Demo Abstract: Continuous Micro Finger Writing Recognition with a Commodity Smartwatch

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Abstract

Input is a significant problem for wearable devices, particularly for head-mounted virtual and augmented reality systems. Contemporary AR/VR systems use in-air gestures or handheld controllers for interactivity. However, mid-air handwriting provides a natural, subtle, and easy-to-use way to input commands and text. In this demo, we propose and investigate ViFin, a new technique for input commands and text entry which tracks continuous micro finger-level writing with a commodity smartwatch through vibrations. Inspired by the recurrent neural aligner and transfer learning, ViFin recognizes continuous finger writing and works across different users and achieves an accuracy of 90% and 91% for recognizing numbers and letters, respectively. Finally, a real-time writing system with two specific applications using AR smartglasses are implemented.

CCS Concepts: • **Computer systems organization** → **Embedded systems**; *wearable devices*; vibration intelligence; • **Text input** → micro finger writing.

Keywords: Micro Finger Writing, Text Input, Wearable Devices, Vibration Intelligence

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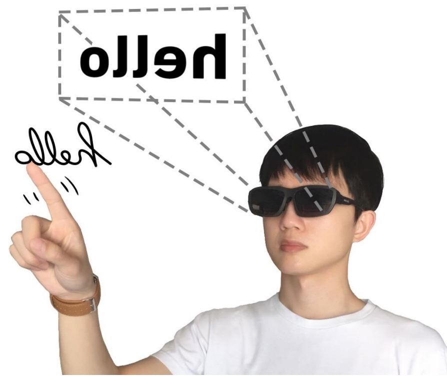

Figure 1. A continuous micro finger writing system

1 Introduction

Wearable devices have grown immensely popular with today's users. As capabilities of wearable devices like smartwatches and head-mounted mixed-reality devices continue expanding, so too does the demand for a subtle, continuous, and unobtrusive way to control the electronics on the go. Today's AR/VR systems rely on either handheld controllers, which have been the primary tool for interactions with artificial worlds, or in-air bare hand gestures which excel at fluid, coarse-grained input. For users to be productive, it is important to have input devices that support continuous tracking which allows fine-grained interactions, such as mid-air hand writing. Mid-air hand writing offers new opportunities for fast, subtle, and always-available interactions, especially on devices with limited input space (e.g., wearables). Similar to writing on a trackpad, using the index finger to interact with the virtual world is a natural method to perform input.

Most common are systems that use worn cameras or depth cameras [4], which are generally accurate at tracking fingers spatially. However, a common weakness across camera-based systems is the inability to detect the finger's micro-level movement or require bulky depth sensors. Additionally, the performance of these computer vision methods is severely affected as the hands move out of the fields of view (FOV) of the cameras. Therefore, most of these systems require users to hold their hands in front of the body for interaction. Finally, being able to track micro-level finger movements is a computational and power-intensive task. Therefore, it requires the headset to have more batteries, making them heavier and limiting their ubiquity. A wide variety of approaches has been considered to enable mid-air hand writing, ranging from using smart rings [3], to wearing gloves or wristbands [1], to using RF waves [2]. However, most of the work requires customized devices, or has coarse-grained hand tracking, or only recognizes static finger gestures.

In this demo, we present ViFin (Vibration Finger), a **continuous fine-grained finger-level** writing method for AR/VR

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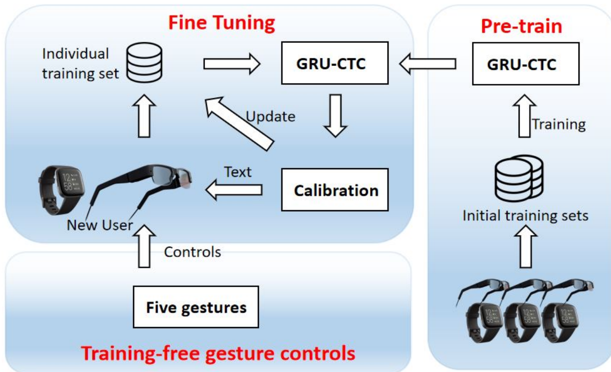

Figure 2. System architecture of ViFin.

interactions using a **commodity** wrist-worn device (as shown in Figure 1). We observe that the micro-finger movement causes vibrations. When users' index fingers write different numbers or letters, the finger produces small, but distinct vibrations, propagating through the hand to the smartwatch. With the IMU in a commodity smartwatch, we can recognize the user's finger writing in the air through finger vibrations. ViFin can detect and recognize the vibration of continuous finger writing. Users can write numbers (0–9) and letters (a–z) with their fingers in the air continuously. Notably, our system requires no cumbersome instrumentation for the hands or fingers, and it works with commodity wrist-worn devices. Additionally, our system works across users with relatively small training and achieves an accuracy of 90% in recognizing numbers and letters through a real-time system evaluation.

2 System Architecture

ViFin is a real-time standalone micro-finger level writing recognition system for AR/VR interaction using vibrations, which are detected by a commodity smartwatch. First, it allows users to write numbers and letters in both discrete and continuous fashion using Gated Recurrent Units (GRU) with an extra connectionist temporal classification (CTC) layer. However, it has two challenges. One is that it requires a user to collect a large amount of training data before using ViFin. Another challenge is that it requires every user to collect training sets because different users write graphemes in a different fashion. In order to reduce the training time and effort required to initialize the system for a new user, ViFin utilizes transfer learning to learn from the common shared features of writing by different users. Nevertheless, with reduced training data, it may happen that a few graphemes are not collected well by users or the accuracy is not good enough for the users. Thus, we design a calibration and update scheme. Unfortunately, a real-time text-input system that only recognizes numbers and letters does not work because it requires extra controls, such as switching input methods between a number and a letter, backspace, enter, etc. Therefore, ViFin also recognizes five training-free gestures: wrist rotation; moving the wrist to the left, right, up and down. ViFin incorporates these five training-free gestures for extra control, which execute in another simultaneous thread on the smart watch. Last, the results are sent to the smartglasses by using the Bluetooth protocol for AR/VR interaction.

Figure 2 is the flow diagram of ViFin. As Figure 2 shows, a group of people collects a large amount of initial training sets for training a pre-trained GRU-CTC model. For a new user, they collect a small, individual training set for fine-tuning the GRU-CTC model. To further improve the accuracy, ViFin has a calibration and update scheme. Inspired by active learning, ViFin allows users to replenish these specific graphemes instead of collecting an entire training set again. Also, to further improve the accuracy and user experience, we add a spell check to correct the written words by Bayesian probability with a dictionary that can be personalized for different text input applications. In another thread, ViFin recognizes five training-free gestures for extra controls, such as "backspace," "enter," etc.

3 Demonstration

We have implemented ViFin as a standalone-application program on a commodity Android ASUS ZenWatch 2 smartwatch, to recognize the continuous micro-finger writing in real-time. Then, the results of finger writing are sent to Madgaze smartglasses. We will demonstrate all of the following. We implemented two applications on the Mad Gaze smartglasses. One of the applications was a movie player. Users were allowed to search for any movie by writing their names using their finger in the air with a smartwatch. During writing, the application displays a list of related movies' names with corresponding numbers. Then users were allowed to choose a movie from a list by writing the corresponding number in order to play the movie. In order to test continuous number writing, we designed another application which allowed user to write and input serial numbers for logistical management. We offered some products with serial numbers and asked users to write using ViFin. In these applications, we use gesture of rotation to wake up ViFin. Once ViFin is awake, rotation means switching the input method between numbers and letters. Also, we use the gesture of left as "backspace" and the gesture of right as "enter." ViFin sleeps if no finger writing is detected within 20 seconds. Finally, we also demonstrate that ViFin works when users are walking and writing at the same time. A demo video of ViFin is available at https://youtu.be/Br1LcEB84XU.

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