# Section 1. Problem Definition

## Introduction

In modern cities, more and more public places (e.g. a big shopping mall, university, library etc.) have been being built up for bringing convenience to people’s life. Although lots of services can be provided with a large size of indoor environment, people tend to lose their way when walking within it. The survey conducted by Olsson et al. [1] shows that the AR indoor navigation related expectation of customers, like locating the services such as ATM, is really significant. Due to the increasing trend in requirement for indoor positioning, many large IT companies have moved their concentration from outdoors to indoors [2].

## Project Aim

The aim of this project is to build a mobile AR application consists of indoor navigation and contextual information displaying.

## Project Objectives

It contains three objectives.

First, to build a mobile app for building visitors, through which users can quickly locate their current position indoor as well as see detailed contextual information of objects in real world shown on real-time vision from camera.

Second, to build a navigation system to direct users to the targeting place. The direction is dynamic according to the users’ current position and orientation.

Third, to build a data collecting system for building owners to input data of the building.

## Value Proposition

Although several prototypes have been raised by researchers, there is still no general and convenient application for providing indoor positioning service.

# Section 2. Literature Reviews

## Problem Analysis

To achieve the goal of quick exploration for an unfamiliar building, current position of users should be provided to users as referenced information. GPS is a widely used technology in outdoor navigation but can not work well indoors since the signals from satellites are too weak to penetrate into walls. A robust indoor positioning system should be designed. Due to the complicated situation of indoor environment, there is still no persuasive solution for indoor positioning service. Efforts made by professionals can be roughly classified into 3 groups [2]: 1) Signal-based positioning, such as WIFI, Bluetooth and cellular wireless connection signal. 2) Sensor-based positioning, such as IMU and camera (often related to AR). 3) Combination of both, such as AR+IMU, WIFI+AR. The first kind of the techniques [3] usually requires equipment infrastructures to be installed inside the building. These equipment infrastructures serve as beacons continuously sending signals which then received by handheld devices (e.g. smart phone) of users through a specific app. After calculation by a patent algorithm, the coordinate position with the highest possibility will be displayed. According to the evaluation done by Khoury and Kamat [3] , this kind of technique can reach high accuracy of 1 - 2 cm but is expensive in deployment. In addition, this kind of techniques can neither keep track of users’ orientation nor provide useful information other than position unless it composes another module for requiring information about building-objects that appear on users’ visiting path. Researchers keep on working, trying to take advantages of advances of recent smartphones as they are widespread with multiple sensors utilized. The second kind of techniques, the sensors-based positioning, means that using sensors built-in to estimate the location of devices. Camera-based positioning technique is now becoming dominant in this filed. The problem becomes what kind of objects indoor should be taken as references to simplified the object-recognition process as well as how to present such information in GUI. To solve this problem, AR is used. This paper will cover the overview of AR next passage. Note that in applications of the third kind of techniques, people often use sensors or signals to calibrate the accumulated deviation from the exact position of devices. As the theory of it is not much different from the first two, this paper is not going to further elaborate it.

## Related Technologies

Augmented Reality(AR) technology is to provide a graphical interface to users with real world perspective superimposed upon by or composited with virtual objects in real-time [4]. It could be used to supplement information, which can not be obtained from general perceptions, to objects in real world. This feature makes AR navigation possible if position information is attached to an object indoor. With reference from Mautz’s paper [5], the author summarizes the system of AR positioning application into three parts. Part 1, a database that storing pictures or videos taken by building manager or data collectors for markers which usually are static objects like doors, projections on walls or barcodes with position information. Part 2, a specific app installed in users’ smartphones that can detect pre-defined markers through cameras and send frames captured by cameras to a server for an information request. It also can draw virtual objects or text upon the real vision in GUI after retrieving useful information from a server. Part 3, a data processing program run on a server that receives those frames, matches them with samples in database and send back results to users’ smartphones after calculation. The system of AR positioning has its own advantages such as low-cost in deployment and instant information displaying during interactions with real world. For convenience, the author classifies these techniques into 2 groups by types of referenced markers: 1) Use references from artificial markers. Since the patterns of artificial markers such as barcodes are really distinguished from nearby environment, they are much easier to be recognized, making the system stable and robust. However, artificial markers are aesthetically defective and the installment of them may be cumbersome. 2) Use references from natural markers. Static objects like doors, windows or room tags can be considered as referenced points for estimation of locations of devices. Although the complexity of the system is increased, it exempts the installation of artificial markers from the construction of such positioning system and gives more natural sense to visitors walking within the building. Hence, this paper will focus on how to navigate users with reference from natural markers. Such existing solutions will be enumerated next passage.

## Existing Solutions

This section is going to discuss about the existing solutions which consists of AR as its unique or main positioning component.

Neges et al. [6] have proposed a solution using natural markers(e.g. exit signs) combined with IMU for error calibration. However, users have to set a starting point before the navigation process.

Xiao et al. [7] described a system using static objects(e.g. doors) as referenced points in a relatively large indoor environment. Although this system doesn't employ AR to represent position information, its algorithm for calculating the position of smartphone is still valuable to AR indoor navigation system.

Kim and Jun [8] designed a system on mobile tablet PC that uses both artificial markers and natural scene as reference in navigation process. The system first obtains the starting position through scanning pre-installed artificial markers. Then in navigation part, it repeatedly captures live image sequence through users’ cameras which to be compared with sample image sequence on database. After matching process, the location information will be shown if users enter a new place where artificial markers are not installed on. However, this system requires more computational power so that it may affect user experience.

Harlan and Gaetano [9] described a system from another angle by using landmarks(e.g. floor-to-wall transitions) as references. Positions of devices will be determined after matching detected landmarks with those on floor plan. It combines WIFI positioning technology to reduce the task of matching computation. It can reach accuracy of 30 cm, but the matching algorithm is complicated.

Bae el at. [10] described a system using 3D point cloud model for references, which constructed from a set of site pictures. Although they improve the performance of the model constructing process, it still needs sophisticated hardware support(server-side) and a relatively long time to build a 3D point cloud model.

For better user experience, the proposed system of this paper is mainly based on the first two solutions mentioned in this section.

# Section 3. methodologies

References

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