Automated Venipuncture Device

Re-imagining blood collection through robotic precision, computervision and modular design to eliminate trial-and-error punctures and enhance patient safety.

The Challenge

Manual Blood Draws: A Problem of Precision

Manual venipuncture remains fraught with complications. Multiple failed attempts cause patient discomfort, anxiety, and increased infection risk. The challenge intensifies for vulnerable populations for infants, elderly patients, pregnant women, and individuals with darker or low-visibility skin tones where vein detection becomes exponentially more difficult. Each puncture attempt strains the trust between patient and clinician.

The core insight: **precision and trust** are inseparable in clinical care.

Our Vision

We are building a **smart, modular robotic system** that automatically identifies suitable veins, aligns with surgical precision, and performs venipuncture with minimal human intervention for while simultaneously enabling efficient blood sample collection through a modular, adaptable architecture.

Precision

Eliminate guesswork with computer vision

Safety

Reduce failed attempts and complications

Automation

Transform trial-and-error into reliable process

Five-Step System Architecture

01

Wearable NIR Belt

Infrared imaging captures high-contrast vein visualization across all skin tones.

02

Real-Time Processing

Raspberry Pi analyzes image, maps vein geometry, computes optimal puncture coordinates.

03

Precision Alignment

SO100ARM six-axis robotic arm positions needle with micrometer accuracy.

04

Controlled Puncture

Piezoelectric actuator penetrates skin to exact depth for 2-3mm precision.

05

Smooth Extraction

Micro vacuum pumping enables gentle, consistent blood collection.

Layered System Intelligence

Sensing Layer

Wearable NIR belt with infrared LEDs and camera captures stable, high-contrast vein imagery. Anti-shake elastic mount ensurespatientcomfort during imaging.

Processing Layer

Raspberry Pi runs advanced image preprocessing: grayscale conversion, CLAHE enhancement, top-hat filtering, vein skeletonization. System identifies longest continuous vein and selects optimal puncture point (cx, cy).

Control Layer

SO100ARM robotic arm executes inverse kinematics solving via CCD method. Motor commands transmit via Arduino and servo drivers for perfectly aligned tip positioning.

Actuation Layer

Modularend-effectors: piezoelectric puncture head for precise 2-3mm depth control and suction head with mini vacuum pump for consistent blood extraction.

Hardware Components

6-DOF SO100ARM

Industrial-grade robotic arm engineered for medical precision and repeatability.

Raspberry Pi 4B

Real-time controller processing vision data and executing motor commands.

NIR Imaging Module

Infrared camera and LEDs for vein detection across all skin tones.

Piezoelectric Actuator

Precision depth control for safe, accurate skin penetration.

Micro Vacuum Pump

Gentle, consistent blood collection with pressure monitoring.

3D-Printed Mount

Lightweight, modular syringe attachment system for adaptability.

Software Intelligence Stack

Core Modules

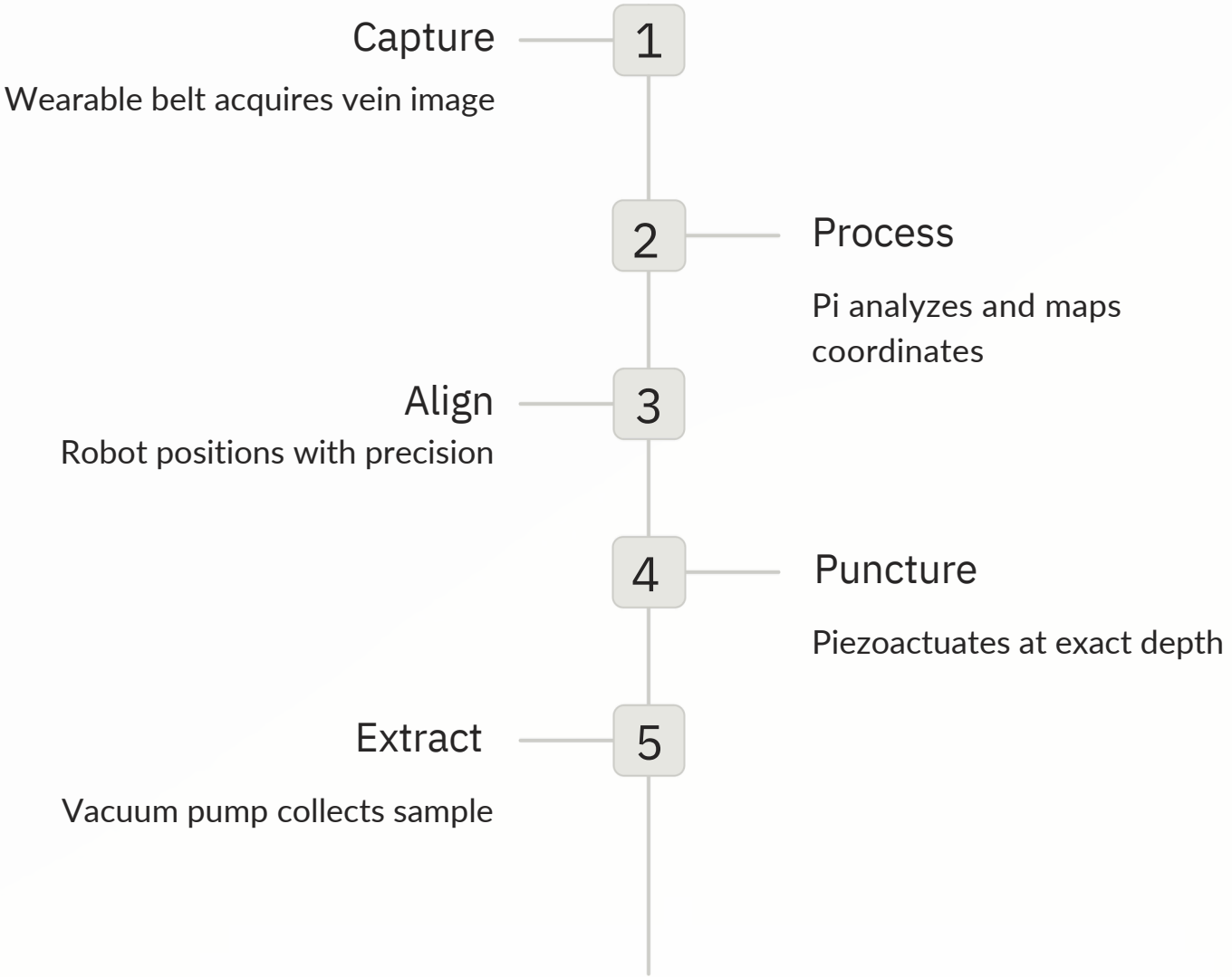
- **Image Acquisition & Enhancement:** Real-time NIR preprocessing with advanced filtering
- **Vein Detection:** Automated identification and optimal puncture point selection
- **Robotic Alignment:** Inverse kinematics computation and trajectory planning
- **Sequence Control:** Coordinated puncture initiation and suction extraction

Technology Foundation

Python · OpenCV · NumPy · PySerial

> We don't guess the vein for we **compute** it with mathematical precision.

Integrated Workflow Demonstration



End-to-end workflow: sensing through actuation, unified by real-time algorithmic control and modular hardware design.

Innovation Breakthrough

Modular Architecture

Dual-attachment end-effectors enable seamless transitions between puncture and collection tasks.

Vision-Robotics Integration

Computer vision directly controls robotic motion for closing the feedback loop between seeing and acting.

CCD-Based Kinematics

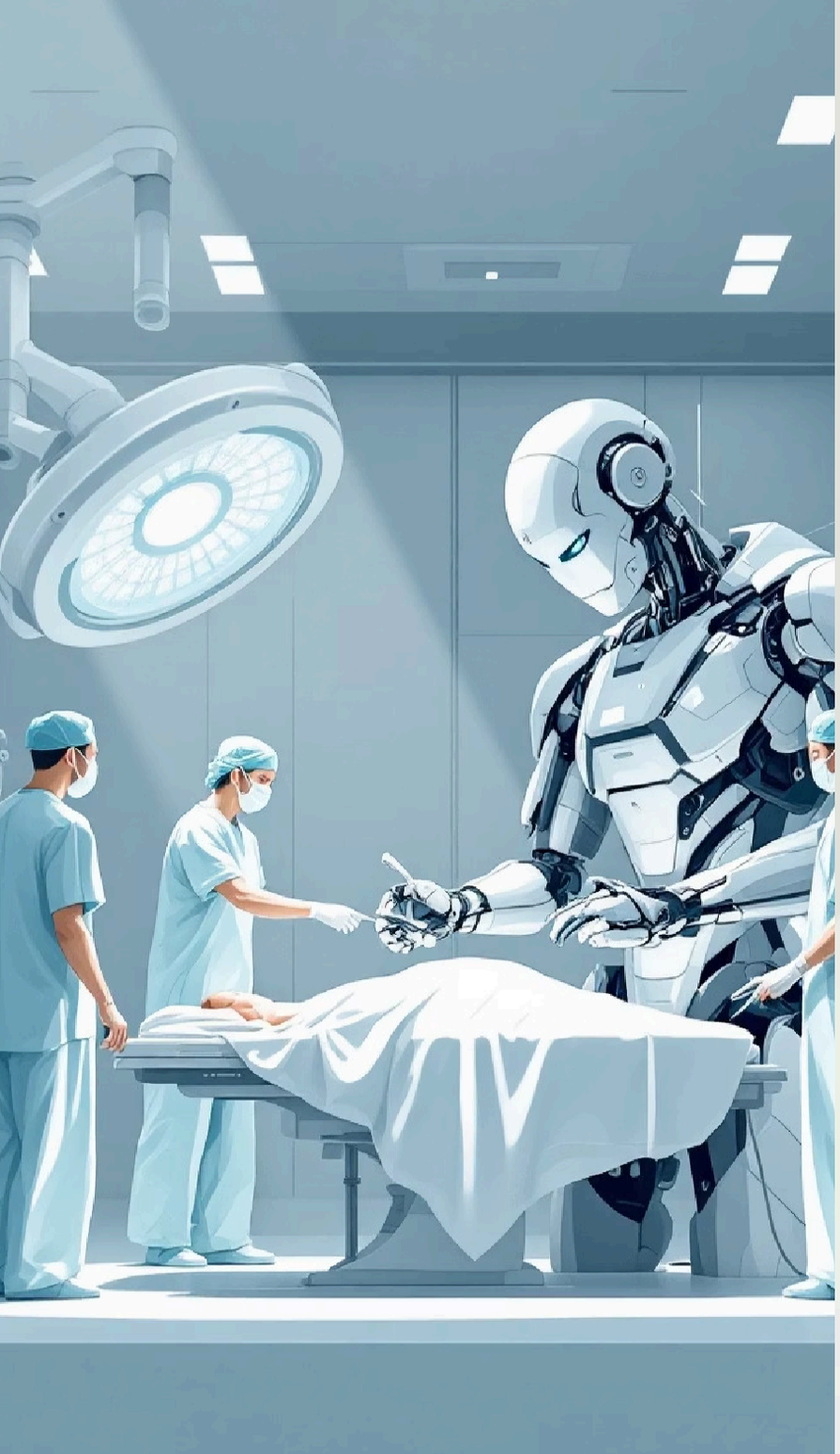
Cyclic Coordinate Descentinverse kinematics delivers human-like precision motion planning.

Piezoelectric Precision

Micro-scale depth control (2-3mm) eliminates complications from over- or under-penetration.

Simulation-Ready Design

Fully modeled and validated before hardware deployment for reducing clinical risk and accelerating adoption.



Future Clinical Expansion

MachineLearningIntegration

Autonomous vein classification and adaptive puncture strategy refinement through clinical datasets.

Depth Sensing Enhancement

Integrated tactile sensors provide real-time feedback for safer, more confident puncture decisions.

Portable Wireless Platform

Battery-powered, wireless-enabled version extends access to rural clinics and resource-limited settings.

Surgical Expansion

Adaptable architecture enables deployment in ENT and specialized surgical procedures requiring precision vascular access.

MOM_Meet_1

With: Sadhya Healthcare Pvt. Ltd., Ahmedabad
Date: 14/09/2025
Attendees: AutoVenipuncture Team & Mr. Mrunal (Director, Sadhya Healthcare)

Discussion & Appreciation

Sadhya Healthcare appreciated the innovation and vision behind the Automated Venipuncture System.

They expressed strong interest in becoming an official partner for further development and validation.

The team affirmed that such a device is highly needed in the medical sector and assured full technical and infrastructural support whenever required.

MOM_Meet_2

With: Sadhya Healthcare Pvt. Ltd., Ahmedabad
Date: 14/09/2025
Attendees: AutoVenipuncture Team & Mr. Mrunal (Director, Sadhya Healthcare)

Suggestions & Future Plan

Advised to continue development without NIR technology for now; Sadhya Healthcare will arrange NIR setup and medical equipment by early 2026.

Recommended a design modification — replacing the CNC plotter-style mechanism with a more robust, adaptable structure suitable for both seated and lying patients.

Suggested introducing advanced robotics to make the device multi-functional for broader medical applications in future collaborations.