Table of Bio-Limb

Abstract

The project proposes the development of an autonomous robotic system designed for safe and efficient medical sample collection. Utilizing advanced machine learning (ML) and artificial intelligence (AI) technologies, the robot is capable of collecting various samples, such as saliva, blood, and diagnostics for diseases like AIDS and other infectious diseases. The user specifies the type of sample and the location for collection, and the robot handles the entire process with high accuracy and minimal human intervention. The system not only improves the safety of healthcare workers but also ensures precise and reliable sample collection, addressing the need for a scalable, efficient, and safe solution in modern healthcare.

Manual sample collection in healthcare environments exposes both healthcare workers and patients to significant risks. Each year, 3 million healthcare workers globally suffer from needlestick injuries, leading to infections like HIV, hepatitis B, and hepatitis C. The risks are especially pronounced in low- and middle-income countries, such as Bangladesh, where inadequate safety protocols and limited protective equipment make the situation worse. Up to 14% of healthcare workers in high-risk environments experience sharps injuries annually, with a higher likelihood in regions lacking proper safety training. Furthermore, manual sample collection is prone to errors such as mislabeling, contamination, and improper storage, particularly when performed by inexperienced staff. Studies indicate that up to 68.2% of all laboratory errors occur during the preanalytical phase, leading to delayed diagnoses, incorrect treatments, and compromised patient safety.

Robotics, along with machine learning and artificial intelligence, provides a safer and more accurate option by automating sample collection to reduce infection risks, human errors, and ensure precise sample handling and storage.

The robotic system will automate the entire sample collection process, ensuring safety and accuracy for both patients and healthcare workers. It utilizes AI and ML to offer the following:

1. High Accuracy: The robotic system operates with 90-95% accuracy, surpassing the capabilities of human operators. This reduces the risk of contamination, mislabeling, and improper handling of samples, ensuring better diagnostic outcomes.

2. Autonomous Navigation and Collection: The robot autonomously moves to the designated location, collects the sample (e.g., saliva or blood), and ensures proper storage with minimal human intervention. This decreases the chances of healthcare workers being exposed to infectious diseases.

3. Eliminating Human Experience Barriers: Unlike humans, robots do not need experience to perform tasks effectively. In healthcare systems, where there may be a shortage of skilled workers, this technology ensures consistent and precise performance, regardless of staff experience levels.

4. Superior Image Processing: The robot's image processing capabilities are more precise than the human eye, enhancing its ability to accurately identify the correct sample collection sites. This reduces the chance of errors in sample acquisition and increases the reliability of the process.

5. AI-Powered Learning: As the robot collects more samples, it learns from each task, improving its performance over time, optimizing its efficiency, and adapting to various medical requirements.

The value of the robotic solution includes improved patient safety, enhanced worker safety, reduction in human error, increased throughput and efficiency, and cost efficiency. In real-world scenarios, this robotic

solution offers safer and faster sample collection processes for healthcare facilities. In developing countries, where safety protocols and experienced healthcare workers may be lacking, this system can eliminate the dangers associated with infectious sample collection, ensuring accurate and timely testing.

Problem Statement

Manual sample collection in healthcare environments poses substantial risks to both healthcare workers and patients. Annually, approximately 3 million healthcare workers globally suffer from needlestick injuries, leading to severe infections such as HIV, hepatitis B, and hepatitis C. These risks are particularly acute in low- and middle-income countries like Bangladesh, where inadequate safety protocols and limited protective equipment exacerbate the situation. In high-risk environments, up to 14% of healthcare workers experience sharps injuries each year, with a higher incidence in regions lacking proper safety training.

Moreover, manual sample collection is highly susceptible to errors, including mislabeling, contamination, and improper storage, especially when conducted by inexperienced staff. Studies reveal that up to 68.2% of all laboratory errors occur during the preanalytical phase, resulting in delayed diagnoses, incorrect treatments, and compromised patient safety.

Additional Statistics and Information:

According to the World Health Organization (WHO), needlestick injuries account for 40% of hepatitis B and C infections and 2.5% of HIV infections among healthcare workers globally.
In low- and middle-income countries, the rate of needlestick injuries is significantly higher due to the lack of resources and training.

The Centers for Disease Control and Prevention (CDC) estimates that 385,000 needlestick injuries occur annually among hospital-based healthcare workers in the United States alone.

A study published in the Journal of Clinical Pathology found that preanalytical errors, such as incorrect sample handling and labeling, contribute to 46-68% of all laboratory errors.

By integrating robotics with machine learning and artificial intelligence, this solution offers a safer, more accurate, and efficient alternative to manual sample collection, ultimately improving patient outcomes and healthcare worker safety.

Robotics Solution

This project proposes the development of an autonomous robotic system designed for safe and efficient medical sample collection. Utilizing advanced machine learning (ML) and artificial intelligence (AI) technologies, the robot is capable of collecting various samples, such as saliva, blood, and diagnostics for diseases like AIDS and other infectious diseases. The user specifies the type of sample and the location for collection, and the robot handles the entire process with high accuracy and minimal human intervention. The system not only improves the safety of healthcare workers but also ensures precise and reliable sample collection, addressing the need for a scalable, efficient, and safe solution in modern healthcare.

Key Features

1. High Accuracy: The robotic system operates with 90-95% accuracy, surpassing the capabilities of human operators. This reduces the risk of contamination, mislabeling, and improper handling of samples, ensuring better diagnostic outcomes.

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How Your Solution Aligns with the Season Theme

The Earth Allies prioritize protecting human health and the environment. The robotic system helps reduce risks for healthcare workers and enhances the precision of medical diagnostics. This support is particularly important for global health in underserved regions. The system also decreases needlestick injuries and exposure to infectious diseases, leading to improved working conditions for medical staff. These efforts align with Earth Allies' mission to safeguard human welfare.

Availability of Similar Concepts

There are several similar concepts and developments in the field of disease sample collection robots, each aiming to enhance safety, accuracy, and efficiency in healthcare settings. Here are some notable examples:

Robot-Assisted Swab Sampling Systems:
Researchers have developed telerobotic systems for untact (non-contact) swab sampling to prevent infection of medical staff during upper respiratory sample collection. These systems use a slave robot controlled remotely by an operator to insert and remove swabs, ensuring precise and safe sample collection1.

Clinical Laboratory Robots:
Companies like Yaskawa's Motoman offer robotic systems for laboratory testing and processing. These robots manage the workflow of specimens through pre- and post-analytic sequences, improving speed, capacity, and accuracy2.

Tele-Nursing Robots:
Tele-nursing involves using robots controlled remotely by human nurses to perform patient care tasks. These robots can handle various tasks, including sample collection, reducing the risk of infection and conserving personal protective equipment (PPE)3.

Marine Robotics for Specimen Collection:
Although primarily used in marine biology, underwater robots equipped with advanced grippers and sensors demonstrate the potential for precise and delicate sample collection. These technologies can be adapted for medical applications to ensure accurate and contamination-free sample handling4.

Origami Paper Sensors:
While not a robot, this innovative approach uses origami paper sensors to detect diseases in water samples. The sensors can be analyzed using a smartphone, providing a rapid and cost-effective method for disease detection5.

The examples above showcase the increasing interest and advancements in robotic systems for medical sample collection. Each contributes to safer, more efficient, and more accurate healthcare practices. However, these robots are developed for specific purposes and are very difficult to maintain. We are working on an all-in-one solution. By utilizing our technologies, healthcare providers can significantly reduce the risks associated with manual sample collection and improve overall patient care.

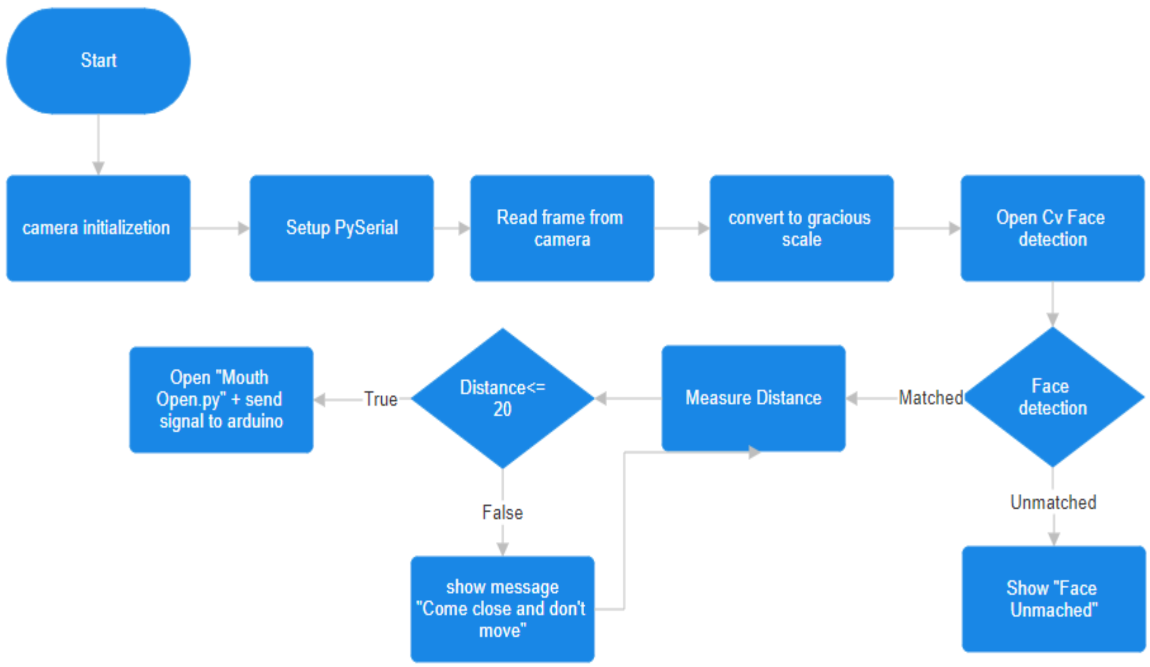
Mechanical Structure Explanation

Tools and technology:

Name	Quantity
Arduino Mega	1
Mg995 Servo	6
6dof arm	1
max30100	1
lcd display 16/2	1
UV light	5
USB web cam	1
step down	1
light on power	1
wire	
female jack	1
Raspberry Pi	1

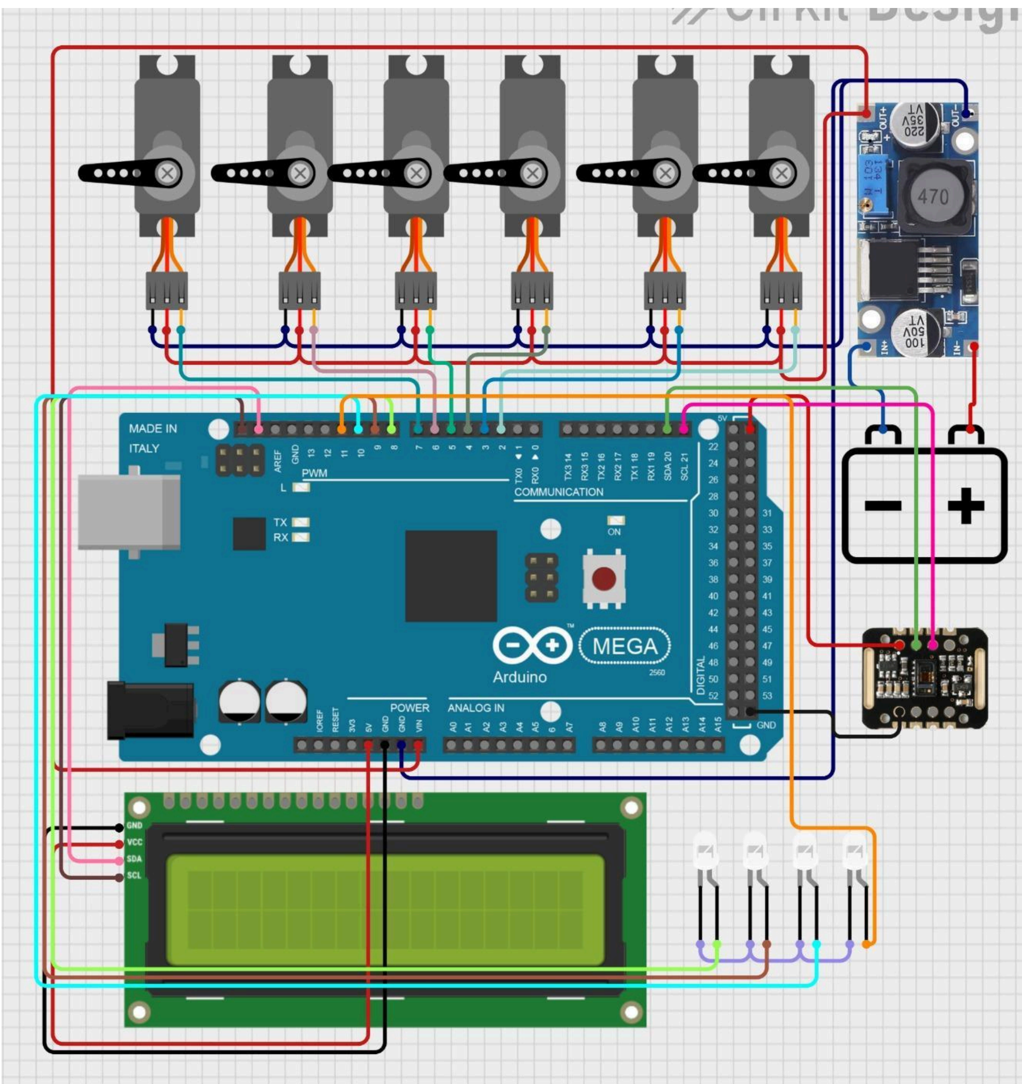
If The camera detected Human Face under its range then it give voice to put his finder on the max30100 sensor. The sensor collects blood rate from the finger of the human & whenever the patient detect then the robot starts. Detection patient mouth by ML technology it gives signal to Arduino MEGA . Then Arduino mega prosses it and send PWM signal to the servo motors so that they can move smoothly & Collect cotton buds and put it down on the mount of the patient to collect the selaiva (samples) then put the cotton buds on the packet. In the time, Arduino Gets input from 30100 Sensor & gives command on 16*2 LCD display . There's also a UV light to kill germs.then Arduino prosses every data and send processed data to Micro Prossesor for output

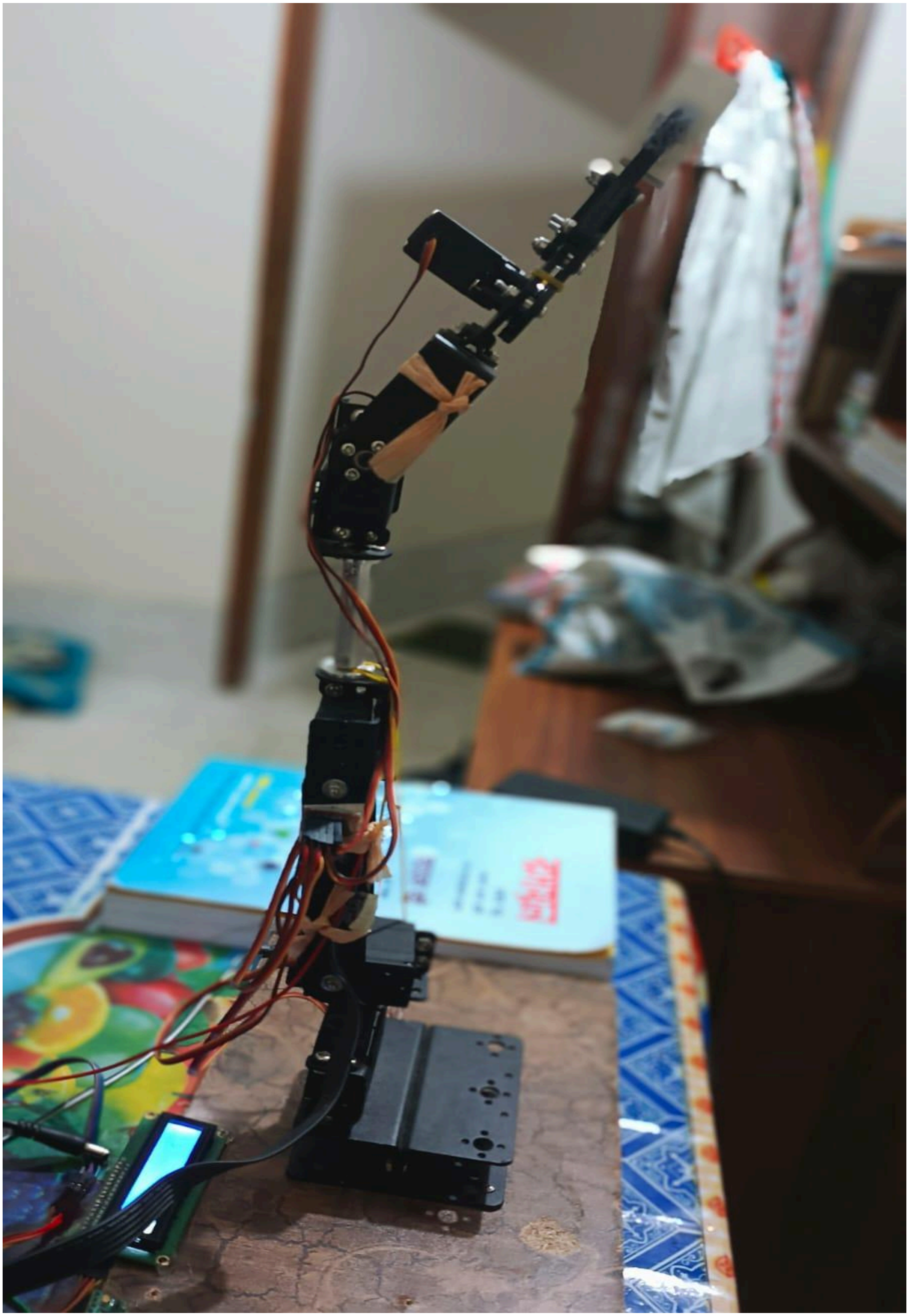
Flowchart:



Start
camera initializetion
Setup PySerial
Read frame from camera
convert to gracious scale
Open Cv Face detection
Face detection
Matched
Unmatched
Show "Face Unmached"
Measure Distance
Distance<= 20
True
Open "Mouth Open.py" + send signal to arduino
False
show message "Come close and don't move"

Circuit Diagram:





Coding Explanation

Algorithmic Brief of the Autonomous Medical Sample Collection Robot

1. **Initialization & Setup**:
   - **Camera Setup**: Use OpenCV to initialize the camera for real-time video feed.
   - **Machine Learning Models**:
     - Load models for face detection and landmark identification using dlib and OpenCV.
     - Configure distance measurement from camera using focal length and reference image dimensions.
     - Define hardware components, such as Raspberry Pi GPIO, serial communication, and sound feedback systems.
2. **Distance Measurement Algorithm**:
   - **Input**: Real-time video feed from the camera.
   - **Face Detection**: Use a pre-trained Haar Cascade model to detect the face in the frame.
   - **Face Width Calculation**: Calculate the face width in pixels.
   - **Distance Calculation**:
     - Use the formula: Distance=(Real Face Width×Focal LengthFace Width in Frame)\text{Distance} = \left(\frac{\text{Real Face Width} \times \text{Focal Length}}{\text{Face Width in Frame}}\right)Distance=(Face Width in FrameReal Face Width×Focal Length)
     - Trigger specific commands via serial communication based on proximity.
3. **Facial Landmark Detection for Mouth State**:
   - **Input**: Video frame.
   - **Detection**: Utilize dlib's HOG-based face detector to detect facial landmarks.
   - **Mouth Landmark Calculation**: Extract the Euclidean distance between landmarks 51 and 57 to determine if the mouth is open.
   - **Action Based on Mouth State**:
     - If the mouth is open for more than a threshold time, send an 'MO' command via serial communication.
     - If the mouth remains closed, prompt the patient with audio feedback to open their mouth and send an 'MC' command.
4. **Patient Monitoring & Command Execution**:
   - Continuously monitor patient proximity and mouth status.
   - Adjust responses dynamically based on proximity and facial state:
     - If the patient is within a certain distance threshold, play a sound alert and send commands.
     - Loop continuously to check for patient behavior or specific medical commands (e.g., sample collection, assistive functions).
5. **Sample Collection Procedure**:

    - **Navigation**: Use autonomous navigation algorithms to move the robot to the patient's location.
    - **Sample Collection**:
        - Identify and localize the target area (e.g., mouth, arm) using computer vision.
        - Deploy an appropriate collection mechanism (saliva, blood, etc.) based on input type and location.
        - Store the sample safely and label it using internal systems.
6. **Safety & AI-Powered Learning**:
    - Use reinforcement learning to improve over time, optimizing efficiency and reducing potential errors in sample collection.
    - Implement safety checks to prevent human errors and ensure the system can safely abort tasks in case of discrepancies.

Key Features:

- **High Accuracy**: Operates at a 90-95% accuracy rate.
- **Autonomous Navigation**: Moves and collects samples without human intervention.
- **Adaptive Learning**: Uses AI to improve with each task, ensuring better outcomes over time.
- **Superior Image Processing**: Outperforms human capabilities in recognizing and tracking required areas for sample collection.

This algorithm leverages AI and ML for efficient medical sample collection, ensuring patient and healthcare worker safety, especially in resource-constrained environments like Bangladesh.

Challenges Faced During the

The development of the sample-collecting robot in Bangladesh presented several significant challenges due to the country's developing status and limited access to high-quality components. Key difficulties included:

1. **Limited Availability of Components**: The local market for advanced electronic and robotic components in Bangladesh is underdeveloped, necessitating the import of critical parts. This led to delays and higher costs associated with shipping and procurement.

2. **High Cost of Components**: The components that were available locally were often priced significantly higher than international rates, making it difficult to adhere to budgetary constraints. For example, the cost of a Raspberry Pi 4B with 8GB RAM, initially priced at $95, escalated to $195 after taxes and import fees, adding financial strain to the project.

3. **Prevalence of Duplicate Components**: Another challenge was the influx of third-party or duplicate components in the market. These counterfeit products often performed poorly, leading to inefficiencies in the project and requiring multiple replacements, further increasing costs and causing delays.

4. **High Import Taxes and Duties**: The high taxes on imported goods added to the overall expense of the project. Critical components like the Raspberry Pi 4B were subject to substantial taxes, with the import cost nearly doubling the original price.

5. **Fund managing**: Managing funds is often challenging, and self-funding is usually the only option.

6. **Long Import Delays**: Relying on imported components meant dealing with significant delays in procurement. The shipping process, customs clearance, and other logistical barriers could extend the delivery time by weeks or even months. This unpredictability hindered progress and slowed down key phases of the project, such as assembly and testing.

7. **Alternative Supplier Search**: To manage costs and minimize delays, we continuously sought alternative suppliers and planned ahead to avoid project disruptions.

Social Impact of Our Robot

1. Improved Patient Safety: With high accuracy and advanced image processing, the robotic system ensures precise and minimally invasive sample collection, reducing discomfort and the potential for errors that could affect patient health.

2. Enhanced Worker Safety: Healthcare workers, particularly those handling infectious diseases, face fewer risks of contracting infections. Automating sample collection significantly reduces the possibility of needlestick injuries or direct contact with contaminated samples.

3. Reduction in Human Error: The machine’s image processing and AI capabilities outperform human operators, eliminating the variability and errors that inexperienced healthcare workers might introduce. This improves the overall reliability and accuracy of test results.

4. Increased Throughput and Efficiency: With automated sample collection, healthcare facilities can manage larger volumes of tests in less time, accelerating diagnostics and treatment, particularly in high-demand situations like pandemics.

5. Cost Efficiency: By reducing the need for highly skilled personnel and minimizing errors, healthcare providers can cut operational costs and enhance overall efficiency, especially in resource-limited settings.

Practical Use

In real-world scenarios, this robotic solution offers safer and faster sample collection processes for healthcare facilities. In developing countries, where safety protocols and experienced healthcare workers may be lacking, this system can eliminate the dangers associated with infectious sample collection, ensuring accurate and timely testing without putting healthcare staff or patients at unnecessary risk.

During crises like the COVID-19 pandemic, the robotic system could significantly alleviate the burden on healthcare systems by handling a high volume of tests efficiently and reducing the exposure risk for healthcare workers. The reduced reliance on experienced staff and the increased accuracy of the robot’s image processing and AI functionalities would improve patient outcomes and diagnostic reliability across diverse healthcare environments.

Robot Mission

The mission of this project is to revolutionize medical diagnostics by developing an autonomous robotic system that ensures safe, accurate, and efficient sample collection. Through the integration of advanced machine learning (ML) and artificial intelligence (AI), the project aims to protect healthcare workers, enhance patient safety, and reduce human error. By providing a scalable and cost-effective solution, the project seeks to improve access to reliable diagnostics in both developed and resource-limited healthcare settings, ultimately advancing global healthcare outcomes.

Entrepreneurship Aspects

1. **Innovative Solution in an Untapped Market**: In Bangladesh, there is currently no device like this autonomous robotic system for medical sample collection. This presents a unique opportunity to introduce groundbreaking technology in a market that has yet to explore such solutions, offering a competitive advantage as a first mover.
2. **Opportunity in Lower Middle-Income Countries**: Bangladesh, along with other lower middle-income countries, faces significant challenges in healthcare infrastructure, including shortages of skilled healthcare workers and inadequate safety protocols. Introducing this technology provides an opportunity to fill these critical gaps with affordable, efficient, and safe solutions.
3. **Affordability for Lower-Income Populations**: By reducing the reliance on highly trained staff and minimizing errors, the robotic system can help lower the costs of diagnostic services, making healthcare more affordable and accessible to lower middle-income populations. This is especially valuable in countries like Bangladesh, where healthcare resources are often strained.
4. **Scalable for Remote and Underserved Areas**: The robotic system can be particularly beneficial in remote areas of Bangladesh and similar countries, where healthcare facilities are limited. With the ability to automate sample collection, the robot can help bring essential healthcare services to regions that may otherwise be underserved.
5. **Potential for Public-Private Partnerships**: In Bangladesh, this project could attract collaboration with government healthcare initiatives, NGOs, and private healthcare providers. Such partnerships can help scale the project across the country and even expand it to neighboring regions with similar healthcare challenges.
6. **Job Creation in Emerging Technology Fields**: While automating sample collection, the development, production, and maintenance of such robotic systems will create new opportunities in Bangladesh in the fields of robotics, AI, and healthcare technology, helping to grow the country’s tech ecosystem.
7. **Social Impact on Public Health**: With no current alternative in the region, the introduction of this robotic system could significantly reduce healthcare worker injuries, improve patient safety, and lead to more accurate diagnoses. This innovation addresses crucial public health concerns and enhances the overall healthcare quality in the country.
8. **Opportunity for Export**: Given that lower middle-income countries worldwide face similar challenges, Bangladesh could become a hub for developing and exporting this technology to other nations in South Asia, Africa, and beyond, creating new revenue streams and international collaborations.

This project aligns with the healthcare needs of Bangladesh and similar countries, offering an affordable and scalable solution that has the potential to transform healthcare systems and create a lasting impact.

Future Scopes and Improvements

The future scope of this autonomous robotic medical sample collection project is vast, with the potential to revolutionize healthcare systems both locally and globally. There is a wide scope for advancement since robotics is not yet widely utilized in this field.

- Accuracy increasing
- Developing Sample analyzing feature
- We can enhance the device's speed through the implementation of improved hardware and the optimization of the algorithm.
- Our current system is designed to detect saliva-based diseases, and we are actively conducting testing for diabetes. We are confident that we will be able to integrate sample collection methods for a wide range of diseases in the near future.
- Market opportunities are huge due to it’s performance and feature

Business canvas Model

Key Partners	**Key Activities**	**Value Propositions**	**Customer Relationships**	**Customer Segments**
• Who are our key partners? Ans: No One yet • Who are our key suppliers? Ans: We have no specific supplier • Which Key Resources are we acquiring from partners? Ans: Non • Which Key Activities do partners perform? Ans: Non	• What Key Activities do our Value Propositions require? Ans: (a) Sample collection for diseases (b) Sample packaging (c) Performance upgrading • Our Distribution Channels? Ans: B to B, B to G • Customer Relationships? Ans:Dedicated Support, Training & Onboarding, Remote Monitoring & Assistance. **Key Resources** • What Key Resources do our Value Propositions require?	• What value do we deliver to the customer? Ans: (a) Safe and efficient robotic sample collection experience for patients and nurses. reducing infection risk and improving accuracy. • Which one of our customer’s problems are we helping to solve? Ans: Protects healthcare workers from infections and prevents errors	• What type of relationship does each of our Customer Segments expect us to establish and maintain with them? Ans: Customers expect reliable support, training, and maintenance services to ensure smooth operation of the robotic system. • Which ones have we established? Ans: Non • How are they integrated with the rest of our business model? Ans: Non • How costly are they? Ans: The complete product will cost approximately 30000$. The current prototype costs 105$	• For whom are we creating value? Ans: Healthcare facilities, hospitals, diagnostic centers, and clinics in both developed and developing countries. • Who are our most important customers? Ans: Hospitals, diagnostic centers, and healthcare providers in regions with high infection risks and limited healthcare

<table>
<tr>
<td></td>
<td>Ans: AI and ML technologies, robotics hardware, sensors, and image processing systems for accurate sample collection.

● Our Distribution Channels?
Ans: Partnership with healthcare suppliers, Hospitals, and Diagnostic Center.

● Customer Relationships?
Ans: Technical support team, AI-powered maintenance, Training and registered valid license.</td>
<td>in manual sample collection.

● What bundles of products and services are we offering to each Customer Segment?
Ans: Autonomous robotic system, AI software, installation, training, and support.

● Which customer needs are we satisfying?
Ans: Ensures safety, accuracy, risk reduction, and efficiency in high-volume sample collection.</td>
<td>Channels

● Through which Channels do our Customer Segments want to be reached?
Ans: Direct sales, medical device distributors, online platforms, government partnerships, and healthcare conferences.

● How are we reaching them now?
Ans: The product is not completely developed yet.

● How are our Channels integrated?
Ans; Sales, marketing, and support are integrated with product demos, education campaigns, and customer support.

● Which ones work best?
Ans: Direct sales, distributor partnerships, healthcare conferences, and government collaborations.

● Which ones are most cost-efficient?
Ans: Online marketing, educational webinars, and distributor partnerships.
● How are we integrating them with customer routines?
Ans: Training, integration with hospital systems, ongoing support, and updates.</td>
<td>worker safety measures</td>
</tr>
<tr>
<td colspan="3">Cost Structure

● What are the most important costs inherent in our business model?
Ans: R&D, manufacturing
● Which Key Resources are most expensive?
Ans: Raspberry Pi 230$, 6DOF Arm 420$, Mg995 Servo 200$ (To complete the task, we will need to invest in more expensive equipment)
● Which Key Activities are most expensive?
Ans: R&D for AI/ML development, manufacturing, Salaries, Component costs, logistics,
🎬 Business Type:
● Value-driven: Focused on premium robotic technology, improved accuracy, faster work, sample analysis capability, and enhanced sample packaging.
🎬 Cost Characteristics:</td>
<td colspan="2">Revenue Streams
🎬 For what value are our customers really willing to pay?
Ans: Automation, safety, and accuracy in sample collection, Reduced human error and infection risks for healthcare workers, Efficient diagnostics through precise, AI-powered systems.

🎬 For what do they currently pay?
Ans: Manual sample collection equipment, traditional medical tools, Staff salaries for lab technicians and healthcare workers.

🎬 How are they currently paying?
Ans: Direct purchases, Hospital budgets, government or private funding, NGO or donor grants in low-income regions.</td>
</tr>
</table>

• **Fixed costs**: Salaries, R&D, rent. • **Variable costs**: Component costs, logistics. • **Economies of scale**: Costs decrease with higher production. • **Economies of scope**: Such technology is very rare.	🎬 How would they prefer to pay? Ans: Leasing, installment plans, government subsidies. 🎬 How much does each Revenue Stream contribute to overall revenues? Ans: Asset sales with installment system (major source), Subscription fees (System updates).

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