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SPECIAL ISSUE PAPER

Online handwriting trajectory reconstruction from kinematic sensors using temporal convolutional network

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Abstract
Handwriting with digital pens is a common way to facilitate human–computer interaction through the use of online handwriting (OH) trajectory reconstruction. In this work, we focus on a digital pen equipped with sensors from which one wants to reconstruct the OH trajectory. Such a pen allows to write on any surface and to get the digital trace, which can help learning to write, by writing on paper, and can be useful for many other applications such as collaborative meetings, etc. In this paper, we introduce a novel processing pipeline that maps the sensor signals of the pen to the corresponding OH trajectory. Notably, in order to tackle the difference of sampling rates between the pen and the tablet (which provides ground truth information), our preprocessing pipeline relies on Dynamic Time Warping to align the signals. We introduce a dedicated neural network architecture, inspired by a Temporal Convolutional Network, to reconstruct the online trajectory from the pen sensor signals. Finally, we also present a new benchmark dataset on which our method is evaluated both qualitatively and quantitatively, showing a notable improvement over its most notable competitor.

Keywords Online handwriting · Trajectory reconstruction · Digital pen · Temporal convolutional neural network · Inertial measurement units

1 Introduction

Digital devices can help pupils and teachers in the learning process by promoting active learning techniques and providing immediate feedbacks [26]. The e-learning literature shows that computer-based analysis of handwriting can be really accurate, sensitive, and reliable to produce relevant and consistent feedbacks for correction or guidance. Several pen-based tablet applications have been designed in order to give immediate and personalized feedback to children [13]. Moreover, children still need to learn to write on paper to acquire different sensations because today, it is still by far the most widely used handwriting medium.

As an answer to that need, digital pens have been designed to allow for handwriting on paper while capturing the handwriting gesture. Here, we focus on such kinds of stylus with the goal to reconstructing the digital handwriting trajectory of the pen. The digital pen that we use in this work is the Digipen stylus developed by STABILO, which is equipped of kinematic sensors to track the pen movements.

Nowadays, a wide range of applications in the domain of remote sensing and tracking systems benefits from recent improvements in deep neural network architectures. Tracking systems are commonly based on Inertial Measurement Unit (IMU) due to the low cost of these sensors. However, IMU-based sensors are quite imprecise due to the poor quality of the IMU signals.

IMU sensors are utilized in other fields to recognize pre-defined movements [15, 30] or recreate pedestrian trajectories [6]. More closely related to this work, a wide range of studies have tackled the OH recognition task, which can be successfully accomplished despite the noisy nature of IMU sensor signals.

In this work, we focus on the more challenging task of trajectory reconstruction. Regarding OH recognition, there is one label for a global shape of handwriting. The model

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