Dorsiflexion Range Of Motion Analyzer

Sheli Zisman and Ron Kroitoro

Supervisors: Dr.Unkelos-Shpigel Naomi &
Dr. Ravid Einat

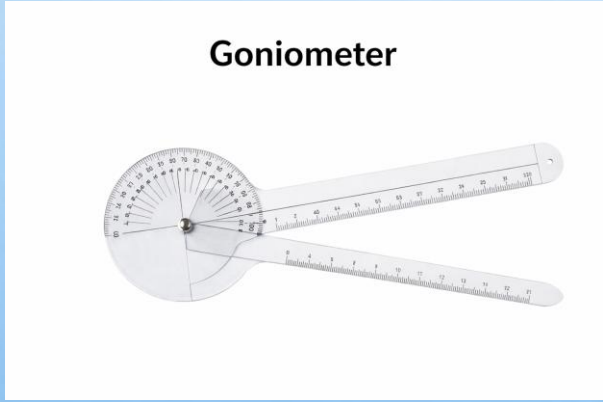
Project Code : 26-1-D-4

The need for our system

The Gap: Traditional dorsiflexion assessment suffers from high inter-rater variability and inconsistent results.

Subjectivity: secudortni stniopyek lacimotana fo noitacifitnedi launaM .rorre namuh

Dependency: Measurements rely on in-clinic evaluations and in expert availability.



The consequences of manual measurement

Liability Risk: Lack of objective data increases malpractice exposure.

Reliability Gap: Significant inter-rater variability and human error.

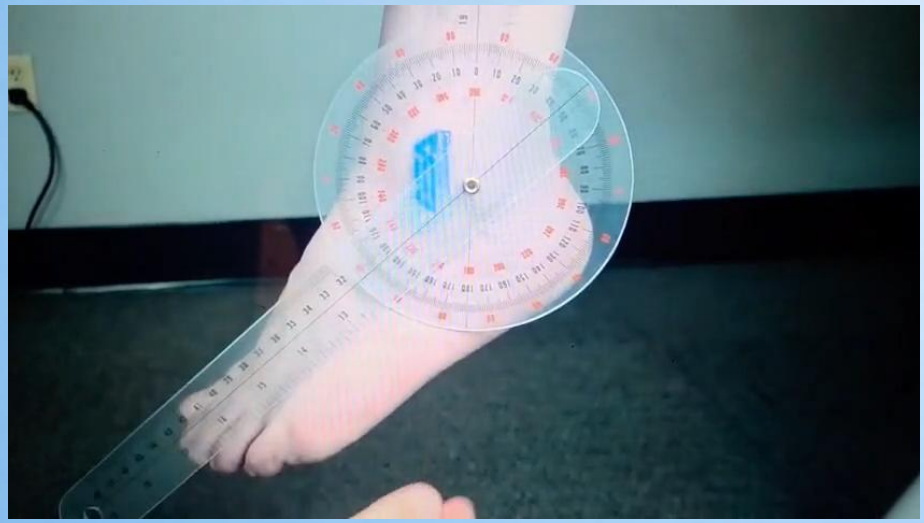
Landmark Challenges: Inconsistent identification due to swelling or lighting.

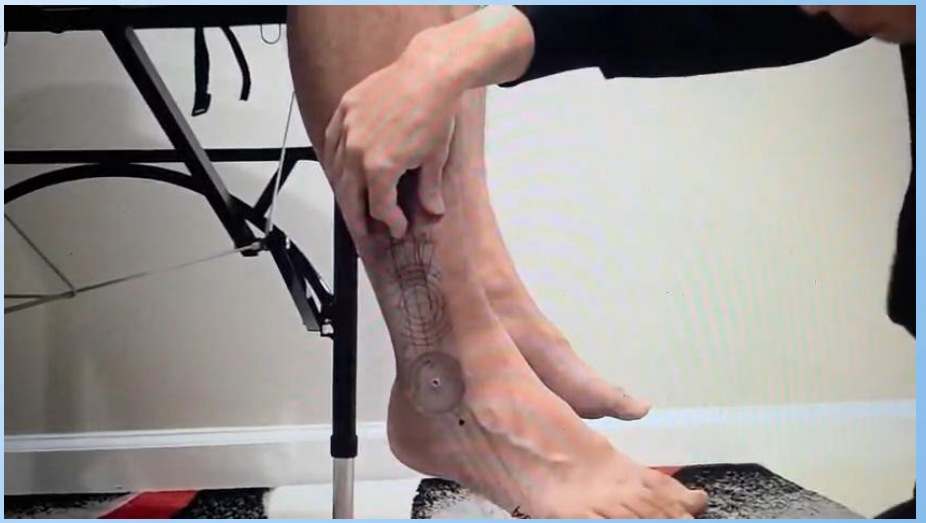
No "Visual Proof": Numerical notes lack verifiable evidence.

Clinical Stakes: Inaccuracies impact surgery and rehabilitation decisions.

1. S. E. Munteanu and C. J. Barton,"Lower limb biomechanics during walking in individuals with restricted ankle dorsiflexion: A systematic review,"Journal of Foot and Ankle Research, vol. 4, Art. 17, 2011
2. N. Collins, P. Teys, and B. Vicenzino,"Reliability of ankle dorsiflexion measurement using different clinical techniques: A systematic review,"Journal of Foot and Ankle Research, vol. 7, Art. 21, 2014
3. C. C. Norkin and D. J. White,Measurement of Joint Motion: A Guide to Goniometry, 5th ed.Philadelphia, PA, USA: F. A. Davis Company, 2016

Lack of Standardization in Manual Goniometric Measurement





The Problem

How can ankle dorsiflexion ROM be measured in an objective and standardized manner to reduce subjectivity and improve clinical consistency?

Interviews

"To be honest, we're so busy that we often just estimate the angle using visual estimation. Even when we do use the goniometer, if you move it just a tiny bit, the result changes completely. It's just not consistent ".

Senior Orthopedic Surgeon *X latipsoH ,.tpeD fo daeH))*

"During dorsiflexion measurement, it is very difficult to accurately identify the correct measurement point, especially when the foot is swollen. Ankle anatomy varies between patients, and the measurement relies heavily on visual estimation and manual goniometry. In practice, this often results in inconsistent measurements and a form of angle 'guessing".'

Orthopedic Resident (Hospital X).

Next-Generation Ankle Assessment

Automated diagnostic tool for precise and objective biomechanical evaluation.

Who:

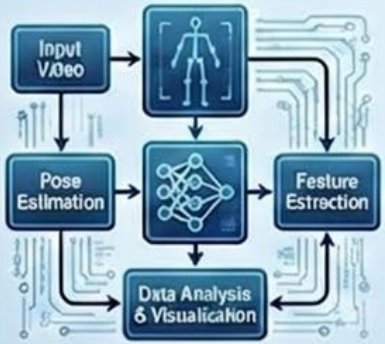
Clinicians, Physiotherapists, and Orthopedic patients.

Mission:

Replacing manual goniometry with objective, AI-driven mobility data.

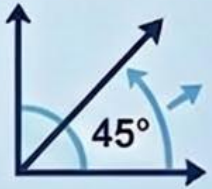
Structure:

Markerless Pose Estimation pipeline utilizing DeepLabCut and ResNet-50.



Tasks:

Real-time keypoint detection, automated angle calculation, and clinical progress tracking.



Our Solution

- **Two-Image Analysis:** ROM is calculated from two images: neutral position and maximum dorsiflexion.
- **Markerless Detection:** DeepLabCut automatically identifies ankle landmarks without markers or manual calibration.
- **Objective Measurement** eulav MOR elbataeper ,dezidradnats A : .noitamitse lausiv evitcejbus secalper
- **Fast Clinical Workflow:** Capture two images and receive an immediate digital result.

System Flow: From Raw Images to Clinical Data

Dual-Image Input

Neutral & maximum dorsiflexion images captured with a smartphone.

AI Engine (DeepLabCut)

DeepLabCut analyzes images to detect landmarks.

Automated Landmark Detection

Accurate, markerless identification of ankle landmarks.

Geometric Logic Engine

Calculates objective angles based on detected landmarks.

ROM Assessment

$$\text{ROM Value} = \Delta\ \text{ROM Value}$$

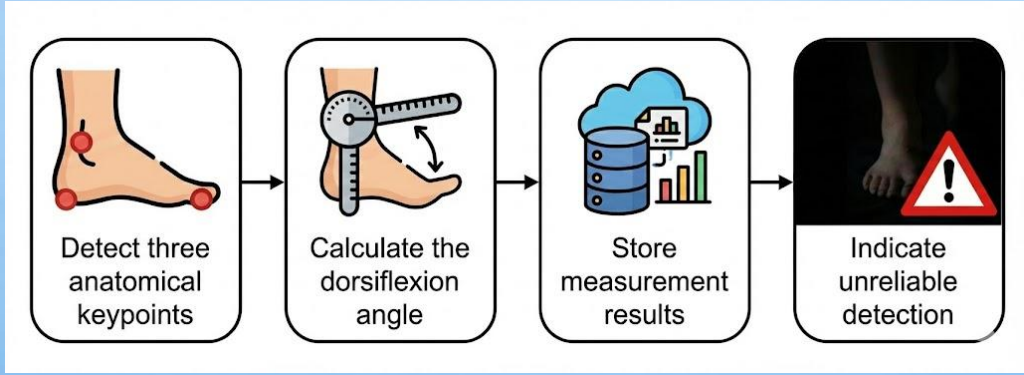
Determines exact ROM by measuring the angle difference.

Final Output

Generates a standardized digital report with ROM value.

Main functional requirements

- Detect **three anatomical keypoints** from a single image.
- Automatically **calculate the dorsiflexion angle.**
- **Store measurement results** for review and comparison.
- **Indicate unreliable detection** (e.g., poor lighting or occlusion).



Main non - functional requirements

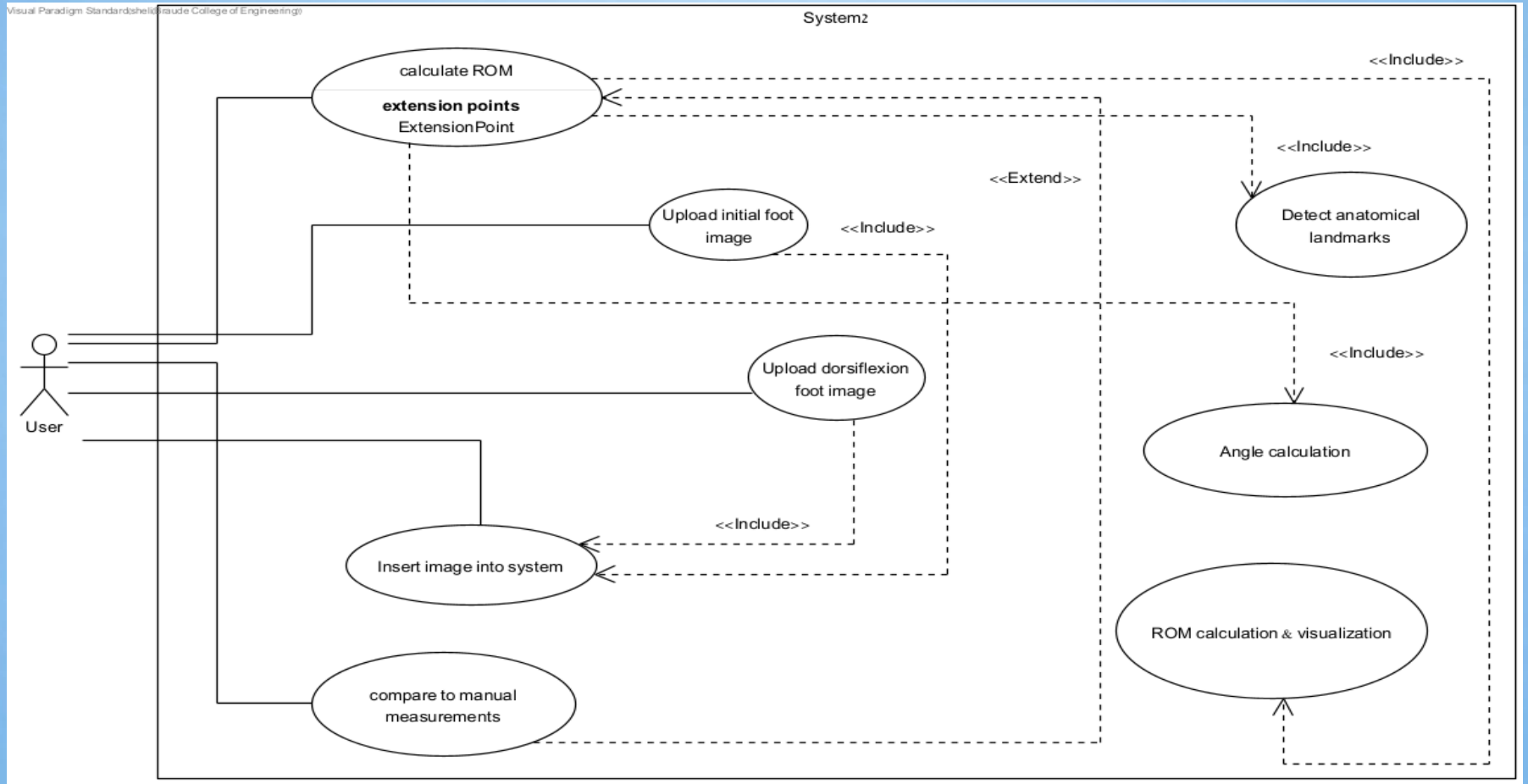
Accuracy: Measurement error of **up to 5°** compared to a clinical goniometer.

Reliability: ≥ 95% successful keypoint detection.

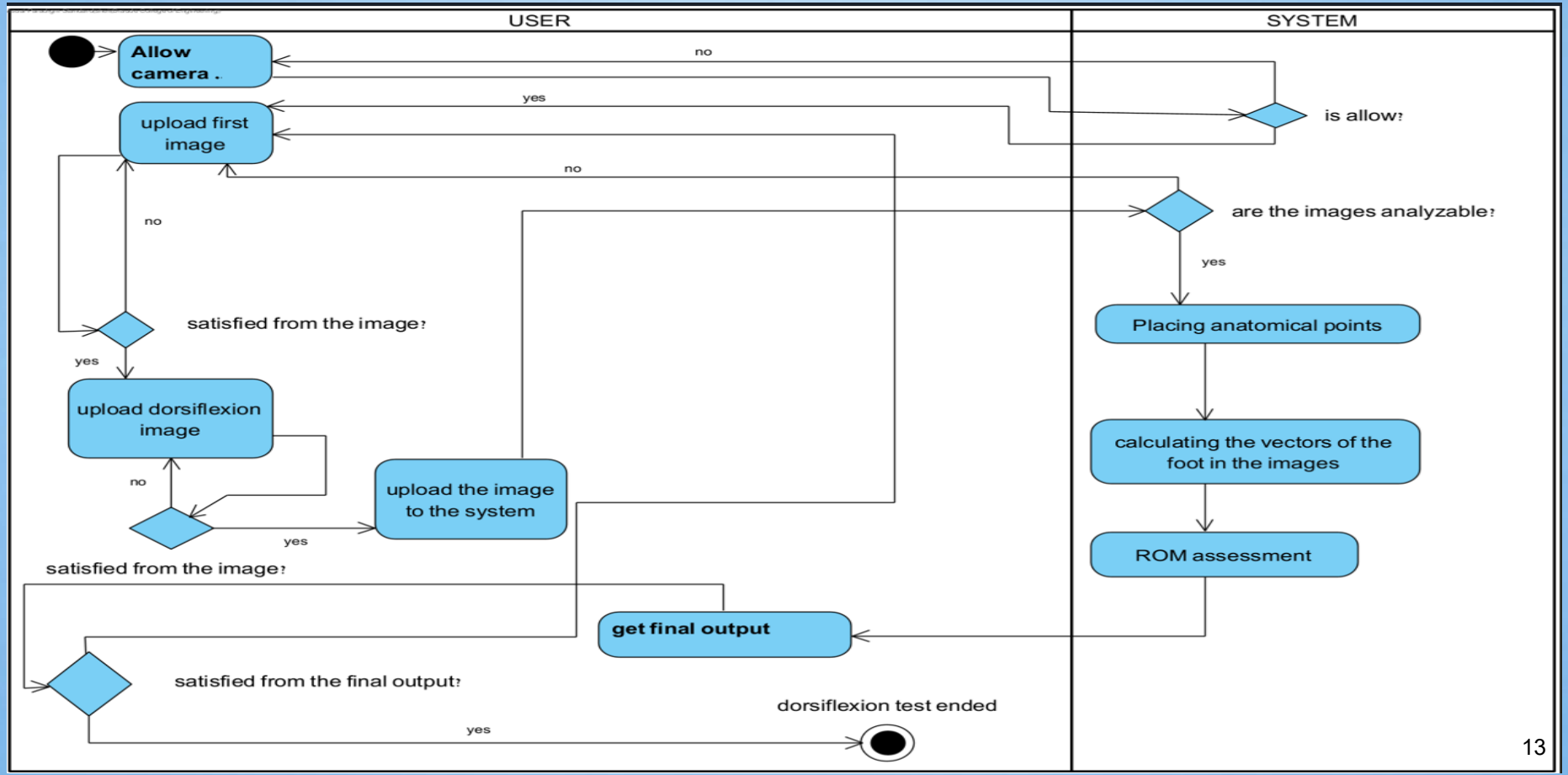
Performance: ≤ 10 seconds per image.

Usability: Full measurement in < 2 minutes for new users.

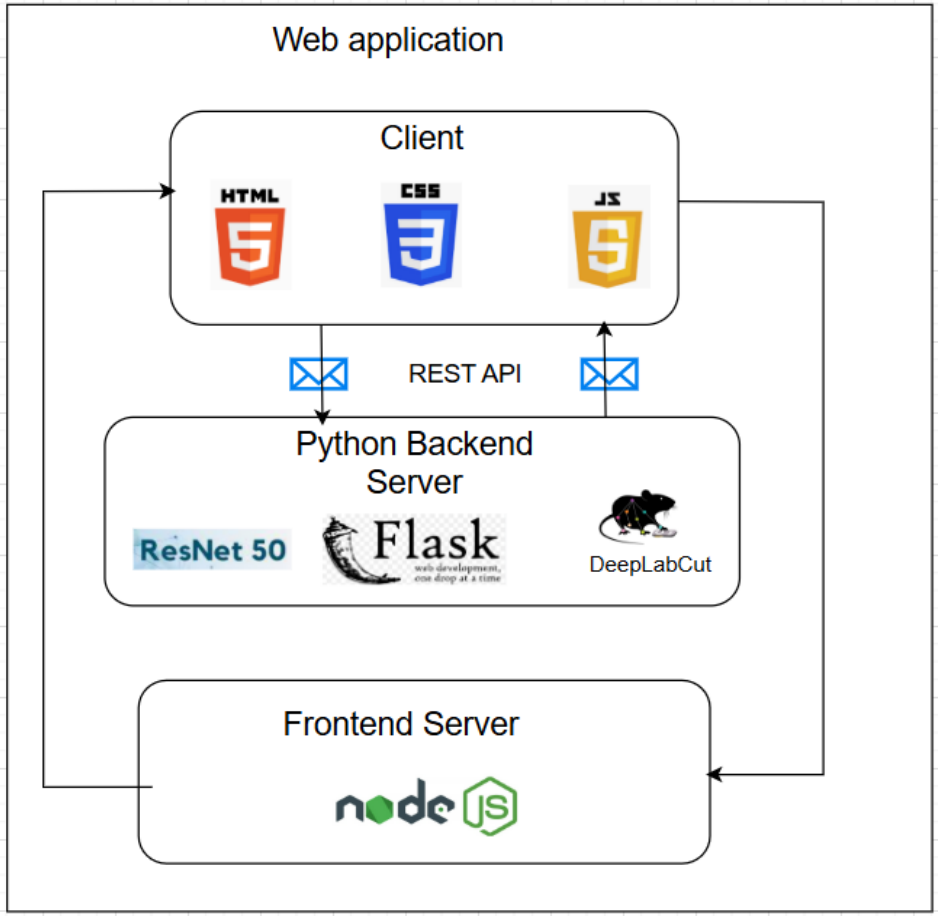
Use - Case diagram

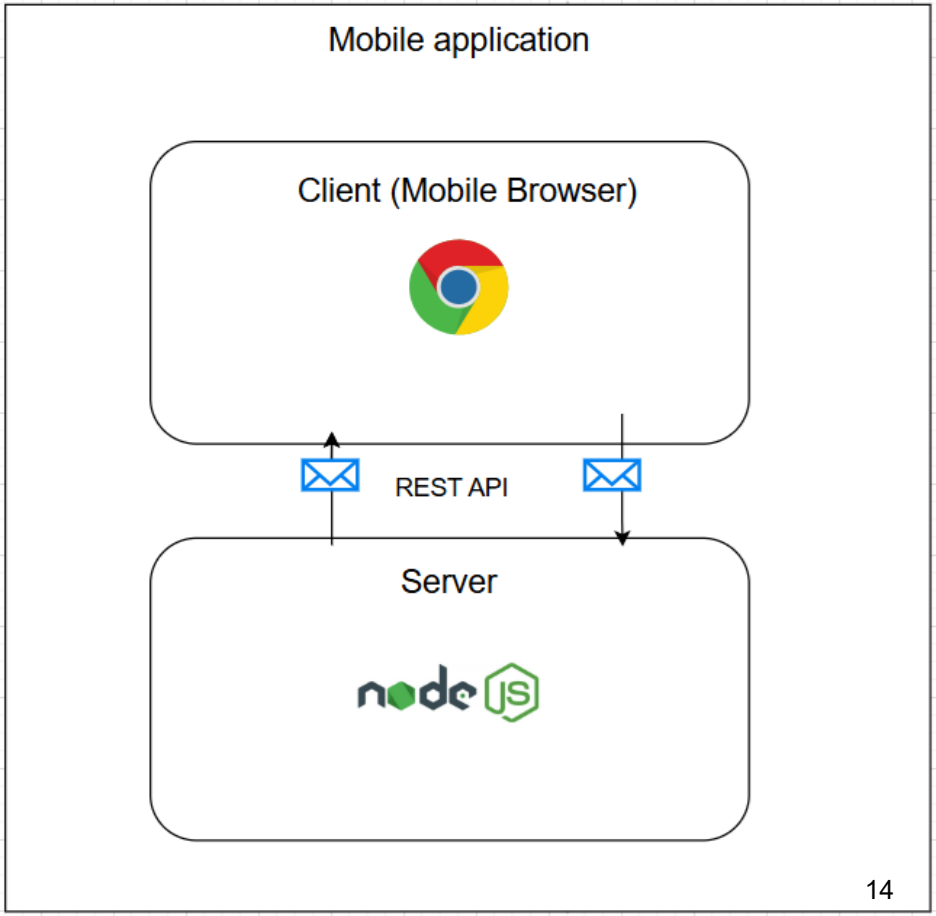


Activity Diagram



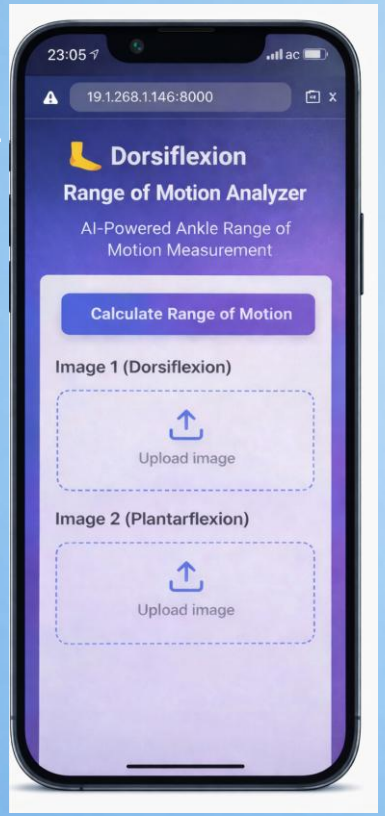
Architecture Diagram

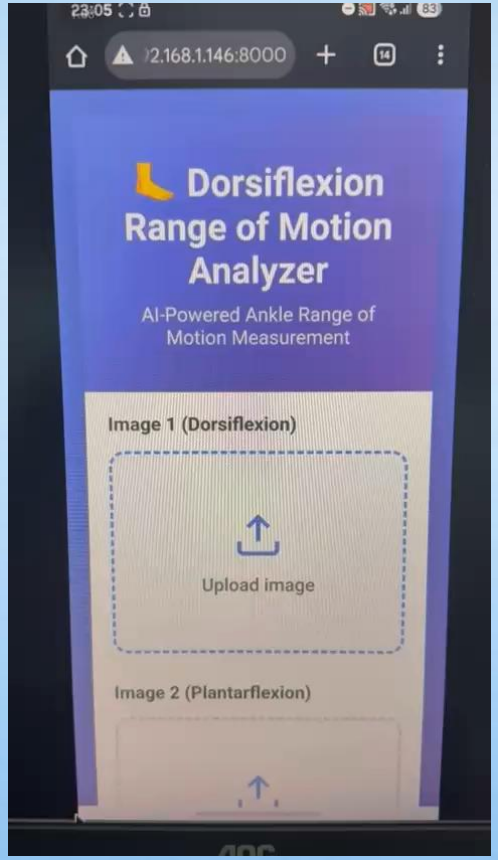




Feature / Method	Our Solution	General AI (e.g. MediaPipe)	Manual Goniometer
Automation (Hands-Free)	✓	✓	✗
Objective Digital Proof	✓	✓	✗
High Clinical Accuracy	✓	✗	✗
Fine-Grain Detection (e.g, 5th Metatarsal)	✓	✗	✗
Remote Assessment Ready	✓	✗	✗

Prototype developed in summer 2025





Expected Achievements

- **Clinical Accuracy** – Standardized measurements with an error of up to 5°.
- **Objective Documentation** – Reliable records for clinical and legal use.
- **Efficient Workflow** – Reduced assessment time in busy clinical settings.
- **Adaptive Landmark Detection** – AI-based identification that handles patient variability.

Challenges of our system

 **Anatomical Variability** – Accuracy across different foot structures.

 **Environmental Robustness** – Stable performance under varying conditions.

 **Clinical Precision** – Measurement error ≥ 5º

 **Data Quality** – Well-annotated clinical images.

Thank You
Questions?