Journal of Information Science and Technology
JIST Journal of Information Science and Technology
Volume 11, NO 1 | JAN – JUN 2021 | 75-82
ISSN: 2651-1053 (Online)
ISSN: 1906-9553 (Print)

# Foot Arch Posture Classification using Image Processing

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Received: February 28, 2021; Revised: May 26, 2021; Accepted: May 27, 2021; Published: June 25, 2021

**ABSTRACT – The foot arch is a key role in supporting the weight of the body and providing propulsion force during push-off, it enables a more natural and aesthetic gait and protects the foot from injury. An effective way to prevent injuries caused by abnormal foot arches is to use suitable personalized insoles. Personalized insoles can reduce and relieve the pain that caused by abnormal of the foot arches, which can be difficult to make for each particular type. Current methods of analyzing foot arches are manual calculation, which is time consuming and prone to human error. Therefore, the objective of this study is to classify foot arches posture and determine different foot arch types based on the foot scan image by develop an application to improve the analysis of personalized insole. As the result, our foot arch type classification gives the satisfied result at 87.5% comparing to the data classified by expert.**

**KEYWORDS:** Image Processing, Foot Arch, Information Technology, Arch Index, Personalized insole

## 1. Introduction

Foot posture is an important component of musculoskeletal assessment in clinical practice and research. One reason is that foot helps humans maintain and relocate their center of gravity; foot posture alignment also related to how the body weight is distributed so that humans can balance their stability. The abnormal feet might introduce health issues such as walking performance or posture maintaining.

An effective way to prevent any injuries caused by abnormal foot arches is to use suitable personalized insoles so that it would perfectly fit each particular type. However, current methods of analyzing foot arch type involve X-ray and getting the image from Presscam analysis tool and then manually identify the foot arch type, which is time-consuming and prone to human errors. It causes the unpopularity of personalized insoles. Based on this, we then propose to develop a system called *Foot Arch Posture Classification using Image Processing (FAP)* to improve the analysis of personalized insole. This system will accept an image from Presscam analysis tool and automatically classify the foot arch type. This will ease insole producers to classify foot arch type for each individual efficiently. An example of an image from Presscam analysis tool is shown in Figure 1. Note that an image from Presscam analysis tool will be called as *foot pressure image* in this paper.

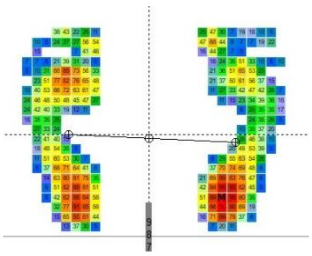

*Figure 1. An example of an image from Presscam analysis tool*

## 2. Background and Related Work

In this section, we provide the background and related works.

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## 2.1 Foot type classification

On the average, there are 2.2% of population that suffer from the abnormally of foot [1]. Their related symptoms are associated with poor health outcomes, and more likely chance to occur when the ages increase [2].

To better understand the problem, a foot type can be classified into three categories shown in Figure 2. The first, the normal foot type or neutrally aligned foot (Figure 2a), contains the characteristic of balancing between the horizontal forefoot and a calcaneus.

The second, cavus foot (Figure 2b), also known as high arches (per cavus) is a condition where the bend in the middle of the foot is abnormally high. When a person with cavus foot type is walking or standstill, their weight highly presses on the ball and heel of their feet. With this, standing for a long time might affect the balance and can cause the sprained ankle [3].

The last, low feet or flat feet (Figure 2c) is where there is no arch in the foot and the whole sole touches the ground. This type of foot is quite common in children because their bones are still developing. However, for the adult, flat feet can cause the lower back and knee pain as their foot cannot absorb the impact while walking. It can also affect the uneven distribution of body weight which, in the long run, can result in shoes wearing down unevenly or more quickly than usual, especially on one side and may cause the further injuries [4].

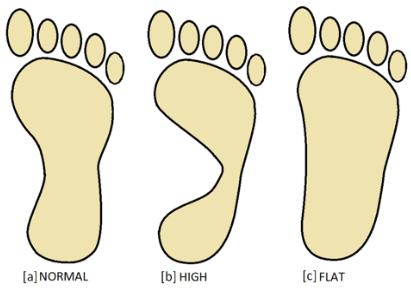



*Figure 2. Foot Arch Types consist of (a) normal foot, (b) cavus foot or high arch foot, and (c) flat foot*

To analyze the foot type traditionally, the clinical protocols in [5] stated the use of the navicular height and the arch index. The navicular height can be obtained by measure from the supported surface to the navicular tuberosity, which is located at the side of the foot. In [6], they use the sided X-ray image to perform the flat feet classification. However, our study is focus on using the foot pressure image for classification. Thus, it is more suitable to use the arch index measurement; in the next subsection, we explained the process of calculating the arch index.

## 2.2 The arch index calculation

The arch index lies in the area of the middle third of the footprint. Thus, the foot area is divided into 3 equal parts; the arch index is calculated by using the ratio of the middle third of the footprint to the entire footprint area (excluding the toes). Based on [7] and [8], the final arch index can be calculated using Equation 1.

$$Arch\ index\ (AI) = \frac{B}{(A+B+C)}$$

*Equation 1 Arch Index Calculation*

where A, B, and C are the area of parts of foot as shown in Figure 3.

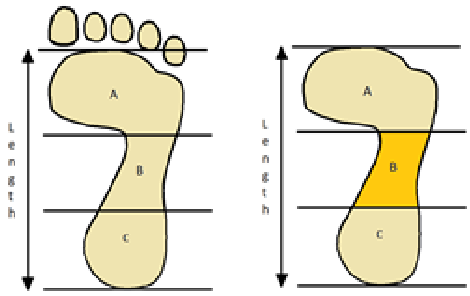



*Figure 3. Area A, B, and C for calculating of the arch index value*

Finally, a range of the arch index scores can have a range from 0 to 0.39. With the mean 0.24, median 0.24 and standard deviation (SD) 0.06, they can be categorized into 3 groups as shown in Table 1.

*Table 1. Foot Arch Type and Arch Index*

| Foot Arch Type | Arch Index |
|---|---|
| High | < 0.21 |
| Normal | [0.21,0.28] |
| Flat | > 0.28 |

The arch index of normal type (± 1 SD from the mean) is 0.21 to 0.28, high type (< 1 SD) is lower than 0.21, and flat type (> 1 SD) is more than 0.28 [7,8].

Therefore, we plan to design a system that would calculate the arch index scores from given input image then interpret the foot type with only the provided information.

# 3. System and Design

In this section, we describe the detail of our system *FAP* and design. Firstly, we acquired an input image data as foot pressure image from Presscam analysis tool. The user stood on SIDAS Foot Scanner (Figure 4a). After that, the obtained plantar surface of the foot transferred to the Presscam analysis tool

(Figure 4b) and the foot pressure image is retrieved.

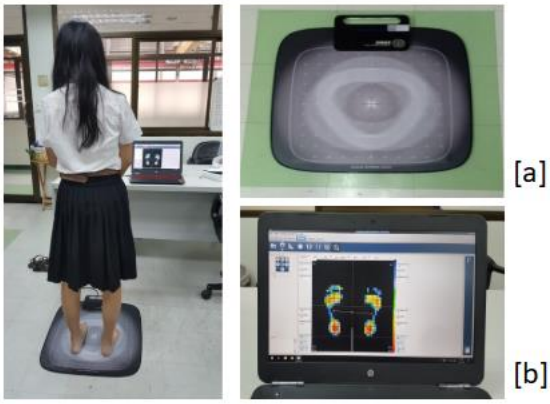
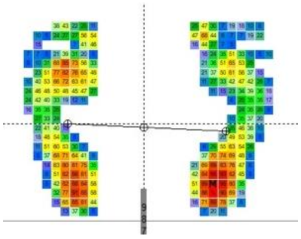
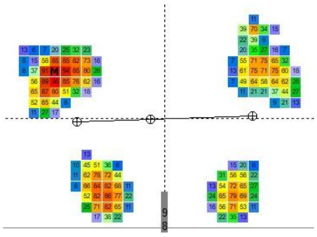



*Figure 4. The data was obtained using: (a) SIDAS Foot Scanner and (b) Presscam analysis tool*

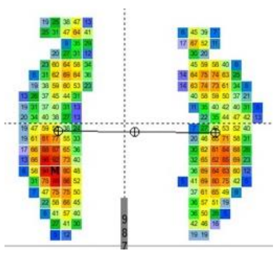
The foot pressure images as shown in Figure 5 were collected as our dataset. There were 100 foot pressure images scanned by SIDAS Foot Scanner. It can be considered that each foot pressure image has 2 sides of foot (left and right). Therefore, there were 200 individual scan images in total, which had a mix of 3-foot types, which were normal (93), high (84), and flat foot (23).



[a] Normal



[b] High



[c] Flat

*Figure 5. Examples of Foot Pressure Image for each Foor Arch Type*

As can be seen in Figure 5, the color in the image is the level of pressure, when a person stands on SIDAS Foot Scanner. Basically, the level is ordered from blue, violet, light violet, green, light green, yellow, dark yellow, orange, and red as low to high respectively. The foot arch type of each image in our dataset has been labelled by experts from Thailand National Metal and Materials Technology Center (MTEC).

As stated earlier, due to the time consuming and prone to human errors caused by manual calculation, personalized insoles are not widely available in the market. Facing this challenge, we propose an approach to classify the foot arch types using image processing.

FAP System has two main modules: User Interaction and Classification by Foot Arch Index. The structure chart is in Figure 6.

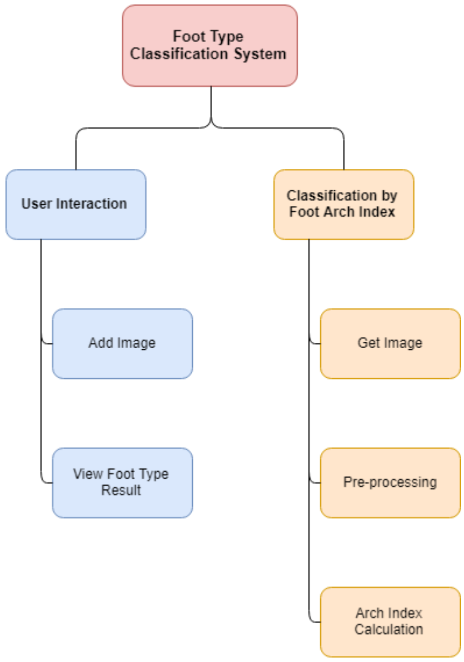



*Figure 6. Structure Chart of FAP System*

The description of each module of FAP System is described as followed:

1. User Interaction: provides for all users to access to FAP System, which can interact by two modules: Add Image and View Foot Type.
    a. Image Adding: allows users to add an image of a foot pressure image or a set of images that users want to classify its foot type.
    b. View Foot Type Result: allows users to view the foot type as an output of the system.
2. Foot Arch index: performs classification of FAP System.

a. Image Getting: allows the system to retrieve the input or foot scan image for the classification by foot arch index.
b. Pre-processing: applies a method for suppressing unwanted information of the input or foot scan image before forwarding to find the arch index.
c. Arch Index Calculation: calculates the arch index value and classify the foot type based on the foot arch index method.

FAP System consists of three main components, which are the web application, web server and the classification module. The reason we select web application technology is due to their popularity and flexibility across platforms.

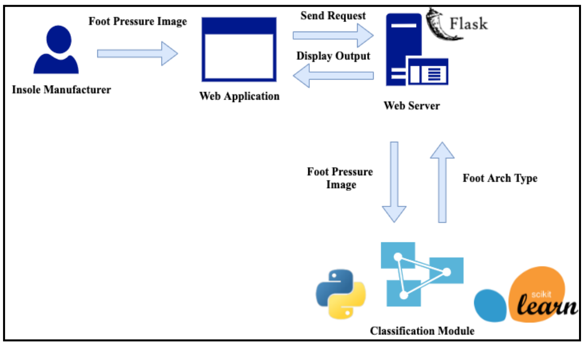



*Figure 7. System Architecture of FAP System*

The system architecture shown in Figure 7, represents the process of FAP System. Firstly, the user or insole manufacturer can upload the foot pressure image to our web application. Then, the application sends a request for connecting to the web server. Once connected, it submits foot pressure image to the classification module.

Next, once the classification module receives a foot pressure image, it performs the foot arch type classification. The process is to classify the foot type of a foot pressure image and send the result (foot type) back to the web server. Then, the output displays on the application.

The system architecture of the classification module (shown in Figure 8) represents how the model proceeds the classification with the input (foot pressure image). Firstly, it receives the image and performs the pre-processing to adjust the distortions on the image file. Then, it calculates the arch index based on the pre-processed image. Finally, the arch index value defined in Table 1to classify the foot arch type.

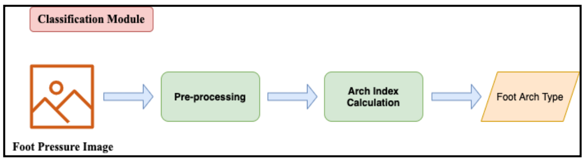



*Figure 8. System Architecture of Classification Module*

## 4. Implementation

In this section, we explain the process of implementing our application. According to the structure chart in Figure 6. Users can make use of the web interface as shown in Figure 9to upload their image and view the result.

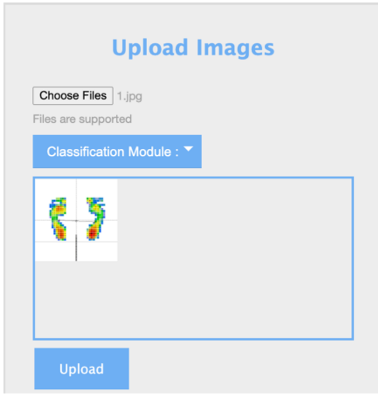



*Figure 9. Upload image page*

Once the user uploads the foot image, the next process is to classify the foot type. For the classification module, our implementation is based on web technology and Python [9]. According to the system architecture of the classification module, as shown in Figure 8, the processes are as followed. In the following explanation, the image in Figure 10 will be used.

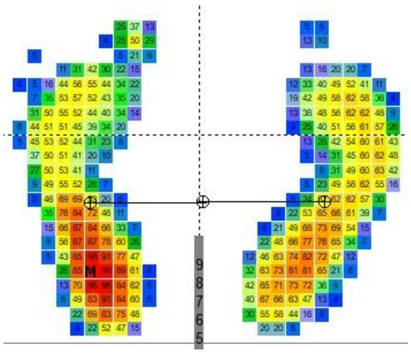


*Figure 10. An example of Foot Pressure Image for Explanation*

Firstly, the classification module receives an image from the user, then it applies the Python program to find the arch index. An image that is accepted by this system is RGB image.

The steps of pre-processing are as follows. In the beginning, the RGB input image is converted into the grayscale using scikit-image[1] library in Python as shown in Figure 11.

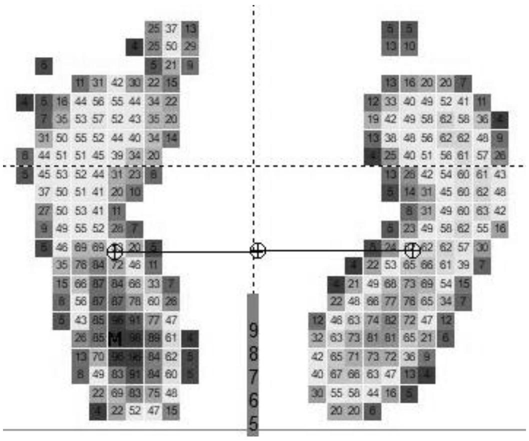


*Figure 11. Grayscale image of Figure 10*

Next, as can be seen in the grayscale image, there are square blocks (see Figure 12). To find the area of foot, the number of pixels can be used instead. Therefore, we convert this image to binary image by mapping each square block to 1 pixel. The size of each square block is 12 x 12 pixels. In order to map each square block to 1 pixel in binary image, the average of color value of a square block is used. The notion is that if the average color value of a square block is close to 0, it will be black. Otherwise, it will be white. The result of this process is shown in Figure 13. The size of the binary image is 40 x 40 pixels.

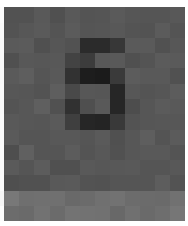


*Figure 12. Square Block*

The next process is to remove the toe parts from the binary image$I$. To do that, we first counting the numbers of black pixels in each line, horizontally and vertically, and collect them as a set of$I_h$ and $I_v$.

The actual width and height of the given foot, $w$ and $h$, are defined using the maximum values of elements within the set of $I_h$ and $I_v$, respectively.

With this, we perform the toe removal process by searching through the set of$I_h$.We then discard any componentsthatcontain values less than a half of the foot width or $w/2$; weassume that the toe would not likely be wider than a half of its corresponding foot.

Note that to avoid removing the arch area, we apply a similar assumption and limit the search by one-fourth of the foot height or $h/4$.

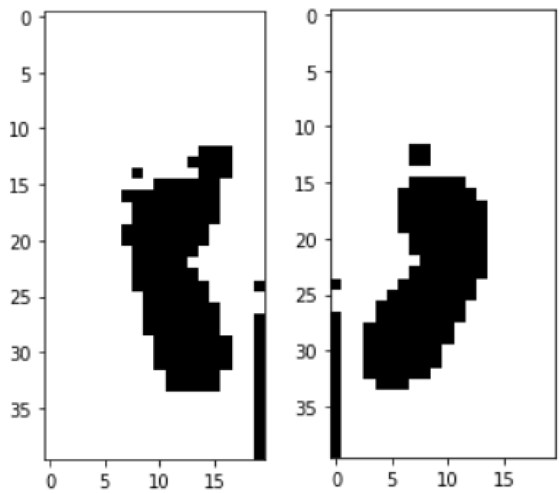


*Figure 13. Binary Image*

After that, the result (Figure 14) is the input for the next process, which is the arch index calculation. To do that, the method we use is as explained in the section of the arch index calculation.

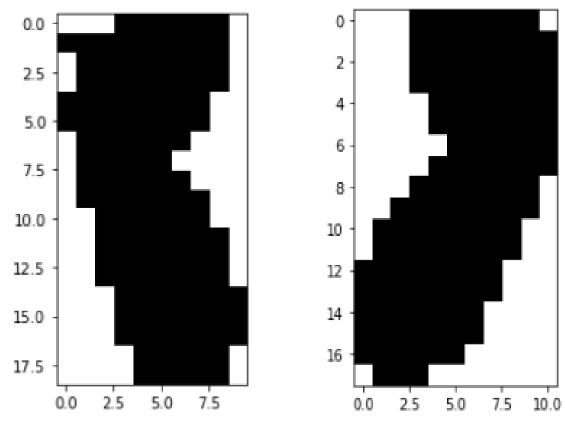
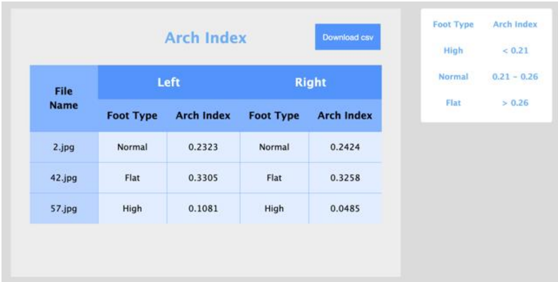


*Figure 14. An image after removing the toe*

Finally, we would use the arch index to interpret the foot type to be high, normal, and flat foot. This result display for the user via our web application interface through the connection of Flask [10] implementation as shown in Figure 15.

[1] https://scikit-image.org/docs/dev/auto_examples/color_exposure/plot_rgb_to_gray.html



Arch Index

Download csv

| File Name | Left | | Right | |
|---|---|---|---|---|
| | Foot Type | Arch Index | Foot Type | Arch Index |
| 2.jpg | Normal | 0.2323 | Normal | 0.2424 |
| 42.jpg | Flat | 0.3305 | Flat | 0.3258 |
| 57.jpg | High | 0.1081 | High | 0.0485 |

| Foot Type | Arch Index |
|---|---|
| High | < 0.21 |
| Normal | 0.21 – 0.26 |
| Flat | > 0.26 |

*Figure 15. Arch index and foot arch types of result*

# 5. Experiment and Discussion

In this section, the detail of the experiment and analysis are presented.

## 5.1 Experiment Description

The input data that we used to calculated and classified foot type were 100 pairs of foot pressure images dataset or 200 feet images in total. They came from the Presscam analysis tool. The dataset consists of 3 foot types as high, normal and flat as shown in Figure 4. The images that we use is in JPEG format with resolution 500 x 500 pixels. To evaluate our system, we conducted our experiment based on 3 types of processed data those are the sets of arch index value from pre-labeled values and our results (It is called Thresholding).

These pre-labeled values were given by the experts are divided into two sets. For the first set of data, the experts had the process of modified the number of rows of squares in images (It is called Labeled by expert) before the calculation, and they had not done for the second set (It is called Labeled by expert (New)). In the end, we conducted 3 experiments to compare between these Labeled by expert, Labeled by expert (New) and our Thresholding data. More details will be discussed later.

The reason behind the stated process of modification is due to the human error nature when doing the classification. To be more precise, when the human would like to calculate the arch index from the foot pressure image (see Figure 5). They need to divide the foot image into 3 parts as required by the method of calculation discussed before. To make the process easier, they would try to adjust the original input by increasing and decreasing the number of rows of squares. For example, if an image has 20 rows, for humans, we will increase the number of rows to 21 so that it would be easier to divide into 3 parts. However, this might lead to the error of calculation.

With this, it can be counted as the advantage of using our system as, unlike humans, the machine will not conduct things based on their convenience. Thus, our system does not need to increase or decrease the row and just use the pixel level of images to calculate the arch index.

To gain more understanding, Figure 16shows the example of the foot pressure image, which has 19 rows of square block in total, which is the foot area. Based on this, the human might decrease the number of rows from 19 to 18 so that the 3-parts division process will be easier. By using the original number of rows, the arch index of the left and right foot is both 0.28, which means that both sides of feet are flat foot. However, if we decrease the number of rows, the arch index of left and right foot will be shifted to 0.26 and 0.27 respectively, and this reflects a normal foot for both cases. Thus, that is why modifying the number of rows of squares in images can lead to the wrong arch type.

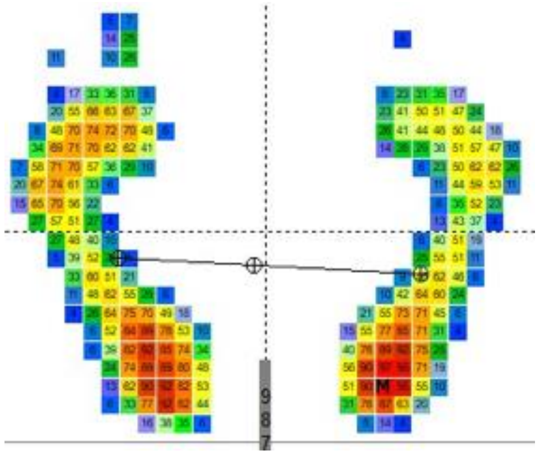


*Figure 16. Example case where the image cannot be divided by 3*

For our approach, FAP will divide 19 by 3, which is equal to 6.33. As can be seen, it is not possible to get 6.33 pixels. FAP will calculate part A, B, and C (see Figure 3) by rounding the pixel up and sharing the pixels that in the middle of A and B or B and C. For example, in this case, the row of pixel of A is 1 – 7, B is 7 – 13, C is 13 – 19.

Thus, we set up experiments to compare the results based on these assumptions. All results presented in this section have been conducted on a 64bit Dual-Core Intel Core 5 dual 2.5GHz machine, with 4GB of RAM under Windows 10. We use Python 2.7 and Flask 1.0.2.

## 5.2 Experiment Results and Discussion

As stated before, we have used the Labeled by expert, Labeled by expert (New) and Thresholding data. We presented the experimental results by using scatter plot with a linear line, where each data point represents each foot image input, each x-axis and y-axis represents the calculation of the Thresholding and Labeled by expert, respectively. Figure 17and Figure 18show the arch index value from the right and left foot.

The result shows that the correctness of our program comparing to data Labeled by the expert on both sides of the foot is 77%. This low number caused by the human nature of increasing and decreasing the number of rows for calculation as stated before.


*Figure 17. Comparison of **right** foot Arch Index Data between labeled by expert with modifying the number of rows and calculating by using a program*

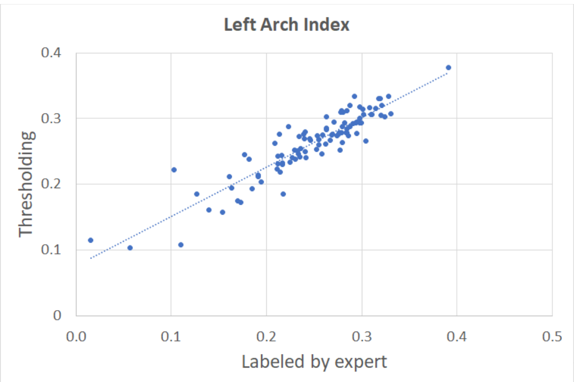



*Figure 18. Comparison of **left** foot Arch Index Data between labeled by expert with modifying the number of rows and calculating by using a program*

Therefore, after discussing these problems with the experts, they admitted that the arch index calculation by modifying the number of rows of squares in images was due to human error. Then, they agreed to change the way of calculating the footprint area by using the exact number of rows of squares to calculate the arch index and classify foot arch type as Labeled by expert (New) data.

This leads to the second experiment. The results are shown in Figure 19andFigure 20. These figures show that the correctness of Labeled by expert data is only 84.5% comparing to Labeled by expert (New) data. This is because, as mentioned, if the number of rows of squares in images is modified, this may lead to wrong arch index value and type.

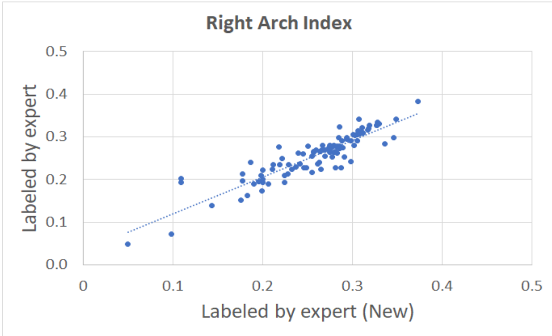



*Figure 19. Comparison between **right** foot Arch Index Data between labeled by expert with modifying the number of rows and **right** foot Arch Index Data labeled by expert without modifying the number of rows*

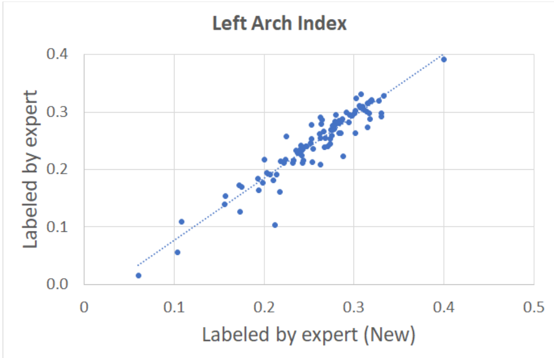



*Figure 20. Comparison between **left** foot Arch Index Data between labeled by expert with modifying the number of rows and **left** foot Arch Index Data labeled by expert without modifying the number of rows*

Finally, we conduct the third experiment to compare between Labeled by expert (New) data and FAP data. The results are shown in Figure 17 and Figure 18. As we can see, the correctness of FAP compared to the one labeled by the expert (New) is 87.5%, which is better than the first and second experiment. In addition, if we observe these scatter plot, it can be seen that the data points are very close to the linear line for both foot sides.

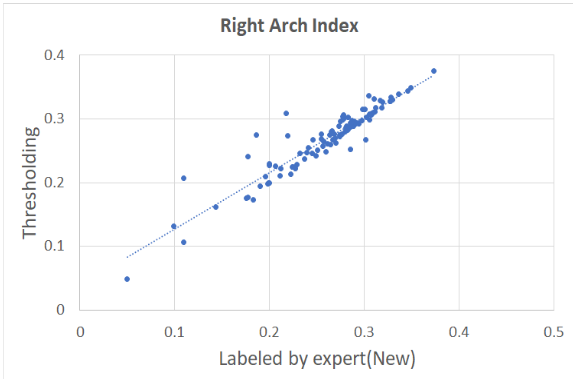



*Figure 21. Comparison of **right** foot Arch Index Data between labeled by expert without modifying the number of rows and calculating by using FAP*

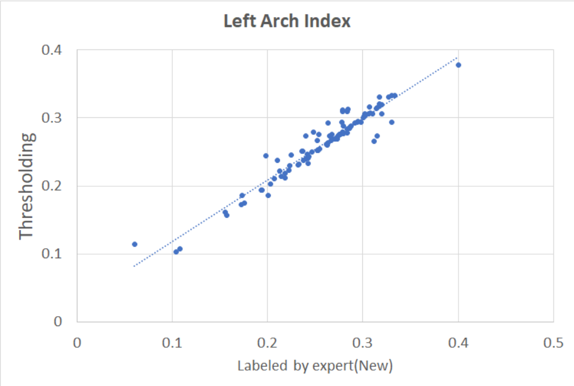



*Figure 22. Comparison of **left** foot Arch Index Data between labeled by expert without modifying the number of rows and calculating by using FAP*

Therefore, it is evidently important that modifying the number of rows of squares in images is necessary to be re-considered since this is a factor of the errors in manual classifying foot arch types. On the other hand, FAP can increase the accuracy of classification when the number of rows of squares in images is not modified and decrease the human error and classification time since our program calculates arch index at the pixel level of images. In addition to this, for the classification time, it is clearly seen that our approach spends less time the manual calculation by humans.

## 6. Conclusion

In the process of creating the personalized insole, it requires the knowledge of the foot arch index which can lead to the prediction of foot type: high, normal, and flat. However, the manual method can cause time-consuming and human errors. Effectively, the reasons for using our proposed approach have been driven by two factors. Firstly, it can reduce human error, especially from fatigued, and improve accuracy of calculation process. Secondly, the classification can be performed in short periods and lead to overall time reduction.

In the experimental result, we observe the actual problem of human errors by their adding or removing the number of rows from the original inputs and this can be a cause of wrong calculation. However, our system does not have the same problem and our results support that statement.

However, there are some limitations to our approach. For example, the thresholding method may not remove toes in some cases. Therefore, to improve the performance of our approach and finding a better way of classifying foot arch types, we aim for applying Machine Learning to extract parameter by a foot feature using different algorithms and analyzing data in the perspective of correctness, high performance and effectiveness.

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