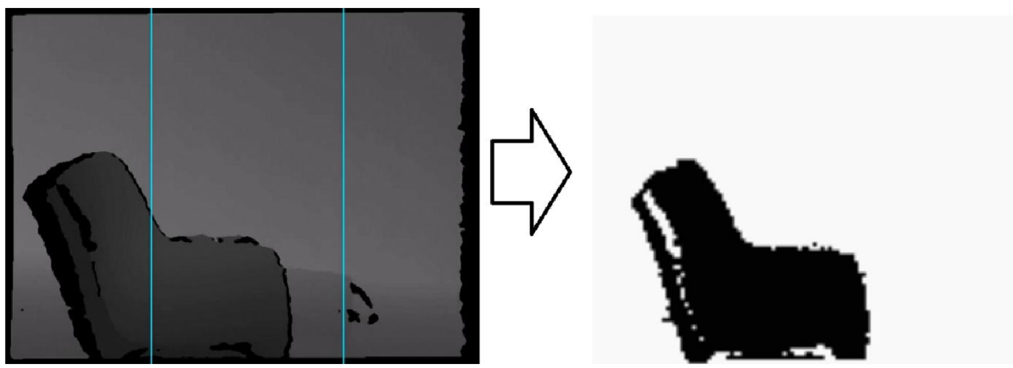

Fig. 4. Depth image slicing

The depth image retrieved from kinect contains all of the information to “slice” the image into the parts that used for blobs tracking. A nice and high-contrast image of the objects can be obtained from kinect by ignoring the data that is out of the defined depth range (coloring pixels out of the defined depth range to white color and coloring the pixels within the defined depth range to black color). A binary depth image is created in the end of depth image slicing process.

3.1.2 Obstacle Tracking And Identification

In this process, A certain portion of captured binary depth image will be taken into consideration as the path. Only the blobs in and along the path will identify as obstacle.

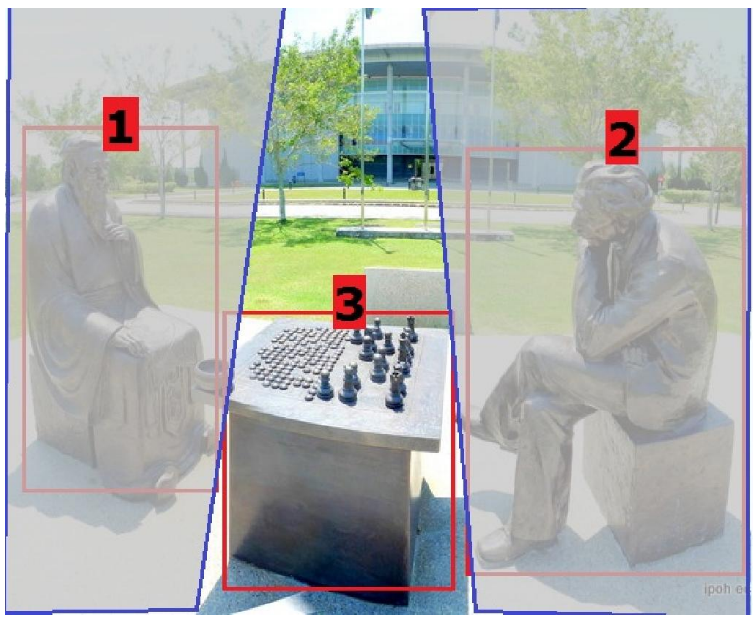

Fig. 5. Obstacle tracking and identification

There are three blobs in the image, only the third blob (3) will be identify as obstacle because (3) is in middle of the path. (1) and (2) are not obstacles because there outside the path.

3.1.3 Path Finding

Path Finding allow user steer clear of those obstacles during walking and point out the way that user can walk through. When Obstacle Tracking And Identification process return result "obstacle detected", path finding process will analysis the binary depth image and check whether left or right is blocked and tell the user which direction is clear to go . If all the path is blocked, the system will ask user to turn around until there is a path that can go thru. Figure 6 at next page illustrates how actually the path finding process works on helping visually impaired person to find the path they can walk through.

Fig. 6. Path finding

3.1.4 Voice Output

The result of path finding process will be processed by this function and voice output will send to user headphones to navigate them.

3.2 Tools

According to Microsoft, Kinect requires 12V at 1.08A power source to power up. However, Laptop USB port only provide no more than 5.25 V and no less than 4.75 V (5V +/-5%) and a device is only allowed to draw 100 mA(0.1A) to a maximum of 500 mA(0.5A) at a time. In order to solve the power shortage and then make the Kinect portable, a Mobile Power Bank is used to power up the Kinect.

3.2.1 Mobile Power Bank

Mobile Power Bank can solve many mobile devices, power supply and power shortage problems and then make work and travel free. Mobile Power Bank appear light weight , small size ,easy to carry and high capacity. Mobile Power Bank with high capacity can store from 1000mA to 20000mA or more. Mobile Power Bank usually provide only the standard USB output interface which is 5V(+/-5%) 1A~2A. However, there are some of the Mobile Power Bank provide variety of connectors and output to the user such as 12V 1A~2A and 19V 3.5A with DC power tip connector.

3.2.2 Power Bank used in the project

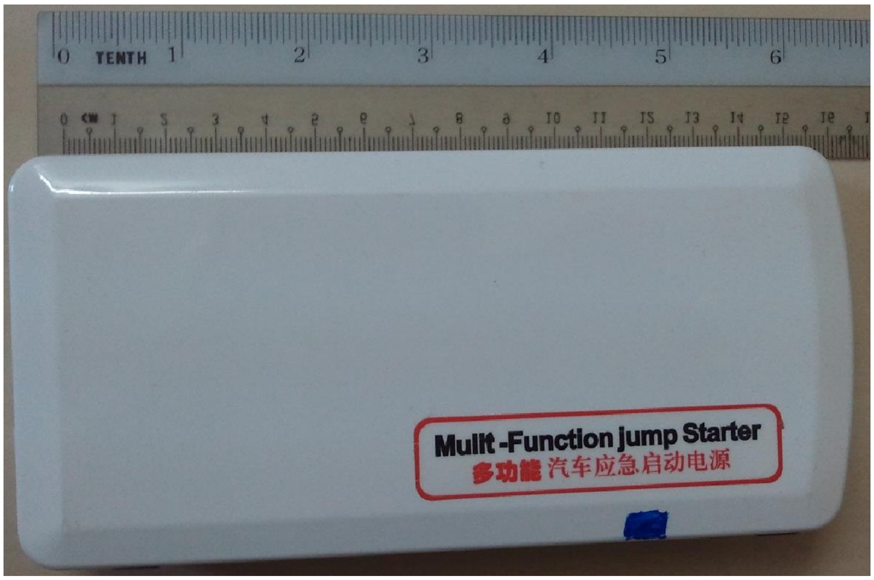

Fig.7. Mobile Power Bank

Figure 7 shows the Mobile Power Bank used in this project. This Mobile Power Bank provides three type of output voltage which is 5V 2A , 12V 2A and 19V 3.5A. It can be used as mobile phone charger, laptop charger, tablet charger and even as an emergency jump starter for car.

Fig.8. Output interface of Mobile Power Bank

As figure 8 shows that, one of the output provided by this Mobile Power Bank is 12V 2A. The power source requirement for Kinect is 12V 1.08A. So that a 12V 2A power source is more than sufficient to power up the Kinect without any problem.

3.2.2.1 Mobile Power Bank Specification

Company	: Taimax Technology
Size	: 160x75x20mm
Weight	: 430g
Output	: 5V 2A , 12V 2A, 19V 3.5A
Input	: 12V 1A
Capacity	: 14000mAh

3.2.3 Power Connector

Fig.9. Output interface used to power up the Kinect

Based on Figure 9, a male DC power tip connector is needed to connect with the Mobile Power Bank 12V output interface. Unfortunately, there is no such connecter provide in the market. To overcome this problem, the following hardware is prepared to do a custom Kinect-Power Bank connecter:-

- Male DC power tip connector

  Inner Diameter: 2.1 mm

  Outer Diameter: 5.5 mm
- Original Microsoft Kinect Adapter
- Voltage tester
- Electrical tape
- Soldering kit

Fig.10. Original Microsoft Kinect Adapter

3.2.3.1 Step to create the power connector

1. Cut and remove the Power Adapter from the Kinect Adapter

Fig.11. Power adapter that remove from Kinect adapter

2. Strip the Wire of Kinect adapter and Male DC power tip connector

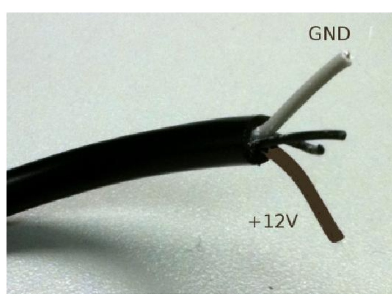

Fig.12. Kinect Adapter wire and its power code(brown="+12V",Grey="Ground")

Fig.13. Male DC power tip connector with strain relief jacket

3. Connect Male DC power tip connector with power bank and test both wire with Voltage tester to determine which cable is +12V and which one is Ground.
4. Solder the Male DC power tip connector's +12V wire with Kinect adapter's brown color wire and do the same things for ground wire.
5. Tape the cable with electrical tape and done.

Fig.14. Custom Kinect-Power bank connecter

7. Last, connect the cable with Kinect and Mobile Power Bank and check to make sure it works.

Fig.15. Mobile Power Bank successfully power up the Kinect

As the result , Mobile Power Bank successfully power up the Kinect and works like a charm. Full charged power bank can power up the Kinect up to 11 hours.

3.3 Implementation Issues and Challenges

3.3.1 Door Detection

Doors are important landmarks for indoor navigation to assist visually impaired person accessing unfamiliar environments. Proposed System encounter difficulties in door detection. It is difficult to differentiate doors from large object with door-like shape and size, such as cabinets and bookshelves.

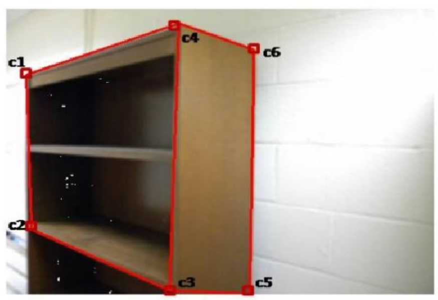

Fig.16. door-like object

Additionally, the design of the doors is also one of the issue that affect the result of door detection. Proposed System may not able to identify doors with special design.

3.3.2 Staircase Detection

Staircases are a common feature in indoor environments. Proposed System encounter difficulties in identifying and navigating staircases. The issues would started with the staircases detection but produces many false alarms. Different of viewpoint, distance and scale is also one of issues that will affect the result of staircases detection.

3.3.3 Wall Detection

In a big indoor environment, the user would prefer to walk beside and follow the wall to go to the destination because it is more easily to determine the direction rather than walking randomly inside the room. Proposed System encounter difficulties in identifying and navigating the user walk along the wall. The issues would started with the wall detection but produces many false alarms. Different of viewpoint, distance and scale is also one of issues that will affect the result of wall detection.

3.4 Requirement Specification

Proposed System must be able to recognize obstacle in and along the path and produce voice output to navigate user in Universiti Tunku Abdul Rahman Kampar Campus (Block G,H,I And N).

Chapter 4 System Overview

4.1 System Overview

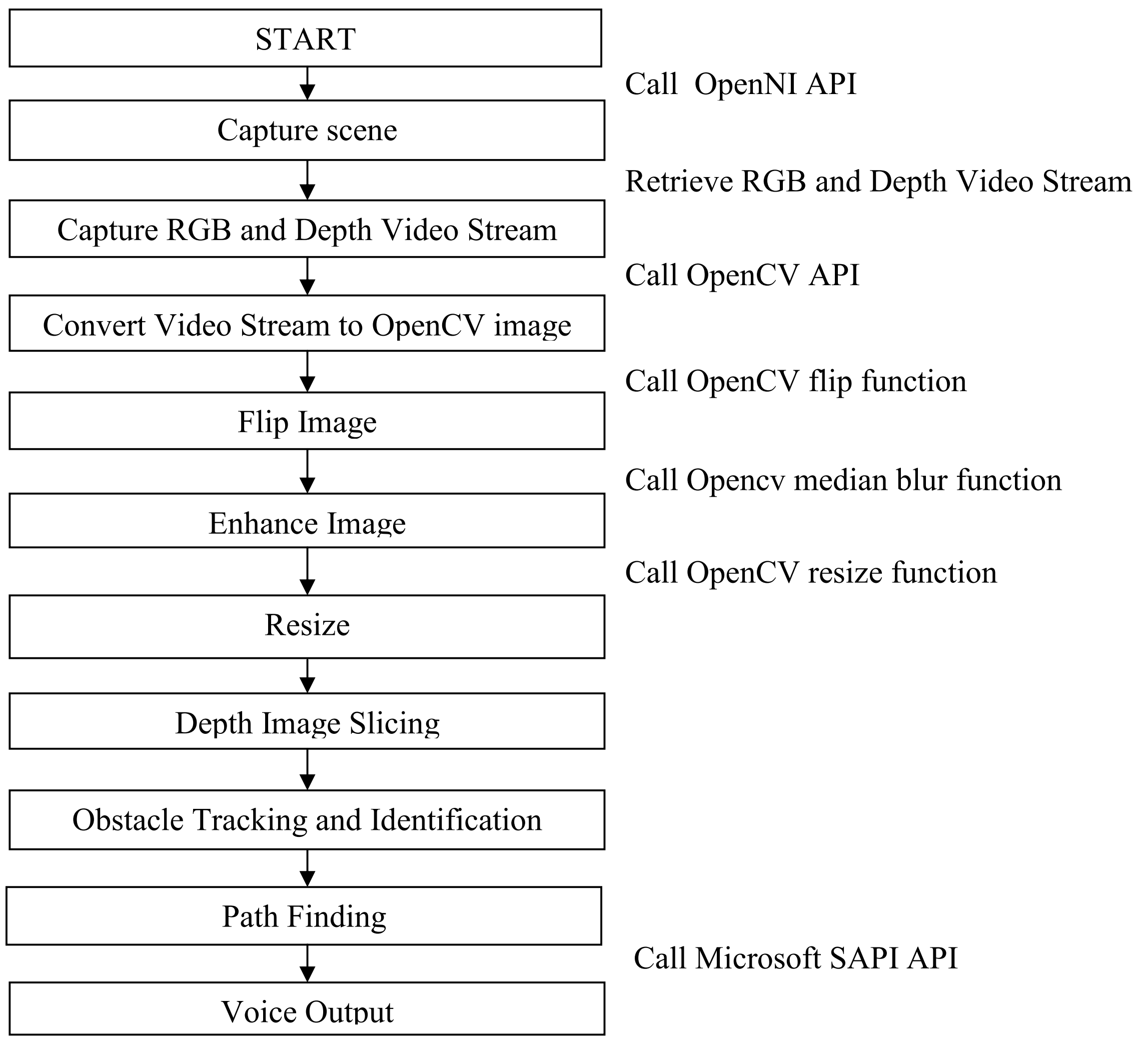

Fig.17. Application Flow Chart

When the application started, the application would initial OpenNI API. Then the OpenNi API will initial Kinect and start capture scene. The first process would be to capture the RGB and Depth video stream. The next process would be convert OpenNI video stream to OpenCV 16 (unsigned) bits one channel image format. After that, convert 16 (unsigned) bits one channel image to 8 (unsigned) bits one channel image. Next, OpenCV flip function will be call to correct the inverted image and the image will be enhance by OpenCV median blur function. OpenCV resize function will be call to resize the image to smaller size, this is to minimize the usage of resources for the next few process and make sure that the application run smoothly.

Depth image slicing process will paint all the pixels that within the defined depth range to black color and coloring pixels out of the defined depth range to white color. A binary depth image is created in the end of depth image slicing process.

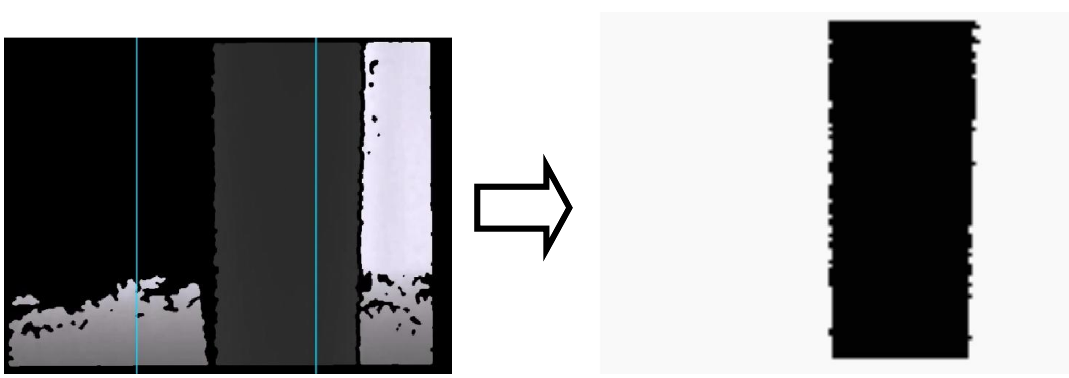

Fig. 18. Result of depth image slicing

A certain portion of captured binary depth image will be taken into consideration as the path(refer to figure 19 middle part). Only the blobs in and along the path will identify as obstacle.

Fig. 19. Result of obstacle tracking and identification and path finding process

When Obstacle Tracking And Identification process return result "obstacle detected", path finding process will analysis the binary depth image and check whether left or right is blocked and tell the user which direction is clear to go . If all the path is blocked, the system will ask user to turn around until there is a path that can go thru.

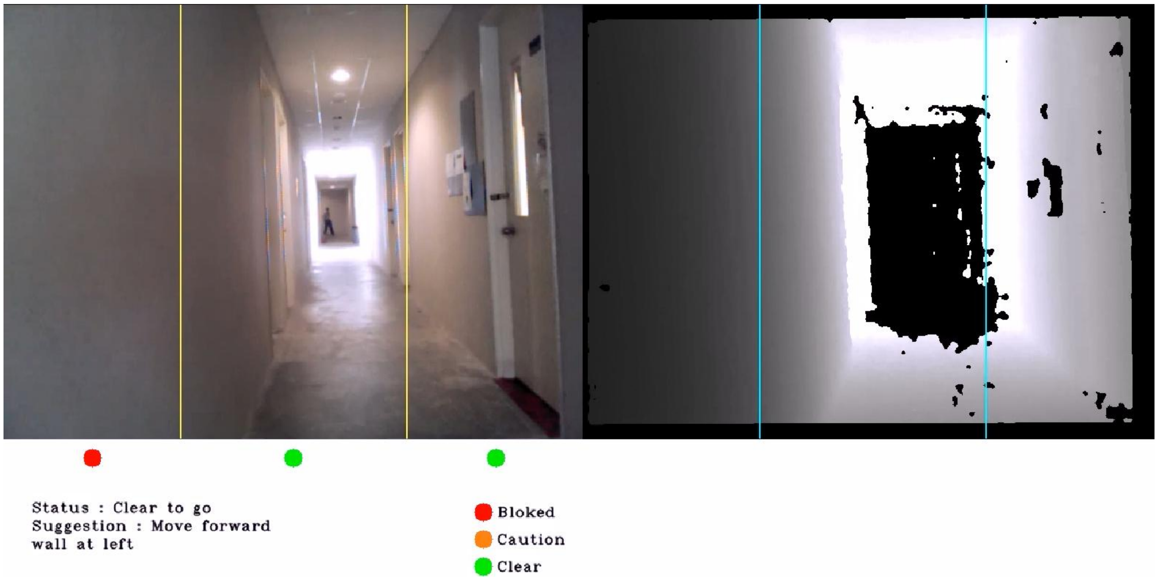

Fig. 19. Result

Path finding process also able to prompt user when the wall is detected . Finally, Microsoft SAPI API(Speech API) will be called to processing the result and turn it into voice output and send to user headphones to navigate them.

4.2 Limitation

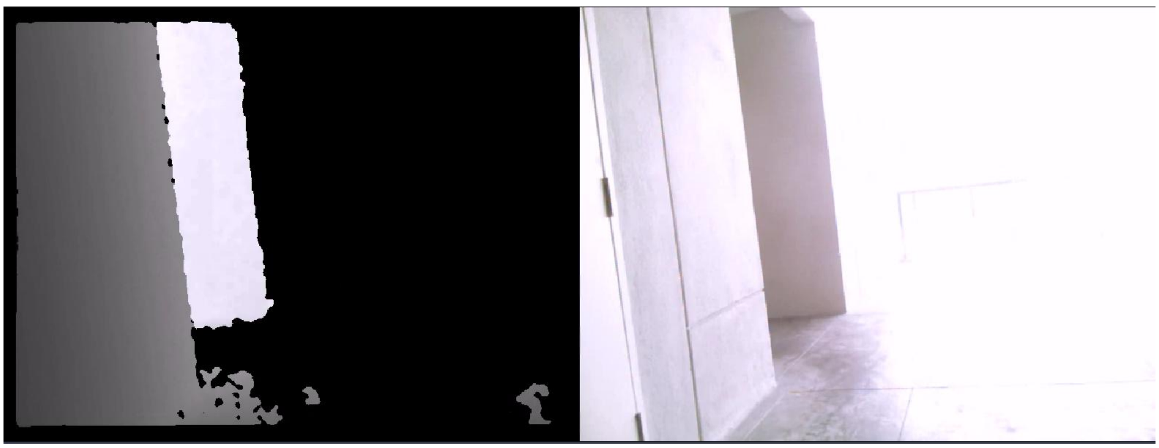

Fig.20. sample 1

Fig. 21. sample2

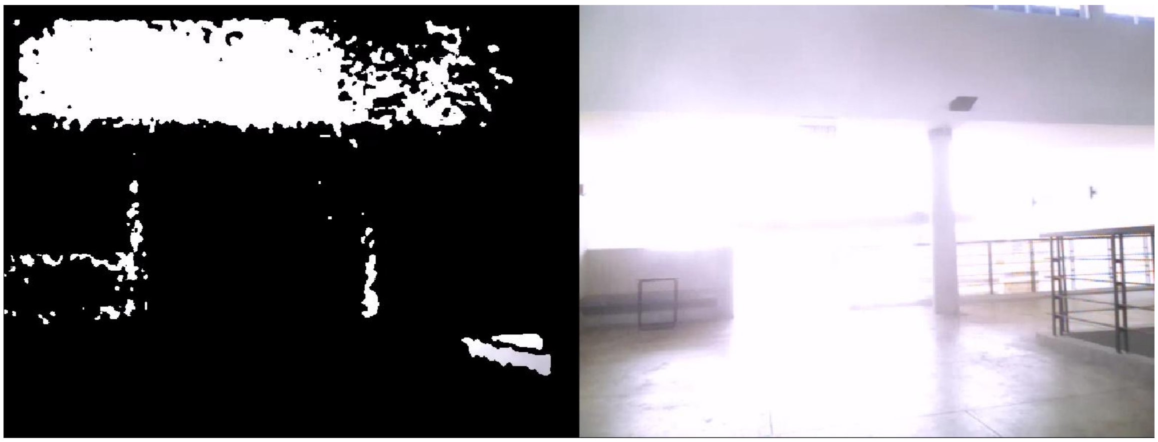

Fig. 22. sample 3

Figure 20, 21 and 22 illustrates some images that captured using Kinect. Right-hand side of the image is RGB view and left-hand side of the image is depth image that captured by Kinect sensor. Depth image pixels are mapped to grayscale based on the actual depth value, closer is brighter, farther away is darker, black equals to undefined pixels and white equals to out of range. Based on Figure 20, 21 and 22, the infrared signal is influenced by reflection of sunlight and causes unexpected result(depth image is filled with undefined pixels), thus the proposed system will only work on indoor environment with low reflection of sunlight.

Chapter 5 Future Direction and Conclusion

5.1 Future Direction

In the future, the color image captured from kinect sensor will use for edge detection and object recognition to recognize the door, wall and staircase. System will prompt the user when system detect a door or wall or staircase in front of or near to the user. The system will integrated with COMPASS or RADAR positioning system to perform indoor positioning and navigation to navigate the user to defined destination.

5.2 Conclusion

The Proposed project is navigation aid for the visually impaired and blind people and to help them to navigate in their surroundings just like people with normal sight. Currently , the system will only work on obstacle tracking and path finding. The system has functionality to allow user steer clear of those obstacles during walking and prompt user with voice output when the obstacle is detected and tell the user which direction can walk through.

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