<TITLE OF THE PROJECT>


Taibah University
College of Computer Science Engineering
Computer Engineering Department


# Indoor environments navigation assistant, guidance, and localization system for visually impaired and blind individuals

**A Project Submitted in partial fulfilment of the requirements for the Bachelor Degree in Computer Engineering**

## Submitted By


**<Name Lastname><Student ID Number>**
**<Name Lastname><Student ID Number>**
**<Name Lastname><Student ID Number>**

Project Advisor
<Title><Name Lastname>


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# ABSTRACT

Visually impaired and blind individuals might face difficult challenges when navigating through indoor environments, especially if they where not familiar with them. Indoor environments can be very unpredictable and filled with obstacles, and they are rich of important visual information which only designed for eyes consumption. These difficulties rise the need of these individuals to assistants and guiders whether by asking strangers, or by taking companions. But these solutions will lead to decreasing the independence of these individuals. We are trying to offer a solution in this project, a wearable and easy to use system that guides and assists the users after determining their positions and scanning their surrounding environments using only a camera and smart phone.

The proposed system is an integration of three systems: Objects Detection, Localization, and Customizable Guidance System. These components rely on analyzing the images captured by a camera and extracting the important visual information from them. The Objects Detection System can detects the surrounding objects and describe them to the users if they asked to, and inform users about obstacles, and users can ask it to alarm them when they face an object with certain characteristics, such as a man wearing red T-Shirt. The localization system will use the camera to detect artificial landmarks to determine the user's location. And finally, the Customizable Guidance System reads to user custom information and instructions after entering specific areas.

-The results obtained.

-The Significance of the results or findings.

**KEYWORDS:** Localization; Obstacles Avoidance; Objects Detection, Customizable Guidance, Pose, Calibration

# ACKNOWLEDGEMENTS

The content of this single page is left to the preference of the student. It is suggested however that the page makes reference to guidance received by the student from his or her supervisor and project Committee members. Reference should also be made to any financial assistance received to carry out the project. Any extraordinary assistance received by the student for example in word processing, data collection, data analysis, and so on, should be properly acknowledged. The acknowledgements should not exceed 250 words.

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# Glossary and List of Abbreviations

## Glossary

**Term 1** Definition of term 1.

**Term 2** Definition of term 2.

## List of Abbreviations

**Abbr.** Full form of the abbreviation.

# Chapter 1

# Introduction

## 1.1 Overview

This project focuses on using a camera and QR codes for precise localization, allowing the device to determine its exact location. When the camera scans a QR code, it not only identifies where it is but can also trigger additional features like specific instructions or location-based descriptions. This localization system is particularly useful for robots to navigate accurately or for visually impaired people to receive important information about their surroundings.

## 1.2 Related Work

# Chapter 2

# Background

## 2.1 Introduction

## 2.2 Indoor Localization System

Indoor Localization is the process of calculating the precise position of an/a object/person within an indoor environment, such as a hospital, office, or shopping mall. The most popular localization technology is GPS, which is useful and works very fine in outdoor environments. But when it comes to indoor environments, GPS signals are weak or unavailable, so other technologies and techniques are used for these environments.

There are various other technologies and techniques that are used for indoor localization, such as Wi-Fi, Bluetooth, RFID, UWB, and the list goes on and on, See [1] for more information. Each one these technologies has its cons and pros, some of them rely on expensive and hard to setup hardware such as sensors, and IMU, while some other use less expensive and complicated hardware such as bluetooth beacons. While a lot of different technologies can give us precise indoor localization results, they usually don't exploit most of the visual information that exist in these environments. Thus, in this project we wanted to provide a system that makes use of these visuals which are information rich. Using only one camera, we will be able to detect landmarks to use them for localization, and extract tons of useful information from the surrounding environment.

## 2.3 Landmarks

Landmarks can be categorized as either natural or artificial. Natural landmarks are formed by nature, such as mountains, rocks, trees, or any other natural formations. While on the other hand, artificial landmarks are human-made structures such as buildings, traffic signs, statues, QR codes, and etc.. While both categorize can be used in various important fields in computer science such as robotics, and computer vision, natural landmarks are much harder to recognize, very diversified and do not have uniform shapes, difficult to customize, and they do not encode data. All of these characteristics can be opposite in the artificial landmarks.

Landmarks have a wide range of useful applications in various fields of computer science, such as robotics, localization, geographic information systems, object tracking, and a lot other useful and important applications. For example, computer vision algorithms leverage landmarks by detecting, identifying, and tracking them to determine the precise location of an object, create a 3D map of the surrounding environment, or to monitor the state of an object, and the list goes on...

### 2.3.1 Artificial Landmarks

While both natural and artificial landmarks are used in computer science applications, artificial landmarks can provide distinct advantages in terms of control, precision, reliability, adaptability, and data encoding. Also there are tons of library that support encoding, detecting, decoding, and tracking artificial landmarks. There are wide variety of artificial markers such as QR, Arcuo, Topotag, and other dozens of markers, see [2] for more details.

### 2.3.2 QR Code

QR Code is an acronym for Quick Response Code, and it is a two-dimensional barcode that encodes/stores data as a block of black and white squares, developed in 1994 by Denso Wave, to track automotive parts in manufacturing. Now QR codes are one of the most used markers due to the huge support by different devices and libraries, their simplicity and ease of use, and their ability of storing large amounts of data compared to traditional barcodes.

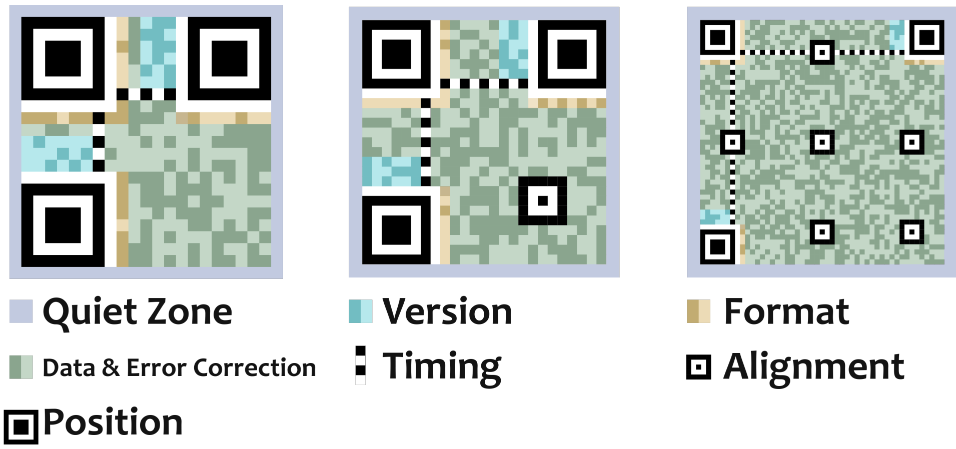


Figure 2.1: These are three QR Codes that store texts. The texts' lengths get larger going from the left to the right. Notice that the alignment patter only appears at the bigger QR Codes, and there are multiple ones at the biggest QR Code.

All QR Codes have standard structure as shown in Figure 2.1. This structure is made out of the following parts:

- **Quiet Zone:** This is a white empty area surrounds the QR Code that helps distinguishing it from its surroundings.

- **Version Information:** QR Codes have different versions/sizes which specified these two areas.

- **Format Information:** This part contains data about the error tolerance and mask pattern used.
- **Data & Error Correction:** This is where the encoded data, and the error correction are.
- **Timing Patterns:** Helps identifying squares and determining the matrix's size.
- **Alignment Marker:** Ensures the code can be read even if it is skewed or scanned from an angle.
- **Positions Markers:** Help the scanner recognize the code, read it fast, and determining the code's orientation.

### 2.3.3 QR Code & Indoor Localization

As we discussed previously, GPS is not the right choice when it comes to indoor localization, and we even mentioned some of the other replacements. But since we want to develop a system that exploits the information rich visuals using a camera, we can use this camera to detect QR Codes and determining the user's precise position as we are going to mention in more details at the methodology section.

There are several useful and interesting ways of determining the user's position after detecting and decoding a QR Code. One way for example, is dividing the environment into several squares, each square has its own QR Code inside of it encoding its position, whether it is put on the floor, roof, wall, or even in a hanging panel from the roof. For better illustration, let us assume that we have a room of 4 meters in width and height, this room is divided into 16 squares with equal sizes so each square has an area of $1\text{m}^2$. If we customized a hat for example, that embeds a camera in its top, the user's position will get determined while navigating in the room wearing the hat.

Although this solution is very computationally cheap, it comes with its own downsides. For instance, the position values are always discrete. So if we needed a continuous and precise position we should not use this method. But actually, this method could be very useful depending on its use. See [3] for example, where they created a localization system for a robot by assigning a QR Code for each floor tile/block, and they also assigned some tiles as obstacles so the robot will avoid trying to move on them. Then they used Dijkstra's algorithm so the robot can find the shortest path from its current node to any other node.

The idea of dividing an environment into smaller pieces is widely used in some industries in different ways and purposes. One of these industries is the

Figure 2.2: This image illustrates how a room can be divided into squares each with its own QR Code.

video game industry. A huge amount of video games divide the game world into a chunk of squares, triangles, hexagons, and other shapes depending on the game's need and performance. But the difference here is that they do not use this technique for localization since the positions for all the objects in the games are known and stored at the RAMs already. They use the technique to categorize the pieces such as walkable ground, water, lava, rocks, and so on. Then these pieces are used along with their categories to find a proper path between two points. Different path finding algorithms can be used, but the most popular and simple one is A* algorithm. See this [4] incredible youtube tutorial made by Sebastian Lague, that explain an implementation of the A* algorithm and how it can be optimized.

Another important and interesting way to calculate a precise and continues values of the user's position is detecting and decoding a QR Code using a camera, then calculating the position and orientation (pose) of it relative to the camera, after that we will be able to use this pose and the QR Code's global position to estimate the user's precise position. This method is heavier at the CPU, and harder to implement. It also need the camera's intrinsic parameters to be known or calculated using camera calibration algorithm. More on details could be found at the methodology section. See [5], where they used this method for implementing their localization system.

### 2.3.4 QR Codes Setup & Design

There are a lot of different ways of how we can setup our QR Codes for the indoor localization system. For example, we can put them on the ceiling, floor, inside a hanging panel, on walls, or any other place you can think of. In our proposed system, we want to create it in such a way that it work fine despite where they are put at, so we will not really care about this.

One significant question that might come to your mind after thinking about a building full of QR Codes is: "Wouldn't this make the building looks distorted and ugly?!". Our answer is: Well, it depends. For example,QR Codes can have custom shapes and colors that might make the place where it is put in looks more pretty if they where designed correctly. Imagine colorful codes with custom cartoonie shapes at the ceiling of a children school. And in this project, we are rally just providing a concept of the system, so the QR Codes can be replaced with any other thing depending on the needs. So depending on how someone is going to implement this system, the artificial markers - whether they are QR Codes or not - might make the building look better or worse, and they even can be designed in a way making the very difficult to find and recognize as if they do not even exist at all.

## 2.4 Customizable Guidance System

## 2.5 Objects Detection System

## 2.6 Related Work

# Chapter 3

# System Design

## 3.1 System Design

The system design chapter presents the overall architecture and key components.

# Chapter 4

# Results and Discussion

## 4.1 Results

This chapter presents the results obtained from the system.

| **Scenario** | **Expected Result** | **Actual Result** |
|---|---|---|
| Scenario 1 | Success | Success |
| Scenario 2 | Failure | Success |

Table 4.1: Results of Various Scenarios

Table 4.1 shows the results obtained during testing in various scenarios.

# Chapter 5

# Conclusion and Future Work

## 5.1 Conclusion and Future Work

The project concludes by summarizing the findings and suggesting future work.

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# Appendix A

## A.1 Sample Data Tables

Here we provide some example data tables that might be relevant for the study.

Table A.1: Example Data Table

| **Item** | **Quantity** | **Price** |
|---|---|---|
| Item 1 | 10 | $100 |
| Item 2 | 20 | $200 |
| Item 3 | 30 | $300 |

## A.2 Sample Figures

Below is an example figure for demonstration purposes.

# Appendix B

## B.1 Additional Information

This appendix contains additional information relevant to the study, including supplementary materials and further explanations.

## B.2 Supplementary Materials

Here you might include additional data or documents that support your research.

## B.3 Further Explanations

This section provides further explanations on specific topics covered in the main document. For example, you might elaborate on methodologies or provide additional insights into the analysis.