Smart System for Predicting Lung Health Using the K-Nearest Neighbors Algorithm on the Internet of Medical Things Platform

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***Abstract*—The lungs play a vital role in oxygen regulation and overall respiratory stability, yet they are highly susceptible to both infectious and non-infectious diseases. Respiratory illnesses such as COPD, pneumonia, lung cancer, tuberculosis, asthma, and hypoxia remain major global health problems and leading causes of mortality. Early detection of lung health conditions is therefore essential to prevent severe complications. Indicators such as changes in nail color, including bluish discoloration, may signal respiratory disorders. Although spirometry is commonly used to assess lung function, its high cost and reliance on clinical procedures limit routine monitoring. This study proposes an intelligent lung health prediction system based on the Internet of Medical Things (IoMT) using the K-Nearest Neighbors (K-NN) algorithm. The system integrates a TCS3200 sensor for nail RGB color detection, a MAX30100 sensor for pulse rate and oxygen saturation (SpO_2), and an MPX5500DP sensor to measure Forced Vital Capacity (FVC) and Forced Expiratory Volume in one second (FEV1). Experimental results show sensor errors of 2.1% (BPM), 0.51% (SpO_2), 5.07% (FVC), and 8.2% (FEV1). The system achieved 97.07% accuracy using K-NN (k = 11), enabling real-time lung health monitoring via smartphone and supporting early respiratory disease detection.**

***Keywords*—Health, Lung, Spirometer, Internet of Medical Things, K-Nearest Neighbors.**

I. INTRODUCTION

Lungs play a vital role in regulating the supply of oxygen to the body. Good lung condition is crucial for maintaining respiratory system stability, but lungs are vulnerable to various diseases. Respiratory diseases, both infectious and non-infectious, are major global health issues. According to the Global Burden of Diseas es 2019 data, the top five respiratory diseases causing death are chronic obstructive pulmonary disease (COPD), pneumonia, lung cancer, tuberculosis, and asthma. COPD ranks third as the leading cause of death from non-communicable diseases according to WHO, with cases continuing to rise in developing countries. Smoking and air pollution are the main risk factors for COPD [1].

Another condition involving the respiratory system is hypoxia, characterized by body condition where the heart rate and oxygen levels are below normal limits. The normal heart rate value is 60 – 100 Bpm, for oxygen saturation is 95 – 100% [2] [3]. If hypoxia occurs, it can reduce the blood's ability to carry oxygen, resulting in other organ functions being disrupted as well. Then a common problem that not many people know is that changes in nail color are related to human health status [4]. If the dominant fingernails are pink, it can be defined as healthy, on the other hand if the dominant color is different, it indicates something is happening to the body. For example, bluish nails indicate that the body is not getting enough oxygen, which indicates a lung problem such as emphysema [5].

There are ways to determine the health status of the respiratory system, namely with a lung function test using a spirometer. The aim is to test whether the ventilation function of the lungs is normal or not by measuring the volume of air that can be inspired and expired by a person [6].

In general, lung volume and capacity are affected by age, height and gender [7]. The variables examined using a spirometer are Forced Vital Capacity (FVC), Forced Ekspiratory Volume in 1 second (FEV1), and ratio FEV1/FVC. FVC indicates the amount of air a person can expel quickly and forcefully after a full inspiration, while FEV1 indicates the amount of air a person can expel in the first second of FVC [8]. A ratio value < 75% indicates an anomaly [9]. As a tool for measuring lung volume, spirometers can only be used by medical personnel and are also relatively expensive, so many people hesitatae to do routine lung health checks [10]. The habbit of being exposed to various types of air pollution and the absence of complaints of disease, even though they are in quite serious conditions, further strengthen this doubt.

Study that has been conducted Nasution et al., have produced a prototype of a tool for early detection of lung health indications. The parameters used are nail color, body temperature, and respiration. Use of piezoelectric sensor that relies on chest movement to obtain lung vital capacity values [11]. Afrisa et al., have applying Bernoulli's law to the venturi tube as a measure of lung volume. Measurement of pressure differences in the pipe is carried out with the help of the MPX5700DP sensor which has a sensivity of 6.4 mV/kPa.

Testing is blowing the mouthpiece pipe and viewing the results on the monitor. The parameters measured are FVC and FEV1 [10]. Luthfiyah el al., focus on development of an IoT –

based Pulmonary Function Monitoring Device of FVC and FEV1 for Children with Bronchial Asthma. This study has produced a spirometer device equipped with an oximeter sensor [9]. This study aims to design a smart system for predicting lung health using the K – Nearest Neighbors algorithm on the Internet of Medical Things (IoMT) platform. This system uses parameters such as nail color (RGB), pulse rate (Bpm), oxygen saturation (SpO2), Forced Vital Capacity (FVC), and Forced Expiratory Volume in 1 second (FEV1). The K – Nearest Neighbors algorithm is used for data classification based on the nearest distance from neighbors and integrates various features with different scales or units, so that hypotheses can be built directly from the nearest value. Health parameters are measured through hardware connected to a smartphone, so that users can immediately know the current health status of their lungs, whetever they are still healthy or not.

II. METHOD

A. Research Design

The type of research that will be used in an experiment, with stages that include data collection, data processing, analys and presentation carried out using the experimental method. The final result is a design of an intelligent system model to predict lung health. Users can use this tool together sith an application that regulates the health check menu. First, place your finger on the TCS3200 sensor to calculate the RGB nail color, then move to the MAX30100 sensor to calculate the pulse rate (Bpm), and oxygen saturation (SpO2). Finally, calculate your Forced Vital Capacity (FVC), and Forced Expiratory Volume in 1 second (FEV1) using a tube connected to the MPX5500DP sensor.

B. Block Diagram

The block diagram consists of three parts: input, process, and output. The hardware is activated with a 220V AC power supply, converted to 12V DC via an adapter, and stepped down to 3.3V using a DC – DC stepdown module LM2596 to match the microcontroller's requirements.

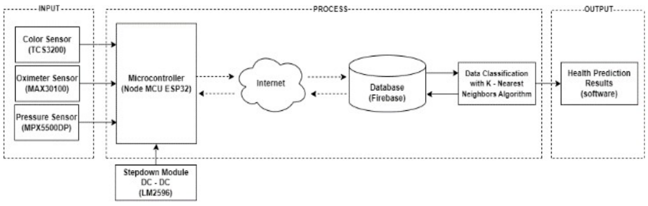

Figure 1. Tool Block Diagram

Fig. 1 shows a block diagram that has three parts. The input involves three sensors: TCS3200 for reading the RGB values of the nail, MAX30100 for calculating the pulse rate and measuring oxygen saturation, and MPX5500DP for measuring respiratory air pressure. Sensor data is processed by the NodeMCU ESP32 microcontroller and displayed, as well as stored in a Firebase database via Wi-Fi connection. The data stored in Firebase is classified using the K – Nearest Neighbor algorithm, and the classification results are displayed to the user as a prediction of lung health, indicating whether it is healthy or not.

C. Flowchart System

Fig. 2 shows the system flowchart that explain how the system works.

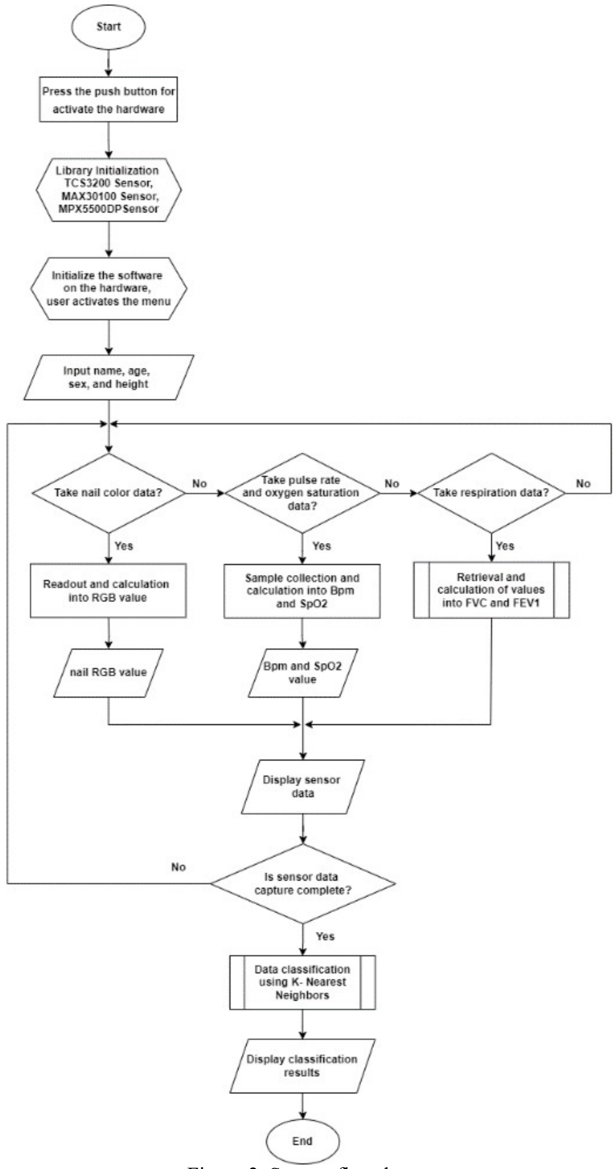

Figure 2. System flowchart

Press the push button to activate the hardware. Initialize all sensors such as TCS3200, MAX30100, and MPX5500DP. After that initialize the software on the hardware to enable checkup menu. Fill in personal data such as name, age, sex, and height.

Checking lung health status is carried out sequentially. First, placed your finger in the hole equipped with the TCS3200 sensor. Select menu “warna kuku” in the software to read and calculate to RGB values. Wait a few moments to get the value. The data has been recorded and will be displayed in RGB format.

Second, move your finger to the MAX30100 sensor. Select menu “Saturasi Oksigen & Denyut nadi” in the software for reading and calculating pulse rate and oxygen saturation values in hemoglobin. Wait a few moments to get the value. The data has been recorded and will be displayed in Beat per minute (Bpm) format for pulse rate and percentage (%) for oxygen saturation.

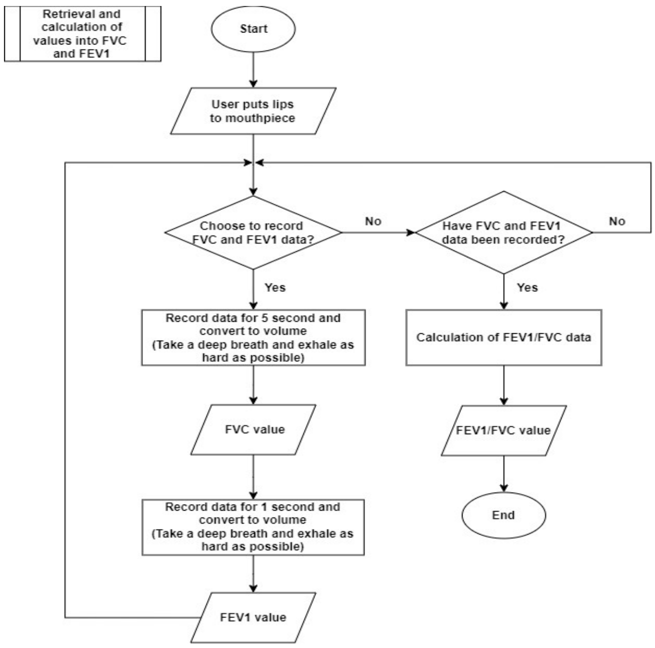

Figure 3. Respiratory Data Flowchart

The final check is shown in the Fig. 3, pinch the nose using noseclip and place the mouthpiece on the lips. Breathe normally through the mouth. Do the command by taking a deep breath, then exhale forcefully until it runs out. Select menu “Respirasi & Vital Capacity” in the software to record data and calculate to Forced Vital Capacity (FVC) and Forced Ekspiratory Volume in 1 second (FEV1) value. The result of calculation will be displayed in litre (L) format. The FVC and FEV1 values that have been obtained will be calculated at the FEV1/FVC ratio value and displayed in percentage (%) format.

D. Algorithm Flowchart

The implementation of the K – Nearest Neighbors algorithm is shown in Fig. 4. Starting with the initialization of the classification variables used for machine learning, these variables include RGB, Bpm, SpO2, age, height, sex, and FEV1/FVC ratio.

Input the value of “K” as the limit for taking the number of classification patterns. Based on K, the number of nearest neighbors, the decision is made by the KNN algorithm on classifying the given dataset. Calculate the distance using the euclidean equation from the closest to the value of K [12], like shown in Equation 1 below.

$$D(x,y) = \sqrt{\sum_{i=1}^{n}(x_1 - y_1)^2} \tag{1}$$

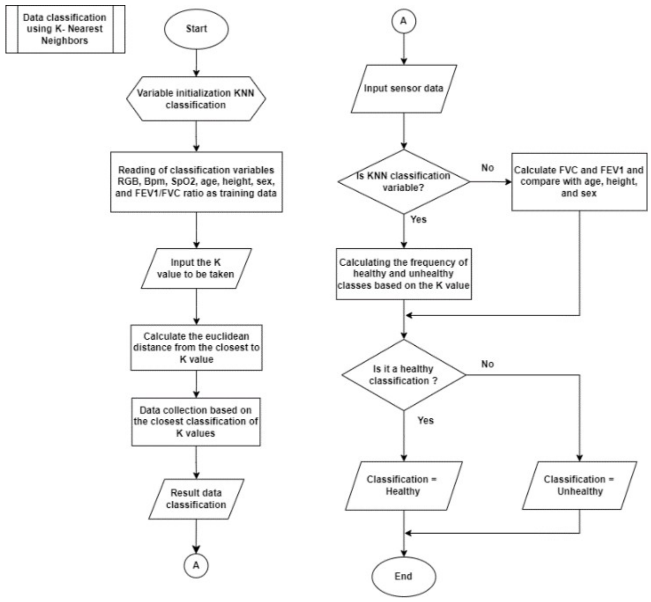

Figure 4. Algorithm Flowchart

Training data can be repeated, meaning that if training has been done but the results are less than satisfactory, it can be done again with different “K” value inputs. Calculate the matrix convolution to measure the accuracy of the training model data until optimal results are obtained. The output of training data is a prediction model.

The results of taking values from the sensor will later be processed in the same way using the prediction model as reference. If the sensor data includes the KNN classification (including RGB, Bpm, SpO2, age height, sex, and FEV1/FVC ratio) it will intermediately calculate the healthiest prediction patterns obtained from the classification results. If not, it will calculate the FVC and FEV1 values against the comparison of the predicted value.

If the measurement data is dominated by healthy conditions, it will display healthy conditions and can be known by the user via smartphone, but if not, it will display unhealthy conditions results. If not, it will calculate the FVC and FEV1 values.

III. RESULT AND DISCUSSION

A. Hardware Design Result

Fig. 5 shows the results of the inner hardware design. The hardware consists of TCS3200 sensor, MAX30100 sensor, MPX5500DP sensor, NodeMCU ESP32, LM2596 module, and push button. All of these components are connected to a PCB and packaged in a black box.

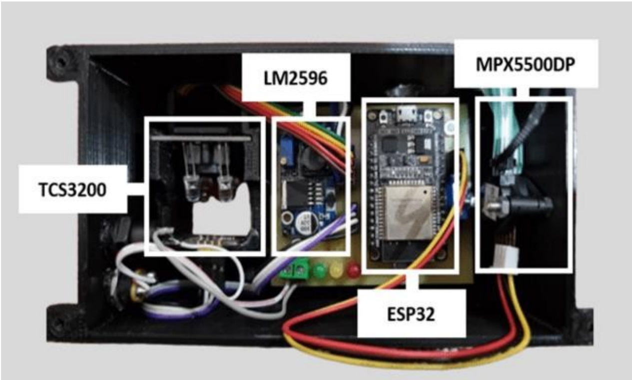

Figure 5. Hardware Design Result (Inside)

Fig. 6 shows the results of the outer hardware design. On the top side is the MAX30100 sensor and a small hose connecting the MPX5500DP sensor to the mouthpiece.

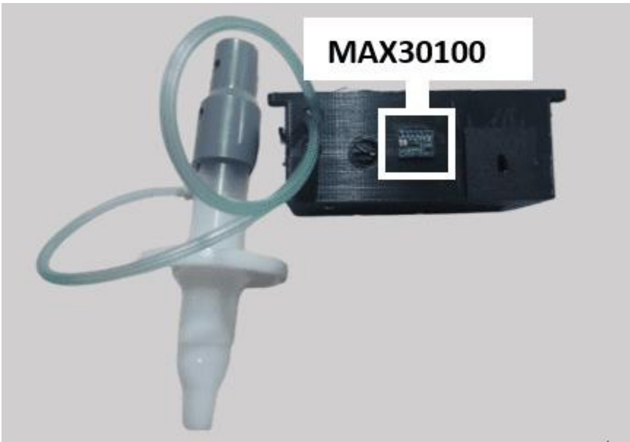

Figure 6. Hardware Design Result (Outside)

B. Software Design Result

The software that has been created has several menus, namely Dashboard, Form Screen, Check Screen, and Result Screen. The software menu display is shown in Fig. 7 and Fig. 8.

Figure 7. Software Design Result

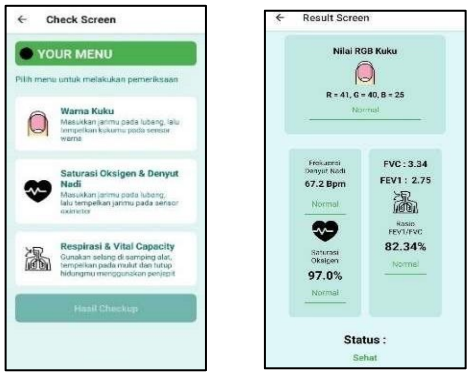

Figure 8. Software Design Result

C. TCS3200 Sensor Testing

The TCS3200 sensor test is carried out by pointing the sensor directly at red, green, and blue colored paper. The goal is to find out the reading of the RGB value intensity in these colors. Tests on red, green, and blue colors are presented in Table 1.

TABLE I
RGB VALUE RANGE RESULTS

Color	Sensor Value		
	R	G	D
Red	115 - 255	42 – 113	43 - 105
Green	23 – 69	85 – 255	35 – 114
Blue	15 – 70	70 - 184	114 – 255

Fig. 9 explains the intensity of RGB values in each of the red, green, and blue colors. This shows the accuracy of the sensor reading of different colors.

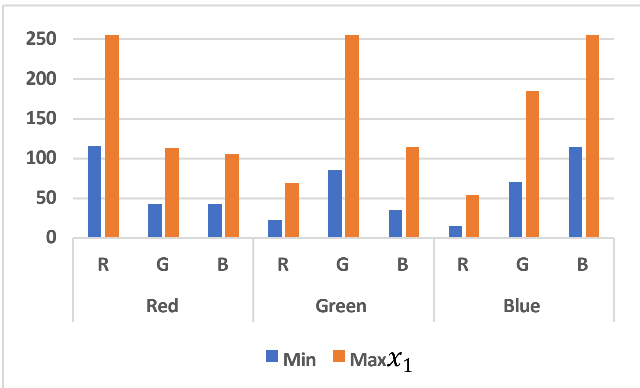

Figure 9. Intensity of RGB Values

The next test continued by taking the RGB value of the normal nail color. Normal nails are characterized by normal blood oxygen levels, so they have a pink color. Tests on normal nail samples are presented in Table 2.

TABLE II
RGB VALUE OF HEALTHY NAIL SAMPLES

Nail Sample	Sensor		
	R	G	B
1	38	28	26
2	54	42	35
3	23	14	8
4	46	28	26
5	61	56	35
6	30	14	17
7	40	22	24
8	28	16	12
9	50	38	40
10	48	30	32
Min	23	14	8
Max	61	56	40
Range	23– 61	14– 56	8– 41

D. *MAX30100 Sensor Testing*

The MAX30100 sensor test on pulse rate and oxygen saturation calculations was carried out 10 times. The purpose of the test was to detemine the accuracy of the MAX30100 sensor. The result of the test will be compared with the pulse oximeter measuring device. The results of the pulse rate (Bpm) tests are presented in Table 3.

TABLE III
BPM TESTING AND COMPARISON TO OXIMETER

Oximeter	Sensor	% Error
57	56	1.75
61	60	1.63
98	98	0
73	76	4.1
57	56	1.75
68	66	2.94
94	93	1.06
70	73	4.28
88	86	2.27
84	83	1.19
Average	2.1 %	

Then, the results of the oxygen saturation (%) tests are presented in Table 4.

TABLE IV
SPO2 TESTING AND COMPARISON TO OXIMETER

Oximeter	Sensor	% Error
96	95	1.04
99	98	1.01
96	96	0
98	98	0
99	98	1.01
95	96	1.05
97	97	0
97	97	0
96	97	0
96	96	1.03
Average		0.51 %

E. *MPX5500DP Sensor Testing*

The MPX5500DP sensor test is carried out by measuring the volume of air produced by the pressure from the sensor. First, measure the initial value of the sensor output before getting pressure and after getting pressure. So that changes in the value read by the sensor regarding the pressure produced by human breathing can be known. The results are presented in Table 5.

TABLE V
READING OF PRESSURE PRODUCED BY BREATHING

Pressure Value (kPa)	
Initial Conditions	End State
0	6.49
0.13	7.42
0.26	8.34
0.40	10.07
0.26	11.39
0.40	11.92
0.53	13.64
0.66	15.63
0.79	16.95
0.93	17.75

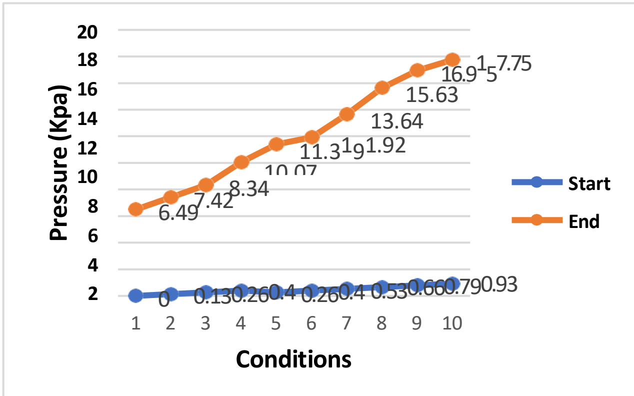

Figure 10. Comparison of the initial conditions to the pressure read

From Fig. 10, we can see the graph generated by the pressure reading by the sensor in the initial condition and its comparison shortly after getting the pressure generated by breathing through the mouthpiece. The resulting pressure difference is used to calculate the air flowrate and total volume of expiration.

To obtain the air volume value, unit conversion is required using the venturi meter principle. Venturi tube is a pipe that narrows at one end. The fluid flowing in the pipe has a density of ρ. The narrower the pipe, the faster the fluid flows and produces small pressure, conversely, the larger the pipe, the greater the pressure on the pipe. With the principle of continuity and bernouli, the calculation of volume value is obtained through the following equation (2) [10]:

$$P_1 - P_2 = \frac{1}{2}\rho\,(v_2^2 - v_1^2) \tag{2}$$

Explanation:
v_1 = Air flow rate at a large area (m/s)
v_2 = Air flow rate at a small area (m/s)
P_1 = Pressure at a large area (Pa)
P_2 = Pressure at a large area (Pa)
ρ = Air Density

Based on the continuity equation (3) [10]:

$$Q = A_1 v_1 = A_2 v_2 \quad (3)$$

Explanation:
A_1 = Large surface area (m/s)
A_2 = Small surface area (m/s)
Q = Pressure at a large area (Pa)

The velocity in the first sectional of the pipe is expressed in (4). By considering (3) volumetric flow rate is expressed in (5) [13].

$$v_1 = \sqrt{\frac{2(P_1 - P_2)/\rho}{\left(\frac{A_1}{A_2}\right)^2 - 1}} \quad (4)$$

$$Q = A_1 \sqrt{\frac{2(P_1 - P_2)/\rho}{\left(\frac{A_1}{A_2}\right)^2 - 1}} \quad (5)$$

FVC is the total volume in t seconds as expressed in (6), where t denotes the time duration in seconds and Q is non zero, while FEV1 indicates the flow rate in a second [13].

$$V = Q_1 (t_1 - t_0) + \cdots + Q_n (t_n - t_{n-1}) \quad (6)$$

Explanation:
V = Volume (m^3)
t = Time (s)

After the conversion is complete, sensor testing can be carried out. The MPX5500DP sensor test on FVC and FEV1 calculations was carried out 5 times. The purpose of the test was to detemine the accuracy of the MPX5500DP sensor. The result of the test will be compared with the spirometer measuring device. FVC (L) tests are presented in Table 6.

Then, the results of the FEV1 (L) test are presented in Table 7.

F. K – Nearest Neighbors

The K – Nearest Neighbors algorithm testing was carried out using varying k values, namely 1, 3, 5, 7, 9, and 11. The aim is to determine the accuracy of each k value used as an approach to health prediction. K value testing is presented in the following table.

TABLE VI
FVC TESTING AND COMPARISON TO SPIROMETER

FVC (L)		
Spirometer	**Sensor**	**% Error**
3.08	2.81	8.76
3.26	3.52	7.97
2.99	2.98	0.33
2.82	2.95	4.6
3.25	3.37	3.69
Average		5.07 %

Table 7, we can see that lowest level accuracy is k = 1 with an accuracy of 94.92 % and the higest accuracy is k = 11 with an accuracy of 97.07 %. The results show that k = 11 is the most optimal value with the highest level of accuracy and produces a classification model that will be evaluated using a confusion matrix [14].

TABLE VII
FEV1 TESTING AND COMPARISON TO SPIROMETER

K - value	Accuration
1	94.92 %
3	96.07 %
5	96.48 %
7	96.80 %
9	96.95 %
11	97.07%

Table 8 shows the model evaluation using the confusion matrix. The model is divided into 2 classes, namely actual data and predicted data. Each class has a correct and incorrect value, this is used to evaluate the performance of the classification model by comparing the number of correct and incorrect predictions [14]. To determine the performance of the model, calculate the performance using the parameters of precision, recal, f-1 score, and accuracy through the equation (7), (8), (9), and (10).

TABLE VIII
CONFUSION MATRIX USING K = 11

Class		Prediction	
		True	**False**
Actual	**True**	169977 (True Positive)	1885 (False Negative)
	False	3968 (False Positive)	24170 (True Negative)

Classification report

1. Precision, percentage of prediction model accuracy [15].

$$\text{Precision} = \frac{\text{True Positive}}{\text{Total Predicted Positive}} = \frac{TP}{TP + FP}$$

$$= \frac{169977}{169977 + 3968} = 0.98$$

2. Recall, percentage of actual data to prediction data [15].

$$\text{Recall} = \frac{\text{True Positive}}{\text{Total Predicted Negatif}} = \frac{TP}{TP + FN}$$

$$= \frac{169977}{169977 + 1885} = 0.99$$

3. F – 1 Score, harmonic mean of precision and recall which describes the between precission and recall [12].

$$F1 - \text{Score} = 2 \times \frac{\text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}}$$

$$= 2 \times \frac{0.98 \times 0.99}{0.98 + 0.99} = 0.9$$

4. Accuration, percentage of correct predictions from the total data [12] [15].

$$\text{Accuration} = \frac{TP + TN}{TP + TN + FN + FP}$$

$$= \frac{24170 + 169977}{200000}$$

$$= 0.9707 \text{ or } 97.07\%$$

G. System Testing

This test conducted directly on a random sample of 5 people with different conditions. The samples tested were required not to do finish doing sport activities and smoking within 3 hours, because it will affect the test result. The results of the test are presented in Table 9.

TABLE IX
SYSTEM TESTING ON SAMPLES

RGB	Pulse Rate	Sp02	Ratio FVC/FEV1	FVC	FEV1	Prediction
28, 26, 17	63 Bpm	98%	87.75%	3.51 L	3.08 L	Healthy
41, 40, 25	67 Bpm	97%	82.34%	3.34 L	2.75 L	Healthy
42, 40, 25	68 Bpm	97%	82.35%	2.55 L	2.10 L	Healthy
34, 26, 17	63 Bpm	97%	74.04%	3.39 L	2.51 L	Unhealthy

From the tests carried out on the samples, the predicted results were stated as healthy and unhealthy.

Fig. 11 shows the healthy prediction results on the samples. The sample is shown for a 21 years old man with a height of 175 cm, then there was no history of lung disease and smoking habits. The results of the RGB nail examination, Bpm, SpO2, FEV1/FVC ratio showed values that were in the normal range. So, the predicted results is healthy.

Figure 11. Result of Healthy Predictions

Then Fig. 12 shows the samples with unhealthy prediction results, which was shown in a 21-year-old man with a height of 171 cm. The results of RGB nail examination, Bpm, and SpO2 showed values that were in the normal range, but the FEV1/FVC ratio showed a value of 74.04 %. The presence of a heavy smoking habit is a strong indication why the FEV1/FVC ratio value decreased to < 75%.

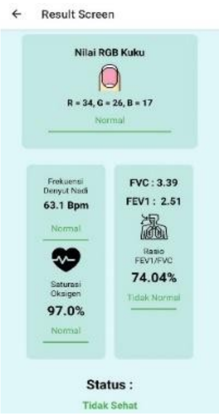

Figure 12. Result of Unhealthy Predictions

IV. CONCLUSION

Based on the result of designing and testing a smart system for predicting lung health, it can be concluded that this tool successfully predicted lung health. In the TCS3200 sensor test, normal nail samples were obtained in the range of R = 23 – 61, G = 14 – 56, B = 8 – 40 with intensity of the "R" value higher than the "G" and "B". MAX30100 sensor shows a very small difference compared to the pulse oximeter, which is only 2.1 % for bpm and 0.51 % for SpO2. MPX5500DP sensor compared to the spirometer, which is 5.07 % for FVC and 8.2 % for FEV1. Application of the K–Nearest Neighbors algorithm to predict lung health based on RGB, Bpm, SpO2, and FEV1/FVC ratio has been designed on the system and obtained results using a value of k = 11 with the highest accuracy of 97.07 %.

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