Laser-scanner based Powered Two Wheeler traffic monitoring

D. Vivet, Y. Prabhakar, P. Subirats, C. Lecomte, E. Violette and A. Benshair

 Powered Two Wheels (PTWs) represent only 2% of the traffic, but 30% of all deaths on the road. European governments have made this particular point a priority for road safety. The present study overcomes the lack of PTW traffic-analysing systems in real traffic conditions. We propose a detection technique based on a single 2D lidar sensor. This system is able to accurately detect and count PTWs with a single sensor in dense traffic on a highway with multiple carriageways. The method consists, first, in generating spatio-temporal observations of vehicles crossing under the lidar, then, in classifying vehicles by using machine-learning techniques, and finally, in evaluating PTW traffic. Such a system has direct industrial applications as it is, a non-intrusive traffic-analysing system that is reliable, easily deployable and inexpensive compared to existing industrial solutions. This work is part of project METRAMOTO supported by the French National Research Agency (ANR).

Introduction: Transport safety and security is the main concern of European road authorities. The number of powered two wheels (PTWs) has steadily increased in recent decades. This evolution has led to some benefits in terms of mobility, but also some drawbacks in terms of safety. For PTWs, the accident risk per kilometre is twenty-four times higher than for light vehicles. PTWs represent only 2% of the traffic but 15.9% of vehicles involved in accidents and represent 30% of fatally injured victims. So, it is vital to transpose to PTW users the progress made in recent years benefitting other road users. In France, between 1996 and 2005, the number of PTWs estimated to have increased by almost 60% compared to 10% for light vehicles. Nevertheless, there is a lack of reliable data and statistics for PTWs on the highway, although there are methods for downtown low-speed traffic monitoring [1] or for highways but with multiple sensors [2] or with vision sensor [3]. So, an elaborate answer to the needs expressed comes up against the absence of simple automatic detection techniques focussed on PTWs in traffic. This work directly answers this societal need and proposes a technology solution for a better consideration of these vulnerable users. The objective was to develop a non-intrusive, inexpensive, reliable and easily deployable system based on a single laser-sensor to detect, count and analyse PTW behaviour in real-time dense traffic on a highway with multiple carriageways.

Measurement system: The measurement system is composed of a single 2D laser scanner (SICK LMS111) installed above the road on a pole or a banner (approximately 5 m to 6 m high) pointing towards the ground (see Fig. 1). All the objects passing below are detected by the laser barrier as their profiles are measured. The scanner chosen has a classical 270 degrees scanning angle, with an angular resolution of 0.5 degrees and a frequency of 50 Hz.

As, in our method [5], a single laser is used, occlusions occur when heavy vehicles are crossing under the acquisition system. Based on the behaviour of such kinds of vehicle, a simulation has been proposed to estimate the optimal laser positioning in order to minimize the shadowing effect and so optimize the possibility of detecting a PTW. Such a simulation has been proposed for a two-lane and a three-lane carriageway.

Vehicle detection and data segmentation: By using the dynamic background, each moving detection corresponding to a crossing object can be extracted. Then, each punctual laser detection \( p_i \) has to be fused into objects \( O_n = [p_1, p_2, \ldots, p_k] \). In the case of 2D image representation, a new method of image segmentation called Last Line Check (LLC [4]) has been developed. This method consists in checking the change in intensity of the last pixel line as an object enters the scene. Each column of the image is considered independently and for each one a flag is activated when a moving object is detected. By studying the spatio-temporal coherence of column flags, objects of sufficient size are extracted. In the case of 3D point representation, a classical 3D-region-growing segmentation is performed. As a result, for each approach, 2D or 3D vehicle-bounding boxes are obtained representing the real size in millimetres of the moving objects. Of course, as the accuracy of each measurement is known, their uncertainty is propagated over the bounding box of the objects. As a result, for each vehicle, their sizes associated with uncertainties are obtained.

Laser system auto-calibration: Based on raw data analysis, the system is self-calibrated. The static environment is estimated dynamically by a probabilistic eroding technique. The first laser scan is considered as the background profile with each distance value having a laser-sensor Gaussian white noise. Then, for each new scan, probabilistic eroding techniques will update the background, as it is the maximum measurable distance that represents the road. The background is thus updated until it represents the road. The polar coordinates, in the laser frame, of crossing vehicles are estimated from subtraction between the estimated background and the current laser scan. Let us note that in such calibrated data, the road corresponds to the largest planar area and can be extracted automatically by a RANSAC process. Depending on the width of the carriageway, the number of lanes observed can be obtained and the angular aperture of the laser can be reduced to focus on the desired area. In this work we focussed on 2 and 3 lanes.

Once this auto-calibration process is complete, raw data is transformed into Cartesian space over time such that a punctual laser detection \( p_i \) is given into the spatio-temporal domain \( p_i = [x_i, y_i, t_i] \). The accuracy of the measurement is also obtained by propagating the laser detection uncertainty over the laser detection \( p_i \). If a moving object goes through the laser barrier, each detected point differing from the background is considered as belonging to a moving vehicle and represented in spatio-temporal space as in Fig. 2.

![Fig. 2 Spatio-temporal 3D laser data representation. (a) successive laser detections, (b) laser impact on the vehicle, (c) spatio-temporal 3D representation.](image)

The segmentation and classification of vehicles has been proposed on the 3D representation but also on the top view image representation where the pixel intensity represents the height of each laser detection. Such image representation is presented in Fig. 3 where we can easily see, in dark red, the shadowing effect representing unobserved areas.

![Fig. 1. Measurement system positioning for the highway experiment](image)
Classification of vehicles: As metric information and uncertainties are available from our sensing method, simple geometric descriptors for the classification can be used. For the experiments width, maximal height and mean height are all used. The length has been discarded as the velocity is an uncontrolled and unobservable factor of influence over this parameter. Different kinds of simple classifiers have been tested over extracted vehicle patterns. We also compared two well known real-time machine-learning techniques: Support Vector Machine (SVM) and weighted K-Nearest Neighbours (KNN). Moreover, because our laser observations are metric data, manufacturer’s information about vehicle shapes, such as height and width can be used directly as a learning data set for classification. Moreover, once the vehicle is classified, based on the variance of the length of the three considered classes (PTW, light vehicle or heavy vehicle), an estimation of the velocity range for each vehicle can be obtained.

Database: Even if the vehicle manufacturers data are used as a training set for the classifier, two large databases have been acquired, representing some hours of recording with around 7000 vehicles. First, a ground-truth database was created by passing three categories of vehicles, PTWs, light vehicles and vans, under the laser scanner in a controlled environment with various scenarios. These data were used to complete the learning data set. Then, a test dataset in real traffic conditions was acquired on a three lane suburban highway linking the region of Rouen to the A13 motorway to Paris. This contains around 6874 vehicles with camera ground truth over some hours of recording with around 7000 vehicles. First, a ground-truth database was created by passing three categories of vehicles, PTWs, light vehicles and vans, under the laser scanner in a controlled environment with various scenarios. These data were used to complete the learning data set. Then, a test dataset in real traffic conditions was acquired on a three lane suburban highway linking the region of Rouen to the A13 motorway to Paris. This contains around 6874 vehicles with camera ground truth over 3.5 hours of traffic.

PTW traffic detection results: First, the method was validated on the controlled site. Different categories of vehicles were passed at various speeds varying from 20km/h to 70km/h in different configurations. The test base contains 52 vehicles with 28 PTWs and 24 other vehicles. As expected in a controlled configuration, the algorithm proposed gives a 100% correct detection and classification rate. The algorithm was then applied in real highway traffic conditions with vehicles crossing the laser barrier at speeds between 70km/h to 130km/h. Over 99.3% of the total vehicles were detected and correctly classified with 93% of PTWs being correctly classified. A summary of the overall results for the accuracy of the system is given in the confusion matrix (See Table 1).

<table>
<thead>
<tr>
<th>Real Class</th>
<th>Estimated Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTW</td>
<td>28</td>
</tr>
<tr>
<td>Others</td>
<td>42</td>
</tr>
<tr>
<td>Others</td>
<td>6802</td>
</tr>
</tbody>
</table>

Table 1: System detection and classification results

Conclusion: This work provides a specific answer to a societal need and proposes a new system for the better consideration of powered two wheelers in traffic. The techniques proposed show that our system is reliable as it performs in dense real traffic conditions on the highway, achieving more than 98% accuracy for vehicle detection and classification. This system is easily deployable as, unlike the to existing methods, it is composed with a single laser scanner and is designed for self-calibration. The measurements given by the system are precise as the vehicle widths obtained are ground-truth comparable. Moreover the installation of the system does not require the traffic to be stopped and can easily be moved to analyse traffic on other roads.

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References


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