Journal of Engineering and Technology for Industrial Applications

ANDROID APPLICATION FOR ACQUIRING IMAGES OF DIABETIC FOOT ULCERS

*Yusely Ruiz-Gonzalez[1], Gustavo Bermúdez Benitez[2] and Juan V. Lorenzo Ginori[3].

[1, 3] Informatics Research Center, Central University "Marta Abreu" of Las Villas, Villa Clara, Cuba.
[2] Culture Municipal Yaguajay, Sancti Spíritus, Cuba,

[1] http://orcid.org/0000-0002-6011-1947 , [2] http://orcid.org/0000-0002-1521-1344 , [3] http://orcid.org/0000-0002-1521-1244

Email: [1]yuselyr@uclv.edu.cu* , [2] gustavobermudez788@gmail.com, [3] juanl@uclv.edu.cu

ARTICLE INFO

ABSTRACT

Diabetic foot ulcers (DFU) are one the most common complications of patients who have diabetes mellitus. DFU study is a worldwide problem and despite the fact that there are computer tools to contribute to its treatment, these are not available in our country or it is necessary to pay for licenses to allow their use. The correct storage of DFU images contributes to the creation of a national database for the subsequent development and fine-tuning of algorithms devoted to segment and analysis these lesions remotely and automatically. So it is important to develop an application for mobile devices that allows standardizing the acquisition of images of DFU and store basic information. Android Studio was used as the programming environment and the minimum functional requirements for the first version were met. Templates were used to take the photos that allow focusing on the specific areas where the lesion is located and to standardize the focal distance. An apk was implemented that allows the acquisition/storage of DFU images/information with a view to the creation of a national database and the development of segmentation algorithms and injury analysis automatically using Digital Image Processing, Computer Vision and Artificial Intelligence techniques
.

I. INTRODUCTION

Diabetes mellitus is a major global health emergency in the 21st century, it currently affects more than 425 million people worldwide, and the number of patients could increase considerably in the next years [1],[2]. This disease can lead to the appearance of skin lesions and ulcers in 25% of patients as a result of poor glycemic control, underlying neuropathy, peripheral vascular disease, or poor foot care. These ulcers are usually found in areas of the foot that encounter repetitive trauma and pressure sensations and are commonly produced by repetitive stress over a skin area that is under pression [3].

Diabetic foot ulcer and related infections constitute a large risk factor for emergency department visits and hospital admission. This type of lesion usually require long time treatments and in some cases cause limb amputation, with the corresponding physical, social and psychological damage to the patients [4], [5] or even cause death.

The observation and analysis of lesions (DFU, diabetic foot ulcer) are the bases for defining the treatment and conduct to follow and the results of therapeutic approaches [1], [2]. These processes are often carried out subjectively or manually, which is inaccurate and unhygienic [6].

The lesions measurements are carried out by a specialist who determines approximately the area of the ulcer using the dimensions of the length and width obtained by measuring it manually with a ruler or caliper, without taking into account changes in its shape, generally irregular. Also when carrying out measurements manually, there is a degree of imprecision and variability depending on the person who is carrying out the task. With the technological developments of recent years, attempts have been made to semi-automate or automate these injury measurement processes so that medical personnel can have reliable measurements, increase processing capabilities and ensure better hygienic conditions.

The relatively low cost of digital photography makes it possible to take a digital photograph of the wound and analyze it manually or automatically, thus improving the precision of the measurements and reducing the risk of infection [7-9]. Digital analyze of the images could also be performed automatically by the use of computer vision and artificial intelligence algorithms [10], [11].

II. THEORETICAL REFERENCE

Internationally, competitions have been developed for the detection and classification of this type of injury [12], [15]. Progress has been made in the creation of software and mobile applications for evolutionary studies, wound remote monitoring and measuring the effectiveness of the different treatments applied [15], [22]. Enabling more efficient therapeutic options for wound care to be proposed in order to improve healing rates.

Some initial studies have also been carried out in our country but, to date and to our knowledge, no application has been registered [8],[23]. Also, with the development and introduction of Heberprot-P, a novel medication prescribed for the therapy of DFU, clinical trials were developed that used manual measurements or proprietary software, which required investments of resources and capital [6].

This research describes an application for Android OS (apk) intended for taking photographs of diabetic food ulcer lesions and creating a file associated with each image. The file will contain the most relevant information regarding its treatment, patient information and evolution.

The programming was carried out in Android Studio [24] and will contribute to the creation of national databases for the subsequent development and fine-tuning of segmentation and analysis algorithms for DFU studies of lesion automatically or semi automatically. Also, could contribute to the telemedicine developments by remote studies of DFU lesions. Likewise, will contribute to the implementation of segmentation and analysis algorithms which use digital image processing techniques, computer vision and artificial intelligence and need large image database for training and test. The acquisition of proprietary data base will a very important point to start the research.

III. MATERIALS AND METHODS

Android Studio is an integrated development environment (IDE), based on IntelliJ IDEA from the company JetBrains, which provides several improvements over the ADT (Android Developer Tools) plugin for Eclipse. Android Studio uses an Apache 2.0 free software license, is programmed in Java and is cross-platform. It was presented by Google on May 16, 2013 at the Google I/O developer conference, with the aim of creating an environment dedicated exclusively to programming applications for Android devices, providing Google with greater control over the production process. Since December 2014, when the stable version of Android Studio 1.0 was released, Google started to recommend it as the IDE to develop applications for its operating system.

The minimum functional requirements of the application (for now on "apk" Camera_DFU V1.1) like access to the camera, to take photo, and to save the picture, among other are shown in Table 1. Version 1.0 of the apk meets all of them. In the future, higher versions may include camera management requirements such as zoom, flash, resolution changes, etc. Interaction with medical personnel, after the application use, could generate new requirements as well.

Table 1: Functional requirements of V1.0 of the apk.

Functional Requirements	What the application does
FR1 Allow the application to access the camera.	The apk must access the device's camera to be able to take the necessary photos (this operation is only carried out after it is installed)
FR2 Select the appropriate template for the photo.	The apk brings a series of templates defined for taking photos which are selected by the user.
RF3 Take the photo.	The apk should take the photo and save it for later analysis
FR4 Decide whether or not to save the taken photo.	The apk allows to save the photo or not according to the user wishes.
RF5 Save the taken photo.	The apk saves the photo taken by the user.
FR6 Save information related to the patient and their injury.	The apk saves the patient data entered manually by the user, the information is stored in a file that can be read as .txt.
FR7 Show previously taken photos.	The apk should be able to display photos taken by the user or display a message in case there are no photos.
FR8 Delete a specific photo after it has been saved.	The apk should be able to delete photos when the user decides.
FR9 Export the information to a specific address in the internal storage.	The apk must allow saving the collected information.

Source: Authors, (2024).

The health personnel who interact directly in taking photos of the diabetic foot ulcer and acquiring the data required for monitoring this pathology are identified as system actors.

The application is installed by double clicking on the installation file. It is necessary to enable access permissions to the camera, microphone and writing in the mobile device. Depending on the phone's operating system, they can be assigned during the apk installation process itself or enabled manually after installation. Manually enabling permissions is done through the configuration/settings menu, applications, _DFU Camera, permissions, on the mobile device.

The Camera_DFU V1.1 software was developed for the Android OS, it runs from Android version 4.0 to higher OS versions. The memory requirements are basically to store the photos and associated files. The files generated for each photo are saved in txt format and are in the order of 500 b. The photos will have the maximum resolution allowed by the mobile device camera

The main screen of the apk has a drop-down menu to access the gallery of photos taken with the apk. If it is the first use of the application, the gallery appears empty, if some photos have been taken, they accumulate until the user decides to export them to a folder for later studies. Also there is some possibility to delete gallery photos.

As a prior step to taking a photo, the user must select a template where the injury will be fixated. Using the template will facilitate further image processing and standardizes the distance at which the photo is taken. There are four options for the templates to select, as shown in Figure 1; named: left leg, right leg, injury and sole of the foot. Each template is associated

with an specify position and extent of the injury to be studied. These templates are important since they allow the user to focus on the specific areas where the injury is located and contribute to standardize the distance to take the photo.
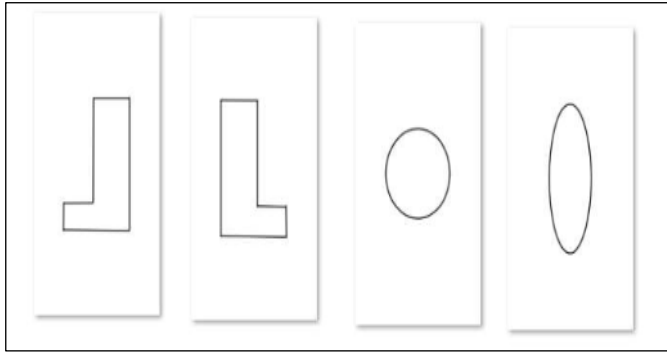

Figure 1: Template options to select before take the photo.
Source: Authors, (2024).

It should be noted that to take the photographs, the device's camera flash was set to activated mode always, in order to achieve uniform lighting of the taken photos, preventing darker or lighter photos from being taken depending on the room/ natural lighting. of the environment. In addition, the maximum resolution allowed by the camera was established, in this way the highest possible image quality will be obtained.

IV. RESULTS AND DISCUSSIONS

Figure 2 represents the apk icon which is show in the mobile device after the installation. When the application it is opened, shows the main screen as it appears in Figure 3.
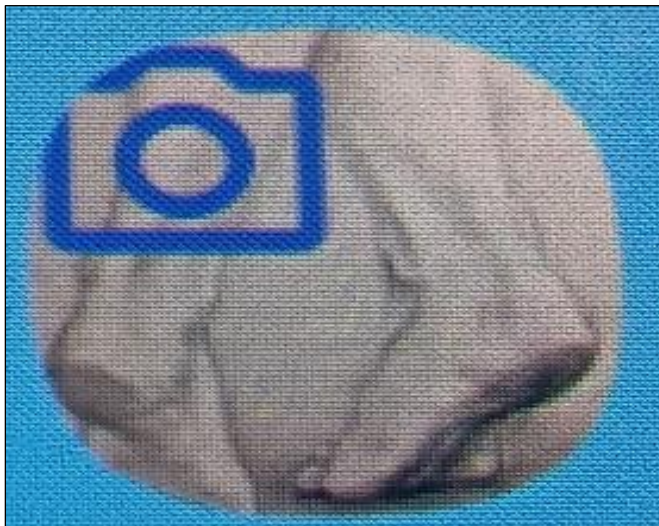

Figure 2: Apk icon.
Source: Authors, (2024).

The main screen has a drop-down menu to access the gallery of photos taken with the apk (Figure 4). If it is the first use of the application, the gallery appears empty (Figure 4a), if photos have been taken, they accumulate until the user decides to export them to a folder for further study (Figure 4b).
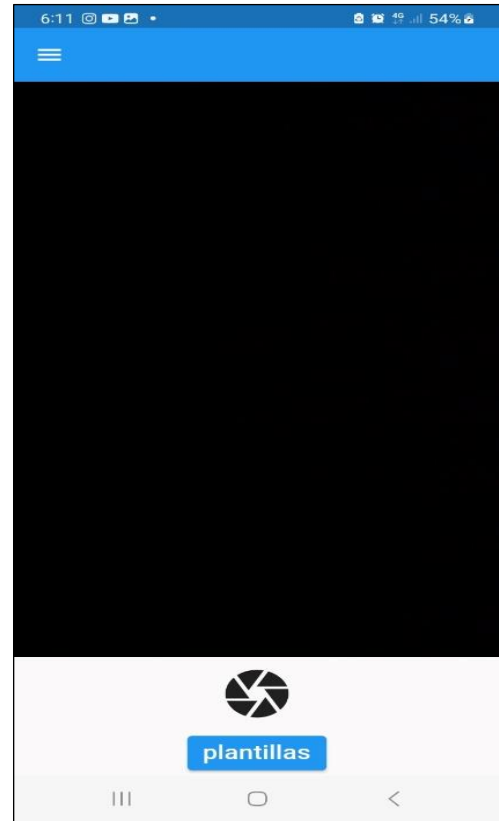

Figure 3: Application main screen.
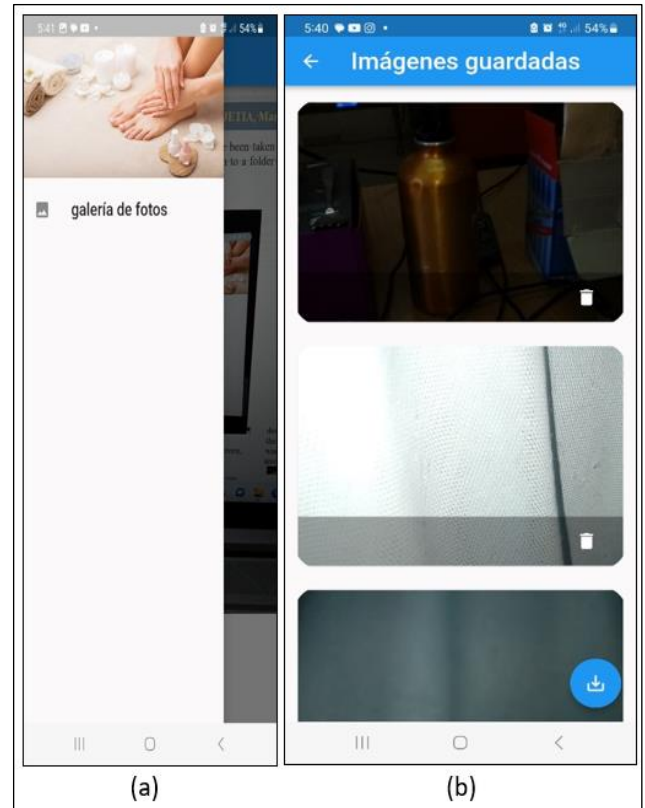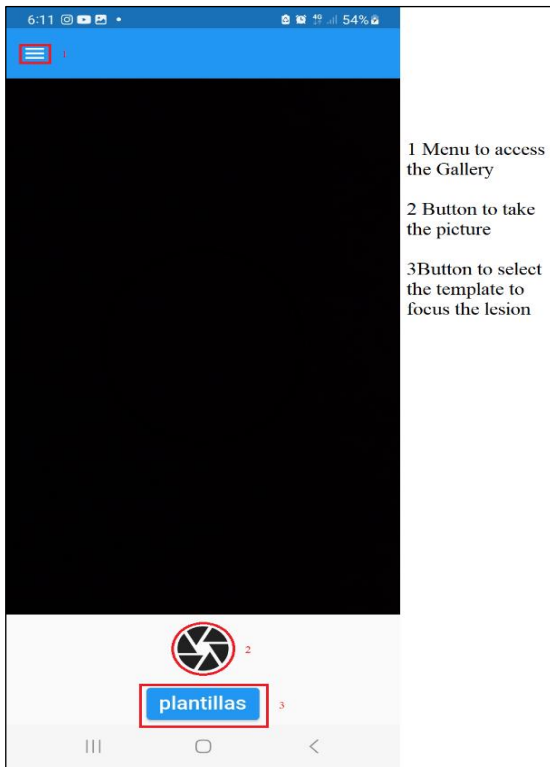Source: Authors, (2024).

Figure 4: Access to the photo gallery a) gallery menu b) pictures already taken.
Source: Authors, (2024).

Figure 5 details the different options provided by the apk: access to the gallery and taking photos (Figure 5a).

1 Menu to access the Gallery

2 Button to take the picture

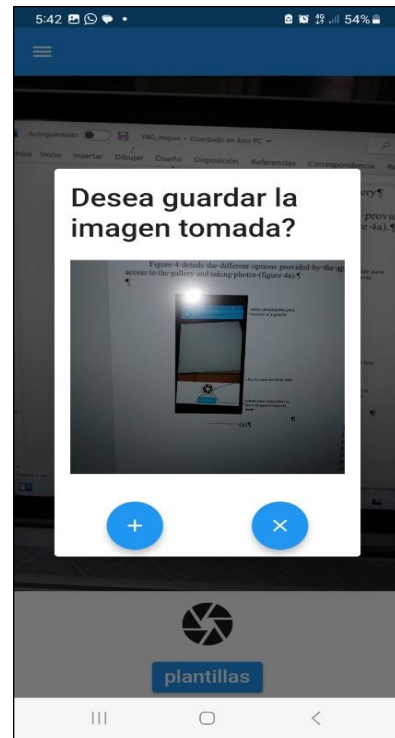3Button to select the template to focus the lesion

(a)

Figure 6: Sub-screen to save or not save the photo.
Source: Authors, (2024).

When accepting the photo taken previously, it is necessary to enter the data for the text file that will be associated with it. Figure 7 show the different fields to enter, some optional and others mandatory. The date and time were also associated and saved in the txt file for each photo, but they are automatically included in, when the photo saved because they are reserved from the phone.
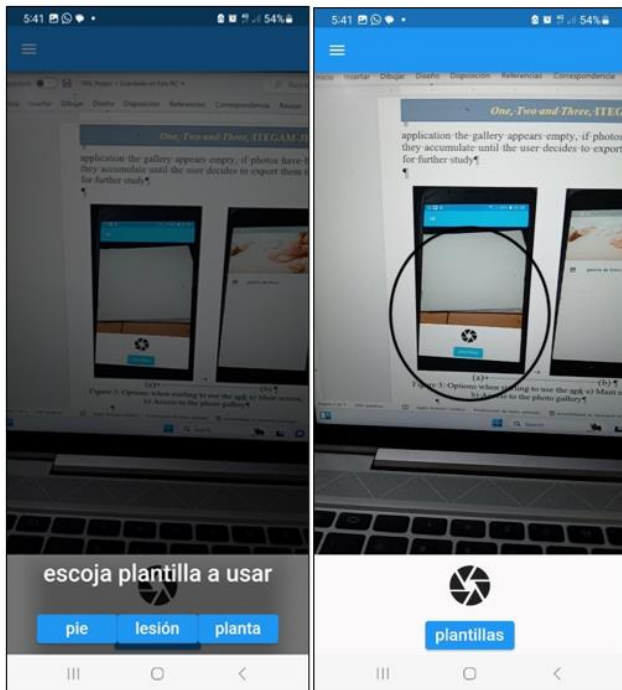
(b)   (c)

Figure 5: (Photo acquisition process a) (buttons on the main screen b) (template menu, c) example of selected template.
Source: Authors, (2024).

After the photo is taken, it is displayed on a subscreen to decide if the user want to save the photo or not (Figure 6). If the user wants to save the photo the left button should be push, so the information associated to photo will be showed (see Figure 7) in order to filled it and further save it in the associated txt file. If the user does not want to save the photo, it is discarded by pressing the right button and the process could be repeated to take another photo.
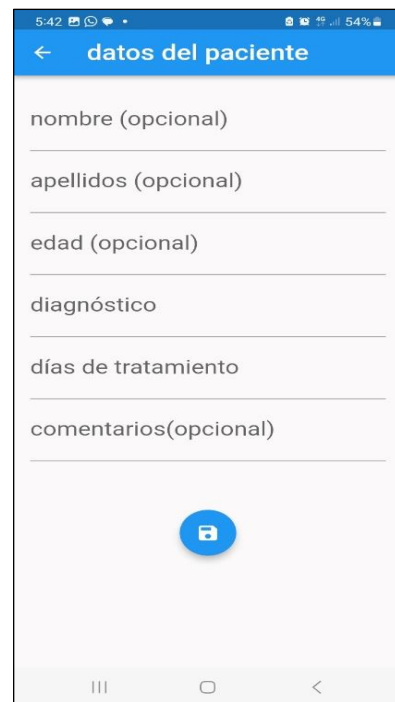

Figure 7: Information to record.
Source: Authors, (2024).

The photo and the .txt file are saved by pressing the button at the bottom of the screen. If the user try to save the file without completing the required fields, an error message is generated (see Figure 8).
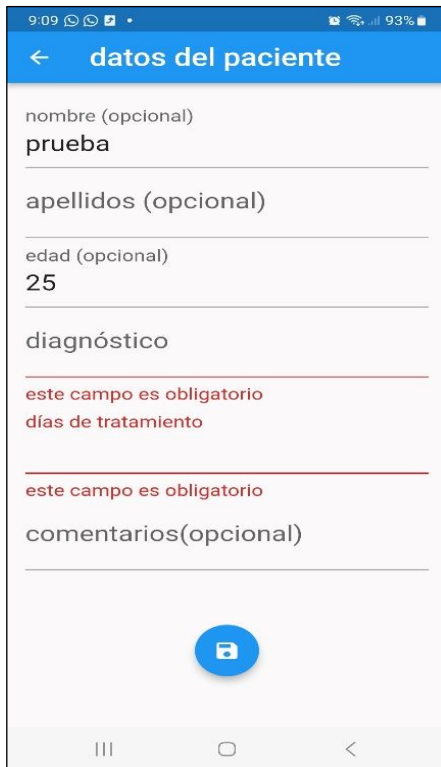
Figure 8: Error message for the mandatory fields.
Source: Authors, (2024).

When managing the gallery, the user can delete photos one by one using the trash button associated with each photo. Also the user can export the photos and associated .txt information files to a specific folder for further study (see Figure 9).
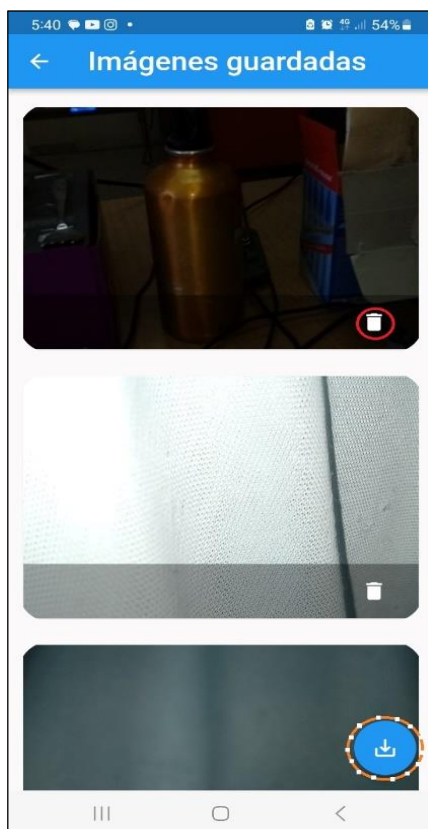

Figure 9: Buttons for managing the gallery, red circle highlights the trash button, orange -- highlight the export button.
Source: Authors, (2024).

The photos are exported to the folder: "My files/download/DFU_camera.apk" (see Figure 9). In this folder there is two other folder, the first one named "photos" for the taken pictures and the second one named "Jsons" for the .txt files. The name of the photo and its associated file matches and are automatically generated by the application.
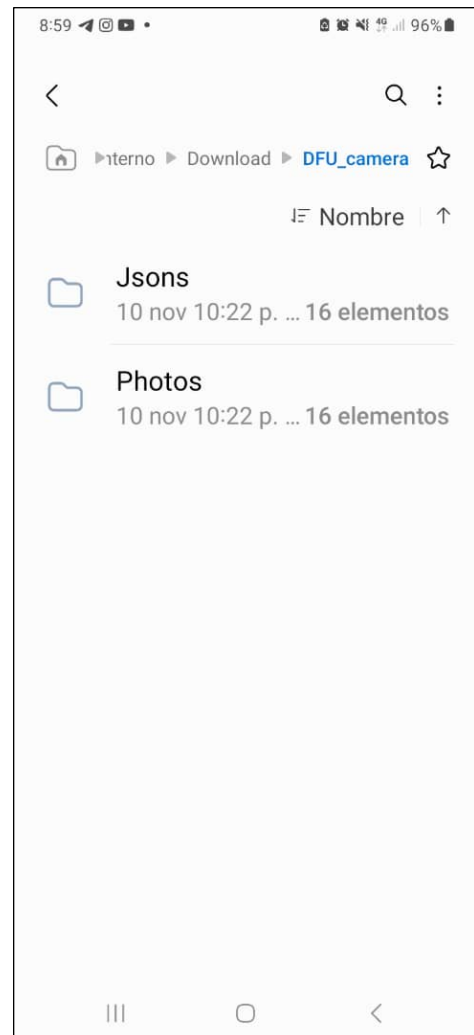

Figure 9: Created folder to save the photos and .txt files.
Source: Authors, (2024).

V. CONCLUSIONS

The diabetic foot ulcer is a condition that attracts the attention of worldwide doctor, health caretaker and researches. Several computer tools have been developed to contribute to its diagnose, treatments following and analysis. Unfortunately, many of the computer tools developed are not available in our country. A mobile device application was designed and implemented that allows acquiring/storing the diabetic food ulcer image (or any other type of lesion) together with some information requested by the user. In addition, with the use of the developed applications allow a certain degree of standardization in the acquisition of the images. The acquired images would be the starting point for the creation of a national database to future works in order to develop algorithms for segmentation and analysis of lesions automatically and remotely, using digital image processing techniques, computer vision and artificial intelligence.

VI. AUTHOR'S CONTRIBUTION

Conceptualization: Yusely Ruiz-Gonzalez, Gustavo Bermúdez Benitez, y Juan V. Lorenzo Ginori.
Methodology: Yusely Ruiz-Gonzalez, Gustavo Bermúdez Benitez.
Investigation: Yusely Ruiz-Gonzalez, Gustavo Bermúdez Benitez.
Discussion of results: Yusely Ruiz-Gonzalez, Gustavo Bermúdez Benitez, y Juan V. Lorenzo Ginori.
Writing – Original Draft: Yusely Ruiz-Gonzalez.
Writing – Review and Editing: y Juan V. Lorenzo Ginori.
Resources: Gustavo Bermúdez Benitez.
Supervision: Yusely Ruiz-Gonzalez, y Juan V. Lorenzo Ginori.
Approval of the final text: Yusely Ruiz-Gonzalez, Gustavo Bermúdez Benitez, y Juan V. Lorenzo Ginori.

VII. ACKNOWLEDGMENTS

VIII. REFERENCES

[1] P. Zhang, J. Lu, Y. Jing, S. Tang, D. Zhu, and Y. Bi, "Global epidemiology of diabetic foot ulceration: a systematic review and meta-analysis †," *Ann Med*, vol. 49, no. 2, pp. 106–116, Mar. 2017, doi: 10.1080/07853890.2016.1231932.

[2] R. Sorber and C. J. Abularrage, "Diabetic foot ulcers: Epidemiology and the role of multidisciplinary care teams," *Seminars in Vascular Surgery*, vol. 34, no. 1, pp. 47–53, Mar. 2021, doi: 10.1053/j.semvascsurg.2021.02.006.

[3] S. A. Bus, "The Role of Pressure Offloading on Diabetic Foot Ulcer Healing and Prevention of Recurrence," *Plastic and Reconstructive Surgery*, vol. 138, no. 3S, p. 179S, Sep. 2016, doi: 10.1097/PRS.0000000000002686.

[4] D. G. Armstrong, A. J. M. Boulton, and S. A. Bus, "Diabetic Foot Ulcers and Their Recurrence," *N Engl J Med*, vol. 376, no. 24, pp. 2367–2375, Jun. 2017, doi: 10.1056/NEJMra1615439.

[5] B. A. Lipsky *et al.*, "2012 Infectious Diseases Society of America Clinical Practice Guideline for the Diagnosis and Treatment of Diabetic Foot Infectionsa," *Clinical Infectious Diseases*, vol. 54, no. 12, pp. e132–e173, Jun. 2012, doi: 10.1093/cid/cis346.

[6] J. I. Fernández-Montequín *et al.*, "Intralesional administration of epidermal growth factor-based formulation (Heberprot-P) in chronic diabetic foot ulcer: treatment up to complete wound closure," *International Wound Journal*, vol. 6, no. 1, pp. 67–72, 2009, doi: https://doi.org/10.1111/j.1742-481X.2008.00561.x.

[7] H. Carrión, M. Jafari, M. D. Bagood, H. Yang, R. R. Isseroff, and M. Gomez, "Automatic wound detection and size estimation using deep learning algorithms," *bioRxiv*, p. 2020.11.13.275917, Nov. 2020, doi: 10.1101/2020.11.13.275917.

[8] P. L. Muñoz, R. Rodríguez, and N. Montalvo, "Automatic Segmentation of Diabetic foot ulcer from Mask Region-Based Convolutional Neural Networks," *Journal of Biomedical Research and Clinical Investigation*, vol. 1, no. 1.1006, 2020.

[9] J. D. López-Cabrera, Y. Ruiz-Gonzalez, R. Díaz-Amador, and A. Taboada-Crispi, "Estrategias de fusión para la clasificación automática de imágenes de úlceras de pie diabético usando técnicas de visión por computadora," *Revista Cubana de Ciencias Informáticas*, vol. 16, no. 1, pp. 163–179, 2022.

[10] R. Niri *et al.*, "Multi-view data augmentation to improve wound segmentation on 3D surface model by deep learning," *IEEE Access*, vol. 9, pp. 157628–157638, 2021.

[11] P. Wang, E. Fan, and P. Wang, "Comparative analysis of image classification algorithms based on traditional machine learning and deep learning," *Pattern Recognition Letters*, vol. 141, pp. 61–67, Jan. 2021, doi: 10.1016/j.patrec.2020.07.042.

[12] Moi Hoon Yap *et al.*, "Diabetic Foot Ulcers Grand Challenge 2020," Mar. 2020, doi: 10.5281/ZENODO.3715015.

[13] Moi Hoon Yap *et al.*, "Diabetic Foot Ulcers Grand Challenge 2021," Mar. 2020, doi: 10.5281/ZENODO.3715019.

[14] Moi Hoon Yap *et al.*, "Diabetic Foot Ulcers Grand Challenge 2022," Mar. 2021, doi: 10.5281/ZENODO.4575227.

[15] M. H. Yap *et al.*, "A New Mobile Application for Standardizing Diabetic Foot Images," *Journal of Diabetes Science and Technology*, vol. 12, no. 1, p. 169, Jan. 2018, doi: 10.1177/1932296817713761.

[16] L. Fraiwan, M. AlKhodari, J. Ninan, B. Mustafa, A. Saleh, and M. Ghazal, "Diabetic foot ulcer mobile detection system using smart phone thermal camera: a feasibility study," *BioMedical Engineering OnLine*, vol. 16, no. 1, p. 117, Oct. 2017, doi: 10.1186/s12938-017-0408-x.

[17] M. Goyal, N. D. Reeves, S. Rajbhandari, N. Ahmad, C. Wang, and M. H. Yap, "Recognition of ischaemia and infection in diabetic foot ulcers: Dataset and techniques," *Computers in Biology and Medicine*, vol. 117, p. 103616, Feb. 2020, doi: 10.1016/j.compbiomed.2020.103616.

[18] "Healogics Photo+ | Wound Measurement App," Healogics. Accessed: Apr. 13, 2021. [Online]. Available: https://www.healogics.com/woundsuite-wound-care-software/wound-measurement-app/

[19] L. Fraiwan, J. Ninan, and M. Al-Khodari, "Mobile Application for Ulcer Detection," *Open Biomed Eng J*, vol. 12, pp. 16–26, 2018, doi: 10.2174/1874120701812010016.

[20] "Digital Planimetry and Measurements on Digtial Images Using PictZar Wound and other Measurements Software." Accessed: Dec. 18, 2023. [Online]. Available: http://www.pictzar.com/

[21] WoundDesk, "+WoundDesk - Mobile enhanced Wound Management for Chronic Wounds," +WoundDesk. Accessed: Dec. 18, 2023. [Online]. Available: https://wounddesk.com

[22] "Wound Zoom's Wound Management System." Accessed: Dec. 18, 2023. [Online]. Available: https://woundreference.com/app/topic?id=wound-zooms-wound-management-system

[23]   G. García Gómez *et al.*, "Mejoramiento de contraste y segmentación en imágenes de úlceras del pie diabético," *Revista Cubana de Angiología y Cirugía Vascular*, vol. 20, no. 3, Dec. 2019, Accessed: Apr. 13, 2021. [Online]. Available: http://scielo.sld.cu/scielo.php?script=sci_abstract&pid=S1682-00372019000300003&lng=es&nrm=iso&tlng=es

[24]   "Guia para desarrolladores." [Online]. Available: https://developer.android.com/guide