Poster: Gait Dependency of Smartphone Walking Speed Estimation using Deep Learning

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ABSTRACT

This paper proposes an accurate estimation method of walking speed using deep learning for smartphone-based Pedestrian Dead Reckoning (PDR). PDR requires to estimate speed and direction of pedestrians accurately using accelerometer and gyroscope. To improve the accuracy of PDR, existing works focused to improve the key factors of speed estimation (i.e., stride and/or step estimation) by adapting deep learning. On the contrary, our research proposes to adapt deep learning more directly to estimate walking speed from sensor data of smartphone. We evaluate the accuracy of proposed method by comparing with conventional PDR method. As a result, we confirmed that proposed method can estimate the speed more accurately.

CCS CONCEPTS

• **Information systems → Location based services**; • **Computing methodologies →** *Supervised learning by regression.*

KEYWORDS

location estimation; deep learning; PDR

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1 INTRODUCTION

Pedestrian Dead Reckoning (PDR) is a promising technique as an infrastructure-free indoor positioning. PDR provides relative position of pedestrians by estimating their walking speed and direction from an accelerometer and a gyroscope of pedestrians' smartphones. Conventional PDR adopts step detection and stride estimation with simple threshold. When step detection and stride estimation fail, the estimated speed should largely deviate.

Because deciding an optimal threshold for any walking behavior is difficult, existing works adapt deep learning, which can handle wide variety of patterns, for step detection and/or stride estimation.For example, Gu et al.[2] proposed a stride estimation method from acceleration and angular velocity using an encoder model that performs dimensional reduction by fully connected layers. As a result, they reported that the stride can be estimated with an error rate of about 3%. However, in the methods which estimate step and stride separately, replacing either one with a deep learning model does not greatly decrease positioning error because remaining one still leads to the error.

Therefore, in this paper, we propose a method to adapt deep learning more directly for speed estimation. We design a neural network for estimating speed by using CNN and LSTM, and compare the estimation accuracy with conventional PDR method. As a result of a comparison using the data of three behaviors (walk, stamp and skip), proposed method outperformed the conventional method.

2 PROPOSED METHOD

2.1 Overview

PDR estimates position by estimating speed and direction. In our proposed method, speed estimation is performed by deep learning, and direction estimation is performed by integrating angular velocity.

2.2 Neural Network for Speed Estimation

3-axis acceleration and its norm data are used for speed estimation. In order to keep the length of data in each data segment,the data is resampled to 100 Hz beforehand.

The neural network consists of CNN layers and LSTM layers. CNN layer extracts features of signal in short time width. LSTM layer gets the features extracted by CNN layers and extracts their time series features. The neural network is implemented with PyTorch.

3 EVALUATION

3.1 Metrics

Table 1 is an overview of the evaluation dataset including three behaviors: walk, stamp, skip. Conventional PDR using finite state machine based on thresholding and our proposed method using deep learning are evaluated with this dataset. The following 3 types of values from the study of Abe et al. [1] are used as the evaluation

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Table 1: Summary of collected dataset.

Subject	8 men (age: mid twenties)
Device position	hand, pocket
Behavior	walk, stamp, skip
Number of routes	102
Walking time of the routes	Avg: 80.48[sec] SD: 54.90[sec]
Length of the routes	Avg: 51.90[m] SD: 31.93[m]

Table 2: Evaluation for each behavior (cPDR: conventional PDR).

	walk		stamp		skip	
	ours	cPDR	ours	cPDR	ours	cPDR
Length error[m]	4.46	10.50	3.01	29.35	10.66	34.16
Error rate per meter[%]	6.89	15.92	68.89	518.24	20.63	63.44
Error rate per second[%]	6.75	16.53	2.62	19.99	39.11	125.26

metrics for speed estimation: Average of estimated path length error; Path length error per meter; Path length error per second. Smaller value means better performance.

3.2 Result

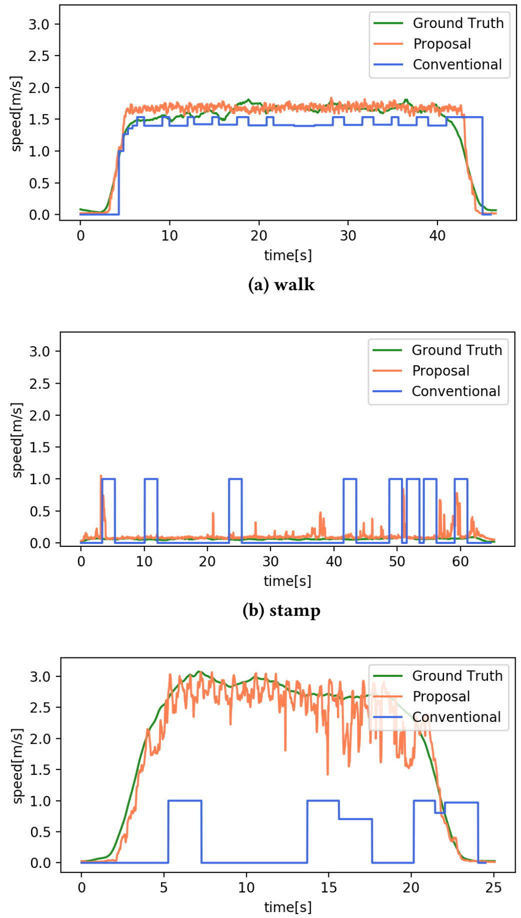
Table 2 shows the evaluation result (conventional PDR is marked as cPDR). Proposed method outperformed the conventional PDR for all behaviors.

Figure 1a shows speed estimation of walk. Proposed method could estimate the speed more accurately than conventional PDR. Figure 1b shows speed estimation of stamp. Conventional PDR mistakenly recognized stamp as walk and led to a larger error. While proposed method also sometimes misrecognizes stamp as walk, the error is less in the proposed method than in the conventional method. Figure 1c shows speed estimation of skip. Conventional PDR led to slower estimated speed because it could not detect skip step, which is different from walk step. Even when it could detect skip step, the estimated speed is slower because the stride of one step is larger for skip than for one walk step. While estimated speed using proposed method is almost the same with the ground truth in Figure 1c, estimated speed is a little slower than the ground truth overall. This is because part of the step was misrecognized as walk.

From these results, proposed method can estimate the speed more accurately than conventional PDR, although we need to improve the speed estimation more to be accurate on stamp and skip.

4 CONCLUSIONS

In this paper, we proposed deep learning based speed estimation which directly estimates the speed from acceleration data. The neural network is based on CNN and LSTM. The comparison showed that proposed method could distinguish walk, stamp and skip more accurately than conventional PDR.



(a) walk

(b) stamp

(c) skip

Figure 1: Estimated speed of walk, stamp and skip.

However, proposed method sometimes output wrong speed on stamp and skip data. The neural network should be trained with the extended dataset which has more behaviors such as jog, run and so on. Then, we need a further ingestigation of how the neural network works with such dataset.

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