Demo Abstract: FingerLite: Finger Gesture Recognition Using Ambient Light

Miao Huang*†, Haihan Duan*†, Yanru Chen†, Yanbing Yang†‡, Jie Hao§ and Liangyin Chen†‡
†College of Computer Science, Sichuan University, Chengdu, China
‡Institute for Industrial Internet Research, Sichuan University, Chengdu, China
§College of Computer Science and Technology, Nanjing University of Aeronautics and Astronautics, Nanjing, China
Email: {yangyanbing, chenliangyin} @scu.edu.cn

***Abstract*—Free hand interaction with devices is a promising trend with the advent of Internet of Things (IoT). The unmodulated ambient light, which can be an exciting modality for interaction, is still deficient in research and practice when most of the efforts in the field of visible light sensing are put into solutions based on modulated light. In this paper, we propose a low-cost ambient light-based system which performs finger gesture recognition in real-time. The system relies on a recurrent neural network (RNN) architecture without complicated pre-processing algorithms for the gesture classification task. The results of experimental evaluation proves that the solution that we put forward achieves a rather high recognition accuracy with our proposed sensor layout across a certain group of users.**

***Index Terms*—visible light sensing, recurrent neural network, finger gesture recognition, ambient light, gestural input, ambient intelligence**

I. Introduction

In the era of the Internet of Things (IoT), utilizing and integrating modalities, such as the prevalent radio frequency (RF), sound and light, to interact with devices is a promising and fascinating vision that will ensure people a more convenient and intelligent lifestyle. The way that people interact with those IoT devices are meant to be diverse and rich in form. Conventional visible light-based communication exploits on LEDs for realizing various applications [1]. For years, however, the ubiquitous ambient light, which does not need any modification to existing lighting fixtures, has not gotten enough attention by researchers compared with other modalities [2].

GestureLite, the system proposed in [3], performs ambient light-enabled hand gestures recognition utilizing K-nearest neighbor (KNN) model in machine learning. Ten gestures are able to be recognized with nine commodity photodiodes (PDs). In [4], the authors built a body gesture recognition system, namely LiGest. By using support vector machine (SVM), also a machine learning model, LiGest distinguishes five gestures and put significant efforts in data pre-processing to realize lighting condition, position and orientation, and user agnostic. In this paper, we propose FingerLite, a cost-efficient finger gesture recognition system utilizing ambient light sensing technology. Compared with the aforementioned systems, FingerLite achieves more fine-grained gesture recognition, i.e. finger gestures, with eight low-cost PDs.

*Both authors contribute equally to this work.

When a hand casts shadow on an array of PDs acting as the sensors, the light intensities sensed by each PD presents a unique pattern under different gestures. And finger gestures are able to be recognized in real-time by trusting deep learning, i.e. recurrent neural network (RNN), with these multi-dimensional data. And a striking improvement in the recognition accuracy can be seen when we change the layout of the PDs into a symmetric trapezoidal shape with a limited number of sensors. An experimental evaluation indicates that FingerLite delivers a good performance with our selected seven finger gestures across various users.

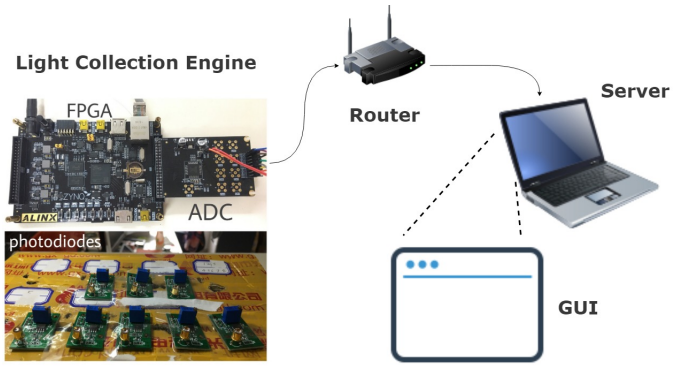

Fig. 1. The system architecture

II. Smart Finger Gesture Recognition System

In this section, a detailed description is given in terms of the system architecture, hardware design, the recognition method and the experimental evaluation and its results.

A. Overview of System Architecture

As is depicted in Fig. 1, the system consists of a light collection engine, a gesture recognition module and a web-based graphical user interface (GUI), which will be further illustrated in Section III.

B. Hardware Design

After trying out a few layout schemes, we finally decided on a symmetric trapezoid shaped by eight Honeywell SD5432-2 PDs depicted in the left bottom of Fig. 1, between which with a 5cm row spacing and a 3cm column spacing. As our system focuses on the finger movement, users are asked to put

their hand at a required position and then make required set of finger movement. And this design helps users to align their hand's position and maximize the sensing capabilities of each PD given the limited number of sensors. The constant incident light of the PDs is then converted into tiny current which is amplified by an LM358 amplifier and turned into readable voltage measurements. The voltage readings are sampled by an eight-channel Analog-Digital Converter (ADC) daughter board (sampling rate 2048Hz) and these sequential data will later be displayed on our GUI and fed to the recognition module. The ADC board is connected to a Field Programmable Gate Arrays (FPGA) board, acting as the encoder and sender of the sampled ambient light measurements. In our prototype, the eight-channel sensed data are transferred via a router through the Ethernet port.

C. Recognition method

At the gesture recognition module, seven finger gestures and a status with no gesture indicated in Fig. 2 are picked out as our pre-defined labels, which are numbered accordingly below, for deep learning-based algorithm based on the observation that these are the most basic hand movements that people interact with physical devices, which can cover the majority of performed gestures in daily life if combined. Specifically, a recurrent neural network (RNN), a deep learning model, is applied in our system to handle the finger gesture recognition task for its capability in processing sequential data [5], the sequential voltage readings in our case. To meet real-time and light-weight requirement, we use only one layer of gated recurrent units (GRU) with 128-dimensional vector for each unit at a sampling rate of 256Hz. We implement the architecture, both through experience and experiments, using Keras with Tensorflow as the backend.

Fig. 2. The Selected Finger Gestures or Status of FingerLite and its Corresponding Labels

D. Experimental Evaluation and Results

The data were collected when four volunteers were recruited to perform the proposed gestures with their right hand locked at a height of 10cm above the collection engine for 100 seconds per gesture, and were then split into training set, validation set and test set with a 60-20-20% ratio. Fig. 3 shows that FingerLite reaches an average accuracy of 99.45% with our test set, even when the size of the users' hand varies from person to person. It is worth mentioning that FingerLite works pretty well with the user's hand at a height of between 5cm and 10cm.

III. Demonstration

For the purpose of live demonstration, a GUI in the form of web page is developed for the users. A user will make

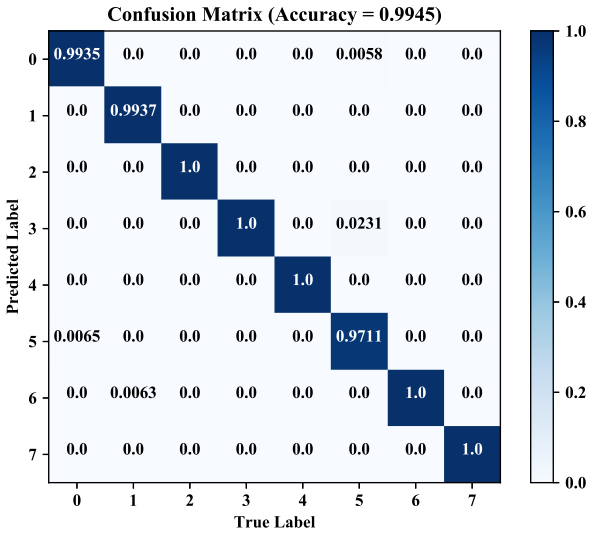

Fig. 3. Confusion Matrix of FingerLite

finger gestures listed in Fig. 2 above the array of sensors. And the real-time voltage measurements of the eight PDs under the gestures will be presented on the web page so that the users have a direct view of what is going on with each of the sensors. The predicted result of the finger gestures produced by the RNN-based recognition module will also be displayed. A preview video for the demonstration is available online at [6].

IV. Conclusion and Future Works

We believe FingerLite that we have proposed in this paper is an excellent demonstration for showing the potential of ambient light-based technology in the application that takes as fine-grained gestural input as finger gestures. Affordable and simple as our system is, the recognition accuracy of our system reaches 99.45%. In the near future, we are planning to integrate the recognition module into the FPGA and thus a more practical and portable system can be engineered. Also, we will work on improving the robustness and reliability of FingerLite under various lighting conditions and for more practical gestures.

References

[1] Y. Yang, J. Hao, J. Luo, and S. J. Pan, "Ceilingsee: Device-free occupancy inference through lighting infrastructure based led sensing," in *2017 IEEE International Conference on Pervasive Computing and Communications (PerCom)*, March 2017, pp. 247–256.

[2] H. Duan, M. Huang, Y. Yang, J. Hao, and L. Chen, "Ambient light based hand gesture recognition enabled by recurrent neural network," *IEEE Access*, vol. 8, pp. 7303–7312, 2020.

[3] M. Kaholokula, "Reusing ambient light to recognize hand gestures," *Dartmouth college*, 2016.

[4] R. H. Venkatnarayan and M. Shahzad, "Gesture Recognition Using Ambient Light," *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies*, vol. 2, no. 1, pp. 1–28, 2018.

[5] Z. C. Lipton, J. Berkowitz, and C. Elkan, "A Critical Review of Recurrent Neural Networks for Sequence Learning," pp. 1–38, 2015. [Online]. Available: http://arxiv.org/abs/1506.00019

[6] https://youtu.be/AiuHjtVlDqA.