THE PEDESTRIAN MOVEMENT ANALYSIS

Jiří Dudáček[1]

Annotation: The kinematical values (distance, time, velocity, acceleration) characterised pedestrian movement are important input data for the next accident reconstruction. When we try to model the pedestrian movement, it is applicable to know the real measured values of walking (velocity and acceleration of different pedestrian categories). Creating of the database (course of velocity and acceleration in dependence on distance) for different pedestrian categories was the reason to elaborate at the Institute of Forensic Engineering in Zilina the work named: The pedestrian movement analysis. The paper shows the methodology and brief conclusions of the work.

Key words: kinematics, pedestrian, velocity and acceleration of movement.

1. INTRODUCTION

When we do a car accident reconstruction (especially car to pedestrian crash) and model the pedestrian movement, it is applicable to know the real measured values of walking (velocity and acceleration of different pedestrian categories). The paper shows the methodology of measuring and realized evaluation.

2. THE METHODOLOGY OF MEASURING

2.1. Conditions, used facilities and measuring devices

The pedestrian movement was analysed as change the position of mass in space and time. The velocity and acceleration values were determined by the next kinematical search aside from forces, which are the reasons of movement. We used video technology for pedestrian movement analysis. The technology allowed recording the course of movement and watching the dependency of distance at the time. We knew the time stream of examined points from known recording frequency of video camera. Then we can determine the velocity and acceleration of the moving points.

The aim was using the video camera to record stochastic pedestrian movement. Pedestrians were passing through chosen crossing. Through the next analysis we determined the dependency of distance at the time in pedestrian movement from zero initial velocity. We were recording the movement through video camera situated on pavement in front of the pedestrian crossing. The measuring scheme is illustrated on the figure 1.

[1] Ing. Jiri Dudacek, PhD., University of Zilina, Faculty of Operation and Economics of Transport and Communications, Department of Road and Urban Transport, Univerzitna 8215/1, 010 26 Zilina, Tel. +421415133533, Fax +421415131523, E-mail: jiri.dudacek@fpedas.utc.sk

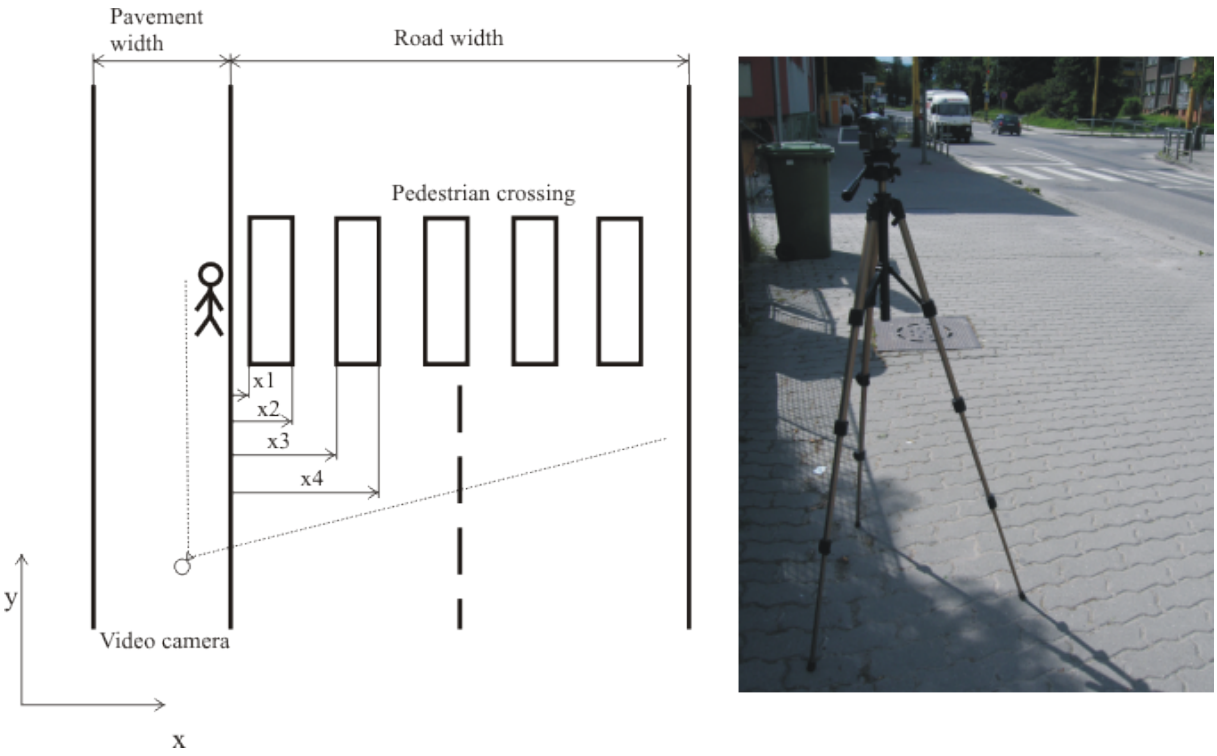

Fig. 1 Scheme of the measuring situation

We were realizing the recording so that pedestrians did not know about it. This way there was eliminated a modification of the movement. The measuring conditions consisted of the crossing without height separation from the road, controlled by traffic lights. The position of a human body at the time (i.e. distance from home position) was determined through road marking. The pedestrians stopped in front of the crossing on stop-light signal and then they started walking on green light signal. Following known measurements of the road, pavement and pedestrian crossing we were able to identify the pedestrian position in relation to home position. The aim was recording the movement of different pedestrian categories (men, women, children, adults, elders, and special cases – people with walking stick; mothers, who led children by the hand etc.).

The next facilities and measuring devices were used.

- Video camera PANASONIC NV – GS17 miniDV.
- Digital photo camera CANON Power Shot 520.
- Stand camera VELBON.
- Measuring tape (10m).
- Software for image processing – CANON Utilities Zoom Browser EX 5.0.
- Software for video processing – Windows Movie Maker.
- Software for video analysis – Virtual Dub 1.6.12.

2.2. The measuring accuracy procedure and data evaluation

When the selection of suitable pedestrian crossing had been made, all needed parameters of recording space (road width, pavement width, road marking in relation to start measuring point) were measured. When the video recording had been realized, the movement analysis started by the pedestrian selection to the categories (children from 3 to 5 years, from 6 to 9 years, from 10 to 14 years, men and women from 15 to 20 years, from 21 to 35 years, from 36 to 50 years, from 51 to 65 years, from 66 to 80 years, over 80 years, special cases). The video recording was made by camera in miniDV format. The necessary video processing (digitalisation) was realized using the software to "AVI" format (Audio Video Interleave – multimedia file format). The video format was suitable for using in the pedestrian movement analysis. The time dependency of distance was determined using the Virtual Dub 1.6.12 software as the human body position in relation to start measuring point at the exact time (the first, second, third and fourth second). The course was noticed in table format. The pedestrians were selected to categories by subjective checking of their age.

3. THE DATA EVALUATION

The final courses of velocity and acceleration in dependence on distance were evaluated in two ways. In the first case we use the premise of constant acceleration in single distance partition. Calculation of the velocity and acceleration values was realized using the next formulas.

The acceleration in the first distance partition, when initial velocity $v_0 = 0$, and movement velocity $v_1 \neq 0$, acceleration $a = const.$:

$$a_1 = \frac{2 \cdot s}{t^2} \quad \left[m.s^{-2}\right].$$

The acceleration in other distance partitions, when $v_1 \neq 0$, $v_2 \neq 0$, $a = const.$:

$$a_2 = \frac{2 \cdot s}{t^2} - \frac{2 \cdot v_x}{t} \quad \left[m.s^{-2}\right].$$

The movement velocity in the first distance partition, when initial velocity $v_0 = 0$, acceleration $a = const.$:

$$v_1 = \frac{2 \cdot s}{t} \quad \left[m.s^{-1}\right].$$

The movement velocity in other distance partitions, when v_x presents velocity at the beginning of partition, acceleration $a = const.$:

$$v_2 = \sqrt{v_x^2 + 2 \cdot a \cdot s} \quad \left[m.s^{-1}\right].$$

Where:
s – the distance moved by pedestrian in specific partition per 1s [m],
t – the time of one partition 1s [s],
a_1 – the acceleration in the first distance partition from zero initial velocity [m.s^{-2}],
a_2 – the acceleration in other distance partitions [m.s^{-2}],
v_1 – the movement velocity at the end of the first distance partition [m.s^{-1}],
v_2 – the movement velocity at the end of the other distance partitions [m.s^{-1}].

In the second case we obtained the polynomial functions of distance with variable time through creating the tendency from measuring data (distance and time). By the next differentiation with respect to time we obtained the searched courses of velocity and acceleration in dependence on distance. The comparison of the acceleration courses achieved through the first and second case is demonstrated in table 1 and figure 2. The values of constant acceleration estimated through the fist case correspond to average values estimated through the second calculation method (using the tendency and polynomial functions).

Table 1 Comparison of the evaluated pedestrian movement data

Measuring data		**Evaluation**				
		Constant acceleration		**Using of polynomial**		
Time [s]	Distance [m]	Velocity [m.s^{-1}]	Acceleration [m.s^{-2}]	Velocity [m.s^{-1}]	Acceleration [m.s^{-2}]	Average value of acceleration [m.s^{-2}]
0,00	0,00	0,00		0,00	1,09	
1,00	0,40	0,80	0,80	0,77	0,59	(1,09+0,59)/2= 0,84
2,00	1,40	1,20	0,40	1,17	0,24	(0,59+0,24)/2= 0,45
3,00	2,65	1,30	0,10	1,30	0,04	(0,24+0,04)/2= 0,14
4,00	3,95	1,30	0,00	1,31	0,00	(0,04+0,00)/2= 0,02

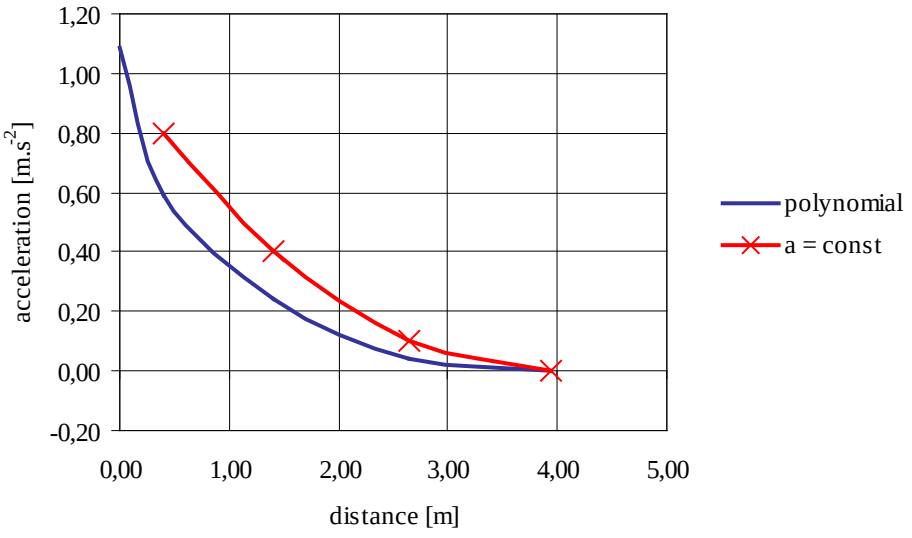

Fig. 2 Comparison of the evaluated pedestrian movement data

4. CONCLUSION

The paper describes the used methodology of measuring and evaluation the pedestrian movement data. Especially, the aim has been the obtaining the courses of acceleration in dependence on walking distance. The values will be used for pedestrian movement modelling in accident reconstructions. All measured and evaluated data are included at the work elaborated at the Institute of Forensic Engineering in Zilina (Slovak Republic).

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Reviewer: doc. Ing. Marián Šulgan, PhD.