A Flexible, Mobile Video Camera System and Open Source Video Analysis Software for Road Safety and Behavioural Analysis

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ABSTRACT

This paper presents a scalable, discreet and mobile video-camera system that takes elevated video data of roadway locations for traffic safety analysis. The video is used to extract microscopic traffic parameters including road-user trajectories, lane changes and speeds. Collected video data is processed using an open-source automatic tracking tool. Trajectories can be then used to analyse road user behaviour for specific locations (intersections or highway sections) or to evaluate the safety effectiveness of a treatment. The different elements of the systems including data collection and processing are discussed. To illustrate its versatility, different applications (case studies) illustrate the use of the video-camera system and open-source video-tracking and analysis tool. This includes video-based conflict analysis at highway ramps and behavioural analysis of pedestrians and cyclists at signalized intersections, including red-light violations.

INTRODUCTION

Video data is more and more widely used in transportation research and practice (*1*). Road safety studies, in particular surrogate safety studies, are often based on video data, e.g. in (*2*) (*3*) and (*4*). Video-based traffic analysis consists of four main steps: data collection, pre-processing, processing, and analysis of video data (*5*). Once video data is collected, it can be processed with various levels of automation, from completely manually to completely automated using computer vision techniques. A typical output of the video processing using computer vision techniques is road user trajectories, i.e. the series of the positions of all road users in each video frame. Trajectories are then analyzed to yield traditional traffic measurements (counts, lane change rate, individual vehicle speeds, gaps, etc.), measures of driver behaviour and microscopic safety observations such as events (conflicts), safety indicators (e.g. time-to-collision) and dangerous behaviour or violations. These measures can then be used for road safety diagnosis or road user behaviour analysis of a particular roadway location (e.g., a signalized intersection, a highway ramp, etc.), including before-after studies.

Each of the four steps, data collection, pre-processing, processing and analysis, presents its own challenges. The main challenge of video data collection is to collect data for the roadway locations under analysis. While in some cases surveillance cameras can be used for this purpose, very often, sites under study do not have video cameras, or when cameras exist, video data is often inappropriate in terms of location, angle, resolution, etc. When video data is collected by a third party, access to the camera is often not possible and therefore all camera parameters must to be inferred from video observations and an orthographic (aerial) image of the site. Moreover, permanent camera installations and maintenance are prohibitively expensive for research purposes. Finally, in many cases, the issue will be the lack of power supply or the lack of infrastructure (building, bridge or post) in which a fixed camera can be mounted. The challenge is therefore to obtain video data for a few hours or days for traffic data collection. These issues lead to the need for a flexible system for video collection to retrieve data that meets the requirements for the analysis of traffic, road user behavior and surrogate safety events.

In this regards, this paper aims at:

1. Presenting a flexible and mobile system for short-term video data collection. The proposed system includes a mast-based video camera unit, which is power independent and simple to install.
2. Integrating a set of open-source automatic tracking algorithms for data processing and surrogate analysis. The outcome is a rich dataset of microscopic traffic data.
3. Illustrating the use of the system and open-source software on three case studies.

BACKGROUND

As mentioned before, the typical procedure for video-based traffic analysis consists of four main steps, outlined in Figure 1. In the collection task, a mobile flexible unit is optimal given that surveillance video cameras are not always available and the quality of the video data often does not meet the basic requirements. The pre-processing task includes vibration correction and calibration. Camera calibration allows the projection of real world measurements (e.g. meters) on to the image camera space (in pixels). The processing consists in extracting the road user trajectories from the video data. Analysis includes the manipulation and interpretation of trajectories, speeds, and/or other parameters of interest. The final outcome can be classical traffic parameters (such as counts and speeds) as well as lane changing behaviours, surrogate safety measures such as the time to collision (TTC), etc.

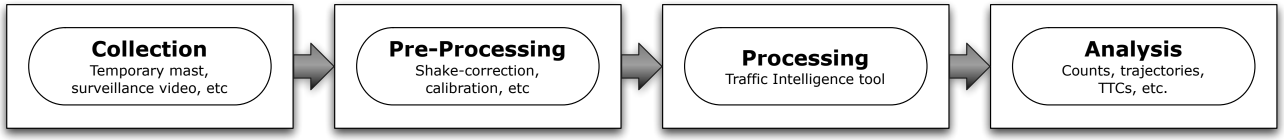

Figure 1: Start to finish steps in video analysis system

Regarding the last two tasks (processing and analysis), important developments and applications of computer vision techniques have been documented in the last years in the field of transportation. Among the various groups working on the development and the use of video analysis software for transportation applications, one can cite the Universities of Lund (*4*) (*6*), Minnesota (*7*) (*8*), Washington (*9*) and British Columbia (*3*) (*5*) (*10*) (*11*). For example, the tool developed at the University of British Columbia initially for automated road safety analysis is composed at its core of a feature-based road-user tracking algorithm adapted initially for intersections, an algorithm to learn motion patterns and a method to compute robustly several surrogate measures of safety such as the TTC. This tool has been used in many recent applications, for surrogate safety analysis (*3*), pedestrian behaviour and safety analysis (*11*), before and after studies (*12*), etc. However, one of the main issues of this tool is its inaccessibility.

A new effort has been undertaken by Saunier (*13*) for the development of a flexible open-source software for video processing and analysis based on computer vision techniques. It is being tested and used in current studies. The advantage of this tool is that it is available under an open source license in order to allow the actual reproducibility of research results and faster adoption of the techniques, with the hope of initiating a larger collaborative effort for the application of video analysis to transportation. It relies on the open source OpenCV library (*14*) and can be compiled on all operating systems (e.g. Windows, MacOSX and Linux). It makes use of a separate open source library for trajectory management and analysis. The project is called "Traffic Intelligence" and also includes various tools for trajectory processing and analysis that are being extended with modules for surrogate safety analysis. The project website has guides and examples to help new users to get started.

Despite these important efforts, video data collection is still a complicated and time-consuming process in practice. In many documented empirical and methodological studies, video data was collected from fixed locations. Obviously the problem arises when video cameras do not exist at the locations of interest (intersections, road section, ramps, bike facilities, etc.), which is often the case for safety studies. Given the important limitations of surveillance cameras and the needs of video data from specific facilities and field of views, a mobile video data collection unit was designed at McGill University and tested for several research projects, as illustrated later.

SYSTEM REQUIREMENTS

During the conception of this video data collection tool, the following characteristics of the required equipment were considered:

- **Mobility:** The primary requirement of a mobile camera system is that it be capable of being installed at locations and of covering angles that fixed surveillance cameras cannot reach. Mobility is advantageous for short-term data collection, one to several days over numerous installations/angles.
- **Height:** A minimum of 7 m (or 23 feet) in height is strongly suggested. The higher the camera is positioned relative to the road, the steeper the viewing angle and the larger the viewing zone where data can be extracted. A steeper viewing angle further reduces occlusion issues and lane parallax error, but introduces stability challenges.

- **Weatherproof:** The electronic components must be shielded from rain, severe wind, and direct sunlight.
- **Video reliability**: Video must be recorded continuously and without interruption or loss of framerate, and the framerate must be constant for accurate and consistent velocity measurement. A minimum frame rate of 15 frames per second is deemed acceptable for most applications.
- **Remote:** The systems should be completely independent and capable of operating autonomously in the field for 24 hours on standby. Every unit is to have detachable recording media to last at least 16 hours of continuous recording.
- **Stable:** Video stability is an issue for high installations, particularly because the equipment is designed to be mobile. Video shake can be introduced from wind on freestanding poles, whereas vehicle vibrations can be transmitted from fixed installations. Video shake is particularly severe in highway environments and from heavy vehicles. A certain amount of video shake can be corrected via software.
- **Vandal-proof and safe:** Vandalism of public property, and particularly that of cameras and other monitoring equipment, is not unheard of. Constant supervision is not a very practical solution and so the camera must be protected against theft, equipment tampering (particularly cable cutting), and especially from falling on the highway as a result of vandalism.
- **Discreet:** The presence of obvious surveillance equipment and other activity should be avoided so as to not distract drivers, for the sake of both safety and to not alter driver behaviour.
- **Easy installation:** The camera should be hassle free to install in 15 minutes or less and not require road closure or “bucket boom” trucks.

Note that prior to building an independent system, extensive research was performed to find if such a system did not already exist to meet required design specifications. Elevated photography is an established field of photography, in which a mast system is used to take high perspective images for such applications as art, surveying/real-estate, and hobby. However, no product with similar requirements to this project readily existed.

An innovative data collection system (Scout™ Video Collection Unit) to obtain traffic counts is offered by Miovision Inc. This system is designed and used to get traffic counts based on post-processing video analysis. Its main specifications are:

- 72 hour internal battery
- Weatherproof
- Mast height between 1.3 to 7.6 meters
- Wide-angle low-resolution camera (800x480 pixels)
- Internal storage (up to 64 Gb via SDHC card)

However, this system does not provide trajectories or any other microscopic traffic parameters related to driver behaviour. Moreover, the video resolution has been proven too low for valuable traffic analysis. The video is encrypted so that only Miovision can process the video data to provide traffic counts. The mast would also present some limitations for data collection on highways in terms of height and stability. No other compatible system was found, so it became readily apparent that a custom solution would be necessary.

SYSTEM COMPONENTS

The data collection system proposed here consists of six main elements as outlined in Figure 2. These elements are: *(i)* Camera unit, *(ii)* Mast and cabling, *(iii)* Pan-tilt system, *(iv)* User interface, *(v)* Power system *vi)* Field installation equipment. Additional details are provided for each element as follows.

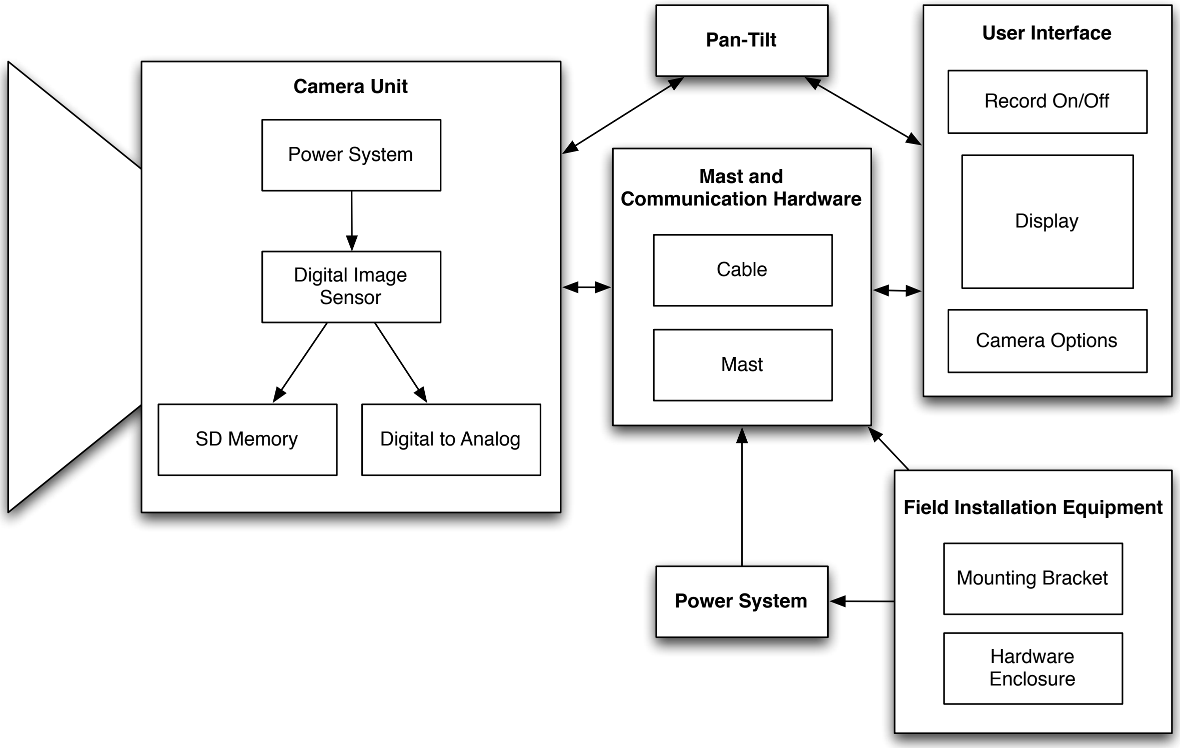

Figure 2 - Full system broken into components

Video Camera

Finding an appropriate camera unit to meet all specifications required several design decisions at an early level. Two alternative designs immediately surfaced:

- **Optical sensor separated from DVR:** This design was initially promising because it would allow for a small optical sensor to be placed at the top of the mast, and for all other parts of the camera unit to be at the base. However, after some research it became apparent that high-resolution CCTV cameras and DVR units were prohibitively expensive. Less expensive systems exist, and one such unit was purchased for testing. An insurmountable problem came about with this system because a large number of conductors (24 – 30 wires) were used in connecting the optical sensor to the DVR unit, which will prove to be a huge problem for the integrated mast cable diameter.
- **Integrated camera unit:** This is by far the most common system available on the market, and as such was an obvious solution. Low-cost, low-power, high-resolution cameras with local storage were so numerous that the problem became as simple as choosing an appropriate unit.

To identify the appropriate camera option, some testing was necessary. Several video cameras were acquired for this purpose. The original camera chosen was the HE6801SI, for which the specifications can be found in Table 1.

Camera and Sensor	Characteristics	Specifications
Heivision HEI6801SI CMOS 2.0 Megapixels	Maximum Resolution	1600x1200 pixels @ 14.985FPS 1280x960 pixels @ 29.97FPS
	Storage	SD Card SDHC
	Interface	Built-in web server
	Weatherproofing	IP66 Standard Compliance
	Communication	Ethernet, RS-232, RS-485
	Power	12VDC
Vivotek IP8151 CMOS 1.3 Megapixels	Maximum Resolution	1280x1024 pixels @ 30FPS
	Storage	SD Card SDHC
	Interface	Built-in webserver
	Weatherproofing	None – subsidized by enclosure
	Communication	Ethernet, RS-485, HD-BNC
	Power	12VDC, 24VAC or PoE

Table 1 – Camera specifications

On paper all specifications met or exceeded those necessary, including being weatherproof. Interesting additional features of this camera were the ability to communicate via WIFI and possibly GSM networks for remote data streaming. The camera also includes an infrared LED array, but it has a tested useable range of only 5 meters so was disabled.

Throughout initial testing, it became clear that the HE6801SI would not sufficiently meet all needs in terms of ease of use. Firstly, the camera is difficult to open and close to remove the SD card for data transferring. Second, it has a sluggish web interface and is not very user friendly. Finally video files are poorly compressed and thus filled a 32 GB SD card in less than 16 hours.

After testing different cameras, the final choice was the Vivotek IP8151. The camera is enclosed in a weather resistant case and affixed to the top of the pole. Specifications can be seen in Table 1.

One advantage is that the IP8151 has a removable lens, which can accommodate any compatible lens to adapt to varying needs (such as 360 degree or zoom lenses). Also, the IP8151 has a very simple web interface that even novice users easily used, and it has an analog output that could be used for future implementations with an HD-DVR.

Mast and Communication Equipment

The mast/cable system is integral in connecting and securing all other components of the system together.

Mast: The mast chosen can be seen in Figure 4 with some specifications as follows:

- 12.2 meter (40 foot) extended length
- 2.2 meter (7 foot) retracted length
- 7 kilogram (15.4 pounds) total weight

This was tested rigorously and proved very stable, low-cost and quickly deployable to 12 meters. It has a minimum internal diameter of 28mm, which was a constraint for the coiled cable.

Cable: As the mast will be telescoping, it was necessary for the cables to be routed inside the mast to be able to lengthen and shorten with the mast and to prevent tangling. It was decided early in the design that a coiled cable capable of expanding at a 4:1 ratio would work well with the chosen mast, with a coiled diameter of maximum 24 mm to prevent it getting stuck in the mast. The mast will contain a dry lubricant to facilitate cable sliding as well. A custom-built 10 conductor retractable cable was acquired.

Base: The mast and cable were combined by the addition of a welded aluminum collection area to the base of the pole. This allowed the excess cable to be collected when the system was retracted, provided a sturdy base for the aluminum mast, and allowed for a junction between the internal mast cabling and the coupling that would connect the mast to the battery/user interface.

Couplings: All couplings used are 10-conductor military-grade weatherproof components. These have proven to be excellent quality couplings in previous field tests.

Pan-Tilt System

The original intention was to build a pan-tilt system using 2 weatherproof servomotors in a bracket. It became clear early on this could create problems in the field for the following reasons:

- Servo motors require constant energy to maintain their position, decreasing battery life
- Small servo motors cannot produce the amount of torque required to hold the heavier IP8151 camera and enclosure at a steady position

A commercially available, weatherproof pan-tilt head was instead sought. The selected pan-tilt, the Vicon V3400APT, is (as of writing this paper) still being tested and fitted to the mast system. A commercial pan-tilt can be easily driven over RS-485 communication protocol, and can be controlled from the web interface of the Vivotek IP8151. One main concern about commercial pan-tilt units is that they can be quite heavy (2 kg and up) and so increase the slow sway of the mast.

As a supplement, a mechanical tilt bracket was designed to allow for the use of the system without such a pan-tilt head. Panning could be performed by the rotation of the mast sections, while tilting could be set at the base or changed while deployed by use of a guy wire. While not as simple as using an electric unit, this system was lightweight and met most needs in the field, especially since the tilt angle only needs to be configured once and does not need to be changed dynamically during recording.

User Interface (UI) and Power System

The IP8151 camera has a simple to use web-based interface that provides users with detailed control over video specifications. This interface is accessed via any laptop with an available Ethernet port and the ability to statically set the IP address.

As field operation is necessary, batteries are required to power the system. The camera is very versatile in terms of power input, so options include 12VDC, 24VAC, and Power over Ethernet (PoE), which requires 48VDC and uses spare Ethernet conductors. The camera itself specified a maximum power consumption of 3.6 Watts. As 12VDC batteries are the most common and least expensive, they were chosen to power the system remotely. Due to overall low power requirements, nearly any larger 12V battery can be used. For this project it was decided to use sealed lead-acid 32AH deep-discharge batteries, theoretically providing up to 106.7 hours of use though in practice this time is lower due to the possibility of battery damage. As a result, it was decided to charge batteries between uses, which typically do not last more than a day or two at a time.

Field Installation Equipment

In order to provide a secure, stable and mobile platform for which other equipment could be mounted, a modular mounting system was developed. The system, which is shown being installed in Figure 4 A-F, has the following components:

Panel: A fully adjustable panel was machined from solid aluminum to provide a rigid surface for which the mast could be attached. Adjustable spacers give a closer fit when attaching the panel to different diameter street poles, while also allowing the mast to be placed at varying distances away from the pole so as to avoid overhead obstacles. The panel is attached to street poles via heavy-duty load-bearing straps.

Bracket: In order to attach the mast securely to the panel, a clamp with a similar design was built. This bracket allows for a solid connection between the mast and panel, which reduces vibration.

Enclosure: A large, waterproof, lockable enclosure was used to secure all exposed hardware that could compromise the mast. The enclosure also allows for easy storage of the power system and other field equipment (tools, computers, etc.).

A: Panel Attached to Host Street Pole

B: Adjustable Mast Receptacle On Panel

C: Bracket Installed Using Mounting Hardware To Secure Pole

D: Mast Installed On Panel Using Bracket, Ready For Enclosure Installation

E: Installed Enclosure And Deployed Mast As Seen To Pedestrians. Power System Is Inside Enclosure

F: Entire Deployed System

Figure 3: Overall installation of mounting equipment to capture equipment

STEPS FROM DATA COLLECTION TO ANALYSIS

In this section the general procedure for video camera installation and data collection is described. This includes the following steps:

Collection: Identification of Sites and Infrastructure for Installations

The choice of sites should be governed primarily by the data collection needs. This can include the evaluation of treatments at signalized intersections, road section, highway ramps, etc. The advantage of the mobile-video data collection system proposed here is the flexibility and simplicity of its use in different environments. Examples of the video data collection and processing will be discussed later in this paper.

Pre-Processing: Definition of Field of View and Camera Calibration

The camera field of view must be chosen so that the data or events of interest can be captured. Some margins are usually necessary, for example to be able to detect robustly road users over long enough periods of time. The objects of interest should be large enough in the image for the computer vision algorithms to perform well (pedestrians are more difficult to detect and track and should therefore appear larger than vehicles (*12*)) and for accurate position estimation.

An important pre-processing step is camera calibration, which allows projecting the position of road users in image space to real world coordinates, typically using an aerial photo of the scene under study. The full camera calibration consists in estimating the camera intrinsic parameters (camera parameters such as focal length) and extrinsic parameters (camera translation and rotation with respect to the scene) (*15*). A 3x3 homography matrix is then derived from these parameters, or can simply be directly estimated using at least 4 non-collinear points in image and world space. Using only a homography matrix has two limitations: 1) it assumes that the world ground plane is flat and 2) it cannot account for camera distortion (non-linear transformation). A simple script is available in Traffic Intelligence to estimate a homography matrix from point correspondences.

Pre-Processing: Video Data Recovery and Storage

Before video data can be processed, some pre-processing must be performed if the video data has stability or strong distortion issues. Video stability is often an issue with mobile equipment which often requires the video to be stabilized. Attention to the format of the recorded video file is essential and often overlooked, in particular because proprietary formats may require extra pre-processing (eg. conversion, additional codecs) to further process with the selected tool. Various file formats (containers) and compression formats are available, offering different trade-offs of quality, file size and ease of compression/decompression. A higher quality video file yields more accurate trajectory data (although the exact effect has not been investigated in detail to the authors' knowledge), at the cost of a larger video file size (a single hour at a single site can use anywhere from 1 GB to 20 GB of data, overhead and extrapolation data included).

Furthermore, it is important to note that any video compression operation introduces new artifacts into the video, impacting the video quality in the same manner that the quality of a paper document decreases every time it is photocopied. This includes any compression performed natively by the camera. Uncompressed video (or video compressed using a lossless codec) is however impractical to store and transmit with the current technology.

The targeted video format has the following characteristics: digital, at least 800 pixels wide, 600 pixels tall, a square pixel ratio, deinterlaced (progressive scan), 15 frames per second or more (29.97 NTSC standardized), and no audio. Frames must be consistently timed in order to obtain realistic and consistent speeds. The greater the number of pixels, the higher the accuracy, particularly for areas closest to the horizon, although the gain in distance from increased pixels offers diminishing returns, particularly for low-angled views, the higher the file size and the more time the video analysis will take.

As stated, camera shake causes discrepancies in video data and is manifested in the camera view by tilting, panning, and rotation of the view. Under normal operation, two major sources of shake exist: vehicle vibrations and wind. The magnitude and frequency of this shakiness is highly dependent on camera installation. Stabilization is the process of removing any global tilt, pan, or rotation in the camera view. This is generally achieved by tracking the movement (local colour changes) of multiple pixels and calculating an overall movement pattern. By applying the inverse transformation of the movement to the entire image, motion compensation is effectively achieved.

Video Data Processing and Analysis

The presented data collection system is integrated with the open source software Traffic Intelligence that provides, in particular, the implementation of a feature-based tracking algorithm that provides vehicle trajectory extraction from video data. This algorithm (*10*) can be divided in 2 steps:

1. Individual pixels are detected and tracked from frame to frame and recorded as feature trajectories using the Kanade Lucas Tomasi feature tracking algorithm (*14*). A moving object (road user or vehicle in this case) will have multiple features on it, which must therefore be grouped.
2. Feature trajectories are grouped based on consistent common motion.

The parameters of this algorithm are tuned through trial and error, leading to a trade-off between over-segmentation (one object being tracked as many) and over-grouping (many objects tracked as one). Readers are referred to (*10*) for more details.

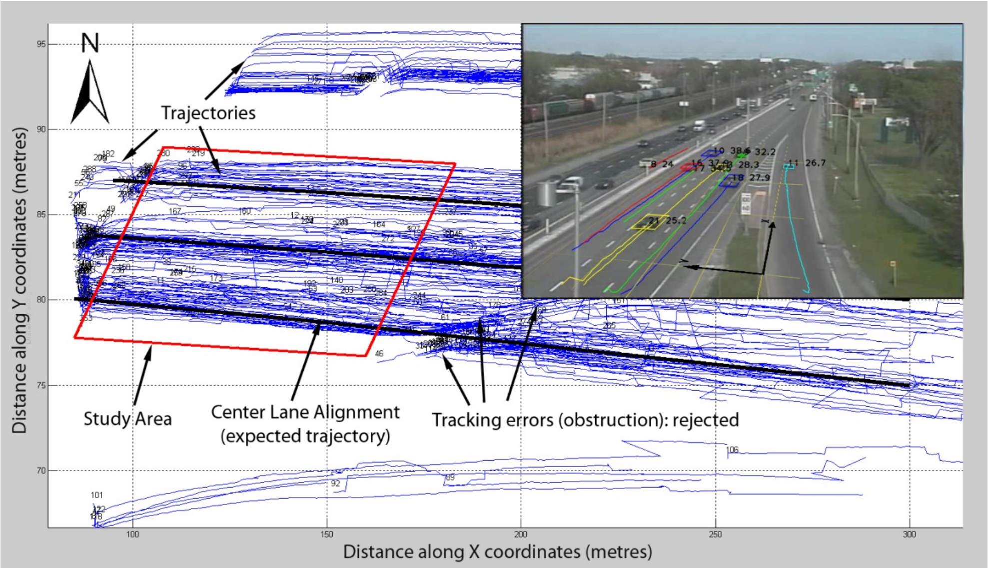

Figure 4: Sample trajectories and associated camera view taken from (*2*)

Tracking can be performed either in image space or in world coordinates if a homography can be estimated. Time is typically measured in frames as a feature position is recorded in every frame. It can then be converted to more convenient units using the constant recording framerate, e.g. 29.97 frames per second for the NTSC format. This means that a displacement of 1 meter from one data point to the next (1 m/frame) represents in this case an object traveling at a speed of 29.97 m/s or 107.86 km/h. This high polling rate produces large datasets of small increments. A sample of the extrapolated trajectories is illustrated in Figure 4 depicting typical trajectory clusters with superimposed road alignments and a defined study area bounding box which eliminates all trajectories outside of the desired study area, including warm-up error typically observed at the video's borders.

Various post-processing methods are applied depending on the application. Most erroneous trajectories are identified by the software. Trajectories are smoothed using a moving average. For applications that demand very high detection accuracy, manual review and flagging of the results are possible. For specific scenes, e.g. on highways, assumptions about road user movement (usually straight with occasional lane changes) can be made to clean and correct the output trajectories.

Based on the resulting trajectories, various measures of road user behaviour can be computed. These measures include common vehicular traffic data (counts and speeds), motor-vehicle lane changes, trajectory density, speed profiles at high temporal resolution, gaps, violations, surrogate safety measures such as TTC, etc; Similar measures for non-motorized users (pedestrians and cyclists) include speed, groups, violations, surrogate safety measures, etc.

CASE STUDIES

This equipment has been tested in several studies for research and practice purpose. Three applications are briefly described including i) a conflict study at highway ramps (exits and entrances) (*2*), ii) a study on pedestrian violations at signalized intersections (*16*) and iii) a study on the effectiveness of a bicycle box treatment (*17*).

I. Conflict analysis on highway ramps

The purpose of this study was to investigate the highway safety effectiveness of a special lane-change ban treatment. This treatment has been implemented in urban highway segments near exit and entrance ramps in the Montréal metropolitan area and this study aimed at investigating its effectiveness at reducing conflicts associated with car-following and lane changing behaviour. Using a traditional surrogate safety approach, time-to-collision conflict measures were computed from automated video-based vehicle trajectory extrapolation and used to identify microscopic behaviour patterns and points of increased conflict density. A sample weighted conflict density map for one of the sites is illustrated in Figure 5. The study used before-after and cross-sectional comparisons and observed artificially-generated areas of conflict density inside the highway normally observed in weaving sections. The study also concluded that the presence of the treatment led to different patterns in the distribution of all TTC measurements and in the spatial distribution of potential collision points. Moreover, road geometric factors seemed to play a greater role in the accident occurrence and time-to-collision distribution. (*2*).

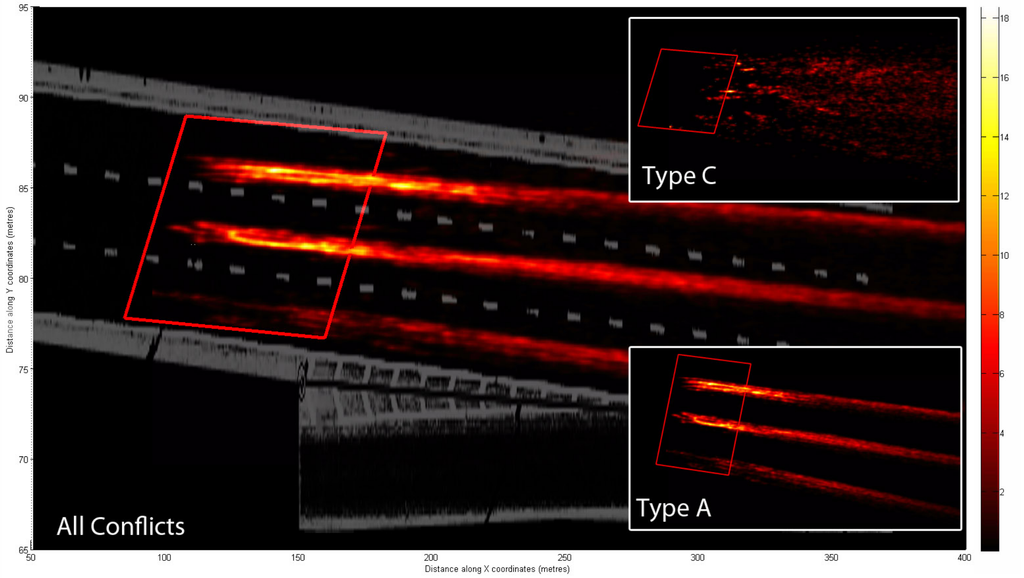

Figure 5: Weighted conflict density map, taken from (*2*)

Analysis of Dangerous Pedestrian Violations at Intersections

The objective of this study was to determine the impact of pedestrian waiting time at an intersection, due to phasing, time of arrival and the presence of a pedestrian signal on the proportion and type of pedestrian violations and dangerous crossing situations. Seven intersections with similar geometry and traffic conditions but different maximum waiting times, four of which had a pedestrian signal, were observed over at least two hours to collect crossing information. Data was collected manually for the analysis, and video data using our mast-camera system was collected for the validation of results and further microscopic analysis. Figure 6 shows the spatial density of pedestrians crossing at an intersection that was automatically computed from the collected video data using Traffic Intelligence. The video analysis was made on the basis of groups of pedestrians and not individual pedestrians, which cannot be distinguished by most computer vision systems. For further details on this study, the readers are referred to (*16*).

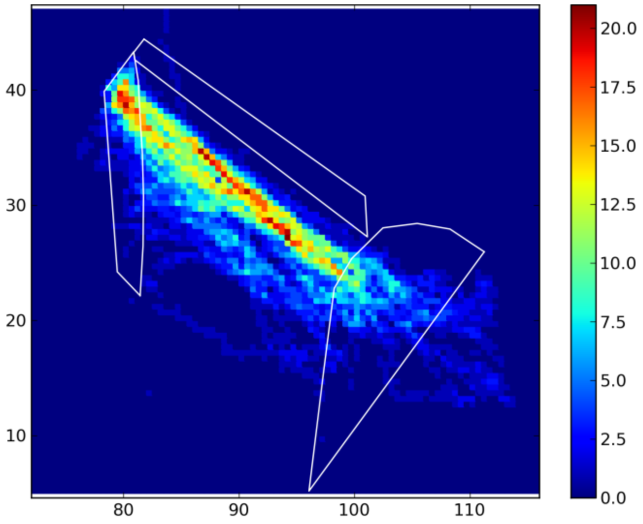

Figure 6: Spatial density of a pedestrian crossing at a Montreal intersection, taken from (*16*)

Effectiveness of a Bicycle Box Treatment

Using data collected with the mobile mast-video camera system, this study evaluates the effectiveness of a bicycle treatment (bike boxes) at an intersection in Montreal using a before-after surrogate safety analysis based on longitudinal video data (Figure 7). Cyclist red-light violations, behaviour at the stop line and potential associated factors were obtained from the collected video data in a semi-automatic way. Violations with a short vehicle-cyclist gap were classified as dangerous (i.e., those situations in which cyclists pass the intersection during the red phase with a small vehicle gap). This study shows that the presence of a bicycle box has a significant impact on the total number of cyclists' violations and different impacts over the short and medium term after the treatment installation; however, the reduction in the number of dangerous violations is not clear.

Figure 7: Image taken by mast system observing Montreal bicycle box (left-most stop).

FINAL REMARKS

Through this research, a mobile video camera based system is proposed to collect, process and analyze microscopic traffic data. This data is essential for detailed behaviour and road safety studies using surrogate safety analysis techniques. Through testing of multiple different types of systems, a large number of design choices have been tested. The hardware specified is easily assembled into the system and can be tailor-made to specifications by the user, such as height, manual or electronic pan/tilt, number of cameras, resolution of camera(s), storage capacity, battery life, and so on. This system takes advantage of open source software for video tracking and analysis, enabling better reproducibility of results. Together, the mobile video data collection unit and the open source Traffic Intelligence software should promote a wider adoption of video analysis in the transportation research and professional communities.

Through three case studies, we demonstrate the usefulness of our system as an advanced metrics collection tool. Applications can include fully- or semi- automatic video data processing. These applications also show the flexibility of our system for video data collection in numerous road environments, such as: urban intersections and streets, bicycle facilities, highway entrance and exit ramps, bridges and tunnels, and high traffic zones.

What has emerged in this project is an inexpensive system coupled with a powerful, open-source analysis tool. Rapid roadside installation decreases risk to field researchers, while an automated tool means less time spent doing manual video work. Furthermore, several system improvements are being planned as future work. A pneumatic mast will be tested to reduce installation efforts, and an electric pan/tilt unit will further reduce installation time. Also, to deal with facilities without adjacent infrastructure for installation, an integrated mobile mast-trailer system will be built.

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