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Vehicle to Vehicle Communication using Li-Fi Technology

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ABSTRACT: for the vehicle are visible light communication (VLC) system, one of key challenges is beam alignment between a lightemitting diode (LED)-based transmitter and a lens-based receiver with a narrow field of view (FoV) for high optical gain. Received optical intensity varies significantly at a mobile receiver due to the delay in beam detection and alignment. In order to maximize the received optical intensity for high signal-to-noise ratio, in this paper, a real-time light source tracking system with a trajectory prediction function based on the Kalman filter is experimentally designed and demonstrated for dynamic VLC applications. A twoaxis gimbal is used to adjust the receiver attitude with the location of a wide FoV transmitter, which is detected by a high-speed camera. As the frame rate of practical cameras may not be equal to the frequency of the beacon signal, there is a variable delay in location prediction and beam alignment. An adaptive control based on the S-shaped speed planning model is proposed to improve the alignment performance. The effectiveness of the scheme is verified in both simulation and experiment. Experimental results show that with the proposed scheme the root mean square error (RMSE) in alignment deviation is improved by.

KEYWORDS: Visible light communication (VLC), trajectory prediction, Kalman filter, adaptive control strategy.

I. INTRODUCTION

Visible light communication (VLC) has been widely considered as a promising technique with many advantages such as low power consumption, low cost and high data rate [1]-[3]. For the vehicular VLC system in the outdoor mobile environment, the received optical intensity is rather low and unstable due to the movement of the VLC transceivers. In [4],[5], the model for vehicular mobility was presented to study the impact of mobile vehicles in VLC systems on received optical intensity and communication performance. A dynamic alignment system was required to minimize error of the alignment between the target light source at the transmitter and the photoelectric detector (PD) at the receiver. In the existing alignment systems for VLC applications, a high-speed camera is installed near the PD at the receiver to locate the target light source through image processing algorithms [5]-[8]. The control instruction is sent to drive themechanical gimbal for alignment. However, due to the processing of image data and mechanical movement, most of the existing target location and alignment systems are limited by the speed of data processing and mechanical response. There is a certain delay in the location and alignment process, which inevitably leads to the hysteresis of the alignment. Trajectory prediction is a key technology for location based services such as path navigation, traffic planning and control, and weapon guidance. Typical trajectory prediction methods include prediction based on space vector data [9], pattern [10],[11], semantic perception[12], regression and clustering [13], and collaborative prediction [14]. A big amount of data were required to find the potential laws of trajectory using the data mining methods. For the trajectory prediction of the target light source in VLC systems, it is necessary to consider the mobility and real-time signal processing so that the alignment of the target light source is implemented in time. An automatic location and alignment system was designed for VLC with an extended Kalman filter and a prediction method based on communication links between transceivers [16],[17]. However, the information exchange between the transceivers was required, which may reduce the alignment speed and overall performance. In this paper, we present a trajectory prediction algorithm and an adaptive control strategy for alignment with the target light source for dynamic VLC applications. A Kalman filter is used to estimate the mobility of the target light source. A twoaxis gimbal is used to adjust the receiver attitude with the location of a wide field of view (FoV) transmitter, which is detected by a high-speed camera. As the frame rate of practical cameras may not be equal to the frequency of the beacon signal, there is a variable delay in location prediction and beam alignment. An adaptive control based on the S-shaped speed planning model is proposed to control the gimbal cooperating with the trajectory prediction algorithm. Compared with the traditional schemes [5]-[8],[16],[17], our scheme is focused on not only the mobility of the target light source but also the control process. The dynamic delay estimation mechanism introduced in our system contribute to an accurate

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estimation of speed planning curve in the adaptive control strategycooperating with the prediction algorithm for fast alignment. Therefore, the alignment deviation is reduced greatly .

II. SYSTEM MODEL

. The function block of the location of target light sources is used to provide the pixel deviation of the target lightsource Relative to the gimbal, in the image space. The raw data about the location of light sources is preprocessed, including outlier elimination, filtering, and coordinate conversion. The angular deviation vector of the target light source, , is obtained for trajectory prediction based on the Kalman filter. The current angular location of gimbal is fed back to the target mobility estimation module. The module estimates the angular velocity and angular acceleration with the Kalman filter. The dynamic alignment delay is estimated by the software timer. An adaptive control strategy is designed base on the speed curve plan. Finally, the predicted location of the target light source is sent to the motion control block, in order to complete the alignment of the target light source, and maintain a stable line-of-sight (LoS) link of VLC. Fig. 1. Block diagram of trajectory prediction of the target light source.

A. Location prediction of the target light source

The location prediction model can be summarized as where is the predicted location of the target light source, is estimate of the relative location of the current target light source is the predicted angular velocity of the target light source is estimated of the angular velocity, is estimate of the angular acceleration, and is the sum of the estimated alignment delay. The target light source emitting a beacon signal together with information signal is detected by the difference between adjacent frames from a high-speed camera [18]. The location of the target light source in the pixel coordinate system at each moment can be defined. The schematic diagram of the light source location is in Fig. 2. Figure 2 shows two planes, the target plane (OTXTYT) and the imaging plane (OIXIYI). The angular deviation of the target light source relative to the gimbal can be calculated by where are deviation angles in the horizontal and vertical directions respectively. is the pixel size, and is the focal length of the lens. Fig. 2. Schematic diagram of the light source location. Owing to the irregularity of the road and the vibration of the vehicle, the location of the target light source contains noise in both the horizontal and vertical directions, which satisfies the Gaussian distribution [19]. As a result, the Kalman filter is used to suppress the influence of noise to a certain extent, and estimate the mobility of the target light source. A state space model is used to describe the mobility of the target light source. For a high-frame-rate camera, the motion state of the target light source represented by each sampling point varies with time. In a very short time, we can assume that the target light source has a uniform acceleration motion. We define the state variables as the angle, angular velocity and angular acceleration of the target light source in the horizontal direction, respectively, while in the vertical direction. We define the observation variables are the current angular location vector of the gimbal, and the deviation angle of the target light source. Therefore, the observation location of the target light source can be obtained .

Therefore, the state space model for the target light source in the discrete-time domain is expressed as: the state vector of the target light source is the observation vector of the target light source. the prediction and observation vectors of noise, respectively. the transition matrix and observation matrix. The angular velocity and angular acceleration are estimated in each recursive process by a linear **Kalman filter [17].**

B. Estimation of dynamic delay:

Estimation of the delay for digital signal processing is important for prediction of the target location. Such a delay is affected by the update rates of the camera and gimbal. Ideally, the update rate of control instruction for the gimbal, , is equal to the frame rate of the camera which varies with time in practice. In order to mitigate the variable frame rate of the camera on the location performance is designed to The prediction with the latest detected location of the target is applied for controlling the gimbal. The consumed time or delay is determined by the following procedures including target detection , trajectory prediction , motion control and data transmission in a specified frame the length of which affects the transmission period. The interval between the prediction and control is accumulated as seen in Fig. 3. Such interval can be measured by an embedded timer with an accuracy of 1 μs. As the procedures in the CPU and programmable motion controller (PMC) run in parallel, there is no additional waiting delay. The total delay is equal to a sum of these six variables represented .

C. Adaptive control based on S-shaped speed planning

To achieve a smooth operation without sudden change of acceleration, we use the S-shaped speed planning curve [20],[21] in the mechanical control for planning the movement process. The input parameters of the S-shaped speed planning curve model are related to the trajectory and the gimbal mobility limit: initial (final) angle of the gimbal initial (final) angular velocity ω and maximum angular velocity/ acceleration/ jerk The output results include the planning

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time angle and angular velocity. An adaptive control strategy was used shown in Fig. 4. The time slot for sending control instructions is given as . In order to complete the predicted trajectory within the control time slot, we adaptively adjust the mobility limit) Of the gimbal so that the planning time is equal to the control time slot, . The red curve represents the trajectory of the target light source, and the blue curve represents the trajectory of the gimbal. In this way, the alignment deviation can be compensated.

III. RESULTS AND DISCUSSION

In this section, numerical and experimental investigations are undertaken to verify the effectiveness of the proposed scheme. Default values of the system parameters are presented in Table I unless explicitly mentioned.

A. Numerical verification

We explore the maximum alignment deviation when the upper limit of the received optical power attenuation is dB, which corresponds to an upper limit of alignment deviation in the simulation. Assuming that the spatial distribution of the light intensity is consistent with the two-dimensional Gaussian distribution. where ⊠ is dispersion degree of light intensity in both X and Y direction (mutually independent).the center location of the speckle on the receiving surface of the PD. The optical power can be obtained by calculating the integral of the light intensity distribution in the effective area of the PD with a radius of *RD*. When the received optical power is 99% (σ:0.33⊠⊠), 90% (σ:0.47⊠⊠) and 50% (σ:0.85⊠⊠) of the total power, the upper limit of angular deviation is 1.63⊠, 1.62⊠, 2.05⊠ respectively. The impact of moving speed on the alignment performance is shown in Fig. 6. The trajectory of the target light source moving at a maximum speed of 0.2 or 1 m/s. With the proposed scheme for the visible light trajectory prediction, the angular deviation (error) of the received speckle is significantly improved in Fig. 6(b). It takes less than 0.5 s to achieve stable performance in the initial stage, which indicates its capability of fast response. For the case of low moving speed, the angular deviation is relatively small. For the moving speed of 1.0 m/s, A Fi maximum angular deviation of 0.1^{o} . To further analyze the alignment performance, root mean square error (RMSE) is applied at different moving speeds in Fig. 7. It is obvious that the alignment deviation with the proposed scheme is much lower than that without prediction. The difference between these two curves increases for fastmoving speed. This indicates the effectiveness of the scheme for dynamic VLC systems.

B. Experimental results

Experimental investigation is made on the effectiveness of the scheme by setting the experimental conditions very close to the simulation. For a practical gimbal, the maximum speed of the gimbal is set to 100 °/s, whilst the acceleration and jerk are unknown. The experimental setup is shown in Fig.8.To make the target light source move at different speeds, the transmitter is placed on a sliding rail driven by a stepper motor. Two sets of lights are installed together on the sliding rail as the target light source. One is a single white LED as a beacon light source driven by 100 Hz, 10 VPP, 50% duty cycle on-off keying (OOK) signal; the other is a circular red LED array driven by 25 Mb/s OOK signal for data transmission. The target light source moves back and forth on the sliding rail. The vertical (shortest) distance between the transmitter and receiver is set to 3 m for relatively large angular speed of the gimbal as the angular speed of tracking a distant target is relatively low. We developed a visible light location and communication system, including three modules: location of the target light source and trajectory prediction, motion control, and VLC. In the first module, there is an industrial camera for image acquisition, a virtex-6 FPGA board for target location, an embedded processor with 2.2 GHz Intel Core i7-5650U CPU and 8 GB DDR3L RAM for DSP related to trajectory of the target light source and PMC. The PMC consists of two independent servo motors with drivers and one motion controller. The VLC module includes a PD and a VLC demodulator implemented with a FPGA evaluation board with analog circuits [18]. In the experiment, the target light source moves back and forth on the sliding rail at the speed of 0.2~1.0 m/s. The camera captures the light from the beacon, guiding the gimbal to align the receiver with the communication light source for LoS transmission. During the alignment process, the embedded processor continuously records the alignment deviation data and analyzes the alignment performance simultaneously.**Angular deviation (°) Angle (°)** .The data of the target light source location is collected by an infrared laser rangefinder on the side of the sliding rail, and then the motion information is calculated. The trajectory of the light source moving at speeds of 0.2 and 1 m/s is It can be seen from Fig.9(b) that the alignment deviation changes periodically at different moving speeds. The greater the moving speed, the greater the overall alignment deviation.. When the target light source moves in the middle part of the sliding rail at a constant speed, an approximately stable alignment deviation is observed, which is caused by the data processing delay and communication delay. When the target light source moves to the edge of the sliding rail and starts to change the direction of motion, the alignment deviation decreases before increases. It is because in this process, the speed of the target light source decreases to zero and then increases in the opposite

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direction. The alignment deviation increases as speed increases. The alignment deviation is significantly reduced with the proposed scheme. This is consistent with the simulation results. The only difference is that when the direction of the target light source changes at the edge When the target light source moves to the edge of the sliding rail, the moving speed of the target light source begins to decrease. Since the feedback process has delayed, the gimbal adjusts its speed more slowly than the target. The alignment deviation caused by this part is shown in the area marked by the red shadow. In addition, the acceleration of the gimbal is less than that of the target light source due to the limited mobility of the gimbal, . This results in additional deviation shown in the area marked by blue shadow. Therefore, the deviation peaks occur when it moves at the edges. We further calculate the RMSE in the alignment or angular deviation at different speeds shown in Fig. 11. It can be seen that the alignment performance can be significantly improved by the proposed scheme. The blue curves of the graph show improvement in the alignment performance in the uniform motion stage with a constant angular velocity, whilst the red curves show improvement in the alignment performance in the whole motion stage. Because of the alignment deviation peaks when the target light source moves at the edge of the sliding rail, the improvement in alignment deviation is smaller than that in the uniform motion stage. In the future work, the alignment performance can be improved by increasing the communication bandwidth of the feedback process or improving the mobility of the gimbal.

IV. CONCLUSION AND FUTURE WORK

A real-time light source alignment system with a trajectory prediction function based on the Kalman filter has been successfully designed and demonstrated for dynamic VLC applications. With a two-axis gimbal for adjusting the attitude of the receiver for beam alignment, the effectiveness of the proposed scheme for minimizing the alignment deviation was verified in both simulation and experiment. Because of variation in the frame rate of practical cameras for the light source detection, the delay in controlling the gimbal varies with time. In order to mitigate the effect of the variable delay in the detection and alignment of the light source, an adaptive control based on the S-shaped speed planning model was applied to improve the alignment performance with the Kalman filterbased trajectory prediction. It has shown that with the proposed scheme the RMSE in alignment deviation is improved by >50%.In future work we can implement GPS ,the system provides the anti-vechicular system .it gives extract missing of the vehicle to the user or a owner. This system is High efficiency, and Low power consumption.

V. ACKNOWLEDGMENT

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