

PEDESTRIAN SENSING WITH FEATURE EXTRACTION

T. J. Chamberlain
Research Student
t.chamberlain@napier.ac.uk

A. Armitage
Lecturer
a.armitage@napier.ac.uk

M. J. Rutter
Lecturer
m.rutter@napier.ac.uk

T.D. Binnie
Reader
td.binnie@napier.ac.uk

Facility of Engineering, Computing and Creative Industries
Napier University
10 Colinton Rd
Edinburgh, EH10 5DT

Abstract

Automated pedestrian sensing and tracking is receiving increasing attention from researchers in a number of areas. Applications are common in security, in urban planning, and in the retail industry. A common approach is to use CCTV and visible image processing, but this involves complicated scene interpretation. This paper describes our research on monitoring the movement of pedestrians using relatively low-cost, low resolution infrared sensors. We describe our data collection system and processing techniques and introduce new data analysis software. Preliminary results show that, as well as the simple tracking of pedestrians, biometric data, such as gait measurement, becomes possible. Our work aims to provide data to improve security and to enable behavioural monitoring of pedestrians in public. This data is important to those working in pedestrian monitoring, market research and in public safety and security.

Introduction

Pedestrian detection and tracking is an area gaining increasing importance in transport. The ability to measure the movement of pedestrians can have a wide-ranging impact on transport infrastructure and systems. The main areas where accurate measurements of pedestrian motion help are in security and surveillance, behavioural studies and transport systems.

Although the security of transport infrastructure has grown in importance over the last decade, the ability to accurately measure the motion of pedestrians is still not widely available. Computer vision systems using visible imaging (CCTV or similar) have advanced considerably in the last few years (1), (2), (3), (4). However, these systems are still limited in their ability to handle crowded scenes, or scenes in which there is a large amount of extraneous detail (such as moving shadows, swaying tree

branches and vehicular traffic). Recently, there has been interest in the use of high-resolution infrared images (5), (6),. Particularly when combined with visible images (7), (8) this could provide a more robust method of tracking pedestrians. The thermal images provide extra information about the presence of hot objects, such as pedestrians, in the field of view. The problem is still not trivial. Typical systems can only deal with limited numbers of pedestrians: three at a time in the system developed by Torresan et al. (8). It's also a problem that such high-resolution cameras are expensive, and not yet widely used. CCTV systems are much cheaper, and are far more widely deployed. However, the difficulties of accurately deriving pedestrian information from these systems means that in most cases the footage is simply recorded and used as a post-event diagnostic tool. Additional systems that can actively collect information about pedestrians have the potential to not only improve our use of CCTV but also aid the monitoring of restricted access areas.

At present the transport research community is producing and using several pedestrian behaviour models (eg (9)). There is still a gap between these models and our ability to confirm on a large scale the actual motion of pedestrians in real environments. This work follows the Permeate (10) project and should enable improvements to the data collection process. In turn, this will improve these models so they become more accurate.

Road junction signalling systems could be improved by the addition of effective pedestrian measurement equipment. Detecting the presence of both the number of pedestrians and the presence of vulnerable pedestrians (such as children, the disabled or infirm) could be used to alter the signal priorities. A survey published in 1999 (11) shows that a disproportionately high number of pedestrian fatalities occur in high risk groups. Any technology that improves this will be advantageous.

We present a method for capturing human motion information and a novel system for extracting stride information. We anticipate that it will enable the extraction of biometric features based on human gait. This will aid the monitoring of restricted access areas and produce individual pedestrian information. This information may further enable the tracking of pedestrians from one sensor to another even when the pedestrian becomes occluded. It may also be able to help identify vulnerable pedestrians.

Data collected

IRISYS thermal detectors contain pyroelectric low resolution (16 by 16) sensor arrays that produce a data matrix of short term temperature change in the field of view (12). As a pedestrian walks under the detectors, the changes in temperature are detected by the elements of the array that cover the area where the pedestrian is walking. This manifests itself as a hot (bright) round object representing the temperature increase caused by the pedestrian's movement – see Figure 1. The dark trail adjacent (lower right) to the brighter area is the negative cooling effect. As the detector measures change in temperature, the area the pedestrian has just passed through is shown as a darker area.

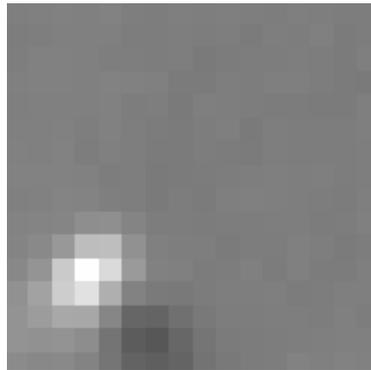


Figure 1: Sensor Image

Each detector has an onboard digital signal processor that uses a real time algorithm to robustly identify and track multiple individuals moving within the field of view. Figure 2 shows a scene with two pedestrians detected and their paths superimposed.

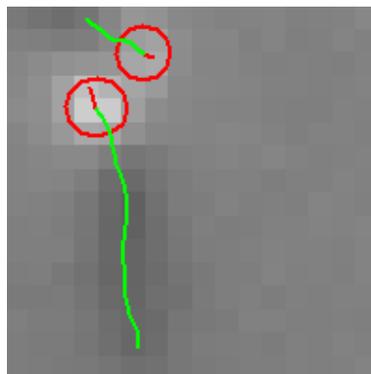


Figure 2: Pedestrians Detected and Tracked

The centroid of each ellipse (pedestrian) is then sent to an attached PC in at a rate of thirty frames per second. This provides sub-pixel accuracy for the location of the pedestrian. Additional size and status information is also provided for each elliptical target.

Our experiments consisted of collecting a range of personal information from each participant such as height, leg length measurements, weight, and gender. We then asked each participant to walk under our sensors in straight lines several times, measuring their walk each time with the IRISYS thermal detectors. Each trajectory was then stored for further processing as described below.

Processing the data

There are several processing steps required to take the data collected and extract information that can be used. Each step builds on the last, to put the data in a format that should help produce an identifiable feature about the pedestrian. Firstly a correction equation must be applied to the data to compensate for the barrel distortion present in each detector. This is caused by the wide-angle germanium lens and mounting in the detector. This distortion is not easily corrected, as it varies from sensor to sensor, but through experimentation we have obtained an algorithm that corrects most of the distortion. Secondly the path of the pedestrian must be extracted; our current algorithm relies on the pedestrian walking in a straight line and by performing linear regression we find a best fit line for the walk of the pedestrian shown in Figure 3. The straight line is a best fit line for the data, established using regression as there is statistical error in both x and y measurements.

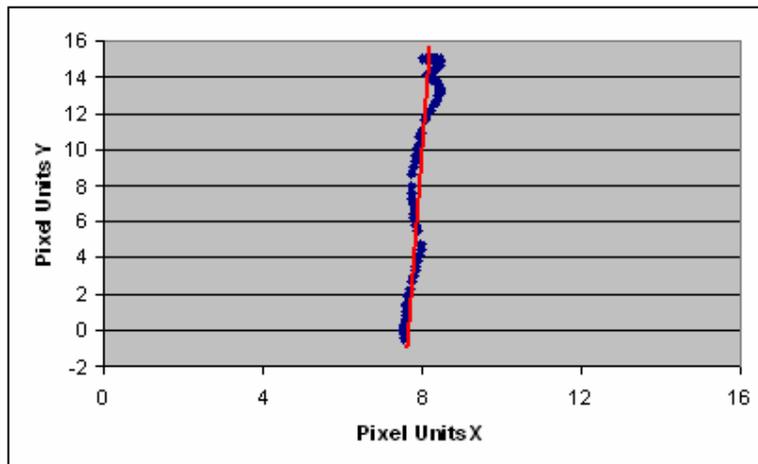


Figure 3: Pedestrian's Path

The line is expressed in its parametric form as described in (13). Any trajectories where the fit of this line is substantially below expected values are discounted at this stage as being poorly matched data. The experiments conducted so far have relied on the participants' cooperation or selected locations where the natural trajectory was approximately linear, maximising the usefulness of data at this stage.

Future work would be needed to improve the modelling of the pedestrian's paths. Options include the fitting of a polynomial or floating average instead of a straight line.

The third stage is to extract the minimum distance from each point to the line that denotes the general direction taken (Figure 3). It is apparent from the diagram that there is a significant variation from left to right and our work is based on the correspondence of this to the location of each step the pedestrian takes.

This data is then filtered, windowed and put through a Discrete Fourier Transform (DFT) to extract frequency information. This frequency information is based on the rate at which the pedestrian walks, which in turn is dependant on personal physiological factors such as leg length. We have still to confirm to what extent the frequency view of this data relates to the individual or their physical features but initial examination shows some correlation. The DFT was selected as the simplest method of extracting frequency information from the data set. In future, work will be done using transforms better suited to short data sets (16, p816).

Analysis of the results

The results collected so far have proved promising. When viewing the plot presented in Figure 2 it is possible to see that there is a left to right swinging motion as the pedestrian walks through the field of view. This left to right motion is more clearly visible in Figure 4 where the motion has been re-scaled and each point expressed as a distance from the best fit line against time (a pixel unit corresponds to approximately 20 cm). This provides an interesting source of data relating to the frequency of the pedestrian's stride and enabling the length of their stride to be measured. This information is then used to extract two different measures. Firstly the magnitude of the oscillation is established by calculating the mean of the absolute value of the points shown in Figure 4. Secondly the frequency of the oscillation is examined to produce walking cadence information. From this, two different measures can be derived. Firstly the magnitude of the oscillation is established by calculating the mean of the absolute value of the points shown in Figure 4. Secondly the frequency of the oscillation is examined to produce walking cadence information. Wagg and Nixon (14) show that cadence information contains a significant individualistic component and can contribute to a biometric measure.

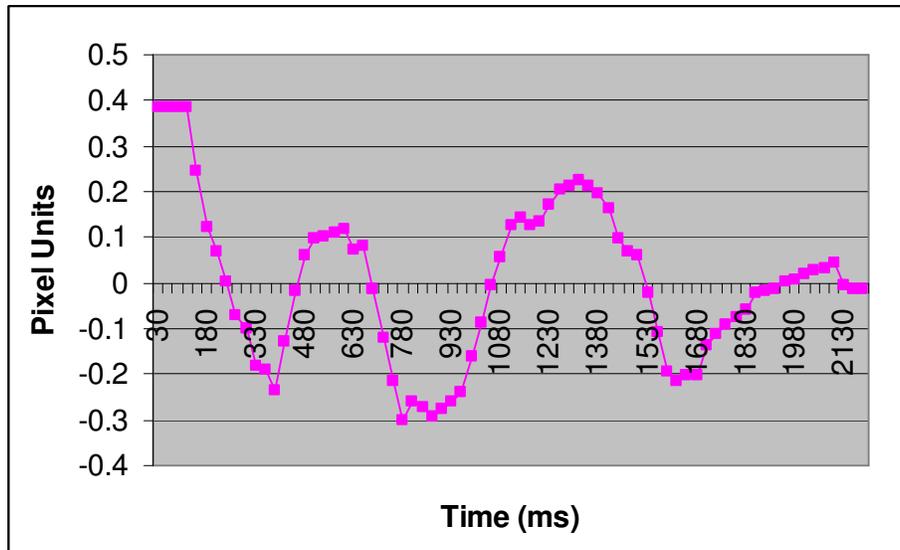


Figure 4: Graph of left to right swing v time

Magnitude of oscillation

In excess of 200 measurements have been collected from 21 different participants using detectors placed in the ceiling of Napier University’s Merchiston library. For this set of data each participant was aware that they were taking part in pedestrian measurement experiments and provided their weight, height, gender and age. A notable difference is present in the measurements from male and females. Figure 5 shows the difference in oscillation magnitudes between male and female participants.

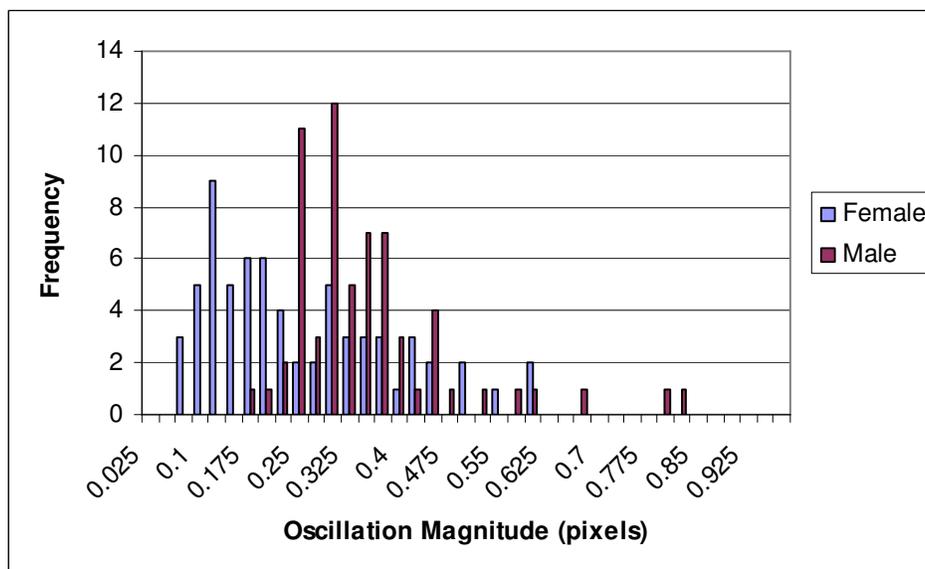


Figure 5 Gender distribution

It is clear from the data that there is significant difference in the means of the measurements from each gender. The information is not sufficiently different to produce an absolute measure of gender, however it is sufficient to produce a measure suitable for inclusion in a statistical model (e.g. a Markov model). An unpaired t-Test assuming unequal variance was performed on the data to check the statistical significance of the difference between the mean of each gender. The test was performed with a confidence measure of 99.9%. The result of this test, (Table 1) shows that we can be 99.9% certain that the mean of the male dataset is higher than the mean of the female dataset. The value of t-stat is larger than t-critical thus establishing the significance of the finding.

t-Test: Two-Sample Assuming Unequal Variances		
99.90%		
	<i>Male</i>	<i>Female</i>
Mean	0.3794	0.2387
Variance	0.0478	0.0182
Observations	67	67
Hypothesized Mean Difference	0.0000	
Degrees of freedom	110	
t Stat	4.4824	
P(T<=t) one-tail	0.0000	
t Critical one-tail	3.1660	
P(T<=t) two-tail	0.0000	
t Critical two-tail	3.3812	

Table 1: t-Test results for different gender means

Estimating gender distributions

Some initial experiments were conducted to see if it was possible to estimate the proportions of each gender from the measurements of oscillation magnitude. In one experiment, pedestrians were aware they were being monitored, in that they had been asked to walk under the detectors (they had been given no other specific instructions). Table 2 shows the estimated and actual numbers from this experiment.

Gender	Estimated	Actual
Female	52	49
Male	21	24

Table 2: Estimated and actual gender distribution (experiment 1)

In a second experiment, measurements were taken of pedestrians who were unaware they were being monitored. Results are shown in Table 3. It should be noted that these results are preliminary, and

further work is required to validate the method. We are aware that the measurements taken so far have been within the context of the University, where the age distribution is not representative of the general population. However, the results are encouraging, and potentially provide a non-intrusive method of establishing the gender distribution within pedestrian cohorts.

Gender	Estimated	Actual
Female	49	48
Male	71	72

Table 3: Estimated and actual gender distribution (experiment 2)

Extracting frequency information

The information shown in Figure 4 can also be processed to extract a measure of cadence. This is achieved by putting the data through a low-pass filter and processing to extract an approximate differential (Figure 6). We find the differential by calculating the gradient of the last five points using a restricted form of linear regression. The gradient is expressed as the angle of this best fits intersect with the y axis.

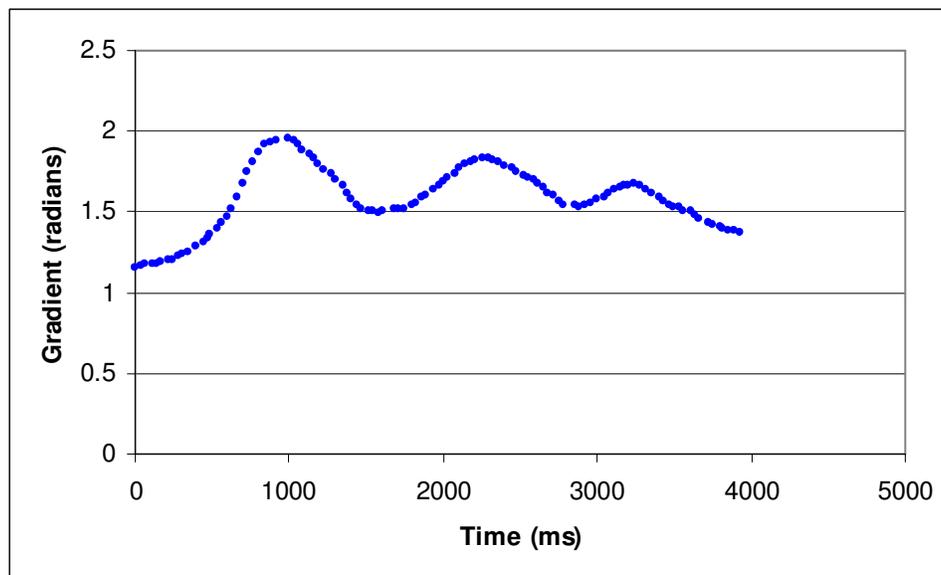


Figure 6: Best fit differential

This best fit differential data can then be normalised, windowed and viewed in the Fourier domain where it is possible to see the most significant frequency features shown in Figure 7. By processing the data in this way we provide an appropriate balance of high and low pass filtering to maximise the information available. This information provides an interesting feature which correlates to human gait cadence.

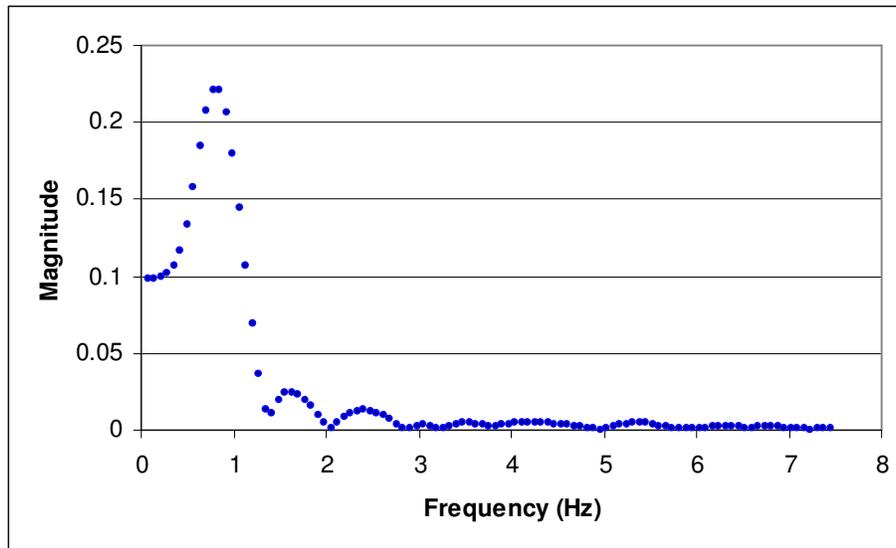


Figure 7: Fourier series

This Fourier spectrum of the data is being used to calculate a weighted count of the number of footsteps in the field of view. Equation 1 shows the formula used for this.

$$f = \frac{\sum_{i=0}^n D_i \times i}{\sum_{i=0}^n D_i}$$

f	is the index of major walking harmonic
D	is the array of magnitudes in the Fourier domain
n	is the number of elements in D

Equation 1

The results are currently being analysed to determine what useful information is present. There is unsurprisingly a broad correlation between the walking frequency and leg length of participant. The data displayed in this section is only a single walking sequence; we have collected the walks from twelve different pedestrians, measuring a minimum of ten walks from each.

Future work

Initial examination suggests that some of the frequency information may well relate to the individual. This study should be furthered to examine if it can assist in identifying pedestrians (even within a small

population). Further work is in progress to further validate the gender distribution algorithm, particularly with respect to measuring a variety of pedestrians more representative of the general population.

Conclusions

The study to date has presented a new and innovative method for obtaining information relating to pedestrian movement and human gait. This information can be easily collected in real time without the need for the pedestrians to even be aware they are being monitored. The detectors are reliable and robust for the detection, tracking, and counting of pedestrians. This research shows that relevant information can be extracted. In particular, we have managed to obtain gait information (length and frequency) and we have also been able to reliably estimate the gender distribution of pedestrian cohorts. However we have yet to establish if this information can be used to identify individuals.

This work demonstrates a new use for low cost thermal sensors not currently used in this context. The pursuit of this investigation could improve not only transport security but also pedestrian detection for pedestrian flow and behaviour analysis. The work could be extended to further inform junction signalling systems by providing measurements of the pedestrians waiting, see (15) for example. Indications of the speed of movement of the most vulnerable pedestrians would also be valuable.

Acknowledgement

We gratefully acknowledge the help and support of Dr Neil Johnson of Infrared Integrated Systems Ltd, Northampton, (www.irisys.co.uk) and Professor Jon Kerridge of Napier University.

References

- (1) D. Gavrilu, "The visual analysis of human movement", Computer Vision and Image Understanding, 73 (1), Jan, pp 82-98, 1999
- (2) J.K. Aggarwal and Q. Cai, "Human motion analysis: a review", Computer Vision and Image Understanding, 73 (3), March, pp 428-440, 1999
- (3) C. Curio, J. Edelbrunner, T. Kalinke, C. Tzomakas and W. von Seeden, "Walking pedestrian recognition", IEEE Transactions on Intelligent Transportation Systems, (1), , pp 155-163, Sept 2000.
- (4) R. Bodor, B. Jackson and N. Papanikolopoulos, "Vision-based human tracking and activity recognition", Proc. 11th Mediterranean conference on Control & Automation, 2003.
- (5) M. Bertozzi, A. Broggi and P. Grisleri, "Pedestrian detection in infrared images", Proc. IEEE Intelligent Vehicles symposium, 2003.
- (6) F. Xu, X. Liu and K. Fujimura, "Pedestrian detection and tracking with night vision", Proc. IEEE Transactions of Intelligent Transportation Systems,6(1), pp 63-71 2005
- (7) A. Leykin and R. Hammoud, "Robust multi-pedestrian tracking in thermal-visible surveillance videos," Proc. IEEE Conf. On computer Vision and Pattern Recognition, June 2006.

- (8) H.Torresan, B. Turgon, C. Ibarra-Castanedo, P. Hebert & X. Maldague, "Combining video and thermal imagery for pedestrian detection", Proc. SPIE Thermosense XXVI, Vol 5405 of SPIE, pp 506-515, April 2004.
- (9) "Pedflow project, Napier University", Retrieved 17th Nov 2006 from:
<http://www.soc.napier.ac.uk/researchprojects/researchprojectid/57742/op/displayoneproject>
- (10) "Permeate project, Napier University", Retrieved 17th Nov 2006 from:
<http://www.soc.napier.ac.uk/researchprojects/researchprojectid/701710/op/displayoneproject>
- (11) U.S. Department of transportation Federal Highways agency, "Research, development, and implementation of pedestrian safety facilities in the United Kingdom" (December 1999)
- (12) IRISYS, Retrieved 17th Nov 2006 from: <http://www.irisys.co.uk/products/smartcounters.htm>
- (13) J. Illingworth & J. Kittler, "A survey of the Hough Transform", Computing Vision, Graphics and Image processing, 44 (1), pp 87-116, Oct 1988
- (14) D. Wagg and M. Nixon, "On Automated Model-Based Extraction and Analysis of Gait," presented at: International Conference on Automatic Face and Gesture Recognition, Seoul, Korea, 2004.
- (15) "Information and Telematics Smart Pedestrian Counter System", Retrieved 17th Nov 2006 from:
http://www.dft.gov.uk/stellent/groups/dft_science/documents/page/dft_science_504480-43.hcsp
- (16) J. Proakis & D. Manolakis, Introduction to digital signal processing, London, Collier MacMillan, 1988