Footprint Pressure-Based Personal Recognition

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***Abstract*—In human, footprint pressure is the biometric system. Everyone has specific pressure patterns. It can help doctors diagnose foot-related diseases. Especially in diabetic patients, who have a problem caused by lack of sensation in the foot, they don't feel any pain when they have ulcers at the high-pressure point. In addition, The specific pressure patterns can be used instead of user authentication because the biometric system is more secure than the password-based system. The password-based system cannot verify that the person who entered the password is valid or not. Therefore the specific pressure patterns are the alternative to user authentication or patient classification. For these reasons, it's interesting to use footprint pressure patterns in personal recognition for diagnosing and classification. In this paper, we used the footprint pressure patterns to identify n = 65 subjects with classification rates of 90.56% using convolutional neural network training for deep learning classification.**

***Index Terms*—footprint, foot pressure, biometric, image processing**

I. Introduction

The biometric systems are the task to use individual identity based on differentiating physiological and behavioral features. These features are used for verifying the right and presence such as fingerprint, palmprint, iris, and footprint. These technologies are seen in films. Fingerprint scanning in investigation films based on actual with Central Intelligence Agency (CIA) and Federal Bureau of Investigation (FBI), which has been operating under the name is called Automated Fingerprint Identification System (AFIS). Palmprint is defined as the measurement of the principal line, wrinkles, and ridge feature to recognize the identity of the individual person. However, the line structure feature does not contain the thickness and width information so It cannot identify the different palmprint with similar line structure.

The organs which are an important structure found in many vertebrates are feet. They have necessary functions for loading the body weight and supporting the body's movement. The footprint is occurred by foot pressure when standing or walking.

Foot pressure measurement technologies are a topic of interest during the past decade [1]-[3]. A simple ink impression on the paper is a simple method. It uses permanent mechanical deformation created by a foot on the specialized material. The sample result as shown in Fig. 1. Its disadvantage is the lack of precision. It also cannot find the distinguishing pressure at the different position and this method must require fresh materials in every experiment. Another method is Pedograph instrumentation, a matrix of small pressure sensors distributed over the sensitive areas. This method can show the clearly distinguishing pressure at the different position on the foot. The problem about Pedograph: when using low-resolution sensor (large-sized sensors), the underestimation of pressure occurred which is due to averaging effect resulting in low accuracy. In contrary, when using high-resolution sensors (small-sized sensors), the accuracy is high but the cost of the instrument is very high.

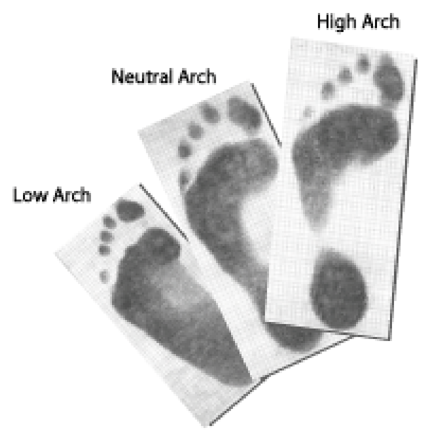

Figure 1. Simple ink impression on a paper.

The optical sensor is an efficient method for foot pressure measurement, which gives a high accuracy, low cost, and suitable for local clinics and small hospitals. This system uses a reflected and scattered light from the light source by the glossy white paper on the sensitive area when the pressure occurred on the system. The sample result of foot pressure from the optical sensor system with 'jet colormap' is shown in Fig. 2, the red area corresponds to the high-pressure area and the blue area corresponds to the low-pressure area.

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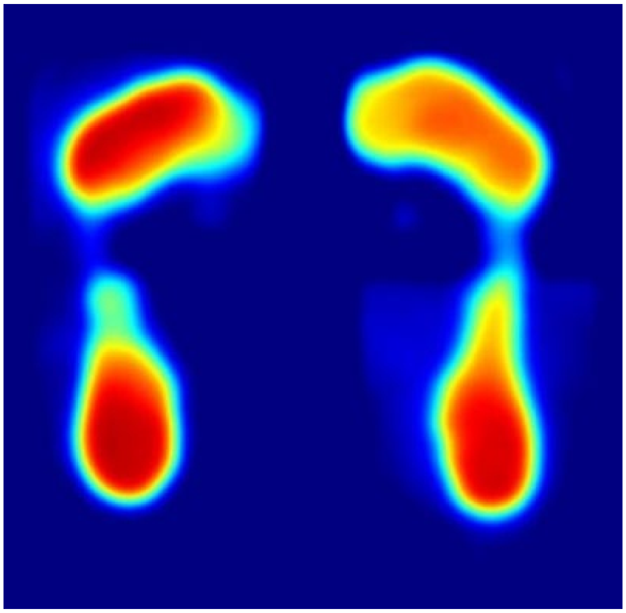

Figure 2. The sample result from the optical sensor system.

II. Methodology

A. Data

Foot pressure data were collected from 40 healthy individuals at King Mongkut's Institute of Technology Ladkrabang (Table I). Data were collected with the optical sensor system [4] at 9 am to 12 am. Each subject performed a total of 3 minutes of standing on the optical sensor system in various postures, a total of 200 images per individual.

TABLE I. Subject Data (Average)

	female	Male
N	24	16
Age (years)	21.6	22.3

B. The Optical Sensor System

The optical sensor system from [4], [5] is used in this paper. This system has 6 main components of the hardware system: the platform, the base, the glossy white paper, the black acrylic box, the led strip, and the four digital cameras. The platform was used for standing, it was made from the transparent acrylic plate (40 cm x 40 cm) thickness 1 cm. The led strip was attached to the sides of the platform and the base was made of steel. On the platform, the glossy white paper was placed and covered with the black acrylic box. The four digital cameras are placed underneath the platform facing upwards. Each pair of the camera was used for each foot.

On standby mode, the display shows the blue screen as background until the system detects foot pressure in color coding like the sample result in Fig. 2. At the points where the foot presses, the air between the glossy white paper and the platform are displaced. Light is reflected and scattered to the digital cameras as shown in Fig. 3. From below, these points were bright then this light was detected by the digital cameras and occurred the foot pressure image. Spots and brightness increase with the amount of pressure.

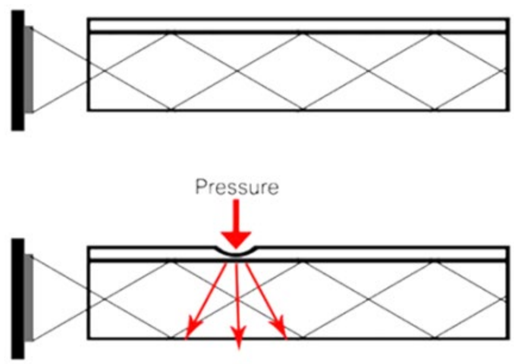

Figure 3. The reflected and scattered light.

C. The Software System

The model of the software system in this paper is developed from [6], [7], it is represented in Fig. 4. It has 4 major sections: footprint pressure image collecting, digital image processing, deep learning, and display the result.

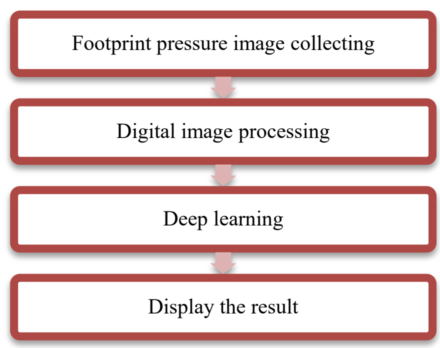

Figure 4. The model of the software system.

1) Footprint pressure image collecting

The first section is footprint pressure image collecting. When the program starts, we type a subject name or number, the folder with a subject name or number was created for collecting the raw image in this section and the resulted image in other section. Then the digital cameras were enabled and the raw footprint pressure images are collected in this folder. These images were used in the next section.

2) Digital image processing

This section is the use of computer algorithms to perform image processing on the raw images. Digital image processing is the practical technology for image recognition, feature extraction, classification and etc. In this paper, the methods which are used for digital image processing include morphological image processing, mean filter, median filter, Gaussian filter, and normalization.

First, the system converts the raw images into grayscale images for use in digital image processing. Next, the grayscale images were performed with digital image processing. The morphological image processing is non-linear operations related to the shape or morphology of features in images [8]. This techniques probe images with a template called a 'structuring element'. The structuring element is positioned at all possible locations in the images and it is compared with the corresponding nearby pixels. 'Closing' is an operator from morphology, closing is ways that tend to enlarge the boundaries of foreground (brightness) regions in images and shrink background holes in such regions.

Mean filter is a simple method of smoothing images, It can reduce the amount of intensity variation between one pixel and the neighboring pixel with a mean (Average). It is used to reduce noise in images. The median filter is normally used to reduce noise in an image too. It can preserve useful detail in the images. Instead of simply replacing the pixel value with the mean, it replaces it with the median of those value. Next method is a Gaussian filter or Gaussian smoothing that used to blur images and remove noise too. Normalization is a process that changes the range of pixel intensity values.

In image processing, normalization is a process that changes the range of pixel intensity values. It is usually to bring the images into a range that is more familiar or normal to the use. In this paper, normalization transforms a grayscale image with intensity values in the range (Min, Max) into a new image with intensity values in the range (newMin, newMax). The linear normalization of a grayscale image is performed according to the equation (1)

$$y = (x - \min)\frac{newMax - newMin}{Max - Min} + newMin \qquad (1)$$

where

x is the intensity value of the original grayscale image.

y is the intensity value of the new image (after normalization).

(Min, Max) is the range of intensity of the original grayscale image

(newMin, newMax) is the range of intensity of the new image (after normalization)

Finally, the grayscale images from the previous step were converted to color coding images with 'jet colormap' for providing better visualization and save the result into the folder with a subject name or number. 'Jet colormap' is represented in Fig. 5, each row in the array contains the red, green and blue intensities for a specific color according to the amount of foot pressure. The intensities are in the range [0,1], *i.e.* the red area corresponds to the high-pressure area and blue area to the low-pressure area.

Figure 5. Jet colormap.

3) Deep learning

Deep learning is part of machine learning methods based on learning data representation. Deep learning models are inspired by information processing and communication patterns in biological nervous systems. It uses a cascade of multiple layers of nonlinear processing units for feature extraction and transformation. This paper uses a simple convolutional neural network for deep learning. Convolutional neural networks (CNNs) were inspired by biological processes in connectivity between neurons. They are essential tools for deep learning and are especially suited for image recognition. The model of convolutional neural networks is represented in Fig. 6.

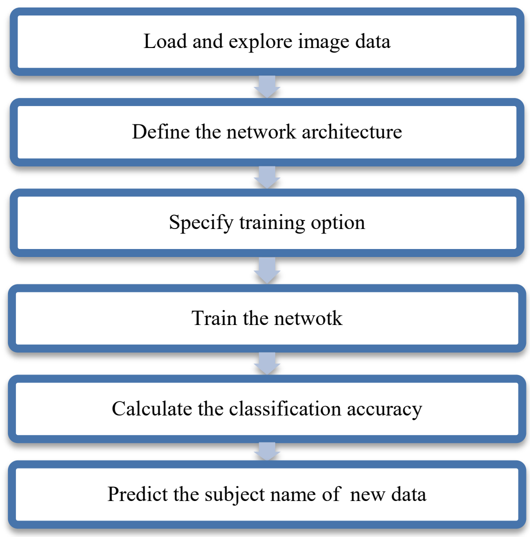

Figure 6. The model of convolutional neural network.

First, the resulted grayscale images (before color coding step) from digital image processing section were loaded in image datastore. The CNNs automatically labels the images based on folder names. The resulted images come from 40 subjects (male: 16 subjects & female 24 subjects) with the optical sensors system, a total of 400 images for each subject. Define the data into training and validation set, In training set contains 750 images for each subject and the validation set contains the remaining images for each subject. Second, we define the convolutional neural network architecture include image input layer, convolutional layer, classification layer, and others. Example, the image input layer is the detail of images which is the height, width, and the channel size. The size of the image is 120*120 pixels (left and right foot in each image) and grayscale images were used in CNNs, so the channel size is 1. Third, After defining the CNNs architecture, we specify the training options such as initial learning rate, the maximum number of epochs. An epoch is a full training cycle on the entire training data set. Fourth, Training the network using the CNNs architecture, the training data, and training options. Fifth, we calculate the validation accuracy by testing the validation data using the trained network.

Accuracy is the fraction of data that the network predicts correctly. Finally, Try the trained network with a new image which is not used in the training and validation set from an old subject.

4) *Display the Result*

The results from the system are displayed on the screen. The result includes the validation accuracy, the random sample results window of footprint pressure images, and the results window for try the trained network with a new image which is not used in the training and validation set. These results are represented in the next chapter 'Results'.

III. RESULTS

The convolutional neural network is trained with the footprint pressure images of 40 subjects and is tested the validation data set using the trained network. This trained network represents 90.56% recognition rate of footprint pressure images.

Footprint pressure images are represented by color coding according to the amount of pressure. The random sample result from 40 subjects is shown in Fig. 7, in each position contains the red, green, and blue intensities for a specific color, i.e. the red area correspond to the high-pressure position and the blue area to the low-pressure area. When we try the trained network with a new image which is not used in the training and validation set from an old subject, the result window is shown in Fig. 8. The window shows the grayscale footprint pressure image and the subject number from classification with the trained network.

Figure 7. The random sample result.

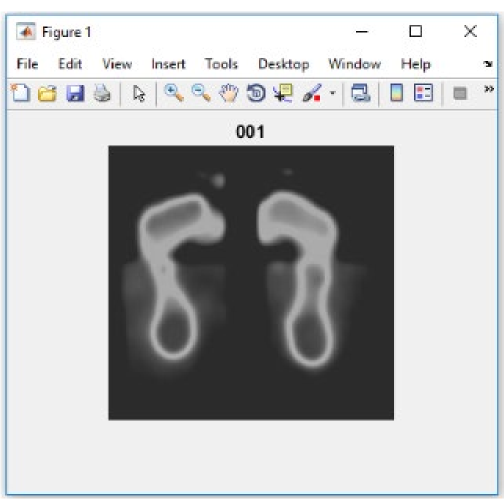

Figure 8. Try the trained network with a new image which is not used in the training and valid ation set from an old subject.

IV. DISSCUSSION

The grayscale footprint pressure images, which is used in the convolutional neural network, were created with digital image processing before the color coding step. The footprint pressure patterns were used in classification for personal recognition because of the inter-subject uniqueness. The limitation of this paper is the system processing time. When we need high accuracy, it is necessary to use a lot of images in each subject, so the system needs to use a long time for digital image processing and data training. In addition, the size of the images is limited too, the size is 120*120 pixels (left and right foot in each image).

V. CONCLUSION

This paper presents the personal recognition from footprint pressure pattern which is the biometric feature in individual identity based on differentiating physiological and behavioral feature. We use the footprint pressure image to identify n = 40 subjects with convolutional neural networks (CNNs), the classification rate of 90.56% was observed. Moreover, this paper includes a personal authentication system for testing new data which is not used in the training and validation set from an old subject. In the future, we expect to increase the system performance with higher accuracy. We will try to increase the number of subject and images for footprint pressure recognition and feature selection based classification [9]. They can increase the efficiency of the personal recognition system.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Chuchart Pintavirooj is responsible for research design, research summary and recommendation. Sarinporn Visitsattapongse contributes for data analysis. Tanapon Keatsamarn's contrition is data analysis and research experiment.

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