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WHEELCHAIR: AN AUTONOMOUS VEHICLE WITH SMARTNESS

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Abstract
Many individuals with disabilities face challenges in mobility, and smart devices enable them to access healthcare systems more effectively. These disabilities may result from temporary or permanent conditions caused by illnesses or accidents. For individuals with severe difficulty or inability to walk, the use of a wheelchair becomes essential. While manual or electric wheelchairs are sufficient for low to medium levels of disability, they are often inadequate for patients with severe disabilities who cannot operate them independently. In such cases, wheelchair users lack autonomous mobility and depend on others to manage their wheelchair. Researchers in the field of wheelchair technology are working towards designing smart wheelchairs to address these challenges. A viable solution involves integrating a health monitoring system into a wheelchair to continuously track the patient's health status and notify caregivers through alerts.
The purpose of the Smart Sensing Wheelchair is to monitor the biological parameters of the patient regularly and notify concerned individuals via messages. The objective of this work is to develop an affordable, smart wheelchair by incorporating a microcontroller-based health monitoring system into a conventional wheelchair. This system detects abnormalities in biological parameters and alerts designated users by sending notifications over the cellular network.
Keywords: Wheelchair; Patient Monitoring; GSM; Temperature; Heart Rate; Oxygen Saturation.

1. Introduction:

Wheelchairs are among the most widely used mechanical devices globally, primarily serving physically disabled individuals and the elderly to facilitate mobility. Traditional wheelchairs require either the assistance of another person or self-operation through manual effort. Statistics reveal that approximately 650 million people, which constitutes about 15% of the global population, experience some form of physical disability. With the growing population, the number of physically disabled and elderly individuals is also increasing, leading to a higher demand for automated wheelchairs.
Advancements in technology have made joystick-controlled, motorized wheelchairs widely available in many parts of the world. However, in developing and underdeveloped countries, these wheelchairs are often neither easily accessible nor affordable. Independent mobility is a significant aspiration for individuals with physical disabilities, particularly for those with quadriplegia or multiple sclerosis. These conditions result in paralysis below the neck, often caused by spinal cord injuries or knee joint disorders, leaving the affected individuals unable to move their lower limbs.
People with disabilities face numerous barriers in their daily lives. Surveys indicate that over 70% of manual wheelchair users develop shoulder pain at some stage of their lives. For quadriplegic individuals or those with severe mobility impairments, traditional manual wheelchairs are not an option due to their inability to operate them.
Wheelchairs can be designed to meet various needs, utilizing control mechanisms operated by hands, mouth, or other functional body parts. A smart wheelchair integrates standard driver modules with a collection of sensors and features a user interface powered by an Android app. This advanced functionality makes smart wheelchairs particularly beneficial for individuals with significant physical disabilities, enabling improved mobility and independence.

Cardiovascular Disease and Patient Monitoring Systems

Cardiovascular disease is one of the leading causes of death globally, accounting for over 15 million deaths annually. In addition, millions of individuals suffer from disabilities caused by cardiovascular illnesses. The delay between the onset of initial symptoms of cardiac diseases and seeking medical assistance varies significantly among patients, often with fatal consequences.

Epidemiological data strongly suggest that deploying resources for the early detection and treatment of heart disease has a greater potential to reduce fatalities associated with cardiac conditions than focusing solely on post-hospitalization care. Therefore, innovative approaches are needed to reduce the time between symptom onset and treatment. Continuous patient monitoring is one potential solution. Additionally, the growing trend toward independent living has increased the demand for personalized, non-hospital-based care solutions.

Heart disease—including heart attacks, coronary heart disease, congestive heart failure, and congenital heart defects—is the leading cause of death for both men and women in many countries. These conditions predominantly affect elderly individuals, who often live alone without round-the-clock monitoring. Pulse rate, which represents the number of heartbeats per minute (bpm), plays a crucial role in assessing the risk of heart attacks and other cardiovascular events.

The human heart beats to pump oxygen-rich blood to muscles and remove cellular waste products from tissues. Pulse rate varies depending on the body's oxygen demand, such as during exercise or rest. It also fluctuates significantly between individuals based on factors like age, fitness level, and genetics. For instance, during physical activity, the heart must beat faster to supply more oxygen-rich blood, making pulse rate a reliable indicator of exercise effectiveness for the body.

Advancements in patient monitoring systems have revolutionized global healthcare by leveraging cutting-edge technology. One critical aspect of patient monitoring is tracking body temperature, which reflects the body's ability to generate and dissipate heat. The human body naturally maintains its temperature within a narrow, safe range, despite significant external temperature variations. Monitoring these vital parameters, such as pulse rate and body temperature, is essential for early diagnosis and improved health outcomes.

2. BLOCK DIAGRAM

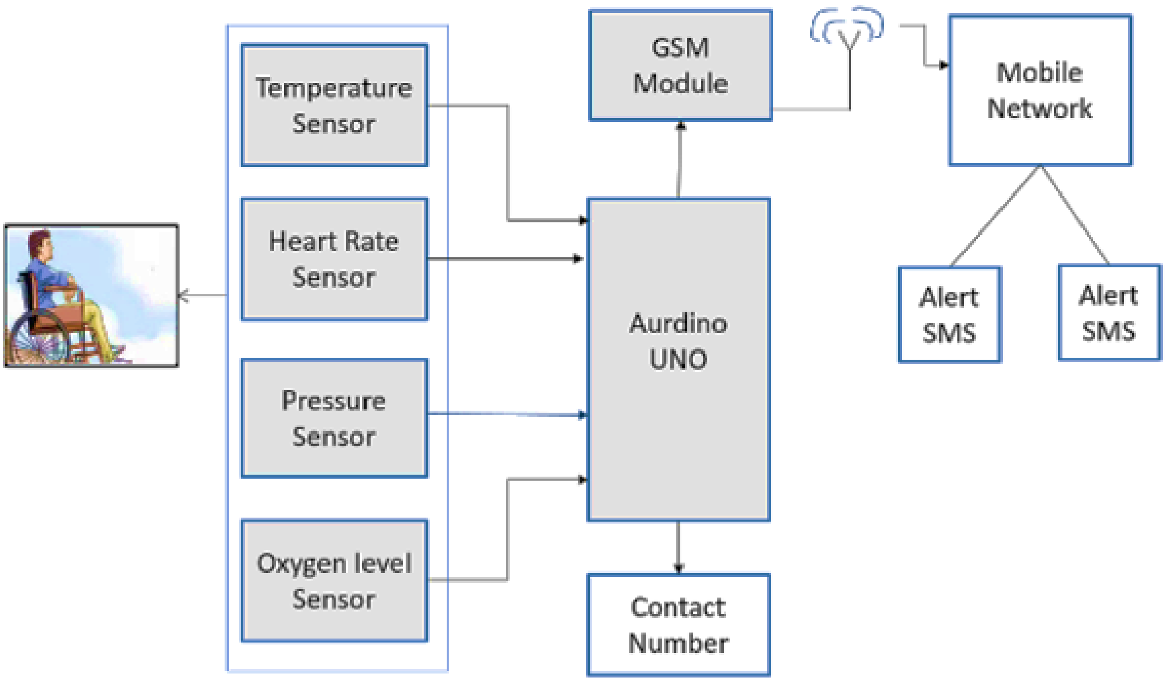

Fig 1: Block Diagram

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3. Proposed System

In this framework, we propose the incorporation of an additional feature that allows for the transmission of information in case of abnormal fluctuations in vital health parameters measured by sensors. This data will be sent to a registered mobile device, enabling timely action to save lives. The **GSM-based Patient Health Monitoring System** primarily aims to enable doctors and the patient's relatives to monitor the patient's health status remotely.

The system measures key health parameters, including heartbeat rate, ECG signals, oxygen levels, and body temperature. If any of these values exceed predefined limits, an immediate alert message is sent to the registered number. The system employs an **AVR Family Microcontroller**, interfaced with an LCD display, a heartbeat sensor, and the MAX30100 temperature sensor. The GSM modem in the system facilitates remote data transmission to the registered number. The system is powered by a 12V transformer and also features a manual health alert button, allowing patients to directly contact their doctor in case of other medical issues.

Additionally, the system includes a feature that enables doctors to check the patient's status at regular intervals by sending a query message. This system ensures efficient communication between patients and healthcare providers while accurately monitoring and updating health parameters, making it a lifesaving solution.

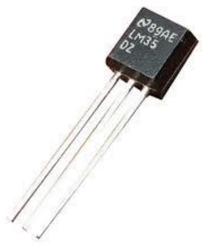

Fig 2:LM35 Sensor

3.1 Temperature Sensor

The **LM35** is an integrated circuit temperature sensor with an electrical output proportional to the measured temperature in degrees Celsius (°C). Unlike thermocouples, the LM35 generates a higher output voltage, eliminating the need for output voltage amplification.

The LM35 series consists of precision temperature sensors with a linearly proportional output voltage to the Celsius temperature. Its main advantage over linear sensors calibrated in degrees Kelvin is that it does not require subtracting a constant voltage to achieve Centigrade scaling.

The LM35 does not require external calibration or trimming and provides typical accuracies of ±0.25°C at room temperature and ±0.75°C across a wide temperature range of -55°C to +150°C. Its low cost is ensured by trimming and calibration at the wafer level.

Features of the LM35 include:

- **Low output impedance**: Ensures ease of interfacing with readout or control circuits.
- **Linear output**: Enables accurate and straightforward readings.
- **Precise inherent calibration**: Requires no additional adjustments.
- **Low power consumption**: Drawing only 60 µA from its supply, it exhibits minimal self-heating (less than 0.1°C in still air).
- **Versatile power supply options**: Compatible with single or dual power supplies.

These features make the LM35 an ideal choice for use in patient health monitoring systems.

3.2 MAX30100 Pulse Oximeter SpO2 and Heart-Rate Sensor Module

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The **MAX30100** is an integrated sensor solution designed for pulse oximetry and heart rate monitoring. It combines two LEDs, a photodetector, optimized optics, and low-noise analog signal processing to detect pulse oximetry and heart-rate signals. The MAX30100 breakout board operates within a voltage range of 1.8V to 5.5V.

Fig 3: MAX30100 Sensor

3.2.1 Features

- **Complete Pulse Oximeter and Heart-Rate Sensor Solution**: Simplifies design by integrating all necessary components, including LEDs, photodetector, and a high-performance analog front-end.
- **Ultra-Low Power Operation**: Extends battery life for wearable devices.
- **Programmable Sample Rate and LED Current**: Allows for power savings.
- **Ultra-Low Shutdown Current**: Consumes only 0.7µA (typical) during shutdown.

The MAX30100 has two LEDs: one emits red light, and the other emits infrared light. For pulse rate detection, only infrared light is needed. Both the red and infrared lights are used to measure oxygen levels in the blood. Oxygenated blood absorbs more infrared light and allows red light to pass through, while deoxygenated blood absorbs red light and allows more infrared light to pass.

The sensor determines pulse rate by analyzing the time intervals between the increase and decrease in oxygenated blood levels caused by heartbeats. The absorption levels for both light sources are processed and stored in a buffer, which can be accessed via I2C communication. This sensor module is compatible with Arduino and is easy to integrate following specific wiring setups.

3.3 Heartbeat Sensor

In this system, an **IR sensor** is utilized to detect heartbeats. Infrared (IR) light operates with less noise and is less affected by ambient light compared to wavelengths in the visible spectrum. The IR sensor functions by emitting light when current passes through it in the forward direction, while blocking current in the reverse direction.

The heartbeat detection process is facilitated by a **plethysmograph**, an infrared photoelectric sensor used to measure changes in pulsatile blood flow from the finger. This sensor records variations in blood volume caused by arterial pulse expansion and contraction in the microvasculature.

This method is non-invasive and provides reliable measurements of changes in finger blood flow during wakefulness and sleep. The key parameter, **Pulse Wave Amplitude (PWA)**, is directly correlated to blood flow. Finger plethysmography can detect pharmacologically induced changes in vascular tone, which are reflected in alterations of PWA.

Key Insights:

- PWA reflects finger blood flow changes.

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- The anatomical structure of the finger helps detect vascular tone changes caused by sympathetic activation or inhibition.
- These measurements, derived from finger plethysmography, provide critical data for evaluating cardiovascular health.

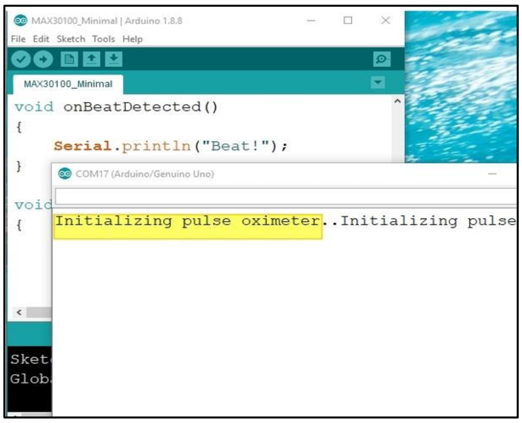

Fig 4: Output of MAX30100

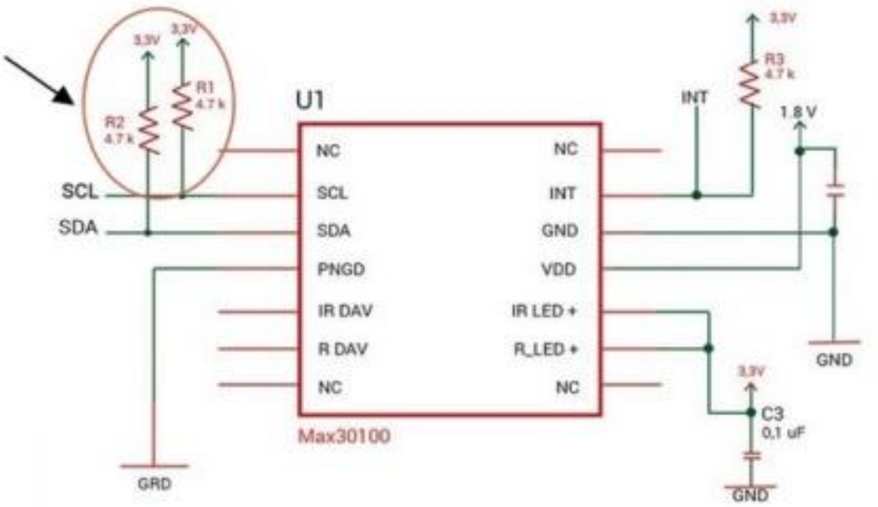

Fig 5: Pin Diagram of MAX30100

3.4 ECG Sensor

An **Electrocardiogram (ECG)** records the electrical activity of the heart muscle from the body surface. The heart's muscle cells are closely interconnected, allowing electrical impulses to propagate efficiently. Specialized cardiac cells, such as the atrial conduction tracks, atrioventricular (AV) node, bundle of His, bundle branches, and distal ventricular conduction system, are designed to transmit electrical activity rapidly through the heart.

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The ECG test measures these electrical signals, which originate in the sinoatrial node, the natural pacemaker of the heart. These signals enable the rhythmic contraction of the heart's muscle fibers, which pump blood throughout the body.

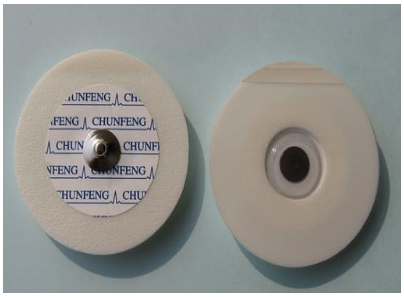

Fig 6: ECG Leads

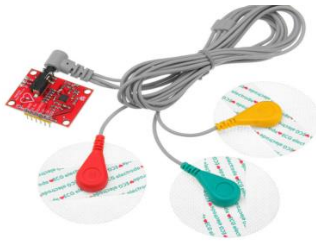

Fig 7: AD3282 Sensor

3.5 Arduino Uno (ATmega328) Microcontroller

The **Arduino Uno** is a microcontroller board based on the ATmega328P. It features:

- **14 digital I/O pins** (6 of which support PWM output)
- **6 analog inputs**
- A **16 MHz quartz crystal**
- USB connection
- Power jack
- ICSP header
- Reset button

The board includes all components necessary to support the microcontroller. It can be powered via USB or an AC-to-DC adapter/battery, making it highly versatile and beginner-friendly. The Uno differs from earlier boards by eliminating the FTDI USB-to-serial driver chip, using instead the Atmega16U2 (or Atmega8U2 in earlier versions) as a USB-to-serial converter.

Key Features:

1. **Enhanced Pinout**: Added SDA and SCL pins near the AREF pin for better I2C communication.
2. **Voltage Adaptability**: IOREF pin supports shields that adapt to the board's operating voltage.
3. **Stronger Reset Circuit**: Improved reliability in hardware resets.
4. **Upgradeable Firmware**: The Atmega16U2 enables USB communication and can be programmed to expand functionality.

The Arduino Uno is the flagship board for Arduino platforms, serving as the reference model for future iterations.

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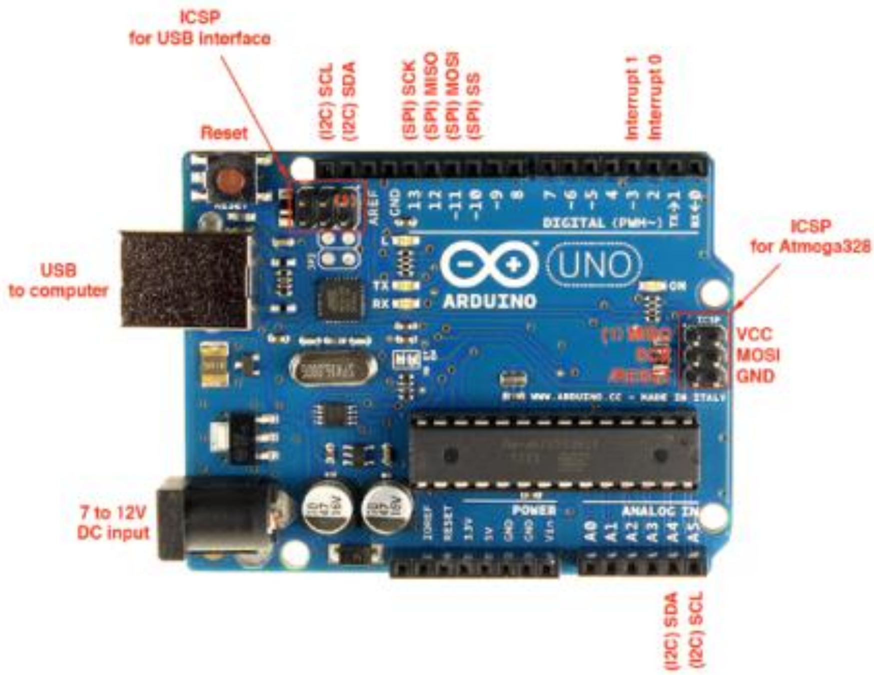

Fig 8: Arduino Uno

3.6 GSM Module

A **GSM modem** is a specialized device that uses a SIM card to connect to a mobile operator's network, functioning similarly to a mobile phone. It can connect to a PC or microcontroller via USB, serial, or Bluetooth interfaces. GSM, or **Global System for Mobile Communication**, is the most widely used mobile communication technology worldwide.

Key Features:

- **SIM Card Requirement**: Operates using a SIM card for network connectivity.
- **AT Command Support**: Controlled via AT commands, shared with traditional dial-up modems.
- **RS232 Serial Bus**: Acts as the communication interface between the GSM modem and ARM microcontroller.
- **Modular Design**: Can connect externally to a PC or other devices via USB.

The GSM modem is versatile, supporting dial-up connections and wireless data communication. It plays a critical role in patient health monitoring systems, enabling real-time data transmission to registered mobile numbers.

Fig 9: GSM Module

4. Software Description

The **Arduino software environment** provides a platform for writing and uploading sketches (Arduino's term for programs) to Arduino boards. This open-source ecosystem supports the development of digital devices and interactive systems that interact with the physical world.

Key Features:

- **Open Source**: Licensed under GNU LGPL/GPL, enabling unrestricted manufacturing and software distribution.
- **Extensibility**: Boards support a variety of expansion shields and external circuits.
- **Programming Flexibility**: Sketches use a mix of C and C++ programming features.
- **Serial Communication**: Includes USB-based interfaces for loading and managing programs.

Arduino boards are available in preassembled or DIY kit formats, appealing to beginners and advanced users alike. They empower developers to build projects ranging from simple LED controllers to complex IoT applications.

Additional Microcontroller Platforms

Several microcontrollers and microcontroller platforms are available for physical computing, such as **Parallax Basic Stamp**, **Netmedia's BX-24**, **Phidgets**, **MIT's Handyboard**, and many others. These tools simplify microcontroller programming by offering user-friendly interfaces. Among these, Arduino stands out due to its unique advantages for teachers, students, and hobbyists:

- **Inexpensive**: Arduino boards are affordable compared to other microcontroller platforms. The most basic version can be hand-assembled, and even pre-assembled modules cost less than $50.
- **Cross-platform**: The Arduino Software (IDE) is compatible with Windows, macOS, and Linux, unlike many other systems limited to Windows.
- **Simple and clear programming environment**: The Arduino IDE is beginner-friendly but versatile enough for advanced users. For educators, it is conveniently based on the Processing programming environment, making it easier for students to transition.
- **Open-source and extensible software**: Arduino software is open source, allowing experienced programmers to expand its capabilities using C++ libraries. Users can incorporate AVR-C code directly for advanced functionality.
- **Open-source and extensible hardware**: Arduino board designs are published under a Creative Commons license, enabling experienced circuit designers to create custom versions of the board. Even novices can assemble a breadboard version to save costs and understand its workings.

5. Advantages

1. **Cost-Effective**: Compared to existing patient monitoring systems, the proposed system is highly economical.
2. **Portable**: Like a wheelchair, the system is portable and user-friendly.
3. **Non-Invasive**: The monitoring system does not interfere with the patient physically, ensuring comfort and usability.
4. **Ease of Use**: The system can be easily attached or removed based on the patient's requirements, enhancing convenience and accessibility.

6. Conclusion

This project focuses on the development of an inexpensive **smart wheelchair** by integrating a microcontroller-based health monitoring system into a conventional wheelchair. The system is designed to detect cardiovascular abnormalities using heart rate data and send alerts to designated cell phones or email IDs via

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the cellular network. The integration of sensors into the wheelchair structure, particularly the armrest, makes it user-friendly and practical.
The goal was to create an affordable and easy-to-use health monitoring wheelchair that enables patients with disabilities to stay connected with their caregivers or medical personnel through SMS updates. This innovation not only enhances the independence of patients but also improves their safety and quality of life.

Future Work

1. **Incorporation of Additional Parameters**: Future versions of the system can include additional health monitoring parameters, such as blood pressure, glucose levels, and respiratory rate, to provide more comprehensive health insights.
2. **Enhanced Accessibility for the Blind**: The system can be adapted to support blind users by integrating obstacle detection sensors, ensuring safer mobility.

These enhancements aim to broaden the system's applicability and improve the quality of care for diverse user groups.

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