Indoor Navigation with Augmented Reality

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Abstract: This paper is a survey of types of Augmented Reality or AR interfaces and different indoor positioning and navigation techniques. Various existing methods are briefly elaborated and compared to build a set of techniques which can be used to develop a visual positioning and navigation system to implement handheld, mobile indoor navigation using augmented reality. The paper also illustrates about the newest and most trending technological advancements and available tools that enhance and ease the implementation of Augmented Reality applications.

Keywords: Indoor Positioning, Visual Positioning System, Indoor Navigation, Augmented Reality, Computer Vision

1 Introduction

In today's world, humans are extensively dependent on smartphones for navigation in unfamiliar environments. While there are many techniques and applications for outdoor navigation using GPS, there are limited options for indoor navigation, which is equally desired in large indoor spaces such as malls, office spaces, and institutions. The trending technology of AR can help us make the navigation feel more interactive and immersive. In AR, the world itself becomes the interface as people exercise more intuitive controls. With the help of direction arrows augmented in the real world seen through handheld devices like smartphones, the user should be navigated in an unfamiliar indoor setting for which the application has been configured.

2 Indoor Positioning and Navigation

Navigation is the task of finding a path from one place to another by finding current location, determining a destination and how to reach that destination from current location. Nicholaus R. Mrindoko and Dr. Lusajo M. Minga have provided a review after

comparing different indoor positioning techniques[1]. While GPS is the primary player for outdoor navigation, indoor navigation techniques have certain additional requirements to be met, due to infrastructural barriers, privacy restrictions, signal attenuation etc. Some of the common indoor positioning techniques such as Wi-Fi are explored here. These techniques however have a lesser accuracy as compared to the GPS as stated by A. Sudarsanan and team in their research paper[6] which is discussed further.

2.1 Older Techniques

Magnetic Beacons. Array of magnetic beacons with sensors can be used for indoor navigation. The navigation area has to be covered with the beacons which generates AC magnetic field with unique signature[2]. The smartphone's internal magnetometer can act as receiver to sense the signals. As the signals are unique the receiver is able to distinguish between the beacons, a result location detection can be done by capturing and analyzing the signals.

Wi-Fi. Nicolas Le Dortz and co-authors explain how to use WI-Fi Fingerprinting for indoor navigation in their paper, using probability distribution comparison[3]. Fingerprints are known locations or landmarks in a building. The strength of the Wi-Fi and the MAC are used for Wi-Fi fingerprinting[4]. During an offline phase, fingerprints are collected at known positions in the building. This database is called the radio map. In the online mode, the current Wi-Fi fingerprint probability distributions are compared with those of the radio map. The user location is estimated by calculating a weighted average of the three offline positions that best match the online measurements[1].

RFID. Radio Frequency Identification consists of two main components reader and transponder(tag). The tag stores a serial number which gets activated when there is energy field generated by the reading unit. This data is forwarded to the reader[15]. The reading chips can be inserted into the mobile phones for activating and capturing the data. As this data is different for every reader the location can be identified by mapping these serial numbers to specific area of navigation stored in the database, hence location is identified. However, RFID offers a range of less than meter which is a limited range.

2.2 Modern Techniques

Vision Based Navigation. Vision based navigation is extensively used for guiding robots in an indoor environment used with object detection techniques. Athira Sudarsan and Team in their paper on "Global Image Descriptor Based Navigation System for Indoor Environment" proposed a novel technique of carrying out vision based navigation which includes creation of a topological map created from keyframes extracted from a walkthrough video of the indoor environment, using the GIST descriptor.[6] Also, a scalable navigation system in an indoor library environment was proposed by Jennifer Pearson and team by the name Bookmark. In their paper regarding the same, they have discussed how existing identifiers of books such as their barcodes can be used to locate the books in the existing infrastructure of a library[5].

Visual Positioning System. VPS is now a popular navigation system under development by Google. For better visual experiences during navigation where the GPS does not suffice, VPS can be used to estimate precise positioning and orientation[7]. VPS uses the visual features in the environment to determine locations. Google Maps can now use your camera to identify your surroundings, visually communicate your route right in front of your eyes.

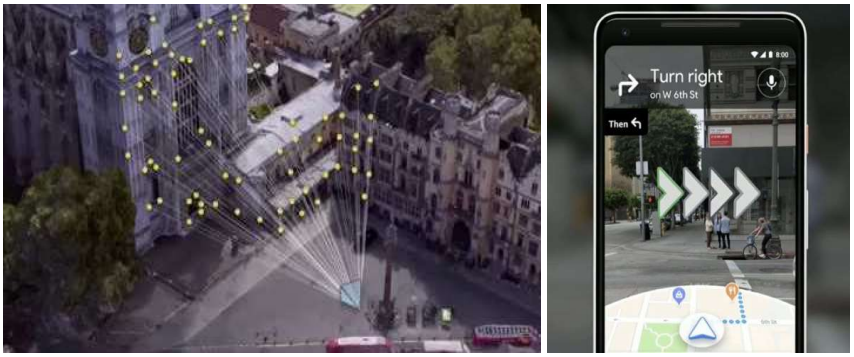

Fig. 1. Google VPS capturing visual features in the environment[7]

3 Augmented Reality

The reality that a human brain perceives is the result of all the sensory information taken as input which creates an experience. The main focus of different techniques in the reality-virtuality continuum is to recreate these sensory experiences with artificial information, so that our brain perceives these as real.

3.1 Reality Virtuality Continuum in History

Many developers and researchers confuse between the terms AR and VR. Paul Milgram and co-authors explained these differences in their paper on the reality virtuality continuum[8]. In AR, we increase the usability of an interface by adding or augmenting sensory information like computer generated images, sounds and in some cases, touch feedback over user's view of the real world. This enhances user's current perception of reality. VR, on the other hand refers to creating a simulated environment using computers and replacing users' environment by placing them inside the created experience. For his invention of Sensorama Simulator[9], Morton Heilig came to be known as the father of VR though the term was formally coined later by Jaron Lanier[10]. The first experiments with a head-mounted 3D display were conducted by Ivan Sutherland[16]. Modern headsets require powerful, low-latency displays which are capable of projecting complete digital worlds without dropping a frame. AR technology does not share this requirement.

3.2 Types of Augmented Reality

Marker based AR. Based on image recognition, marker-based AR works by recognizing a visual marker in the environment and generating a digital image only when a known marker is sensed. The markers are simple and unique, such as the QR codes[11]. It finds its applications in the manufacturing and construction industry.

Markerless AR. In markerless AR, sensors in devices are used to detect the real-world environment. With the emergence of smart devices, elements such as GPS, accelerometers, velocity meter, digital compass are pre-included in the device which make the existence of Markerless AR possible.

Projection based AR. This is a relatively newer trend in AR, which works on the principle of advance projection technology that forecasts light onto real world surfaces and senses human interaction with the light. This process is carried out by distinguishing between the expected and altered projection[11].

Superimposition AR. Superimposition based AR works with object detection and recognition. It recognizes an object and then replaces it by superimposing a digital image over it[11].

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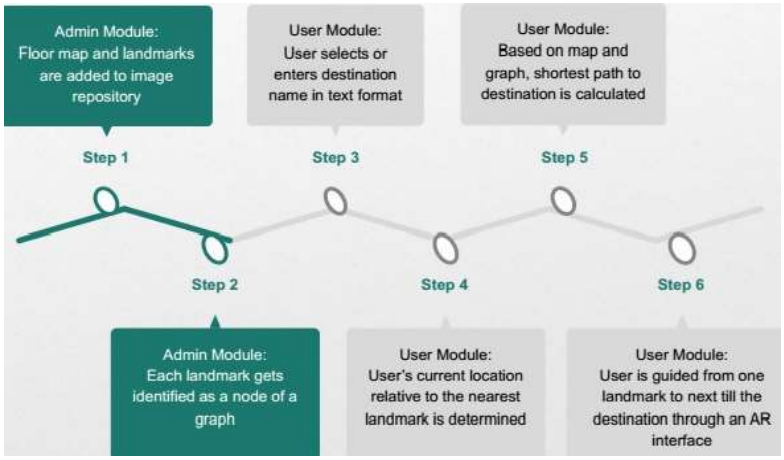

Fig. 2. Implementation of an indoor navigation system with arrows or direction guides augmented in the real world. Owner setup and Visitor navigation are referred to as Admin Module and User Module respectively.

To navigate in an unfamiliar indoor setting with direction guides augmented in the real world to navigate from source location to destination, sample flow of implementation

for on a smartphone device shown in Fig. 2 can be used. The flow consists of two parts- owner setup and visitor navigation.

The owner, also referred to as the admin here, provides the floor map (or coordinates) and landmarks of the indoor structure to the system. Each landmark is identified as a node of a graph which is used for location identification with associated coordinates. To use the system for navigation, the visiting user captures his current location by getting a nearby landmark in his/her camera view. The system compares it to the existing stored landmark images and uses landmark detection algorithms to determine user's current location. The user then selects a destination from a list displayed by the system. Based on the navigation technique used and owner-visitor inputs, shortest path is calculated and arrows get augmented in the user's real-world view. For implementing the proposed system, some of the useful technologies and hardware are explored hereby.

Sensors like accelerometers, magnetometers, gyroscopes etc. most of which are available in modern smartphones, are required for such a system. Cameras are required to visually scan to collect data about the surrounding area to take this information, which determines where surrounding physical objects are located, and then formulates a digital model to determine appropriate output[11]. AR devices require significant computer processing power. The processing components utilized may include some of components like CPU, GPU, RAM, Bluetooth/Wifi microchip, GPS microchip, or more[14]. To develop AR, different popular software includes Unity, Vuforia, ARCore for Android based and ARKit for iOS based mobile equipment. According to ARCore documentation resource, it uses three main technologies to integrate virtual content with the real world as seen through your phone's camera – motion tracking, environmental understanding and light estimation[12]. In order to identify and recognize landmarks for source detection in the indoor navigation system different machine learning features provided under MLKit can be combined and used[7][13].

5 Inferences

Among the various navigation techniques surveyed, Wi-Fi fingerprinting, RFID etc. have an external hardware requirement such as Wi-Fi access points or beacons. Vision based navigation and VPS, on the other hand, can be implemented without these external hardware resources, though using them jointly will definitely improve accuracy of computer vision. The various augmented reality types, and implementation methods studied show the various possible implementations of this technology. AR can be implemented with head mounted displays as well as hand held devices like smartphones. Marker based AR is the easiest to implement but it restricts the experience to areas where markers are available. To make the user interaction more immersive, we can best try to implement markerless AR which is harder to implement than marker based but more flexible as required for navigation.

6 Conclusions

Indoor navigation is clearly implementable with smartphones in the present day, and possibly with lesser hassles in a few years. The future of AR is fairly good with the advancement in hardware, sensors and graphics. Both indoor navigation and AR are most likely to be found all across devices and applications. Using this technology, the power of smartphone cameras and computer vision can be combined indoor maps to reimagine walking navigation. Thus, the idea of development of an AR interface on smartphones for indoor navigation has merit in the form of a mobile application.

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