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SMARTSTEP

Mobile Application for Accurate Foot Measurement Using Image Processing

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ABSTRACT

Precise foot measurement is a key to designing comfortable and proper-fitting shoes, in particular in custom shoe design, orthotics, and medical shoes. Ill-fitting shoes can cause a set of problems ranging from minimal discomfort to serious foot disorders, especially among those with irregularly shaped feet or medical conditions. Foot measurements are traditionally done by hand with scales, rules, or with markers. Although easy, they are time-consuming, skill-dependent measurements and tend to vary. They also are not scalable in situations requiring frequent or bulk foot measurements.

With the expanding market of smartphones and image processing technology, there is a chance to streamline and digitalize the process through a simple mobile application. The project is aimed at the creation of a mobile application that allows a person to scan the shape of his/her foot through the smartphone's built-in camera and obtain accurate 2D measurements of the foot length and width. The application shall be light, user-friendly, and free to access. The application makes use of open-source libraries like OpenCV to process images and Flutter or Android Studio to create the mobile application.

For ensuring measurement precision, the application employs a simple reference object, like an A4 sheet of paper or a readily available coin, that is kept alongside the foot in the image. The reference object is then applied to determine a pixel to centimeter proportion that makes results independent of the device. The image is then processed through OpenCV algorithms like contour detection and thresholding to segment out the foot and determine its measurements. The principal intention of this application is to assist users of any type—be they consumers, students, designers, or professionals in the shoes industry—to accurately measure the foot from the comfort of home or from a workshop environment, not requiring access to costly 3D scanners or commercial foot measurement software. The solution is especially valuable in environments where cost and mobility are factors.

Developed through a summer internship at the Footwear Design and Development Institute (FDDI), under the aegis of the Centre of Excellence (COE), the project is a practical illustration of how free and open-source tools can be used to computerize traditional processes within the footwear industry. The latest iteration of the application includes support for the major functionalities of real-time camera capture, auto-detecting foot contour, reference-based calibration, and on-screen presentation of foot length and width measurements in centimeters. The application also supports saving and comparing previously taken scans locally to monitor changes over time.

In the next iteration, the application can be augmented with sophisticated functionalities such as AI-powered foot type classification (e.g., detection of flat feet), recommendations based on sizing, cloud synchronization of user profiles, and also photogrammetry-based 3D scanning. Nonetheless, the priority at the moment is to have a dependable, affordable, and widely applicable 2D foot measurement solution for education, design, and the workplace.

LITERATURE REVIEW

Kabir et al. (2021) carried out a scoping review to analyze the measurement methods and quality of mobile foot measurement applications. The investigation indicated that there is no standard measurement protocol and that there is a need to develop improved precision and reliability in the apps to make them effective tools for foot care experts and patients looking for custom shoes [1]. Rafiq et al. (2022) created OptiFit, a smartphone-based application using computer vision algorithms to measure foot dimensions automatically, covering length, width, height of the arch, and instep circumference. The application proved to have a high precision in foot measurement capturing, posing a potential application in designing custom-fit shoes to avoid foot issues that are caused by poorly fit shoes [2]. Niu et al. (2021) presented a 3D foot reconstruction method based on images taken on a standard smartphone. The method entailed capturing several images from different angles to produce a 3D foot model to allow accurate measurement of foot parameters. The method is a cost-friendly and affordable solution to personalized shoe customization [3]. A journal paper published in the Journal of Foot and Ankle Research in 2015 proved the possibility of building a precise 3D model of a foot from just three images captured by a normal smartphone. The technique delivered accurate measurements of the dimensions of a foot, offering a cost-effective alternative to conventional foot scanners in the process of custom shoe manufacturing [4]. A paper by Jäger et al. in 2023 compared 3D foot scanning to conventional 2D digital scanning and manual measurements of the foot in children. The study proved that 3D scanning delivered a better overview of foot morphology, which plays a critical role in designing a proper-fitting shoe. Nonetheless, the study also reported a call to standardize measurement procedure to achieve uniformity across varying methods [5]. A paper tested the NDKare smartphone application intended for diabetic foot evaluation. The application reliably and accurately acquired 2D measurements of diabetic foot lesions through mobile phone photography. The tool proved to have potential in remote diagnosis and evaluation of the health of the foot in patients suffering from diabetes, highlighting the potential of mobile applications in healthcare [6]. A review by El-Rashidy et al. in 2023 discussed the usefulness of iPhone applications in podiatry, including diagnostic imaging, measurement instruments, telemedicine applications, and patient education. The study proved that iPhones displayed reliability when measuring angles, evaluating foot and ankle morphology, and taking ulcer images, demonstrating the potential of smartphone applications in managing foot health [7].

REFERENCES

1. Mobile Apps for Foot Measurement in Pedorthic Practice: Scoping Review. JMIR mHealth and uHealth. https://doi.org/10.2196/24202
2. OptiFit: Computer-Vision-Based Smartphone Application to Measure the Foot from Images and 3D Scans. Sensors. https://doi.org/10.3390/s22239554
3. 3D Foot Reconstruction Based on Mobile Phone Photographing. Applied Sciences. https://doi.org/10.3390/app11094040
4. Low-Cost 3D Foot Scanner Using a Mobile App. Footwear Science. https://doi.org/10.1080/19424280.2015.1038308
5. How to Measure Children's Feet: 3D Foot Scanning Compared with Established 2D Manual or Digital Methods. Journal of Foot and Ankle Research. https://doi.org/10.1186/s13047-023-00618-y
6. Assessment of a Smartphone-Based Application for Diabetic Foot Ulcer Measurement. Wound Repair and Regeneration. https://doi.org/10.1111/wrr.12905
7. Exploring the Potential of iPhone Applications in Podiatry: A Comprehensive Review. Egyptian Rheumatology and Rehabilitation. https://doi.org/10.1186/s43166-023-00234-5

PROPOSED METHODOLOGY

Problem Statement

Conventional methods of foot measurement in custom shoes and orthotics are based on manual tools such as rulers and calipers or sophisticated 3D scanners. These are expensive and not mobile, rendering them unusable in most applications. The focus of this project is to create a free smartphone application that utilizes the embedded camera and free open-source software to precisely measure 2D foot dimensions of length and width, avoiding the requirement of special hardware but still ensuring clinical-grade precision.

Data Collection & Preparation

To facilitate development and testing of the algorithms, a prototype dataset will be assembled:

- Foot Images (Approx. 200): Taken with an Android smartphone under a range of lighting and environment conditions. Each image has an A4 paper or a 2 ₹ coin of reference.
- Ground Truth Measurements: Heel to toe manual foot length and ball width of the forefoot measured using digital calipers to validate.
- Detailed Annotation:
- For each image, note down the reference item's pixel size and actual dimensions in centimeters.

70% of the dataset will be used to train, 15% to validate, and 15% to test. The data will be locally stored in JSON.

Image Preprocessing Pipeline

Every image will pass through a standard pipeline:

- Color Adjustment:
    - Convert to RGB.
    - Use histogram equalization on the V-channel in HSV space to even out lighting.
- Reference Object Detection:
    - Convert image to grayscale.
    - Use thresholding and contour detection to identify a rectangular (A4 sheet) or circular (coin) reference object.

    - Take its measurement in pixels and calculate pixel-to-centimeter scale.
- Foot Segmentation:
    - Applying a 5x5 Gaussian blur.
    - Use Canny edge detection.
    - Extract the contours and determine the biggest one that isn't the reference object.
    - Create a binary mask that distinguishes foot from background.

It is first tested on Python and OpenCV before migration to Flutter using opencv4 or Android Studio with Java.

Contour Analysis & Measurement Algorithm

With a clean mask and known scale:

- Bounding box measurement
    - Enclose the segmented foot by a minimum-area rectangle.
    - Extract its width and height in pixels.
    - Convert to centimetres using the scale.
- Landmark-Based Adjustment (Optional):
    - Find points of extreme values along a contour's boundary.
    - Redetermine to make it more accurate.
- Validation:
    - Compare test results to the test dataset.
    - Measure Mean Absolute Error (MAE) and percentage within ±5 mm of true values.

The algorithm lives within a Java or Dart module based solely on OpenCV.

Mobile App Architecture & UI

The Flutter or Android-native application has two screens:

- Capture Screen:
    - Live camera view with foot and reference object guides.
    - "Capture" button takes a picture and initiates analysis.
- Outcome Display
    - It displays length and width in cm.
    - Displays the segmented mask and the reference used for transparency.
    - "Save" saves a JSON-formatted file of image path, results, and timestamp into local storage.

All functions execute offline; no cloud processing.

Performance Evaluation

Assess both technical and end-user perspectives:

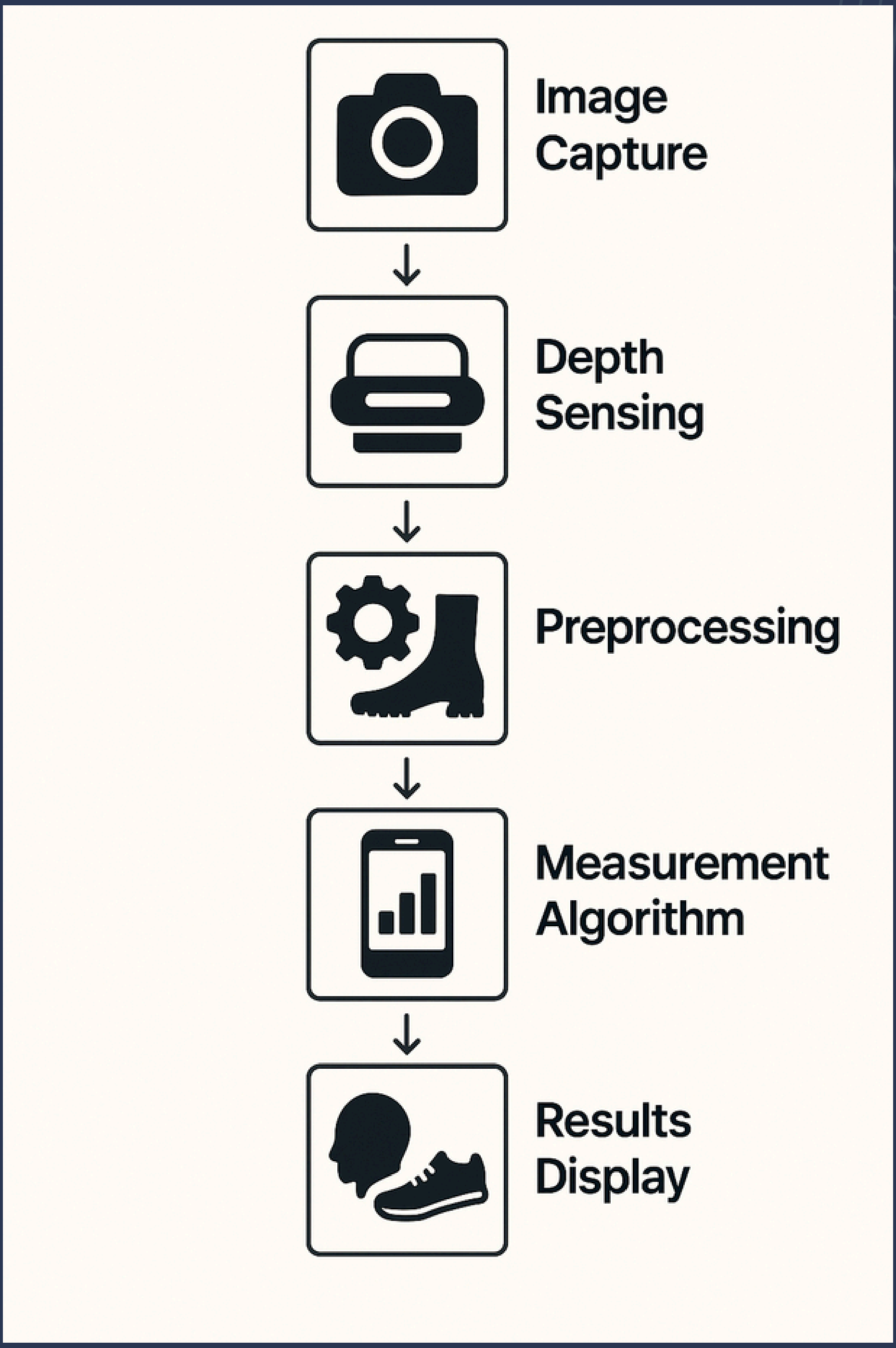
- Precision
  - Calculate MAE over the test set.
  - Report the percentage of values within ±5 mm.
- Runtime:
  - Record the average processing time (goal <1 sec).
  - Assure minimal memory consumption to support middle-end phone compatibility.
- Usability:
  - Obtain feedback from 5–10 end-users on ease of use and results accuracy.

Future Enhancements (Optional)

Once the MVP is solid, improvements could include:

- AI-Based Segmentation: Include a light TensorFlow Lite U-Net model to enhance the segmentation.
- 3D Preview: Allow the use of angled photos and create a mesh in Meshroom as a demo.
- Profile Tracking: Take advantage of JSON profiles to monitor growth or changes over time.
- Export Options: Allow export of measurement logs to CSV or PDF to support business applications.

Block Diagram



KEY INVENTIONS

Invention	Description
SMARTSTEP: A LIGHTWEIGHT AND FULLY OFFLINE FOOT SCANNING APP	This project introduces SmartStep, a fully offline and lightweight mobile application designed to measure foot dimensions using a smartphone camera. Built using Flutter and OpenCV, the app eliminates the need for manual tools or expensive 3D scanners. It runs on-device, does not require internet access, and uses only free, open-source software—making it ideal for educational, research, or resource-constrained clinical settings.
REAL-TIME FOOT SEGMENTATION USING OPENCV	A core part of the application is its ability to isolate the foot from the background in real time. This is achieved using OpenCV's classical image processing techniques, including grayscale conversion, Gaussian blur, Canny edge detection, and contour filtering. The system identifies the largest valid contour as the foot region, providing a clean and efficient method of segmentation without requiring any machine learning or training data.
REFERENCE OBJECT-BASED PIXEL-TO-CENTIMETER SCALING	To convert pixel distances into real-world units, the app uses a reference object like an A4 sheet or a ₹2 coin placed beside the foot. The app detects the reference object using contour area or shape analysis and calculates a pixel-to-cm ratio. This calibration allows users to get accurate foot length and width regardless of device resolution or camera distance.
MEASUREMENT EXTRACTION FROM CONTOUR GEOMETRY	After foot segmentation and scaling, the app calculates the foot length (heel to toe) and width (ball of foot) by fitting a bounding rectangle around the segmented foot mask. These measurements are converted into centimeters using the previously computed scale factor and are displayed directly in the app UI.

USER-CENTERED INTERFACE WITH VISUAL FEEDBACK	The app interface is built in Flutter and includes clear guidance elements such as: • Real-time camera preview • Visual overlay of detected foot boundary • Bounding box on the reference object • Foot length and width shown in centimeters This ensures users can verify whether their foot was correctly detected before accepting a scan, increasing both usability and transparency.
SECURE LOCAL RESULT STORAGE AND HISTORY ACCESS	The application stores measurement data (length, width, date/time) and image references locally using either JSON files or SQLite. Users can review past scans and track changes over time. No data is uploaded or shared externally, ensuring complete offline security and privacy—critical for clinical or personal health data.
OPTIMIZED PERFORMANCE FOR MID-RANGE DEVICES	The entire app is optimized for smooth execution on commonly available Android devices. All processing is lightweight, ensuring that the segmentation and measurement steps can be completed in under one second per capture. There is no use of GPU-intensive models, ensuring low memory and battery usage—ideal for use in clinics, homes, and educational setups.
MODULAR ARCHITECTURE FOR EXTENDABILITY	The codebase is modular, separating camera capture, image processing, measurement, and storage functions. This makes the app easier to maintain, debug, and extend in the future. Potential extensions include: • Arch-height estimation using simple foot shape ratios • Optional AI-assisted segmentation using small on-device models • Exporting reports in PDF/CSV format for clinics or research

KEY TOOLS AND TECHNOLOGIES

TIMELINE

01

Week 1:
Setup, UI Design, and Image Pipeline Prototyping

02

Week 2:
Foot Detection, Reference Calibration, and Initial Integration

03

Week 3:
UI Enhancements, Data Storage, and Testing

04

Week 4:
Final Fixes, Evaluation, and Documentation

FUTURE FEATURES

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