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Research Article

Artificial Neural Network Based Image Detection Applied to Foot Massage Machines

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ABSTRACT

For nearly two decades, many massage machine (MM) manufacturers have developed a lot of distinct types of FMM. Common massage goods on the sale are roller and pressing models. However, stimulating all acupuncture points (AP) is extremely hard for distinct sizes of feet accurately. Besides, the massage roller cannot be manipulated all alone. Thence, the author proposed a novel computer vision skillfulness to make out the foot acupuncture points (FAP) by ANN. First, the sole of users' soles is captured and image preprocessing procedures are executed to segment the region of interest (ROI) of soles. FAP is mapped to foot images (FI) to obtain reference massage positions. Afterwards, the YCbCr color space is used to part the brightness to get done the segmentation of the FI in the skin detection. To improve the success rate of image segmentation (IS), ANN is used to train plantar image set. Finally, a FMM was redesigned to raise the rate of ID and user convenience. Experimental results confirm the practicality of the proposed ID method for FMM.

1. Introduction

In 1913, Dr. Fitzgerald proposed the notion of foot reflexology (FR) massage [1]. Foot massage (FM) technology was not valued by the medical profession until the 1970s. Since ancient times, the concept of AP corresponding to body organs has long been adopted in TCM treatment. Therefore, to combine AP with the concept of reflexology, a variety of roller-type and push-type FMM have been circulated on the market.

The rotate-type MM can suit distinct feet, but the rollers are limited in certain massage areas. Moreover, for distinct foot shapes, it is hard to accurately press all AP for the push-type MM. Besides, the massage roller cannot be manipulated all alone. Therefore, how to discover the corresponding AP will be the most problem to be solved in the research of FMM. In 2022, Asma B. etc. proposed a novel prior-shape snake segmentation method for plantar foot thermal images [2]. The proposed method still has certain limitations.

This is the most frequently mentioned FR map during the development of FMM [3] (Fig. 1). I plan to design an FMM, which can give distinct APs corresponding force. However, none of the existing FMM can accurately press all APs. Not only that, all of these machines are designed for adult feet.

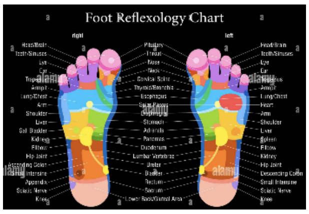

Fig. 1. FR chart [3]

The ANN is used to detect FAP to ameliorate the above problems. First, a camera is used to capture patterns on the bottom of the user's feet. An image preprocessing procedure is performed to segment ROI of the sole. The FAP are mapped onto the FI to obtain the reference position for FM. Not only that, to fulfil the segmentation of the FI, the YC_bC_r color space is used in skin detection to separate the brightness. Finally, ANN is used to train the plantar image set to rise the success rate of IS.

2. Mechanism design

Fig. 2 shows that a portable FMM is re-designed to raise the rate of ID and user convenience. Among them, an

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LCD module can display the location of AP, therapy time, and the related physical message.

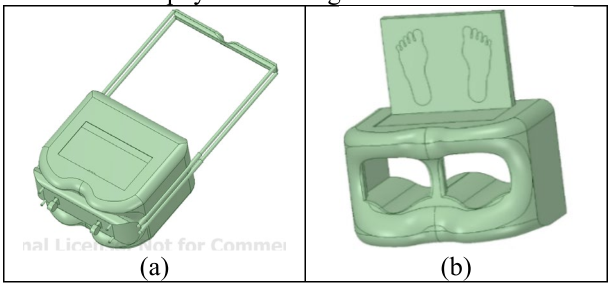


Fig. 2. 3D design diagram for FMM

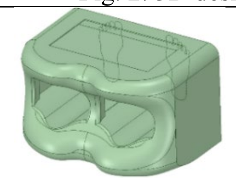


Fig. 3. ankle and foot fixer

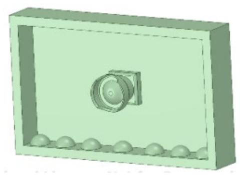


Fig. 4. ID system

The overall design consists of four major institutions: an ankle and foot fixer (Fig. 3), an ID system (Fig. 4), a hardware structure of MM (Fig. 5), and an embedded electronic control equipment.

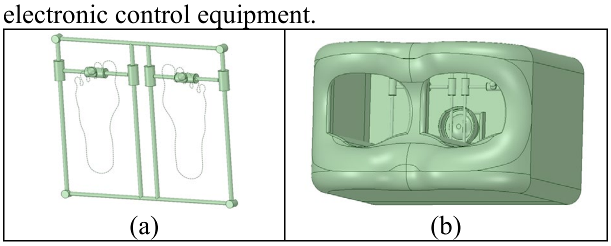


Fig. 5. Hardware structure of MM

The support frame is designed to be used by everyone. Fig. 5(a) shows the percussive massage guns and x-y axis connecting rods, driven by servo motors. The percussive massage guns can reach all FAP by x-y axis connecting rods. The main hardware structure of massaging foot acupoints is shown as Fig. 5(b). Not only that, to bring about the implementation of ID system, some special airbags are used to fix the distinct size feet.

3. AP detection via computer vision

3.1. *FI obtaining and edge detection (ED)*

A 3 by 3 masked convolution operation is used for ED. Data extraction [4] is shown in Fig. 6. In order to reduce the register requirement, the author use the line buffer to fetch row data. In addition, the author regulated the length of line buffer for distinct image size.

I will segment the ROI of the plantar image to reduce computation time. In addition, the edges of the FI need to be calculated to find out the mapping range of AP. Because the FI is curve, the detection results will produce many discrete segments. So here I use Laplacian of Gaussian (LoG) operator to calculate the curves ED.

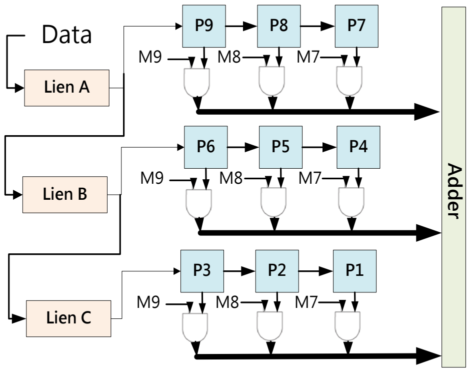


Fig. 6. 3×3 Mask convolution operation

Second-order Laplace function is

$$\nabla^2 L = \frac{\partial^2 L}{\partial x^2} + \frac{\partial^2 L}{\partial y^2} \quad (1)$$

and Gaussian function is

$$G(r) = -e^{\frac{d^2}{2\sigma^2}} \quad (2)$$

where $d^2 = x^2 + y^2$, σ is the standard deviation. LoG operator is as follows.

$$\nabla^2 LoG(r) = -\left[\frac{d^2 - \sigma^2}{\sigma^4}\right] e^{-\frac{d^2}{2\sigma^2}} \quad (3)$$

3.2. *FR IS*

The principal procedure of the FR IS contains color model and brightness compensation. The YC_bC_r color model is used to realize the segmentation of plantar reflexology image [5]. (Y: the brightness, C_b : blue intensity, C_r : red intensity) Furthermore, Zhang [6] proposed an adaptive brightness compensation method considering that most images are still not light-compensated. The modified formula proposed in this paper is as follows.

$$L_c = \frac{H_{std}}{D_{avg}} \quad (4)$$

where

$$H_{std} = \frac{\sum_1^i [max(V_R,V_G,V_B) + min(V_R,V_G,V_B)]}{2 \times j} \quad (5)$$

$$j = i - \sum_1^i (V_R = V_G = V_B = 0)$$

H_{std} varies from image to image. i is represented as the quantity of pixels in the image. j is expressed the quantity of non-black pixels in the image. V_R, V_G and V_B are the red, green, and blue components of the pixel, respectively. D_{avg} is the non-black pixels of V_R, V_G and V_B. In addition, to obtain training data, ANN [7], [8], [9] is used. Fig. 7 shows ANN segmentation process.

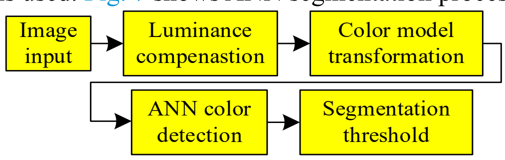


Fig. 7. ANN Segmentation Process.

3.3. *AP detection*

The projective transformation of a 2D plane [10] can be represented by a linear transformation on homogeneous 3-vector represented by the following equation.

$$x' = Px \quad (6)$$

where $x' = [x'_1 \quad x'_2 \quad x'_3]^T$, $x = [x_1 \quad x_2 \quad x_3]^T$ and $P = \begin{bmatrix} p_{11} & p_{12} & p_{13} \\ p_{21} & p_{22} & p_{23} \\ p_{31} & p_{32} & p_{33} \end{bmatrix}$. Let that the corresponding inhomogeneous coordinate of a pair of matching points x and x' on the plane be (x, y) and (x', y'). The projective transformation can be written as shown below. Thus, standard FAP can be mapped to the user's foot soles by Eq. (7).

$$\begin{bmatrix} x'_1 \\ x'_2 \\ x'_3 \end{bmatrix} = \begin{bmatrix} p_{11} & p_{12} & p_{13} \\ p_{21} & p_{22} & p_{23} \\ p_{31} & p_{32} & p_{33} \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = \begin{bmatrix} p_{11}x + p_{12}y + p_{13} \\ p_{21}x + p_{22}y + p_{23} \\ p_{31}x + p_{32}y + p_{33} \end{bmatrix} \quad (7)$$

$$x' = \frac{x'_1}{x'_3} = \frac{p_{11}x+p_{12}y+p_{13}}{p_{31}x+p_{32}y+p_{33}} \quad (8)$$

$$y' = \frac{x'_2}{x'_3} = \frac{p_{21}x+p_{22}y+p_{23}}{p_{31}x+p_{32}y+p_{33}} \quad (9)$$

4. Experimental results

FI is sliced into three mapped areas in this article. The ratio of Range 1, Range 2 and Range 3 was 3.5:3:3.5 (Fig. 8). Range 1, Range 2, and Range 3 cover 12, 7, and 4 main APs, respectively. Fig. 9 shows the results of sobel operator edge enhancement. Fig. 10 shows that RGB monochrome image histogram. In addition, the RGB color mode is converted to the HIS mode, and then displays the images of the three components of the HIS, as shown in Fig. 11.

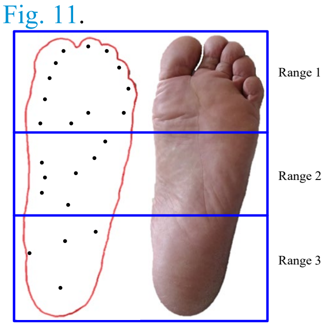


Fig. 8. Mapping area

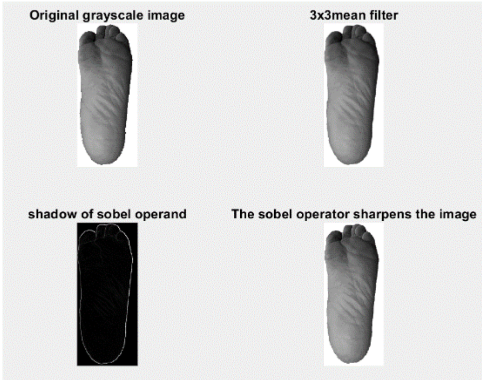


Fig. 9. Results of sobel operator edge enhancement

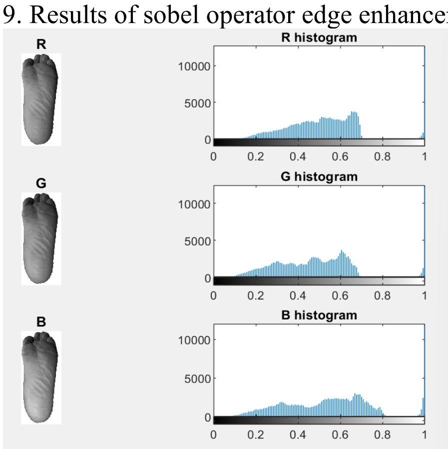


Fig. 10. Results of RGB monochrome image histogram

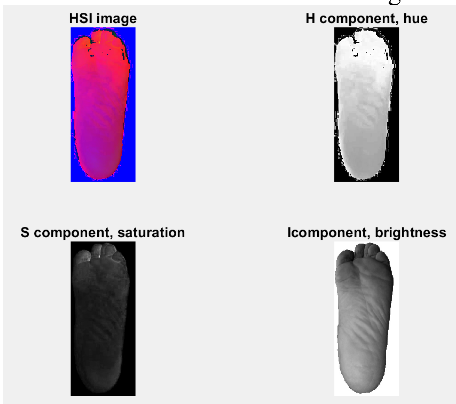
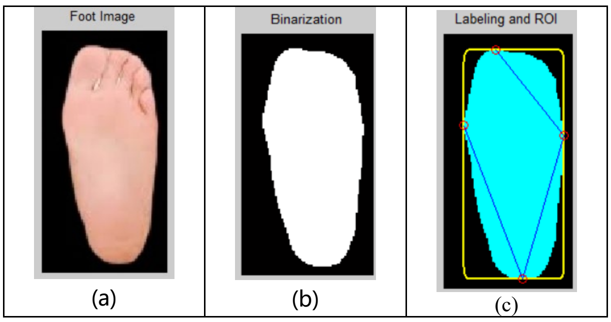


Fig. 11. The images of the three components of the HIS



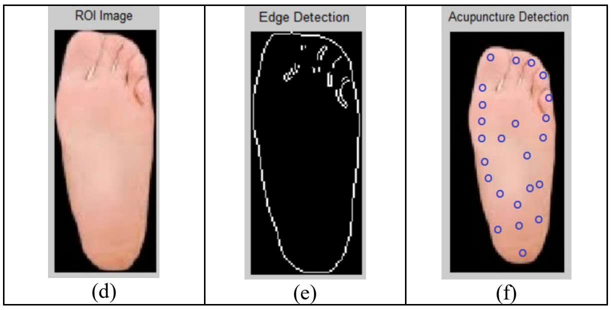


Fig. 12. Consequent of image processing and acupoint mapping

The outcome of image processing and AP mapping is shown as Fig. 12. Fig. 12(b) indicates the skin color segmentation results of ANN. The outcome makes sure that the FI segmentation is distinct.

5. Conclusion

In this article, I proposed an ANN based computer vision technique to identify FR points. A camera is used to capture patterns on the bottom of the user's feet. Besides, I segment ROI of the soles by performing an image preprocessing procedure. The FAP are mapped onto the FI to obtain the reference position for FM. In addition, to fulfil the segmentation of the FI, the YC_bC_r color space is used in skin detection to separate the brightness. Also, in order to improve the success rate of IS, I use ANN to train the plantar image set. Not only that, but a FMM was redesigned to raise the rate of ID and user convenience. The experimental outcome shows that the superiority and practicability of the proposed ID method for FMM. However, the literature [11] shows that neural networks trained by BP are vulnerable to adversarial attacks. Therefore, in the future, the likelihood ratio method, proposed by Jinyang Jiang etc., will be used to improve the success rate of IS and the robustness of ANN under adversarial attacks.

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Authors Introduction

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He is a contract-based professor of Department of Electrical Engineering of National Yunlin University of Science and Technology. His areas of research interest include robotics, image detection, electromechanical integration, innovative inventions, long-term care aids, and application of control theory. He is now a permanent member of Chinese Automatic Control Society (CACS) and Taiwan Society of Robotics (TSR). He is also a member of Robot Artificial Life Society.