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Demo: Driver Gaze-Aware Adaptive LiDAR Sensing for Advanced Driver Assistance Systems

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***Abstract*—Light detection and ranging (LiDAR) plays a crucial role in machine perception for advanced driver assistance systems. Existing LiDARs, however, do not adapt their sensing strategy to complement driver's perception. We demonstrate a novel LiDAR prototype that dynamically adapts its range and resolution over the field of view, according to real-time driver gaze. Our gaze-aware LiDAR emphasizes scanning peripheral zones the driver may overlook, i.e., critical areas during driving. Our demonstration showcases enhanced perception, highlighting the potential of hybrid human-machine sensing for safer driving.**

***Index Terms*—LiDAR, ADAS, Human-Machine Systems, Eye tracking**

I. INTRODUCTION

LIDAR, a key component of advanced driver assistance systems (ADAS), provides high-resolution perception of the environment. Recent research has developed adaptive LiDARs that tailor their scanning profile to side-information on the environment [1]–[4]. However, existing adaptive LiDAR methods primarily depend on external cameras and offline street maps, lacking real-time adaptability to human driver's behavior. In summary, existing LiDARs ignore the driver's perception, leading to redundant sensing within the driver's field of view (FoV). This redundancy results in suboptimal use of LiDAR resources, which could be better allocated outside the driver's FoV to enhance overall perception of the hybrid human-machine system.

II. SYSTEM DESIGN AND IMPLEMENTATION

A. System design

We develop a spinning LiDAR that dynamically adjusts its scanning parameters based on real-time driver gaze (Fig. 1). Unlike a standard spinning LiDAR that employs a uniform angular resolution and a uniform range over the 360° FoV, our LiDAR adapts its range and resolution in different regions within the FoV. These regions are based on the driver's region of focus (RoF_{driver}) obtained from a gaze-tracking camera.

Our gaze-aware spinning LiDAR enhances the angular resolution outside RoF_{driver} by reducing the LiDAR's spinning rate. Furthermore, it also enhances the scanned range of the LiDAR outside RoF_{driver} by increasing the LiDAR's dwell time to acquire each point within the point cloud. Spending a longer time outside RoF_{driver} leaves less time for our LiDAR to scan RoF_{driver} leading to a reduced range and resolution within RoF_{driver}. This is usually acceptable as RoF_{driver} is already monitored by the driver.

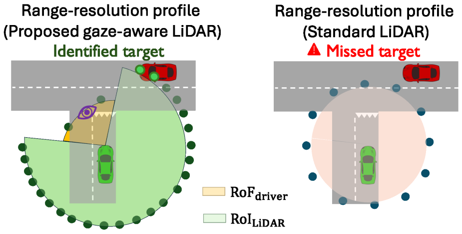

Figure 1. Our system identifies the driver's focus region, RoF_{driver}, and sets the LiDAR's region of interest, RoI_{LiDAR}, as its complement. By dynamically adjusting its parameters, it improves range and resolution outside RoF_{driver} compared to a standard LiDAR.

B. System implementation

Our system (Fig. 4) extends the previously proposed ELLAS system [4], which comprises the VL53L1X time-of-flight LiDAR sensor [5] mounted on a custom spinning platform. An Arduino controls the platform's spin rate, which determines the resolution, and the LiDAR's timing budget, which controls its range. Our extension integrates real-time gaze information from a basic web camera facing the driver. This information is used to determine RoF_{driver} and its complementary region, i.e., $[0, 2\pi] \setminus RoF_{\text{driver}}$.

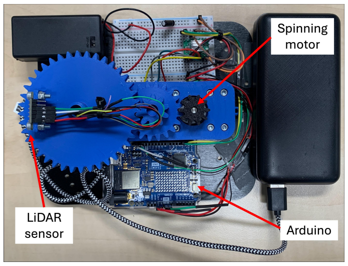

Figure 2. Setup of the VL53L1X time-of-flight LiDAR sensor and the Arduino.

Our gaze-aware adaptive LiDAR was mounted on top of a real vehicle to scan the 180-degree FoV in front of the vehicle. The gaze information of the driver was obtained using

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a web camera within the car. The test environment (Fig. 4) included two pedestrians and a cyclist. In our proof-of-concept experiment, the driver was looking approximately 60 degrees to the left. With our design, the LiDAR employs a spin rate of 3.75 rpm and a timing budget of 20 ms when scanning RoF_{driver}. These parameters are set to 22.49 rpm and 140 ms to scan outside RoF_{driver}. We demonstrate the point clouds acquired with two LiDAR configurations: one using our proposed gaze-aware adaptation and another in a comparable standard LiDAR mode. For the standard mode, we used the maximum timing budget of 140 ms and a spin rate of 8.43 rpm. These settings ensure that the standard mode has the same overall frame rate as our gaze-aware mode, which is 0.14 fps.

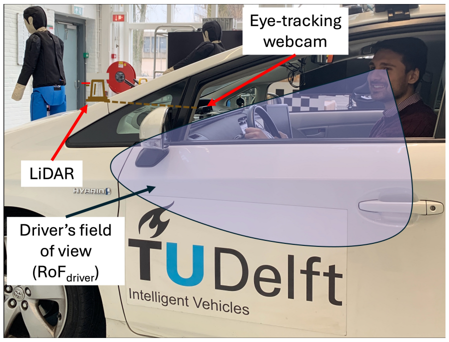

Figure 3. Our car-mounted LiDAR system adapts its sensing strategy based on gaze data from a web camera. We tested it in an environment with two pedestrians and a cyclist.

C. Results

Our gaze-aware LiDAR acquired a high-density point cloud representation of the two pedestrians and a bicyclist outside RoF_{driver} (Fig. 4). A high-density point cloud is due to the fact that our LiDAR has a longer dwell time outside RoF_{driver}. With our gaze-aware approach, we observed that the LiDAR also acquires a high-density point cloud representation within RoF_{driver}. This is because our method uses a shorter timing budget than the standard LiDAR in RoF_{driver}, which is better suited to scan medium range targets such as the left wall.

III. VISITORS' EXPERIENCE

Our prototype features a web camera connected to an Arduino-based LiDAR (Fig. 2). It can be demonstrated in a conference hall without a vehicle. Visitors can experience how timing budget and rotational speed affect LiDAR detection. Acting as drivers, they'll have their gaze tracked by a web camera, optimising LiDAR range and resolution. Visitors can observe point clouds generated with and without gaze tracking, highlighting the benefits of our gaze-aware LiDAR control.

IV. CONCLUSION

We present a novel LiDAR prototype that adapts its sensing to real-time driver gaze for enhanced perception. The prototype integrates an adaptive spinning LiDAR system with a simple camera monitoring driver gaze. Experimental results show that our LiDAR acquires a higher-density point cloud than a comparable standard LiDAR, especially outside the driver's focus. This hybrid human-machine system can enhance road safety in advanced driver assistance systems. Future work will focus on extending our evaluation across diverse driving scenarios and gaze profiles, and on benchmarking our approach against existing gaze-adaptive and sensor fusion systems using quantitative performance metrics.

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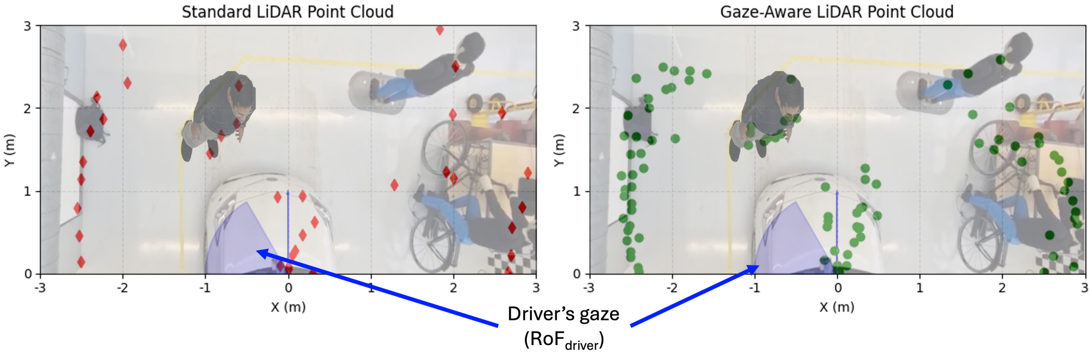

Figure 4. A comparison of point clouds generated by a standard LiDAR setup and our gaze-aware LiDAR setup. The driver's gaze region, in light blue, shows where the driver is looking. A standard LiDAR uses the same parameters over a rotation, while our gaze-aware LiDAR uses different parameters in the RoF_{driver} and its complementary region. This adaptation, in range and resolution, results in a high-density point cloud representation of targets outside the driver's FoV for the same frame rate as a standard LiDAR.