Abstract

The widespread use of LED lamps in all illumination environments is witnessed by the early 21st century. The usages of LEDs in indoor communications are gradually investigated in the last two decades. Companies like Pure-LiFi and oledcomm (with the product Li-Fi MAX), as well as many research institutes, are researching on the secure and high-speed light-based communication approach with good adaptivity. The fast development of visible light communication (VLC) provides a great chance for visible light positioning (VLP) systems. Moreover, researchers are seeking a feasible indoor positioning technology and establish an indoor GPS like system. As the GPS signals have severe multi-path effects and strong signal attenuations. Visible light with its light of sight (LOS) property and fewer reflections and diffractions gain advantages in the positioning accuracy over other RF-based techniques.

There are several positioning algorithms, the simplest one in structure is the received signal strength (RSS) which has good signal noise ratio (SNR) property, but is not feasible in situations with rotations and intensity disturbance. And Time Difference of Arrival (TDOA) is one of the complicated algorithms, with high demands in hardware, but good robustness in rotations. Among the positioning algorithms, Phase Difference of Arrival (PDOA) is one of the compromises. PDOA is similar to the TDOA based method in concept, however, using continuous sine waves rather than short pulses, reducing the hardware complexity greatly. Meanwhile, PDOA has both the high accuracy and rotation robustness properties.

In this thesis, our first concern on the classical PDOA systems is the use of local oscillators (LOs). The LOs are usually using hardware devices and the modulation frequencies are constrained by the multiples of a fundamental LO's frequency. Also, such LOs are used in both transmitting and receiving sides, causing clock precision related errors. Hence, a system with virtual LOs (VLO) is proposed, using software generated signals, and a new algorithm with higher frequency allocation flexibility is also proposed. Therefore, the interferences of harmonics from the modulation frequencies are avoided and less band is occupied. The proposed optimizations are hence promising in the combination of the VLC and VLP systems.

Further researches reveal that PDOA systems using LOs (even with VLO) have an issue of pseudo synchronization. In actual applications, the signals received are truncated with a random time schedule and unsynchronized to the transmitter side. This causes a confusion of phases at the receiving end with leap solutions in inverse trigonometric functions, ending up with sudden phase changes. Therefore, a novel LO irrelevant positioning scheme is further

proposed. The scheme with one extra transmission frequency is added on the transmitter side, with totally five signals carrying four distance information. The proposed algorithm has two distinguished differential processes on phase extractions. The distance difference measurements are extracted from the differential of PDOA signals, hence called DPDOA algorithm. Our proposed DPDOA algorithm requires no pseudo synchronization at the receiver ends and completely removes the LOs. Experimental validations illustrate sub-decimetre level positioning accuracy.

In actual applications, the LED lamps have phase/time models different from the ideal sphere model and the performance of the PDOA/TDOA based system is hence compromised. A neural network (NN) based solution is proposed for the first time to address the onsite modeling and positioning problem in a single hidden layer NN. The proposed scheme saves position solving calculations and enhances the positioning performance evidently.

After examining phase and time-based VLP systems, it is found that phase/time measurements have generally higher SNR requirements than the RSS measurements. Meanwhile, the RSS as the most cost-efficient algorithm has higher SNR tolerance when no rotation or intensity disturbance occurs. The DPDOA algorithm is capable of functioning under rotation and intensity disturbances. Hence, we propose a hybrid algorithm of using both DPDOA and RSS measurements with selection based strategies. As the DPDOA signals contain both RSS and PDOA information, no extra cost incurs. We design the T-selection and the V-selection strategies using DPDOA and RSS measurements as fundamental positioning standard, and show that the T-selection based hybrid system outperforms the V-selection based system.