



Digital Assistant for Ventilators Using SVM Algorithm and Speech Recognition

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Abstract

Many health care assists had been developed to help the clinicians in treating the patient. A single monitor for managing an instrument seems very expensive. The transferring of data from the single setup also requires high communication costs. The personal assistant developed has many drawbacks due to the changes in prosodic cues according to the people's language slang and the trouble in analysing the paralinguistic information. The network data and energy consumption required for the transfer of information from the health care devices becomes quite large. The project, involves an easy transmission module and assisting method to avoid these issues. This project is involved in assisting a practitioner, physician or respiratory therapists in proper handling of a ventilator, in accordance with patient's health state and parameter. On providing ventilation, it is important to notice the ventilator readings such as *i*-PEEP, *P*peak, *P*plat (developed values in the patient's respiratory system) which are the response of the patient etc.,. On observation of these readings, the parameters such as *e*-PEEP, VT, RR and *FiO*2 (values to be set by the clinician) have to be adjusted for better ventilation and for the purpose of weaning of patient in a short period. The preliminary work involved is the data acquisition and logging. The SVM algorithm has been developed with many data points as the parameters obtained from data. The protruding idea is to analyse the patient's age, gender, weight, disorder, type of surgery and its duration. Thus, the value of the parameter that has to be adjusted can be determined intricately with the protruding idea of digital assist.

Keywords: *i*-PEEP, *P*peak, *P*plat, *e*-PEEP, VT, RR, *FiO*2, data acquisition, logging, SVM

1. Introduction

A ventilator is equipment used to provide ventilation by moving air into and out of the lungs, to deliver breathe to a patient, who is physically unable to breathe. The modern mechanical ventilators are integrated and microprocessor controlled machines. It has been designed in such a way to change their inflow parameters such as RR, *FiO*2, VT and Peep. This serves as a beneficial evolution, if utilized properly, but there occurs a barrier between the technology, clinician and the varying health status according to an individual. As there are no specific standards and each clinician provide ventilation according to their

experience. The existing medical care model faces the problem with the big data that is being transferred from equipment. The big data will also involve some unwanted formats and information. Current standards of care consist of generalized approaches, such as the use of positive end expiratory pressure to inspired oxygen fraction tables, which fails to account for the inter and intra-patient variability between and within patients. The conventional mathematical models are benefited for either assisted ventilation or controlled ventilation. When the patient is capable of triggering breaths i.e. can turn out from the assisted to the controlled ventilation, it provides

the work in the same mode and it doesn't get changed. Each patient requires varying amount of ventilation, according to their body need and health conditions. However, there is no standard for patient specific mode selection. The respiratory and the cardio vascular system have been linked in many ways resulting in complex system responses. Maintaining blood oxygen saturation level of patients is very critical in medical field. Adequate amount of inspired oxygen is delivered to patients using mechanical ventilator by varying its variety of modes to get required blood oxygen level. During weaning, the reduction in ventilator support is associated to an increase in patient's effort until the complete amount of work of breathing is sustained by the patient. In most patients with difficult is been weaned from MV respiratory muscle force. So to solve these issues many research has been conducted with the artificial lung models to analyse the tidal volume, pressure requirements etc., according to the disease and the physical status. Thus, an assisting device for the handling of equipment would connect the clinician, in a better way for the treatment. The project, deals with providing an accurate input values for the ventilator to cause enhancement in patient's health in a short span of time. [1-6]

2. Background

Initially, the iron lung came into existence. It is moreover like an enclosed machine in which the patient has to be placed for ventilation. It will provide the stable level of ventilation at any condition. After lots of evolution the mechanical ventilation and the modern ventilation with several modes came into existence. But there occurred the confusion of providing proper ventilation according to the patient's health status. As there are no specific standards and each clinician provide ventilation according to their experience. So to solve this issue many research has been conducted with the artificial lung models to analyse the tidal volume, pressure requirements etc., according to the disease and the physical status. Thus many assisting device had been developed to help the clinicians in treating the patient. The assisting devices were developed with the help of many software tools. A single computer for managing an instrument seems very expensive. The transferring of data from the single setup also

requires high communication costs. The project 'A mathematical programming and stimulation based framework' along with introducing a broadband network, connecting the sensors and controllers of many instruments with a single system or PC. Analysing the experimental results of the equipment, by comparison of certain threshold values, that has been uploaded as data. The developed module has avoided manipulations and ended up with the proper calibrations as required in the equipment, in accordance with the different conditions. The personal assistant developed has many drawbacks due to the changes in prosodic cues according to the people's language slang and the trouble in analysing the paralinguistic information. The project, 'Building the next generation of personal digital assistant' is using extended dialog history, and so expanding the history element will increase the interaction time with the user. Improving the context awareness, will help in the machine interactions and bringing out more environmental predictions. Implementation of certain process with the interacted machines or sensors will reduce manual works. The constrained human machine dialogue, which was caused by the project, was so flexible and adaptable to user's requirement. The transfer of information requires certain networks which is the transmission path. The network data and energy consumption required for the transfer of information from the health care devices becomes quite large. The 'Bluetooth low energy technologies for applications in health care' involves incorporating of Bluetooth modules in the health care devices and monitoring devices such as mobile phones and systems. Transferring of data is done by connecting with the Bluetooth modules of healthcare devices. The data transfer has occurred with low energy consumption. The process remained cost effective. During anaesthesia or intensive care, the one lung intubation situation is difficult to analyse. The breathing sounds were recorded by providing the ventilation manually. In the project, 'Detection of one lung intubation by monitoring lung sounds', an AR (Auto regressive) model has been developed with many estimated outputs of the lungs. The OLI (One Lung Detector) has been used that monitors each point source of the lung. The algorithm is modified according to the data obtained from the OLI detector. Thus, the

breathing sound has been obtained with the model developed. It also involves many values such as the amplitude, pressure etc. The error signal and the false trade-off alarm are corrected. To develop an intelligent ventilator and control it will provide a better experience and treatment effect for respiratory patients is still a difficult task needed to be solved. The existing problems focus on the control algorithm and the mechanical structure. In the project, 'Intelligent control algorithm in CPAP ventilator', a CPAP ventilator had been designed in combination with the artificial neural networking system, to gain the equipment intelligence. Introducing an ANN mathematical modelling, that will provide inputs to the patient according to their condition. The ventilator can obtain the patient's respiratory waveform in real time through high precision pressure sensor and flow sensor, and then adjust the output pressure through the ANN algorithm.[7-12]

3. Methodology

3.1 Arbitrary parameters

The mechanical ventilation deals with the mechanics caused by the pressure, resistance and elastance. The pressure caused in the respiratory system is the summation of pressure due to resistance work and pressure due to elastance work. Both the resistance and the elastance are involved in respiratory physiology. For example the pressure has to be appropriate to overcome the resistance caused in respiratory tract. The appropriate pressure can be derived from the equation below:

$$\text{Pressure} = (\text{Resistance} * \text{Flow}) + (\text{Elastance} * \text{volume})$$

Where,

Pressure – air pressure to be applied

Resistance – resistance developed in respiratory tract

Elastance – elastance developed in lungs

Flow – airflow to be maintained

Volume – volume of air to be provided

Initiation phase – the negative pressure triggered in a patient or caused by artificial ventilation before the inspiratory phase. When a patient can cause this initiation phase then a control mode of ventilation can be provided besides when the patient stops triggering an assist mode of ventilation has to be provided.

Inspiratory phase – a positive pressure been

developed due to inhalation of air. The phase ends by achieving maximum pressure (PIP or Ppeak) and volume (TV).

Exhalation phase – the positive pressure developed in the inspiratory phase gets reduced during exhalation of air from lungs. When the pressure gets reduced and turns negative the initiation phase begins.

Flow- intrudes the analyses of two phases the inspiratory phase and the expiratory phase. In a ventilator flow graph the inspiratory phase will be present above the axis indicating the positive cycle while the expiratory phase will be present below the axis indicating as a negative cycle.

Minute ventilation – it is the rate at which the breath is delivered for respiration. In clinical terms, it is the peak inspiratory flow caused.

The expression of minute ventilation is as follows:

$$\text{Minute ventilation} = \text{TV} * \text{RR}$$

Where,

TV – tidal volume

RR – respiration rate

FiO2 – it is fraction of oxygen present in inspiratory air. The room air contains about 21% of oxygen but artificial ventilation can provide the inspiratory air of even about 100% oxygen according to the patient needs.

i-PEEP – the intrinsic pressure that remains in lungs due to incomplete exhalation to prevent collapsing of the lungs. The i-PEEP can be obtained from the total PEEP and e-PEEP as the expression below.

$$\text{i-PEEP} = \text{Total PEEP} - \text{e-PEEP}$$

e-PEEP – the extrinsic peep set by the clinicians to avoid derecruitment of lungs.

Occlusion pressure – the pressure drop that occurs in the first milliseconds of triggered breath is the PO1. It represents the drive of the patient. In general it determines the effort that meets up the patient needs.

Driving pressure – the pressure exerted to expand the lungs. The driving pressure can be calculated as follows:

$$\text{Driving pressure} = \text{Pplat} - \text{PEEP}$$

I: E ratio – the ratio is dependent on inspiratory time, flow rate and expiratory time.

Pplat - the pressure transferred to small airways and alveoli. It is an important clinical sign for the purpose of diagnosis. It represents the compliance of the lungs. The compliance must be higher than

the elastance to avoid the collapse.[13-16].

The above mentioned parameters have to be provided according to the patient's status. The status also comprises the PBW of the patient. The PBW expression is as follows:

PBW for men = $50 + 2.3 * (\text{height in inch} - 60)$

PBW for women = $50 + 2.3 * (\text{height in inch} - 60)$

3.2 Conditions and plan of control

- (i) ARDS is a widespread infection of blood stream due to inhaling high concentration of smoke or chemical fumes. It causes aspirating vomit, drowning and severe pneumonia.
- (ii) Obstructive lung disease causes narrowing of smaller bronchi and larger bronchioles. So the resistance of the respiratory tract will be increased. The work has to be increased to overcome the resistance developed.
- (iii) In case of asthma exacerbation, there occurs stiffness of the chest. This will reduce the expiratory flow. Thus the work has to be increased to overcome the resistance.
- (iv) The COVID-19 patients experience high respiratory drive. This will cause diaphragm injury, double triggering and short cycling. The respiratory drive is increased as a secondary response due to hypoxemia and hypercarbia. Hypoxemia refers to insufficient oxygen supply and hypercarbia is incomplete exhalation of carbon dioxide in lungs.
- (v) On occurrence of pulmonary fibrosis the lung compliance gets decreased and cause difficult exhalation.
- (vi) Atelectasis is the complete or partial collapse of lungs. In the lungs the alveoli becomes deflated and filled with alveolar fluid. The oxygenated and the deoxygenated blood get collapsed and hypoxemia is caused.
- (vii) Derecruitment is the effectuated response of atelectasis. It causes loss of gas exchange surface area. The PEEP has to be increased in lungs by providing e-PEEP.
- (viii) Recruitment is the recovery stage after derecruitment by introducing pressure to increase PEEP. The pressure causes reopening of collapsed lungs.
- (ix) The resting position of the patient is also a causal factor, when they are made to lie down their lungs becomes boggy and heavy with oedema or infiltrates, the heart will also compress the lungs and the abdominal portion also comes up and compresses the inferior portion of the lungs.
- (x) If a part of lung does not involve in gaseous exchange then the body will minimize the perfusion of lungs by causing constriction. This condition is called hypoxemic vasoconstriction. During ill conditions this mechanism will be overwhelmed.
- (xi) A lung with poor compliance is called as stiff lung. To overcome this condition a lot of pressure to cause expansion and delivering of small tidal volume is essential.
- (xii) Air trapping is also a major issue in which the patient doesn't fully exhale before the next breath starts. The pressure and volume accumulates within the respiratory system and leads to increasing distension and pressure. In simple words it is breath stacking caused due to fast RR or being ventilated with large TV.
- (xiii) When we intubate a patient with right ventricle failure to positive pressure ventilation the preload will increase and the afterload will increase. This will cause crimping of small capillaries and the lungs become deteriorated. So positive pressure ventilation is not preferred for right ventricle failure patient.
- (xiv) Shunting is a condition in which alveolar hypoventilation occurs. It occurs as a result of decreased partial pressure of oxygen.
- (xv) When there occurs, accumulation of blood within the pleural cavity it leads to hemothorax. It is accompanied with reduced breath sounds on the affected side and rapid heart rate.
- (xvi) When a patient experiences chest pain, fast breathing, coughing, fast heart rate and low oxygen there is a possibility that the air leaks into the space between the lungs and chest wall as a casual for pneumothorax.
- (xvii) Cardiac arrest patients usually experience dead space, where the area has ventilation but no perfusion. Even when the patient is intubated with the air flow only intubation occurs and no perfusion.
- (xviii) The vasoconstriction is caused in many COPD patients. The casual factors are hyperinflation and increased auto PEEP. A

patient, who is to be intubated at this condition, must be provided ventilation without e-PEEP.

- (xix) In COPD, bronchospasm and asthma patients the resistance of the airway tract increases as the diameter has been decreased.
- (xx) A patient experiencing increased PIP and Pplat indicates abnormal compliance. The clinical signs or the conditions that occurs in a patient are atelectasis, hemothorax, pneumothorax, and pulmonary oedema.
- (xxi) Congestive heart failure patients can be provided with increased PPV so as to increase stroke volume and cardiac output. This procedure must be done only for short duration, when undergone for an extended period would cause damage.
- (xxii) A patient experiencing GI bleed might have haemodynamic collapse with the initiation of pressure ventilation, metabolic acidosis and tachypnea. Providing a high RR will provide the acid base balance.
- (xxiii) In general anything related to airway problem will affect the resistance. The collapse of the problem in the alveolar lining of the lungs will affect compliance.

3.3 Specifications for management

(i) ET position management

1. Undergoing flexible endoscopy procedure and causing glottis visualization, to ensure the glottis position.
2. Tracheostomy is done to make incision in the neck to place a tube into a person's windpipe.
3. Check the inline suction catheter. It could be connected with the closed circuit from the ventilator machine and breathing tube or ET tube. They can be used after the ventilator has been disconnected from the patient. The suction catheter must be checked for every 24 hours.
4. If the heat and moisture exchanger has been used, make sure that there are no secretions or leakages from it.

(ii) HME management

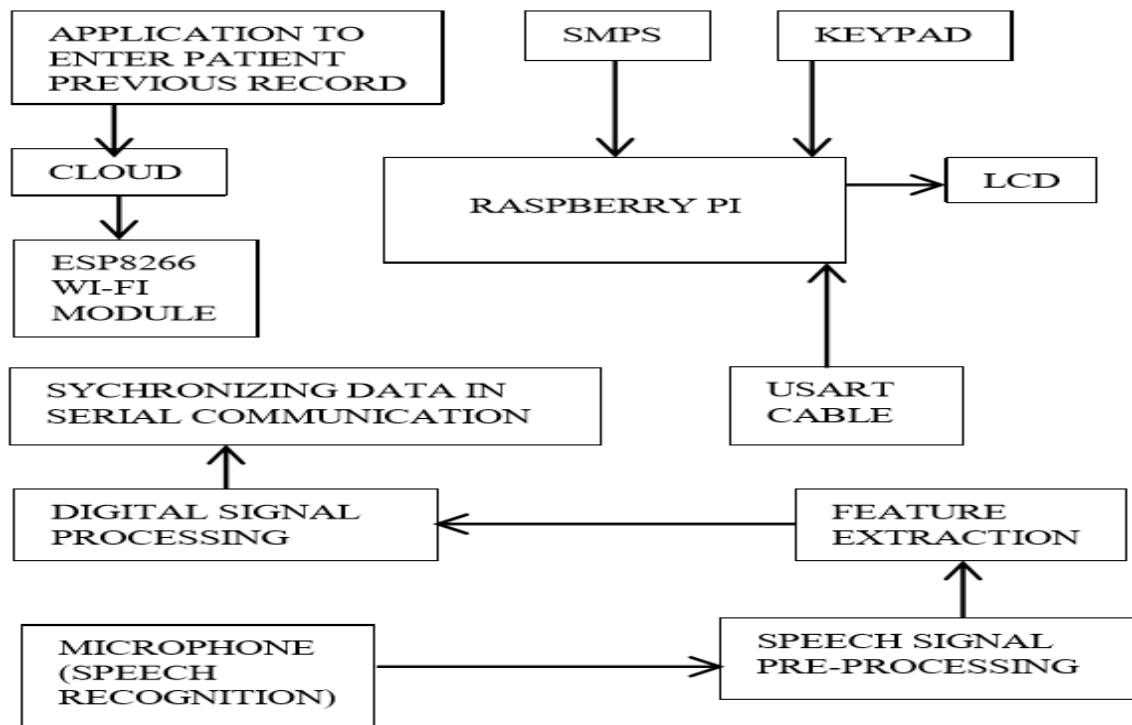
The HME prevents drying of respiratory mucosa; it picks up some of moisture from expired air. The moisture water droplets retain some of the heat from the gas which has carried them. Hence the inspired air will take

the water droplets into the lungs of the patient.

1. During physically active conditions the patient, requires a good breath to feel fresh. So the HME condition must be set in such a manner that it would provide breathe with more humid.
 2. In an unclean environment which contains bacteria, viruses and many people around, the patient requires protection. In such condition a HME with a filter could be preferred.
 3. The water source has to be checked as it humidifies the chamber of HME.
- (iii) Neurological system management
1. Some patients require very high doses of sedation and even occasionally neuromuscular blockade to maintain ventilator synchrony.
 2. Monitor the sedation level of patient and analgesia level.
 3. Monitor the ventilator synchrony with the patient and their ability to liberalize.
 4. A patient with moderate to severe ARDS would require deep sedation, when there occurs any pulmonary improvement the level of sedation can be lowered.
 5. The patient must be allowed for daily awakening trials (interrupting sedation).
- (iv) Cardiovascular system management
1. Hypotension occurs in patient, due to high doses of sedatives and analgesics. This is to maintain the ventilator synchrony.
 2. Heart rate and BP over the last 24 hours should be monitored.
 3. Monitoring of vasopressin is also essential, as it maintains BP.
 4. The blood pressure goals for most patients should be a mean arterial pressure of 65mm of Hg.
 5. In patient with chronic hypertension, maintaining a mean arterial pressure greater than 75mm of Hg will reduce the risk of renal replacement therapy.
 6. The hemodynamic status and the cardiac function can be evaluated using the EKG.
- (v) Pulmonary system management
1. Determination of volume, pressure, Pplat, driving pressure, PEEP, RR and FiO₂.
 2. In volume assist control the Ppeak and the Pplat must be monitored.

3. In pressure assist control and pressure support the peak TV and MV must be monitored. When a patient is spontaneously breathing it is important to monitor changes in MV.
- (vi) Agitation and delirium management
Agitation is the state of anxiety or nervous excitement caused in a patient, further serious disturbance in mental abilities that cause reduced awareness of surrounding and sleep deprivation and the condition is stated as delirium. This would require prolonged mechanical ventilation.
 1. Minimize sources of ventilator agitation such as ventilator dysynchrony and ambient noise.
 2. Attempt to patient's audio visual disorientation by helping re-orient.
 3. Don't use physical restraints to address agitation.
 4. Whenever possible determine and address the source of agitation.
- (vii) Sedation and pain management
 1. Use of sedation should be minimal and include daily sedation interruption.
 2. Frequently assess and treat pain.
 3. Beware of painful stimuli including suction, turning and mobilizing the patient.

- (viii) Sleep management
 1. Use of hypnotic drugs should occur only when strictly necessary and only after addressing sleep disruption caused by pain and noise.
 2. Early mobilization must be avoided.
 3. The patient must engage in bed rest as little as possible.
- (ix) Liberation management
 1. If the patient's requirements of FiO2 are 50% or less than 50%, then ventilator liberation can be performed.
 2. For liberation the PEEP requirements must also be less than 10cm Of H2O.
 3. If they meet the above criteria a two minutes test of readiness for spontaneous breathing can be performed.
 4. For a patient undergoing spontaneous breathing it is important to monitor BP and arterial blood gas for evaluation of oxygenation and acid-base balance.
 5. In case of pressure support, to assess readiness reduce all pressure settings to zero range for two minutes of time.



(a)

3.4 Block diagram

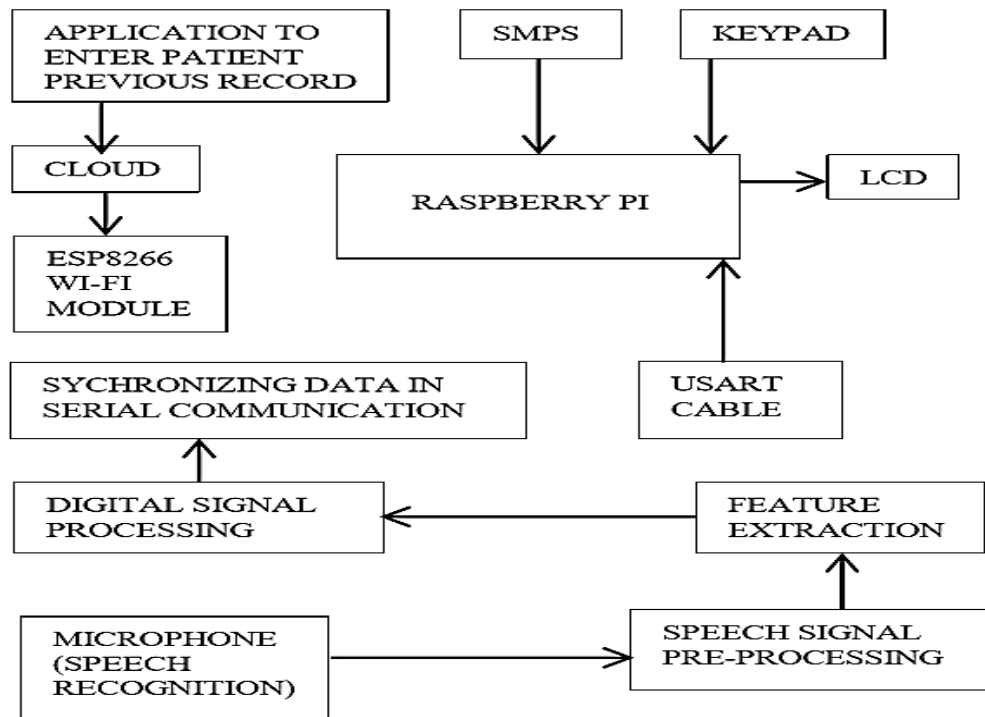


Fig 1 (a &b) Block diagram

6. In case of assist control mode, switch them to pressure support mode and make all the pressure settings to zero for two minutes of time. The test performed is called as rapid shallow breathing index test. In this method we can monitor the TV, MV and RR as the ventilator is on and besides only artificial ventilation is cut off and not the entire analysing set up.
7. The other classic technique is spontaneous breathing trial. In this method the patient is removed from the ventilator and oxygen is supplied to the ET tube with a T-piece adapter.

3.5 Working

The preliminary process involves the leading up works done before the scheme designed and developed. Many medical assessments and records of the individuals undergoing ventilation and the results obtained from many researches have been analysed methodically, to bring out the mathematical integration with values. The preparatory process implements the technique of

data logging. The course of approach is utilization of a computer to collect data through sensors, analyse the data and output the result of collection and analysis.

The data obtained are stored and the pools of information are uploaded onto the cloud. The data from the cloud is transmitted to the device by using the Message Queuing Telemetry Transport (MQTT) algorithm. It's a lightweight publish and subscribe protocol for simple messaging, designed for constrained devices with low bandwidth. It makes it easy to establish a communication between multiple devices. The postulated basis is that the transmitting end or a device will publish on a topic and the receiving end or a device will subscribe the same topic and receive the message.

The data processing technique intrudes the Support Vector Method algorithm (SVM). It is utilized in the project for the representation of different classes in a hyperplane in multidimensional space. In the project, the different parameter values obtained are considered as the data points. The data points are distributed on the axis planes such as x and y.

The working of the project is initiated by the Switched Mode Power Supply (SMPS), which is a kind of high frequency power conversion and power supply device. The SMPS is composed of input electromagnetic interference filter (EMI), rectifier filter circuit, power conversion and pulse width modulation (PWM) controller circuit.

The project incorporates a mode select button to choose the keypad or the WI-FI module to obtain the patient information, who has to be ventilated. When the keypad mode is chosen the LCD display will display certain requirement parameters for processing. The parameters are age, gender, weight, disorders or surgery, duration of surgery, Ppeak, Pplat and i-Peep developed in a patient. For the real time processing, ESP8266 WI-FI module is the suited mode, so the patient records from the ventilator and the hospital system can be obtained. The ESP8266 WI-FI module can give any microcontroller access to the WI-FI network. The records can also be obtained offloading.

The data obtained is then processed in the microcontroller (Raspberry Pi), which contains the dual inline package.

On completion of the data processing, the LCD display will display the values such as the e-Peep, VT, RR, inspiratory flow and FiO₂ that has to be adjusted by the clinicians.

4. Result

S.No	Existing scheme	Proposed scheme
1	Speech recognition is not defined according to an individual.	Speech recognition is defined according to an individual.
2	Misguidance is possible.	Misguidance is avoided.
3	Only procedure is provided and not the values.	Exact parameter values are provided.
4	Specific to treatment.	Specific to patient and surgery.
5	The data transfer speed is comparatively low.	Increased data transfer speed.
6	Energy consumption is high.	Energy consumption is comparatively low.

The outcomes that are obtained from the project is that the values to provide proper ventilation such as Fio₂, VT, RR, binspiratory airflow, e-PEEP. These values has been obtained from the project according to the patient's health parameters such as their age, gender, weight, disorders, surgery and its duration etc.,

Conclusion

The project is therefore featured to act as an assisting device with its integrated circuit and algorithm developed. The concept evaluated in the unit can therefore avoid the complications in the analysis of the respiratory health by the signs and response of the patient occurred during the treatment and also intrudes the above mentioned parameters in the result. The confirmation of the health status is attained by the clinician interaction with the device using speech recognition. The novelty lies beside is the project has been trained with the prosodic clues of the clinician who utilizes the assist. The project can contribute an improved vision when AI is introduced, which should contain long dialog history, by aligning the dialog history in such a manner, that it would provide step by step instruction for the treatment. This would cause the project the more effective real time processing assist device.

Abbreviations

i-PEEP – Intrinsic Positive End Expiratory Pressure, Ppeak – Peak Pressure, PIP – Peak Inspiratory Pressure, Pplat – Plateau Pressure, e-PEEP – extrinsic Positive End Expiratory Pressure, VT – Tidal Volume, RR – Respiratory Rate, FiO₂ – Fraction of Oxygen, SVM – Support Vector Mechanism, MV – Minute Ventilation, CPAP – Continuous Positive Airway Pressure , ANN - Artificial Neural Network, PO₁ – Occlusion Pressure, PBW – Predicted Body Weight, ARDS – Acute Respiratory Distress Syndrome, COVID-19 – Corona Virus Disease[2019], COPD – Chronic Obstructive Pulmonary Disease, ET - Endotracheal tube, HME – Heat and Moisture Exchanger, BP – Blood Pressure, EKG – Electrocardiogram, SMPS – Switched Mode Power Supply, MQTT – Message Queuing Telemetry System, EMI – Electro Magnetic Interference, PWM – Pulse Width modulation, LCD – Liquid Crystal Display, AI –

Artificial Intelligence.

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