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ENGD3000-1920 Individual Project

A ROBOTIC ARM FOR SMART INTUBATION

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Abstract

Endotracheal intubation is a life-saving procedure. Most commonly performed worldwide in the Intensive Care Unit (ICU) and emergency department (EDs). It is a complicated procedure skill introduce to medical students in the operation theatre during Anesthesiology rotation. Due to so many complications to perform this procedure, it is susceptible to failed attempts. This report includes a detailed investigation of Endotracheal intubation procedure and cause of failure. To prevent failure of the Endotracheal intubation procedure, the robot prototype is designed to perform this procedure. This report focuses on the design process, code, research work, and mathematical algorithms performed for designing an electric control system, 3D model, and vision system for *Smart Intubation* robot.

Acknowledgements

I would like to show my special gratitude to my supervisor Professor Abbes Amira for providing me their invaluable knowledge, guidance, and pointing me to the right track throughout the project. I would also include my colleague Carlos Eduardo De Marchi for his support and contribution to the vision system design for the *Smart INTUBATION* robot. Also special thanks to queens building workshop staff for helping me with 3D printing and evaluating my 3D model design.

Contents

Introduction

Endotracheal intubation is an emergency procedure that is performed on people who are in serious condition and not able to breathe on their own. Endotracheal intubation prevents the patient from suffocation and opens an airway for easy breathing. In the intubation process, a flexible plastic tube is slipped inside the trachea with the help of an instrument called a laryngoscope is used to hold tongue aside, So the upper trachea potion just below the vocal cords is visible by the doctor. Endotracheal tubes are available in different sizes depending on the patient's age and throat size. There is a small cuff present on the tube that inflates to hold the tube in place when inserted. The patients are given general anesthesia before performing this procedure to prevent any risk and discomfort feeling to the patient [1].

The patient who requires endotracheal intubation is evaluated by an anesthesiologist or ambulance EMT, to minimize the risk of complications like:

- Teeth injury
- Injury to the tissues of the throat or trachea
- Bleeding in vocal cords.
- Lung complications or injury
- Aspiration
- Brain damage
- Cardiac arrest
- Death can occur

there are more serious complications for the patients who are suffering from other medical problems. Therefore, the patients are fully monitored by the doctors at each step while intubation [2].

A study done by the Royal College of Anaesthetists and Difficult Airway Society in year 2011 to identify the complication occurring during the process of endotracheal intubation in ICU and ED. The endotracheal intubation data from all NHS around the UK was collected for over 1 year. Then it was reviewed by expert panels of the doctors. Which concluded about 61% events in ICU endotracheal intubation lead to injury or death, and about 31% even in ED leads to the same result. This result shows the risk to the life of the patients due to incomplete planning, inadequately skilled staff, and equipment to manage it successfully [3].

The other cause for the wrong intubation process is due to small mouth opening, patient with arthritis, now available any source of light, obesity, and obstruction by blood or airway swelling [4]. On the bases of difficulty associated with intubation procedure, it is classified in 4 grades as per view available by laryngoscope called Cormack-Lehane system [5].
As shown in table-1 below:

Grade	Description	Approximate Frequency	Difficulty level of intubation
1	Full view of glottis	68-74%	<1%
2a	Partial view of glottis	21-24%	4.3-13.4%
2b	Only arytenoid cartilages seen	3.3-6.5%	65-67.4%
3	Only epiglottis seen, no glottis seen	1.2-1.6%	80-87.5%
4	Neither glottis or epiglottis seen	Very rare	>90%

Table-1. Cormack-Lehane system

In the current pandemic situation of COVID -19, one patient out of six needs breathing support. Coronavirus causes lung damage to the infected person causing body oxygen level to drop and hard to breathe. So ventilator demand is increasing in a COVID-19 treatment facility. the approved way for providing breathing support is by endotracheal intubation. Mechanical ventilation like CPAP machines is not good for COVID-19 patients, according to the American Society of Anesthesiologists. So endotracheal intubation and ventilation is the best way to support COVID-19 patient's, while the immune system fight the virus.

The project aims to design a smart endotracheal intubation system as effective and efficient as possible using software/ simulation packages, such as OrCAD, MATLab and PTC Creo to simulate circuits and designs 3D model for the intubation system and to test prototype for functionality and efficiency.

Objective

- To design 4 axis robotic arm for smart intubation device.
- To design automated insertion of endotracheal intubation tubes system.
- To develop circuit for intubation system on OrCAD.
- To simulate all designs in MATLab for testing system efficiency.

To accomplish all the above-mentioned aim and objective a proper plan needs to be executed and need to focus on all key points as shown in Figure 1.

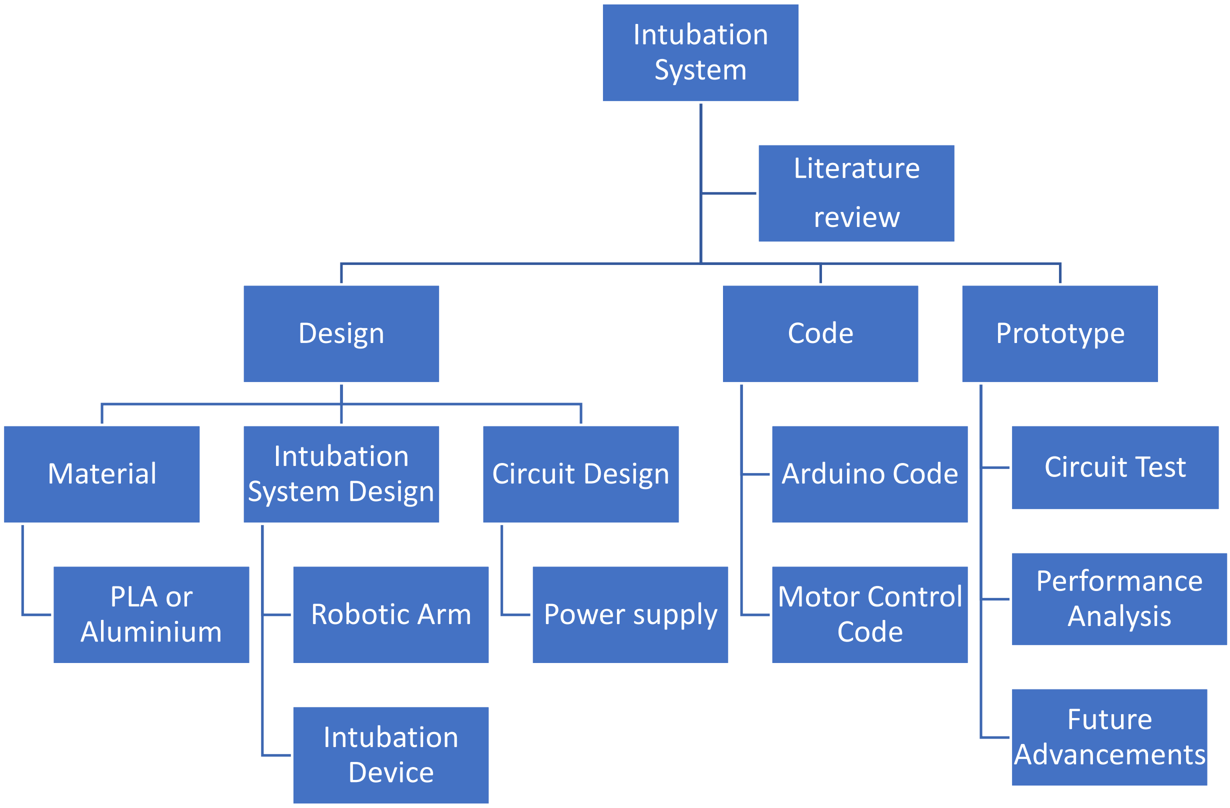

Fig.1 Work brake down chart.

Work is divided in to three sections design, code, and prototype.

1. In design, focus on selection of electric components for the model and use of CAD software PTC Creo for design all parts required for prototype design, then all parts were converted to stl file format. So, that design files can be open in 3D printer slicer software.

2. In code, all programming and mathematical calculation were done and simulation for steeper motor is tested on MATLab. Control system circuit is build using Arduino Meg and steeper-motor controller for arm, intubation device, and camera for transfer of video to monitor.

3. In the prototype, all work done separately is combined together and assemble all 3D printed parts of robotic arm. Several tests are performed for testing of efficiency of system and making any changes if required.

Project Management

A complete plan was designed for breaking down the project key components. For a proper understanding of the project and providing enough time for research and analysing different designs created before finalizing the most effective and efficient design for Endotracheal intubation. To begin with the project first thing required to be done was studying about endotracheal intubation process and problems associated with it. Then focus on studying mechanism of available machines in market which perform intubation. After studying all material related to intubation available online and in books. Then design process for building model for the project begin. CAD and electric circuit simulation software were used for design and testing of design. For more detailed explanation of all the step taken for successful completing the project can be seen in (Fig. 2) having a Gantt chart created for keeping track of work and progress did on the project.

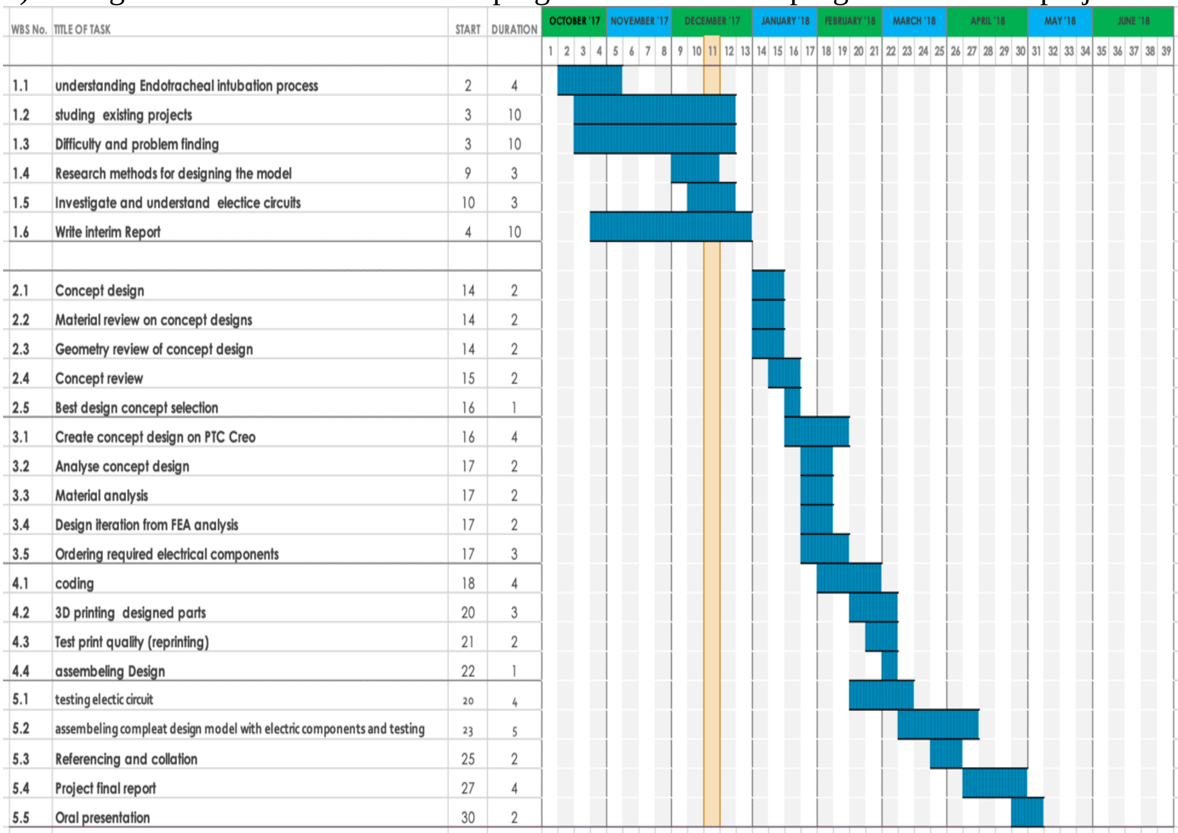

Fig. 2 Gantt chart.

Every week's meeting was conducted with the supervisor for discussing the progress report on the project. Issues raised regarding report structure, design, project layout, and funds required for ordering the project material were discussed and solved by the supervisor. As per the Fund allowance provided by the university research department for buying required hardware. An order was places and design is finalized depending on the provided fund. But due to the fast-spreading of COVID-19 all around the world international delivery service was closed down, resulting in late delivery of items, and some items are still not delivered. All this affected the progress of my project.

Literature survey

To proceed with the design of the smart Endotracheal intubation system. A study is conducted on Existing and going on projects for the development of the intubation system. Before going into detail of the project, there is a need for understanding the process and equipment used for endotracheal intubation.

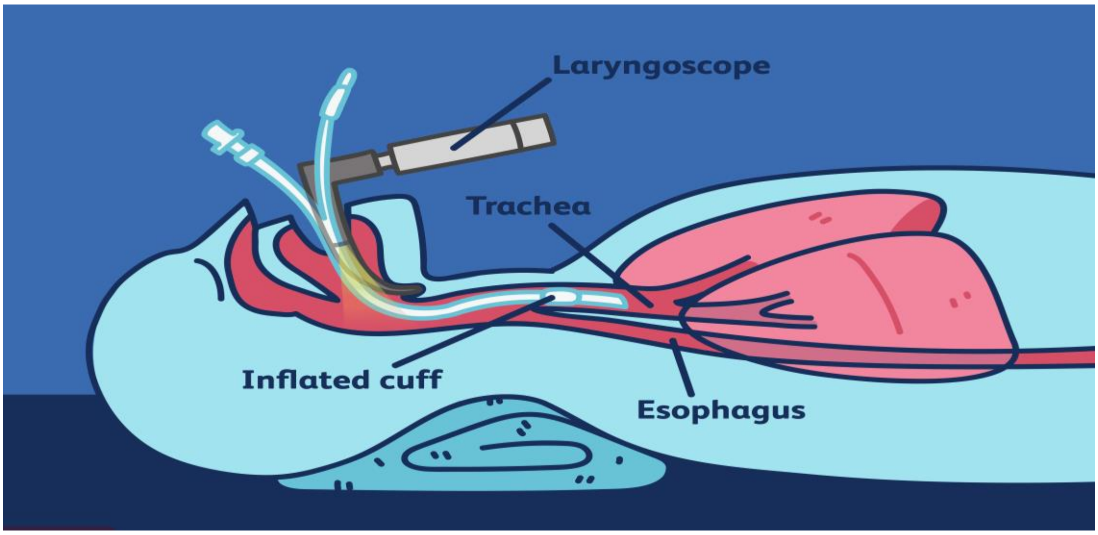

Fig.3 Endotracheal intubation process.

Equipment used in intubation is a flexible plastic tube and laryngoscope as shown in Fig.3 above. To perform intubation doctor gives general anesthesia to patients. then laryngoscope is inserted inside the mouth, by pressing the tongue using laryngoscope epiglottis is raised to see the trachea. Then the doctor inserts the tube inside the trachea avoiding any damage to vocal cords and other sensitive tissues. When the tube is placed at a correct position in the trachea so that both lungs are getting an equal and good supply of oxygen, then a small balloon around the tube end is inflated to prevent any movement of the tube. Afterward, the tube is connected with a ventilator that controls oxygen supply for the patient. When the person no longer has difficulty breathing, the doctor will remove the tube from the person's throat.

The laryngoscope shown in Fig.34is most commonly used laryngoscope is a metal build and a small light is present in front of it for clearing out the vision of the doctor inside the mouth while performing the intubation process. But still, it involves a lot of trouble for doctors because every patient has different visibility of there trachea there for it is divided into 4 different groups on the bases of glottis view. The Blade for laryngoscope comes in different shapes and sizes depending on the patient's throat structure and windpipe dimension. There are a lot of problems associated with this design of laryngoscope.

Fig.4 Laryngoscope

In Fig.5 new and improved version of old laryngoscope is demonstrated. The new laryngoscope has a small 3-4 inch screen attached to it on top in which the voice box of the patient can be seen easily. It solves a lot of problems associated with the tube insertion process. There is a camera attached in front with LED light to see in low light condition, making easy for doctors to locate a correct position to hold the laryngoscope and reduce the risk of harming the soft tissues around the vocal cord. It improved endotracheal intubation process speed and provide more clear/ safe way for doctors to perform intubation. But there were still some problems associated with it. Most common problems is placement of tube at correct position of tube inside trachea so that bot lungs receive equal flow of oxygen and prevent from any tissue damage of lungs and trachea od the patient. But still Video laryngoscope is gaining popularity among anesthesiologists in hospital because of its features of video recording has made it easy for unexperienced and experienced anesthesiologists to perform intubation with more success rate and aid the management of difficult intubation.

Fig.5 Improved Laryngoscope

The first project report used for studying available machines to perform Endotracheal intubation is by the Laboratory Animal Centre of Second Military Medical University

China. The report talks about the endotracheal intubation and comparing the success rate of performing it among paramedics is lower than physicians. Its main focus is to design a system for endotracheal intubation in animals and increase success rates of pre-hospital ETI performed by paramedics. The intubation robot design is named as Remote Robot-Assisted Intubation System (RRAIS). Some important parts of the robot are tongue depressor, posture mechanism, and feeding mechanism. RRAIS is controlled using the joystick and the camera is embedded in the tip of the tube so that everything can be accurate and monitored by any level anesthesiologists. The video captured by the camera on the tube is telecasted live on any screen (Tv, laptop, etc.) so each step taken by anesthesiologists is correct and prevents any tissue damage. Then this robot was tested for results it was quite a success full project. Testing is done on pigs and there was no death of pigs. Oxygen saturation was about 95%. the disadvantage of using this robot system is the time it took for intubation is more as compared to direct laryngoscope. But as per the result, it can be told intubation in the first attempt is successful by using RRAIS robot then direct laryngoscope [6].

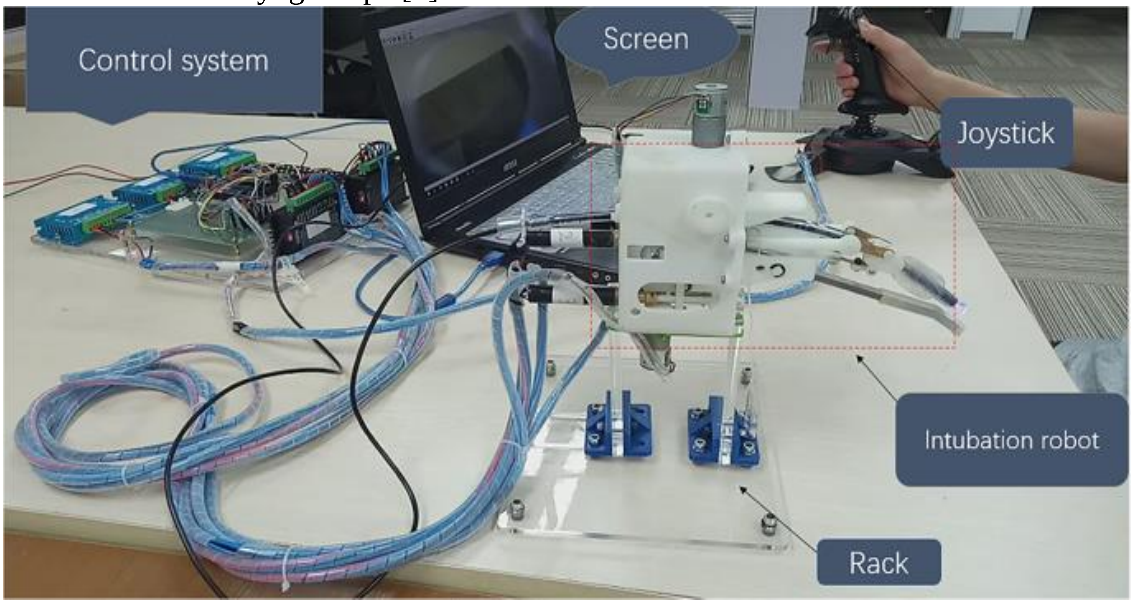

Fig.6 Remote Robot-Assisted Intubation System (RRAIS) design [6].

The second report taken into consideration is the Kepler intubation system (KIS). The project was undertaken by the Department of Anesthesia, McGill University, Canada. The project design involves a robotic arm attached with a video laryngoscope and is joystick is used for controlling the robot arm to perform intubation. The Robot arm stable for this design is 4-axis as chosen by the McGill University. There are a lot of features involving the robot arm like increasing or decreasing speed for the intubation process. Movement of the complete arm can be recorded so it can perform ETI without any assistance from anesthesiologists in the hospital. the video laryngoscope is controlled using the vertical positioning joystick. It is used to position the laryngoscope into the mouth of the patient the entire aim is to manipulate the Pentax's crosshair overlying the vocal cords. After attaining the correct position, the tracheal tube is pushed forward into the trachea by the KIS operator. Then the ventilator tube is connected with the trachea tube. Then video laryngoscope is removed using KIS. This robot system was tested on 12 patients in hospital it was a successful procedure to perform ETI in the first attempt by anesthesiologists but one patient case there was a problem in the intubation process due to the fogging of video laryngoscope, making vision impossible to see. There was the same problem faced by this system which we have seen in the first report that we studied the time. Direct laryngoscope takes about 30-40s time, but KIS took time between 80-100s for performing the same process, but the patient did not receive any kind of injuries or damage. It is also seen when there was more use of KIS it was possible to improve the ETI performance time [7].

Fig.7 The Kepler intubation system [7].

The third project report has taken into consideration in the design of IntuBot by the research department of Case Western Reserve University's, USA. IntuBot is 3D printed for pre-clinical testing. It is an example of simple mechanical design and easy to control robot system. It is designed assuming placing the robot above the reclining patient head. The automation is focused on the finding of vocal cord using the camera image recognition method for locating vocal cords. the camera is attached in front of stylet which is attached to the tip of the tracheal tube with the freedom to move in 0 to 90 degrees, with respect to airway geometry consideration of the patient. There is the same problem with the design of IntuBot which includes the entire design is heavy and bulky. It is not as comfortable to use as demonstrated in the above-mentioned report. There are more technical problems like error and improvement of image detection code and stepper motor are slipping some steps which cause an error in the motion of the trachea tube. The current model structure is lasered cur wood. It needs to improve in order to make the IntuBot design more comfortable and lightweight to be used. There was no real human test conducted by this machine. it was just a prototype to demonstrate how Artificial Intelligence can be used to improve the ETI procedure [8].

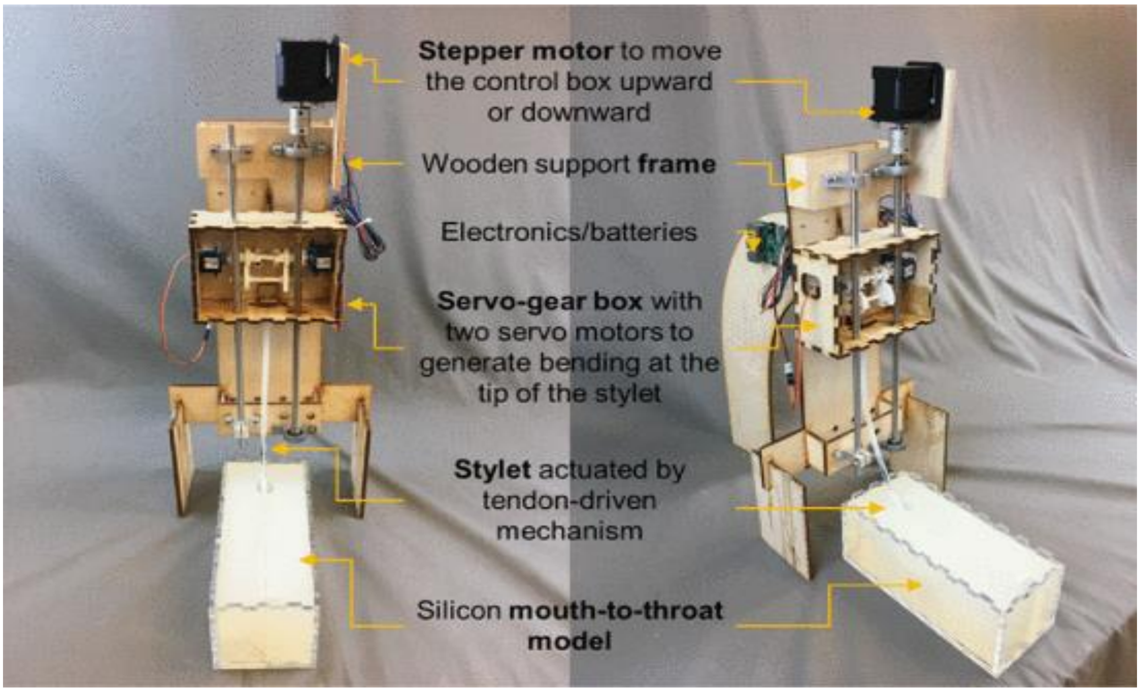

Fig.8 IntuBot design [8].

After going through all the report mentioned above there was a lot of things to consider for the design and development of Smart Intubation System. Below mentioned are some important problem faces by design demonstrated above:

1. Time: we can see in all report result there is a common problem of time. the robot takes more time for a laryngoscope when compared with the direct laryngoscope.
2. Control system- there were some control problems in each system which reduced speed of performance and made the system more complicated to use.
3. Fog on the video camera: as per the 2-project report we need to solve the problem of fog accumulation on the camera lens.
4. Design- the design of the robot system needs to be light, and easy to handle.
5. Use of new and available technology.

After find out of all common problems faced by 3-project taken in consideration The design specification was concluded.

Design Specification

For the development of effective and efficient model design, a lot of simulations and sketches are performed. Similarly, using MATLab and Visual paradigm software visual diagrams and simulations were done. Figures below show different tables and diagrams drawn with their explanation.

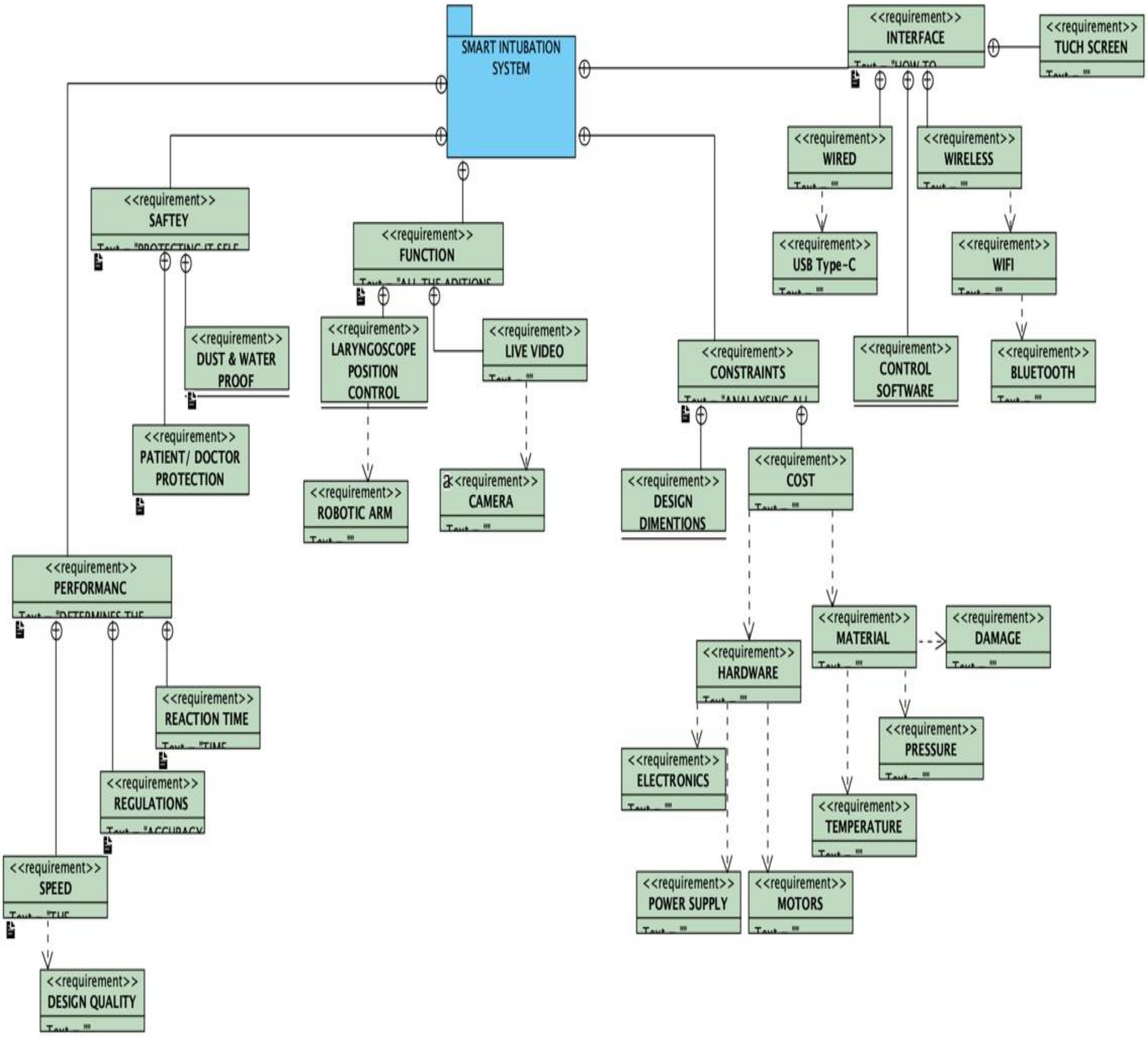

Fig.9 – Requirement Diagram

A requirement diagram represents the key need that needs to be entitled by the design in order to be effective and efficient. Above shown requirement diagrams showcase the factors taken into consideration while designing the overall system. The key needs for this design are performance, safety, functions, constraints, and interface. These needs are further divided into parts depending on what depends on which factor.

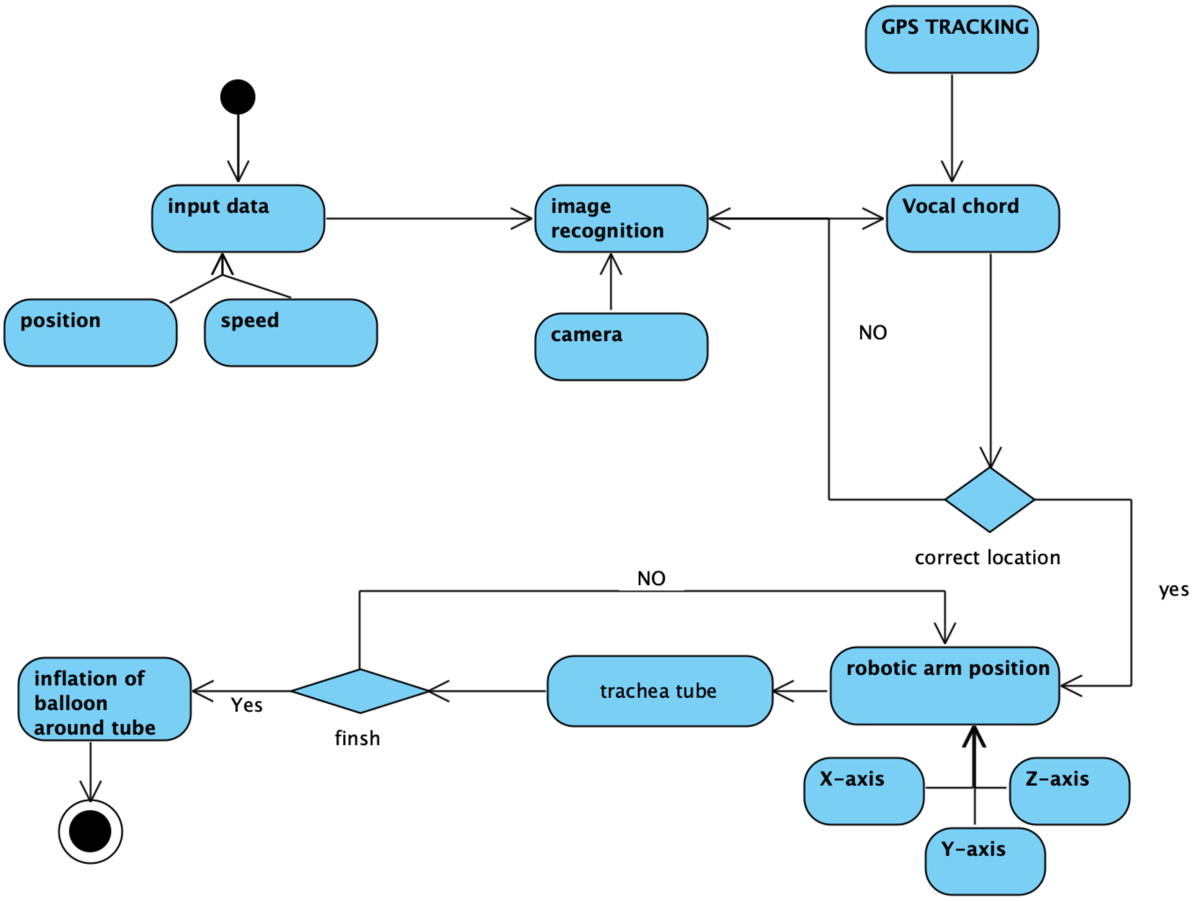

Fig.10 Activity Diagram

An activity diagram shown above is a representation of different steps taken to complete the task from start to end. the diagram show:
The first step: anesthesiologists to position the laryngoscope by providing the position and inputting the value of speed required for performing the task.

The second step: vocal cord image recognition done by camera present in the tip of the continuum robot. It will not proceed to the third step until the vocal cord image is recognized.

The third step: it involves the insertion process of the trachea tube to the trachea and it steps when the tube arrives at a safe distance not so deep or far away from lungs. Just at the correct position where an equal amount of oxygen is supplied to both the lungs, it is done with the help of a camera present in front of the continuum robot.

The Forth step: when the tube is the correct position then the balloon around the tube is inflated and the continuum robot and laryngoscope are taken out of the patient mouth.

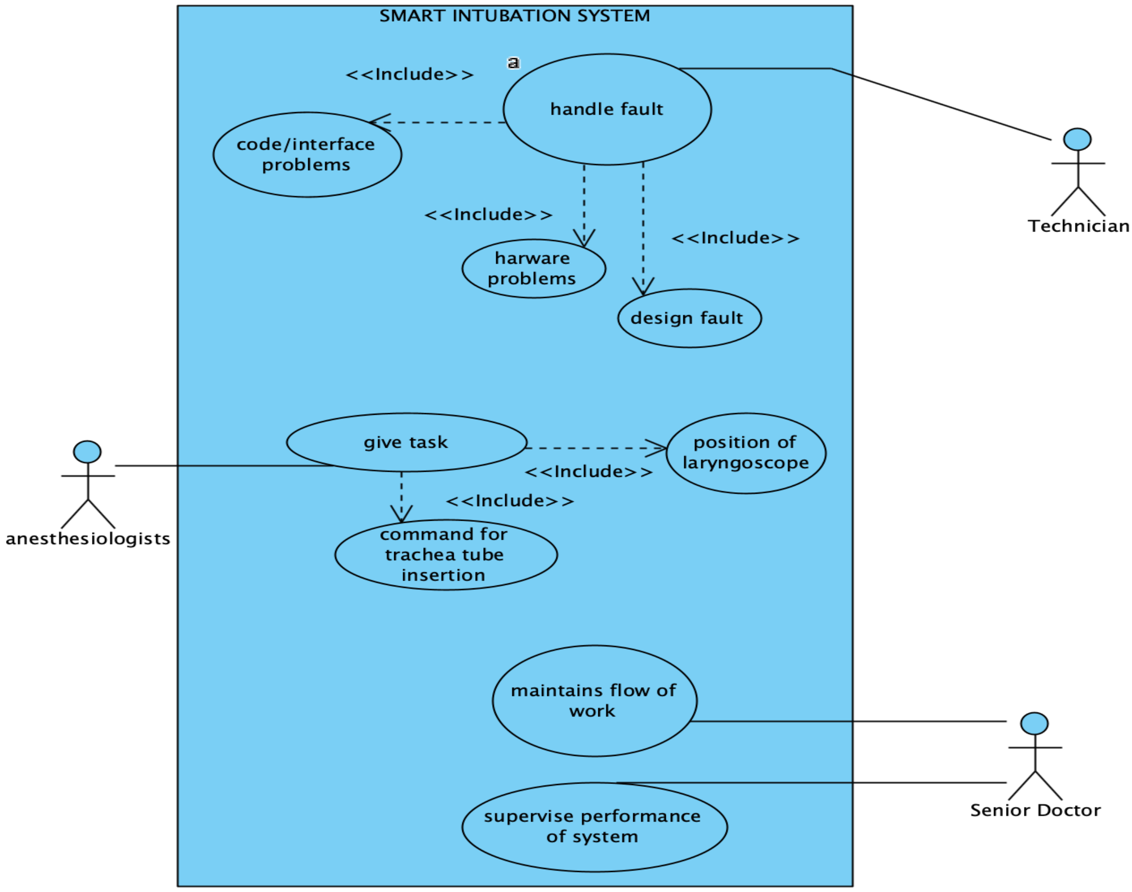

Fig.11 Use Case Diagram

A use case diagram shown above demonstrates the overall users of the system. It showcases the responsibility of different users for the successful functioning of the Smart Intubation System. The entire system involves three users Senior doctor, technician, and anesthesiologists. each user has its own responsibility related to the design. The Technician is involved with Maintenance and servicing of the machine parts and updating of software. anesthesiologists are the user who performs endotracheal intubation in a patient using this system. Then there is a senior Doctor who supervises and guides anesthesiologists.

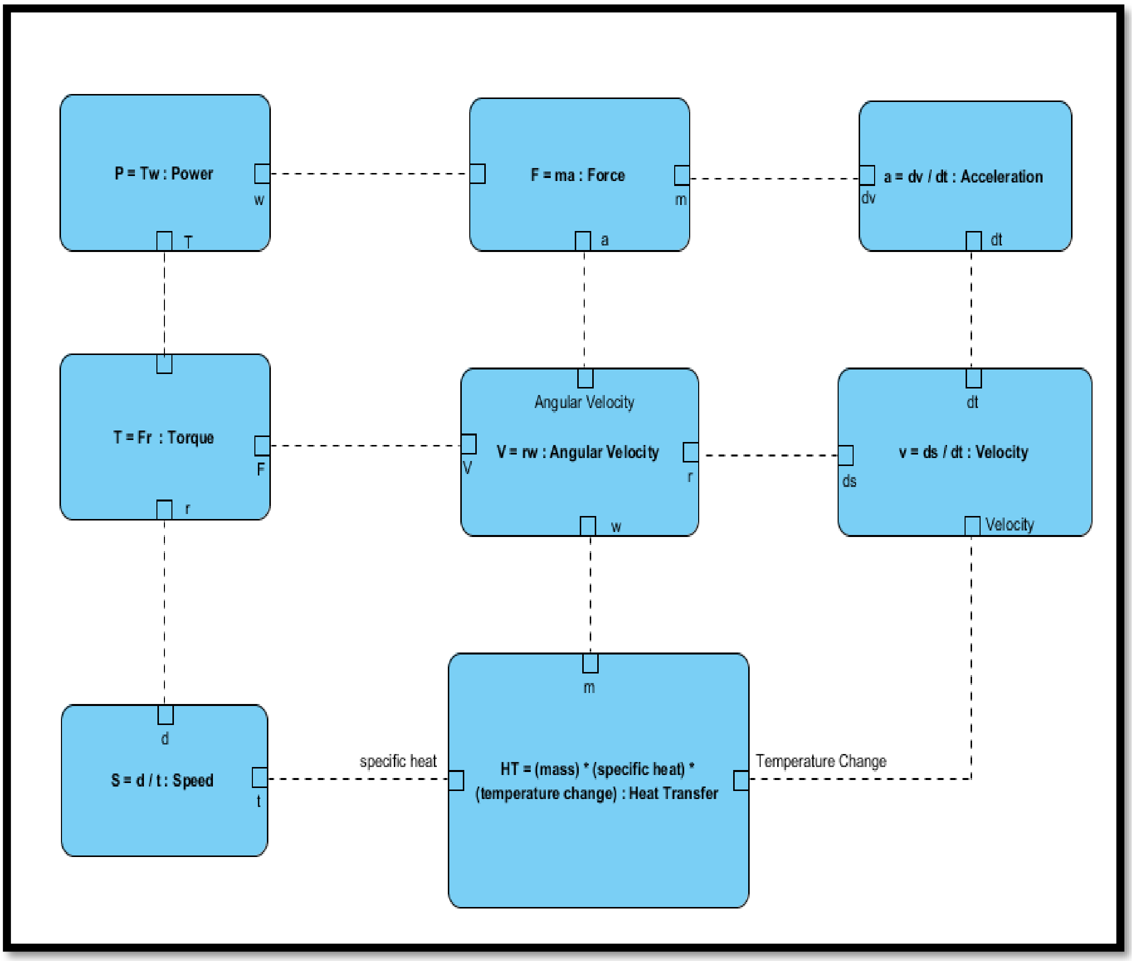

Fig.12 Parametric Diagram

A parametric diagram is shown in fig.12 demonstrates an analysis of how internal components of the system perform when their property change. When different components are combined together in the system it undergoes some changes with respect to their formulas. The most common working properties used by the system are torque, angular velocity, speed, acceleration, force, and power. So by using a parametric diagram, we can determine the relationship between different properties of the system using their formula equation. This shows how a change of environment and physical conditions affect the model build quality.

Hardware/Material

An engineering model is a combination of different hardware and software. So, for the selection of required hardware for the design of the smart intubation system. All hardware components and materials used for design were analysed in detail concerning some important factors mentioned below:

- Power Consumption
- Price
- Ease of Use
- Portability
- Speed
- Design Quality

All this factor helped in selection of low-cost best hardware for building model. A fixed bugged was provided by the university there for it is important to analyse all required items bases on their price and work efficiency. As per test analyses the list of all hardware needed, and software used for coding is mentioned in the table 2 below:

Hardware	**Software**
• Electronic Circuit • Stepper Motor • Power Module • Stepper motor driver • Joystick • Wireless Bluetooth module • 8mm Bearing • White PLA filament • Spur gear 80T & 20T	• Arduino • C++ Programming • CAD • MATLab • Visual paradigm

Table 2 – Design Criteria of Hardware & Software.

Two materials were provided by the university Aluminum and PLA filament. A test analysis was conducted for the selection of perfect material for building a model for the project. In the below table 3, you can see different factors used for comparing the materials:

Property	PLA	ALUMINUM
3D Printer	easy to use with 3D printer	Cannot use in 3D printer
Weight	Lighter then aluminum	Heavy then PLA
ERROR	No error (Machine printed)	Can have error (human error)
Time Taken	Fast (3D printer is used)	Slow (CNC machine is used)

Table 3- Material Property Comparison.

The beat and fast way for proceeding forward are to use 3d printer instead of using different CNC machines for building. The 3D printer is more precise and provides better quality of build design. The most important factor is price and time. The material (PLA)

used for 3D printing is cheap and lightweight. On the other hand, Aluminum is heavy and expensive to buy.
After the comparison and all analyses, PLA was used for building all parts for the robotic arm.

3D Model

After successful simulation of all the proposed requirements for the design and development of new and advance endotracheal intubation method machines. The below image demonstrates the proposed plane for the Smart intubation system. 4-axis robot arm is used for inserting a tube inside the trachea of the patient. The gripper of the robot arm is replaced from the designed intubation device, which is a combination of laryngoscope and tube inserting mechanism. A camera is attached to the tip of the tube from which video is transmitted wirelessly to the screen where the doctor can see and operate the machine without harming tissues inside the mouth. Image recognition is been used to detect vocal cord with the help of the camera, which controls the tube inserting process. Only when the vocal cord is detected in a video streamed on the screen by the camera, device start inserting the tube in the trachea. When the tube is inside the trachea, we need to place the tube at such a position where equal oxygen is supplied to both the lungs. therefor camera is used to detect the correct location inside the trachea, with the help of Image recognition. when the tube is inserted correctly. Camera and laryngoscope are taken out leaving the tube inside the mouth, so it can be connected with a ventilator.

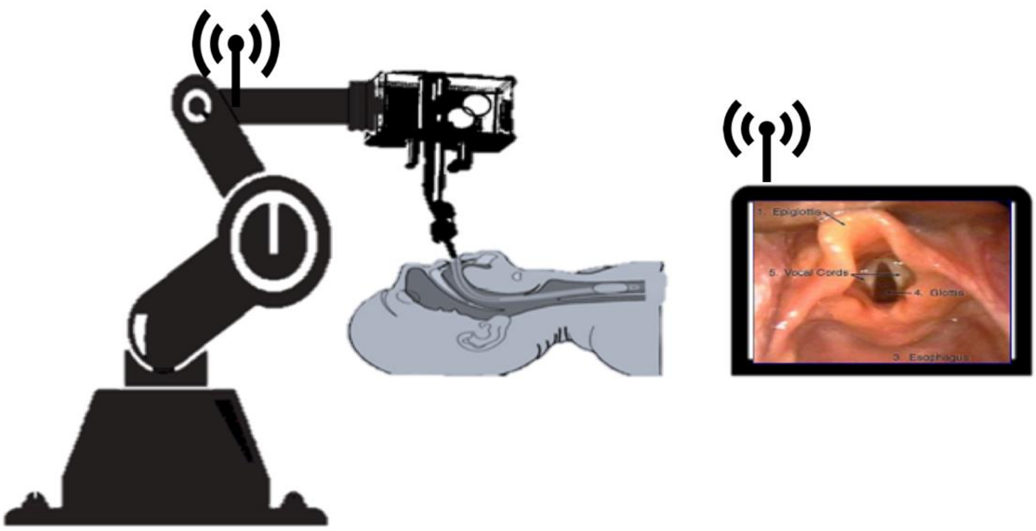

Fig.17 Proposed Smart Intubation System Design.

There are different parts designed for the robotic arm. Base, Shoulder, First arm, second arm, Compound planetary gear and Intubation devise. Each part is designed in PTC Creo CAD software, their functions are explained below:

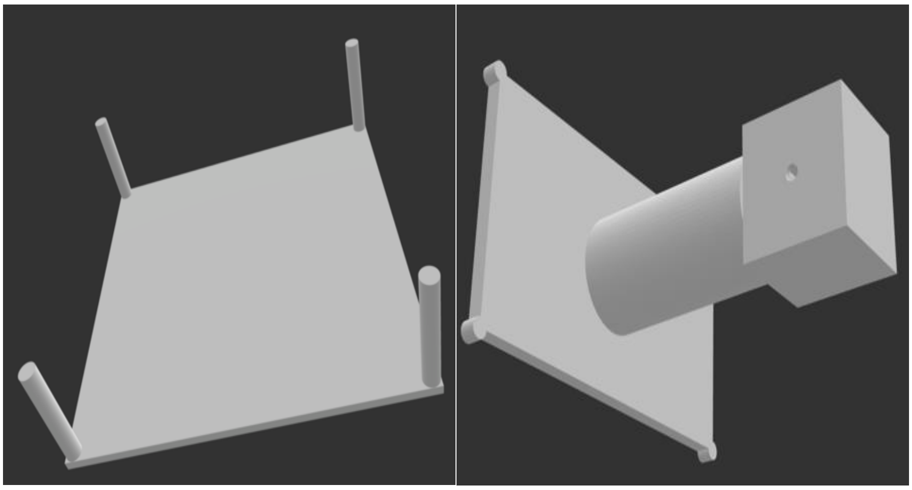

Fig.18 Base and Shoulder design.

The image above demonstrat the base and shoulder designed for Arm. The base is used to install all designed electric circuits for controlling Stepper motor and power supply. The shoulder is designed to provide hight to the robotic arm and Nema 23 is placed in the head of shoulder design, to provide torque for the motion of the first arm.

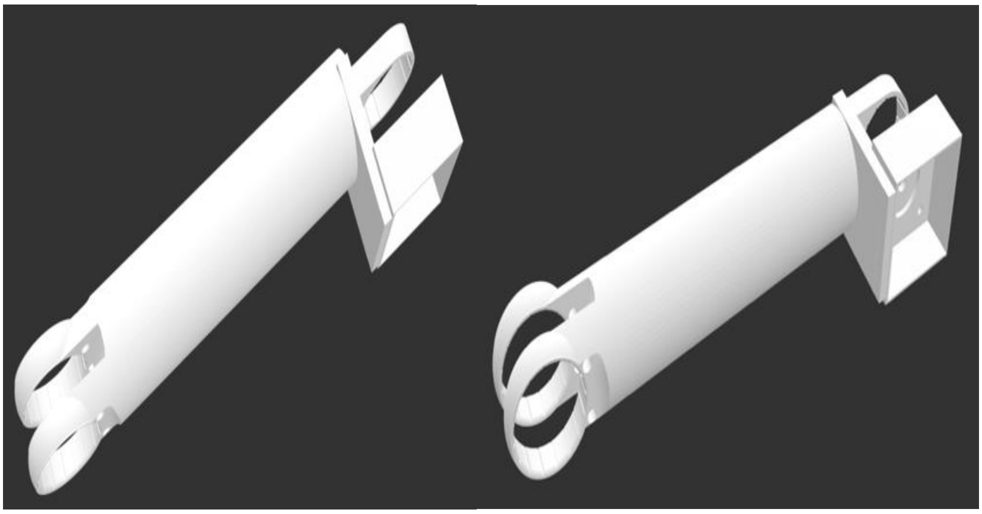

Fig.19First arm.

The image demonstrated above shows a 3D model for the first arm designed in CAD software. The first arm is connected to shoulder through NEMA 23 motor using Compound planetary gear. it provides support to the second arm. NEMA 17 is placed at first arm head to provide torque and motion to the second arm. The first arm can move about -+90 degrees. It uses Compound planetary gears to control the position of the second arm.

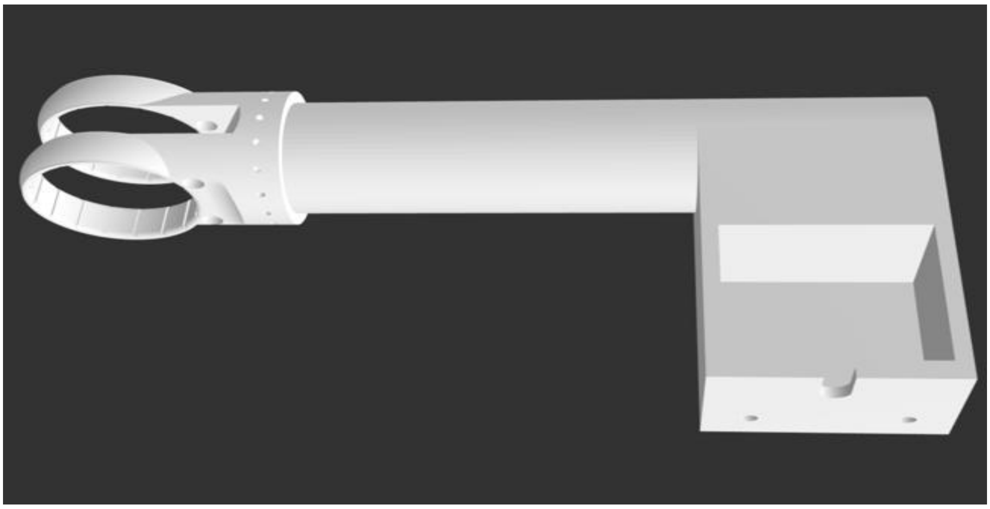

Fig.20 Second arm.

The image demonstrated above shows a 3D model for the second arm designed in CAD software. The second arm is supported by NEMA 17 stepper motor placed in the first arm. The second arm can move about -+90 degrees from its original position. NEMA 17 is placed at the front end of the arm to provide rotation motion to the intubation device. The second arm provides the required force for a laryngoscope to press the tongue to lift epiglottis, so windpipe can be seen through the camera.

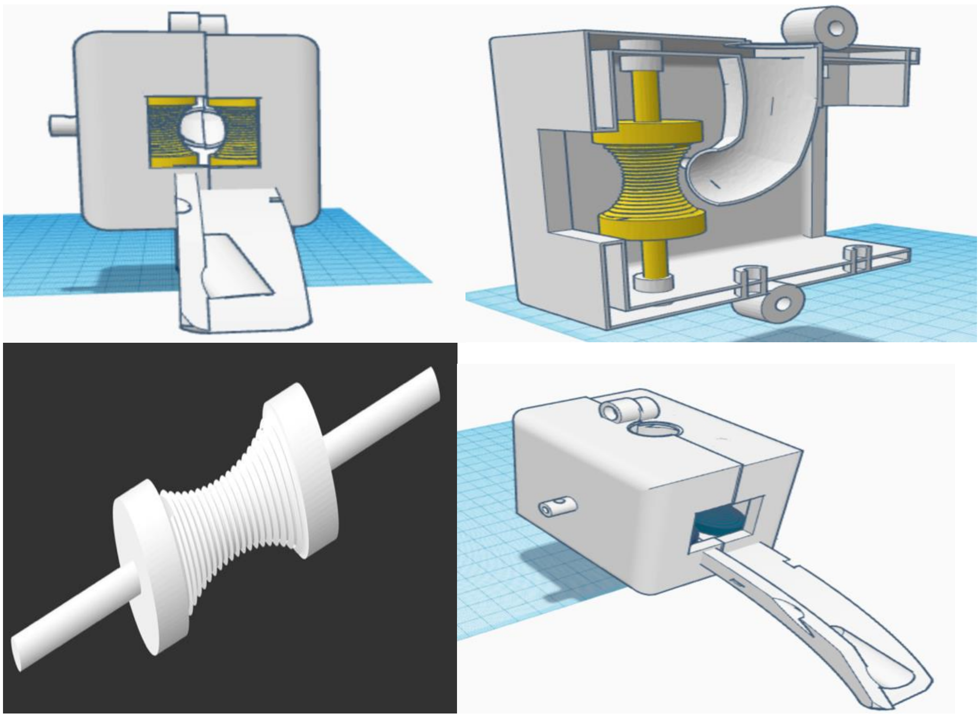

Fig.21 Laryngoscope and tube inserting device.

The image demonstrated above shows a 3D model for the intubation device designed in CAD software. The intubation device is a combination of two functions laryngoscope and tube inserting device. It uses two Hyperboloidal gears controlled by NEMA 11 stepper motor for clockwise and counterclockwise motion of the tube. A laryngoscope is attached in front of the intubation device for lifting epiglottis, for a clear view of the trachea, to insert tube without damaging soft tissues and vocal cord.

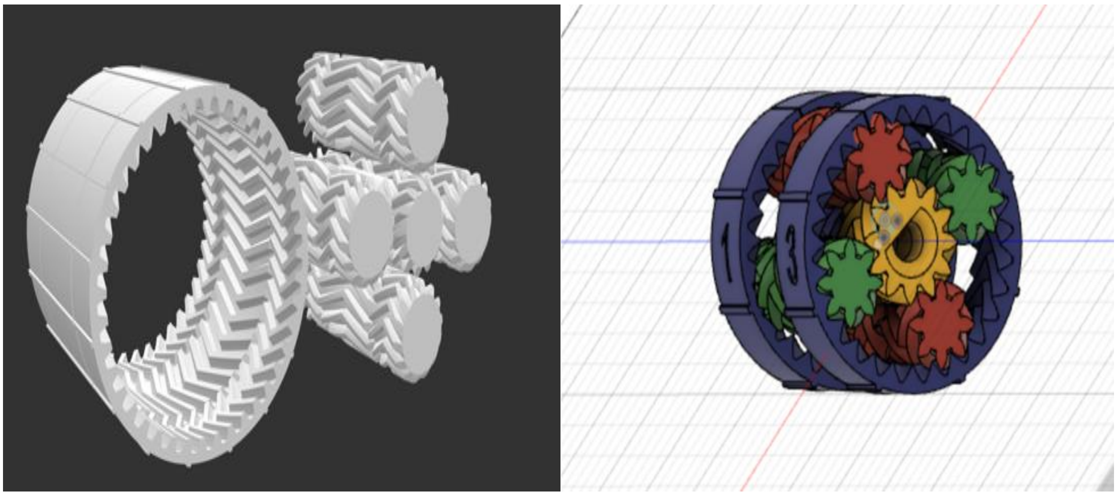

Fig.22 Compound Planetary Gear.

The image demonstrated above shows a 3D model for the Compound Planetary Gear designed in CAD software. Compound Planetary Gear is used to provide the required torque for lifting the arms and for correct positioning of the arm. To design Compound Planetary Gear, the mathematical equation was used for finding gear ration. Gear is required for the robotic arm to increase torque power for the stepper motor, so the motor can lift the load of the attached parts. The total torque for the system is calculated to determine maximum load robotic arm can lift and stepper motor can move without skipping steps. the formula used for gear ratio calculation are:
Teeth Sun + (Teeth Planets*2) = Teeth Ring Gear (must be true for gear)
R1 = Teeth Ring Stage 1
P1 = Teeth Planet Stage 1
S1 = Teeth Sun Stage 1
R2 = Teeth Ring Stage 2
P2 = Teeth Planet Stage 2
S2 = Teeth Sun Stage 2)
Final Ratio = 1 / (((R2 - ((R1 / P1) * P2)) / R2) * (S1 / (R1 + S1)))

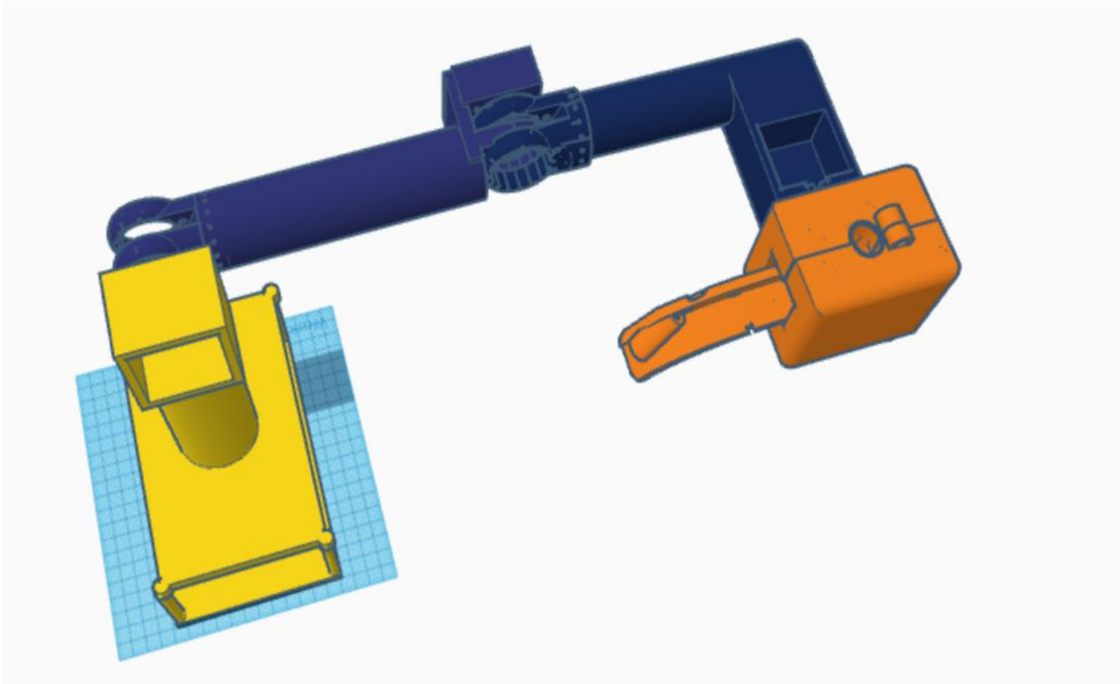

Fig.23 compleat assembely of design.

The image demonstrated above shows an assembly of all 3D parts designed in CAD software for the robotic arm. The complete design dimension was calculated as per the requirement for the project. Many factors were considered:

- Required torque value for the proper functioning of the robotic arm.
- The safety of the doctor operating the device.
- Portability of the device.
- Easy interface so anyone can operate the system without any difficulty.

Electric circuit design

Coding for controlling all stepper motor is done in Arduino IDE using c++ language.To control stepper motor using Arduino Uno liberary called <Stepper.h> need to be included in starting of the code. In Fig.24 you can see schematic and circuit connection made between Arduino UNO and stepper motor. Arduino Uno pins used for connecting four stepper motor are pin D2,D3, D4, and D12. It can be seen in Fig.24 to control stepper motor with Arduino Uno, stepper motor Driver A4988 stepper driver is required because stepper motor required more voltage for functioning properly but arduino output voltage is max +5V, therefore external power supply is used to power up the stepper motor and stepper motor driver connected to Arduino Uno are used to control each step of the motor. To select the correct power supply for the stepper motor, check the datasheet for each stepper motor and find value for the maximum current required. then add all the current values of stepper motor the final value after adding, shows how much total current should power supply to provide so all stepper motor can function without any error. The power supply selected for this project is switching power supply with the power of 201W, voltage supply of 24V, and current supply of 8.3A.

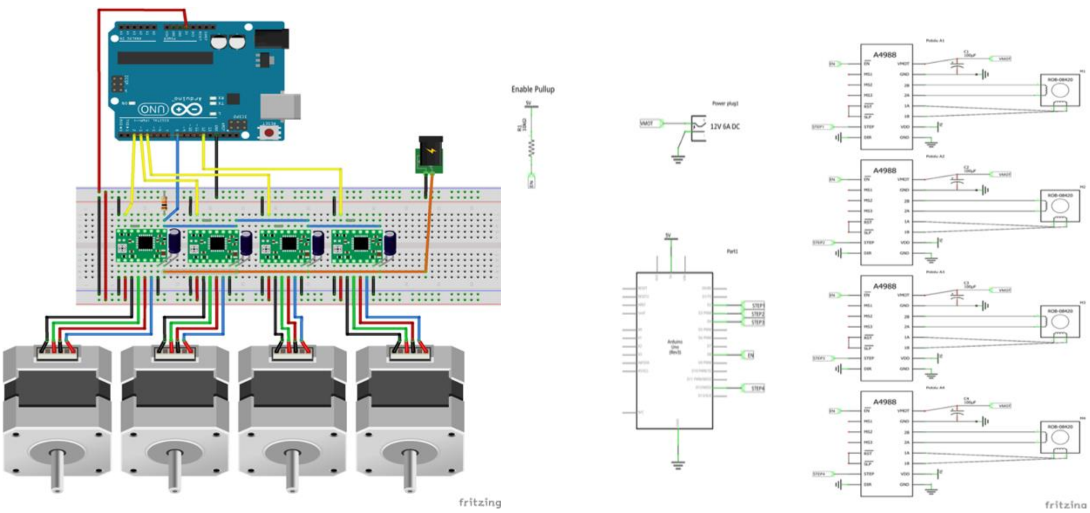

Fig.24 Electric Circuit and Schematic design.

The Robotic arm control module for controlling the stepper motor is designed using MATLab GUI as shown in (Fig.25) below. On the command window, we have buttons and options to select for performing a different task using the robotic arm, as we can see arm left and right button for the horizontal motion of the device and Arm up and arm down button for vertical motion. We can select degreed by which motor will move and also have to select which part of the robotic arm to move to perform a specific function. This command prompt is only used when the doctor supervising the system finds some error message displayed by the machine on the screen. To control Arduino Uno using MATLab a serial communication is a setup. A command (a=serial ('COM3','BAUD', 9600) ;) is used to define the serial port on which Arduino is connected. For starting serial communication, a command fopen(a) is used and transmitting data from MATLab to Arduino Uno fprintf (a, x) is used, where x is the value you get by pressing the button on command window design using MATLab GUI.
The complete code is done in MATLab you can see the code in appendices of the report.

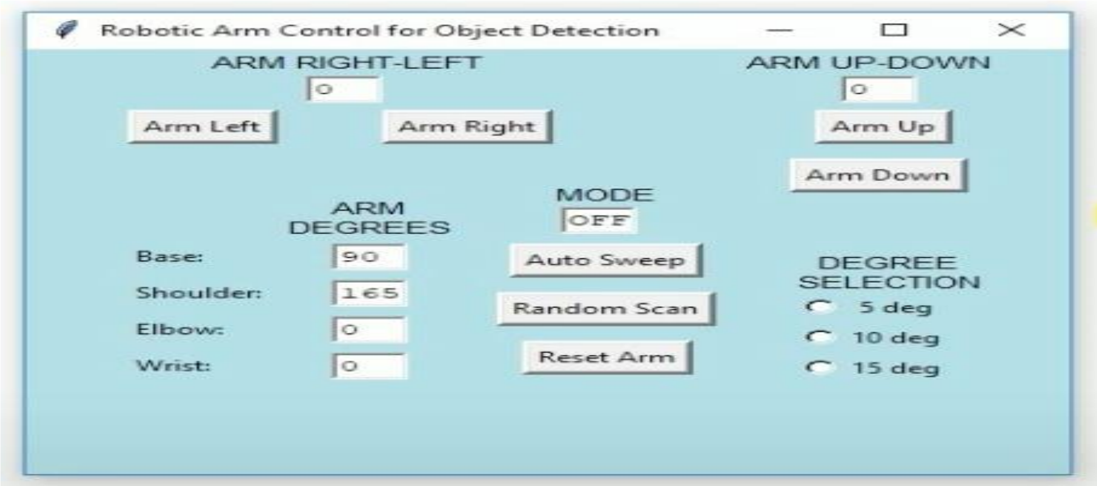

Fig.25 GUI for contoling robotic arm.

The code for image recognition using the camera is written using MATLab. In Fig.26 it can be seen how the ball is detected when two different shape objects are placed in a video stream using the camera. the code uses Kanade-Lucas Tomasi object tracking algorithm, a inetial image of ball was used with code to determine ball shape and inetial points on image were marked which help code to detemine different shapes. For eleminationg noise intracking system Kalman Filter is used in matlab, so when object hide behind some other object, code can predict ball movement and re-track accordingly. To detection ball ForegroundDetector system is used,(Fig.26) it do comparision between color video frame to background model to detect individual pixel are part of background or forground .When ever ball is detected by the camera, a command is generated in MATLab code which is send to Arduino Uno using serial communitcaion. The value send to Arduino Uno controll the movement of the intubation tube. On detecting ball it command to move clockwise and code is not able to detect ball it stop the motion of tube. Code needs some improvement as we need to do recognition of vocal cord and trachea tube end. for image recognition, a lot of factors need to be considered like different people have different shape and size of the trachea and vocal cord, so a lot of training set of images is required for improving image recognition performance and accuracy. The code used for this image recogination and image tracking of ball can be seen in appendices of the report.

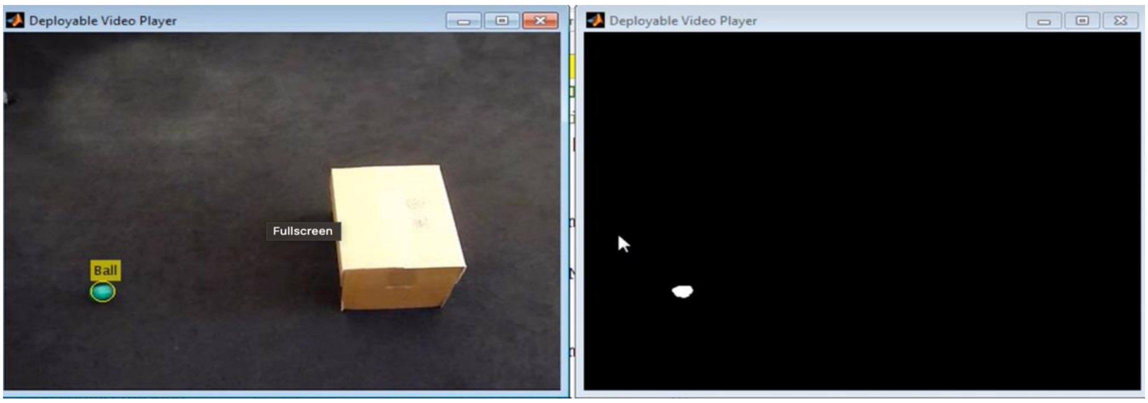

Fig.26 Image recognition using MATLab.

Results

All aims and objective mentioned in the report were achieved. Just 3D printing of robotic arm was not done, due to which practical examination of the complete Smart Intubation system was not possible. Due to the spread of COVID-19 in UK universities were closed, affecting the project final step of assembly and testing. But all-electric and mechanical design for the project was tested and simulated in MATLab and PTC Creo in a different condition, providing successful results. On the bases of tested results demonstrated in the report, it can be said the project was overall successful. All newly added features developed and advanced the performance for the proposed design of the Smart intubation system in comparison with previously done projects for endotracheal intubation.

The Smart intubation robotic arm is designed to provide first aid to any emergency patient or patient with berating problem inside or out-side hospital. The sites it can cover:

1. Ambulance use can fulfil the requirement for first-aid required for patient require breathing support system. In previse study it has been seen lot of endotracheal intubation failure accurse outside hospitals.
2. Battlefield, it can be placed inside army hospital tents. About 10%-15% soldiers die due to airway obstruction, so providing with The Smart Intubation robot arm is best way to save lives in battlefield.
3. Airports, Railways stations, subways station etc. It can be located just like automated external defibrillator (AED). Not just paramedics can perform it, but even any passer-by can use it and stream live video to hospitals for doctor supervision.

As per current situation in COVID-19 higher critical patients need berating support system, it could be a best and fast way to improve doctors speed of attending patients with need of intubation.

Discussion

Work done lays down all groundwork performed for engineering the model for automated intubation, to fulfil the long-term goal of the project. But there is still some work that needs to be done, which is mentioned in the future work section of the report. But it can be said all the problems in present robot systems for intubation were gathered and solved in this report. The first problem, all present designs take more time for intubation on comparing with direct laryngoscope intubation. This problem was due to difficulty in controlling the device by doctors, because of the difficult interface of the system. It is solved by making a complete system automated just need the supervision of doctors and computer control interface for the device if requires any assistance from doctor. Fig.27 show the comparison of time taken by the old robot system and direct laryngoscope intubation.

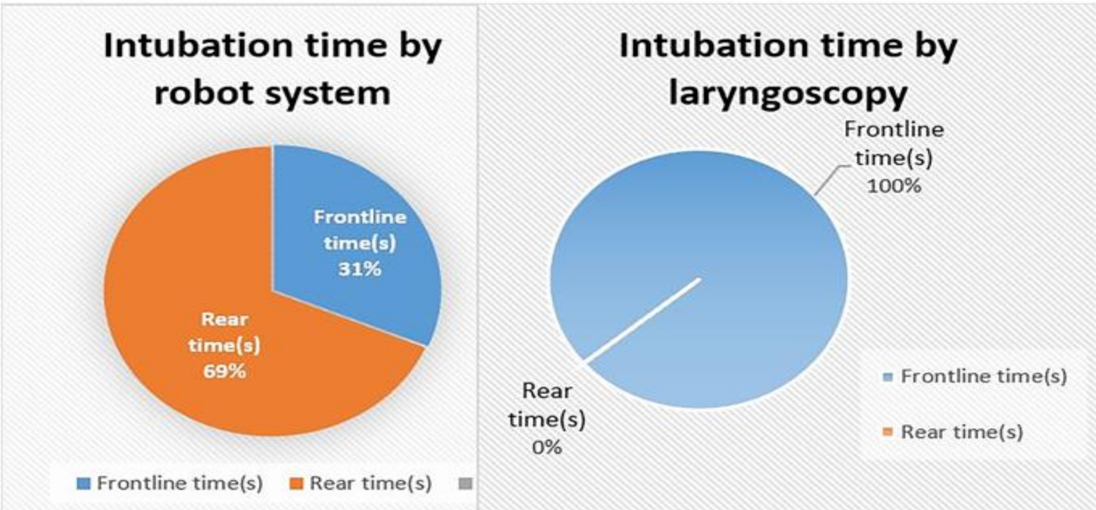

Fig.27 Comparing frontline time and rear time for two intubation approaches [6].

The second problem, all older robot intubation devices were less efficient because of low design quality and heavy design. To solve this problem lot of different design was proposed and tested on simulation software for their work performance and mass. The best design was selected which is 20% more efficient and lighter than the existing robot intubation systems.

The third problem, all older versions of the intubation system do use image recognition and self- automation, therefor it was introduced in the design we proposed for increasing work quality and performance. Providing easy to use the system even for non-experienced anesthesiologists.

Future Work

As mentioned above as a result, due to COVID-19 it was not possible to do physical modelling and testing robot real-world performance. So, the first thing needs to be done in 3D printing the parts using PLA, designed in CAD software. After assembly entire system efficiency needs to test. The second thing to consider is improving Image Recognition, by improvising in Algorithms used in code and removing ball image detection which is used in the current code by testing image recognition of different images of the vocal cord. The third thing needs to be done is performing the intubation process using the proposed design on a manikin. Then evaluating the design with the help of experienced anesthesiologists. The fourth thing need to improve can be video quality as in current design standard camera is used.

The robotic industry is growing very fast, so a lot of new technology and improvement in existing tech is been made at great speed. So, we can always make some improvements to the design presented in this report. It is best to upgrade the design whenever its performance and compatibility is not as per need of users. We can also introduce Virtual Reality control in Intubation procedure, it can provide more high accuracy for performing many medical surgeries. So, in future Virtual reality feature can be introduced to perform intubation process.

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Appendices-I(Code)

1. Image Recognition code

```
video = vision.VideoFileReader('singleball.avi');
player = vision.DeployableVideoPlayer('Location', [10,100]);

while playControls
while ~isDone(video)
step(player,step(video));
end
reset(video);
end
delete(player);
%% Detect the ball in the video

fgDetector = vision.ForegroundDetector(...
'NumTrainingFrames', 10, 'InitialVariance', 0.05);
blobAnalyzer = vision.BlobAnalysis('AreaOutputPort', true, ...
'MinimumBlobArea', 70, 'CentroidOutputPort', true);
player = vision.DeployableVideoPlayer('Location', [10,100]);
fgPlayer = vision.DeployableVideoPlayer('Location', player.Location + [500 120]);
reset(video);
while playControls
while ~isDone(video)
image = step(video);
I = rgb2gray(image);
fgMask = step(fgDetector,I);
fgMask = bwareaopen(fgMask,25);
[~, detection] = step(blobAnalyzer,fgMask);
step(fgPlayer,fgMask);
if ~isempty(detection)
position = detection(1,:);
position(:,3) = 10;
combinedImage = insertObjectAnnotation(image,'circle',position,'Ball');
step(player,combinedImage);
else
step(player, image);
end
step(fgPlayer,fgMask);
end
reset(video);
end
delete(player);
delete(fgPlayer);

%% Track the ball in the video
% Pick kalman filter parameters for use with configureKalmanFilter
kalmanFilter = [];
```

```
if 1
motionModel = 'ConstantAcceleration';
initialEstimateError = 100*ones(1,3);
motionNoise = [25, 10, 10];
measurementNoise = 25;
else
motionModel = 'ConstantVelocity';
initialEstimateError = 1000*ones(1,2);
motionNoise = [25, 10];
measurementNoise = 25;
end

%% Set up loop for tracking
player = vision.DeployableVideoPlayer('Location', [10,100]);
fgPlayer = vision.DeployableVideoPlayer('Location', player.Location + [500 120]);
isTrackInitialized = false;
isObjectDetected = false;

reset(video);
while playControls
while ~isDone(video)
image = step(video);
I = rgb2gray(image);
% Detect the ball
fgMask = step(fgDetector,I);
fgMask = bwareaopen(fgMask, 25);
[~, detection] = step(blobAnalyzer,fgMask);
step(fgPlayer,fgMask);

% Track the ball
if size(detection,1) > 0
detection = detection(1,:); % only use the largest object
isObjectDetected = true;
else
isObjectDetected = false;
end

if ~isTrackInitialized
if isObjectDetected
kalmanFilter = configureKalmanFilter(motionModel,...
detection, initialEstimateError, motionNoise, ...
measurementNoise);
isTrackInitialized = true;
trackedLocation = correct(kalmanFilter, detection);
label = 'Initial';
position = [detection 10];
combinedImage = insertObjectAnnotation(image,'circle',position,label);
step(player,combinedImage);
else
trackedLocation = [];
```

```
label = '';
step(player,image);
end
else
if isObjectDetected
predict(kalmanFilter);
trackedLocation = correct(kalmanFilter,detection);
label = 'Corrected';
else % ball is missing
trackedLocation = predict(kalmanFilter);
label = 'Predicted';
end
position = [trackedLocation 10];
combinedImage = insertObjectAnnotation(image,'circle',position,label);
step(player,combinedImage);
end
step(fgPlayer,fgMask);

end
reset(video);
isTrackInitialized = false;
isObjectDetected = false;
end
delete(player);
delete(fgPlayer);
%%
release(video);
```

2. Stepper motor code

```
#include <MIDI.h>
#include "pitches.h"
#include <Stepper.h>

//ARDUINO PINS
//configured for stepper motor control pin
#define stepPin_M1      2
#define stepPin_M2      3
#define stepPin_M3      4
#define stepPin_M4     12
#define enPin 8

unsigned long motorSpeeds[] = {0, 0, 0, 0, 0};
unsigned long prevStepMicros[] = {0, 0, 0, 0, 0};
const bool motorDirection = LOW;
bool disableSteppers = HIGH;

MIDI_CREATE_DEFAULT_INSTANCE();
void setup()
{ pinMode(stepPin_M1, OUTPUT);
```

```
  pinMode(stepPin_M2, OUTPUT);
  pinMode(stepPin_M3, OUTPUT);
  pinMode(stepPin_M4, OUTPUT);
  pinMode(dirPin_M1, OUTPUT);
  pinMode(dirPin_M2, OUTPUT);
  pinMode(dirPin_M3, OUTPUT);
  pinMode(dirPin_M4, OUTPUT);
  digitalWrite(dirPin_M1, motorDirection);
  digitalWrite(dirPin_M2, motorDirection);
  digitalWrite(dirPin_M3, motorDirection);
  digitalWrite(dirPin_M4, motorDirection);
  pinMode(enPin, OUTPUT);

  MIDI.begin(MIDI_CHANNEL_OMNI);
  MIDI.setHandleNoteOn(handleNoteOn); is recieved
  MIDI.setHandleNoteOff(handleNoteOff);
  Serial.begin(115200);
}

void loop()
{
  MIDI.read();
  digitalWrite(enPin, disableSteppers);
  singleStep(1, stepPin_M1);
  singleStep(2, stepPin_M2);
  singleStep(3, stepPin_M3);
  singleStep(4, stepPin_M4);
}

void handleNoteOn(byte channel, byte pitch, byte velocity) //MIDI Note ON
Command
{
  disableSteppers = LOW;
  motorSpeeds[channel] = pitchVals[pitch];
}

void handleNoteOff(byte channel, byte pitch, byte velocity)
{
  motorSpeeds[channel] = 0;
}
void singleStep(byte motorNum, byte stepPin)
{
  if ((micros() - prevStepMicros[motorNum] >= motorSpeeds[motorNum]) &&
(motorSpeeds[motorNum] != 0))
  {
    prevStepMicros[motorNum] += motorSpeeds[motorNum];
    digitalWrite(stepPin, HIGH);
    digitalWrite(stepPin, LOW);
  }
}
```

Appendices-II (Interim report)

1.INTRODUCTION

Intubation is a medical procedure that involves inserting a flexible plastic tube into a person's trachea or stomach to make sure the adequate amount of oxygen or to feed or provide medications to the person. It is carried out in emergency rooms or if the same one is not able to breathe by itself.
Same different types of Intubation tubes Doctor use:
• Nasogastric intubation,
The tube is put in the stomach by passing through the nose to provide medications and to remove air from the stomach of the person.
• Endotracheal intubation,
The tube is put in the trachea by passing through nose or mouth to help a person in breathing while under anesthesia or due to a distressed airway.
• Fiber-optic intubation
In which a doctor inserts the tube into the throat to examine the throat or assist endotracheal intubation when a person cannot extend or flex their head.

2. Procedure

In the intubation procedure, a doctor gives anesthesia to sedate the person. The Doctor then uses a laryngoscope to locate sensitive tissues of mouth by inserting it into the mouth of a patient, with a laryngoscope doctor press the tongue to raise the epiglottis to see the trachea. Then the doctor inserts the flexible tube by avoiding damage to vocal cords and other sensitive tissues. If the doctor same time use inserts a tiny camera to help guide them.
Once a tube is inserted in the trachea, A small balloon around the tube that is inflated to hold the tube in place and to keep air from escaping.
The Doctor checks patient breathing to make sure the tube is in the correct spot. Then the tube is attached to a ventilator.
When the person no longer has difficulty breathing, the doctor will remove the tube from the person's throat.

3.Risks of Intubation

- Trauma to the teeth, mouth, tongue, and/or larynx
- Accidental intubation in the esophagus (food tube) instead of the trachea (air tube)
- Trauma to the trachea
- Bleeding
- Inability to be weaned from the ventilator, requiring tracheostomy.
- Aspirating (inhaling) vomit, saliva or other fluids while intubated
- Pneumonia, if aspiration occurs

4. When Is Intubation Necessary?

Intubation is required when general anesthesia is given to the patient while operation which makes body muscles paralyze including the diaphragm, which makes it important to use ventilators for a

patient. If the patient is very ill or having difficulty breathing on their own, they are kept on the ventilator for a longer time.
While doing surgery the doctor has to put the patient over a ventilator using an intubation tube. After surgery, the patient is given reverse the effects of anesthesia, which help a patient to recover and start breathing by on their own, but in same surgery like open-heart procedures, the patient is kept over ventilators until they are awake enough to protect their airway and take breaths on their own.
Intubation is performed also in respiration failure by the patient. There are many reasons for this like injury to the lungs, severe pneumonia and breathing problem such as COPD. All this lead to less intake of oxygen due to which the doctors have to put patient over ventilator until a patient is once again strong enough to breathe without assistance

5. Aim and Objective

5.1 The project aims to design an intubation system as effective and efficient as possible using software/ simulation packages, such as OrCAD and PTC Creo to simulate circuits and designs of the intubation system and to prototype the system for functionality and efficiency.

5.2 Objective

- To design 4 axis robotic arm for smart intubation device
- To design automated insertion of intubation tubes system
- To use 3D printer in order to build the pars needed for the project
- To Develop circuit for intubation system on OrCAD

6. Work Breakdown Structure

To work on a given topic of the project. I have divided on my work in different parts first I will be starting my project by studying the literature behind the intubation system like reading articles and books related to the intubation system and gathering information about what work is going in this section and what development can be made in existing work. then I have divided my work into three field design, code, and prototype.

4. In design, I will be using CAD software to design and simulation of all parts required to build a prototype of the project.
5. In code, I will be using Arduino ide and python to code motor for arm, intubation device, and camera for transfer of video to monitor.
6. In the prototype, I will be printing all parts from a 3D printer, assembling all parts, test running prototype and fixing errors of the prototype.

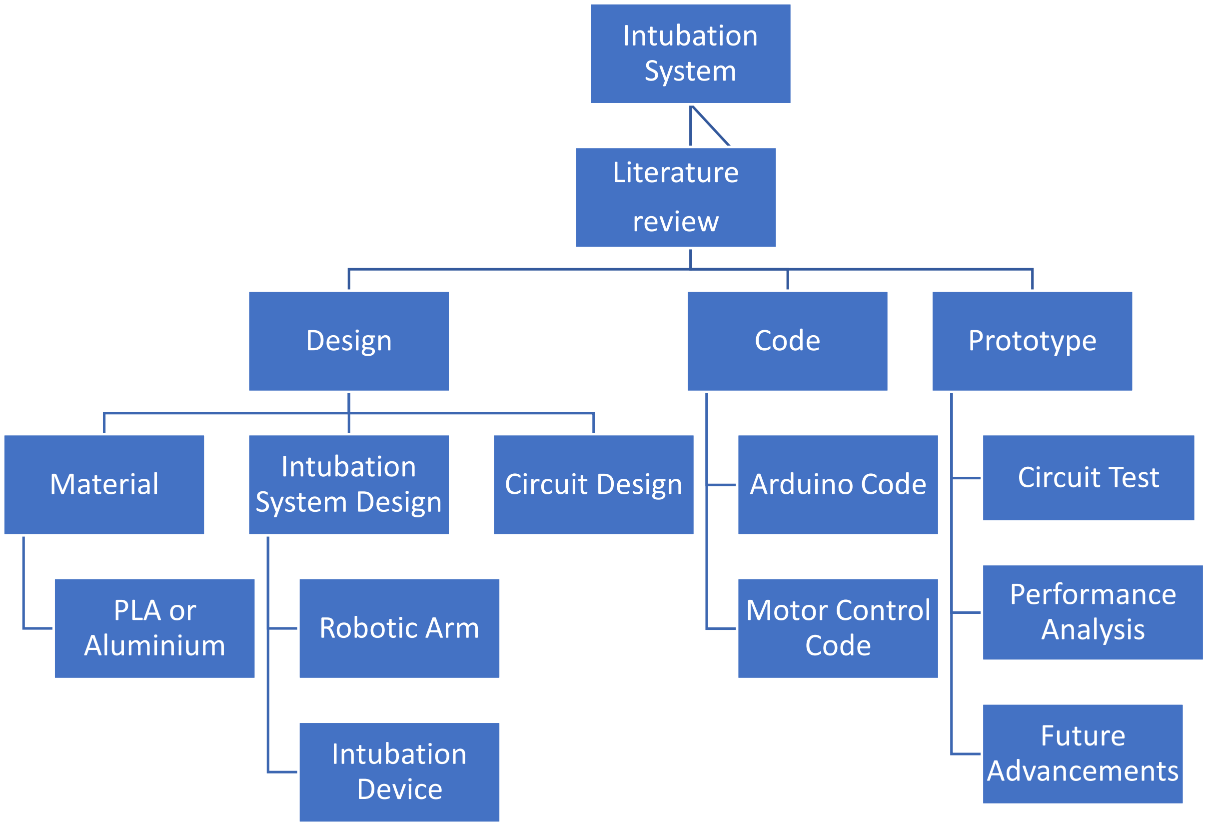

Fig.1 Work brake down chart

7. Design description (Introduction)

This project involves research on existing Trachea intubation systems and building a prototype to demonstrate a better and safe way for the tracheal intubation system as shown in Fig.1&2. Which are efficient and effective for all types of medical emergencies in hospitals. The project involves 4 axes robotic arm controlled by joystick used to place the intubation device incorrect place to start the intubation process. Then intubation device will start inserting an endoscope camera that will transmit video signals to screen, so we can see and detect the right place to stop in the trachea. When the camera is at the correct position then the intubation device starts inserting the tube. when a tube is at the correct position then devise to take back the camera out of the trachea.

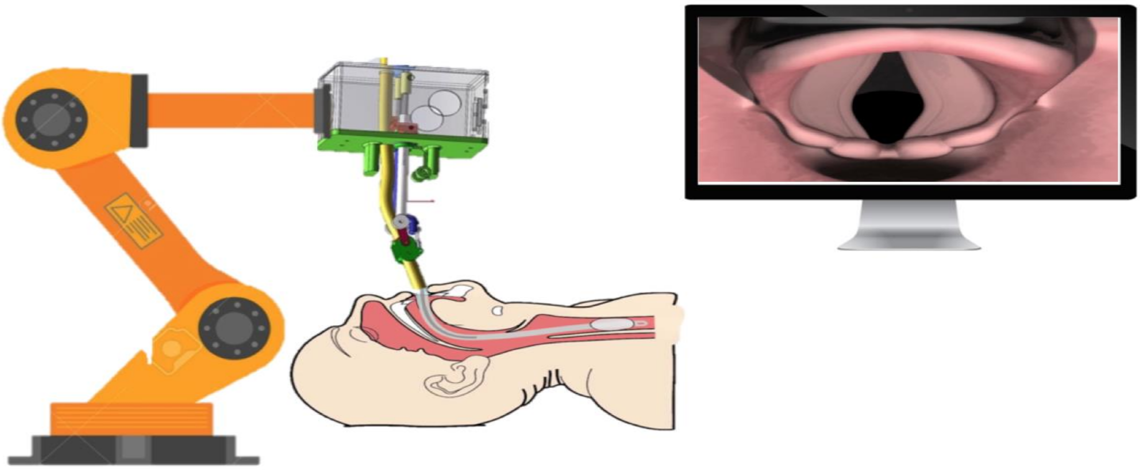

Fig.2Smart Intubation System

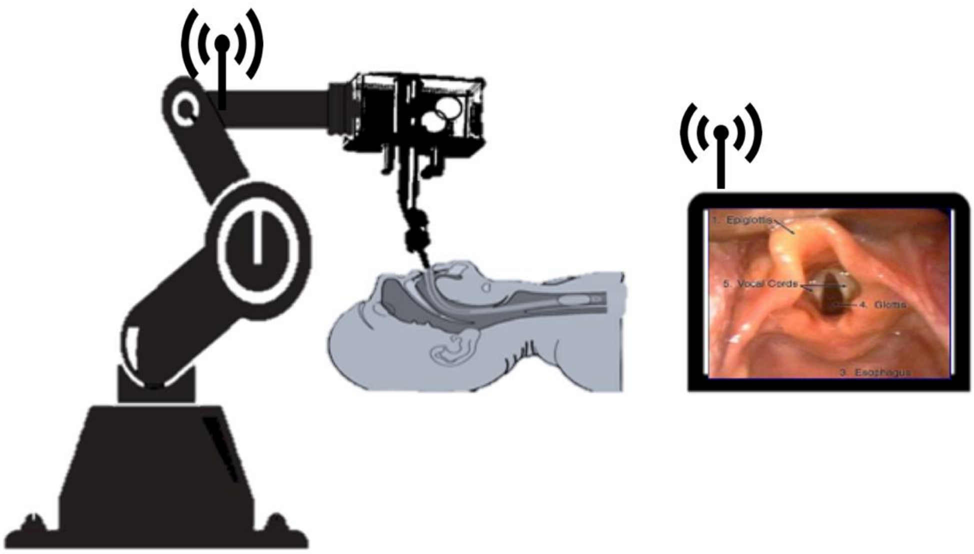

Fig.3 Proposed Smart Intubation System

7.1 Material used

The material I am using for the making of all the parts of the intubation system is PLA (polymeric material) instead of Aluminium because
When we compare both the material we found out PLA batter then aluminum to make a prototype of intubation system

- PLA is plastic therefore it is easy to use with 3Dprinter due to its low melting point compared to aluminum.
- PLA is lighter when compared with the same dimensions and thickness of parts with Aluminum.
- To use aluminum for designing parts, it involves using CNC machines on the other hand PLA is used as filament for 3D printer so faster results.

- As PLA is going to be used by a 3D printer therefore chances of error are very less when compared to aluminum.

7.1.1 Material Property Comparing Table:

Property	PLA	ALUMINUM
3D Printer	easy to use with 3D printer	Can not use in 3D printer
Weight	Lighter then aluminum	Heavy then PLA
ERROR	No error (Machine printed)	Can have error (human error)
Time Taken	Fast (3D printer is used)	Slow (CNC machine is used)

Table.1

7.2 Parts and mechanism

Robotic Arm (4 axes)
I will be using a 4axis robotic arm because it can reach all points in 3 dimensional (x, y, z) space and can be used to rotate the intubation devise as per the desired location. It will use 4 stepper motor which will be controlled by Arduino Uno and stepper motor driver. the joystick is used to control the robotic arm.
All parts of the robotic arm in Fig.3

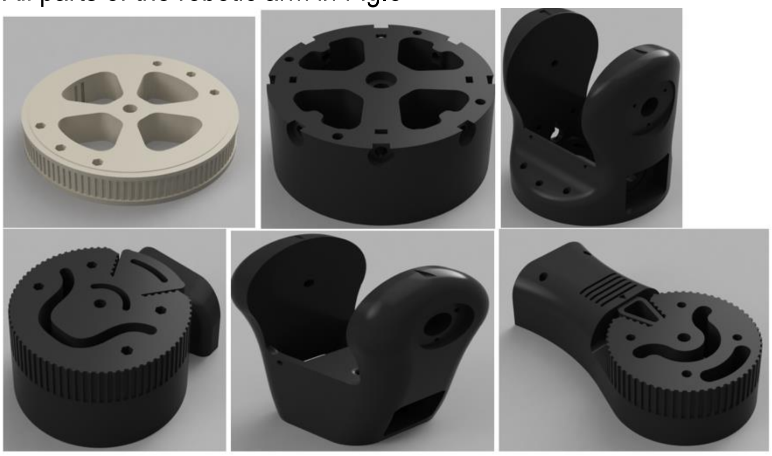

Fig.4 All Parts For 4 Axes Robotic Arm

We are using 4 different stepper motor for 4 parts base, shoulder, elbow, and wrist.
So for circuit design, we need to calculate target voltage required by each stepper driver because each stepper motor require a different amount of current for performing the task
Calculation:

<u>1.Nema 17 (base motor)</u>

Maximum current rating: 1.2A
Running current: 1A

$V_{ref} = 0.5\ \Omega * 1A$
$V_{ref} = 0.5V$

<u>2.Nema 23 (shoulder)</u>

Maximum current rating: 2.8A
Running current: 2A

V_{ref} = 0.5 Ω * 2A
V_{ref} = 1V

3.Nema 17 5:1 Geared Stepper (elbow)

Maximum current rating: 0.4A
Running current: 0.3A

V_{ref} = 0.5 Ω * 0.3A
V_{ref} = 0.15V

4.Nema 17 (wrist)
Maximum current rating: 0.4A
Running current: 0.4A

V_{ref} = 0.5 Ω * 0.4A
V_{ref} = 0.2V

7.3 Intubation device

It is placed at the wrist of the robotic arm it is used to insert a laryngoscope in the mouth to press the tongue to rise epiglottis to open the path to trachea then it starts inserting camera and tube. You can see the design of the intubation device made in PTC Creo.

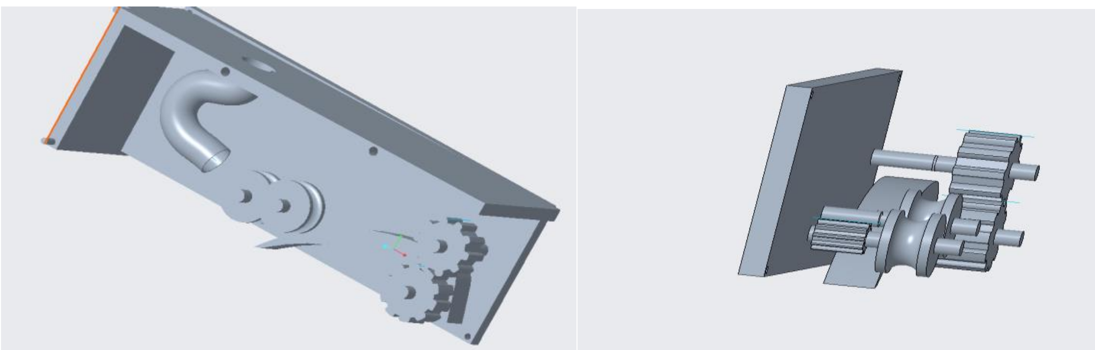

Fig.5 First Design

To make design more efficient new design for the intubation device is made. the problem in the first design was its size and problem with using a laryngoscope. So, to solve this problem laryngoscope is added outside the device which results in reducing the dimension of the intubation device and provide a more easy way to operate the device

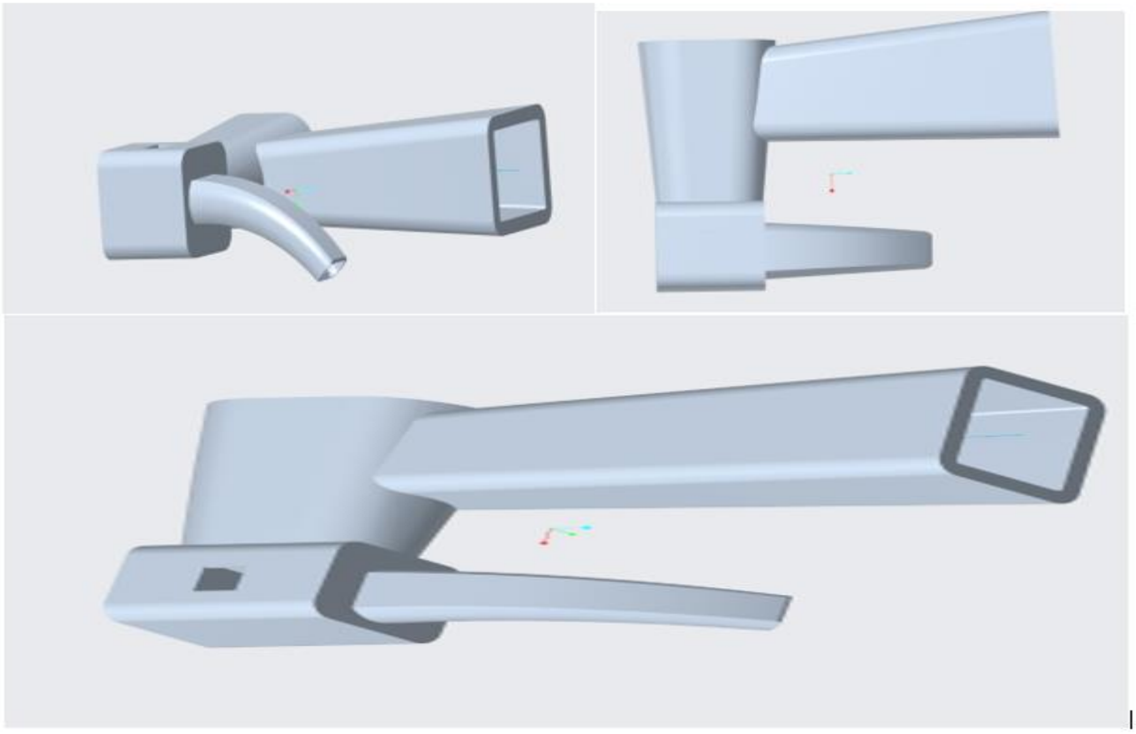

Fig.6 Final Design

7.4 Camera & elephant trunk robotic arm

We are using an endoscope camera with a diameter of 5.5mm with led in front to see in the dark and provide 720p video clarity. I will be designing a small elephant trunk robotic arm having camera attached on the front which will help in giving shape to the tube so the tube can enter without hearting the patient and help in placing the tube at the correct position in trachea, so both the lungs get proper supply of air for respiration of patient.

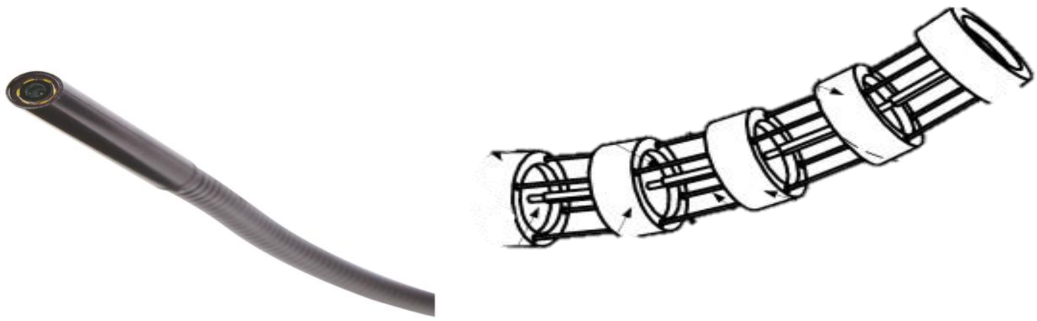

Fig. 7Camera and Trunk Robotic Arm Design

8.Timeline For Task Need To Be Done In Coming Months:

month	work
January	Ordering components,3Dprinting parts, and assembling
February	Making circuit connections and coding
March	Testing prototype and Final Report writing
April	Testing prototype and Final Report writing

Table.2