Demo : Intelligent Vehicular Perception of Non-Line-of-Sight Environment using Visible Light Communication with Stereo Cameras

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***Abstract*—In this work, we explore the use of multi-camera setups through stereo-vision enabled cameras to perceive immediate and non-line of sight environments of a vehicle. Our proposed system uses visible light communication between a transmitter and receiver vehicle to convey information about the scene in front of the transmitter vehicle. Such a system virtually enables a "see-through-the-vehicle-in-front", functionality by combining scene perception with vehicle-vehicle communication. We posit to demonstrate this functionality using a device-device communication setup using a stereo camera that does perception mapping and visible light communication reception from a LED transmitter.**

I. Introduction

Vehicles today are increasingly being integrated with cameras, for applications ranging from driving and parking assistance to real–time environment monitoring. However, the use of such camera systems has been limited to treating the camera as a passive sensing interface rather than an active receiver for communication. A prototype Visual MIMO system [1] was demonstrated for a safety application through brakelights and integrated cameras (The concept of Visual MIMO proposes use of cameras and optical arrays as receivers for information communicated through light). It has taken a few years for the community to appreciate the use of cameras in the vehicular networking context. Today, there is an increasing trend in the interest in using Visual MIMO communication for vehicular networking [2], [3], [4], [5]. With the synergistic advancements in IEEE 802.15.7 (currently revision 1) [6] standardization of VLC efforts, it seems that the use of VLC communication receivers in vehicular networking and camera communication, might getting closer to commercial adoption in future.

This work presents our recent exploration in using multi–camera systems for Vehicle-to-Vehicle communication (V2V). Multi–camera or camera–array systems can be very useful for vehicular networking applications from a multiple–input multiple–output (MIMO) system perspective. The additional camera can help provide meta data, for example, tracking information, while the primary camera can be used for active data reception. Additionally, the multi–camera setup (virtually) expands the receiving pixel array, thus enabling a potential throughput scaling capability.

We propose to leverage the use of stereo or depth-enabled cameras for extending perception beyond a vehicle's immediate scene. We aim to address the fundamental problem of the obstruction of the scenes by vehicles driving in front of a user's vehicle. In essence, our system enables a "see-through" functionality beyond the front vehicle. Such a functionality can be very helpful for early dissemination of safety information, intelligent perception mapping, traffic management etc. Stereo-cameras help estimate the distance between vehicles. We use object detection computer vision models to detect, or perceive, the entities in the scene – e.g. vehicles, pedestrians, and traffic-light. We leverage from existing deep learning models for vehicle, pedestrian, road sign and traffic light detection. We train YOLO [7] system for brakelight detection on our real-world footage on vehicles on highways. We integrate camera communication with perception in a way that the vehicle in front communicates compressed information to the vehicle behind which uses the compressed information as meta-data to improve its perception beyond its immediate line-of-sight.

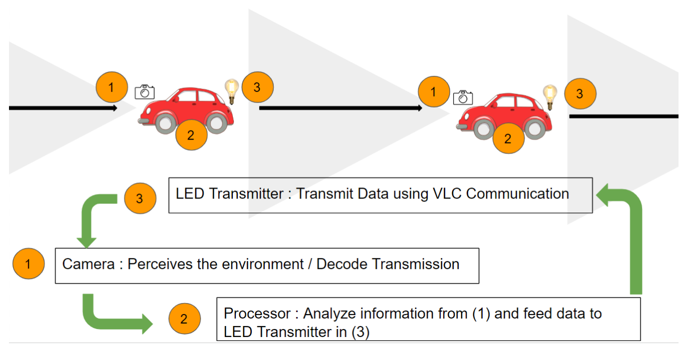

Fig. 1. V2V Camera and Perception Demo Setup.

II. Demo

Our demonstration, illustrated in Figure 1, constitutes a stereo camera, a NVIDIA Jetson Xavier board, a LED and an Arduino controller. We consider that each vehicle is integrated with a stereo-camera controlled by a GPU module in the front of the vehicle, and a VLC LED transmitter at its back. We refer to a transmitter (front) vehicle as the one blocking the view for a receiver (behind) vehicle that the user is driving. The stereo camera, controlled by the Jetson Xavier is placed in the front of the car. The camera captures image frames of the view

978-1-7281-4571-6/19/$31.00 ©2019 IEEE

from the front of the transmitter vehicle. The Jetson Xavier further perceives the environment by identifying the objects in the frame and correlating them with the depth information provided by the stereo camera. This perceived information is analyzed in the Jetson Xavier to predict or detect events that can be escalated into a warning. These warnings are converted into packets of data which are transmitted using a VLC LED transmitter that is placed at the rear of the transmitter vehicle. The information is modulated using ON-OFF keying in the form of ON-OFF pulses (ON = bit 1, OFF = bit 0). The receiver vehicle consists of the same stereo camera setup which conducts the processing of frames for perception and includes the capability of decoding the transmitted information using algorithms that understand and act upon the transmitted warnings. This cycle of perception, transmission, reception, and processing of warnings is repeated periodically. To detect objects in the frames and also locate the sources of the transmissions, we use state of the art deep learning networks using YOLO models.

For the demonstration, we set up a stereo camera and a LED transmitter 2 meters apart on a table. The LED transmitter is controlled by an Arduino Nano and the stereo camera is controlled by a NVDIA Jetson Xavier board. The demonstration will exemplify the object detection, depth mapping and the packet transfer using visible light communication in tandem and in real-time.

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