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INDOOR NAVIGATION SYSTEM FOR BLIND PEOPLE USING COLOR QR CODE

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ABSTRACT

In this paper, we proposed an indoor navigation system to support blind and partially sighted people. The system consists of two parts. First part is the encoder or the QR code generator which will be used by the building manager to generate three different QR codes namely building information QR code, floor information QR code and room information QR code. The building manager is required to install this QR code in the building. Second part is the decoder which needs a mobile phone. The decoder will take the destination room from the blind person and then using the information stored inside the QR code will build the floor map and provide the navigation instruction. The experiment was done using our generated data set for three different virtual buildings. The result shows that the decoder succeeded to decode and build the virtual map for all QR code with distance less than 60 centimeters.

Keywords: *Aiding Blind People, Indoor Navigation, Virtual Map, Color QR Code.*

1. INTRODUCTION

In recent years many researchers provide indoor navigation that helps blind or partially impaired people to navigate within a building. This is to help visually impaired people to navigate in an unfamiliar place.

Indoor navigation system needs to provide partially impaired people with many inputs such as:

- Information about the current location.
- The direction, to help the visually impaired person reach their destination.
- Extra information about the current location to help the visually impaired person to understand more about the location.

Existing system which provides help in the above problems are the Virtual-Blind-Road [1], electronic mobility cane [2], geometric features aided [3] and electronic Travel Aids [4]. However, Virtual-Blind-Road [1] is unable to provide the virtually impaired person with updated information, such as alternative way if the room is closed when it is scheduled to open if there are any construction works. Electronic mobility cannot determine the shortest path [2] and it is unable to provide information about the current location. Geometric features require heavy training which may not be available for partially impaired people [3] and electronic Travel Aids is mostly for obstacle avoid [4]

The aim of this study is to design an algorithm for indoor navigation based on the latest color QR code to help blind and partially sighted people to navigate and get updated information about the location. The proposed system depends on a smartphone without the need to connect to the internet or any extra equipment. This makes the system suitable for any location. The proposed system has two parts, first, the color QR code generator which can generate 3 different color QR code as follows:

- Build QR code information, which can provide information about the building and the floor maps.
- Floor QR code information which can provide information about the rooms and their directions.
- Room QR code information which can provide information about the room and time schedule.

The second part is the color QR code decoder. The proposed color QR code decoder has the following features:

- Read the generated color QR code and identify its type.
- Receive a voice command from the partially impaired person such as read from history.
- Provide voice command for the partially impaired person.

This paper consists of six sections. Section 2 reviews the related research works. Section 3 explains about color QR code encoder and decoder. Section 4 is the system architecture. Section 5 discusses the experiments and finally section 6 is the conclusion and future works.

2. RELATED RESEARCH WORK

This part explains in detail five research works which will be used as our benchmark. We will show the system architecture for each research. Then we will present a comparison table between each existing system.

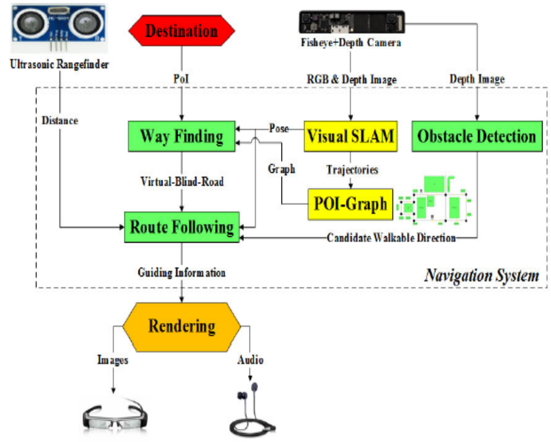
Our benchmark is to provide an indoor navigation system for partially sighted and blind people. Research such as bus navigation [22], obstacle avoidance and fall detection [23] and drug pill recognition [24] is out of our research scope.

2.1 Virtual-Blind-Road [1]

The proposed system consists of a combination of hardware and software algorithms:

- Hardware consists of the depth camera, fisheye camera, ultrasonic sensor, Microprogrammed Control Unit (MCU), Central Processing Unit (CPU), display glasses and speakers.
- Software consists of visual Simultaneous Localization and Mapping (SLAM), obstacle detecting, way-finding, route following and speech synthesis.

The system will use the camera and sensors to detect the user location and find the obstacles. Then using the inputs, the algorithm will use the CPU to find the way and show guiding information and surrounding information. The speakers also will read the information for the user. The prototype of this system is shown in Figure. 1.



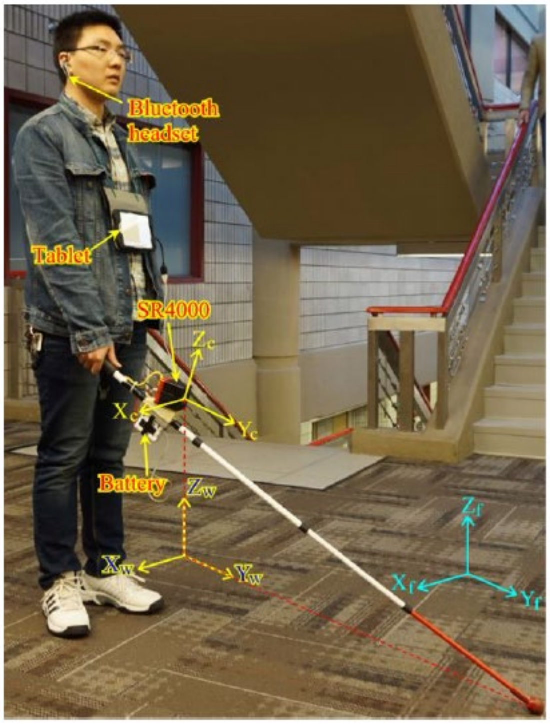
From our findings, their proposed system is using many hardware and software combinations which cause a costly system. In addition, the proposed system is unable to provide the virtually impaired person with updated information, such as if the room is closed when it is scheduled to open because there are unexpected construction works to be done, what is the alternative way for the person to walk.

2.2 Electronic Mobility Cane [2]

The proposed system consists of a combination of hardware and software algorithms:

- Hardware consists of Smart Cane, Swiss Ranger Camera SR4000 for 3D perception, Windows 8.1 tablet computer, and server computer.
- Software consists of client-server architecture. Simultaneous Localization and Mapping (SLAM) algorithm, and wayfinding service.

The SR4000 camera is mounted on the white cane. The camera is configured to send its detection to the client computer (Windows 8.1 tablet). Then the client computer sends the detected frames via Wi-Fi to the server computer which has the wayfinding algorithm. The result will be sent back to the client computer which has a speech interface to tell the user about the way. The prototype of this system is shown in Figure 2.



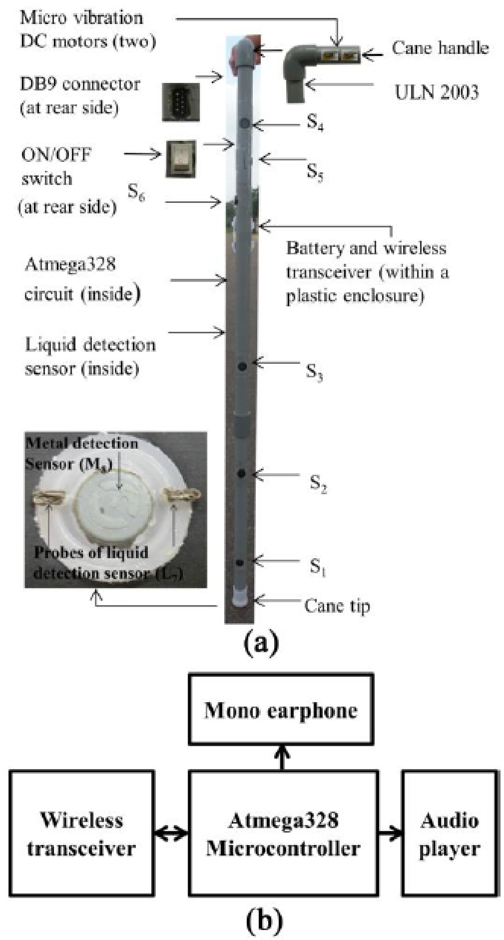
We also found out that their proposed system is used many hardware and software combination, therefore, the system is costly. Furthermore, electronic mobility cane cannot determine the shortest path. In addition, the proposed system is unable to provide the virtually impaired person with updated information, like alternative way in case of unexpected activity.

2.3 Geometric Features Aided [3]

The proposed system consists of a combination of hardware and software algorithms:

- Hardware consists of six ultrasonic sensors, a liquid detection sensor, a metal detection sensor, wireless transceivers, microcontroller circuits and a battery for power supply.
- Software consists of way finding with reduced information overload algorithm.

This algorithm samples the environment information by using above mentioned sensors and constructs the logical map of the surrounding environment. It interprets the distribution of obstacles in the surrounding by applying the relevance of their distance from each other. Then the sensor output will send to the trained microcontroller to determine the direction for the user. The microcontroller will send the direction to the headphone to tell the user the direction overview of this system, which is shown in Figure 3.



Their proposed system is also costly because it used many hardware and software combinations. The system also required heavy training which may not be available for partially impaired people. In addition, the proposed system is unable to provide the virtually impaired person with updated information.

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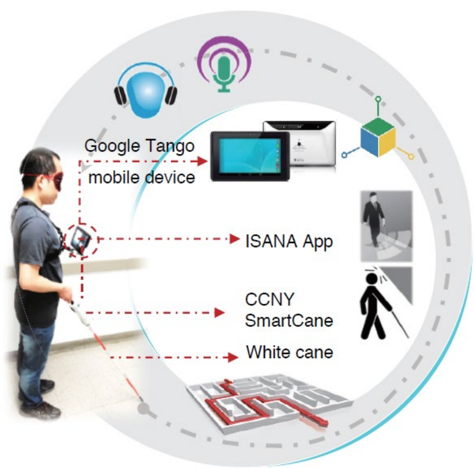
2.4 Vision-based Mobile [4]

The proposed system consists of a combination of hardware and software algorithms:

- Hardware consists of Google Tango mobile, which has an embedded RGB-D camera providing depth information, a wide-angle camera for visual motion tracking, and a 9-axis inertial measurement unit (IMU), Smart Cane, keypad and two vibration motors.
- Software consists of indoor semantic maps localization and obstacle avoidance.

The system needs the building symmetric map as input then using the Tango mobile camera it can select the user location in symmetric maps. Then the system will use the wide-angle camera to recognize the obstacles. Based on the obstacle detection and user location in the map, the algorithm will give the instructions to the cane so that the motors can vibrate left or right to give the direction to the user. The overview of this system is shown in Figure 4.



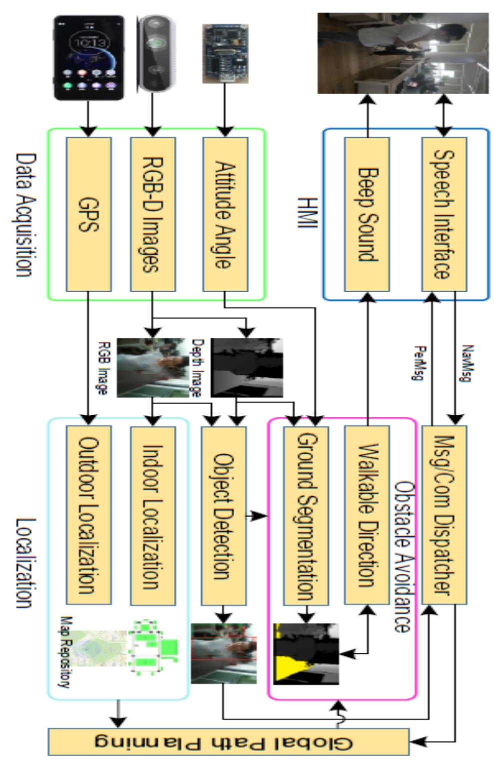
Their proposed system is costly because it used many hardware and software combinations. The system needs a symmetric map for the building to be pre-installed on the device which makes the system only suitable for the frequently visit building. In addition, the proposed system is unable to provide the virtually impaired person with updated information.

2.5 Wearable Travel Aids [5]

The proposed system consists of a combination of hardware and software algorithms:

- Hardware consists of microphone, RGB-D camera which captures the depth and color images, IMU sensor, smart phone and map repository.
- Software consists of speech interface module, common objects dataset, recognition system, global path-planning module and obstacle-avoidance module.

Their algorithm works as follows: the localization model will find the estimated user location using the building map and the GPS. Using the information from the localization model and the user destination from the input interface, the global path planning model will select the shortest path. Obstacle-Avoidance Module will use the camera input and the objects dataset to recognize the object and decide the type of the obstacles, then using the shortest path algorithm, will give the direction with obstacles data to the end-user. The overview of this system is shown in Figure 5.



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Their proposed system is costly because it used many hardware and software combinations. The system also needs a building map and obstacles data set which makes the system only suitable for the frequently visit building. In addition, the proposed system is unable to provide the virtually impaired person with updated information, in terms of alternatives way in case of unexpected activity.

2.6 Comparison between Existing Systems

The existing systems are compared based on five aspects (a) the needs for special hardware (b) if the system provides the obstacles to avoid (c) the direction information for the user (d) if the system provides information about the current location and (e) the need for Wi-Fi connection. (a) requires high cost due to the need of special hardware. (b) will affect the reliability of the system. (c) and (d) will affect the system efficiency and (e) will affect the system suitability as if the system does not need Wi-Fi which will make the system able to use in high-security places. Table 1 shows the comparison.

Table 1. Comparison between existing systems

	Require special hardware	Obstacles avoidance	Provide direction	Location information	Require Wi-Fi connection
[1]	Yes	Yes	Yes	No	Yes
[2]	Yes	Yes	Yes	No	Yes
[3]	Yes	Yes	No	No	Yes
[4]	Yes	Yes	Yes	No	Yes
[5]	Yes	Yes	Yes	No	Yes

3. COLOR QR CODE OVERVIEW

Color QR code is a special type of barcodes. The key feature of this barcode is it can encode data with larger capacity. In addition, the encoded data can be stored in different data layers. Color QR code is shown in Figure 6.

Figure 6. Color QR code

The size of QR code is attached to the:

- QR code version, which may vary from version 1 to 40.
- Error correction level (7%,15%, 25%, or 30%).
- Data type (data bits, numeric, alphanumeric, or binary data).
- Number of colors.

Table 2 shows the data size in byte for different versions of QR code.

Table 2. Comparison between existing systems

Version	Error Correction	2 color	4 color	8 color
1	L	152	304	456
	M	128	256	384
	Q	104	208	312
	H	72	144	216
2	L	272	544	816
	M	224	448	672
	Q	176	352	528
	H	128	256	384
….				
8	L	1,552	3104	4656
	M	1,232	2464	3696
	Q	880	1760	2640
	H	688	1376	2064
9	L	1,856	3712	5568
	M	1,456	2912	4368
	Q	1,056	2112	3168
	H	800	1600	2400
….				
21	L	7,456	14912	22368
	M	5,712	11424	17136
	Q	4,096	8192	12288
	H	3,248	6496	9744
….				

There are many researches about encoding and decoding QR code. We apply our proposed fuzzy encoder and decoder color QR code which is produced in our earlier works [7, 8, 9, 10].

3.1 Color QR Code Encoder

The overview of color QR code encoder is shown in Figure 7. The main idea is to form color QR code using color multiplexing of monochrome QR code to generate one colored QR code. The decoder of the QR code needs to perform color de-multiplexing to the color QR code to retrieve the monochrome QR code.

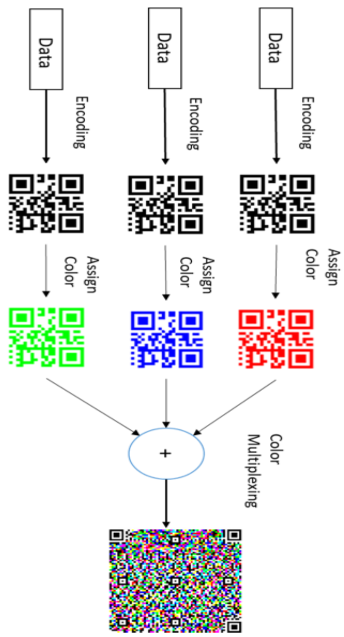

Figure 7: Color QR code encoder

3.2 Color QR Code Decoder

The overview of color QR code encoder is shown in Figure 8. The main idea for color QR code decoder is to perform color multiplexing to obtain many black and white QR code, then decode those QR code separately.

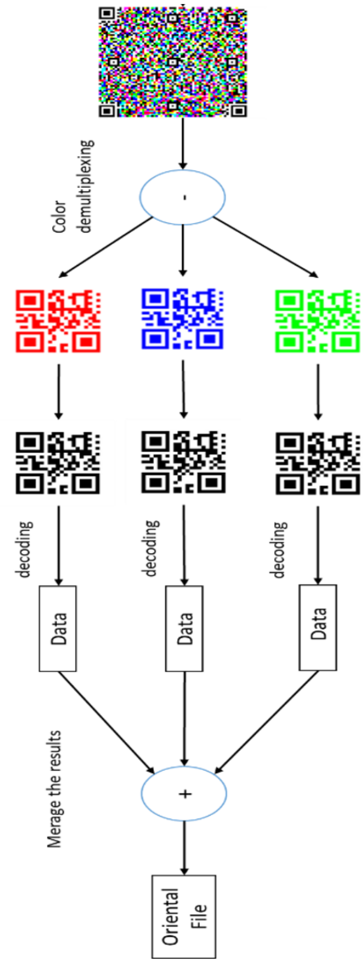

Figure 8: Color QR code decoder

4. SYSTEM ARCHITECTURE

Our proposed navigation system has two main parts, the encoder and the decoder. Obstacle avoidance is also an important part in the system architecture. These parts will be explained in the following sections.

4.1 QR Code Encoder

The QR code encoder system requires the building manager to generate multiple QR codes mainly three different types of QR codes:

- Building information QR code
- Floor information QR code
- Room information QR code

Building information QR code is used to store general information about the building such as building name/working hours/floors map for each floor and each room inside that particular floor, and also the basement floor map. This type of QR code can be displayed at the building entry. Figure 9 show the interface for building information QR code encoder.

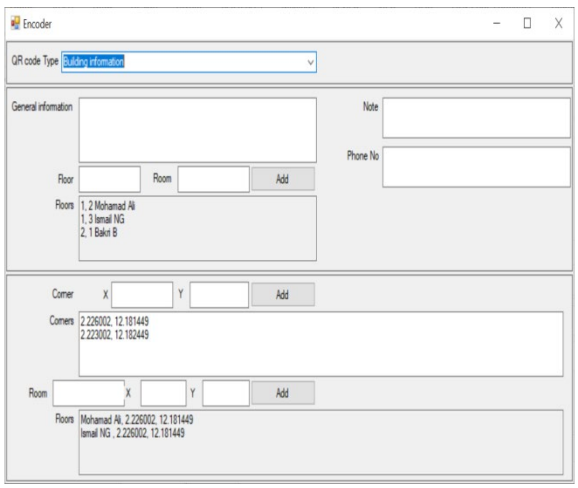

Figure 9: Building information QR code encoder interface

Floor information QR code will store information about the floor and the location of each room. This QR code can be at the front of each floor entry. Figure 10 show the interface for floor information QR code encoder.

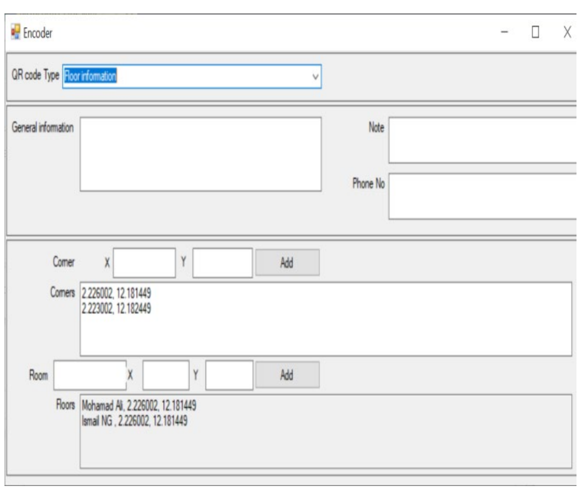

Figure 10: Floor information QR code encoder interface

Room information QR code will store information about the room whether it is open or close and the schedule of available time in case it is close. Figure 11 show the interface for room information QR code encoder.

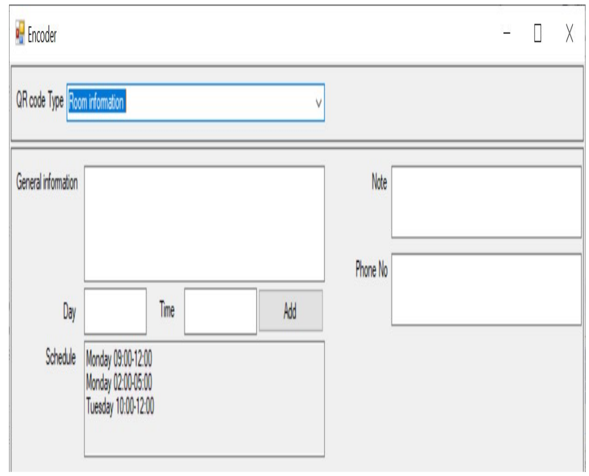

Figure 11: Room information QR code encoder interface

Each type of QR code can have additional notes/messages or contact numbers to be read to the blind person.

The generated QR code can be printed if the data will not be changed or if the data need to be changed frequently the QR code can be displayed on the screen.

The encoder system will ask the building manager to select the type of the QR code, then, the building manager is required to insert the data.

We will take advantage of the multiple data layers in color QR code and store the data in a different data layers, this will facilitate the decoder work. Since we have three different types of QR code based on the data stored on it, we will have three different color QR code as mentioned. Detailed information is as follows:

a. Building information QR code

This QR code consists of three data layers:

- Layer 1: will store General information, Note and Phone number. The encoded data will be stored in JavaScript Object Notation (JSON) format. We select JSON as it is the universal format to share data [11, 12, 13]. The JSON for layer 1 is as follows:

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```
{
  "General information":"data",
  "Note":"data",
  "Phone number":"data"
}
```

- Layer 2: will store the Floors data, Room Number and Room Name in JSON format. The JSON for layer 2 is as follows:

```
[
  {
    "Floor":"data",
    "Room Number":"data",
    "Room Name":"data"
  },
  {
    "Floor":"data",
    "Room Number":"data",
    "Room Name":"data"
  }
]
```

- Layer 3: will store the corners and rooms data for the basement. The corners data is to help the decoder to refer to the floor overview. The room location data shows the location for that room within the floor. The building manager can store the location for the facilities such as bathroom, elevators, etc. as normal rooms. The JSON format for corner and room data is as follows:

```
{
  "corners":[
    {
      "x":"data",
      "y":"data"
    },
    {
      "x":"data",
      "y":"data"
    }
  ],
  "rooms":[
    {
      "name":"data",
      "x":"data",
      "y":"data"
    },
    {
      "name":"data",
      "x":"data",
      "y":"data"
    }
  ]
}
```

The generated color QR code for building information is shown in Figure 12.

Figure 12: Building information QR code

b. Floor information QR code

The floor information QR code consists of two data layers:

- Layer 1: will store General information, Note and Phone number. The JSON for layer 1 is as follows:

```
{
  "General information":"data",
  "Note":"data",
  "Phone number":"data"
}
```

- Layer 2: will store corners and room data for the floor. The corners data is to help the decoder to obtain the floor overview. The room location data is to determine the location for that room within the floor. The building manager can store the location for the facilities such as bathroom, elevators, etc. as normal rooms. The JSON format for corner and room data is as follows:

```
{
  "corners":[
    {
      "x":"data",
      "y":"data"
    },
    {
      "x":"data",
      "y":"data"
    }
  ],
  "rooms":[
    {
      "name":"data",
```

```
      "x":"data",
      "y":"data"
    },
    {
      "name":"data",
      "x":"data",
      "y":"data"
    }
  ]
}
```

The generated color QR code for floor information is shown in Figure 13.

Figure 13: Floor information QR code

c. Room information QR code

Room information QR code consists of one data layer. This layer store General information, Note, Phone number and schedule data. The encoded data is stored in JSON format. The JSON for layer 1 is as follows:

```
{
  "General information":"data",
  "Note":"data",
  "Phone number":"data",
  "schedule":[
    {
      "day":"data",
      "from":"data",
      "to":"data"
    },
    {
      "day":"data",
      "from":"data",
      "to":"data"
    }
  ]
}
```

The generated color QR code for room information is shown in Figure 14.

Figure 14: Room information QR code

The generated QR codes needs to be located in a suitable location where the receiver camera can access the QR codes easily. The QR codes can be printed or displayed on the screen based on how frequently the data inside the QR code is updated.

4.2 QR Code Decoder

Special equipment is not required for our proposed decoder. Only a device like the smart phone, tablet or smart glasses with a camera and GPS is needed. The device must install our decoder.

The decoder will decode the QR code, get the destination from the user, then using the user location and the data from the QR code, the decoder will find the best direction and give the voice command to the user. Figure 15 show an overview of the proposed system.

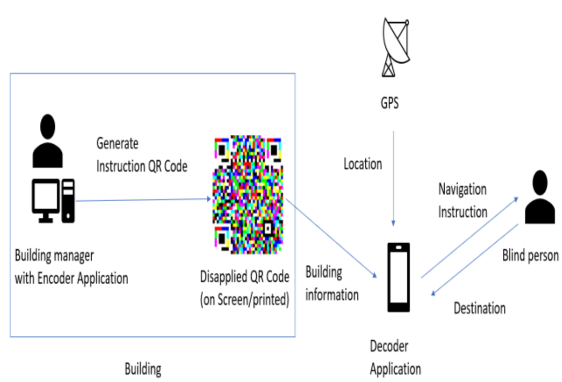

Figure 15: Overview of the proposed system

The decoder has the following functions:

- Read all types of QR code (building information, floor information and room information).
- Get the destination room from the blind person.
- Get the current location from GPS.
- Find the path using the data from the QR code and the user location.
- Give voice command about the direction for the blind person.

The decoder algorithm works as follows:

1- Get the destination room from a blind person. This can be done using the voice command from the device. Then, the user will repeat the voice command to get user confirmation.

2- Get the user location, which can be done using the GPS in the user device.

3- Read the QR code using the device camera. The decoder will ask the user to turn around in order to detect any QR code. Then, using the information in the QR code, the decoder can give the next command to the user.

4- Select the type of QR code. This is done by detecting the number of colors in the QR code as follows:
   - 8 colors for building information
   - 4 colors for floor information
   - 2 colors for room information.

5- Give the next voice command to the blind person. This is done using the following steps:
   - The navigation starts from the building entrance where the building information QR code is located.
   - The decoder will read the building information QR code using the data stored in the QR code. The decoder will perform the following:
     - Read the building information and the note from data layer 1 if it is requested from the blind person.
     - Find the destination room from the data stored in data layer 2.
     - Draw the basement navigation borders from data stored in layer 3. This will be explained in the next section.
     - Store this QR code data for future use if it is needed.
   - If the destination room is at the basement floor, find the nearest path using the GPS service in the device and give the navigation instruction to the blind person.
   - If the destination is in different floor, then the decoder will find the nearest path to the elevator or stairs and give the navigation instruction to the blind person.
   - Once the blind person reaches the destination floor, the decoder will read the floor information QR code as follows:
     - Read the general information and the note from data layer 1, if it is requested from the blind person.
     - Draw the floor navigation borders from data stored in layer 2.
     - Store this QR code data for future use if it is needed.
     - Give the navigation instruction to the blind person.
   - Once the blind person reaches the destination room, the decoder will read the room information QR code and give the room information, note and schedule to the blind person.

The flow for the decoder algorithm is shown in Figure 16.

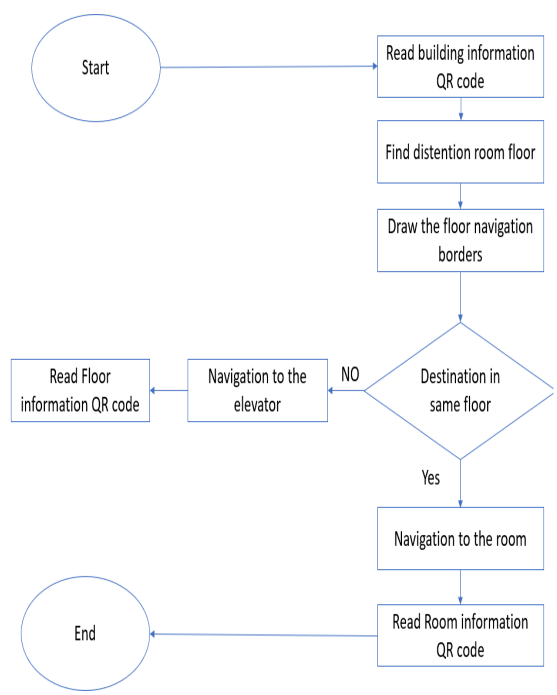

Figure 16: Decoder algorithm

4.3 Draw the floor navigation borders

This part is to help blind person to avoid walls and obstacles. The process starts by reading the floor JSON from the QR code which contains information about the corners and the rooms. The floor JSON has the following format:


```
{
  "corners":[
    {
      "x":"data",
      "y":"data"
    },
    {
      "x":"data",
      "y":"data"
    }
  ],
  "rooms":[
    {
      "name":"data",
      "x":"data",
      "y":"data"
    },
    {
      "name":"data",
      "x":"data",
      "y":"data"
    }
  ]
}
```


The decoder used the located corner in rectangle and then link between the corners with lines. The lines are drawn between the corners that has equal x or equal y. Figure 17 show example of the output.

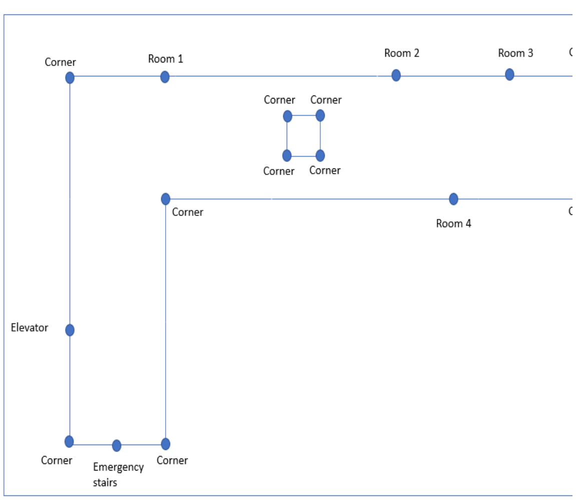

Figure 17: Floor navigation border

5. EXPERIMENTAL IMPLEMENTATION AND SIMULATION

We use our encoder to generate QR codes for three virtual buildings as shown in Table 3. The encoder interface is shown in Figures 9, 10 and 11. The buildings have different floor numbers between 3 to 20 floors. Each floor has 5 to 15 rooms.

Table 3. Encoder dataset

	Floors	Room per floor
Building 1	3	5
Building 2	10	6
Building 3	20	15

The generated data set consists of 3 building information QR codes, 33 floor information QR code and 52 room info QR code (consisting of 2 floors for each building). The versions of QR codes generated are as follows:

- Building information: a total of 3 QR codes, each version 8, 14 and 21. QR code version 8 is used for Building 1, QR code version 14 is used for Building 2 and QR code version 21 is used for Building 3.
- Floor information: a total of 33 QR codes, 3 QR codes version 8 for Building 1, 10 QR codes version 14 for Building 2 and 20 QR codes version 21 for Building 3.
- Room information: a total of 52 QR codes version 9, which is the same size are needed for all rooms.

The generated QR codes are used to evaluate the decoder. We snap a photo for the QR codes. Then, we use the simulation application to decode the QR code. Figure 18 shows the decoder interface simulation. The QR code file is selected, then the decode button is pressed to decode the QR code. The result will be shown in layer 1, layer 2 and layer 3.

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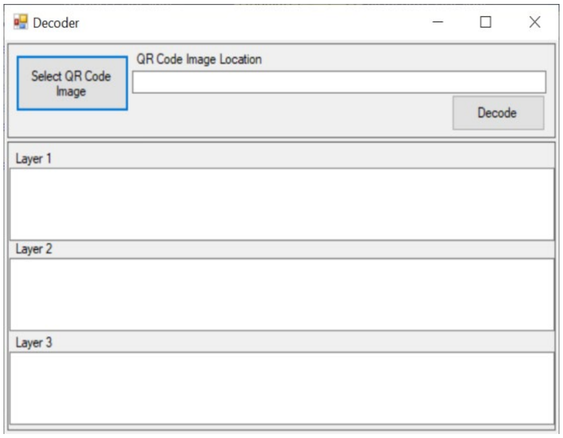

Figure 18: Floor navigation border

Figure 19 shows the result for decoding Building 1 QR code. Layer 1 shows the building general information, layer 2 shows the floor data and layer 3 shows the corners and room data.

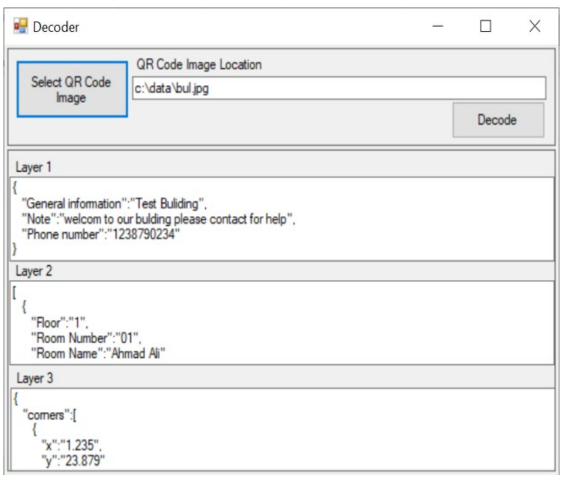

Figure 19: Building 1 decoding result

6. RESULT AND DISCUSSION

6.1 Comparison with existing system

We benchmark our proposed navigation system with the existing system in terms of the following criteria: i) Require special hardware ii) Obstacle avoidance iii) Provide direction iv) Location information v) Require Wi-Fi connection. Table 4 shows that our proposed system can provide the partially sighted and blind person with all the mentioned criteria.

Table 4. Feature comparison with existing system

	Require special hardware	Obstacle avoidance	Provide direction	Location information	Require Wi-Fi connection
[1]	Yes	Yes	Yes	No	Yes
[2]	Yes	Yes	Yes	No	Yes
[3]	Yes	Yes	No	No	Yes
[4]	Yes	Yes	Yes	No	Yes
[5]	Yes	Yes	Yes	No	Yes
Our system	No	Yes	Yes	Yes	No

6.2 Usability evaluation

We tested our decoder with the generated QR code from the encoder data set explained in section 5. Table 5 shows the decoder results for decoding the building information QR code. The decoding test is done by considering the distance between the camera and the QR code.

Table 5. Decoding results for building information QR code

Distance cm	Building 1	Building 2	Building 3
60	✓	✓	✓
100	✓	✓	
200	✓		

The results in Table 5 show the decoding success for building 1, 2 and 3. For Building 1, the decoder succeeded to decode all distances; 60, 100 and 200 centimeters. For Building 2, the decoder succeeded to decode distances of 60 and 100 centimeters and for Building 3, only 60 centimeters. This result is due to a larger QR code size used to test for building 2 and 3. In addition, further distance causes color overlap issue.

Table 6 shows the decoder results for the floor information. The results show that the decoder succeeded to decode all floor information QR code for Building 1. The decoder succeeded to decode the floor information QR code with a distance of 60 and 100 centimeters for Building 2. For Building 3, decoder only succeeded to decode with a distance of 60 centimeters because it has many rooms, which cause high-density floor QR code and results in colors overlap.

Table 6. Decoding results for floor information QR code

Distance cm	Building 1	Building 2	Building 3
60	✓	✓	✓
100	✓	✓	
200	✓		

Finally, we tested the decoding success for room information QR code with a distance of 200 centimeters. The result shows the decoder's success to decode all the QR codes. This is because the QR code is single color and the data size is almost the same for all the rooms.

7. CONCLUSION AND FUTURE WORKS

In this paper, we explain our proposed in-door navigating system for blind people using color QR code. The results show, by using a color QR code we can provide an indoor navigation system at a low cost as the system require only a mobile phone to work. The proposed system requires the building managers to install QR codes in the building. The system can provide indoor navigation, but it does not provide obstacles detections which will be implemented for our future works.

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