MediSense: An Integrated System for Hospital Monitoring and Inventory Management

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***Abstract*—MediSense is an integrated hospital monitoring and inventory management system that combines sensors and artificial intelligence (AI) to improve efficiency and accuracy in healthcare facilities. This system is designed to track medical supplies, detect environmental conditions, and provide real-time data to hospital staff, ensuring better resource management and patient care.**

MediSense utilizes various sensors to monitor critical factors such as temperature, humidity, and movement, ensuring proper storage conditions for vaccines, medications, and other medical supplies. Additionally, an AI-powered camera system allows staff to update inventory by simply sending an image of a medication. The AI, in conjunction with a chatbot, enables users to specify whether they are adding or removing a certain quantity, automatically adjusting the inventory records accordingly.

This solution minimizes human error, optimizes stock levels, and enhances hospital logistics by providing automated alerts for restocking and potential environmental risks. By integrating real-time monitoring with AI-assisted inventory updates, MediSense improves hospital efficiency, reduces waste, and ensures that essential medical supplies are always available when needed.

Introduction

In modern healthcare facilities, inventory management and patient monitoring are critical aspects that directly impact operational efficiency and patient care. Hospitals often face challenges in maintaining updated records of medical supplies, ensuring the proper storage conditions for sensitive medications, and tracking patient occupancy in real time. The integration of artificial intelligence (AI) and sensor-based technology can significantly improve these aspects, reducing human error and optimizing resource allocation.

MediSense proposes an intelligent monitoring system that incorporates a camera with AI capabilities and various sensors to enhance hospital infrastructure. By automating inventory tracking and real-time patient monitoring, this project aims to improve hospital efficiency and healthcare outcomes.

I. General context

Healthcare institutions rely on accurate inventory tracking and efficient patient monitoring to provide quality medical services. However, current systems often depend on manual data entry and periodic audits, which can lead to discrepancies, mismanagement, and potential health risks.

Technological advancements in AI, sensor networks, and automation present an opportunity to transform traditional hospital infrastructure. By leveraging AI-driven image processing and sensor-based monitoring, MediSense seeks to address inefficiencies in hospital inventory management and patient care.

Furthermore, the project aligns with the United Nations' Sustainable Development Goals (SDGs), particularly:

- Goal 3, Good Health and Well-being: Enhancing hospital infrastructure to improve healthcare services[1].
- Goal 9, Industry, Innovation, and Infrastructure Implementing innovative solutions to modernize hospital facilities[2].

II. Problem Statement

Hospitals face several critical challenges. One of those is inventory management, ineffective inventory management in healthcare settings can lead to reduced operational efficiency and delays in patient care. When staff lack accurate information about current stock levels and locations, they often waste time manually counting stock or searching for supplies. This time could be better spent caring for patients[3]. Many hospitals lack a standardized inventory management process, but a standard process can significantly decrease spending. There are two different types of healthcare inventory management, so it's important to understand the benefits and disadvantages of both. Healthcare facilities can manage inventory using one of the following methods:

- Periodic inventory requires employees to update inventory data manually. For this method, employees take inventory periodically. For example, they may take inventory once a week or at the end of a similar period of time. While this method may be sufficient for small healthcare facilities, it is not ideal for hospitals and larger healthcare organizations.

  This inventory management method leaves significant room for error and takes time away from other important tasks. Larger healthcare facilities benefit more from the perpetual inventory method.
- The perpetual inventory management method continually and automatically updates inventory data. The advanced software needed to operate a perpetual inventory system can cost more than practicing manual periodic inventory, but its benefits surpass its cost. Perpetual inventory systems account for important details such as purchases, deliveries, additions, and subtractions. They allow medical staff to track equipment use at all times so all supplies are accounted for[4].

The manual tracking of medical supplies, vaccines, and medications leads to inconsistencies, shortages, and waste. In addition, medications require specific humidity and temperature conditions, which are often not continuously monitored, meaning that the inadequate environmental control for medication storage is also a challenge. Another potential problem is the lack of real time patient monitoring, because the absence of automated monitoring systems results in delayed responses to critical health conditions. One of the main benefits of remote monitoring in healthcare is the ability to deliver patient-centered care more efficiently. Through continuous monitoring, healthcare providers can gain real-time insights into patient health, making it easier to intervene when necessary. This proactive approach leads to better remote patient monitoring outcomes by preventing conditions from worsening and reducing hospital readmissions[5]. MediSense aims to address these issues by developing an integrated system that utilizes AI-driven cameras and sensors to provide real-time inventory tracking, patient monitoring, and automated environmental regulation.

A. *Inventory Management*

Using a database that will analyze the stock levels in real-time, hospitals will be able to maintain an up-to-date database of medical supplies and medications. Inventory mismanagement in hospitals leads to financial losses, medication shortages, and operations inefficiencies.

B. *Patient Monitoring*

By implementing sensors to track patient vitals, bed occupancy, and environmental conditions, the hospitals using our systems will be able to enhance their efficiency. Real time monitoring solutions incorporating AI and IoT sensors can provide continuous health assessments, reducing mortality rates.

Your vital signs measure your body's basic functions. Vitals display a snapshot of what's going on inside your body. They provide crucial information about your organs.

Therefore, the importance of vital signs monitoring is that it allows medical professionals to assess your wellbeing. Based on the results, a doctor may conduct further tests, diagnose a problem, or suggest lifestyle changes[6].

C. *Real Time Actualization*

Using the real-time update system, we can maintain complete control over the data presented by the sensors, which allow us to monitor the hospital's status.

By leveraging this system, we can ensure that all sensor data is continuously updated and accurately reflected in our monitoring interface. This enables real-time decision-making, allowing medical staff to quickly detect anomalies, respond to emergencies, and optimize resource management. Additionally, the system enhances operational efficiency by providing precise insights into critical parameters such as temperature, humidity, equipment functionality, and patient status, ensuring a safer and more responsive healthcare environment.

D. Temperature control

A pharmacy temperature monitoring system, alongside proper storage and transport conditions, directly affects medications effectiveness and safety. When temperatures deviate from the recommended range, important parts of the product can break down, making medications ineffective or even harmful.

Implementing a temperature control system allows for continuous monitoring and regulation of environmental conditions. By integrating ventilation control mechanisms, we can maintain a stable temperature and ensure the integrity of pharmaceutical products [7].

III. Delimitation of the Object of Study

The study focuses on equipping a hospital facility with a smart monitoring system comprising:

A. Four types of sensors

- Pressure Sensor (MF01): Detects patient presence on hospital beds and updates availability in real-time.
- Humidity and Temperature Sensor (DHT11): Monitors storage conditions for medical inventory and activates a fan to regulate temperature.
- Heart Rate Sensor (ARD-366): Monitors patient vitals and alerts medical staff to irregularities.
- Authorized Code Sensor (RFID): Provides secure access to restricted areas, specifically the storage room.

B. AI-integrated Camera

Captures images of medical inventory and analyzes stock levels using AI algorithms.

C. Three actuators

- Fan: Regulates temperature in storage areas.
- LED Lights: Indicate system status and alerts.
- Buzzer: Provides auditory alerts for critical conditions.

IV. Problem Definition

Hospitals face significant challenges in managing medical supplies, ensuring patient monitoring, and maintaining optimal environmental conditions for critical storage areas. Inefficiencies in these processes can lead to medication shortages, improper storage conditions, and delays in patient care, ultimately impacting hospital operations and patient safety.

Traditional inventory management systems rely on manual updates, increasing the risk of human error, while patient monitoring requires constant attention from medical staff. Additionally, medical supplies such as vaccines and medications require strict environmental control, where deviations in temperature and humidity can compromise their efficacy.

To address these challenges, MediSense integrates AI-powered inventory management, real-time patient monitoring, and automated environmental control. By leveraging advanced sensors and AI-driven analytics, the system enhances hospital efficiency, ensures accurate stock management, and improves patient care through automated alerts and monitoring.

V. Requirements Analysis

The MediSense system is designed to meet the following functional and non-functional requirements:

A. Functional Requirements:

- Real-Time Patient Monitoring: The system must track patient presence and vital signs using sensors.
- Automated Inventory Management: AI-integrated cameras must capture images of medical supplies and update stock levels accordingly.
- Environmental Monitoring: The system must regulate temperature and humidity for medical storage using sensors and actuators.
- Automated Alerts: The system should notify hospital staff of inventory shortages, critical patient conditions, and environmental risks.
- User Interaction: The AI-based chatbot should allow medical staff to manually add or remove inventory items when needed.

B. Non-Functional Requirements:

- Scalability: The system should support integration with additional sensors and devices.
- Reliability: The system must provide accurate data with minimal downtime.
- Security: Patient and inventory data must be securely stored and accessed only by authorized personnel.
- Usability: The system interface should be intuitive and accessible to hospital staff.
- Efficiency: The system should process and update data in real time with minimal latency.

VI. Hardware Development

The MediSense system integrates multiple hardware components to achieve seamless hospital monitoring and inventory management. The development process includes selecting, assembling, and testing the following hardware elements:

A. Sensor Integration:

- Pressure Sensor (MF01): Installed on hospital beds to detect patient presence and update bed availability.
- Humidity and Temperature Sensor (DHT11): Placed in medical storage areas to regulate environmental conditions.
- Heart Rate Sensor (ARD-366): Attached to patients to monitor vitals and detect anomalies in real time.

- AI-Integrated Camera: Positioned in inventory storage to capture images of medical supplies for AI-driven stock analysis.
- RFID sensor: Used to keep a record of authorized personnel entering the storage room with all the medicines.

B. *Actuator Implementation:*

- Fan: Connected to the DHT11 sensor for automated temperature control in medical storage.
- LED Lights: Implemented to visually indicate system status and alerts.
- Buzzer: Installed to provide auditory alerts for critical conditions such as inventory shortages or abnormal patient vitals.

C. *Microcontroller and Communication:*

- Arduino-based Control Unit: Manages sensor data collection, processing, and actuator activation.
- Wireless Communication (Wi-Fi/Bluetooth): Enables real-time data transmission to hospital staff via a central monitoring system.

Fig 2. ARD-366 Sensor Circuit (Heart Rate Sensor). The heart rate sensor continuously monitors the patient's pulse in real time. A normal resting heart rate for an adult typically ranges between 60 and 100 beats per minute (BPM). If the system detects an irregular pulse—such as bradycardia (below 60 BPM) or tachycardia (above 100 BPM)—it triggers visual (LED) or audible (buzzer) alerts. This feature ensures quick medical response to potential health risks [8].

Fig 4. DHT11 Sensor Circuit (Temperature and Humidity Sensor). This sensor measures temperature and humidity to ensure optimal storage conditions in a medicine warehouse. Proper storage helps maintain the effectiveness and safety of medications. A normal storage temperature for most medicines typically ranges between 15°C and 25°C (59°F to 77°F). If the temperature falls below or exceeds this range, the system activates a cooling or heating mechanism, such as a fan or heater.

Additionally, the sensor monitors humidity levels. In a medicine warehouse, the relative humidity should be maintained between 30% and 50% to prevent moisture damage and degradation of pharmaceutical products. If humidity deviates from this range, the system can trigger dehumidifiers or ventilation systems to restore a stable environment.

Fig 6. MF01 Sensor Circuit (Bed Pressure Sensor). A pressure sensor is placed under the mattress to detect whether a patient is occupying the bed. The normal pressure exerted by a lying person on a mattress varies, but typically ranges between 15 and 30 mmHg over soft tissues, depending on body weight and distribution. If the pressure sensor does not detect sufficient force, it assumes the bed is unoccupied, updating real-time bed availability for hospital staff. This automation improves patient management and resource allocation during emergencies.

Fig 7. Room and Storage Sensors Integrated. This figure illustrates the integration of the sensors into a unified monitoring system. The system continuously collects heart rate, temperature, humidity, and bed occupancy data, processing it through a microcontroller. Actuators such as buzzers, LEDs, and relays respond to abnormal conditions by triggering alerts or activating devices like fans. The system can also transmit real-time data to a central monitoring unit, allowing healthcare providers to maintain constant supervision over patients.

Fig 8. Serial Monitor Display. The serial monitor displays real-time sensor readings, including heart rate, temperature, humidity, and bed occupancy status. Using clear visual indicators such as warning messages and color-coded alerts, medical staff can quickly assess the patient's condition. If any parameter falls outside the normal range, the system immediately issues alerts to ensure timely medical intervention.

Fig 1. ARD-366 Sensor in Room #1

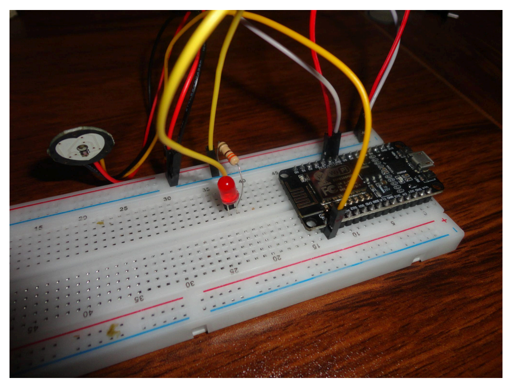

Fig 2. ARD-366 Sensor Circuit

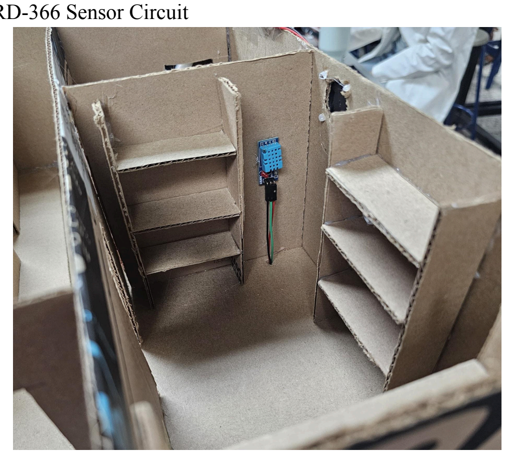

Fig 3. DHT11-Sensor in Storage

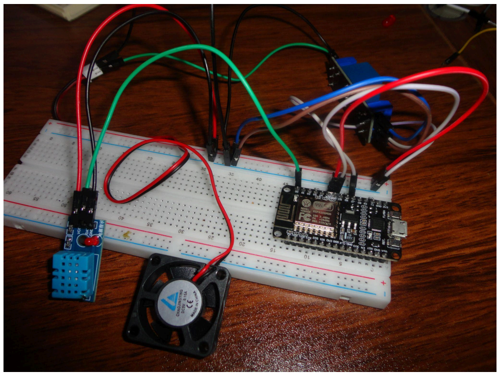

Fig 4. DHT11 Sensor Circuit

Fig 5. MF01 Sensor in Room #2

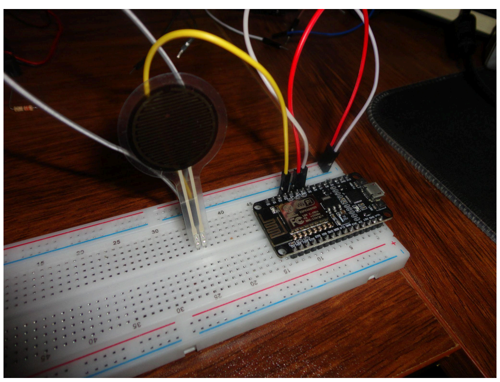

Fig 6. MF01 Sensor Circuit

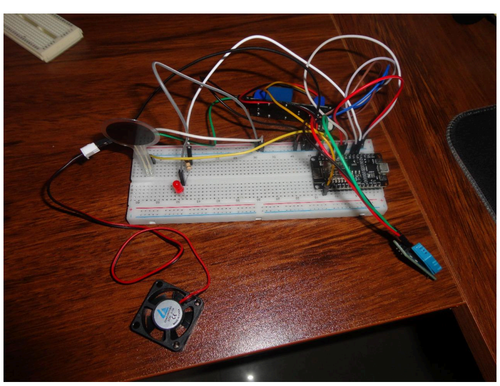

Fig 7. MF01,DHT11 and ARD-366 Sensors Integrated

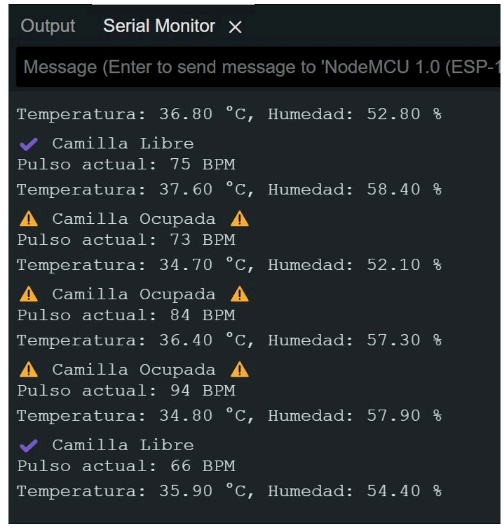

Fig 8. Serial Monitor

Fig 9. RFID Sensor

VII. Software Development

By using Arduino, we were able to program various sensors and built a dashboard in Oracle APEX through the App Builder tool. This system enables the monitoring of the pulse, bed status, temperature, humidity, and device controls, all from one interface.

We used a pulse sensor to measure heart rate (BMP), a temperature and humidity sensor to monitor environmental conditions in the storage room, and a pressure sensor to detect bed occupancy. Additionally, access control and device state monitoring were incorporated. These devices include the LED light and buzzer, which are activated when the patient's pulse is at an abnormal level. The Arduino boards are programmed to continuously read sensor data and transmit it to the database for visualization.

We utilized Oracle APEX to design and implement the dashboard. It allowed us to create a responsive web application that organizes the incoming sensor data into an easy-to-read format. The dashboard displays key information such as pulse rate, bed status, room temperature, humidity levels, and the on/off states of light and alarm as seen in Figure 10. It also provides interactive features to navigate between different sections, ensuring the management and monitoring of the hospitals' environment efficiently. (Figure 11).

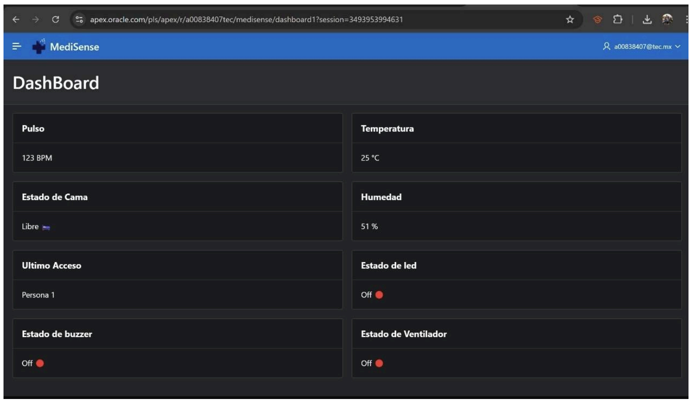

Fig 10. Main Dashboard

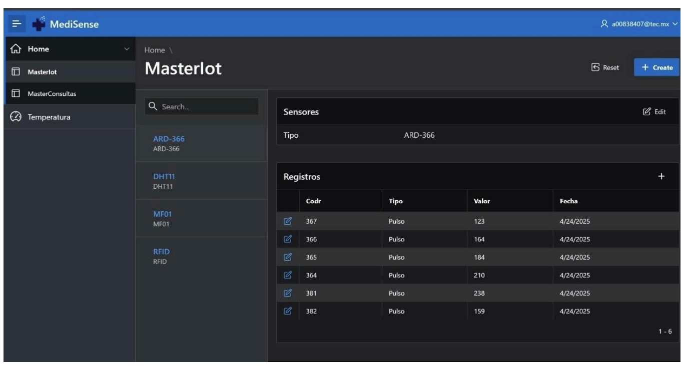

Fig 11. Database of all Sensors

Fig 12. Serial Monitor sending data to OracleAPEX

VIII. General Code

```
#include <DHT.h>

#define PRESION_PIN D3   // Sensor de presión (interruptor)
#define PULSO_PIN A0     // Sensor de pulso (analógico)
#define DHT_PIN D0       // Sensor de temperatura y humedad (DHT11 o DHT22)
#define BUZZER_PIN D6    // Buzzer
#define RELAY_PIN D7     // Relay para ventilador
#define LED_PIN D8       // LED indicador del ventilador
#define DHTTYPE DHT11    // Cambiar a DHT22 si es necesario
DHT dht(DHT_PIN, DHTTYPE);

const int umbralPulsoCritico = 700; // Umbral para detectar un pico de pulso (ajustar según el sensor)
const int maxMuestra = 100; // Cantidad de muestras para calcular BPM
unsigned long tiempoUltimoLatido = 0; // Para calcular el tiempo entre latidos
int latidosPorMinuto = 0; // Para almacenar el BPM

// Variables para detectar picos de pulso
int pulsoAnterior = 0;
int pulsoActual = 0;
bool pulsoDetectado = false;

void setup() {
  Serial.begin(115200);

  // Configurar pines de sensores y actuadores
  pinMode(PRESION_PIN, INPUT_PULLUP);
  pinMode(PULSO_PIN, INPUT);
  pinMode(DHT_PIN, INPUT);
  pinMode(BUZZER_PIN, OUTPUT);
  pinMode(RELAY_PIN, OUTPUT);
  pinMode(LED_PIN, OUTPUT);

  digitalWrite(BUZZER_PIN, LOW);
  digitalWrite(RELAY_PIN, LOW);
  digitalWrite(LED_PIN, LOW);

  dht.begin();
}

void loop() {
  // Leer estado del sensor de presión [10]
  int presion = digitalRead(PRESION_PIN);
  if (presion == LOW) {
    Serial.println("⚠️ Camilla Ocupada ⚠️");
  } else {
    Serial.println("✔️ Camilla Libre");
  }

  // Leer el pulso actual (valor analógico)
  pulsoActual = analogRead(PULSO_PIN);
  Serial.print("Pulso actual: ");
  Serial.print(pulsoActual);
  Serial.print(", ");

  // Detectar el pico del pulso y calcular el BPM [11]
  if (pulsoActual > umbralPulsoCritico && pulsoAnterior <= umbralPulsoCritico) {
    // Se detecta un pico (cuando el valor supera el umbral y el anterior no lo superaba)
    pulsoDetectado = true;
    latidosPorMinuto++; // Contamos el latido
    Serial.println("Pulso Detectado");
    digitalWrite(BUZZER_PIN, HIGH);  // Activar buzzer si el pulso es crítico
```

```
    } else {
      pulsoDetectado = false;
      digitalWrite(BUZZER_PIN, LOW);   // Desactivar buzzer si no es crítico
    }

    // Mostrar BPM cada 5 segundos
    if (millis() % 5000 == 0) {
      Serial.print("Latidos por minuto (BPM): ");
      Serial.println(latidosPorMinuto);
      latidosPorMinuto = 0;  // Reiniciar el contador de BPM para el siguiente
ciclo
    }

    // Leer temperatura y humedad [9]
    float temperatura = dht.readTemperature();  // Temperatura en Celsius
    float humedad = dht.readHumidity();        // Humedad relativa (%)

    if (isnan(temperatura) || isnan(humedad)) {
      Serial.println("Error al leer el sensor DHT. Revisar conexiones.");
    } else {
      Serial.print("Temperatura: ");
      Serial.print(temperatura);
      Serial.print(" °C, Humedad: ");
      Serial.print(humedad);
      Serial.println(" %");
    }

    // Comprobar si la temperatura es anormal y activar ventilador
    if (temperatura > 38.0 || temperatura < 20.0) {  // Valores de referencia
      Serial.println("⚠️ Temperatura Anormal, Activando Ventilador y LED
⚠️");
      digitalWrite(RELAY_PIN, HIGH);  // Prender ventilador
      digitalWrite(LED_PIN, HIGH);    // Prender LED indicador
    } else {
      digitalWrite(RELAY_PIN, LOW);  // Apagar ventilador
      digitalWrite(LED_PIN, LOW);    // Apagar LED indicador
    }

    // Guardar el pulso actual como el anterior para la siguiente iteración
    pulsoAnterior = pulsoActual;

    delay(1000);  // Esperar 1 segundo antes de la próxima lectura
}
```

VII. AI Implementation

The core of MediSense's intelligence relies on the integration of Google's Gemini model to perform real-time image analysis for medication inventory tracking. Once a photograph of the hospital storage room is captured, it is sent to Gemini, which processes the image using advanced computer vision techniques. The model identifies individual medication units, classifies them based on their visual features, and extracts relevant textual information from labels using built-in OCR capabilities. This approach eliminates the need for locally trained models or custom datasets, leveraging Gemini's general-purpose vision-language capabilities to adapt to various packaging formats and lighting conditions. The extracted data is then parsed and structured to update the hospital's inventory database automatically. By relying on Gemini, MediSense ensures scalability, high accuracy, and reduced development complexity, making it a robust AI-powered solution for medical inventory automation (Figure 13).

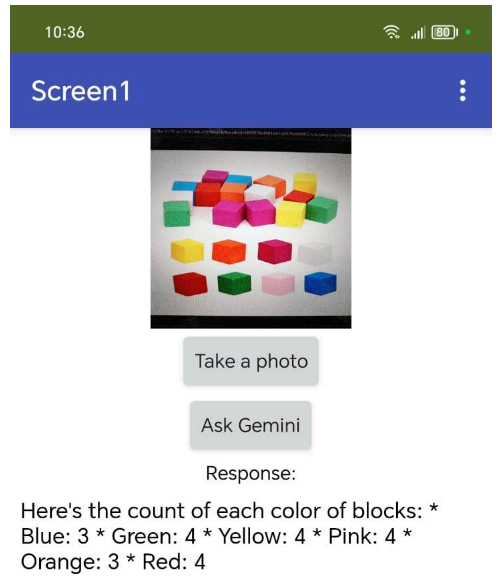

Fig 13. AI Application

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