JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

DETECTION OF PRESSURE POINTS ON DIABETIC FOOT

[1]Chaithra Kulal, [2]Dheeraj, [3]Meghana R Bhat, [4]Neema B Shetty, [5]Nagaraja Rao
[1234]Student, [5]Associate Professor
[12345]Electronics and Communication Engineering,
[12345]Shri Madhwa Vadiraja Institute of Technology and Management Bantakal, Udupi

Abstract: Diabetes mellitus is a serious global health concern that can lead to various complications, including foot ulcers which are particularly severe. Early detection and prevention of foot-related issues in diabetic patients are crucial to reduce the risk of amputations and other complications. Although plantar pressure distribution analysis is an effective tool for identifying these issues, commercially available systems can be expensive and have data linkage constraints. To address these limitations, this project proposes an alternative method for detecting foot pressure points and dimensions using image processing. The approach involves capturing a complete image of the foot through a camera and extracting the necessary data, such as pressure points and foot dimensions. The challenges associated with obtaining accurate images and precise pressure points are discussed, and the relevance of this work for monitoring foot health in diabetics is emphasized. By detecting foot-related problems early, healthcare providers can take the necessary measures to prevent serious complications. Overall, this project has significant implications for detecting foot-related problems early and reducing the risk of diabetic foot problems.

Index Terms **– OpenCV, KNN Clustering Algorithm, Canny Edge Detection**

I. INTRODUCTION

Diabetes mellitus is indeed one of the major challenges in global public health today. The increasing prevalence of diabetes worldwide has significant implications for individuals, communities, healthcare systems, and economies. The threat has increased dramatically over the past two decades. According to epidemiological studies, the number of patients with diabetes mellitus increased from about 30 million cases in 1985 to 177 million in 2000, 285 million in 2010, and it is estimated, if the situation continues, that more than 360 million people by 2030 will have diabetes mellitus. This demonstrates a significant increase in the prevalence of diabetes mellitus over the years.

Patients with diabetes mellitus are prone to have multiple complications. One of the major complications is foot ulcer. Foot ulcers are a common problem in individuals with diabetes and can lead to serious complications if not properly managed. Diabetes can cause damage to the nerves and blood vessels in the feet, resulting in reduced sensation and poor blood circulation. These factors make the feet more susceptible to injuries and slow healing. When a foot ulcer develops, it can become infected and may lead to more severe complications such as cellulitis, osteomyelitis (bone infection), and even amputation in some cases. Diabetic foot ulcer is a major source of morbidity and a leading cause of hospitalization. Once diabetic foot ulcer has developed, there is an increased risk of ulcer progression, leading to infection, gangrene, amputation, and even death, if necessary, care is not provided. Proper foot care, regular monitoring, and early detection of foot ulcers are crucial for individuals with diabetes to prevent complications. It is recommended that individuals with diabetes inspect their feet daily, maintain good foot hygiene, wear proper footwear, and seek medical attention if they notice any signs of a foot ulcer or other foot-related problems.

Measurements of foot pressure points will provide an indication of foot related problems in diabetic patients through which problems like foot ulcer can be predicted earlier and the patients can take necessary measures. By regularly monitoring foot pressure points and analyzing pressure maps, healthcare professionals can identify areas of high pressure and abnormal gait patterns that may increase the risk of foot ulceration. Early detection allows for timely intervention, such as offloading techniques, customized footwear, or orthotic devices, to redistribute pressure and alleviate the excessive load on vulnerable areas. The measurement of foot pressure points is a non-invasive and painless procedure that can be performed during a routine foot examination. The pressure is measured using a specialized device that records the distribution of weight on the patient's feet as they stand or walk on a pressure-sensitive surface. The data collected is then analyzed to create a pressure map that can reveal any areas of high pressure, indicating regions of the foot that are at increased risk of developing ulcers. It may contribute to the development of foot ulcers. For example, patients with reduced sensation in their feet may unconsciously alter their gait to compensate, leading to abnormal pressure distribution and an increased risk of foot ulcers. Overall, foot pressure measurements are a valuable tool in the prevention and management of foot ulcers in diabetic patients.

Plantar pressure distribution analysis is an increasingly popular research area in the study of foot diagnosis and gait evaluation. It provides valuable insights into the interaction between the foot and the ground during walking or standing, and it offers a non-invasive means of assessing foot function and identifying potential issues. By analyzing plantar pressure distribution, researchers can evaluate how forces are distributed across different regions of the foot during gait. This assessment helps in understanding foot function, identifying abnormalities, and detecting any areas of excessive pressure or high-pressure zones that may indicate potential foot

pathologies or gait abnormalities. There are many types of plantar pressure measurement systems that are commercially available and have different constraints such as the high cost, and the data linkages as collected by the computer. Nowadays, the majority of researchers adopt the plantar pressure to analyze the data using electronic sensor-based systems. Conventionally however, these sensors lack the required resolution to measure or predict the pressure of small regions, such as the toes. Plantar pressure distribution analysis provides quantitative data on foot function, aids in the identification of foot pathologies, assists in treatment evaluation, and helps guide the development of personalized interventions. As technology continues to advance, plantar pressure analysis methods are likely to become even more sophisticated, enabling more comprehensive foot assessments and enhancing our understanding of foot-related conditions and gait mechanics.

Our project proposes a method where foot pressure points and foot dimensions are detected through image processing using python. Image processing techniques allow for non-invasive pressure point detection. It does not require the use of physical sensors or devices attached to the foot, which can be uncomfortable for patients, especially those with diabetic foot complications. Implementing image processing methods for pressure point detection can be more cost-effective compared to using specialized sensor-based devices. Image processing relies on standard imaging equipment, such as cameras, which are widely available and relatively affordable. Image processing enables the analysis of the entire foot surface, providing a comprehensive view of pressure distribution across different regions. Image processing techniques can not only detect pressure points but also provide additional foot-related information such as foot dimensions, arch height, or foot posture. These additional parameters can contribute to a more comprehensive understanding of foot health and aid in personalized interventions. Image processing allows for visual representation of pressure points, enabling healthcare professionals to easily interpret and communicate the findings to patients. Visualizing pressure points can enhance patient engagement and understanding of their foot health. Image processing techniques can be automated, allowing for efficient analysis of large datasets. Moreover, the results obtained from image processing can be integrated into electronic health records or telemedicine systems, enabling remote monitoring and consultation for diabetic foot management.

II. LITERATURE REVIEW

In [1], the idea is to use foot pressure distribution as a quantitative parameter for evaluating anatomical deformity of the foot and for diagnosing and treating pathological gait, falling, and pressure sores in diabetes. The author proposes a deep learning model that could predict pressure distribution of the whole foot based on information obtained from a small number of pressure sensors in an insole. In paper [2], human intervention in the SWME is minimized by using an automated testing system relying on computer vision. It follows a parametric model, which considers three distinct plantar areas for better performance. Here the factor that negatively influences the performance of the algorithm is the lighting conditions at the time of acquisition of plantar images. In paper[3], Velostat sheet is used to measure the applied pressure on the foot according to the variation of the resistance value along with other sensors. Here Microcontroller Unit (MCU) is used for Communication, which is a disadvantage because it adds extra weight to the insole and also handling of MCU is difficult. It has proved the feasibility within Laboratory environment. 3D foot measurement cannot be widely used due to the limitations of measurement equipment and related algorithms in paper [4]. In this research a fast and convenient foot measurement method is proposed based on deep learning and image segmentation algorithms. The HED model is used to detect the edges of A4 paper; the traditional image segmentation algorithm Grab Cut is used for segmentation of the foot area. In the future, it will focus on the study of three-dimensional parameters such as the circumference of the metatarsal toe, the circumference and height of the anterior tarsal bone.

An automatic digital image processing system is created for detecting footprints from an optical pedobarographic for analyzing foot plant morphology and pressure distribution as mentioned in [5]. This methodology uses Four transforms to grayscale for segmenting the footprint region with fixed thresholds. Definitive masks perform a logical AND operation that eliminates false detected binary objects. In Combining the binary mask with the intensity image allows determining the pressure distribution on the foot plant. In paper [6], measurement-based method which adopts the reference measured parameters such as; the weight of a subject, contact-area size, age, and the pressure level distribution over a plantar image captured by EMED plantar pressure. This modeling adopts the dynamic with load category. Prediction of foot ulceration was examined using MATLAB. Based on a specific threshold value, the algorithm converts the image from RGB format into Index image format. A statistical technique is considered to measure relationships between the potential predictor. For future work, more data analysis is required. In paper [7], data of plantar pressure are collected with the flexible force sensor. In An 8-neighborhood connected-component labeling algorithm was proposed to segment and cluster the plantar pressure images. A total of 67 subjects were selected for the experiment. The landing and departure time of each step was extracted from the video shot by the camera. The segmentation accuracy was 99%, some subjects failed to land their heels first in the random speed test, results in recognition error. In [8], plantar pressure sensor system is developed by using the Flexiforce sensor with data acquisition of NI-USB6008 as an interface to gather measurement data. There are four Flexiforce sensors that are placed at the most identified points at the right foot, which are heel, mid foot, forefoot and toe. This pilot study proposes an alternative way to detect an early sign of foot ulcer by identifying the pattern of plantar or foot pressure for diabetes patients via LabVIEW software. In this method the number of samples taken are less and perfect measurement was not obtained for different foot size. It proposes an economical and personalized insole system for the determination of plantar pressure in dynamic environments [9]. A number of precision sensors are intended to be replaced by a small number of practical sensors in order to reduce the size and weight of existing systems and to increase the economic efficiency. This has a disadvantage in terms of communication due to the usage of Arduino Pro Mini. In [10], microclimate-based approach to the prediction of DFU and re-ulceration which include Temperature, Pressure, Shear force and humidity. It tells Sensor systems capable of measuring microclimate including temperature, pressure, and humidity have been trialed. It denotes the development of potential Microclimate sensors. To gather real-time microclimate data during free living activities, the lifespan and durability of sensors will be critical, which is the biggest barrier.

III. PROPOSED METHODOLOGY

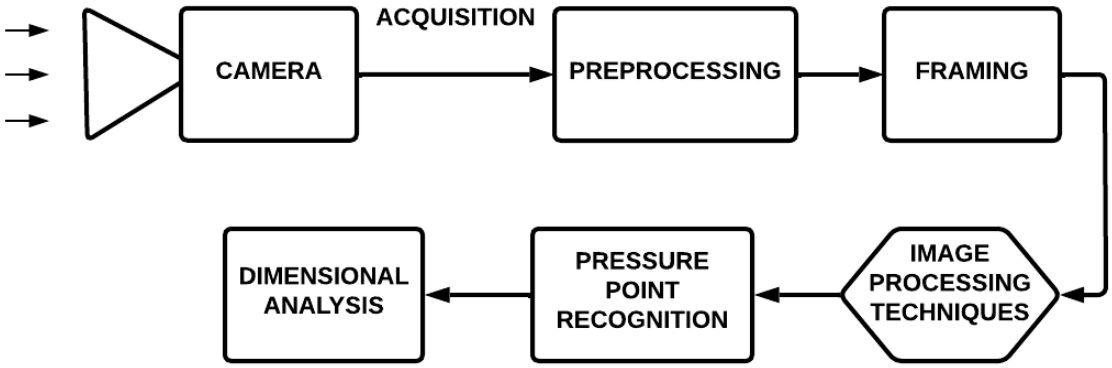


Figure 3.1: Block Diagram of the Proposed Project

Figure 3.1 signifies the Block Diagram of the project. First step is Image Acquisition.

Image Acquisition: By placing the foot on the glass slab and the camera beneath it, the image of the foot is taken. The photograph can be taken in two different ways. One method is to record foot motion using a mobile camera, then edit the video into frames. The alternative method is to utilize a camera that can be connected to a microcontroller, such as an Arduino, and will output image frames directly. The foot image capture procedure using a glass slab is shown in Figure 3.2. Depending on the user's preference, any camera can be used to take the image. Ensure the foot is well-illuminated to obtain a clear image.



Fig 3.2 Image Capture using Glass Slab

Preprocessing: For image processing we have used python coding. The captured foot image or video is taken as input. The image is preprocessed to enhance the image quality and reduce noise. Thresholding is applied which separates the foreground(foot) from the background, based on the intensity values of pixels.

Algorithm Used: K-Means Clustering Function performs k-means clustering on the input image using the specified number of clusters The function reshapes the image to a 2-dimensional array, performs k-means clustering, and reshapes the clustered image back to its original shape. The function returns the clustered image.

Pressure Point Detection: It is important to identify specific areas or points on the foot where high pressure exists. The overall intensity or pressure distribution across the foot can be determined by combining the pixel values for each frame. The pixel values within the identified pressure points can be summed or averaged. Identify the high-intensity point on the foot by analyzing the combined pixel value. Pressure points of each frame are obtained and later they are combined to get accurate pressure points. Figure 3.3 shows the jupyter notebook which we have used to run the code.

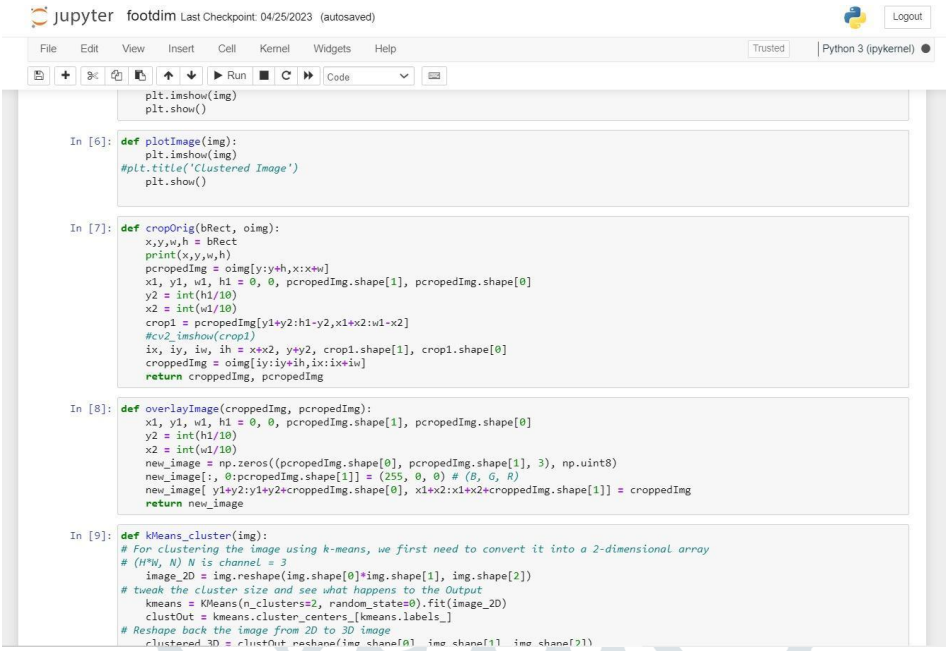


Figure 3.3 Jupyter Notebook

Foot Dimension: Dimension of the foot is obtained in order to develop insoles for required diabetic patients. In order to get the dimension, capture an image of the foot along with A4 as the reference. Figure 3.4 shows the foot dimension detection process by taking the A4 sheet as reference. Make sure that the A4 sheet and foot are in the same plane and properly aligned. Detect and locate the A4 sheet in the image using image processing technique edge detection and thresholding. Extract the edges of the A4 sheet. Measure the dimension of the A4 sheet. Out of several frames mid-frame is selected to obtain dimensions of the foot. By taking this as reference dimensions of foot is obtained.



Figure 3.4 Foot Dimension by Taking A4 Sheet has Reference

Figure 3.5 signifies the flow of work for the proposed project. Capture high-quality images or video frames of the foot using a camera or any imaging device. Ensure that the foot is properly positioned and visible in the captured images.

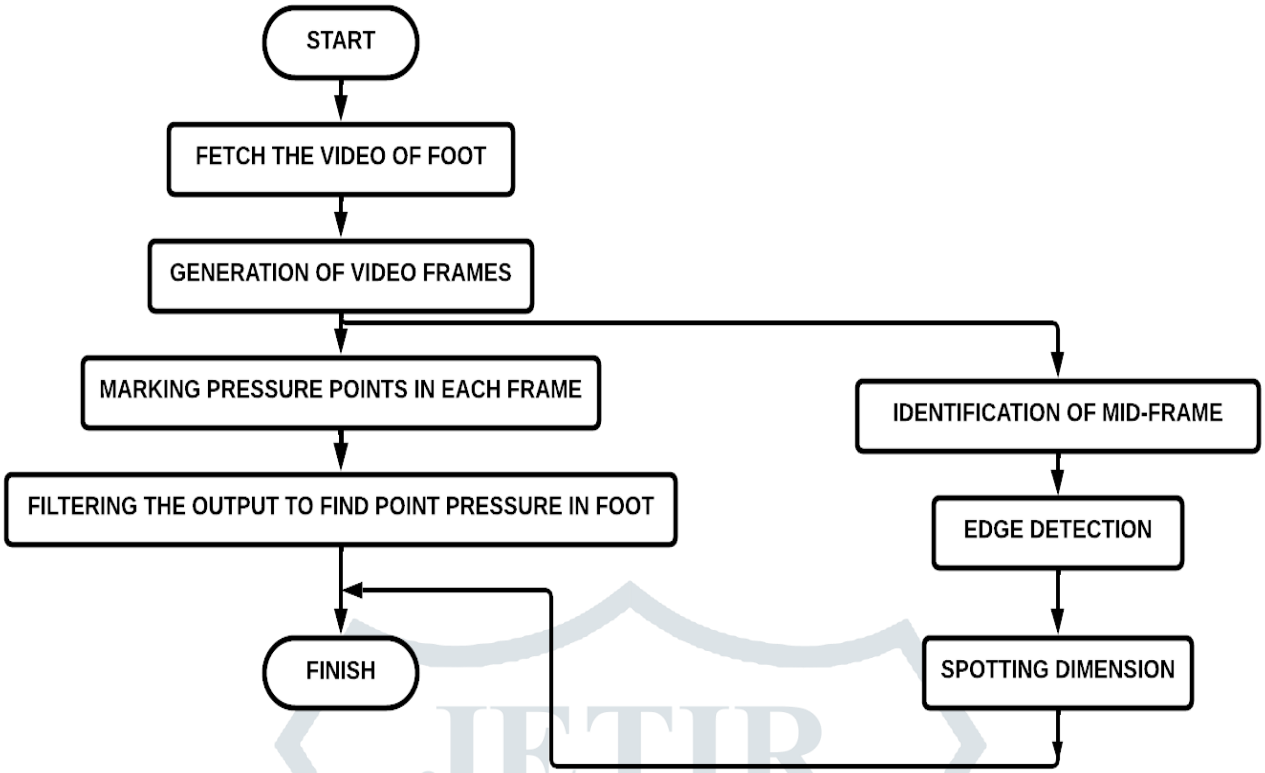


Figure 3.5: Flow Chart of Detection of pressure points on Diabetic foot

First step is to capture the video of the foot. Using OpenCV's video capture functionality, read the foot video frame by frame. This involves initializing a video capture object and looping over the frames until the end of the video is reached. Next step is the Frame extraction. Extract individual frames from the video using the video capture object. Each frame represents a still image of the foot. Preprocess each frame to enhance the clarity of the foot region and remove any noise or artifacts. Apply techniques such as resizing, cropping, and image enhancement filters. Further step is Pressure Point detection. In this process, apply image processing techniques to recognize the pressure points on each frame. This could involve feature extraction methods, template matching, or machine learning algorithms depending on the specific requirements of your project. The goal is to identify specific regions or points on the foot that indicate high pressure. Calculate the combined pixel values for each frame to determine the overall intensity or pressure distribution across the foot. This can be achieved by summing or averaging the pixel values within the identified pressure points. Analyze the combined pixel values to identify the high-intensity point, which indicates the region of highest pressure on the foot. This point could correspond to the location of a significant pressure point or a potential area of concern.

In order to detect foot dimensions, consider the midframe of the video captured. Use image segmentation techniques to isolate the foot region from the background. This can involve thresholding, edge detection, or region-based segmentation methods to extract the foot region accurately. Identify key landmarks or reference points on the foot, such as the tips of the toes, the heel, or the arch. This can be done using techniques like edge detection, corner detection, or template matching. This method is Landmark Localization. Once the landmarks are localized, extract the relevant foot dimensions using appropriate measurement techniques. This could include measurements such as foot length, foot width, arch height, or specific ratios and proportions. Depending on the camera setup and image acquisition process, it might be necessary to calibrate the measurements to obtain accurate real-world dimensions. We can accomplish this by using known reference objects, such as A4 sheets, in our work.

IV. Results and Discussion

The aim of the project is to obtain the foot pressure points and dimensions. Figure 4.1 is the unprocessed image whose pressure points need to be detected. This image is taken as input and is processed. Figure 4.2 shows the preprocessed image enhancement of quality and reduction of noise if present. Figure 4.3 is the thermal image that differentiates each point of foot based on intensity. According to the difference in temperature in each foot point, pressure points will be obtained for each frame. Further these pressure points of each frame will be combined to get the accurate pressure points. Fig 4.4 is the final image obtained with accurate pressure points.



Figure 4.1 Unprocessed Image



Figure 4.2 Preprocessed Image

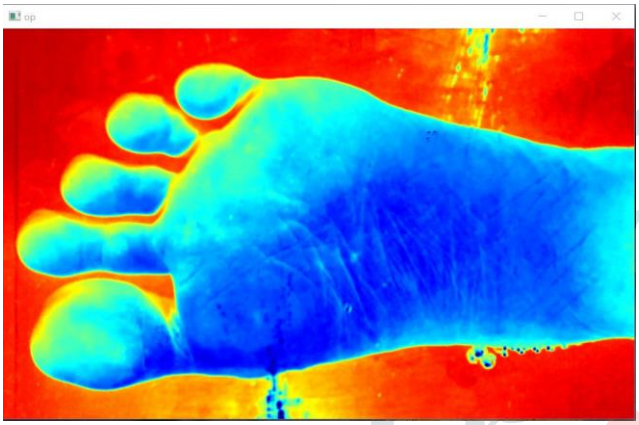


Figure 4.3: Thermal Image

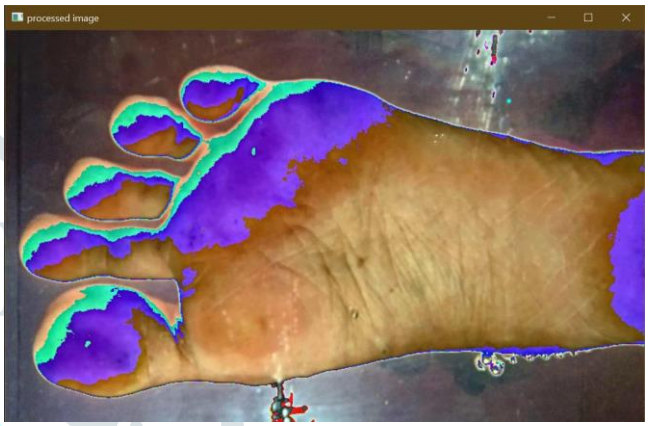
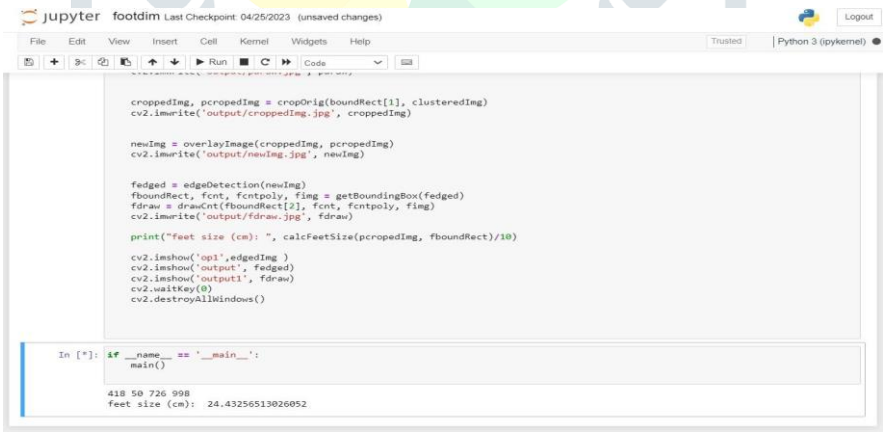


Figure 4.4 Processed Image

Foot Dimensions are obtained by taking the A4 sheet as reference. Fig 4.5 shows the dimensions obtained. Fig 4.6 shows the foot dimension with A4 sheet as reference and Fig 4.7 is the Foot dimension outline which is used to design insoles for required patients.

Figure 4.5: Foot dimension



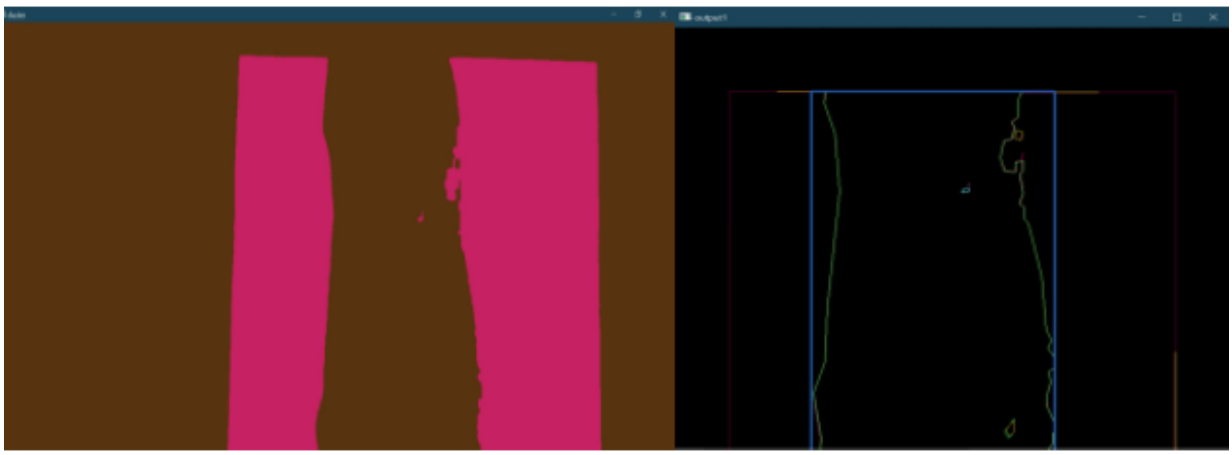


Figure 4.6: Dimensions of foot by taking A4 sheet as reference

Figure 4.7: Foot Dimension outline



Comparison Between Image Processing And Sensor Based Approach :

Sensor-based approach: In this approach, pressure sensors are placed on the footbed or insole of a shoe to measure the distribution of pressure exerted by the foot. The sensors can be designed to measure forces in specific areas or over the entire foot surface. By analyzing the sensor data, pressure points and patterns can be identified.

Advantages:

- Direct measurement: Sensors provide real-time, direct measurement of pressure points.
- Accuracy: Sensor-based approaches can provide precise pressure readings.
- Versatility: Pressure sensors can be integrated into various types of footwear or footbeds.

Disadvantages:

- Limited coverage: Sensors only measure pressure at the specific points where they are placed, potentially missing pressure points in other areas.
- Intrusiveness: The presence of sensors may alter the natural foot movement and affect user comfort.
- Calibration and maintenance: Sensors require calibration and periodic maintenance to ensure accurate readings.

Image processing approach: In this approach, cameras or depth sensors capture images or depth maps of the foot in contact with a surface. The images are then processed using computer vision techniques to detect pressure points based on variations in color, shape, or texture.

Advantages:

- Comprehensive coverage: Image processing can analyze the entire foot surface, providing a more complete pressure point analysis.
- Non-intrusive: Foot pressure can be detected without the need for physical sensors, offering greater comfort and freedom of movement.
- Flexibility: Image processing techniques can be applied to various imaging devices, such as cameras or depth sensors.

Disadvantages:

- Environmental factors: Lighting conditions, background clutter, and occlusions can affect the accuracy of image-based pressure point detection.

In summary, sensor-based approaches provide direct pressure measurements at specific points, while image processing techniques offer comprehensive coverage of the foot surface without the need for physical sensors.

V. Future Work and Conclusion

There are various potential areas for future work on this project. One possibility is to integrate the foot pressure point and dimension detection system with other diagnostic tools, such as thermal imaging, to create a more comprehensive system for detecting foot-related problems in diabetic patients. Another potential area of development is to test the system on larger datasets to validate its accuracy and effectiveness. Finally, integrating the system with telemedicine platforms can enable patients to remotely monitor their foot health and receive medical advice. Overall, further refinement and development of the system can lead to significant improvements in detecting and preventing foot-related problems in diabetic patients. In conclusion, this project highlights the importance of early detection and prevention of foot-related issues in diabetic patients. The proposed alternative method of detecting foot pressure points and dimensions through image processing offers a more accessible approach compared to commercially available systems. By detecting foot-related problems early, healthcare providers can take timely action to prevent serious complications and improve patient outcomes. This project has significant implications for reducing the risk of diabetic foot problems and enhancing the quality of life for diabetic patients.

VI. References

[1] Mun, F., & Choi, "Deep learning approach to estimate foot pressure distribution in walking with application for a cost-effective insole system", Journal of NeuroEngineering and Rehabilitation, 19(1), 1-14, 2022.

[2] Costa, Coelho, L., & Silva, M. F., "Automatic Segmentation of Monofilament Testing Sites in Plantar Images for Diabetic Foot Management", Bioengineering, 9, 86, 2022.

[3] Khandakar, A., Mahmud, S., Chowdhury, M. E., Reaz, M. B. I., Kiranyaz, S., Mahbub, Z. B. & Faisal, M. A. A., "Design and Implementation of a Smart Insole System to Measure Plantar Pressure and Temperature", Sensors, 22(19), 7599, 2022.

[4] Wang, H., Liu, F., & Fan, R., "A research on foot size measurement algorithm based on image", In Journal of Physics: Conference Series (Vol. 1903, No. 1, p. 012004), IOP Publishing, 2021.

[5] F J Buchelly, D Mayorca, V Ballarín and J Pastore, "Digital image processing techniques applied to pressure analysis and morphological features extraction in footprints", Journal of Physics: Conference Series, Volume 705, 2020.

[6] Ali Hussein Sabry, W. Z. Wan Hasan, Mohd Nazim Mohtar, Raja Mohd Kamil Raja Ahmad, Hafiz Rashidi Ramli, S. P. Ang, Zainidi Haji Abdul Hamid, "Image processing based foot plantar pressure distribution analysis and modeling", Journal, Vol. 17, Issue 2, Pages 594-605, 2022.

[7] Chao Zhang, Su Pan, Yaowu Qi, Yudan Yang, "A Footprint Extraction and Recognition Algorithm Based on Plantar Pressure", Traitement Du Signal, 36(5), 2019.

[8] Nor Salwa Damanhuri, Nor Azlan Othman, Wan Fatimah Azzahra WanZaidi, Samihah Abdullah "A Development of Plantar Pressure Sensor for Foot Ulcer Detection in Diabetic Neuropathy Individuals" Journal of Physics: Conference Series, Volume 1535, 2020.

[9] Kang, J. W., Kwon, Y. M., Lim, M. J., & Chung, D. K., "A Study on the Cost-Effective Personalized Plantar Pressure Measurement System", International Journal of Internet, Broadcasting and Communication, 11(4), 11-17, 2019.

[10] Jones, P., Bibb, R., Davies, M., Khunti, K., McCarthy, M., Webb, D., & Zaccardi, F., "Prediction of diabetic foot ulceration: The value of using microclimate sensor arrays", Journal of diabetes science and technology, 14(1), 55-64, 2020.