Visual Odometry Based Vehicle Lane-changing Detection

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***Abstract*—Lane-changing detection is necessary for accurate positioning, to allow vehicle navigation system to generate more specific path planning. Lane-changing detection method in this paper is more of a deterministic task, proposed based on curve analysis obtained from visual odometry. From the visual odometry trajectory, we have the estimation of vehicle lateral/longitudinal position, yaw, and speed. We also used the road lane information from digital map provided by OpenStreetMap to narrow the lane-changing event possibility. The analysis is conducted on sequences from KITTI dataset that contains lane-changing scenarios to study the potential of lane-changing detection by using visual odometry trajectory curve. Cumulative sum and curve fitting methods were utilized for the lane-changing detection from visual odometry curve. The detection was conducted on several visual odometry approaches for comparison and system feasibility. Our analysis shows that trajectory generated by visual odometry is highly potential for a low-cost and effective lane-changing detection with 90.9% precision and 93.8% recall accuracy to complement more accurate routing service and safety application in Advanced Driver Assistance System.**

Keywords—lane-changing, localization, visual odometry

I. Introduction

Navigation systems nowadays provide lane-level instructions in taking a route for completing a journey. For instance, multi-lane roads may have different destinations for each lane, hence the routing service or navigation application would provide instructions to use the specific lane for the driver. However, vehicle localization itself has yet to provide lane-level position that would complement the service. Thus, lane-level positioning system would be highly desired in outdoor localization technology where it will estimate vehicle's current lane correctly.

Lane-level positioning is not only useful for navigation system, but it is also required in emerging technologies such as advanced driver assistance systems (ADAS) [1], road traffic estimation in lane-level detail, and electronic toll-collection system. The current positioning systems technology can provide sub deci-meter accuracy and while it satisfies the need for ordinary location-based services [2][3], it lacks information on vehicle's exact lane position. This brings to an interesting field of research where many researchers had proposed different techniques to achieve lane-level accuracy in localization [4]-[8]. Unfortunately, these systems need high specification Global Navigation Satellite System (GNSS) device such as RTK-GPS or laser sensors that are expensive and not practical for ubiquitous implementation. Meanwhile, low cost solutions as proposed in [6][9][10] used camera as visual sensor to detect road and lane markings for lane estimation in positioning system. However, these methods will face difficulties in case the road markings are faded or obstructed camera's line-of-sight.

Besides developing localization system that is able to sense the correct lane of the vehicle, lane-level accuracy can also be achieved if lane-changing or lane-keeping are detected and correctly identified. This information can be fused with the available road information on lane diffusion from digital map like OpenStreetMap (OSM) to obtain the lane-level position. Recent studies on lane-changing by can mainly be categorized into three approaches: (1) trajectory prediction model and matching [11]-[14], (2) road lane marking interception [15][16], and (3) vehicle kinematics based characterization [17][18]. These are explained in the next section.

II. Related Works

The first approach requires trained lane-changing trajectory model and matched with the vehicle trajectory to observe driver's intention of changing lane. For instance, [14] utilized the Constant Yaw Rate and Acceleration (CYRA) model – also known as Constant Turn Rate and Acceleration (CTRA) model - for trajectory prediction while [11]-[13] trained datasets of possible trajectories from experiments with different drivers. However, the studies are more practical in the early detection of lane-changing to prevent collision with other vehicles and the confirmation on lane-changing was not observed. Besides, since predicting vehicle trajectory also relies on driver's driving habit, it is not a deterministic task to confirm any lane-change that occured at a specific time.

Meanwhile, the second technique detects interception or vertical movement of road lane marking to update vehicle's lane position[15][16]. Again, this is prone to the visibility state of the markings and is challenging in bad weather conditions[16]. This method was also meant for early recognition of manoeuvres and risk assessment. Lastly, in the third approach, detection by characterizing vehicle kinematics technique was proposed by observing the inertial change of the vehicle. The suggested methods used inertial sensor equipped on the vehicle's steering to observe yaw rate and lateral acceleration for lane-changing characterization. In fact, the lane detection techniques also applied the same in-vehicle sensor to capture vehicle kinematics aside from lane-marking cross analysis for lane-change detection [15][16]. The kinematics only method as presented in [17][18] is an interesting approach because it does not rely on prediction model nor affected by weather constrains.