Extracting Pedestrian Behavior Using Low Cost GNSS Receiver Data

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Abstract

This study presents the design and implementation phases of a pedestrian – positioning field data collection experiment by performing Post Process Kinematic positioning using high-sensitivity GNSS receivers. The aim of this research is the investigation of the impact that various parameters, such as pedestrians' characteristics, mobile phone use and walking pace may have on the characteristics of the pedestrian's behaviour using low cost GNSS receiver data. Pedestrians' characteristics include age, gender, body mass index, cellphone use. For this purpose, a controlled experiment was designed involving participants walking along a 220m track in a pedestrian area under different types of distraction (no distraction, hand-held conversation and texting) and different walking pace (normal-fast). The study sample size was 36 participants (20-73 years old), 15 male and 21 female who walked during the morning and afternoon hours. The equipment utilized involved a u-blox EVK-M8/NEO-M8T GNSS receiver in a small bag and a GNSS antenna located on the pedestrian's cap. An initial evaluation in terms of accuracy, availability and sampling rate was performed against a reference trajectory ensuring the suitability of the system for the designed approach. Pedestrian's behaviour was captured through six behaviour indicators: average and maximum speed, average and maximum acceleration and average and maximum deceleration. Within the framework of the statistical analysis, discrete choice models were developed to investigate the impact of mobile phone use as well as various other parameters on the aforementioned indicators. In particular, the results showed that walking speed, acceleration and deceleration are reduced with mobile phone use, regardless of the manner in which the cellphone is used (hand-held conversation, texting). At the same time, it was shown that older pedestrians move at lower speeds than younger, while gender does not appear to have a statistically significant impact on any of the explored variables.

Keywords: walking, distraction, pedestrian's behaviour, discrete choice analysis, experiment, GNSS receiver

1. Introduction

The understanding of pedestrian behaviour is a prerequisite for the design of efficient pedestrian relevant ITS/MaaS (Mobility as a Service) applications, and consequently the improvement of pedestrian safety, mobility and comfort. Pedestrian behaviour analysis strongly relies on the implementation of reliable trajectory extraction techniques, with the majority of studies utilizing vision-based approaches for extracting the positioning information due to the ability of performing contactless localization for a large number of subjects.

Previous studies on pedestrian behaviour exhibit the effect of different contributory parameters. For example, Azmi et al., (2012) compared walking behaviour in urban and rural neighborhoods, with the explored parameters being age, gender and the area type. Nazir et al., (2014) developed relationships among speed, flow, density and pedestrian space, with age being the contributory parameter. Pinna and Murrau (2018) observed pedestrian behaviour, when interacting with other pedestrians on sidewalks with reference to age. Generally, results showed that the speed of individual pedestrians decreases as age increases, while in Azmi et al., (2012) male pedestrians exhibited higher speeds than female ones. Alsaleh et al., (2017) assessed the effect of mobile phone use while walking at urban crosswalks, segregating between visual i.e. texting\reading and auditory i.e. talking\listening distractions. They also explored pedestrian behaviour in pedestrian-vehicle interactions. Vehicle speed was found to decrease with mobile phone use.

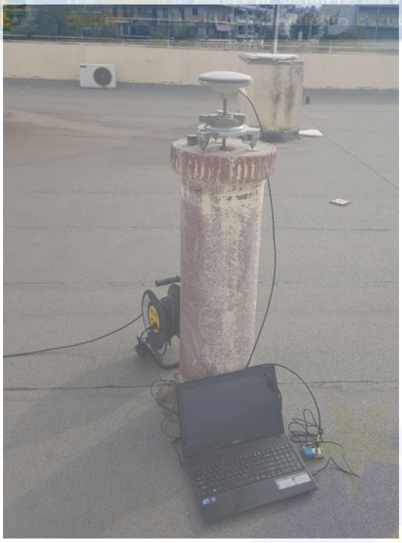
The aim of this research is the investigation of the impact that various parameters, such as pedestrians' characteristics, mobile phone use and walking pace may have on the characteristics of pedestrian's behaviour employing low cost GNSS receiver data.

2. Experimental procedure

For the purpose of the study, a controlled experiment was designed involving participants walking along a 220m track in a pedestrian area under different types of distraction (no distraction, hand-held conversation and texting) and different walking pace (normal-fast).

The experiment involved a base (non-distracted) and two distracted walks where participants were engaged in mobile phone conversation under two different use modes: hand-held and texting. Participants walked in two scenarios without distraction and in four scenarios under the different predefined types of mobile phone distraction with normal or fast walking pace. In addition to walking, participants filled-in a questionnaire, to collect data relevant necessary data.

For the collection of pedestrian track data, the low cost GNSS receivers u-blox EVK-M8 /NEO-M8T and u-blox C94-M8P, the high-quality geodetic type Pinwheel 702-GG satellite antenna of NovAtel®, as well as the RTKLIB software and the RTKGPS + mobile application were employed. The satellite antenna (NovAtel Pinwheel 702-GG) was initially placed on a geodetic pedestal with known coordinates. The antenna was then connected to the u-blox C94-M8P receiver and to a computer. At the same time, the next step was to place sensor equipment on the pedestrians. The equipment utilized involved a u-blox EVK-M8/NEO-M8T GNSS receiver in a small bag and a GNSS antenna located on the pedestrian's cap. Also, u-blox EVK-M8/NEO-M8T GNSS receiver connected to mobile phone on which the RTKGPS + application was installed through which the data were collected and saved on the mobile phone.



The experiment was carried out between October 2018 and November 2018 during morning and afternoon hours in the NTUA Campus facilities. It was performed at weekends, when no lessons are being held in NTUA, in order to exclude pedestrian interaction effects from the experiment. The study sample size was 36 participants, aged between 20 and 73 years old (average year: 29 years), with 15 male and 21 female pedestrians. In addition to the experiment, participants filled-in a questionnaire to obtain information on elements of their walking behaviour, use of mobile phone while walking, socioeconomic characteristics, and so on. Participants' characteristics are illustrated in Table 1.

Table 1: Sample characteristics

Parameter levels	Number	Parameter levels	Number
Age		Mobile phone use while walking	
< 25	9	Never	0
26 – 35	22	Rarely	3
36 – 45	5	Some times	8
Gender		Often	19
Male	21	Always	6
Female	15	Mobile phone accessories while walking	
Main means of transport		Hand-held	31
Car	14	Hands-free (wired)	16
Walking	10	Texting	25
Moto	2	Internet	22
Public transport	10	Daily walking time	
Bicycle	0	<30 min	6
Taxi	0	30 – 60 min	15
		>60 min	15

Interestingly enough, all of the participants use their mobile phone while walking, while, 44% use it with hands-free mode, 69% do texting, 61% use internet and 86% use it with hand-held mode.

3. Methodological framework

In this study, pedestrians' behaviour was captured through six behaviour indicators: average and maximum speed, average and maximum acceleration and average and maximum deceleration. Within the framework of the statistical analysis, discrete choice models were designed to investigate the impact of mobile phone use as well as various other parameters on the aforementioned indicators. First, the aforementioned walking behaviour indicators were classified into three categories according to their measured values magnitude – namely, low, "normal" and high. The three categories were initially formed based on the distribution of the variables between the participants. The lower and upper 25% (1st and 4th quartiles) formed the low and high category, respectively, while the remainder 50% (2nd and 3rd quartiles) the medium category. The classification of the explored parameters into the distinct walking behaviour categories is presented in Table 2.

Table 2: Parameter classification

Examined Variable	**Classification**		
	Low	Medium	High
Average speed	<1.43m/s	1.43m/s -1.77m/s	1.77m/s
Maximum speed	<2.09m/s	2.09m/s -2.65m/s	2.65m/s
Average acceleration	<0.13m/s^2	0.13m/s -0.23m/s^2	0.23m/s^2
Maximum acceleration	<0.56m/s^2	0.56m/s -1.04m/s^2	1.04m/s^2
Average deceleration	<0.12m/s^2	0.12m/s -0.19m/s^2	0.19m/s^2
Maximum deceleration	<0.63m/s^2	0.63m/s -1.01m/s^2	1.01m/s^2

The effect of the different scenario parameters on walking behaviour was established with the design of discrete choice models (ordered probit with random effects). In these models, the aforementioned indicators were the dependent variables, while independent variables varied between the different indicators and included mobile phone use mode, walking pace, age, gender, mobile phone use familiarity and so on. Indicatively, the estimated model for the explored variable of average speed is presented in Table 3.

Table 3: Probit model for average speed

Dependent Variable: average speed			
	Variables	**Estimates**	**t value**
	(Intercept)	3.4460	4.415
Scenario's characteristics	type (fast)	2.4078	8.537
	distr (handheld)	-0.6572	-2.696
	distr (texting)	-1.4341	-5.344
Participant's characteristics	age (>50 years)	-1.0762	-2.471
	Body mass index (overweight)	-0.7249	-2.210
Mobile phone use while	walk.cell.use (sometimes)	-0.8243	-2.681
	freq.walk.celluseHH	-1.8351	-2.417

walking	(often)		
	freq.walk.celluseHH (always)	-2.1736	-2.857
	perc.walk.celluseinternet (75-100%)	-1.3290	-2.359
	mu_1	3.1009	9.884
	sigma	2.0217	7.115
Number of Observations		208	
Initial log – likelihood		-206.9334	
Final log – likelihood		- 138.5286	
AIC		301.0573	

The resulting model for average walking speed indicates that participants walking while using their mobile phone, generally, tend to reduce their average speed with the texting mode exhibiting the highest reduction, followed by the hand-held mode. Furthermore, as expected participants who were in a hurry exhibited higher values of average speed compared to walking with normal pace. Other contributory parameters considering average walking speed include participant's age and body mass index and mobile phone use while walking. In particular, participants who sometimes use their mobile phones while walking demonstrated lower values of average speed compared to participants who never use their mobile phones while walking. In addition, participants who use their mobile phones while walking for 75 – 100% of their total walk time exhibit lower average speeds than participants who use their mobile phones while walking less than 25% of total walk time. Last, participants older than 50 years of age exhibited lower speeds compared to pedestrians aged between 17 – 30 years of age, while overweight participants exhibited lower values of average speed compared to participants with normal body mass index.

4. Results

Based on the results of the present research, mobile phone use is significantly affecting walking behaviour in both normal and fast walking pace. Results showed that walking speed, acceleration and deceleration are reduced with mobile phone use, regardless of the manner in which the mobile phone is used (hand-held conversation, texting), with texting causing the greatest decrease. In this research, average walking speed for normal pace walking was 1.53 m/sec, while average walking speed under distraction was equal to 1.43 m/sec. Reduction of average speed has also been exhibited in previous studies. In particular, Yoshiki et al., (2017) measured an average speed of 1.7 m/sec without distraction, an average speed of 1.45 m/sec under hand-held mobile phone use and an average speed of 1.4 m/sec under texting. Alsaleh et al., (2017) estimated 1.66 m/sec average speed without distraction and 1.49 m/sec under distraction from mobile phone use.

Results also demonstrate the effect of age on walking speed, while gender does not appear to have a statistically significant impact on any of the dependent variables. More specifically, a decrease in all six dependent variables is noted for pedestrians aged over 50 years compared to pedestrians under 50 years old in both fast and normal walking. On the contrary, pedestrians aged 30-50 years of age walk with higher values of average and maximum speed and exhibit higher deceleration and acceleration rates compared to pedestrians under the age of 30 when walking in normal pace. In a similar research, Willis et al., (2004) found that the average speed is 1.47 m/sec for pedestrians aged 16-25, 1.55 m/sec for pedestrians aged 26-50 and 1.38 m/sec for pedestrians 51-64 years old.

Further parameters, including body mass index and frequency of mobile phone use while walking were also found to affect several of the explored pedestrian behaviour indicators. Identifying contributory factors of pedestrian behaviour considering pedestrian related characteristics can support the development of more accurate pedestrian models and their incorporation into dedicated Mobility as a Service (MaaS) applications for pedestrians to improve their mobility and safety.

5. References

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