Footprint classifier by means of digital image

Clasificador de huellas plantares mediante imagen digital

LAZARO, David†*, LOPEZ, Marlene, HERRERA, Carlos, SANTIAGO, Raúl, PADILLA, Alfredo and PINAL, Francisco

Tecnológico Nacional de México, Instituto Tecnológico de Celaya
Departamento de Maestría en Ciencias en Ingeniería Electrónica. Campus I, Antonio García Cubas Pte #600 esq. Av. Tecnológico. Celaya, Gto. México

ID 1st Author: David, Lazaro / ORC ID: 0000-0002-8645-1528, CVU CONACYT ID: 859636

ID 1st Coauthor: Marlene, Lopez / ORC ID: 0000-0002-4294-2560, CVU CONACYT ID: 866095

ID 2nd Coauthor: Carlos, Herrera / ORC ID: 0000-0003-4293-623X, CVU CONACYT ID: 217055

ID 3st Coauthor: Raúl, Santiago

ID 4th Coauthor: Alfredo, Padilla / ORC ID: 0000-0002-1642-7274, CVU CONACYT ID: 30188

ID 5th Coauthor: Francisco, Pinal / ORC ID: 0000-0002-6116-6464

DOI: 10.35429/JSTA.2019.16.5.6.11Received July 10, 2019; Accepted September 12, 2019

Abstract

Flat foot and cavus foot are two types of foot that can cause health problems at an advanced age. These types of foot may change because they evolve with age. Due to this, it is possible to correct the flat and cavus foot. Footprints can be used in order to detect these types of foot. This paper presents the development of a digital podoscope which, with the help of software, can generate a prognosis classification (cavus, normal or flat). The podoscope consisted of a glass supported by a metal frame with a camera at the bottom and lighting on the sides. The software consisted of a user interface developed with Visual Studio and image processing with MATLAB. The feet of 51 children of age range between 6 and 12 years were classified in an approximate time of 1 hour and a half over four days. The estimated time of each standing classification was approximately 1.5 minutes.

Podoscope, Classification, Foot, Arc Index

Resumen

El pie plano y el pie cavo son dos tipos de pie que pueden causar problemas de salud a una edad avanzada. Estos tipos de pie pueden cambiar porque evolucionan con la edad. Debido a esto, es posible corregir el pie plano y el pie cavo. Las huellas se pueden usar para detectar este tipo de pie. Este artículo presenta el desarrollo de un podoscopio digital que, con la ayuda del software, puede generar una clasificación de pronóstico (cavus, normal o plano). El podoscopio consistía en un vidrio sostenido por un marco de metal con una cámara en la parte inferior e iluminación en los costados. El software consistía en una interfaz de usuario desarrollada con Visual Studio y procesamiento de imágenes con MATLAB. Los pies de 51 niños de edades comprendidas entre 6 y 12 años se clasificaron en un tiempo aproximado de 1 hora y media durante cuatro días. El tiempo estimado de cada clasificación de pie fue de aproximadamente 1,5 minutos.

Podoscopio, Clasificación, Pie, Índice de arco

Citation: LAZARO, David, LOPEZ, Marlene, HERRERA, Carlos, SANTIAGO, Raúl, PADILLA, Alfredo and PINAL, Francisco. Footprint classifier by means of digital image. Journal of Scientific and Technical Applications. 2019, 5-16: 6-11

* Correspondence to Author (email: ml703084@itcelaya.edu.mx)
† Researcher contributing first author.

Introduction

In the literature there are reported classifications of the foot as: cavus foot, normal foot or flat foot. The detection of flat and cavus foot is of great importance since these can lead to health problems such as: flat foot is related to a lower quality of life in adults (Pita-Fernandez et al., 2017), since the force generated by a flat foot towards the ground is less than that generated by people with normal foot (Boozari, Jamshidi, Sanjari, & Jafari, 2013). There is also a correlation between medial tendon dysfunction and flat foot (Herráiz Hidalgo et al., 2014). Finally, there is an increased risk of ankle injury (Levinger et al., 2010). On the other hand, the cavus foot is related to lower weight of patients (Woźniacka, Bac, Matusik, Szczygiał, & Ciszek, 2013). This type of foot can lead to a major complication such as the cavovarus foot.

The detection of these types of feet should be done at an early age because the foot evolves in ages between six and seventeen years (Stavlas, Grivas, Michas, Vasiliadis, & Polyzois, 2005).

There are different techniques to detect flat and cavus feet, the most expensive include three-dimensional x-rays, scanners and pressure sensors (H. W. Chang et al., 2012; Razeghi & Batt, 2002). Other techniques classify them according to the footprint. Among these techniques are the Chippaux-Smirak index, the Stahelli index, the Hernández-Corvo index, the Clark angle, the arc index, among others (Diéguez et al., 2011; Onodera et al., 2008).

As for the equipment, there are several models of podoscopes on the market. Among them is the PODO'LINE fluorescent podoscope (Figure 1a), which consists of a crystal and a mirror to observe the patient's footprint. Likewise, there are digital ones such as the DS-SCANN2D-ANALYZ which works as a scanner (Figure 1b); however, all these devices only deliver images of the footprint. These podoscopes have the disadvantage of needing a specialist to make an interpretation of the images shown.

Figure 1 Commercial podoscopes

Source: <http://www.medicaexpo.es/fabricante-medical/podoscopio-1684.html>

Image processing allows for the creation of a podoscope that, apart from capturing the image, is able to issue a preliminary diagnosis without the need of a specialist. This device would facilitate mass analysis for the general population. It should be noted that this analysis would be preliminary, so that when detecting an anomaly, the patient is informed and can go with a specialist for a thorough analysis and obtain an adequate treatment.

For the reasons stated above, this paper proposes a podoscope capable of making a preliminary diagnosis based on the calculation of the arc index. The proposed device uses image processing to provide a pre-diagnosis of cavus and flat foot abnormalities in approximately two minutes.

Methodology

The equipment presented in this text consists of a glass supported by a metal frame and a camera at the bottom which captures the image. On the sides of the glass there are LEDs to illuminate the contact area between the patient's footprint and the glass (Figure 2). On the other hand, an application was designed with Visual Studio for image capture; while image processing is done with the MATLAB software.

The glass where the patient's feet are placed is a 12 mm thick glass capable of supporting weights of up to 90 kg. The camera is a Logitech webcam model C920, which has a maximum resolution of 15 Mpx. For this study, a resolution of 1600 x 1200 pixels was used. The lighting consists of LEDs and is controlled via software with the Arduino UNO board which works in conjunction with a voltage control card designed specifically for this purpose according to the block diagram of Figure 3.

Figure 2 Built podoscope

Figure 3 Card block diagram

Figure 4 shows how the entire system interacts. The control of the podoscope is performed by the computer which has a two-way connection to the camera, while the Arduino simply receives orders from the computer through UART communication. The Arduino receives instructions that processes to generate a PWM signal. The voltage control card receives the PWM signal and with a low-pass filter converts it to a DC voltage in a range between 0 and 12V to power the LEDs. The function of this card is to control the closed loop voltage in such a way that no matter how many LEDs are connected to the card, the card will maintain a constant voltage.

Figure 4 Block diagram of electronic components

The Arduino was programmed according to the diagram shown in Figure 5. The program consists of three states: INITIAL, CONFIGURE and SAMPLE. In the initial state, it generates a PWM signal with a work cycle equal to zero, i.e. a logical zero, this is so that the LEDs turn off when it is in this state. From the INITIAL state it can go to any of the other two and return. When it is set to CONFIGURE, it receives via serial the PWM work cycle to be generated and saves it. This works as a preview to see the position of the patient’s feet before and during the sampling, in addition to monitoring the light intensity. When it returns to the INITIAL state, it saves the data of the work cycle. When it is in SAMPLE, it generates a PWM with the previously saved work cycle. When generating the PWM signal, the conditioning card converts it to a DC voltage and sends it to the LEDs in order to light them with the necessary intensity. After the camera captures the requested images, the Arduino returns to the INITIAL state.

Figure 5 Arduino program diagram

The user interface was made with Visual Studio 8 (Figure 6). With the help of this interface, the user can choose the intensity of the illumination in a range of 0% to 100%; likewise, it is possible to observe the footprint in real time. The interface has 3 buttons: CONNECT, SAMPLE and CONFIGURE, a text box, and a slider. The CONNECT button starts serial communication with the Arduino. If the Arduino is not connected, sampling will not be possible. The SAMPLE button sends the signal to the Arduino to turn on the LEDs and take 10 samples from each patient. The CONFIGURE button shows the slider to choose the intensity of the LEDs and sends the Arduino to the configure state. The text box serves to enter the name with which the samples will be saved; if a sample with that name already exists it will send an error message.

Figure 6 User interface

For the classification, the arc index technique was used, as it is one of the most reliable reported in the literature (Aruntammanak, Aunhathaweesup, Wongseree, Leelasantitham, & Kiattisin, 2013; Banwell, Paris, Mackintosh, & Williams, 2018). All image processing and mathematical operations were performed in MatLab.

The arc index (AI) is obtained by dividing the footprint into three areas (Figure 7) of the same height without considering the toes, where A, is the upper part of the footprint where the metatarsal of the foot is found; B is the part of the middle of the foot where the arch is located; and C is the part of the retro foot where the heel of the foot is located. Subsequently, the area B is divided by the sum of the total area of the footprint (Equation 1). If $AI < 0.21$, the foot is cavus; if $0.21 \leq AI \leq 0.26$, the foot is normal; and if the $AI > 0.26$, the foot is flat (Diéguez et al., 2011).

$$IA = \frac{B}{A+B+C} \quad (1)$$

Before calculating the arc index, it is necessary to apply processing to the original image, for this purpose, the following steps were performed:

1. The original image was binarized (Figure 8a) to obtain the footprint.
2. The image was cleaned to eliminate noise.
3. Toe prints were removed.
4. Then the left footprint and the right footprint were separated (Figure 8b).
5. The images were aligned on their major axis (Figure 8c).
6. Finally, the index was calculated and classified.
7. The resulting images were saved in folders according to their classification.

Figure 7 Lines to calculate the arc index
Source: (Diéguez et al., 2011)(Figure 3)

The podoscope tests were performed at Mariano Matamoros Elementary School. Parental consent was requested to take pictures of the children's footprints. The images were acquired during the Physical Education class whereby all the children had sports uniform.

The footprints of 60 children were taken. 9 were ruled out for the following causes: 2 female students with tights, 1 male with problems to stand up and 6 male students whose footprints were not clear enough for processing. The footprints of 26 males and 25 females between 6 and 12 years old were classified. The tests lasted approximately 1 hour and a half over 4 days. The classification of each child's footprints lasted approximately 1.5 minutes.

Figure 8 Patient's footprint images

Results

The general analysis of the footprints showed 53.9% classified as flat feet, 25.4% as normal feet and 20.7% as cavus. For male children 61.5% of the feet were classified as flat feet, 26.9% as normal feet and 11.6% as cavus. As for the female, 46% of the feet were classified as flat feet, 24% as normal feet and 30% as cavus. One case of a child was also observed, who presented a flat foot and the other cavus. This only represents 4% of the total population. On the other hand, it is more common for them to have problems on one foot, that is, while one foot is classified as normal, the other foot is classified as flat or cavus. Of these cases, there were 4 males and 8 females, which represents 23.4% of the total population analyzed.

The percentages of flat foot occurrence resemble studies previously reported in the literature ((C. H. Chang et al., 2014; Chen et al., 2011)).

Conclusions

The device showed good efficiency when taking the footprint and sorting it in a short time. The types of feet that can generate problems in advanced ages such as cavus and flat feet, represented a percentage of 74.7% of the total footprints analyzed, which indicates that these types of foot are very common at an early age; therefore, this type of technology should be implemented nationwide in primary schools for the early diagnosis of flat and cavus feet. In this way, greater attention would be encouraged at an early age and could be corrected in time to avoid the discomforts that can be generated at an advanced age.

Acknowledgments

We thank the staff, parents and students of Mariano Matamoros Elementary School for their participation in device testing.

We thank the National Council of Science and Technology (CONACYT) for providing the necessary financial resources to carry out this project.

We also thank the National Technological Institute of Mexico Instituto Tecnológico de Celaya for providing the knowledge and facilities necessary for the implementation of the device.

References

- Aruntammanak, W., Aunhathaweessup, Y., Wongseree, W., Leelasantitham, A., & Kiattisin, S. (2013). Diagnose flat foot from foot print image based on neural network. In BMEiCON 2013 - 6th Biomedical Engineering International Conference. <https://doi.org/10.1109/BMEiCon.2013.6687684>
- Banwell, H. A., Paris, M. E., Mackintosh, S., & Williams, C. M. (2018). Paediatric flexible flat foot: How are we measuring it and are we getting it right? A systematic review. *Journal of Foot and Ankle Research*, 11(1), 1–13. <https://doi.org/10.1186/s13047-018-0264-3>

- Boozari, S., Jamshidi, A. A., Sanjari, M. A., & Jafari, H. (2013). Effect of Functional Fatigue on Vertical Ground-Reaction Force in Individuals with Flat Feet. *Journal of Sport Rehabilitation*, 22(3), 177–183. <https://doi.org/10.1123/jsr.22.3.177>
- Chang, C. H., Chen, Y. C., Yang, W. T., Ho, P. C., Hwang, A. W., Chen, C. H., ... Chang, L. W. (2014). Flatfoot diagnosis by a unique bimodal distribution of footprint index in children. *PLoS ONE*, 9(12), 1–11. <https://doi.org/10.1371/journal.pone.0115808>
- Chang, H. W., Lin, C. J., Kuo, L. C., Tsai, M. J., Chieh, H. F., & Su, F. C. (2012). Three-dimensional measurement of foot arch in preschool children. *BioMedical Engineering Online*, 11. <https://doi.org/10.1186/1475-925X-11-76>
- Chen, K. C., Yeh, C. J., Kuo, J. F., Hsieh, C. L., Yang, S. F., & Wang, C. H. (2011). Footprint analysis of flatfoot in preschool-aged children. *European Journal of Pediatrics*, 170(5), 611–617. <https://doi.org/10.1007/s00431-010-1330-4>
- Diéguez, S. L., Jesús, A., Sánchez, L., Luisa, M., Sánchez, Z., & Martínez-lópez, E. J. (2011). Análisis de los diferentes métodos de evaluación de la huella plantar. *Retos. Nuevas Tendencias En Educación Física, Deporte y Recreación*, 19(Figura 1), 49–53. Retrieved from http://www.retos.org/numero_19/RETOS_19_49-53.pdf
- Herráiz Hidalgo, L., Arranz, J. C., Rodríguez, M. R., de la Peña, M. J., Alonso, R. C., Moreno, E. Á., & de Vega Fernández, V. M. (2014). Posterior tibial tendon dysfunction: What other structures are involved in the development of acquired adult flat foot? *Radiología (English Edition)*, 56(3), 247–256. <https://doi.org/10.1016/j.rxeng.2014.05.001>
- Levinger, P., Murley, G. S., Barton, C. J., Cotchett, M. P., McSweeney, S. R., & Menz, H. B. (2010). A comparison of foot kinematics in people with normal- and flat-arched feet using the Oxford Foot Model. *Gait and Posture*, 32(4), 519–523. <https://doi.org/10.1016/j.gaitpost.2010.07.013>
- Onodera, A. N., Sacco, I. C. N., Morioka, E. H., Souza, P. S., Sá, M. R. de, & Amadio, A. C. (2008). What is the best method for child longitudinal plantar arch assessment and when does arch maturation occur? *Foot*, 18(3), 142–149. <https://doi.org/10.1016/j.foot.2008.03.003>
- Pita-Fernandez, S., Gonzalez-Martin, C., Alonso-Tajes, F., Seoane-Pillado, T., Pertega-Diaz, S., Perez-Garcia, S., ... Balboa-Barreiro, V. (2017). Flat Foot in a Random Population and its Impact on Quality of Life and Functionality. *Journal of Clinical and Diagnostic Research : JCDR*. <https://doi.org/10.7860/JCDR/2017/24362.9697>
- Razeghi, M., & Batt, M. E. (2002). Foot type classification: a critical review of current methods. *Gait & Posture*, 15(3), 282–291. [https://doi.org/10.1016/S0966-6362\(01\)00151-5](https://doi.org/10.1016/S0966-6362(01)00151-5)
- Stavlas, P., Grivas, T. B., Michas, C., Vasiliadis, E., & Polyzois, V. (2005). The evolution of foot morphology in children between 6 and 17 years of age: A cross-sectional study based on footprints in a mediterranean population. *Journal of Foot and Ankle Surgery*, 44(6), 424–428. <https://doi.org/10.1053/j.jfas.2005.07.023>
- Woźniacka, R., Bac, A., Matusik, S., Szczygiel, E., & Ciszek, E. (2013). Body weight and the medial longitudinal foot arch: High-arched foot, a hidden problem? *European Journal of Pediatrics*, 172(5), 683–691. <https://doi.org/10.1007/s00431-013-1943-5>