Mechatronic Design and Robust Control of an Artificial Ventilator in Response to the Covid-19 Pandemic

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MECHATRONIC DESIGN AND ROBUST CONTROL OF AN ARTIFICIAL VENTILATOR IN RESPONSE TO THE COVID-19 PANDEMIC

REVIEW PAPER

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ABSTRACT:

Human lungs use the reverse pressure generated by contraction motion of the diaphragm to suck in air for breathing. A contradictory motion is used by a ventilator to inflate the lungs by pumping type motion. A ventilator mechanism must be able to deliver in the range of 10 – 30 breaths per minute, with the ability to adjust rising increments in sets of 2. Along with this the ventilator must have the ability to adjust the air volume pushed into lungs in each breath. The last but now the least is the setting to adjust the time duration for inhalation to exhalation ratio. Apart from this the ventilator must be able to monitor the patient's blood oxygen level and exhaled lung pressure to avoid over/under air pressure simultaneously.

- The ventilator we here design and develop using arduino encompasses all these requirements to develop a reliable yet affordable ventilator to help in times of pandemic. We here use a silicon ventilator bag coupled driven by servo motor with one side push mechanism to push the ventilator bag.

- Our system makes use of blood oxygen sensor along with sensitive heart Beat sensor to monitor the necessary vitals of the patient and display on a webpage using IoT. To adjust the

- time duration for inhalation the option command given in the IoT application to set. The entire system is driven by arduino controller to achieve desired results and to assist patients in COVID pandemic and other emergency situations.

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INTRODUCTION:

We introduce the catronic design and robust control of a low-cost artificial ventilator in response to the COVID-19 pandemic. The proposed design is mainly based on the automated regulation of the tidal volume flow required during the breathing cycle generated by the compression of an AMBU[15], due to the movement generated by a crank mechanism following a desired breathing profile. Therefore, the regulation of the compression cycle of the AMBU becomes apath control problem, which for the purpose of this work is achieved by a robust slip-mode supertorque control strategy[17]. When designing control schemes for devices where ensuring their operation and operational reliability becomes a critical issue, it is necessary to implement some robust control schemes. [16]Among the most popular robust control schemes are PID controllers.which are considered robust in the sense of rejecting disturbances and do not depend on the mathematical model of the system, but only on an error signal and the correct tuning of the controller, which can even be done by heuristic methods. However, there are certain limitations with this type of controller, such as: B. the linear operating ranges and the inability of a PID-type controller to track time-varying signals. In this sense, the use of a control scheme based on sliding modes and its Supertorsionvariant is proposed in this work.

LITRATURE SURVEY:

1.Inverse pnumatic artificial muscles for application in low cost ventilator:

The primary goal of this project is to create cost efficient artificial ventilator. An electronically controlled mechanical gripper is used to periodically press an BVM resuscitator which is a bag valve mask to create a artificial respiratory movement in the patients body. For regulating the pressure auto titrating positive airway methord is used and a 1000ml glass syringe is used for the smooth transportation of air and two joint linkages are used to connect the plunger to the crank. This total setup is controlled by a microcontroller. It has two modes in it, controlled and assisted mode and the volume of air is displayed using a LCD display.

2.Two early artificial ventilator:

This was the first model of artificial ventilator machine, it was the first attempt made by the british to produce a ventilator . It consists of an airtight box in which the body of the patient was enclosed and to which a large syringe was attached. This system works on the principal of the change in air pressure created during the forward and the backward movement of the piston attached to the air tight container, this process makes the lungs of the patient to expand and relax creating a breathing motion.this journal was first not given permition to be published due to the unclear literature produced by the author . The second machine consists of two cylinder with capacity of 500ml, the airpumps produce positive and negative pressure alternatively and this setup is connected to the patient through a nasal tube. It produces three phase inspiration, expiration and a postexpiratory pause. This machine was powered mechanically by using hands, the author first experimented this machine on postmortem room at st georges hospital but only once it worked properly so he didn't recomented it to the royal humane socity.

3.Novel approach of designing of a lowcost artificial ventilator:

This device was invented as the solution for shortage and heavy cost of ventilator machine during covid19 pandamic. This device consist of a simple electric pressure cycled respirator which is powered electrically and also sensor and alert device that is used to measures the strain and respiratory rate and sound of alarm produced by the ventilator. The injectors and regulators are used in it to produce a pressure about 3-6 Bar. ARMbased architecture sutch as LPC2148,LPC17688 emberded system and NXP were used as the GUI processor and primary controller. The author says that this ventilator can be used used during emergency situation when there is a shortage of ventilator but this not as reliable as a fully functional ventilator machine.

4. Artificial ventilation during transport:

This is a study of examining the performance of the self-inflating resuscitator and the flow-inflating resuscitator during a transportation. For this comparition test they both were equipped with inline manometry and several mechanical ventilators during simulated transportation test. Thirty anesthesia providers were randomly used for this ventilator test. This test was performed in different transpoart and The end result showed that the selfinflating resuscitator performed very well when compared to the flow inflating resuscitator. The mechanical ventilator Hamilton-T1 perfomed well in every aspect of the test compared to the other ventilators with the odd ratio of 95% CL: 1.81.

5.Lowpower wireless system for temperature and humidity monitoring in artificial ventilation:

This device is all about converting the dry air passing through the ventilator to a warm humidified air to avoid problems caused by it sutch as cough and mucous formation in the patients lungs. This system works by a measuring device connected to the ventilating tube near the HME which constantly moniters the temperature and the humidity of the air from ventilator device. a reading device is connected to a Computer. Thease devices are connected wirelessly with the help of a Bluetooth module to transfer the collected datas from the sensors to the computer. The developer of this device mainly focus on the power consumption of this device so that it should be less power consuming. the power consumption when all the components are working is about 15 mA, once fully charged it would last for about 5 days and 16 hours. An rechargeable Li-Ion battery of 2050 mAh is used in this device. The results shows that the dependence of humidity loss on frequency-volume ratio requiring future investigations.

6.Prototyping of Artificial Respiration Machine Using AMBU Bag Compression

An AMBU bag is a manually operated breathing unit which is used as a primary source of transportation of air in this device. This device is mechanically powered by grippers which pumps the AMBU bag. This device has the major common features present in the modern ventilators. it is capable of adjusting the BPM of patients at the desired level and the volume of the air delivered by this ventilator is adjustable. the inspiration to expiration ratio and Peep rate can also be adjusted with this device. This system comes with two modes The first one involves mandatory ventilation while the second one is characterized by assisted ventilation. This ventilator has a inbuilt triggering mechanism which alters the respiration pattern once it detects a change in air pressure and it can also be set a time interval for this alteration of the respiration pattern.

7.Moisture Exchangers Do Not Prevent Patient Contamination of Ventilators

It is a study where 33 mechanically ventilated patients in an intensive care unit were tested to verify the statement that the Servo humidifier acts as a bacterial barrier in the ventilators. During this study the servo motor used in the patients was changed once daily, and the connecting tubes were changed once weekly and Daily bacterial cultures were taken from the trachea of the patient as well as from the humidifier, the tubing and the ventilator. In 25 of the patients, the same bacterial strain as in the trachea of the patient could not be seperated from the outside of the humidifier, from the tubing or the ventilator. In 8 patients a breakthrough of bacterial from the trachea through the humidifier could be seen in it. The result shows that the clinical importance of the establishment of a bacterial strain in the ventilator is not clear.

8.Empowering eHealth with Smart Internet of Things (IoT) Medical Devices

This paper talks about the use of Internet of Things with medical devices within a connected health environment promotes the quick flow of information and enables easy access to it. In this case the patient's vital parameters are transmitted by medical devices onto secure cloud based platforms where they are stored and analyzed. IoT helps to store data for millions of patients and perform analysis in realtime promoting an evidence based medicine system. This paper is mainly focused on future directions and innovation in smart wearable embedded solutions and IoT with applications in connected health, biomedical signal processing and smart environments.

9.An Accelerated End-to-End Probing Protocol for Narrowband IoT Medical Devices

The author states that the medical device control in a dense wireless networks such as hospitals often leads to a communication problem between the central and the medical devices. So The end to end probing methord in medical devices performed according to the proposed protocol using random linear network encoding of correctly received encoded symbols. They are thus ensuring the quality and accuracy of the information in a hospitalized patients.this works on the RLNC techinique to optimize the probing time and here they use TDMA code to avoid inter floor interference in multi hop medical wireless devices network for enabling hospital wide communications. This system will be very helpful during a pandemic situation like covid19 where a large number of patients can be monitored regularely without missing any data.

10:An IoT architecture for preventive maintenance of medical devices in healthcare organizations

This paper talks about the detecting of the errors and risks that occurs in the medical devices with the help of effective integrity monitoring mechanisms.according to this paper all the medical devices present in a healthcare center sutch as hospital is interconnected and monitored at the same time using this protocol,and continuously growing volumes of large data streams, collected from sensors and actuators embedded into network enabled sensors and microprocessors of medical equipment, require a scalable platform architecture to support the necessary storage and real-time processing of the data for device monitoring and maintenance.this techinique reduces the amount of maintenance invested onto the devices.

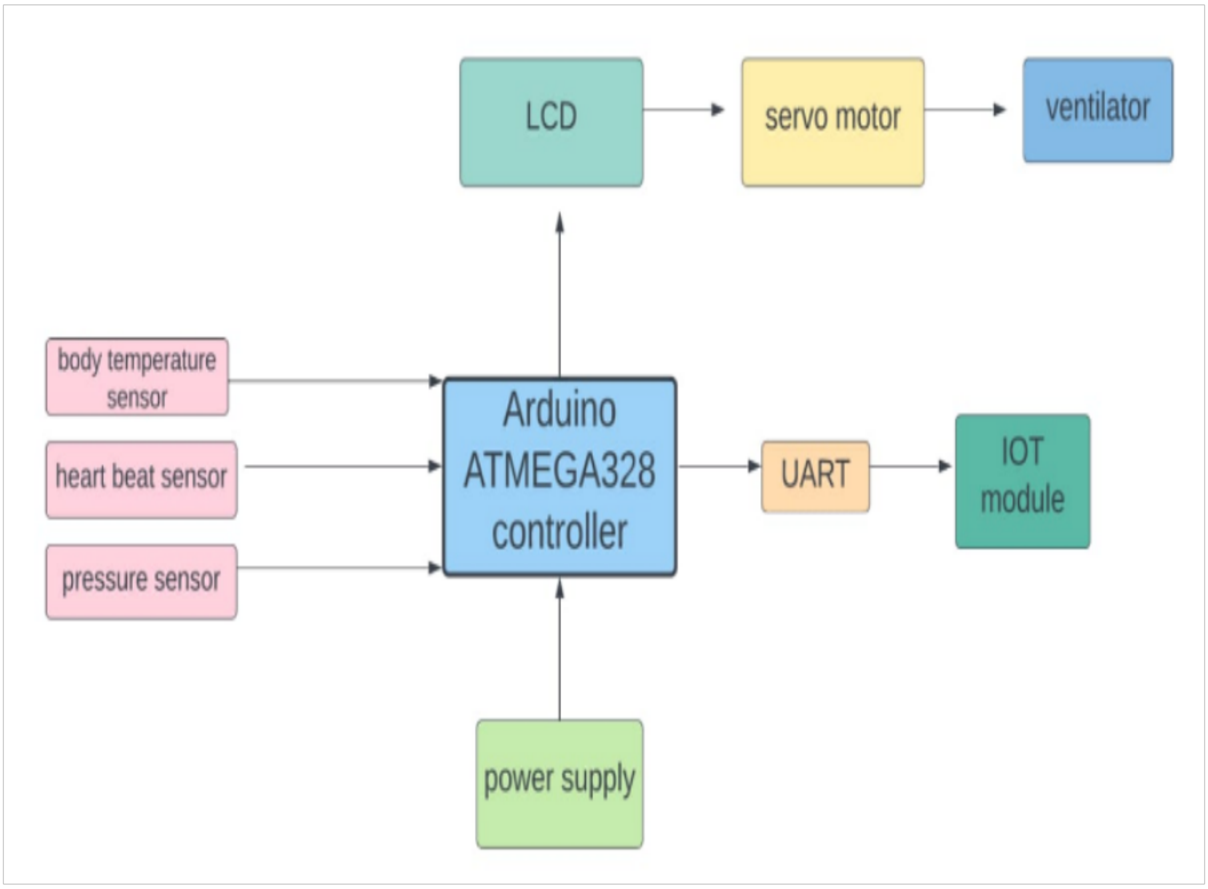
OBJECTIVE:

The objective of this project is to create ventilator that is less in cost when compared to the regular ventilators which uses high cost materials,The maintenance is comparatively low compared to others.This device is highly portable due to its less weight design and comes in handy when traveling. Easy to use as the patients work is to just wear the device and as it is remotely operated the doctor can adjust the ventilator pressure accordingly. During a emergency situation when no one is around the patient he don't need any help of others near him to use the ventilator.

METHODOLOGY

Our proposal for a ventilator is based on a slider-crank mechanism [15] [17]. This mechanism is composed by three parts pointed out as components from 1 to 3, these are the slider, connecting rod, and the crank respectively. The motion is generated by means of a DC motor connected to a gearbox system, which transmits power and enough torque to compress the silicon bag with the lower part of the slider.For the mechatronic design of the proposed ventilator, a DC motor is used to provide rotatory motion to the mechanism of the system. The dynamic model of the DC motor is derived from the application of the Kirchhoff laws for the electrical part and the rotational equilibrium equations for the shaft. this expiratory cyclic system is controlled by arduino board in which the inputs have been encoaded with the help of Arduino IDE [3]. The body temperature sensor, blood pressure sensor, pressure sensor collects the respective datas from the patients body and sends it to ARDUINO ATMEGA328 CONTROLLER. An android web application is developed where the recived datas will be displayed and the intensity and pressure of the ventilator can be controlled remotely [2].

FLOW CHART DIAGRAM:



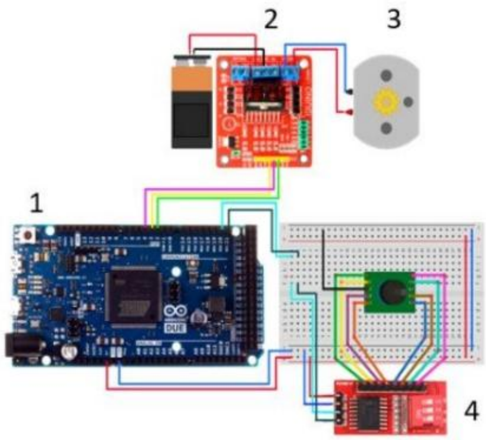
MAJOR COMPONENTS USED:

Sliding mode twisting controller:

[17] Sliding-mode control is considered to be a nonlinear control scheme that has certain properties of

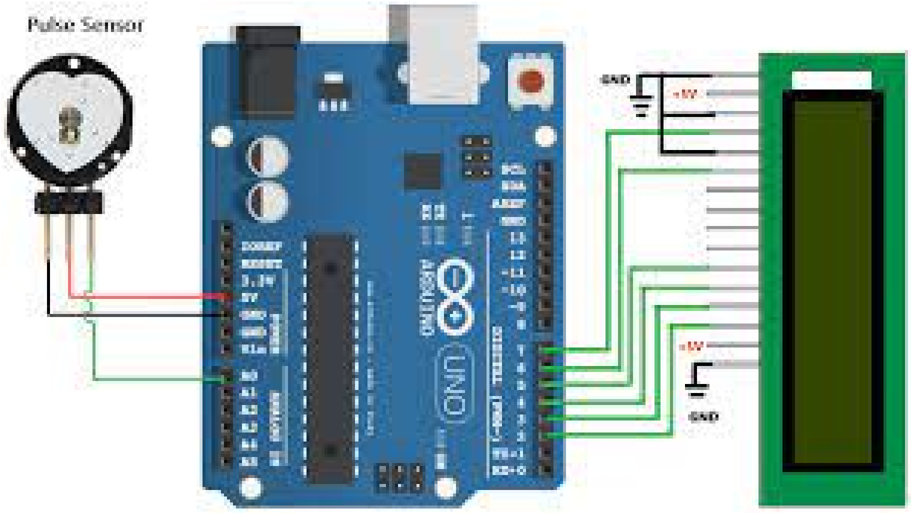
interest for the design of robust controls, including the relative simplicity of the design, the invariance to the dynamic properties of the system, and the external disturbances, a wide range of operating modes such as closed-loop control and trajectory tracking. The Supertorsion Algorithm (STA) is a second order sliding mode controller and is mainly used for systems with
principal dynamics of relative degree one.The electrical system is the brain and heart of the device hardware and software along with its GUI interface.

The following components had been used for the smooth device operation: motor driver, stepper motor, pressure sensor, Arduino Uno.



Sensors:

Pressure sensor is an important parameter of a ventilator system. We are using a semiconductor base strain sensor. Here, we are mounting the strain sensor at once onto the HEM clear out out that is located close to the mouth of the patient (to make sure correct strain measurement). Blood pressure sensor is used in this ventilator to monitor the status of the patients body condition so that the correct amount of pressure and intensity can be given by the ventilator.



GUI:

[11] The GUI has been synchronized with the device's microcontroller. The flow order is the first that the user can enter based on the patient's condition, after which the system checks the home position of the ventilator arm. If the condition with the reference set is true, it will go to the starting position; otherwise it compares the current pressure to the pressure threshold and time. Therefore, the next step will be to inflate the insufflator through the mechanical arms. After that, the current pressure around is compared with the threshold pressure, and if it is less than the threshold pressure, the insufflator value is continuously compressed as quickly as possible to reach the threshold pressure, at the same time check the state of inhalation time, if time is not completed, then it maintains the pressure until inhalation time and this process continues until inhalation time is over.When the inhalation time is up, decompress the insufflator and reset the clock, and this cycle is complete until the user commands it to stop.

Automated-AMBU bag:

[14] [3] AMBU bag is a medical device which is called as artificial manual breathing unit which is simply a silicon bag which is used as a manual ventilator, in which we have automated it by creating a external device which produces mechanical movements which is powered by a servo motor, where the oxygen in a pipe or tank first passes through an air filter and then into the ventilation system. A servo motor for medical devices with a maximum power consumption. To control the flow rate, rhythm, and amount of oxygen, three electrical circuits are built into the blower, including a speed control circuit, a timer circuit, and a battery protection circuit.A pressure relief valve has been installed in the AMBU bag, which is activated when the air pressure exceeds 40 cm H2O.

OTHER COMPONENTS USED:

HARDWARE:

- Arduino Uno
- Blood Oxygen Sensor
- Servo Motor
- IoT Board

SOFTWARE:

- Arduino IDE
- Embedded C language
- Android Application Page

CONCLUSION:

By a breaf study of all the research paper, we can come to a conclusion that the IOT controlled artificial ventilator device are indeed helpful to common people.so with the help of this system the deaths caused due to the lack of ventilator system during a heavy demand for ventilator arrises like this covid 19 pandamic, and even a common man can be able to afford this ventilator.

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