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Validation of pedestrian throw equations by video footage of real life pedestrian/vehicle collisions

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ABSTRACT

A total of 11 real life vehicle/pedestrian collisions in 2012–2014 were captured by CCTV cameras/car cameras in Hong Kong. Some of the footage was recorded in HD format at 30 frames per second, enabling accurate determinations of impact speeds with pedestrians, exact points of impacts and final rest positions of pedestrians as well as kinematics of the collisions. The calculated impact speeds from footage analysis were used to validate the published empirical and semi-empirical pedestrian throw equations. The applicability of these equations to collisions on sloped carriageways was discussed. The presented results, including 6 forward projection trajectory cases, enrich the existing limited real life data from footage analysis for further validation of the published methodologies.

1. Introduction

To estimate impact speeds of striking vehicles in pedestrian/vehicle collisions with no tyre marks found at scenes, reconstructionists commonly use pedestrian throw equations when points of impact and rest positions of pedestrians are known. The two common methods to address the throw equations are empirical [1–4] and semi-empirical [5]. The former is simply a statistical approach to develop equations to encompass the results from a large number of real cases, while the latter bases on physics with the empirical data from real cases. Both methods require data to prove their validities; data includes crash test data using cadavers or dummies and real life data from pedestrian/vehicle collisions with impact speeds obtained from skid marks and CCTV footage. Of these, real life pedestrian/vehicle collisions caught on CCTV coverage [6,7] are particularly important for validations as the footage usually provides additional information on the dynamics of the collisions and the exact points of impact.

Hong Kong, being a modern metropolis, has a significant number of CCTV cameras installed in its urban areas. Some of these CCTV cameras are equipped outside commercial and residential buildings mostly for security purposes, and they sometimes inadvertently covered parts of nearby carriageways. A more direct source of information on a street level comes from car video recorders, commonly known as car cameras or dash cameras, and these have also became popular in Hong Kong. The combination of CCTV cameras and car cameras not only provide unbiased accounts of events surrounding an accident but may also provide crucial speed information for the parties concerned.

Over the past two years, our laboratory has received from the Hong Kong Police Force over 50 pieces of CCTV footage recording courses of serious traffic accidents, mostly fatal ones, and our laboratory was requested to determine accident scenarios such as speeds of vehicles and drivers' views of pedestrians and other vehicles. Of the footage related to pedestrian/vehicle collisions, some clearly captured the courses of the collisions, including points of impact, post impact movements of pedestrians and final resting positions of pedestrians. These pieces of footage enabled us to determine the accurate speeds of the striking vehicles and provided valuable data for the studies of pedestrian/vehicle collisions.

In this study, we present details of a total of 11 pedestrian/vehicle collisions, which had been captured by CCTV cameras and car cameras. Impact speeds of the striking vehicles were calculated by analyzing the footage, and pedestrian throw distances were measured at the scene according to the positions recorded. The results from video analysis were compared against speeds

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calculated by pedestrian throw equations for validation of the described models.

2. Method

The 11 traffic accidents discussed in this paper occurred in Hong Kong between 2012 and 2014. Hong Kong Police took initial investigations and seized the relevant footage, and then made requests to our laboratory for determinations of causes of accidents and measurements of speeds of striking vehicles from the footage. All the footage submitted to our laboratory was in their original formats (.avi or .mov) or raw data of surveillance camera system, apart from Case 5 in which the original footage was converted into DVD format (.VOB). The known resolutions of the footage ranged from 640 × 480 to 1920 × 1080. Table 1 summarizes details of the video files recorded in their metadata.

The selected cases were considered suitable for the study as the footage provided means in which speeds of striking vehicles could be determined and the points of impact with pedestrians, i.e., the position on the road where the impact occurred, could be verified. The final resting positions of the pedestrians were either captured by the footage or recorded at scenes by photos or police scaled sketch plans; bloodstains on road surface in the latter were assumed as the final resting positions of pedestrians if no scene photos of pedestrians were available.

2.1. Video analysis

The video file in Case 3 was viewed and examined using the accompanied proprietary viewer whilst other files by common video players such as KM Player and Forevid. All the video files were examined frame by frame, and image frames of interests were extracted for further analysis or subsequent reconstructions at scenes.

To measure distances travelled by the striking vehicles equipped with car cameras during the accidents, landmarks such as lane lines appeared in the footage were used. In some cases, on-site reconstructions using the accident vehicles and the corresponding cameras to locate both positions of vehicles and pedestrians at various time frames were conducted, and direct measurements were made accordingly.

Making reference to the footage, pedestrian throw distances were measured at scenes between the captured points of impact and the captured final resting positions of pedestrians or the final resting positions recorded in scene photos or scaled sketch plans of the accident locus.

2.2. Calibration of cameras

Each accident footage bore a time stamp on its screen and an average frame rate was determined by counting the number of individual frames in each second. Then, control footage of the corresponding camera was made by placing a calibrated timer in front of the camera, and the control footage was exported/copied the same way as the accident footage. The frame rate of the control footage was determined by counting the number of individual frames against the calibrated timer in the control footage, and further examination would proceed if the frame rate of the accident footage agreed with that of the control footage as well as the information in the metadata. The determined frame rates from the calibrated timer would be used for calculating impact speeds of vehicles from the accident footage.

Table 1
Details of video files recorded in metadata.

Case	Format	Frame rate	Resolution
1	AVI	15	1440 × 1080
2	AVI	28.4	640 × 480
3	DAV	NA	NA
4	AVI	50	640 × 480
5	VOB	25	NA
6	AVI	15	1440 × 1080
7	AVI	24	704 × 576
8	AVI	24	1920 × 1080
9	AVI	30	640 × 480
10	AVI	30	1440 × 1080
11	MOV	30	1920 × 1080

2.3. Data analysis

Analysis of the footage frame-by-frame enabled determination of whether or not the striking vehicles were under braking before hitting the pedestrians, e.g. visual clues from inside a vehicle jerking forwards or braking sound heard from the footage. Distance-time analysis across multiple frames from the footage also enabled determination of the dynamics of the striking vehicles at moments of impact. For cases with braking noted before the impact, impact speeds were corrected from general equations of motion. The mass ratio effect correction for the pedestrians was however omitted from the calculation of speed for ease of comparison, suffice to say that the pedestrians were of normal or slim build and not overweight and should weigh less than 70 kg as assessed from the footage. On the contrary, average speeds of the striking vehicles 0.2–1.4 s before impacts were calculated and assumed as impact speeds for cases with no signs of braking before the impacts. Table 2 summarizes the calculated impact speeds and the corresponding details of the collisions.

3. Results

A total of 11 pedestrian/vehicle collisions were analyzed and they were classified by their post impact trajectory patterns into the two major categories as described by Ravani et al. [8]; there are 6 forward projection trajectories and 5 wrap trajectories as listed in Table 2.

Vehicles involved in the accidents were taxis, vans, buses, a saloon car and a medium goods vehicle. Of the 11 collisions, seven occurred when pedestrians were running across pedestrian crossing facilities; three on uncontrolled pedestrian crossing and four on traffic light controlled crossings with red pedestrian traffic lights. Two other cases were jaywalking. The remaining two collisions had relatively rare scenarios; the pedestrian in Case 4 was pushing a trolley of scrap paper along the nearside of carriageway and was knocked down by a taxi, whose driver was found driving inattentively and using an electronic device; the pedestrian in Case 2 was found having abused drugs, walking across an expressway and knocked down by a light bus at the imposed speed limit of 80 km/h.

Cases 4, 6 and 9 were taken place on sloped carriageways and the remaining cases were on level roads. The carriageways of Cases 10 and 11 were paved with concrete. The pedestrian in Case 8 was found to slide across half of its distance on concrete and half on asphalt. The remaining cases took place on asphalt.

Analysis of the footage frame by frame revealed that 7 accidents occurred with the striking vehicles under braking, 3 accidents with the striking vehicles having no signs of significant braking and the remaining one with the striking vehicle probably under braking.

All the collisions could be classified as full impacts instead of glancing or tangential in nature. The pedestrians had been stopped solely by the friction of the road, not hitting any road fixture or kerbs. Second strikes of the pedestrians on the bonnets were evident from the footage for all the wrap trajectory collisions;