VL-Loc: An Indoor Localization System Based on Mobile Phone and Illumination Facility

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ABSTRACT

With the increasing demands on location based services, indoor positioning technology is emerging. In this paper, we present an indoor imaging visible light positioning scheme, whose main algorithm is combined with image processing and pedestrian dead reckoning. We have developed and demonstrated a positioning system with a commercial mobile device and indoor illumination facilities. The hardware, algorithm, software, and deployment of the positioning system is analyzed, and it can achieve 3-dimensional sub-meter level indoor localization.

KEYWORDS

Indoor localization, visible light positioning, image sensor, illumination, pedestrian dead reckoning.

1 INTRODUCTION

In the last decade, motivated by the growing interests and applications in Location Based Services (LBS), indoor localization becomes a popular research area [1]. Due to the limited indoor performance of conventional Global Navigation Satellite System (GNSS), a series of indoor localization methods are proposed [2]. With the high luminous efficiency, low energy cost, and long life, Light Emitting Diode (LED) has been widely used nowadays, and has the potential to achieve indoor Visible Light Positioning (VLP) [3].

Generally, an indoor VLP system utilizes the existing lighting infrastructure as transmitter. While performing illumination, the light sources also transmit light signal, and work as beacons of the positioning system. Then, a receiver will positioning itself with the feature of captured light signal. According to the detector in receiver, VLP systems can be divided into Photo Diode (PD) based [4] and Image Sensor (IS) based [5]. To consider a Commercial Off-The-Shelf (COTS) mobile device is usually integrated with IS and Inertial Measurement Unit (IMU), an IS based VLP system is suitable for commercial usages, and can be aided by IMU based positioning methods. In our previous researches, various IS and IMU based VLP algorithms and systems have been proposed [6-8] and demonstrated with sub-meter level accuracy. In this paper, we present an indoor imaging VLP scheme based on image sensor and inertial measurement unit. Then, we also demonstrate it by a COTS mobile device and indoor illumination facilities which are driven by plug-and-play modulators.

2 PRINCIPLE OF POSITIONING SYSTEM

2.1 System Framework

The framework of the proposed positioning system is as Fig. 1 shows. The system is consists of several light sources work as transmitter and a receiver. For each light source, it is composed of a commercial LED lamp and a dedicated driver which is integrated with a modulator. Different light sources are distributed in indoor scenario, work as beacons while perform lighting. For the receiver, it is a mobile device such as mobile phone and tablet which equipped with image sensor and inertial sensors. Then, by applying the proposed positioning algorithm which combined with imaging positioning and pedestrian dead reckoning, the location of receiver can be obtained, and the positioning related information will be displayed by a software.

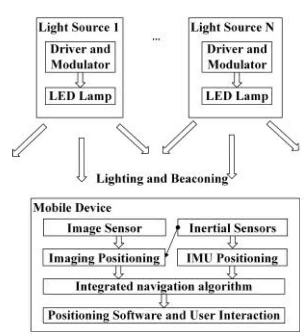

Figure 1: Framework of proposed positioning system.

2.2 Transmitter and Receiver

Fig. 2 shows the hardware of the system's transmitter and receiver. The transmitter is a plug-and-play light source which combined with a commercial LED lamp, driver circuit, and a reprogrammable modulator. On the other hand, the receiver is a COTS mobile phone (or tablet) which installed with our positioning software.

Figure 2: Hardware of transmitter and receiver.

2.3 Algorithm and Software

In the presented positioning system, a specific software is utilized at receiver, and it is embedded with the proposed positioning algorithm. The flowchart of the positioning algorithm and the interface of software are shown in Fig. 3. The proposed positioning algorithm is a hybrid method which includes imaging positioning algorithm and IMU positioning algorithm. For the imaging positioning algorithm, the 3-dimensional (3D) location of receiver can be calculated with the captured image of light source. For the IMU positioning algorithm, the relative location of receiver can be calculated by the output of the IMU in receiver. Thus, by combining the results of these 2 positioning algorithm, the location of receiver can be obtained, and the positioning accuracy is sub-meter level. Thus, the beacon information, 3D coordinates, and orientation of the receiver will be displayed on the interface of software.

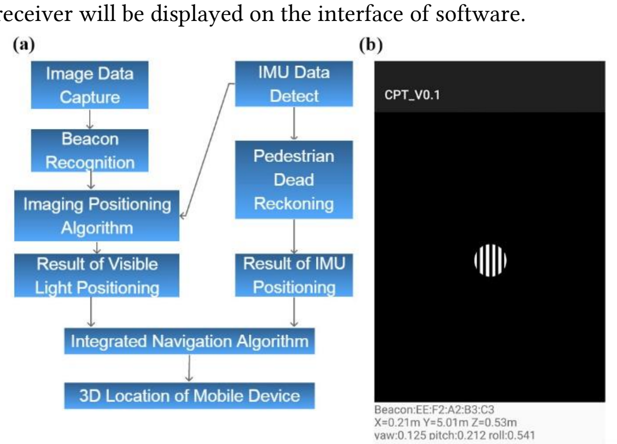

Figure 3: (a) Flowchart of algorithm, (b) Software interface.

3 SYSTEM DEPOLYMENT AND SETUP

To deployment the presented positioning system, we plan to mount 10 light sources in the scenario as positioning beacons, and measure the 3D coordinates of these beacons as reference. Thus we need to know the map of positioning scenario previously to plan the distribution of light sources. The 10 light sources can be directly powered by 220V grid voltage, and the electric power of each light source is 50W. For the receiver, we will use a COTS mobile phone (or tablet) which is integrated with image sensor and IMU. The operating system of receiver is Android 7.0.

In the demonstration, according to the positioning algorithm, the receiver should near one of the light sources at the beginning (or we mount a light source near the starting point previously), and the receiver is hand-held by a walking man during the demonstration with its screen maintain upward.

4 CONCLUSIONS

In this paper, we present and demonstrate an indoor positioning system. The positioning algorithm is mainly based on imaging visible light positioning and pedestrian dead reckoning. Moreover, the hardware and software of the localization system are developed and introduced. The deployment of the positioning system is analyzed and the accuracy is about sub-meter level, which is suitable for a series of applications in different scenarios such as supermarket, airport, and parking lot.

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