A Visible Light Positioning System for Indoor Localization and Orientation Tracking

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***Abstract*—Visible Light Communication (VLC) is a new and efficient technique of position tracking based on light-emitting diodes (LEDs) for lighting and communication. This research uses the potential of VLC technology in an attempt to compute both the position and orientation of a target unit equipped with a substantial amount of photo detectors. The study develops a specialized test bed. This allows us to take real-time data as LEDs offer modulated outputs and photodiodes measure and calculate light intensity arriving. A machine learning model is used to model the relationship between received light intensities and the corresponding position and orientation. Strong and efficient spatial tracking algorithms are the subject of this project. Triangulation techniques are used in such algorithms for proper positioning and patterns of light intensity based on angles are examined in order to decide direction. This system is thoroughly tested and it demonstrates moderate accuracy and stability in experimental results. This includes laboratory experiments in controlled environments, as well as experiments in the outside world. This is to maintain the stability and ability to adapt of the system. The results achieved aim to fill gaps in current tracking technologies, providing a low-cost system, as well as one that is not affected by interference. This research can be used in many areas such as robotics, virtual reality, industrial automation and precise navigation. This work dramatically advances the state of spatial tracking by promoting VLC, thus making a considerable contribution to communication as well as control systems, provoking substantial technical innovation as well as practical engineering progress.**

***Index Terms*—Visible Light Communication, Positioning, Orientation, Spatial Tracking, LED, Photodiodes**

I. Introduction

Visible Light Communication (VLC) is an emerging technology in wireless communication that utilizes the visible light spectrum to transmit data while providing illumination. VLC systems operate by modulating the intensity of LED light sources at frequencies imperceptible to the human eye, thereby data transmission is achieved without any effect on ambient lighting [1], [2]. Since LED light infrastructure is being mounted in indoor environments more and more, VLC becomes an inexpensive and power-saving alternative to traditional radio frequency (RF) based communication systems [3].Compared to RF technologies such as Wi-Fi, Bluetooth and infrared, VLC offers several advantages such as the availability of greater bandwidth, immunity to electromagnetic interference and improved spatial confinement for greater security and localization precision [4], [5].These attributes make VLC extremely attractive to be used in electromagnetically sensitive areas such as hospitals, airplane cabins and industrial automation [4], [6]. IPS are RF based traditionally, which typically suffer from multipath interference, signal attenuation and low accuracy on the order of meters [5]. VLC based IPS can achieve centimeter accuracy in ideal circumstances with geometrical localization techniques such as received signal strength (RSS) based trilateration and angle-of-arrival (AoA) estimation [1], [7]. Experiments have demonstrated that VLC systems are capable of sub meter accuracy using only normal ceiling mounted LEDs and simple photodiode receivers [8], [10].

However, the main deficiency of current VLC based positioning systems is that they are focused on location estimation alone, without regard to the orientation (angular pose) of the target object. This separation restricts their usefulness in applications where full pose information is critical, e.g., robotics, augmented reality (AR) and high-accuracy navigation [7], [11]. Simultaneous position and orientation tracking alternately known as simultaneous pose estimation (SPO) is crucial in dynamic environments where devices are constantly moving and rotating [13].

Recent efforts have begun bridging this gap by incorporating photodiode arrays [7], hybrid sensor fusion methods [3], and optimization algorithms to enable orientation estimation along with localization. For instance, multi face sensor modules, i.e., pyramid shaped receivers, have been used to record angular light intensity patterns from various directions, thereby estimating orientation [5], [11]. Besides, machine learning techniques have been applied to VLC positioning to improve robustness under the real world environment with multipath interference and light intensity fluctuation [13].

The current research proposes a VLC based system capable of real time simultaneous position and orientation estimation using modulated LEDs and an array of photodiodes embedded in a geometrically designed receiver. The system aims to