

A Multidimensional Human Health State Portrayal System Based on Stress Footprint Images

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Abstract: In recent years, due to the accelerated pace of life and increased life stress, more and more people are stepping into subhealthy state, which has caused widespread concern in the society. This project aims to analyze the footprint stress image, extract some of the footprint characteristic values from it, use the multi-dimensional health indices such as BMI, Broca's formula, body fat percentage to assess the human health level, analyze the user's physical health to output data, including height, weight, BMI, standard weight, body fat percentage, body posture assessment, in order to provide some implications for the field of health detection through footprint pressure images.

Keywords: Human health state, Footprint pressure images, Multidimensional, Footprint features.

1. Introduction

Entering the 21st century, health has become a serious global problem that human beings cannot avoid, and health is increasingly considered a decisive factor for sustainable human development. Nowadays, as the quality of life improves, the proportion of obese people is increasing, and the overweight in China has now reached 22.87%. Nearly one-third of deaths worldwide each year are related to obesity, lack of exercise, and smoking. In today's society, people are gradually paying attention to health issues, and the investment in their own health assessment is also increasing year by year[1]. According to statistics, the number of medical checkups per capita will be 0.48 in 2021, an increase of 18% year-on-year. And there is a growing demand for multidimensional assessment of health status.

In recent years, research on the human footprint has been moving forward. Research on the human footprint has been moving forward, and countries such as the United States,

Japan, the United Kingdom and Canada have conducted a series of studies on footprinting techniques, and all have made some progress[2]. In the field of health, the main focus at home and abroad has been on defining three different foot types (high arched foot, normal foot, flat foot) and the correction of deformed feet as well as the analysis of sports injuries and their treatment, and less on the use of footprint pressure images to portray the health status of the human body.

2. Feature Extraction

2.1. Image pre-processing

This project uses a better flexible array type pressure sensor to collect footprint pressure data. During data collection, the pressure sensor generates pressure data due to the influence of the tester's own gravity, and transmits the pressure data to the computer through the row and column scanning circuits as well as the pressure signal acquisition circuit, and when data collection is complete, the data will be saved in a .txt file according to the format shown in Table 1.

Table 1. Footprint pressure data storage format

Timestamp		Line number
Node number, both 01 (temporarily useless)	Child node number, both 01 (temporarily useless)	The row corresponds to the 80 columns of the pressure value

2.2. Data pre-processing

In order to facilitate the study, the following processes are proposed for the pressure data in this paper: (1) separation of the original data; (2) footprint data filtering.

2.2.1. Separation of raw data

The raw data, i.e., the data stored in the .txt file. The raw data is separated into several frames of footprint pressure data according to the data storage format according to the time stamp, and the size of each frame is 80×80 , where the size of each value represents the pressure value in kPa sensed by the pressure sensor at the corresponding position in 80×80 pressure sensors[3]. The image of the footprint data obtained from the same original data after separation is shown in Figure 1, and the color bar on the right side is the legend of

the color of Jet color space corresponding to the pressure values.

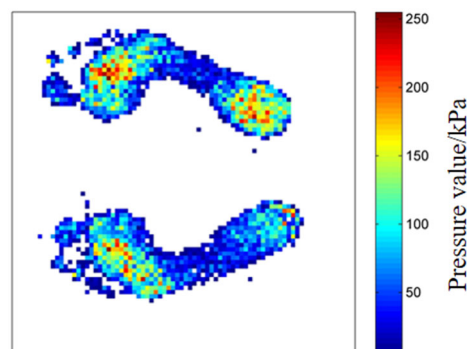


Figure 1. Footprint pressure image

2.2.2. Footprint data filtering

Due to human and hardware factors, the analog-to-digital conversion of pressure sensors, power supply, data lines and other line transmission will generate noise. For these noises, although the PCB in the pressure test board has been designed to minimize the impact, but not completely eliminated. Compare Gaussian filtering, linear filtering, spatial domain filtering and other filtering methods, Gaussian filtering is based on the pixel points to be filtered and the gray value of its domain points, according to the Gaussian formula generated by the parameter rules for weighted averaging, so as to effectively filter out the high-frequency noise superimposed on the ideal image; linear filtering is the use of convolution kernel and the two-dimensional image to be processed, for each pixel point of the image to calculate the product of the neighboring image and the corresponding

$$N8(P) = (x,y+1) \cup (x,y-1) \cup (x-1,y) \cup (x+1,y) \cup (x-1,y+1) \cup (x-1,y-1) \cup (x+1,y+1) \cup (x+1,y-1) \quad (1)$$

$N8(P)$ is the 8-connected region of P , as in Figure 2.

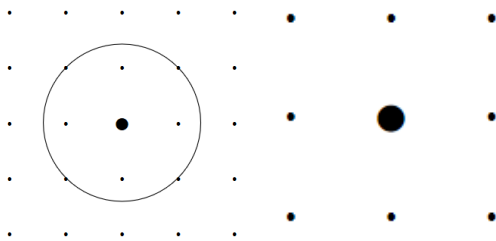


Figure 2. 8 Connected areas

The eight-connected region filtering method is implemented as follows.

S1: finding the connected region C_i of the plantar pressure image using eight connected regions and counting the total number of pressure points S_i in each connected region.

S2: Set a threshold value t . When $S_i \leq t$, the pressure points in the connected region are considered as noise points. Here the empirical value of t is $t=4$.

3. Footprint Basic Features

3.1. Extraction of feature values

In this project, the footprint features actually used are foot length and foot width as well as foot pressure distance, and several feasible methods are proposed below for obtaining these two features

3.1.1. Foot length and foot width

(1) Measurement method I

① Determination of measurement baseline Find out the most prominent point of the backward heel edge of the barefoot footprint and the center point of the second toe (if the second toe does not appear, find out the middle point of the space between the bunion and the third toe) and take the line of the two points as the center line of the barefoot footprint, i.e. the measurement baseline[6].

② The measurement of foot length and foot width determines the most protruding point of the front edge of the longest toe of the footprint and makes the vertical line of the footprint centerline at one point; determines the most protruding point of the rear edge of the heel of the footprint and makes the vertical line of the footprint centerline at another point and measures the distance between the two

element of the matrix and summing to obtain the value of that pixel; spatial domain filtering, on the other hand, is a direct operation on the pixels of the original input image[4]. Since the purpose of footprint pressure data filtering is to eliminate the interference of redundant pressure points, and in view of the characteristics of the footprint pressure data, this experiment decided to use the eight-connected region filtering method with higher applicability and fit to filter the footprint pressure data[5]. The eight-connected region, also called eight-neighborhood, refers to eight positions of a location, such as upper, lower, left, right, upper-left, lower-left, upper-right, lower-right, etc. For each point that is not 0, if there is a point in its eight-connected region whose value is also not 0, then these two points are considered to belong to a region, and its defining equation is Eq. 1.

points as the foot length of the barefoot footprint. The distance between the two parallel lines is the width of the barefoot footprint in Figure 3.

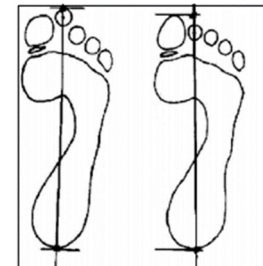


Figure 3. Baseline method

(2) Measurement method II

Take the inner side of the barefoot footprint (i.e., near the thumb side), find the slope of the tangent line at each point of the outer edge, and take the analysis stop point when the rate of change of the slope is 0. Take a moving point A from the stop point to move up along the outer edge at the tangent line, and the tangent line through the point A to do the vertical line and the other side of an intersection point B, if the tangent line at the intersection point is parallel to the tangent line at point A, the distance between AB is the foot width[7]. Do AB line parallel and move up and down until there is no intersection with the footprint, at this time the distance between the two lines is the footprint foot length in Figure 4.



Figure 4. Tangent method

(3) Measurement method III

Take the barefoot footprint to take the barefoot footprint, seek the curvature at each point of the outer edge on both sides, and take the distance between the two foot sides as the foot width at the minimum curvature. Connect the two foot side,

make the line parallel and move up and down until there is no intersection with the footprint, at this time the distance between the two lines is the footprint foot length.

3.1.2. Foot pressure distance

Take the distance from the bunion pressure bump to the heel posterior edge bump as x_1 , the distance from the metatarsal pressure anterior edge bump to the heel pressure posterior edge bump as x_2 , and the distance from the little toe pressure anterior edge bump to the heel pressure posterior edge bump as x_3 ; as the independent variable.

3.2. HOG features

The histogram of orientation gradients feature is a feature descriptor used in computer vision and image processing for object detection[8]. The pressure histogram describes the proportion of different pressure magnitudes in the whole footprint pressure image, reflecting the statistical distribution of pressure in the pressure image, and has the advantage of not being affected by changes in the rotation and translation of the pressure image, so it has considerable generalization ability in classification recognition based on footprint pressure data.

3.2.1. Plantar area of foot f_s

Assuming that p is the pressure point in the footprint pressure image, then f_s is calculated as

$$\begin{cases} n = \sum_{i,j=1}^{80} p(i,j) \neq 0 \\ f_s = \frac{1}{9} \cdot n \end{cases} \quad (2)$$

In the above equation, $p(i, j)$ represents the magnitude of the pressure value at the i -th row and j -th column position in the plantar pressure image, n refers to the total number of non-0 pressure points in the footprint image, and the unit of f_s is cm^2 .

3.2.2. Pressure histogram f_H

In this paper, the magnitude of the pressure value of the footprint pressure image is quantified as 5 to 255 different pressure values, then the definition equation of f_H is

$$h_p = \frac{1}{n} \cdot \sum_{i,j=1}^{80} p(i,j) = k \quad (k = 5, 6, \dots, 255) \quad (3)$$

$$f_H = [h_5, h_6, \dots, h_{255}] \quad (4)$$

Where $k = 5, 6, \dots, 255$. Figure 5 shows the pressure histogram features of different objects, which can be seen that the plantar pressure distribution of different objects is different, so it can be used for object identification and other foot abnormal foot detection.

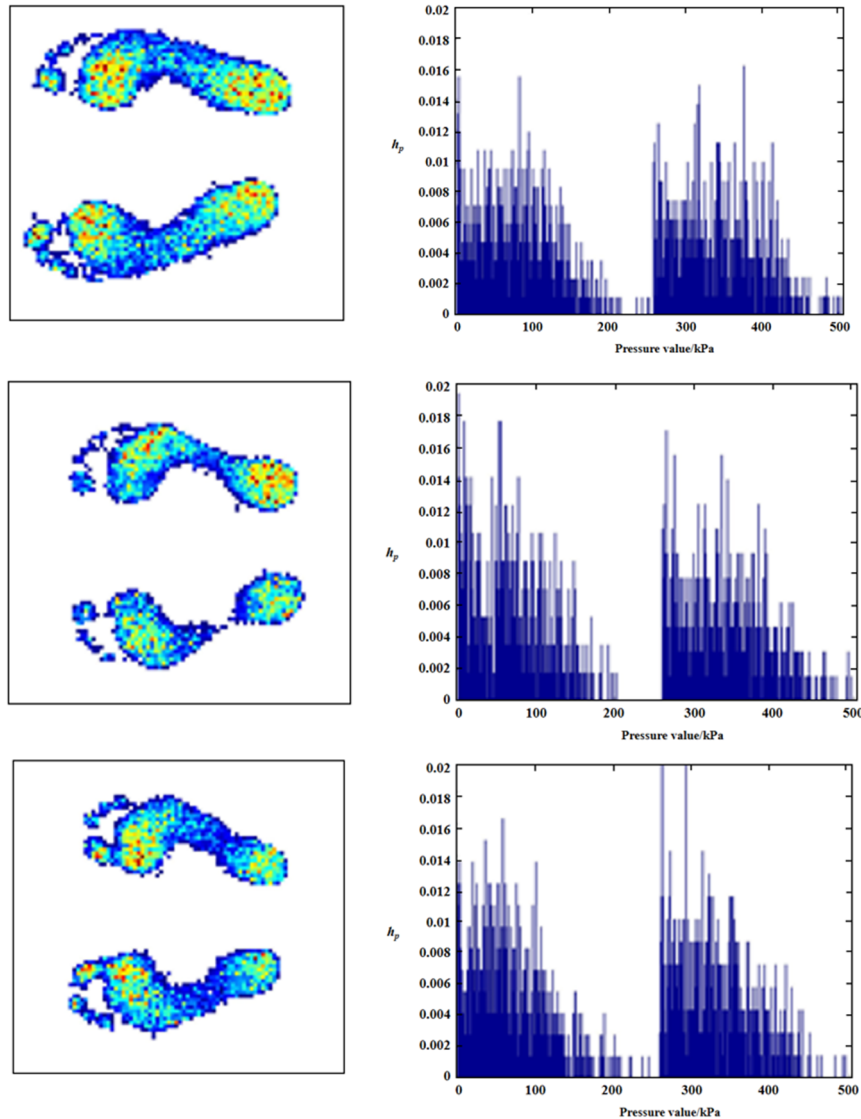


Figure 5. Pressure histogram characteristics

3.3. Speeded-Up Robust Features

Speeded-Up Robust Features (SURF), is a robust algorithm for local feature point detection and description. The current SURF algorithm is an improvement of the Scale Invariant Feature Transformation (SIFT) algorithm, which maintains the excellent performance characteristics of the SIFT operator while solving the shortcomings of high computational complexity and time consuming of SIFT, and improves the execution efficiency of the algorithm, providing the possibility of the algorithm's application in real-time computer vision systems.

4. Parameter Estimation

4.1. Height prediction

On the basis of extracted footprint features: pressure data; foot length f_L ; foot width f_W ; plantar area f_S . The distance from the bunion pressure bump to the heel pressure posterior edge bump l

4.1.1. Prediction of height

Since in the process of growth and development, all parts of the human body have a certain proportional relationship with height, people can predict their height by the proportional relationship between foot length and height.

4.1.2. Construction of regression model

Construct the prediction model based on the predictor variables.

4.1.3. Construction of user figure model

Use the model to estimate the continuous or ranked values of the given inputs. If the accuracy of the model is considered acceptable, plus he can be used to predict variables with unknown class labels.

(1) The first method

$$4H = \text{foot length} \times 4 + 68 \text{ cm} + \text{foot length} \times 5.5 + 32.5 \text{ cm} + \text{foot length} \times 7.3 \text{ cm} + 242.2 \text{ cm} - 2.56 \times \text{foot length} = \text{foot length} \times 13.94 + 339.7 \text{ cm} \quad (5)$$

Therefore,

$$H = (f_L \times 13.94 + 339.7 \text{ cm}) \div 4 \quad (6)$$

where the foot length is the measured parameter f_L .

(2) The second way

The distance from the bunion pressure bump to the heel posterior edge bump is x_1 , the distance from the metatarsal pressure anterior edge bump to the heel posterior edge bump is x_2 , the distance from the little toe pressure anterior edge bump to the heel posterior edge bump is x_3 , and the height is y then

$$y = 89.163 + 1.992x_1 + 0.825x_2 + 0.911x_3 \quad (7)$$

4.2. Weight estimation

Weight calculation: "Pressure method"

The data information is obtained through a pressure test plate, which consists of 3×3 pressure sensors per cm^2 evenly distributed, for a total of 80×80 pressure sensors[9]. When collecting data, the pressure sensors generate pressure data due to the influence of the tester's gravity and transmit the pressure data to the computer through the row and column scanning circuits as well as the pressure signal acquisition

circuit. At the end of data collection, the data is saved in a .txt file according to a certain format. In the .txt file the pressure value of each sensor is stored, because each sensor has an area of s with sensors $1, 2, 3, \dots, i, \dots, 6400$, and its pressure is $P_1, P_2, P_3, \dots, P_i, \dots, P_{6400}$, so its pressure value is:

$$F_i = P_i \cdot S = F_1, F_2, F_3, \dots, F_i, \dots, F_{6400} \quad (8)$$

Then the weight definition equation is

$$\text{Body weight (G)} = \text{total pressure} = \frac{\sum_{i=1}^{6400} (F_i)}{s \sum_{i=1}^{6400} (P_i)} \quad (9)$$

where the unit of G is Kg.

5. User Profiling

5.1. Foot characteristics and health assessment

In recent years, due to the accelerated pace of life and increased life stress, more and more people are stepping into a subhealthy state, which has caused widespread concern in the society. This project aims to extract some of the footprint feature values from the footprint stress images by analyzing them, and assess the human health level using multi-dimensional health indices such as BMI, Broca's formula, and body fat percentage.

The height and weight data obtained from the footprint feature estimation have been obtained in the early stage of the project, from which the BMI (obesity degree calculation) of the tested person's body can be calculated, where

$$BIM = \frac{G}{H^2} = \frac{4S \sum_{i=1}^{6400} (P_i)}{(f_L \times 13.94 + 339.4)} \quad (10)$$

Where S is the area of each sensor, P_i is the pressure of each sensor, and f_L is the foot length.

Body fat percentage is the proportion of body fat weight in the total body weight, also known as body fat percentage, which reflects the amount of body fat in the human body[10]. In the assessment of human health, fat is always one of the core elements. The body fat percentage allows further analysis of the body's health status at this time.

By processing height and weight, it is also possible to obtain the Broca Index, which has been modified for Asian people by Kyoto University in Japan, and this can be used as a description of the health status of the body to show a more intuitive picture of the health status of the individual and be used for health assessment.

5.2. Broca formula

For those under 165 cm: standard weight (kg) = height (cm) - 100

For people above 165 cm: standard weight (kg) = height (cm) - 110

Based on the Broca formula, Professor Katsura of Kyoto University in Japan proposed the following formula.

$$\text{Standard weight (kg)} = [\text{height (cm)} - 100] \times 0.9$$

Since this paper mainly focuses on Asian groups, the second set of Broca's formula is chosen.

Body fat percentage = $1.2 \cdot \text{bmi} + 0.23 \cdot \text{age} - 5.4 - 10.8 \cdot \text{sex}$ (1 for men, 0 for women)

The user's physical health is analyzed by BMI, Broca's formula and body fat percentage, and the data is outputted,

including height, weight, BMI, standard weight, body fat percentage and body posture assessment.

6. Data Processing and Presentation

The previously extracted foot symmetry is inputted into the computer, fitted in the computer, the most appropriate model is selected, the data is calculated, and the processed data is then presented to the user in a clear and understandable manner through the cell phone application.

7. Propose Future Development

Establish a long-term tracking project. Based on the existing database, we compare the user's data with the current database of perfect body shape, and give the user certain suggestions to help him correct his body shape.

It is also possible for the user to freely select the existing data in the database and use it as a template for the project to make relevant suggestions to help the user reach his or her goals.

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