SMART CAM VENTILATOR WITH HEART BEAT MONITORING & GSM ALERT

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Abstract— Ventilators play a crucial role in supporting patients with respiratory difficulties, requiring precise control over breathing cycles to ensure effective oxygenation. The primary objective of this project is to design and fabricate a cam-operated smart ventilation system with automatic fast and slow ventilation based on real-time oxygen level monitoring. The system is designed to deliver breathing rates ranging from 10 to 30 breaths per minute, with the ability to dynamically adjust based on patient needs. Additionally, it controls the tidal volume (amount of air delivered per breath) and modifies the inhale-to- exhale ratio for optimal respiratory support. The proposed system integrates an oxygen (O_2) sensor to continuously measure oxygen concentration in the patient's airflow. This data is processed by an Arduino-based microcontroller unit (MCU), which determines whether to operate in fast or slow ventilation mode by activating a relay-controlled bag mechanism. A carbon dioxide (CO_2) sensor is also incorporated to monitor the exhaled air, ensuring efficient gas exchange and preventing CO_2 build- up. The cam mechanism enables smooth and controlled ventilation cycles, providing mechanical reliability and adaptability. To enhance patient safety, the system includes a GSM-based alert module that notifies medical personnel in case of abnormal oxygen levels or emergency conditions. This automated system reduces the need for constant manual supervision, ensuring more reliable and efficient ventilator operation. By integrating sensor-driven automation, cam-based mechanical control, and real-time alerts, this project aims to enhance critical care ventilation, making it more adaptable and responsive to patient conditions.

Keywords— Smart ventilation system, Relay-controlled bag mechanism, Tidal volume control.

1. Introduction

In modern healthcare and industrial settings, maintaining an optimal indoor environment is crucial for ensuring human well-being. Ventilation systems play a significant role in regulating airflow, temperature, and humidity, which directly impact air quality and comfort. Additionally, continuous health monitoring, particularly for patients with cardiovascular conditions, is essential for early detection of medical emergencies. The Smart CAM Ventilator with Heartbeat Monitoring & GSM Alert is designed to address both these aspects by integrating automated ventilation control with real-time patient health monitoring. Traditional ventilation systems operate at a constant rate, regardless of environmental conditions, leading to inefficiencies in energy consumption and airflow management. To overcome these limitations, this project introduces a CAM-driven mechanical system that dynamically adjusts ventilation speed based on environmental factors. The system intelligently switches between fast and slow ventilation modes, ensuring optimal airflow while conserving energy. This automated mechanism makes the system more adaptable and efficient than conventional ventilation methods.

In addition to ventilation control, the system is equipped with a heartbeat monitoring sensor that continuously tracks the patient's pulse rate. Any detected irregularity, such as a sudden increase or decrease in heartbeat, triggers an instant GSM alert, notifying caregivers or healthcare professionals.

This feature ensures timely medical attention, reducing the risk of complications and enhancing patient safety.

The integration of mechanical automation, IoT-based health tracking, and wireless communication makes this system a smart and reliable solution for hospitals, ICUs, elderly care facilities, and even home healthcare settings. By combining adaptive ventilation with proactive health monitoring, this project not only enhances patient care but also promotes energy efficiency and environmental sustainability.

II. EXISTING SYSTEM

Before the development of a "Cam Operated Smart Ventilation System with Automatic Fast/Slow Ventilation and Patient Heartbeat Monitoring with GSM Alert," several related systems and technologies existed in different domains, such as mechanical ventilation, patient monitoring, and communication-based alert systems. However, each of these technologies typically operated independently or lacked the integrated functionality envisioned in this project.

- TRADITIONAL MECHANICAL VENTILATION SYSTEMS:

These systems are primarily used in hospitals to support patients who are unable to breathe adequately on their own. They provide controlled amounts of air or oxygen to the patient's lungs. Limitations: Traditional ventilators often lack real- time adaptability, relying on manual settings and constant monitoring. They also don't typically adjust ventilation rates based on patient conditions automatically, and there is limited integration with other

patient vital signs like heart rate.

- AUTOMATED VENTILATION SYSTEMS:

Most automated ventilators do not incorporate monitoring of heart rate or offer direct communication with medical staff via alert systems (such as GSM). These systems

also tend to operate based on predefined parameters, not real-time patient physiological feedback like heart rate, making them less responsive to sudden patient condition changes.

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- GSM-BASED ALERT SYSTEMS:

These systems typically don't integrate directly with ventilation systems. Alerts are often only triggered based on predefined thresholds and do not adjust treatment (e.g. Ventilation settings) in real-time. Additionally, there is no automation in the intervention process.

Limitations: GSM-based alert systems have several limitations. They depend on cellular network coverage, which can be weak in remote areas, and may experience delays or failures during network congestion. Operating costs can rise with frequent use, and SMS messages are

limited to 160 characters, restricting information. The systems are vulnerable to security risks like interception and are dependent on cellular infrastructure, meaning

they can fail during outages. Battery life can also be impacted by constant use, and the range of communication is limited to GSM network coverage. Additionally, they offer limited interactivity and struggle with transmitting large data, such as images or videos, due to slow speeds.

III. PROPOSED SYSTEM

The proposed system aims to design and fabricate a smart mechanical ventilation system capable of delivering automated breath cycles (10-30 breaths per minute) with adjustable airflow and air volume, based on real-time oxygen sensor data. The system utilizes a cam mechanism to control ventilation rates and incorporate modern health monitoring features such as vital sign tracking and emergency alert

systems.

The cam-operated mechanism in the proposed smart ventilation system plays a crucial role in controlling the delivery of air to the patient's lungs. This mechanism uses a rotating cam to drive a mechanical linkage that compresses and releases a ventilation bag, thereby regulating the flow of air. As the cam rotates, it causes the bag to inflate (inhalation) and deflate (exhalation) in a precise manner, ensuring that each breath cycle delivers the appropriate volume of air. The cam's design can be adjusted to modify the compression ratio, allowing for control over the amount of air forced into the lungs with each cycle. This mechanical operation is key to providing fast or slow ventilation depending on the patient's needs. The system's ability to adjust the cam's movement in real time, based on the input from oxygen sensors and a microcontroller, allows for highly adaptable ventilation, making it ideal for patients with varying levels of respiratory distress.

The oxygen sensor in the proposed ventilation system is a critical component that continuously monitors the patient's oxygen levels to ensure appropriate ventilation. Typically, these sensors are non-invasive devices that measure the oxygen saturation (SpO2) in the patient's blood, providing real-time data on how well oxygen is being delivered to the tissues. This information is sent to the microcontroller in the system, which processes the data and adjusts the ventilation rate accordingly. If the oxygen saturation drops below a certain threshold, the system will increase the breathing rate or the air volume delivered to the lungs, ensuring the patient receives adequate oxygen. By providing continuous feedback on the patient's respiratory status, the oxygen. By providing continuous feedback on the patient's respiratory status, the oxygen sensor enables the system to deliver dynamic and responsive ventilation, optimizing air supply in real-time based on the patient's changing condition. This makes the system more efficient and responsive, particularly in emergency or critical care situations.

The microcontroller in the proposed ventilation system acts as the brain of the entire setup, processing data from various sensors and controlling the system's response. It receives real-time inputs from the oxygen sensor, which measures the patient's oxygen saturation, and uses this data to adjust the ventilation rate and air volume delivered through the cam-operated mechanism. The microcontroller is programmed to monitor the patient's condition continuously and make real-time decisions about when to switch between fast or slow ventilation modes based on the oxygen levels. It also manages other parameters like the inhale-to-exhale ratio and ensures the correct functioning of the system's components. Additionally, the microcontroller interfaces with the alarm system, triggering alerts if the patient's oxygen levels fall outside safe limits. By integrating these functions, the microcontroller enables automated and adaptive control of the ventilator, ensuring that the system responds intelligently to the patient's changing needs while maintaining consistent care.

Ventilation control in the proposed system is a dynamic process that adjusts the airflow delivered to the patient based on real-time monitoring of their respiratory needs. The system is designed to deliver ventilation in two modes: fast and slow, depending on the patient's condition. When the oxygen levels detected by the sensor drop below a threshold, the system automatically switches to fast ventilation, increasing the rate of breaths and volume of air delivered to help restore oxygen levels quickly. Conversely, for less critical cases, the system operates in slow ventilation mode, delivering a controlled, lower rate of breaths with a balanced air volume. The microcontroller plays a key role in managing this control, processing sensor data and adjusting the ventilation rate and air volume to provide optimal breathing support. Additionally, the system can modify the inhale-to- exhale ratio to ensure that each breath cycle matches the patient's needs, promoting effective gas exchange. This automated control ensures that the ventilator adapts in real- time, providing personalized care and enhancing the efficiency of oxygen delivery. The airbag and ventilation bag are essential components of the proposed ventilation system, working together to facilitate the delivery of air to the patient's lungs. The ventilation bag is a flexible, airtight reservoir that holds the air that will be delivered to the patient during the inhalation phase of the breathing cycle. The airbag, driven by the cam-operated mechanism, compresses and inflates this bag to push air into the patient's lungs. As the cam rotates, it applies pressure to the bag, forcing air into the respiratory system, simulating natural breathing. During exhalation, the bag deflates as the pressure is released, allowing the patient to breathe out. The capacity of the ventilation bag can be adjusted to ensure the right volume of air is delivered per breath, based on the patient's requirements. This system's flexibility ensures that it can accommodate varying levels of oxygen needs and can be programmed for fast or slow ventilation modes, depending on the severity of the patient's respiratory condition.

Real-time monitoring and data transmission are crucial features of the proposed ventilation system, ensuring continuous oversight of the patient's condition and enabling remote monitoring by healthcare professionals. The system is equipped with sensors that track vital signs such as oxygen saturation, heart rate, and respiratory rate, providing up-to- date information on the patient's respiratory status. This data is processed by the microcontroller the microcontroller and displayed locally for immediate feedback. Additionally, the system is designed to transmit this data to a remote location, allowing medical professionals to monitor the patient's condition in real time, even from a distance. Wireless communication technologies, such as Wi-Fi or GSM, facilitate the transmission of vital information to a centralized monitoring platform or directly to healthcare providers via SMS alerts or automated calls in case of critical events. This

real-time data transmission ensures that medical personnel are always informed of the patient's condition and can make timely interventions if necessary, improving patient care and response times.

The emergency alert system in the proposed ventilation system is designed to enhance patient safety by notifying healthcare providers or emergency contacts when the patient's condition requires urgent attention. If the oxygen levels fall below a critical threshold or if other vital signs, such as heart rate or respiratory rate, indicate a potential life-threatening situation, the system triggers an alarm to alert medical staff immediately. Additionally, the system can send automated messages or make phone calls to a designated healthcare provider or emergency contact using a GSM modem or similar communication technology. This ensures that help can be dispatched quickly, even in situations where the patient is in a remote or understaffed location. The emergency alert system not only provides immediate notification to those responsible for the patient's care but also helps reduce response times, which is crucial in preventing complications or further deterioration of the patient's health.

IV. METHODOLOGY

The first step in the methodology involves designing the system and selecting the necessary components that contribute to the functionality of automated ventilation and health monitoring. The core function of the system is to automatically regulate airflow based on environmental and patient health conditions. To achieve this, the oxygen sensor,

pressure sensor, and heartbeat sensor are integrated into the system. The oxygen sensor ensures that an adequate oxygen supply is maintained for the patient, while the pressure sensor monitors the airflow inside the ventilation chamber, preventing excessive pressure that could be harmful. The heartbeat sensor continuously tracks the patient's pulse rate and provides critical data that determines if medical intervention is required.

At the centre of the system is the Arduino UNO microcontroller, which acts as the primary control unit. It is responsible for processing sensor data, making real-time decisions, and controlling the mechanical components accordingly. A relay unit is incorporated to regulate power distribution, ensuring that the system operates efficiently without overloading any component. The ventilation mechanism consists of a CAM-operated system, spur gears, ball bearings, frame stand, and an Ambu bag, which together form the core of the automated air circulation process. The GSM module is integrated to send emergency alerts in case

of abnormal patient health conditions, enabling timely intervention from medical professionals or caregivers. An LCD display is also included in the system to visually present real-time sensor readings, allowing users to monitor the patient's health status and ventilation operation directly.

A. BLOCK DIAGRAM

Simplified block diagram of Microcontroller based heart beat sensor and Pulse sensor are display system is shown in figure. With this system the parameters of our body can be mentioned and it is viewed by various doctors where ever required. The signals from the patients are picked up by the sensors. The different signals obtained from various combinations are given to the amplifier section where ACSignals picked up with this signal are eliminated. This signalis given to the microcontroller Arduino Uno. In this analog signal is converted to digital. This digital signal is displayed in LCD display as per the hardware program.

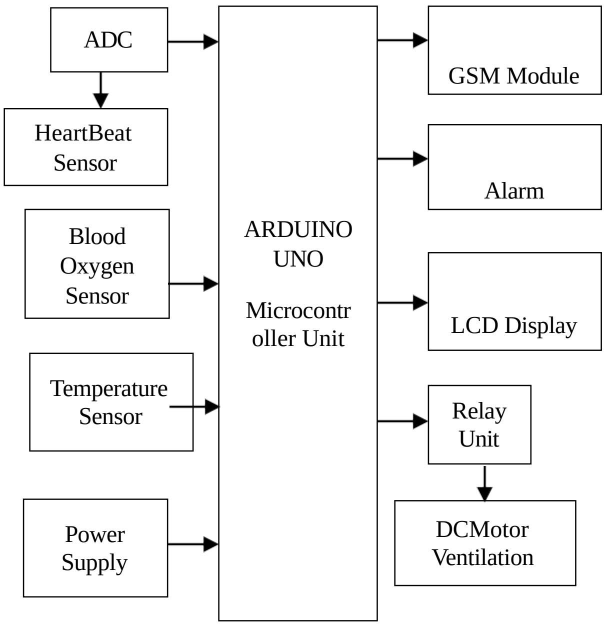


Figure1:Block Diagram

B. System Design and Requirements Definition

The first step is the preparation of the data which are necessary for data mining during data understanding, data preparation and big data. The data under discussion here consist of medical information, such as clinical reports, records, images, and other various forms of information that can be transformed into data that can be understood by a machine.

C. Data Acquisition

The data acquisition process begins with sensors measuring heart rate, oxygen level, and temperature, converting these physical quantities into electrical signals.

These signals are then conditioned and digitized by the Arduino Uno's ADC. The digitized data is processed by the Arduino, which may involve filtering, calculations, and threshold comparisons. Optionally, the processed data can be transmitted via the GSM modem for remote monitoring or stored locally for later analysis.

D. Data Processing and Analysing

Collecting, analysing, and leveraging the data such as consumer, patient, physical, and clinical data ends in big data.

It is at this stage that human intervention, as a part of machine learning methods, takes place and experts investigate and analyse the data to extract the data with finest structures, patterns, and features.

E. Decision Making

The Arduino Uno, the system's central processor, makes decisions based on sensor data. It continuously monitors heart rate, oxygen level, and temperature readings, comparing them to pre-set thresholds. If readings exceed or fall below critical values, the Arduino takes actions like triggering alarms, sending alerts via the GSM modem, adjusting settings for devices, or updating the LCD display. These decisions are implemented through conditional statements and loops within the Arduino's programming.

F. Output

The output of this system is primarily displayed on the LCD display. This display shows real-time sensor readings, including heart rate, oxygen level, and temperature. It can also indicate system status, such as alarm conditions or normal operation. Additionally, if the GSM modem is activated, the system can send text messages to designated recipients, providing remote monitoring and alerts. In specific applications, the system might control external devices like fans or heaters, with the output being the adjusted settings or physical changes in the environment.

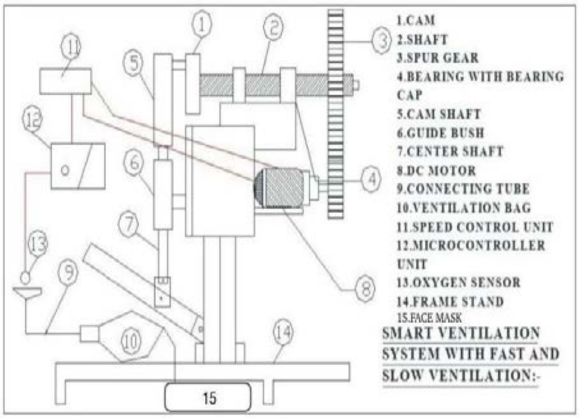
V. WORKING

The major parts that are effectively employed in the design and the fabrication of the Cam operated smart ventilation system with automatic fast slow ventilation with patient heart beat monitoring system with GSM alert are described below:

The frame is constructed from mild steel, which is a type of carbon steel that contains a low amount of carbon, typically around 0.05% to 0.25%. Mild steel is widely used in construction and manufacturing due to its excellent properties, nsuch as ease of welding, forming, and machining. It also offers a good balance of strength, ductility, and cost-effectiveness.

This makes it a perfect choice for creating a frame structure that needs to provide stability and durability without being overly heavy or difficult to work with. The frame itself is designed with an L-shape resembling the letter which consists of two perpendicular sections.

This design is known as an L-angle frame. The angle formed between the two sides of the frame is typically 90 degrees, making it ideal for supporting or holding other components at right angles.



The spur gears, which are designed to transmit motion and power between parallel shafts, are the most economical gears in the power transmission industry. Perhaps the most often used and simplest gear system, external spur gears are cylindrical gears with straight teeth parallel to the axis. They are used to transmit rotary motion between parallel shafts and the shafts rotate in opposite directions. They tend to be noisy at high speed as the two gear surfaces come into contact at once. Internal spur gears: The internal spur gear works similarly to the external spur gears except that the pinion is inside the spur gear. They are used to transmit rotary motion between parallel shafts but the shafts rotate in the same direction with this arrangement.

Mechanical ventilator, also known as a breathing machine, if a condition makes it very difficult for you to breathe or get enough oxygen into your blood. This condition is called respiratory failure. Mechanical ventilators are machines that act as bellows to move air in and out of your lungs. Your respiratory therapist and doctor set the ventilator to control how often it pushes air into your lungs and how much air you get. You may be fitted with a mask to get air from the ventilator into your lungs. Or you may need a breathing tube if your breathing problem is more serious. When you’re ready to be taken off the ventilator, your healthcare team will “wean” you or decrease the ventilator support until you can start breathing on your own.

Mechanical ventilators are mainly used in hospitals and in transport systems such as ambulances and MEDEVAC air transport etc. In some cases, they can be used at home, if the illness is long term and the caregivers at home receive training and have adequate nursing and other resources in the home.

Being on a ventilator may make you more susceptible to pneumonia, damage to your vocal cords, or other risks or problems.

Divers use blood oxygen sensors to measure the blood oxygen in their breathing gas. Open circuit scuba divers test the gas before diving as the mixture remains unchanged during the dive and partial pressure changes due to pressure are simply predictable, while mixed gas rebreathe divers must monitor the partial pressure of oxygen in the breathing loop throughout the dive, as it changes and must be controlled to stay within acceptable bounds.

A blood Oxygen Sensor is a test used to measure the oxygen level of the blood. It can easily measure how well oxygen is being sent to parts of the human body furthest from your heart, such as the arms and legs. A device like a clip called a probe is placed on a body part, such as an ear lobe or a finger. In this device, a light is used to measure how much oxygen is in the blood.

VI. OUTPUT AND OPTIMIZATION

Our proposed system utilizes the CAM principle with several advanced features aimed at precision control, portability, battery operation, compact size, and noise reduction. The system supports multiple operation modes such as Child Mode, Paediatric Mode, and Adult Mode selected based on the lung capacity, breath rate, and inspiration-to- expiration ratio of the subject. These parameters typically depend on the subjects age.

The system's automation is driven by a microcontroller, mechanical switches, and two servos. The servos are positioned opposite each other at a 180-degree angle. The motor shafts are connected to a mechanical pulley system that rotates based on motor direction. A rigid cot wire links the arms of the servos to the pulleys. As the motor rotates, torque is transferred via the pulleys, creating tension in the cot wire.

This tension pulls the mechanical arms to compress the Ambu-bag, enabling controlled ventilation.

VII. CONCLUSION

The automated mechanical ventilation system represents a monumental leap forward in the realm of respiratory care technology, significantly enhancing the quality of care provided to patients who require respiratory support. It introduces a precise and automated solution that addresses the complexities involved in patient ventilation, effectively managing the intricate process of delivering air to patients across a variety of age groups and medical conditions. Leveraging cutting-edge automation, this system ensures the delivery of accurate, consistent ventilation tailored to the patient's individual needs. Unlike manual ventilation, which is subject to the variability and potential errors introduced by human intervention, this technology minimizes human error and enhances the predictability of outcomes. This results in safe and effective care, giving clinicians the confidence that their patients are receiving the precise level of respiratory support needed, regardless of external factors such as operator fatigue or inexperience.

What sets this ventilator apart is its ability to serve a broad spectrum of patient needs, offering a solution that is both flexible and reliable. Whether used in a critical care setting, an intensive care unit (ICU), or during long-term patient management in a home care environment, the system adapts seamlessly to the requirements of diverse medical conditions.

The efficiency of automation ensures that the system is quick to adjust and calibrate according to the evolving needs of patients, enhancing the overall quality of care.

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