IMU trajectory estimation via step detection

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In this work is provided the new approach for task of estimation the trajectories and steps of a person. Data is the readings of the accelerometer and gyroscope, which are installed in the human's smartphone. The main point of our method is to predict not only trajectories, but also human steps in order to make trajectory estimation closer to ground-truth. In our reseach is used the architecture, which is a concatenation of famous neural networks ResNet-18 and LSTM. Our research consists of 3 main parts: prediction a velocity vector and step label for one window, prediction instant velocities and leg stationary (label) for a window and apply attention mechanism for instant velocities. The results of the evaluation process shows that our approach gives accurate results in evaluating trajectories and steps. Moreover, to our knowledge, this paper is the first work dedicated to the simultaneous prediction of the trajectory and steps of a person.

Key words: *IMU navigation; step detection; trajectory estimation; neural networks; accelerometer and gyroscope, attention*

1 Introduction

IMU data are widely used for step counting. These methods for step detection and step counting do not use machine learning (ссылка).They are based on analysis of smartphone accelerometer readings. Modern technologies show satisfactory results. However, the system has a clear drawback: the measurement error is quite large. The main problem of this aproch is that smartphone's coordinate system and human's coordinate system are very different. During the movement of a person (speed, running, jumping) the smartphone is in a moving with acceleration and rotating reference system. This is the first cause of a big error. The second one is the inaccuracy of sensor measurements. Also IMU data are widely used for trajectory estimation. However,

2 Related work

3 Data

In the experiment, we used a dataset RuDaCop [1]. The data consists of 1200 of trajectory measurements for different positions of the smartphone (in the hand, in the bag, in the pants pocket). For each object, the readings of an accelerometer, gyroscope, human coordinates in the world reference system, the state of the right and left legs (0 - raised, 1 - on the ground) were taken. When collecting data, the following requirements are met:

1. The trajectories are on flat horizontal surfaces - there are no stairs or significant changes in the height of the landscape.
2. All trajectories are closed. This means that the start point is equal to the finish point. Participants were asked to use a marker to mark the start position, which suggests that the difference in the starting and finishing positions is not more than 5 cm for each legs.
3. The participants only walked, there was no other movement (jumping / running).
4. Participants were not limited in speed.

Пример показаний аксселерометра представлен на изображении 1.

(Здесь надо вставить пример данных какой-нибудь)

4 Problem statement

$$\underset{F_{\text{tr+st}}}{\arg\min}\, \mathcal{L}\left(F_{\text{tr+st}}\left(\mathcal{A}, \mathcal{W}\right), \mathcal{T}, \mathcal{S}\right) \qquad (1)$$

As a loss function, it is proposed to use a combined function $\mathcal{L}\left(F_{\text{tr}}\left(\mathcal{A}, \mathcal{W}\right), \mathcal{T}, \mathcal{S}\right) = = \mathbf{MSE}\left(F_{\text{tr}}\left(\mathcal{A}, \mathcal{W}\right), \mathcal{T}\right) + \mathbf{BCElogloss}\left(F_{\text{st}}\left(\mathcal{A}, \mathcal{W}\right), \mathcal{S}\right)$.

This loss function allows you to train the model in such a way that the regression problem is solved for the real outputs of the model, and classification for the categorical outputs.

5 Algorithm

5.1 Coordinate frames

5.2 Preprocessing

Показания акселерометра и гироскопа нарезаются на перекрывающиеся окошки фиксированной длины. Искомое отображение F_{tr+st} по окошку выдается двумерный вектор - смещение за количество временных отсчетов равных длине окна (скорость человека в данном временном интервале).

$(\mathcal{A}, \mathcal{W}) \subset \mathbb{R}^{\mathcal{T}\times/}$, где T - количество отсчетов (временной показатель), $(a_t, w_t)^T \in \mathbb{R}^6,\ t \in [1..T]$ - вектор, составленный из показаний акселерометра и гироскопа в момент времени t. Для того чтобы получить обучающую выборку, используем скользящее окно шириной w и размером шага s_w. Разобьем ряд $(\mathcal{A}, \mathcal{W}) = \mathcal{X}$ на подпоследовательности $Y_j = \{\mathbf{x_i}, \ldots, \mathbf{x_{i+w-1}}\}$, где $\mathbf{x_i} = (a_x^{(i)}, a_y^{(i)}, a_z^{(i)}, w_x^{(i)}, w_y^{(i)}, w_z^{(i)})$ - одно измерение. Получим множество $Y = \{Y_j, j \in [1..m]\}$, где $m = \frac{T-w}{s_w}$ - количество подпоследовательностей, $i = w(j-1)+1$ - номер измерения, которое является первым в подпоследовательности под номером j. Каждой подпоследовательности $Y_j = \{\mathbf{x_{w(j-1)+1}}, \ldots, \mathbf{x_{wj}}\}$ длины w поставим в соответсвие точку (вектор) $(\mathbf{v_{wj}}, \mathbf{s_{wj}}), \mathbf{v_{wj}} \in \mathbb{R}^2$ - скорость в плоскости движения,, $\mathbf{s_{wj}} \in \{0, 1\}^2$ - метка положения ноги человека (0 - нога движется, 1 - нога покоится, находится на земле. То есть задачу можно сформулировать следующим образом: необходимо обучить нейронную сеть по подпоследовательности длиной w предсказывать скорость и положение ног.

5.3 Architecture

6 Experiments

6.1

6.2 Instant velocity

6.3 Attention mechanism

7 Results

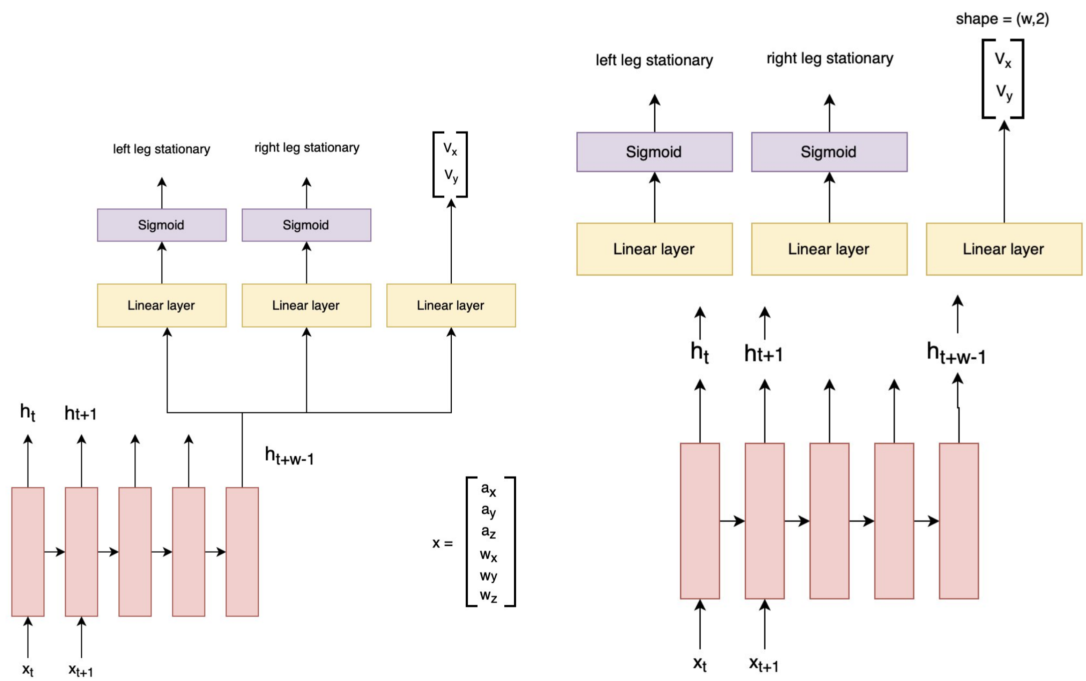
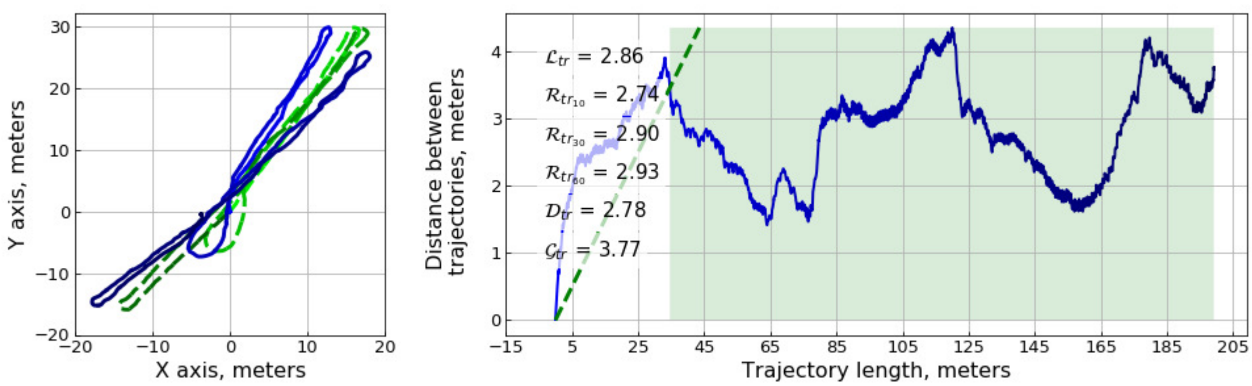


Рис. 1



Литература

[1] Andrey Bayev, Ivan Chistyakov, Alexey Derevyankin, Ilya Gartseev, Alexey Nikulin, and Mikhail Pikhletsky. Rudacop: The dataset for smartphone-based intellectual pedestrian navigation. In *2019 International Conference on Indoor Positioning and Indoor Navigation (IPIN)*, pages 1–8. IEEE, 2019.

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