TRB TRANSPORTATION RESEARCH BOARD OF THE NATIONAL ACADEMIES
90th Annual Meeting 2011

Pedestrian Stride Frequency and Length Estimation in Outdoor Urban Environments using Video Sensors

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Introduction

- Walking is a key non-motorized mode of travel and a vital component of most trips
- Walking has traditionally received research and practice focus secondary to motorized modes
- There is a lack of pedestrian data, in particular microscopic data, to meet the analysis and modeling needs
- Distributions based on empirical measures are crucial for studies trying to estimate the impact of a shift from motorized modes to active transportation on the level of physical activity

Objective: extract automatically pedestrian stride frequency and length from video data collected non-intrusively in outdoor urban environments. Pedestrian walking gait is usually described by the relationship $v=f \times l$, with the following walking parameters

- the walking velocity v
- the vertical stride frequency f (number of times a foot touches the ground per time unit)
- the stride length l

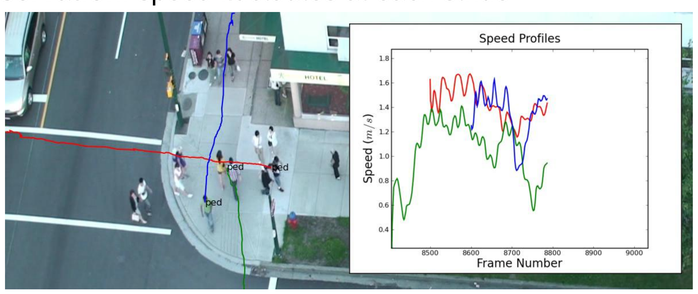
Relevant Work

- Biomechanics and transportation research
- Structural engineering: footbridge dynamic behavior under human loading (London Millennium Footbridge closed in 2000)
- Stride length and frequency are not commonly measured, even less automatically and non-intrusively in the field

Walking parameter	*Range of the mean*	*Range of the standard deviation*
Walking speed (m/s)	1.19 – 1.60	0.15 – 0.63
Stride frequency (Hz)	1.82 – 2.0	0.11 – 0.186
Stride length (m)	0.75 – 0.768	0.07 – 0.098

From *Crowd-structure interaction in lively footbridges under synchronous lateral excitation: A literature review.* **Venuti, F. and Bruno, L.** 3, 2009, Physics of Life Reviews, Vol. 6, pp. 176-206

Observation: speed fluctuates at each stride

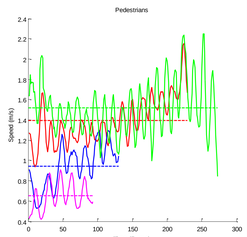


Sample data from *Automated Collection Of Pedestrian Data Using Computer Vision Techniques.* **Ismail, K., Sayed, T. and Saunier, N.** TRB Annual Meeting , 2009

Proposed Method

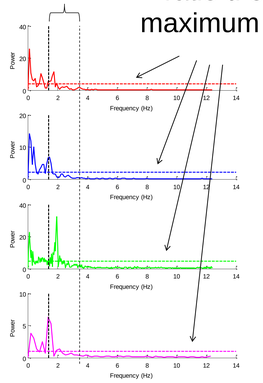
Condition 1
Frequency Search Interval $[f_{min}, f_{max}]$

Condition 2
Threshold: ratio α of the maximum power



Speed Time Series

Smoothing
+Mean value subtraction
+Fast Fourier Transform (FFT)
+ Absolute Value

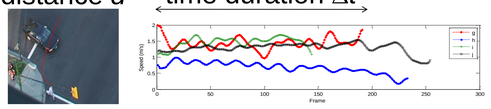


Power Spectrum

A set F of maximum N_f frequencies may satisfy conditions 1 and 2

Final stride frequency
$f = mean(F)$
or $argmax_{f \in F}(Power(f))$

distance d time duration Δt



Stride length
$l=d/(\Delta t \times f)$

Another Cue to Classify Pedestrians and Motorized Vehicles

A frequency f can be computed, and $n_{oscillations} > n_{pedestrian\ oscillations}$

yes / no

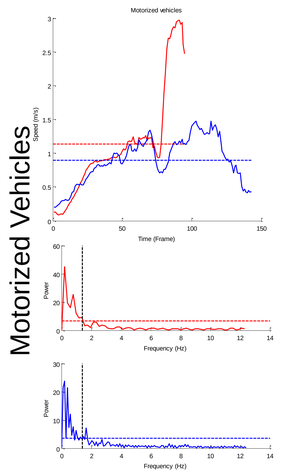
$l < l_{pedestrian}$

a frequency f' can be computed in $[0, f_{min}]$ and $n_{oscillations} < n_{pedestrian\ oscillations}$

yes / no

yes / no

- Pedestrian
- Motorized Vehicle
- Unknown

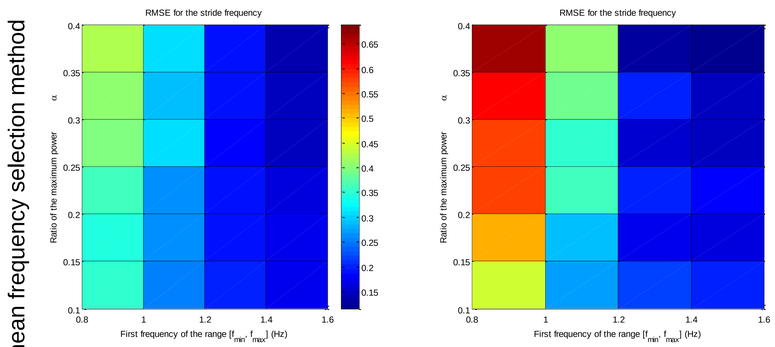


($n_{oscillations}$: number of times per second that the speed profile goes through its mean value)

Experimental Validation

Dataset	*RMSE for stride frequency (Hz)*	*RMSE for stride length (m)*	*Number of pedestrians with calculable stride frequency*
Rouen (France)	0.170 (0.123)	0.061 (0.040)	101 / 102 (75)
Vancouver (Canada)	0.161 (0.090)	0.057 (0.030)	42 / 50 (11)

Performance Evaluation

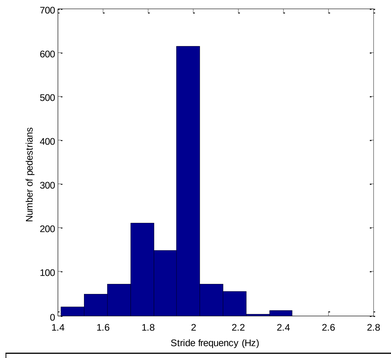


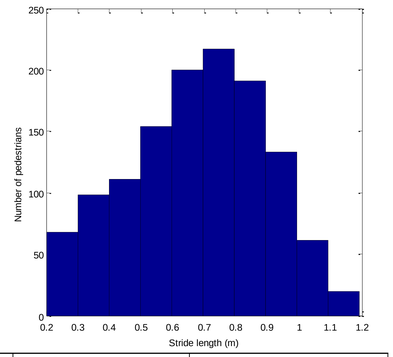
Rouen dataset, N_f =10 Vancouver dataset, N_f =20

Confusion Matrix for Road User Classification

	Type predicted by the classification method		
True type	Motorized vehicles	Pedestrians	Unknown
Motorized vehicles	87	2	5
Pedestrians	6	95	1

Experimental Results





Dataset		*Stride frequency (Hz)*	*Stride length (m)*
Rouen	annotated dataset (manual)	1.908 ± 0.214	0.748 ± 0.139
	annotated dataset (auto)	1.901 ± 0.173	0.759 ± 0.163
	whole dataset	1.897 ± 0.147	0.678 ± 0.217
Vancouver	annotated dataset (manual)	1.703 ± 0.311	0.625 ± 0.119
	annotated dataset (auto)	1.753 ± 0.174	0.679 ± 0.132

Acknowledgements: the data was collected in the French National project SICAP from PISTES framework, sponsored by the Road Safety Foundation. The authors wish to thank David Doucet from the CETE-NC (Rouen, France) for the video collection, and Professor Christian Cardinal (École Polytechnique de Montréal) for his help with the Fourier analysis.