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Smart Health Mirror for Home Checkup

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KEYWORDS

Internet of Things (IoT), Deep Learning, Skin Disease Detection, Facial Emotion Recognition, Smart Health Mirror, Raspberry Pi, Home Healthcare Monitoring, MLX90614 Temperature Sensor, and GSM Alert System.

ABSTRACT

The Smart Health Mirror for Home Checkup functions as an advanced health assessment system which enables users to perform routine health checks from their residence. The device uses a Raspberry Pi system together with biomedical sensors which include an MLX90614 infrared temperature sensor and a pulse oximeter to measure essential health parameters such as body temperature and oxygen saturation. The system provides users with instant health data access through its user-friendly design which combines a two-way mirror with a display. The proposed system uses deep learning and computer vision methods to enable advanced health assessment. The system uses CNN and YOLO-based models to identify common skin disorders which include eczema and melanoma and atopic dermatitis. Media Pipe serves two functions which include detecting facial landmarks and recognizing emotional expressions. The GSM module transmits alert notifications during extraordinary events while voice communication system enhances user experience. The system provides an interactive and affordable solution which reduces hospital dependency while promoting preventive medical care.

INTRODUCTION

The conventional medical procedures undergo a fundamental transformation because digital healthcare technologies have developed home-based health monitoring capabilities that replace hospital-centered therapy. Intelligent systems are needed because people age and face more health problems while they struggle to reach medical facilities. Smart healthcare solutions deliver immediate health information through their use of embedded systems and biological sensors and artificial intelligence and Internet of Things (IoT) technology. The devices enable users to track their vital signs which include heart rate and oxygen saturation and body temperature to support preventive healthcare practices. Home-based health monitoring provides remote and underdeveloped area residents with a cost-effective solution that decreases their need for hospital visits while enabling them to receive immediate medical treatment.

Health monitoring equipment has gained improved measurement accuracy and functional performance because healthcare systems now use computer vision technology and artificial intelligence capabilities. Deep learning models use Convolutional Neural Networks (CNNs) and object detection algorithms like YOLO to achieve positive results in medical picture analysis through their ability to recognize patterns and identify diseases. Media Pipe-based systems use facial analysis and emotion detection technology to assess mental and emotional well-being, which represents a fundamental aspect of overall health. Advanced technology enables real-time analysis of facial expressions together with skin conditions to identify stress and exhaustion and dermatological issues at their initial stages. AI-driven diagnostics permit personalized health assessments while improving decision-making precision through its implementation without needing direct involvement from medical staff.

The existing health monitoring devices are numerous but most present systems function as independent devices which can only assess one specific health indicator such as heart rate or temperature. The separate systems require multiple devices together with manual data analysis because they do not provide system integration or intelligent features or user-friendly interactive interfaces. The traditional health checkup methods require clinical facilities and medical personnel which make them difficult to use for routine health assessments. The current smart mirrors do not have advanced artificial intelligence disease detection capabilities but they can be used for fitness assessment and beauty applications. There is a need for a smart health monitoring system which provides easy operation and complete health tracking functions within a single platform.

The researchers present a Smart Health Mirror for Home Checkup system which uses embedded technology to merge computer vision artificial intelligence and biomedical sensors into one functional medical device. The system operates on a Raspberry Pi platform which employs contactless MLX90614 temperature sensors and pulse oximeters to monitor vital signs while deep learning models detect skin diseases and identify facial emotions. A two-way mirror with voice interaction and GSM-based alarm notifications enables users to see their health information in real time. The device enables users to monitor their health status at home through its affordable interactive system which supports ongoing self-assessment thereby enhancing healthcare prevention methods and personal health understanding.

LITERATURE SURVEY

Recent studies have examined how smart mirrors combined with Internet of Things (IoT) technology enable residential health monitoring through everyday health assessments. Sharma et al. developed a smart mirror system which uses biological sensors to track body temperature and heart rate while storing data in cloud-based systems [1]. The research demonstrated that smart mirrors could promote preventive healthcare practices while increasing public understanding of health issues. Ali et al. developed an affordable home healthcare system which uses Raspberry Pi and physiological sensors to enable real-time monitoring through AI technology [2]. The research demonstrates that smart mirror platforms can function effectively although their primary focus lies on basic vital sign assessment with no advanced image-based disease detection capacity.

The medical field has become highly interested in deep learning because it applies to medical picture analysis for skin condition detection. Singh et al. used skin images to develop a Convolutional Neural Network (CNN) system that can identify three dermatological conditions which include dermatitis and eczema and melanoma [3]. Their model achieved high classification accuracy which demonstrated deep learning's effectiveness in detecting diseases at their initial stages. Current methods fail to work in real-time embedded systems because they depend on clinical data and smartphone images. The system design lacks embedded artificial intelligence which requires immediate skin analysis features for effective home health monitoring systems.

The ability to recognize facial expressions has become essential for intelligent healthcare systems because emotional health affects physical health. Patel and his team developed a real-time facial emotion recognition system which operates efficiently on low-power devices through their use of MediaPipe together with neural networks. The approach achieved successful emotion recognition because lightweight models work effectively with embedded platforms to identify tension sadness and happiness. The systems operate effectively yet developers create them as standalone solutions without connecting to systems that monitor physiological health. The combination of emotional analysis and physical health measurements provides a complete assessment of a person's overall well-being.

Numerous studies have examined both GSM-based alarm systems and remote patient monitoring systems. Radhakrishnan et al. [5] developed an IoT-based monitoring system which alerts users to instances of abnormal health conditions. Hassan et al. conducted research on home healthcare diagnostic accuracy through testing various sensor combinations that included non-contact temperature sensors and pulse oximeters. The technologies enhance safety and responsiveness through their improvements but they fail to provide AI-based visual analysis together with intelligent user interface functionality. The existing literature clearly demonstrates the need for a complete smart mirror system which combines sensor monitoring and deep learning diagnosis with emotional assessment and real-time notifications in one home solution.

The recent advancements in healthcare diagnostics now focus on developing multimodal health monitoring systems which need both physiological data and contextual information with visual data. The study by Howard et al. introduced deep learning frameworks designed specifically for vision applications on mobile and embedded systems which demonstrated strong performance under limited processing power. The YOLO-based object detection system, which Redmon and Farhadi introduced, allows for real-time picture analysis appropriate for visual diagnostics related to health. The healthcare industry depends on these models because they deliver accurate results at high processing speeds. The majority of systems perform poorly because they fail to connect with sensor-based health monitoring systems and they only support specific tasks which include object detection and picture categorization. The need for a complete smart health mirror system which delivers continuous health evaluation for residential spaces becomes more critical according to this requirement.

PROPOSED METHODOLOGY

The Smart Health Mirror system operates as an AI-powered home healthcare system through its integration of embedded hardware components and biological sensors and intelligent software modules. The system operates through its core component which is a Raspberry Pi that handles all data collection and processing and control functions. The Raspberry Pi connects with various sensors which include an MLX90614 infrared temperature sensor and a pulse oximeter to measure essential health indicators that include body temperature and heart rate and oxygen saturation. The system utilizes a USB webcam to capture real-time facial and skin images while an ADC converter ensures accurate conversion of sensor signals. The system enables real-time monitoring through its ability to process collected data on-site without needing to connect to external servers.

The Raspbian operating system powers the system's software architecture, which was created in Python. The sensor data acquisition modules run continuous operations to gather physiological data and perform basic data preprocessing tasks, which help, reduce environmental disturbances while, enhancing measurement precision. Computer vision algorithms process camera data to detect skin and facial areas that require examination. Media Pipe facial landmark detection enables precise face alignment and emotion feature extraction. The system processes inputs through deep learning models which use trained deep learning models to analyze the incoming data. The system enables efficient operation on embedded devices with restricted resources through its modular software design, which enables smooth operation between sensor data collection, image analysis, and AI-based assessment.

The system utilizes deep learning models which include Convolutional Neural Networks (CNNs) and YOLO-based object detection systems to perform intelligent health analysis. The CNN model learns to identify three skin diseases through training on skin disease datasets which include atopic dermatitis and melanoma and eczema. YOLO enables real-time detection through its ability to detect affected areas with precise and fast performance. The system performs simultaneous facial emotion recognition while it analyzes facial expressions to identify emotional states which include tension and neutrality. The device combines physiological indicators with visual diagnostics to create a complete health assessment system which enhances early detection and preventive healthcare capabilities.

The system consists of three components which work together to improve user experience and safety through control interfaces and alarm systems and real-time feedback system. A screen behind a two-way mirror shows health data and analysis findings, enabling people to examine information in a natural way while facing the mirror. To improve accessibility, text-to-speech modules are used to deliver voice feedback through speakers. The GSM module sends alert notifications to predefined contacts when it detects abnormal health readings. The system enables users to operate it through push buttons which enable them to choose between system control and manual mode. The system establishes a smart health monitoring system which remains reliable and flexible and user-friendly for typical home environment use.

A. System Architecture

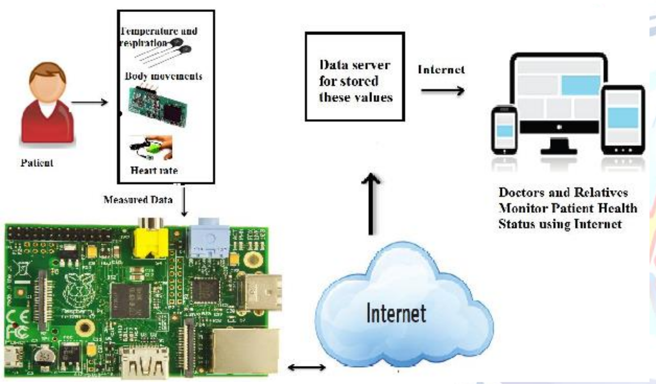

Fig 1 System Architecture

B. Methodology

Sensor-Based Optical Sensing and the Acquisition of Physiological Data

The Smart Health Mirror system's core element operates through its physiological data collection module which enables users to measure essential health metrics without needing direct contact with the system. The system incorporates biomedical sensors which include an MLX90614 infrared temperature sensor that enables non-contact body temperature measurement and a pulse oximeter that measures heart rate and oxygen saturation (SpO_2) levels. The sensors were selected for home healthcare systems because they provide reliable performance while using minimal power and maintaining multiple application capabilities. A USB webcam operates as an optical sensing device which captures high-resolution face and skin images in real time. The system uses multiple sensing elements to collect continuous health information through non-invasive methods.

The proper communication protocols work to ensure that sensor data transmission maintains both accuracy and reliability. The pulse oximeter uses the I^2C protocol because it enables data transfer with reduced wiring requirements. The MLX90614 sensor utilizes I^2C connection for its temperature measurements which require both immediate readings and synchronized tracking. The system employs an ADC converter to process analog signals when needed to maintain signal quality throughout operations. The USB webcam records continuous video frames which it transmits directly to the CPU. The method of multi-sensor fusion uses optical measurements together with physiological data to enhance the precision of measurements.

The system collects sensor data at repeated intervals while applying filters to decrease system noise and measurement inaccuracies for better system performance. The analysis process begins with preprocessing steps that include threshold validation and signal smoothing to prepare the data. Environmental factors such as lighting conditions and ambient temperature must be included in optical sensing systems to achieve their maximum detection performance. The collected physiological and visual data receives synchronization through timestamping which maintains consistency during the analysis process. The standardized data collection method ensures the AI diagnostic modules and embedded processing receive accurate input, which establishes a dependable framework for effective health monitoring systems.

Design of the System Architecture and Embedded Control Framework

The design centers around the Raspberry Pi which serves as the primary processing unit and control center for the Smart Health Mirror's system. The Raspberry Pi manages all functions required to collect sensor data, capture images, process signals, and control the system. The system becomes an embedded platform suitable for multiple hardware components because of its compact design and processing capabilities and its ability to connect different types of devices. The system architecture allows sensors and processing modules and output devices to exchange information through its modular system design. The method enhances system reliability and system expansion capabilities and system maintenance.

The current system operates with Raspbian, which is a Linux-based operating system designed specifically for Raspberry Pi devices. Python serves as the primary programming language because it provides extensive compatibility with machine learning tools and image processing frameworks and sensor libraries. Dedicated modules handle specific functions that include sensor interface and camera control and data preparation and system monitoring. Inter-process communication ensures that these modules work together without any operational issues. The ADC converter functions as a critical component that converts analog sensor signals into digital data for processing by the Raspberry Pi system.

The system architecture requires error-handling mechanisms together with hardware-level synchronization to maintain its continuous operational capabilities. The system uses GPIO pins to connect push buttons which enable users to control the system and choose different operational modes. The system uses standard connectors to connect peripheral parts which include speakers and display modules and communication interfaces to simplify the integration process. The system design includes power management and system startup functions which protect data during interruption events. The integrated control architecture provides complete system interoperability between hardware and software components which enables the system to operate intelligently while monitoring its status in real time.

AI-Based Diagnostic Decision Making and Automated Health Analysis

The system creates advanced medical diagnostic results through its health analysis module, which processes physiological and visual data using computer vision and artificial intelligence techniques. The system uses computer vision algorithms to process webcam photos of the face and skin to identify regions which need examination. MediaPipe enables precise facial alignment which helps in extracting emotion-related features through its facial landmark detection capabilities. The system uses this capability to assess emotional states which include stress and neutrality because these states are essential for determining overall health assessment. The system introduces emotion analysis as a psychological element which enhances traditional methods of monitoring physiological functions.

Convolutional Neural Networks (CNNs) are used to categorize dermatological problems such atopic dermatitis, melanoma, and eczema in order to diagnose skin diseases. The CNN model learns to recognize skin features by training on labeled skin photo datasets. YOLO-based object detection technology allows users to track and identify affected skin regions during actual time operation. The systems achieve high accuracy with low delay time because their design targets embedded platform performance. The combination of CNN and YOLO enhances both system classification accuracy and its ability to detect objects in real time.

The diagnostic decision-making process obtains crucial health information through its combination of data from physiological sensors and AI model results. The system uses threshold-based logic to process sensor readings and detect exceptional medical conditions such as fever and low SpO_2 levels. The system uses confidence scores to verify AI predictions which helps to decrease false positive results. The system determines health status through data integration and recommends appropriate treatment methods. The automated decision-making system provides immediate feedback with recommendations which supports preventive health care while reducing human work and enabling early detection.

Embedded Systems: Signal Transmission, Alert Mechanism, and Power Management

The Smart Health Mirror system requires signal transmission and communication to achieve its goals of delivering immediate alerts while keeping users engaged with the system. The system uses a GSM module to enable both wireless communication and warning notification systems. The system automatically notifies designated contacts when critical diagnostic results or problematic health metrics are found. The system provides immediate alerts which enhance user safety for older users and users with chronic medical conditions. The system operates at higher reliability because its GSM-based alert system functions without requiring internet connection.

The system provides local input through its auditory and visual interfaces which operate in real time while delivering remote notifications. The system becomes accessible to users of every age group because its speaker module delivers voice-based alerts through text-to-speech technology. A buzzer operates as an emergency warning device which delivers immediate notifications. The user experience becomes natural and interactive through a two-way mirror display which shows health data and test results. Users can easily switch between monitoring modes and control system operations through push buttons.

The system design includes power management which ensures the embedded system maintains continuous and stable operation. The system provides regulated power supply to sensors and Raspberry Pi and communication modules which enables proper voltage distribution to all components. The system uses protection circuits and voltage regulators to defend against damage caused by overloads or voltage swings. The system has starting and shutdown protocols which protect data integrity and enable safe operation of the system. The system achieves extended operational life through its use of energy-efficient components and its distribution system which provides power to essential home-based equipment.

RESULTS

The experimental evaluation results show that The Smart Health Mirror system operates effectively for its intended purpose of tracking health data and conducting health assessments in real time. The MLX90614 temperature sensor together with its embedded pulse oximeter system delivered accurate and stable measurements of body temperature and heart rate and SpO_2 levels during standard indoor testing conditions. The mirror interface successfully displayed sensor data at low latency while the embedded data processing system operated reliably according to their evaluation results. The system maintained continuous operation during monitoring sessions while preprocessing techniques improved measurement precision and reduced measurement errors. The two-way mirror display system enabled users to see their health information through a natural observation method which increased system usability. The research results demonstrate that home health assessment systems achieve operational efficiency through their sensor integration and built-in control systems.

The AI-based analysis modules accomplished their work by executing health evaluations through automated processes. The system achieved accurate real-time detection of both neutral and stress-related facial expressions through its utilization of Media Pipe for facial emotion recognition. The YOLO system successfully identified affected skin areas with high certainty, while the CNN-based skin disease classification algorithm accurately identified eczema and melanoma through its analysis of collected medical images. The GSM alert system successfully delivered notifications during emergency situations, which allowed users to receive immediate alerts. The system operated correctly through buzzer alerts and voice feedback, which improved both communication and security. The research results show that home healthcare monitoring achieves precise and interactive effectiveness when deep learning-based visual analysis combines with physiological sensing technology.

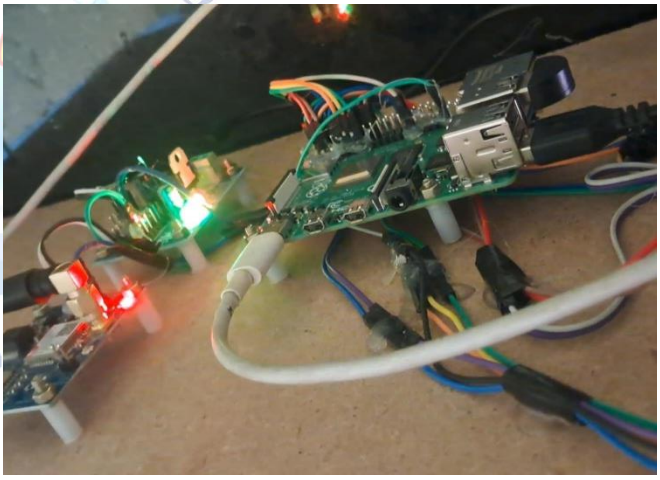

Fig 2: Integration of Embedded Sensors and Processing Units

The image demonstrates the completed integration process between Raspberry Pi and multiple attached devices which include power supply circuits and sensor connection systems and communication equipment. The lighted status LEDs provide confirmation that stable power delivery enables proper startup of the embedded system. The system provides four connection points through which users can connect the webcam and sensors and control modules through USB and GPIO ports. The embedded control framework demonstrates its ability to manage multiple hardware processes while maintaining operational control through this system design. The system maintains continuous operation under powered conditions which proves that it achieves reliable voltage regulation and proper grounding. The graphic shows how all system components of Smart Health Mirror work together as a unified embedded system which allows them to process and acquire data in real time.

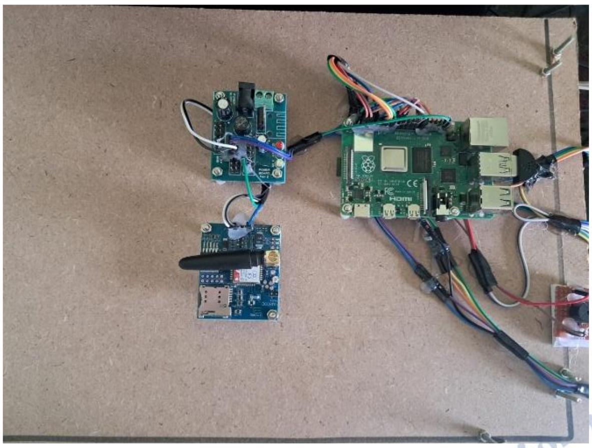

Fig 3: Performance of Embedded Connectivity and GSM Communication

The communication subsystem which operates with the Raspberry Pi uses the GSM module together with its associated circuitry as its primary component. The system achieves confirmation of successful network initialization and message transmission readiness through both the antenna connection and indicator LEDs system. The system achieves reliable serial communication for alert notifications through proper wiring between the processing unit and the GSM module. The system demonstrates its ability to function without internet access through its capacity to send emergency notifications via cellular communication. The system achieves better transmission dependability because its structured layout minimizes both electrical noise and signal loss. The Smart Health Mirror system becomes suitable for home monitoring and remote alert systems because it uses GSM integration to provide real-time health alerts during critical medical situations which enhance system protection.

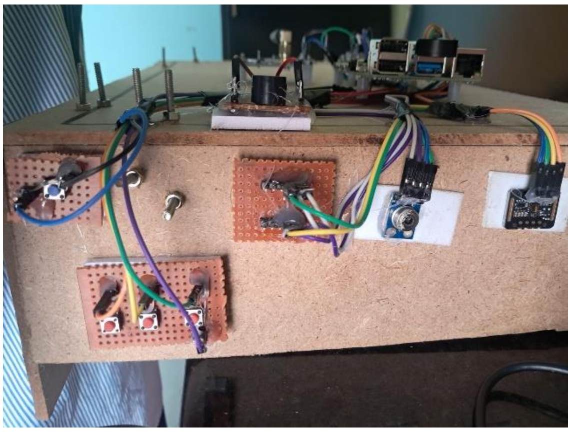

Fig 4: Full Hardware Assembly for Smart Health Mirror

The third figure presents the Smart Health Mirror prototype which displays all its components including sensors and control buttons and buzzer and processing unit on a compact frame. The buzzer delivers immediate sound notifications while the push buttons allow users to select different operating modes. Sensor modules need to be situated at specific points for accurate data acquisition during user interactions. The system achieves extended operational life through its insulated components and properly installed wiring which also minimizes short circuit risks. The entire setup demonstrates that the system can be effectively used in home environments. The prototype demonstrates practical usability through its structured design and robust installation which enable users to monitor their health status with minimal effort.

Health & Detection Report

Name : Swathi
Age : 20
Date : 2025-12-30 13:47:32

Sensor Readings

Ambient Temp : 28.39 °C
Object Temp : 27.37 °C
Heart Rate : N/A bpm
SpO2 : N/A

Detection Results

Emotion : neutral
Skin : Melanoma (95.1%)
Eye : Black (60.3%)

Fig 5: The Smart Health Mirror's generated health report

CONCLUSION

The study presented a Smart Health Mirror for Home Checkup that uses biological sensors and embedded systems and artificial intelligence to create contactless health monitoring systems which operate continuously. The device achieved multiple functionalities through its combination of USB webcam optical image acquisition and pulse oximeter and MLX90614 temperature sensor physiological sensing capabilities. The suggested approach enables effective data collection, processing, and display in real time by using a Raspberry Pi as the central processing unit. The two-way mirror interface allows users to access health information during their daily activities which improves system usability and enables home-based health assessments.

The system's diagnostic capabilities receive substantial enhancements through its implementation of deep learning and computer vision techniques. The combination of CNN and YOLO models enables both accurate skin disease identification and precise skin disease localization, while Media Pipe facial landmark detection allows users to recognize different emotional expressions. The automated diagnostic decision process uses sensor data together with AI predictions to deliver precise health assessments and immediate warning systems. GSM-based communication enhances operational security while increasing responsiveness through its ability to deliver immediate alerts during emergency situations. The research demonstrates efficient health monitoring technology on low-power embedded devices through its ability to connect various hardware elements with its modular design and embedded control system.

The Smart Health Mirror provides a flexible and interactive and affordable solution for preventive healthcare services. The method promotes better health awareness and proactive self-care by lowering reliance on frequent hospital visits and facilitating early detection of possible health issues. The system will support additional sensor and advanced machine learning model and cloud analytics system integrations because its current capabilities enable such expansion. The proposed method shows how AI-based smart devices can transform traditional medical practices into remote home care solutions which propel the progress of digital health services and personalized health tracking systems.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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