METRAMOTO: Powered two wheelers traffic measurement for road safety and risk assessment

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Abstract

The safety of powered two wheelers (PTW) plays an important role for the public authorities and the road administrators. Since past few years, there has been a notably significant rise in the number of PTW but it is allowed a lack of data and information on PTW use. The state of the art conducted in 2009 showed that there is no technical solution as such that can be adapted to measure of the traffic of this specific category of vehicle and the research development in this domain isn’t much active which is an issue of concern.

The project METRAMOTO aims to detect in the traffic to get enough measurers to be used to the relative statistics with the circulation of PTW. These tools have been developed around several sensors technologies used for road traffic measurement. This work has been realized by distinguishing the ones who need intrusive intervention on the road infrastructure (hybrid sensor piezo-electric + electromagnetic loop and magnetometers) to the one non-intrusive (image analysis and laser range finder).

Keywords: Powered two wheelers; traffic measurement; traffic sensors.

Résumé

La sécurité des deux roues motorisés (2RM) constitue un enjeu essentiel pour les pouvoirs publics et les gestionnaires routiers. On observe depuis plusieurs années une augmentation du parc des 2RM et pourtant il manque des données et des informations sur ce mode de transport. Un état de l’art effectué en 2009 a montré qu’il n’existe pas de solution technique adaptée à la mesure du trafic de cette catégorie de véhicule et la recherche/développement dans ce domaine est peu active. Les objectifs poursuivis dans le projet METRAMOTO ont été de développer des outils pour détecter le trafic afin de produire des mesures pouvant être utilisées pour établir des statistiques relatives à la circulation des 2RM. Ces outils ont été développés autour de plusieurs technologies de capteurs de tracé routier. Les travaux ont été réalisés en distinguant celles qui nécessitent une intervention intrusive sur l’infrastructure routière (capteur hybride piézo-électrique+boucle électromagnétique et magnétomètres), de celles qui sont non-intrusives (analyse d’images et télémétrie laser).

Mots-clé: Deux roues motorisés; mesrure du trafic; capteur de trafic.

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1. Context

Over the past ten years, road safety has improved noticeably in France. This is characterized by a decrease in the number of accidents as well as fatalities. However, PTW accidentology figures are not as good as other vehicle categories. Despite representing only 2% of the traffic (IAU, 2009), PTW are involved in 25% of road fatalities on French roads (ONISR, 2009).

Sales and registrations of PTW have increased significantly during the past twenty years. From 1996 to 2005, the number of registered PTW has increased by 60% while the light vehicle population has increased only by 10%.

On the one hand, there is a permanent lack of knowledge regarding PTW usage. Data available over road networks are partial. Road usages as well as mileage are difficult to analyse. On the other hand, it is well understood that the increase of PTW is motivated by constant travel times, easy parking and the absence or deficiency of public transportation.

Detecting PTW is a need expressed by road administrators. In fact, they want to be able to obtain statistics about this category of vehicles. Despite advanced traffic analysers are able to easily detect light and heavy vehicles, their performances are barely acceptable for PTW.

The missing data would enable the administrators to:
- Obtain statistics about PTW such as traffic counting and speed measurement.
- PTW road usage with respect to the type of roads.
- Take into account PTW in road management policies.
- Take into account PTW in road safety audits.
- Compute a risk exposure index for PTW with regard to the accidentology.

A non-exhaustive state-of-the-art shows that it is really difficult to detect PTW in real traffic conditions. This is mainly caused by the fact that PTW adapt their trajectories, thanks to their small size, to the traffic flow (See Figure 1). Regular traffic monitoring sensors, for instance electromagnetic loops, are not able to decently detect PTW when they are too far way from the sensor area. The recent work of Rosey and Subirats (CERTU, 2010) highlighted that there is no off the shelves product able to accurately detect PTW in Europe. Some systems use electromagnetic loop, radar or infrared sensors. The situation is even worse for computer vision based system or sound based approaches as no satisfactory solution has been proposed. As a matter of fact, the existing works, mainly based on computer vision, suffer from changes in light conditions, vehicle occlusions, merged vehicles and difficulties to track them. Several on going and recent projects deal with the road safety of PTW. Their topic can be grouped into three categories:
- Accidentology: RIDER, Sumotori, 2RM, 2besafe
- Behaviour / interaction with other vehicles or road infrastructures: Simacom, SafeRider, Damoto, 2beSafe
- Driver protection: Proteus, Biocasq, Damoto

All things considered, the METRAMOTO project started in 2010 for three years. Its purpose is to investigate how several technologies could be used to detect and count PTW to obtain metrics about this category of vehicles.

![Fig. 1. (a) PTW trajectories in high traffic; (b) PTW trajectories in low traffic (credit CETE Normandie-Centre)](image-url)
2. Objectives

The goal of METRAMOTO project is to develop technical solutions, based on several technologies, that would be able to detect PTW in real traffic. It will allow to overcome lack of knowledge in the fields of mobility, road management and road safety.

Four technologies were investigated. They can be grouped into two categories:

- Intrusive, with respect to the road infrastructure: hybrid piezoelectric sensor combined with electromagnetic loops, magnetometers.
- Non-intrusive: laser range finders, cameras.

These two categories answer different needs. Intrusive approaches can be used for permanent traffic monitoring while non-intrusive technologies enable temporary traffic analysis. Both categories fulfill expectations of road administrators. METRAMOTO is an innovative project as it focuses specifically on the PTW and uses technologies with high potential. The research is conducted with specifications fully compatible with the majority of road networks. As a result, the products are designed to ensure industrial transfers by the end of the project.

3. Project organization

3.1. Proposed approach

Scientific and technical outcomes are expected from the project. They have to address several scientific and technical challenges:

- Image processing of complex scenes.
- Signal processing methods.
- Detection and classification of vehicles.
- Operational constraints regarding the sensor installation.
- Real time processing.

3.2. Project tasks organization

The organization of project tasks is given by the figure 2 below.

![Fig. 2. METRAMOTO project organization](image)

3.3. Expected results

From a scientific standpoint, new detection and classification techniques are expected. They will be able to detect PTW in real traffic conditions. Four PhD students were involved in the project. From a technical point of view, several prototypes should be launched by the end of the project. In order to assess the performance of the proposed approaches, tests had been carried out on both closed and open roads. Indicators able to encompass PTW traffic information will be introduced. They will be used for road safety studies as well as road management purposes.
4. Technical and scientific main results

In this part, we will depict the main results obtained during the project thorough the different technologies used

4.1. Computer vision

4.1.1. Monocular vision

The goal was to develop methods to detect PTW from a single image (Fromeyer, 2013). There are two main steps for the detection method: first, an automatic calibration to find the lanes of the road; second: the detection-classification based on image segmentation using temporal gradient, calculation of separative parameters and classification with adaptive thresholds. Then, the algorithms would be embedded in an autonomous device. The system was developed with constraints given by road administrators: an easy installation, designed for urban applications and a battery that enable traffic monitoring for a week. From those specifications, the prototype was designed to work in the following conditions: over road installation with a viewpoint optimised in order to avoid mutual occlusions and headlight glare. The hardware architecture uses off the shelves product. The main contribution is focused on the software. A particular attention was played on the design of a shadow removal algorithm in order to improve the robustness of the product. The prototype can be seen in Figure 3a. Results regarding the vehicle detection and tracking is also presented (Figure 3b).

![Fig. 3. Monocular vision prototype(a) Vehicle classification example(b) (credit NEAVIA)](image)

The experimentation on controlled site confirmed the monocular vision feasibility and the experimentation on the real suburban experimental site A13 has given good results for daily conditions (see section 7).

4.1.2. Stereovision

Inspired by robotics applications, the stereovision system is based on two fisheye cameras. In order to accelerate the 3D reconstruction, both cameras are vertically aligned (Tronson, 2012) (Eynard & al., 2013). Their optical axes are collinear in order to ease the epipolar geometry. A first step involves the calibration of the system. Once the intrinsic and extrinsic parameters are obtained, pixels in one image can be matched in the second image. This second stage enables to obtain a 3D reconstruction of the surrounding scene. The main advantage of stereovision is a decreased sensitivity to shadows and occlusions compared to monocular vision. From the height map, object detection techniques are then applied. Two approaches were tested: 3D based only and 2D+3D based. The second technique allows faster processing but is sensitive to the quality of the 2D information. Figures 4 and 5 illustrate the key steps of both methods.

![Fig. 4. Stereovision lower image (a); Stereovision upper image (b); 3D image (c) (credit LITIS, Ifsttar)](image)
The experimentation on controlled site confirmed the feasibility as well as the experimentation on the real suburban experimental site A13 with daily conditions (see section 7).

4.2. Laser scanner

A fully functional prototype has been developed. It embeds real time data acquisition algorithms. PTW detecting and counting techniques have also been designed. They are about to be transferred onto the prototype hardware. The laser scanner used enables to detect PTW up to 130 km/h. The prototype installation requires an overhead infrastructure, a bridge for instance. The device is then placed between the left two most lanes. This placement gives us the opportunity to be able to count the PTW flow during congestion periods for instance.

Two signal processing techniques were developed. The first approach, introduced by Prabakhar et al (2013), uses a newly detection technique named “Last Line Check”. Then the classification is performed thanks to a SVM based detector. Good detection performances were obtained during offline tests on data from real traffic. Figure 6 below gives an example of PTW detection and classification.

![Figure 6](credit CETE Normandie-Centre)

The second approach uses low-level techniques to achieve a real time performance while outperforming the first approach. It was evaluated on real congested traffic conditions (Figure 7).

![Figure 7](credit CETE Normandie-Centre)
The experimentation on the real suburban experimental site A13 shows feasibility from a large vehicles panel with a good detection and classification for PTW (see section 7).

4.3. Hybrid sensor

This sensor combines piezoelectric cable and electromagnetic loops. A smart layout is used to reach good performances. This intrusive sensor is mainly targeted for freeways. Electromagnetic loops are used to distinguish PTW from other categories of vehicles. The piezoelectric cable is used to detect the shock caused by a vehicle passing over the cable. The sensors are connected to a data logger also in charge of processing the signals. The hybrid sensor outputs four characteristics: vehicle type, date, location on the road and vehicle speed.

The sensor was designed based on the work of (Maria & al., 2013). Two electromagnetic loops are required to detect the speed of all vehicles except the PTW. The main breakthrough of this work is the placement of the piezoelectric cable with respect to the road and the loops. The simulation carried out highlighted two layouts that were tested.

Tests were first performed under controlled traffic conditions. PTW are well detected and their speed is estimated with a precision of 5km/h.

Fig. 8. Hybrid sensor outline (a); Real hybrid sensor (b) (credit CETE Ile de France, STERELA)

The sensor was installed on a real suburban experimental site A13 as shown in Figure 8 and has given good results during experimentation tests (see section 7).

A theoretical study was also performed to improve the shape of the electromagnetic loops only (Kerbouai & al., 2013). On going works are done to include the piezoelectric cable and as a result optimise the hybrid layout.

4.4. Magnetometer

The use of magnetometers for traffic monitoring is motivated by the modification of the local earth magnetic field when a metallic object passes nearby. PTW are small compared to other categories of vehicles.

A preliminary study was required to ensure that magnetometers sensors would be able to detect PTW (Pitton & al., 2012). A specific packaging was designed to allow the installation of the magnetometers in the road (Figures 9).

Fig. 9. Magnetometer sensor (a); Magnetometer experimentation (b) (credit CEA-LETI)
The second stage aimed at finding an optimal sensor network layout. The main target was to be able to detect PTW on two lane roads. 18 sensors were used: 13 for the detection and 5 additional sensors to measure the speed. Each sensor signals are then combined to perform the classification. It showed that PTW could be detected in different situations.

![Magnetometers configuration on road (a); PTW followed by car (b) (credit CETE Ouest)](image)

The third step consists in evaluating the performance of the sensor network under real traffic conditions. The final configuration uses 4 sensors per lane and one additional for speed measurement. A database was created in order to perform design and train PTW detection algorithms. Three approaches were tested. The best result was obtained when a preliminary filtering based on adaptive filtering (ATDA) is used. A SVM classifier is then used to discriminate the vehicle signatures. The detection rate reach 88% for the PTW and 98% for all vehicle categories.

5. Experimentation and assessment

5.1. Controlled environment

After one year and half, all technologies, except the magnetometers, were evaluated within a controlled framework. Several scenarios representing different traffic conditions (speeds, positions,...) were executed. A database of 140 recordings was gathering for each technology. The goal was to evaluate the performance of each technologies and more importantly their ability to detect PTW (Buraga & Subirats,. 2013). An average recognition rate of 88% was reached. Theses trials confirmed the expected potential of all technologies.

![Fig. 11. 3 scenarios with PTW and car (credit CETE Mediterranee)](image)

5.2. Real suburban road

At the end of the project, several tests were performed on a real road. Located in the suburban area of Paris, the site is known to be a high traffic road with up to 1400 PTW per hour. The Figure 12 presents the location where the computer vision based systems; the laser range finders as well as the hybrid sensor were evaluated.
This experiment confirmed the ability of all sensors to classify the vehicles for the following conditions: 3 lanes road, different traffic conditions (congestion, dense or free flow).

Fig. 12. Real suburban experimental site: A13(a), High traffic on A13(b) (credit Google Maps, CETE Mediterranée)

During these experiments several large databases from all sensors were realized with a ground truth long period. These experiments also highlighted the limits of the computer vision based and laser scanner based technologies. They respectively suffer from night light conditions and rain as well as high speeds for the laser scanner. Conclusion chapter presents the main results for PTW classification and counting.

5.3. Real urban road

The final test site was located in Paris, Rue de Rivoli. The first interest of this kind of urban site is the high PTW traffic mixed with cars and bikes. Moreover, the number of road lanes can vary according to the volume of traffic. The second interest is the capability for sensors to fit on roadside location. Stereovision and scanner laser technologies provided databases for future data processing. The figure 13 presents the urban test site.

Fig. 13. Real urban experimental site: Rue de Rivoli, Paris (a) (credit Google Maps)

6. Indicators

Several indicators will result from our new ability to accurately count PTW. The expected measures are: a lane-wise count of the PTW in real time over six minutes or delayed every hour, and vehicle-wise speed. From a road management standpoint, these metrics will allow to gain a better knowledge of PTW habits. It will enable to know what is the PTW traffic for a given road but also how it is distributed over days, seasons or even years. It will also give the opportunity to detect peak hours. The location of the PTW on the road is also important information. Existing measure and indicators used for light and heavy vehicle could be reused. A recent study demonstrated that peak hours for PTW are different from light vehicles (CETE IF, 2013).

From a road safety point of view, information about the PTW traffic is essential to measure the risk faced by this category of vehicles. It is important to compare data from accidents and traffic in order to find dangerous roads as well as traffic conditions for PTW. Moreover, the gain of knowledge about PTW speeds and trajectories are high value added information.

Finally, the expected outcome is to fill a knowledge gap regarding PTW habits and the risk specific to this category of vehicle.
7. Conclusions and perspectives

The following tables give the PTW counting results during 2 experimental phases on suburban test site A13.

<table>
<thead>
<tr>
<th>Experimentation</th>
<th>Reference (PTW nbr)</th>
<th>PTW count (nbr)</th>
<th>Count error (nbr)</th>
<th>Count error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stereovision day1</td>
<td>2603</td>
<td>2553</td>
<td>-50</td>
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<tr>
<td>Stereovision day2</td>
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<td>2501</td>
<td>-16</td>
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<td>Monocular vision day1</td>
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<td>2902</td>
<td>+32</td>
<td>+1.1</td>
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<tr>
<td>Monocular vision day2</td>
<td>2587</td>
<td>2447</td>
<td>-140</td>
<td>-5.4</td>
</tr>
<tr>
<td>Laser day1</td>
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<td>2755</td>
<td>+37</td>
<td>+1.4</td>
</tr>
<tr>
<td>Laser day2</td>
<td>2587</td>
<td>2613</td>
<td>+26</td>
<td>+1.0</td>
</tr>
<tr>
<td>Hybrid sensor day2</td>
<td>2352</td>
<td>2321</td>
<td>-31</td>
<td>-1.3</td>
</tr>
</tbody>
</table>

Table 1. PTW counting results for 3 lanes motorway A13

Table 1 shows the results for these 3 technologies are good for PTW counting.

The second table below presents the counting results for the other vehicle except PTW.

<table>
<thead>
<tr>
<th>Experimentation</th>
<th>Reference (Non-PTW nbr)</th>
<th>Non-PTW count (nbr)</th>
<th>Count error (nbr)</th>
<th>Count error (%)</th>
</tr>
</thead>
<tbody>
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<td>Monocular vision day1</td>
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<td>Monocular vision day2</td>
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<td>11847</td>
<td>-279</td>
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<td>Laser day1</td>
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<td>-400</td>
<td>-4.0</td>
</tr>
</tbody>
</table>

Table 2. Non-PTW counting results for 3 lanes motorway A13

Table 2 shows the results for these 3 technologies are also good for Non PTW counting.

The key contributions achieved after three years within the framework of METRAMOTO project can be summarized as follows:

• **Scientific:** stereo-vision sensor designed for traffic monitoring, sensor characterization and design, signal processing techniques enabling PTW detection, a multi sensor database of real free flow traffic.
• **Technical:** two prototypes are operational and ready to be transferred to the industry.
• **Usage:** the field of application as well as the limits of each technology is now known.

Future research and dissemination will be focused on:

• Industrial transfers: two prototypes, one portable based on monocular-vision (Neavia) and the other one based on the hybrid sensor approach (Sterela/CETE Ile de France), should be available soon.
• A portable prototype based on the laser range finder should also be developed (CETE Normandie-Centre).
• Stereovision image processing algorithms should be optimised to run in real time (IFSTTAR/LITIS).
Acknowledgements

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