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Integrating Technology in Critical Transport The Era of Smart Stretchers

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ABSTRACT

Critical Ambulatory Transport Vehicle (CATV) initiative is the development of a smart stretcher that integrates real-time patient monitoring. This stretcher is not merely a transport device; it represents a comprehensive solution designed to ensure patient well-being throughout the transport process. By embedding real-time vital sign monitoring into the stretcher, healthcare professionals can continuously track critical parameters such as heart rate, blood pressure, oxygen saturation, and Temperature and ECG. This continuous monitoring is crucial for detecting any changes in the patient's condition, allowing for immediate medical interventions when necessary. Also Providing Supportive and Assistive Medical Devices The stretcher is equipped with a multi-parameter monitor, offering a minimal view of the patient's health status and enabling informed decision-making by medical personnel enabling a Greater chance of patient Safety and Crisis prevention.

Keywords: Patient Safety, Real-time Monitoring, Critical Transport, Healthcare Technology, User Experience

1. INTRODUCTION

Main objective of this research paper is by incorporating features such as real-time vital sign monitoring, a multi-parameter monitoring system, and an Ambu bag ventilator and other. This proactive approach to patient care is crucial in emergency situations where every second counts, and the ability to provide immediate respiratory support can be life-saving The incidents that have occurred due to the lack of monitoring include instances of sudden cardiac events, respiratory distress, or other critical events that were not promptly identified and addressed during the transfer process. These incidents highlight the urgent need for a systematic approach to monitoring patient vital signs during transfers to ensure timely intervention and optimal patient outcomes. Addressing this problem requires the implementation of a comprehensive monitoring system that can track and alert healthcare providers to any changes in the patient's condition during the transfer process. By proactively monitoring patient vital signs, healthcare teams can mitigate risks, improve patient safety, and enhance the quality of care provided during these critical transitions.

2. GENERAL IDEATION AND AIM SELECTION

2.1 AIM AND OBJECTIVE

This research recognizes the importance of reliability in critical care transport. The incorporation of a robust battery backup system ensures that all monitoring and ventilator functions remain operational, even in the event of a power failure. This reliability is vital in emergency scenarios where every second counts, and it reinforces the commitment to maintaining patient safety and stability throughout the transport process. In addition to these advanced features, the CATV places a strong emphasis on the ergonomic design and safety of the transport vehicle. Adjustable side rails, secure harness systems, and easy maneuverability are integral components that contribute to preventing falls and ensuring patient comfort. By focusing on the user experience for both patients and healthcare providers, the CATV aims to streamline the transport process, making it as efficient and safe as possible. Ultimately, the CATV aspires to set a new standard in critical patient transport. By combining cutting-edge technology with a deep understanding of patient needs, this research aims to enhance the quality of care provided during transfers. The successful implementation of the CATV will not only improve patient outcomes but also foster greater confidence among healthcare providers in managing critical situations.

In conclusion, the CATV (Critical Ambulatory Transport Vehicle) represents a significant leap forward in the field of emergency medical services. By focusing on patient safety, real-time monitoring, and reliable support systems aims to transform the landscape of critical patient transport. As healthcare continues to advance, initiatives like the CATV will play a crucial role in ensuring that critically ill patients receive the highest level of care during their most vulnerable moments. Through innovation and dedication, the CATV seeks to enhance the overall effectiveness of emergency medical services,

3. CRITICAL ANALYSIS

3.1 PROBLEM STATEMENT – BACKED DATA RESEARCH

Critical need for monitoring patient vital signs during the transfer of patients from the Intensive Care Unit (ICU) to the laboratory and imaging center. Incidents have been occurring due to the lack of continuous monitoring during these transitions, leading to potential risks and adverse outcomes for patients.

3.2 KEY FEATURES:

1. Patient Transfer Capabilities: The CATV facilitates seamless transfers from bed to bed and between various locations within the hospital, including imaging centers, laboratories, operating theaters, and emergency rooms. It is specifically designed to accommodate patients experiencing critical conditions, minimizing the stress associated with mobility and transfer.

2. Monitoring Functions: The vehicle is equipped with a three-parameter basic monitoring system that includes: ECG Monitoring: Continuous monitoring of the electrocardiogram (ECG) with an integrated alarm system to alert medical staff of any abnormalities. Pulse Oximetry (PPG): Real-time monitoring of blood oxygen levels to ensure patient safety during transfers. Non-Invasive Blood Pressure (NIBP) Measurement: Regular assessment of blood pressure to monitor the patient's vital signs effectively.

3. Safety and Comfort: The CATV is designed to reduce patient stress during transfers, providing a comfortable environment that prioritizes safety. It includes a battery backup system to ensure the functionality of critical monitoring equipment and other medical devices during transport.

4. Additional Features: The vehicle is equipped with slots for syringe pumps and intravenous (IV) bags, allowing for the administration of necessary medications and fluids during transit. The design considers the unique needs of patients in various states of health, particularly those in emergency situations or experiencing shock.

4. PROPOSED METHODOLOGY

ECG MONITORING

Objective: To design and implement a system capable of acquiring, processing, and visually representing Electrocardiogram (ECG) signals using the AD8232 ECG module, Arduino microcontroller, and OLED display. The system also identifies key ECG components such as the P, Q, R, S, and T waveforms and calculates the heart rate. A portable ECG monitoring system capable of displaying ECG waveforms and heart rate in real time.

- Operates at 2.0V–3.5V, 170 µA current.
- Supports 2/3 electrode setups with high noise filtering (CMRR: 80 dB).
- Provides analog ECG signal output

Implementation Steps:

1. **Hardware Setup**:
    - Connect the **AD8232 ECG module** to the Arduino microcontroller through its analog output pin.
    - Use the Arduino's **Serial Plotter** to visualize the analog ECG data from the AD8232 and identify the PQRST waveform patterns.
    - Interface an **OLED display** with the Arduino through the **I2C communication protocol** for displaying the ECG waveform in real time.

2. **Signal Processing and Filtering**:
   - Implement **filters** to improve signal clarity:
     - A **moving average filter** to reduce noise.
     - **Baseline detection** to stabilize the signal and remove drift artifacts.
   - Process the ECG signal to detect key features, including **P wave**, **T wave**, and the **R peak (used for heart rate calculation)**.
3. **Display Mechanism**:
   - Develop an algorithm to map the ECG waveform onto the **bit and pixel-based graphics** of the OLED display. This step involves ensuring that the OLED accurately represents intricate waveforms such as the PQRST components.
4. **Heart Rate Calculation**:
   - Calculate the heart rate (in beats per minute) using the detected **R-R intervals** from the ECG signal.
   - Display the heart rate and waveforms dynamically on the OLED.
5. **Testing and Validation**:
   - Test the system with various ECG signals to ensure accuracy in identifying waveform components (PQRST) and calculating heart rate.
   - Validate the results against a standard ECG system.

Working:

1. The **AD8232 ECG module** captures the user's ECG signal and sends it to the Arduino via the **analog pin**.
2. The Arduino processes the raw analog signal, applies filters, and detects waveform features using signal processing algorithms.
3. The processed signal is displayed on the Arduino's **Serial Plotter**, providing a real-time visualization for identifying PQRS and T waves.
4. The ECG waveform is then mapped onto the **OLED display** using **bit and pixel manipulation techniques** through the I2C communication protocol.
5. Heart rate is calculated from the R-R intervals, and the results are continuously displayed on the OLED alongside the waveform..

PULSE OXIMETER

Objective: To create a portable pulse oximeter system that measures and displays SpO2 levels and pulse rate using the MAX30100 sensor, Arduino, and OLED display. This system is designed for real-time monitoring during critical conditions, such as in a Critical Ambulatory Transport Vehicle (CATV).

Implementation Steps:

1. **Hardware Setup**:
   - Interface the **MAX30100 Pulse Oximeter Sensor** with an Arduino UNO microcontroller via the **I2C protocol**.
   - Connect an **OLED display** for real-time visualization of SpO2 and pulse rate.
2. **Signal Processing**:
   - Use red and infrared (IR) light signals from the MAX30100 to measure oxygen saturation (SpO2) and pulse rate.
   - Apply **digital filtering techniques**, such as low-pass filters, to minimize noise caused by motion artifacts.
3. **Real-Time Display**:
   - Process the pulse oximetry data using Arduino and display it on the OLED in a clear format:
     - **SpO2** as a percentage (e.g., 98%).
     - **Pulse Rate** as beats per minute (e.g., 72 bpm).
4. **Testing and Validation**:
   - Test in simulated conditions to ensure accurate and reliable SpO2 and pulse rate readings.
   - Validate results against standard medical-grade pulse oximeters.

Outcome:

1. A compact and portable pulse oximeter system suitable for real-time monitoring.
2. Accurate and noise-free measurements of SpO2 and pulse rate.
3. Effective display of processed data on an OLED screen for immediate interpretation.

Working:

1. The **MAX30100 sensor** emits red and IR light through the fingertip and measures the light absorbed by the blood.
2. Arduino processes this raw data using the ratio of red to IR light absorption to compute SpO2 levels and detects pulse rate from periodic light fluctuations.
3. Digital filters ensure noise-free output, while the OLED displays SpO2 and pulse rate dynamically via I2C communication.

AMBUBAG VENTILATOR

Ambu Bag Ventilator with Arduino Integration

1. **Basic Specifications:**
    - Made of silicone, latex-free, and self-inflating.
    - Capacity: 500–1500 mL (adult).
    - Includes pressure release valve and oxygen reservoir.
2. **Idea Overview:**
    - Mechanized press automates bag compression.
    - Arduino controls motorized operation for consistent ventilation.
    - Sensors monitor airflow, pressure, and oxygen levels.
3. **Outcome:**
    - Portable and automated ventilator system.
    - Ensures safe, real-time respiratory support with minimal manual effort.
    - Integrated oxygen flow via a flowmeter for effective oxygenation.

STRETCHER

1. Ergonomic Design:
- Lightweight, durable, and designed for patient comfort.
- Adjustable positions for optimal patient posture during transport.
- Safety straps and restraints ensure secure placement.

2. Mobility:
- Equipped with sturdy wheels or casters for smooth movement across hospital corridors, elevators, and ambulances. Compact and versatile design fits various medical environments.

3. Equipment Compatibility:
- Built-in slots and mounts for attaching essential medical equipment like IV pumps and monitors.
- Stability features to prevent dislodging of devices during transport.

4. Battery Backup:
- Integrated battery systems for powering attached monitoring devices during transfer, ensuring uninterrupted functionality.

5. Quick Transfer Mechanism:
- Features quick-release systems for easy transfer of patients to operating tables or other equipment.

NON-INVASIVE BLOOD PRESSURE (NIBP) MONITORING

Non-Invasive Blood Pressure (NIBP) monitoring is a vital medical tool used to measure blood pressure without invasive procedures. In this system, an inflatable cuff, controlled by two motors and a solenoid valve, is connected to an HX710B pressure sensor and managed by an Arduino Uno. The system ensures real-time blood pressure readings, displayed on an OLED screen and the Serial Monitor, for continuous monitoring during patient transport in the Critical Ambulatory Transport

Working Principle:

1. **Cuff Inflation and Deflation**:
   - Two DC motors inflate the cuff by pumping.
   - ng air into it through tubing connected to an air pump.
   - The solenoid valve is responsible for controlled deflation by releasing air in a gradual manner after inflation.
2. **Pressure Sensing**:
   - The HX710B pressure sensor, attached to the cuff, measures the air pressure during inflation and deflation.
   - Oscillometric vibrations (from arterial wall movements) are detected during deflation, indicating systolic and diastolic pressures.
3. **Data Processing**:
   - The Arduino Uno processes raw pressure data from the HX710B sensor.
   - Blood pressure readings are calculated and displayed in real-time on the OLED screen or Serial Monitor.

This system leverages the Arduino Uno, solenoid valve, and HX710B pressure sensor to create a safe, reliable, and real-time blood pressure monitoring device. Its integration into the CATV ensures continuous NIBP measurements, improving patient care during transport.

PROPOSED WORK

The research focuses on developing a smart stretcher with integrated health monitoring capabilities for continuous and accurate patient assessment during both stationary and mobile scenarios. The stretcher features ergonomic design for comfort and includes safety straps, adjustable positioning, and mounts for essential medical devices such as syringe pumps and ventilators. The health monitoring system is powered by two Arduino UNO boards. The first Arduino is connected to an AD8232 ECG module and an OLED display, processing electrical activity of the heart to display real-time ECG data. The second Arduino interfaces with a MAX30100 pulse oximeter, a temperature sensor, and an NIBP module to measure SpO2, pulse rate, body temperature, and blood pressure. All data is shown on OLED screens, with efficient communication handled via the I2C protocol. Digital filtering techniques remove motion noise, ensuring accurate results even during transport.

The system operates on a battery backup, ensuring uninterrupted functionality in diverse environments such as hospitals, ambulances, or home care. It is housed in a compact acrylic enclosure, which can be mounted onto a metal stretcher with options to attach additional devices. By combining advanced sensors and microcontroller systems, the stretcher provides real-time, reliable health monitoring, making it versatile and efficient for critical patient care.

5. SCOPE OF THE WORK

The future of this system holds immense potential in transforming healthcare delivery through advancements in technology and integration. One promising area is the development of AI-driven algorithms for predictive analytics, enabling early detection of critical health conditions such as arrhythmias or hypertensive crises. The incorporation of wireless and IOT technologies could allow seamless data transfer to cloud platforms for remote monitoring, telemedicine, and big data analysis. Additionally, modularity in design can facilitate easy integration of new sensors for advanced parameters such as glucose levels, respiratory rate, and hydration status.

1. **Advanced Algorithms**: Develop enhanced algorithms to improve sensor accuracy and signal processing capabilities.
2. **Expanded Monitoring**: Integrate additional monitoring features such as respiratory rate and glucose level detection.

3. **IoT Integration**: Connect the system to cloud platforms for remote patient monitoring and data storage.
4. **Smart Stretcher Expansion**: Add functionalities such as ventilator integration and automated alerts to make the stretcher more versatile.

Opportunities:

This health monitoring system offers immense opportunities in various areas. In emergency care, it proves to be a critical tool for ambulatory services, providing continuous monitoring during patient transport. It is adaptable for home healthcare, offering an affordable and reliable solution for patients with chronic illnesses. In clinical environments, the system supports real-time monitoring in hospitals, particularly in ICUs and high-dependency units. It can also play a vital role in public health, being deployable in remote or underserved areas where traditional systems are not available. Furthermore, it holds significant value in medical education, providing students with hands-on experience in real-time monitoring and healthcare technology. The system addresses a strong need for continuous monitoring by offering real-time tracking of vital health parameters like ECG, blood pressure, SpO2, heart rate, pulse rate, and temperature. It is a highly affordable and portable solution compared to existing alternatives, making it accessible for widespread use.

6. RESULTS AND CONCLUSIONS

This integrated system offers a portable solution for continuous health monitoring, leveraging advanced signal processing techniques and multiple I2C Bus. The first Arduino UNO is connected to an AD8232 ECG module and an OLED display. The AD8232 ECG module captures the electrical activity of the heart and produces analog signals, which are fed into the Arduino UNO's analog input pin. The Arduino processes these signals to detect the QRS complex and filters out noise using mathematical equations and digital signal processing techniques. The filtered ECG signal is then displayed on the OLED screen, providing real-time visualization of the heart's electrical activity. This setup helps in monitoring the heart's performance and detecting any abnormalities. second Arduino UNO is interfaced with a MAX30100 pulse oximeter sensor, a mini temperature sensor, an NIBP module, and another OLED display. The MAX30100 sensor measures SpO2 levels and pulse rate by emitting light through the fingertip and detecting the changes in light absorption caused by blood flow.

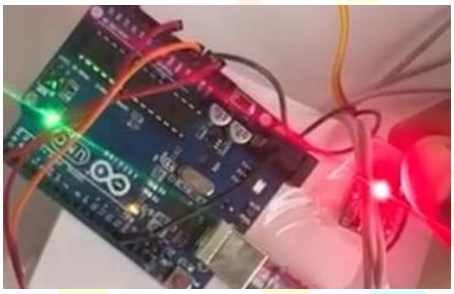

Figure 1. Arduino With Max30100

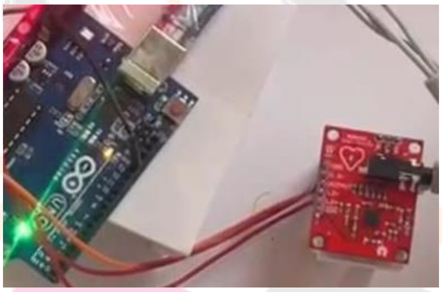

Figure 2. Arduino with AD8232 ECD Mod

The NIBP module measures blood pressure using an inflatable cuff and sends the data to the Arduino via the I2C protocol. The mini temperature sensor monitors the patient's body temperature and sends the analog data to the Arduino. All these readings are processed by the Arduino UNO and displayed on the OLED screen. The interface with the I2C protocol enables the system to manage multiple I2C devices efficiently, allowing simultaneous monitoring of various health parameters. The OLED displays are placed externally for easy visibility, while the Arduino boards and other components are securely housed inside the acrylic enclosure. The system is powered by a power bank with a battery backup to ensure uninterrupted operation, making it suitable for use in various settings, including home care and clinical environments. Additionally, the acrylic enclosure can be fitted onto a general stainless steel or metal stretcher. By welding appropriate mounts to the stretcher, separate sections can be added for additional syringe pump units or a ventilator bag mask. This setup would transform the system into a smart stretcher, capable of monitoring patient vitals during ambulatory transfers. Furthermore, each sensor incorporated into the system includes motion noise detection and removal filters. These filters are designed to eliminate motion noise caused by the movement of the stretcher, ensuring accurate and stable readings of patient vitals when the patient is in a steady state. This feature enhances the system's reliability during patient transfers, providing healthcare professionals with precise and timely information about the patient's health status All these readings are processed by the Arduino UNO and displayed on the OLED screen.

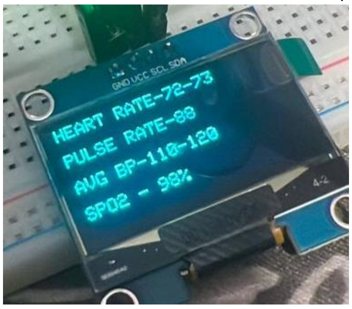

Figure 3. Oled 2 with vitals

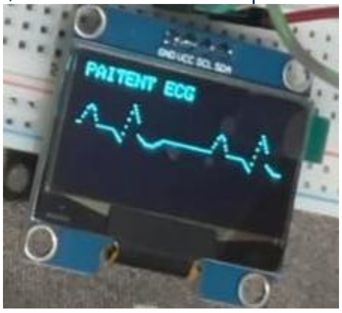

Figure 4. Oled 1 with ecg

The interface with the I2C protocol enables the system to manage multiple I2C devices efficiently, allowing simultaneous monitoring of various health parameters. In conclusion, this research integrates advanced sensors and microcontrollers to create a multifunctional health monitoring system. It provides real-time monitoring and display of critical health parameters, including ECG, blood pressure, SpO2, pulse rate, heart rate, and temperature.

Figure 5. Application of ECG via Laptop (Mount on Stretcher)

By employing noise removal techniques, digital filtering, and efficient interfacing with multiple I2C devices, the system ensures accurate and reliable health monitoring, offering a valuable tool for continuous patient care. The ability to mount the system on a stretcher further enhances its functionality, making it a versatile solution for both stationary and ambulatory patient monitoring.

The result of the proposed research is the development of a Mountable health monitoring system that integrates multiple sensors and microcontrollers to monitor and display vital health parameters in real-time. The system is able to accurately capture and process ECG signals, measure blood pressure, SpO2 levels, pulse rate, heart rate, and body temperature while on a patient on stretcher during transport .The system provides reliable and accurate readings of these health parameters. The integration of motion noise detection and removal filters ensures that the readings remain stable and precise even during ambulatory transfers.

The hardware assembly on an acrylic board, fitted onto a stainless steel or metal stretcher, transforms the system into a smart stretcher. This smart stretcher is capable of monitoring patient vitals continuously during transfers, offering a portable and reliable solution for healthcare professionals. The inclusion of a power bank with battery backup ensures uninterrupted operation, making the system suitable for various settings, including home care and clinical environments. When Compared to Philips and over Patient simulator it is above average in accuracy

Table 1 Result Comparison

Parameter	Developed System (Avg Value)	Philips IntelliVue MP50 (Gold Standard)	Accuracy (%)
ECG (R-R interval)	580 ms	740 ms	80.08%
SpO2	95%	97%	97.9%
Heart Rate	62 bpm	70 bpm	88.57%
Blood Pressure (Sys)	118 mmHg	122 mmHg	98.4%
Blood Pressure (Dia)	78 mmHg	82 mmHg	95.12%
Temperature	36.2°C	36.7°C	98.62%

Figure 6. Obtained ECG Signal

Overall, the research demonstrates the feasibility and Low Budget Implementation of a larger concept that can be explored in the wide spectrum. Implementation of this system has the potential to enhance patient care by providing real-time, accurate monitoring of critical health parameters, thereby aiding in timely interventions and improving patient outcomes during both stationary and

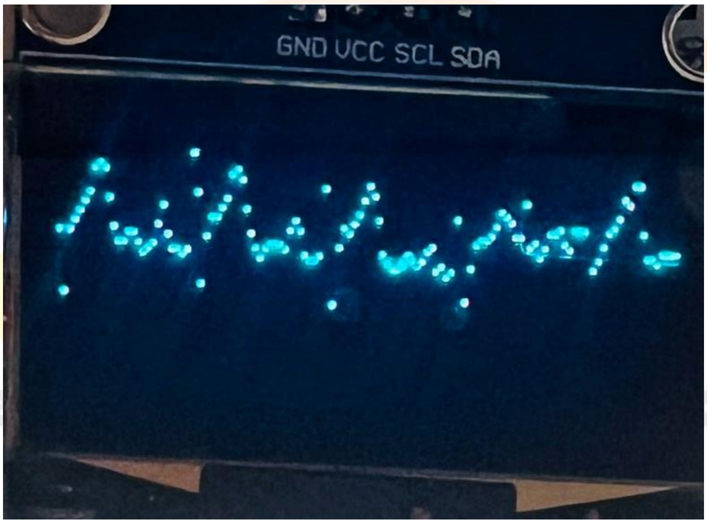

Figure 7. Output of ECG on 128 x 64 OLED DISPLAY

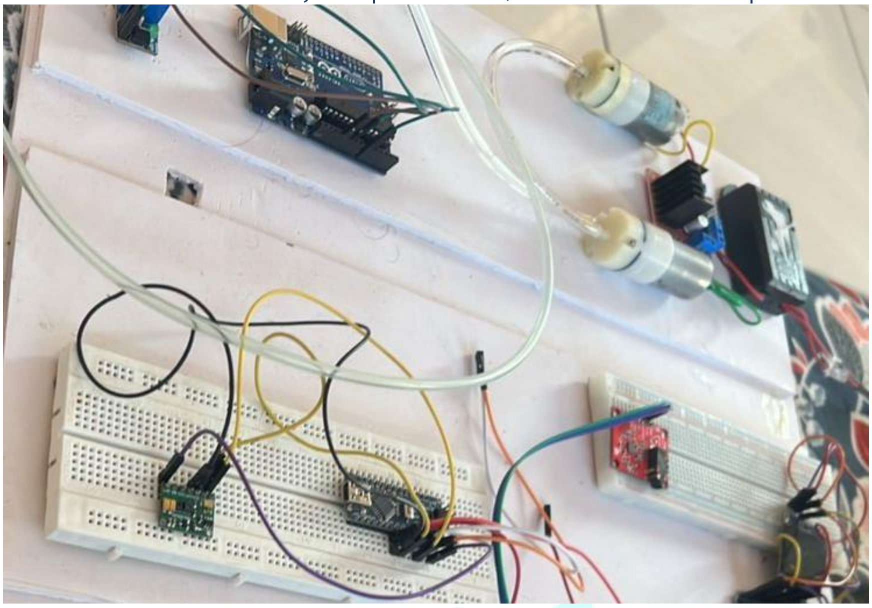

Figure 8. Application of ECG Via Laptop (Mount on Stretcher)

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