LARYNGOSCOPY FOR VISUALIZATION AND MONITORING OF ENDOTRACHEAL ACTIVITY WITH IMPROVED PARAMETERS

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ABSTRACT: Laryngoscopy is a procedure used for surgical measures essentially during visualization of Larynx. These conventional devices are inserted in Larynx of the patient through mouth for getting the images of the tract. These results can be better interpreted if it may get added parameters of Temperature and p^H of the Larynx. Therefore, there remains a necessity of an improved deliberation in the existing device, as visualization alone is least adequate for the laryngologist to have appropriate elucidation for effectual pathological diagnosis (for diseases like Tracheomalacia, Poly chondritis and Laryngitis etc). This Laryngoscope for Tracheal Diseases Diagnosis intends to facilitate efficacious diagnosis and interpretability of laryngeal diseases through a system that aims to monitor the pH (± 0.1pH accuracy) and temperature (readings having ±2°C accuracy) of larynx of the patient along with the provision of video visualization .Results for p^H parameter of the suggested system is monitored at human saliva and Temperature is monitored at Room temperature. These tests for performance of this device intends to be an endeavour to reduce impediments in diagnostic procedures of laryngoscopy.

Key words: Laryngoscope, pH, temperature, humidity, visualization, endotracheal diseases, Tracheomalacia, Poly chondritis, Laryngitis.

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INTRODUCTION

Laryngoscopy is a procedure used characteristically for visualization of larynx by tracheal intubation of surgical patients (Lossius *et al*., 2012), allowing upper airway management and performance of critical care procedures in various traumatic circumstances as well as for pathological diagnosis (Bailey 1996). The procedure of laryngoscopy can be performed by either direct or indirect means of vision. Direct laryngoscopy limits the laryngologist to visualize larynx by direct line of sight, through a hollow tube, lighted at the inserted end, with the patient under the condition of general anaesthesia (Elsharkawy *et al* .,2012) whereas, indirect laryngoscopy allows visualization of the larynx by obtaining an image of the glottic region either by video or mirror source of indirect vision. The instrument used for these procedures is known as Laryngoscope (Wang *et al*., 2006). It consists of a blade attached to its handle to provide appropriate vision of laryngeal conditions (Mort *at al*., 2004). There are various types of curved as well as straight blades available in a variety of sizes, nowadays. The most accepted of all curved blades is Macintosh, whereas the Miller blade is commonly the most preferred type of straight blades (Collins 2014). Despite all the ease of compatibility it provides, it is a detriment to the operator due to its high incidence of poor glottic visualization (Kriege *at el*., 2018). Laryngoscopes are diversified into various types upon the basis of advancement and limitations of their usage. These types include Conventional Laryngoscope, Suspension Laryngoscope, Fiber Optic Laryngoscope, Video Laryngoscope and Robotic Micro Laryngoscope (Rodney *at el.,* 2016). Thus far, the improvements introduced in laryngoscope are not wide enough to provide exact acknowledgement of the internal condition of larynx. As visualization alone, is least adequate for the laryngologist to have appropriate elucidation for diagnosis of laryngeal diseases, without any testing. To facilitate the diagnosis of diseases in larynx and vicinity there must be an improved deliberation to analyse other internal parameters. Enhanced Laryngoscope for Endo-Tracheal Diseases Diagnosis is aimed to provide more effectual diagnosis and interpretability of laryngeal diseases through a system that intends to monitor the pH, temperature, humidity of larynx of the patient with the provision of video visualization. This study though being highly progressive in technological aspects includes limitations of not yet being well evaluated across a vast range of patients with different anatomical responses and adaptations, thus limiting its generalized usage. Up till now, the advancements are only specified to the aspect of visual analysis (Ruetzler *et al.*, 2020), yet visualization alone is not enough to provide adequate acknowledgement of the inner condition of larynx (Kuo *et al.,* 2020), As some diseases alter the temperature and humidity level of larynx, laryngopharyngeal reflux disease can change in pH of larynx and can cause damage to the mucosal lining (Wang *et al*., 2020) including mouth cavity, larynx, pharynx or it can result in ear inflammation as well (Włodarczyk *et al*., 2019) therefore, further investigation of laryngeal pathologies during the visual analysis of the larynx and vicinity is required.

This device intends to be an endeavour to reduce impediments in diagnostic procedures.

Comparative Analysis among Existing Laryngoscopes: Table 1 shows a comparative analysis, illustrating various types of existing laryngoscopes, related research articles, their significant components, comparative overview and their drawbacks, comparing it with our proposed laryngoscope.

Table 1. Summary of Literature review on various types of existing Laryngoscopes.

Existing types of Laryngoscopes	**Papers and Reports** (Citations)	**Significant Components**	**Comparative Overview (functional compatibility)**	**Drawback(s)**
Conventional Laryngoscope	(Smith *et al*., 1999)	Light source, battery, holding handle, and removable blades (Macintosh or Miller).	Basic and easy functional procedure.	Poor glottic visualization along with the existence of a wide blind region.
Suspension Laryngoscope	(Jahn *et al*., 1996)	Laryngoscopic blade, and metallic suspension arm with a handle.	Facilitates in diagnostic and surgical procedures by enabling laryngologist to operate more invasively allowing both hands to be free.	It needs to be fixed at a specified angle and to keep the suspension laryngoscope adequately positioned, sometimes excessive force is placed on the upper jaw and tongue which can be painful for the patient.
Fiber Optic Laryngoscope	(Herth *et al*., 2017)	Blade (having 6mm of thickness), Fiber optical light, flexible insertion tube	Facilitates patients by providing limited mouth opening, while surgical procedures. It is designed to be rotated around the bottom of the tongue to enable comfortable insertion.	Laryngoscope requires more time to get disinfected, requires experienced operators, does not facilitate prolonged intubation and the operator must do additional learning to assemble and disassemble the device.
Video Laryngoscope	(Lossius *et al*., 2012) , (H. E. Wang et al ., 2006), (Mort 2004), (Jofee 2014), (Kriege *at el* ., 2018)	High-resolution digital camera, blade and an LCD attached to its handle	Facilitates better visualization of vocal cords by displaying image on the attached screen of laryngoscope.	Highly expensive.
Robotic Micro Laryngoscope (Retractor)	(Rodney *at el*., 2016)	Push-rod, tube, posture regulator, robotic arms.	It is a typical robot-assisted laryngoscopic system, being less troublesome, and a more compatible option when compared to traditional laryngoscope for glottic surgery.	This laryngoscope has a limitation of not yet being well evaluated across a vast range of patients with different anatomical responses and adaptations, this limits the generalized usage of this laryngoscope.
Suggested Laryngoscopy Technique	Authors of the current paper	Raspberry pi 3 Model B, 3.5'' Raspberry Pi	Provides exact acknowledgement of the internal conditions	This laryngoscope has a limitation of not yet being well evaluated across a vast

	LCD, Raspberry Pi Camera, DHT11 sensor, pH sensor and a light source.	(temperatureand pH) of larynx to have appropriate elucidation for diagnosis of laryngeal diseases through visualization of larynx and vicinity.	range of patients, thus limiting its generalized usage.

MATERIALS AND METHODS

The methodology of this project was elucidated through the block diagram provided below which shows the principal parts and their relation in this project. As shown in Figure 1, when the data was detected by the sensors, it was then submitted to the microprocessor which controlled all the parameters. The camera was also interfaced with the microprocessor, which processed and displayed the results on the LCD.

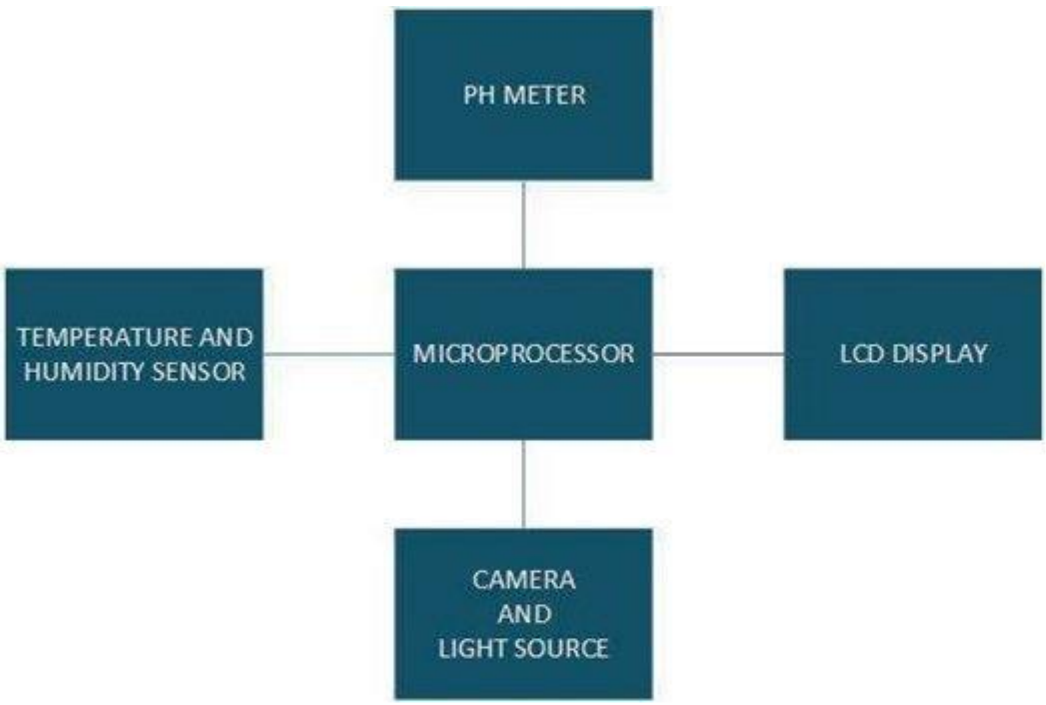

Figure 1. Block Diagram of the project methodology.

The diagnostic procedure of Laryngoscopy was achieved more effectually through p^H, temperature and humidity sensors by interfacing these parameters with the most compatible microprocessor unit to analyse diseases related to the larynx and vicinity. The microprocessor was also is interfaced with a camera. Similarly, LCD was interfaced with the microprocessor to acquire internal visualization of larynx and vicinity.

Prototype Laryngoscope Design at Software: Frame designing of this Laryngoscope was finalized through the SolidWorks software as shown in figure 2. This software was used to provide focus on the designing of 3D integrated objects in an environment that considered all features of developing a fine product and supported in maximizing the design to give a finely presentable final look of the product as shown in the figure below. It was used to bring designs and ideas to life to improve the aspect of innovation in this device.

This design ensured to meet the performance requirement of the product prototype, that too by defining the location of sensors (Temperature and p^H) and light source at tip of curved blade. Moreover, the camera was embedded at the tip of the blade also connected to the framed LCD to show the internal conditions of the Larynx.

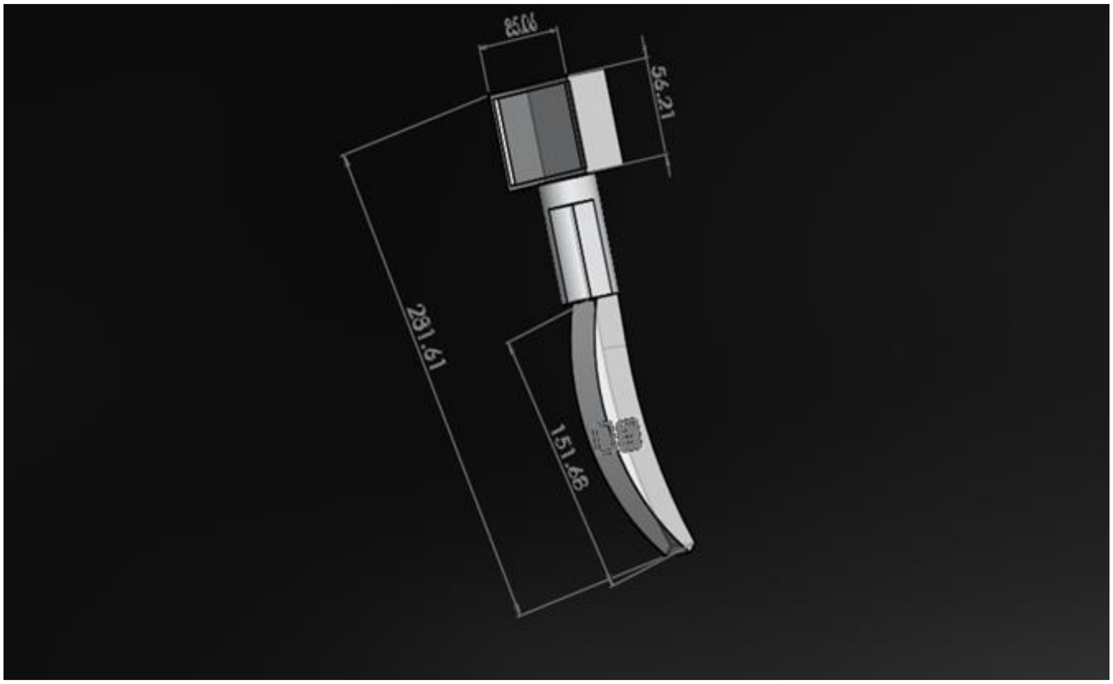

Figure 2. Dimensions and Design of suggested Laryngoscope at Solid Works

Prototype Laryngoscope Hardware Structure Design: Hardware Body/ Frame of this Laryngoscope was constructed of transparent plastic, and it was 09 inches in total length, it may be sterilized by sterilizing liquid (in case of testing at animals or humans). Light source (LED), Camera, Temperature and p^H sensors were attached at the tip of the Miller blade so that measurements and recordings could be taken as soon as the solution/temperature was introduced at the tip. Results were displayed at the screen attached at the other end of Laryngoscope. The image of this Laryngoscope can be seen in figure 3.

Figure 3 Hardware Design of the Proposed Laryngoscope

Flow chart of Methodical Implementation: Initialization, as represented by the flowchart in Figure 4, was done progressively by going through plain, systematic and critical stages of literature review including detailed study of related research articles, journals and books to gather information about recent advancements and evolution in laryngoscope. Moreover, designing of the blades of laryngoscope was done through SolidWorks. The proposed method is illustrated in Figure 4. Initially, the microprocessor evaluates the display and the sensors that are interfaced with raspberry pi. When the command is given, it receives the input data from the sensors and camera and transfer it back to the microprocessor to display the measured parameters.

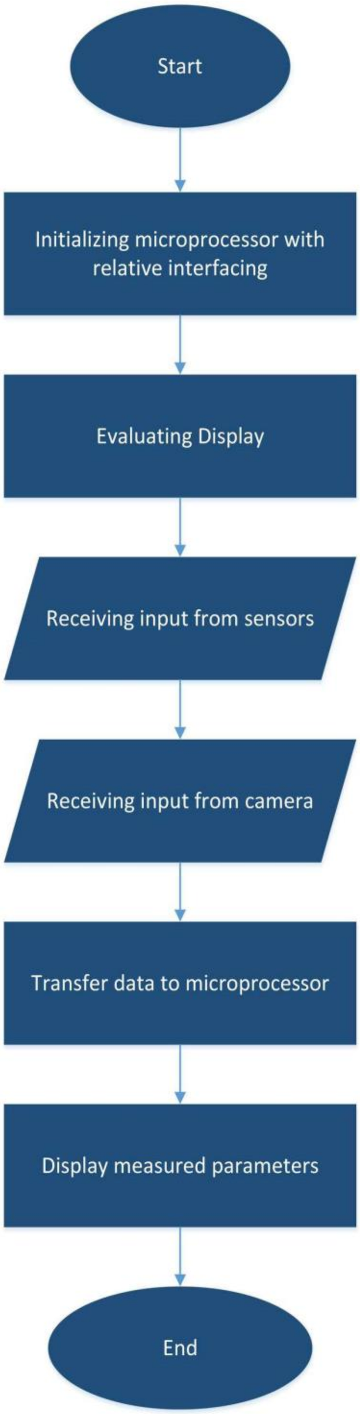

Figure 4 Flow chart of generalized Methodology

As shown in Figure 5, interfacing of temperature, humidity sensors, video camera (embedded inside the blade), pH, Optical light source and LCD was done with microprocessor. To interface the camera, sensors and LCD with the raspberry pi, certain drivers and libraries are significantly important to be installed. The cycle, as shown in Fig 2.4, is conducted only once and it is not repeated every time the system is initiated. Flow chart shows the systematic process of installation of required program and testing the compatibility of that program which aids in the connection between components and microprocessor.

Testing for the Parameters: The experimentation was done to test different parameters of enhanced laryngoscope for endo-tracheal disease diagnosis to verify the accuracy level of pH, temperature and humidity sensors and camera. Temperature was evaluated through DHT11 sensor, pH was tested through sensor (PH-107). Raspberry Pi camera was used to find the image quality and image resolution. Light source plays an important role in displaying quality images through camera. Furthermore, the Miller blade was designed and used in this study helped in both direct and indirect visualization of larynx and it may also assist to control the unnecessary movement of tongue during the procedure.

Experimental Setup: Three Different setups were used to check the performance of Laryngoscope; each setup was specific for each parameter in the Laryngoscope.

Setup for the testing the Temperature Sensor (DHT11) of Laryngoscope: In order to test and cross check the accuracy of Temperature Sensor (DHT11) placed at the tip of proposed laryngoscope, following setup were used; To test the working of the temperature sensor, it was interfaced with Raspberry Pi and with the help of python programming; the code was fed in the terminal window. After saving the code on desktop location, file was opened which lead the user to a new window where the whole program was opened. The room temperature was first noted with the help of air conditioned then it is checked by temperature thermometer inside the Laryngoscope whose results were displayed at Raspberry Pi LCD when the program was executed.

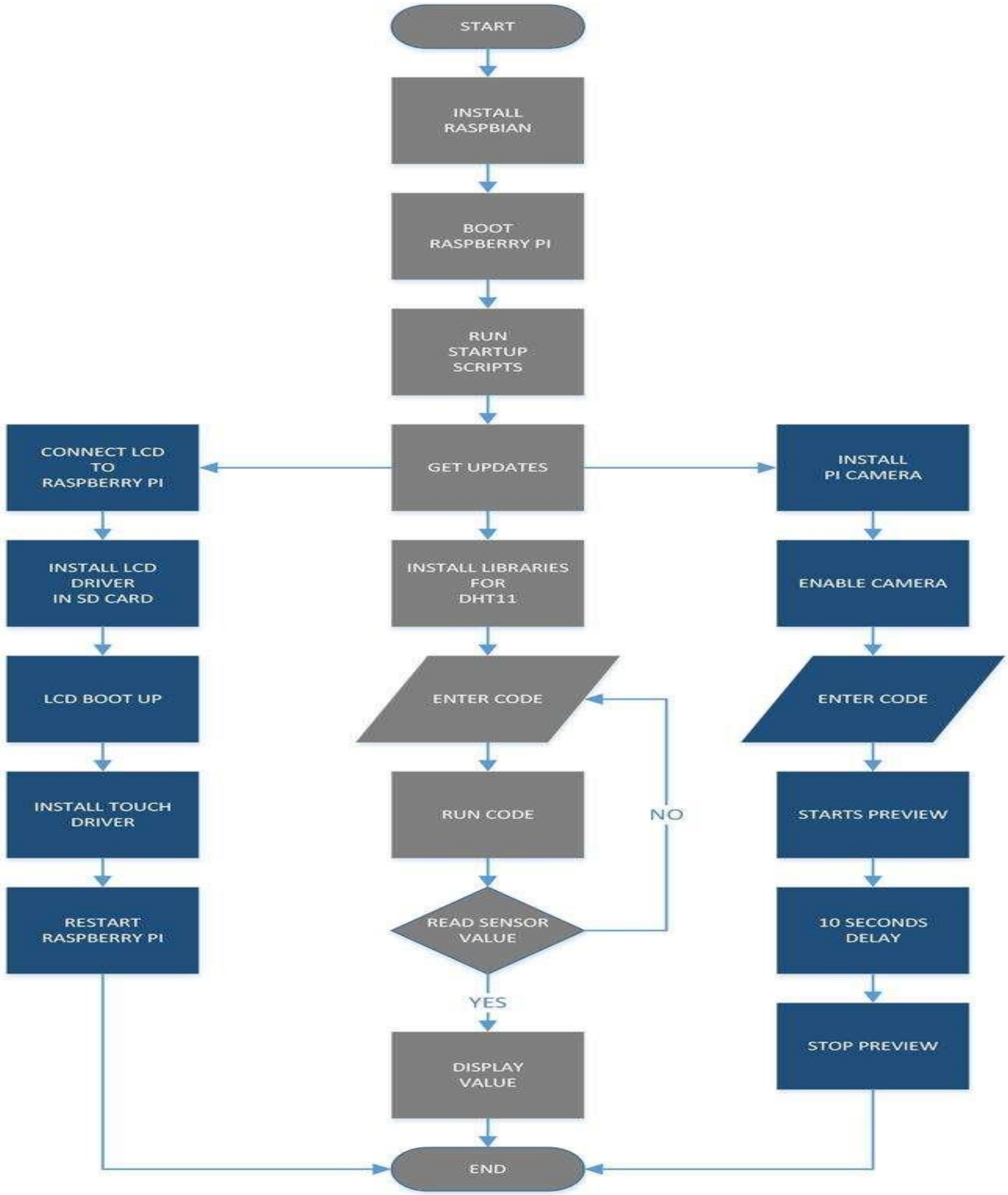

Figure 5 Detailed Flow chart of Laryngoscopy System

Table 2.1 shows the difference between multiple temperature recordings from regular room air condition and from laryngoscope. This was done in order to cross validate the results of DT sensor. The results were noted in Centigrade. and they show ±2°C accuracy deviation.

Table 2 Actual and Measured Temperature values from suggested Laryngoscope

S.No.	Actual Temperature in °C	Measured Temperature in °C
1	20	23
2	20	22
3	20	22
4	20	22
5	20	22
6	20	22
7	20	22
8	20	23
9	24	24
10	24	22
11	24	23
12	24	23
13	24	24
14	24	23
15	24	23
16	24	23
17	26	25
18	26	26
19	26	25
20	26	25
21	26	27
22	26	24
23	26	25
24	26	25
25	26	27

2.Setup for testing the pH sensor (PH-107): The pH sensor which is placed in the suggested Laryngoscopy system at the tip of the blade was tested on human saliva as saliva is a body fluid. Saliva of single human subject was tested (with their ethical consent) eight times against different buffer calibrations solutions one by one by taking it in a small container, Buffer Solution is to calibrate the pH meter due to the fact that they refuse to changes the pH (Millero *.et al;* 1993).Then the tip of laryngoscope (at which electrode of Ph sensor is present) was immersed in the saliva or it may also be done by absorbing the saliva in a tissue and touching the electrode on it for monitoring. The sensor detected the pH of the subject and the results were displayed it on LCD. These reading were displayed in table 3 which represented ± 0.1 difference in pH accuracy.

Table 3 pH Calibration and Measurements

S.No.	Buffer calibration	Callibration Result	pH of Saliva 6.9 avg.	Measured pH of saliva
1	6.86	6.8	6.9	6.5
2	6.86	6.9	6.9	6.7
3	6.86	6.7	6.9	6.5
4	6.86	6.8	6.9	6.9
5	4	4	6.9	6.9
6	4	3.8	6.9	6.4
7	4	4.1	6.9	7
8	4	4	6.9	6.6

3.Set up for testing the Camera results: Since we did not perform laryngoscopy with a human or living subject practically, we took photographs through the 5MP Raspberry Pi camera which is under plastic casing of the laryngoscope body placed at the tip of miller blade, to evaluate the quality of images it produced, and it gave quality image with video preview that may provide assistance in the visualization of larynx and vicinity. These camera images are shown in figure 6.

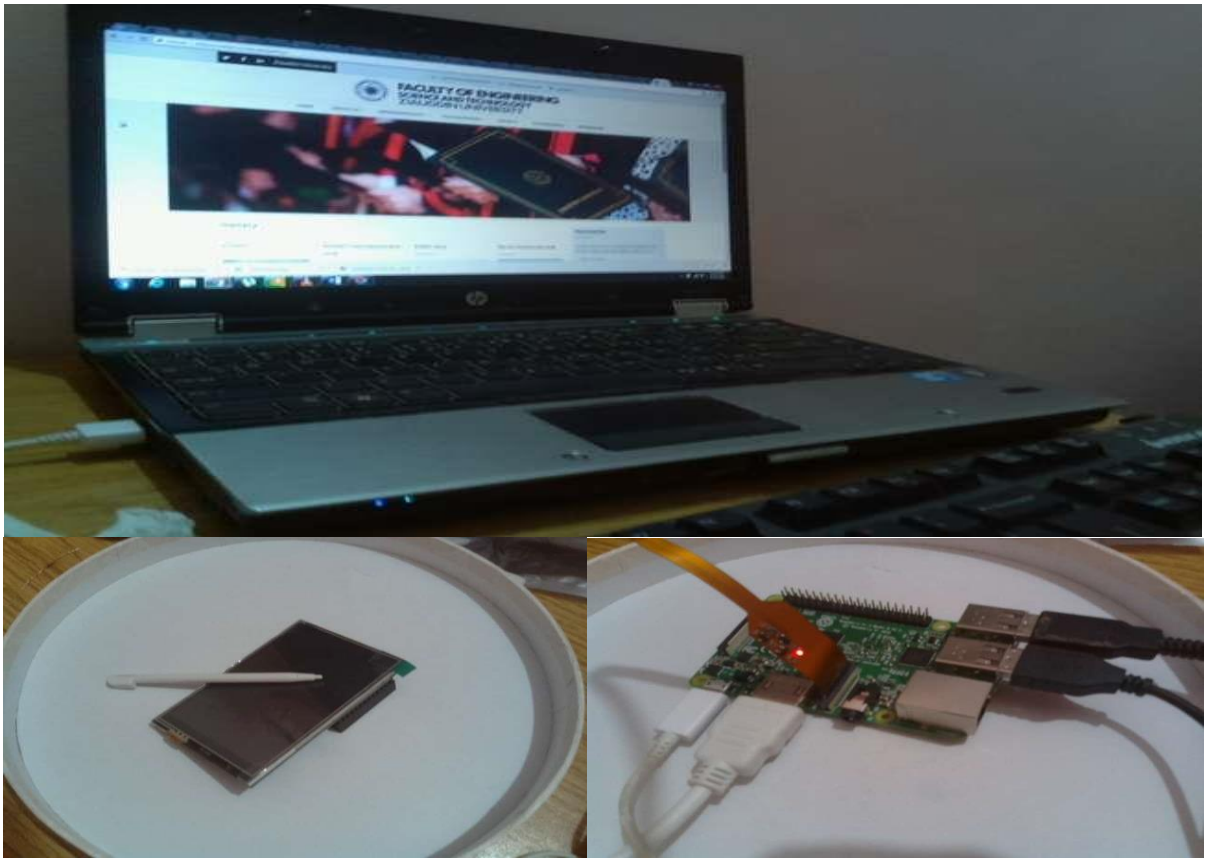

Figure 6 Images from 5MP Raspberry Pi

RESULTS

Results of Temperature Monitoring:

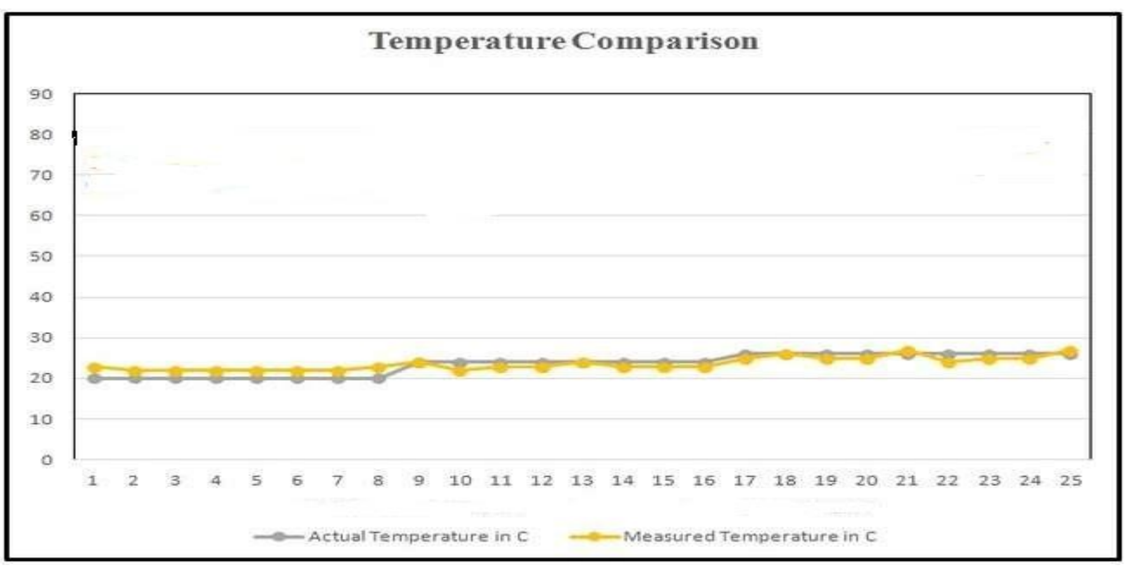

Figure 7 Comparison of Actual and Measured values of Temperature

The line graph shown in Figure 7 illustrates the information and comparison between the actual value and measured value of temperature. It is clearly evident from the line graph that the difference between the actual value and the measured value of temperature in ˚C is not greater. The measured value gave an accuracy of ±0.2 which is defined in the product specification.

Results for p^H Monitoring: The graphical representation of testing result data is given below.

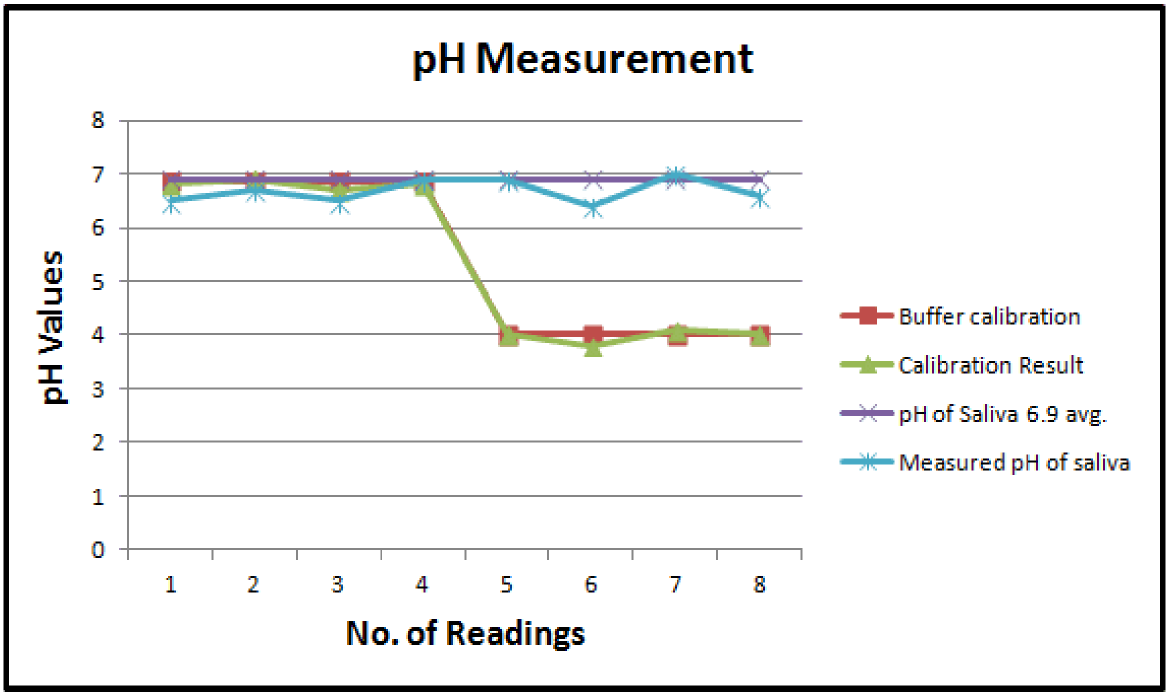

Figure 7 pH Measurement

The graph in Figure 7 demonstrates the information and compares the results of buffer calibration, calibration result, actual pH of saliva and measured pH of saliva. It is evidently shown that the calibration was done properly as the buffer calibration shows the very close similar results as the value of buffer solution, with slight variability of ± 0.1 value.

Results from Camera Monitoring: The pictures taken through 5MP Raspberry Pi Camera were legible, clear and can be visualized without difficulty however the visualization of laryngeal tract was actually not performed through this camera.

DISCUSSION

This research showed that a laryngoscope can be used to acquire better interpretability and facilitate diagnostic procedures through various parameters (pH, temperature, and humidity) along with the provision of video visualization.

To achieve these objectives, a Miller blade was used embedded with DHT11 sensor, PH-107 sensor and Raspberry Pi Model-B camera in the blade of laryngoscope. Although the results are not taken at human or animal but from the results it may be concluded that these sensors for pH and Temperature monitoring may be used to monitor the pharyngeal pH level and humidity in order to diagnose laryngeal injuries that could be caused by gastro-oesophageal reflux.

In this way this study evaluated multiple parameters concerning internal conditions of larynx and vicinity to facilitate diagnostic procedures.

Conclusion: This project being an enhanced video laryngoscope prototype has not been used for the real time monitoring therefore the limitation of not yet being well evaluated across a wide range of patients with different anatomical responses and adaptations; this limits the generalized usage of this laryngoscope, also the resolution of the camera used in this study is of 5MP which may not be sufficient for detail vision of organ but since it is a prototype study we used the low budget camera. This project can be enhanced further by adding camera of higher resolution in Miller blade for better visualization and these added parameters in this Laryngoscope of pH and temperature may be merged with robot to perform robotic laryngoscopy. This significant approach of this research is to inspire accurate and effectual robotic-laryngeal surgeries in future.

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