Health monitoring application using fuzzy logic based on android

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Abstract. In this paper, we propose an application for health monitoring condition. In the previous, there are several researches about health monitoring using fuzzy logic to conclude health condition. Users can monitor his health condition using the application. Fuzzy logic can infer the user's health condition when the application is used. The data used are pulse rate, oxygen saturation and body temperature. Fuzzy logic processes the data received and the results are displaying on the mobile application. The result of health condition classification compare by actual tools and real condition.

1. Introduction
Health is the most important thing for all of the people, activities become more productive by being healthy. Not a few people who are too focused on work to be success, as a result many people forget their health conditions, and health problems occur due to unstable health conditions. Determinants of health conditions can do with the vital signs checks. Examination of vital signs is a measurement of the most basic body functions for find out clinical signs and useful to more accurate at coming up with the correct diagnosis of a disease and the function for determining the right medical planning[1]. Many people neglect to go to check their health conditions to the doctor, because activities that are too busy.

For examination of vital signs can be through the condition of the pulse rate, oxygen saturation, and body temperature. The pulse is the number of our arteries pulsing in one minute because the heart pulse. The pulse rate will be exactly the same as the heart rate, the pressure also describe the rate of heart contraction, because this heart contraction causes an increase in blood pressure and pulse in the arteries. Body temperature is a measure of the body's ability to produce and get rid of heat., according to WHO, according to WHO normal human body temperature ranges between 36.5°C-37.5°C. Oxygen saturation or oxygen levels in the body is the presentation of hemoglobin which binds to oxygen in the arteries, normally between 95-100%. The vital signs checks by yourself, can be useful to monitor directly the health conditions early.

The main aim of this research is to make an application which can help the people to monitor their health condition based on data of pulse rate, oxygen saturation, and body temperature.
2. Related work
Systems for health monitoring condition have been developed using various architectures, similar to the approach we developed. M. A. Saputro et al. [1] using mobile application to monitoring health condition, Nandkishor et al. [3] utilizing pulse rate, oxygen saturation, and body temperature sensor is applied to the wearable device for collecting and analysing information health condition in application and get the result using fuzzy logic [2][4]. Todor Ivascu [7] real time health monitoring using fuzzy logic with doctor for patient consultation. Learn about monitoring and diagnosing diseases using fuzzy logic [5] [6]. Discuss about smartphone for health monitoring condition [8] [9] [10] [11].

The rest of this paper is organized as follows. In Section 3, explained about system overview and fuzzy logic methods and design of fuzzy logic used. In Section 4, explained about result and experiment. Finally, conclusions are presented in Section 5.

3. Materials and methods
The system that will be designed aims to monitoring health condition, designed using the values obtained from the pulse rate, oxygen saturation, and body temperature which can be used as a measuring instrument for the health condition. The output value obtained from wearable device will be send and processed through in application using fuzzy logic, the data will be stored in the local SQLite database storage. In Figure 1 will be show the system overview.

![System overview](image)

**Figure 1.** System overview.

3.1. Design of fuzzification
The result of fuzzification aims to get fuzzy input for health condition value obtained from the sensor.

| Parameters         | Linguistic                        |
|--------------------|-----------------------------------|
| Age                | Teenager, Adult, Old             |
| Pulse Rate         | Low, Normal, High, Bad           |
| Oxygen Saturation  | Critical hypoxia, moderate hypoxia, mild hypoxia, normal |
| Body Temperature   | Cold, Normal, Hot                |

The result of fuzzification will be used in the inference to obtain health condition rules. The linguistic value of the input sensors used by application using fuzzy logic. For Age has three linguistic values, Pulse Rate has three linguistic values, Oxygen Saturation has four linguistic values, and Body Temperature has three linguistic values.
Figure 2. Membership function of age (years).

The membership function of age based on the figure 2 we can use that graph to get the age input value. This membership is useful for classification the age of user will be used in fuzzy logic and has three linguistic values teenager (10-18 years), adult (25-30 years) and old (≥40 years). The membership function of age has the following characteristics:

\[
\text{Teenager} = \begin{cases} 
1, & 18 \leq x \leq 25 \\
(x-10/8), & 10 < x < 18 \\
(30-x)/5, & 30 > x > 25 \\
0, & 10 \geq x; x \geq 30
\end{cases} \quad (1)
\]

\[
\text{Adult} = \begin{cases} 
1, & 30 \leq x \leq 40 \\
(x-25/8), & 25 < x < 30 \\
(45-x)/5, & 40 > x > 45 \\
0, & 25 \geq x; x \geq 45
\end{cases} \quad (2)
\]

\[
\text{Old} = \begin{cases} 
1, & x \geq 45 \\
(x-30/10), & x > 30; x < 40 \\
0, & 40 \leq x
\end{cases} \quad (3)
\]

Figure 3. Membership function of pulse rate (bpm).

The membership function of pulse rate based on the figure 3 we can use that graph to get the pulse rate input value. This membership is useful for classification the pulse rate of user will be used in fuzzy logic and has four linguistic values low (0-59 bpm), normal (60-91 bpm), high (91-100 bpm) and bad (>100 bpm). The membership function of pulse rate has the following characteristics:
\textbf{Low} = \begin{cases} 1, & x \leq 59 \\ \frac{(60-x)}{(60-59)}, & 60 > x > 59 \\ 0, & x \geq 60 \end{cases} \quad (4)

\textbf{Normal} = \begin{cases} 1, & 60 \leq x \leq 90 \\ \frac{(x-84)}{(85-84)}, & 85 > x > 84 \\ \frac{(90-x)}{(90-89)}, & 90 > x > 99 \\ 0, & 85 \geq x \land x > 99 \end{cases} \quad (5)

\textbf{High} = \begin{cases} 1, & 100 \geq x \geq 91 \\ \frac{(x-90)}{(101-90)}, & 101 > x > 91 \\ 0, & 100 \geq x \land x \geq 91 \end{cases} \quad (6)

\textbf{Bad} = \begin{cases} 1, & x \geq 101 \\ \frac{(x-100)}{(101-100)}, & 101 > x > 100 \\ 0, & 100 \geq x \land x \geq 101 \end{cases} \quad (7)

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure4.png}
\caption{Membership function of oxygen saturation (\%)}
\end{figure}

The membership function of oxygen saturation based on the figure 4 we can use that graph to get the oxygen saturation input value. This membership is useful for classification the oxygen saturation of user will be used in fuzzy logic and has four linguistic values critical, moderate, mild and normal. The membership function of oxygen saturation has the following characteristics:

\textbf{Critical} = \begin{cases} 1, & x \leq 84 \\ \frac{(85-x)}{(85-84)}, & 85 > x > 84 \\ 0, & x \geq 60 \end{cases} \quad (8)

\textbf{Moderate} = \begin{cases} 1, & 60 \leq x \leq 90 \\ \frac{(x-84)}{(85-84)}, & 85 > x > 84 \\ \frac{(90-x)}{(90-89)}, & 90 > x > 99 \\ 0, & 90 \geq x \land x \geq 99 \end{cases} \quad (9)

\textbf{Mild} = \begin{cases} 1, & 100 \geq x \geq 91 \\ \frac{(x-90)}{(91-90)}, & 91 > x > 91 \\ \frac{(101-x)}{(101-100)}, & 101 > x > 100 \\ 0, & 100 \geq x \land x \geq 101 \end{cases} \quad (10)
The membership function of body temperature based on the figure 5 we can use that graph to get the body temperature input value. This membership is useful for classification the body temperature of user will be used in fuzzy logic and has three linguistic values cold, normal and hot. The membership function of body temperature has the following characteristics:

\[
\text{Cold} = \begin{cases} 
1, & x \leq 34 \\
(x-34/36-34), & 34 < x < 36 \\
0, & x \geq 36 
\end{cases}
\] (12)

\[
\text{Normal} = \begin{cases} 
1, & 36 \leq x \leq 37 \\
(x-34/36-34), & 34 < x < 36 \\
(39-x)/39-26, & 39 > x > 36 \\
0, & 34 \geq x ; x \geq 39 
\end{cases}
\] (13)

\[
\text{Hot} = \begin{cases} 
1, & x \geq 39 \\
(x-37/39-37), & 37 > x > 39 \\
0, & 37 \geq x 
\end{cases}
\] (14)

3.2. Design of inference
This section explains how to use fuzzy rules in fuzzy logic.

| Pulse Rate | Age         |                  |            |            |
|------------|-------------|------------------|------------|
|            | Teenager    | Adult            | Old        |
| Low        | Unwell      | Unwell           | Unwell     |
| Normal     | Healthy     | Healthy          | Healthy    |
| High       | Unwell      | Unwell           | Unwell     |
| Bad        | Not healthy | Not healthy      | Not healthy|
Table 2 shows Design the rules of pulse rate health condition using fuzzy logic. The rules are:

[R1] = IF Age = Teenager and Pulse Rate = Low then Stats = Unwell
[R2] = IF Age = Teenager and Pulse Rate = Normal then Stats = Healthy
[R3] = IF Age = Teenager and Pulse Rate = High then Stats = Unwell
[R4] = IF Age = Teenager and Pulse Rate = Bad then Stats = Not Healthy
[R5] = IF Age = Adult and Pulse Rate = Low then Stats = Unwell
[R6] = IF Age = Adult and Pulse Rate = Normal then Stats = Healthy
[R7] = IF Age = Adult and Pulse Rate = High then Stats = Unwell
[R8] = IF Age = Adult and Pulse Rate = Bad then Stats = Not Healthy
[R9] = IF Age = Old and Pulse Rate = Low then Stats = Unwell
[R10] = IF Age = Old and Pulse Rate = Normal then Stats = Healthy
[R12] = IF Age = Old and Pulse Rate = High then Stats = Unwell
[R13] = IF Age = Old and Pulse Rate = Bad then Stats = Not Healthy

Table 3. Rules for oxygen saturation health condition.

| Oxygen Saturation | Age      |
|-------------------|----------|
|                   | Teenager | Adult  | Old    |
| Serious           | Not healthy | Not healthy | Not healthy |
| Moderate          | Not healthy | Not healthy | Not healthy |
| Normal            | Unwell   | Unwell  | Unwell |
|                   | Not Healthy | Healthy | Healthy |

Table 3 shows Design the rules of oxygen saturation health condition using fuzzy logic. The rules are:

[R1] = IF Age = Teenager and Oxygen Saturation = Serious then Stats = Not Healthy
[R2] = IF Age = Teenager and Oxygen Saturation = Moderate then = Not Healthy
[R3] = IF Age = Teenager and Oxygen Saturation = Mild then = Unwell
[R4] = IF Age = Teenager and Oxygen Saturation = Normal then = Not Healthy
[R5] = IF Age = Adult and Oxygen Saturation = Serious then Stats = Not Healthy
[R6] = IF Age = Adult and Oxygen Saturation = Moderate then Stats = Not Healthy
[R7] = IF Age = Adult and Oxygen Saturation = Mild then Stats = Unwell
[R8] = IF Age = Adult and Oxygen Saturation = Normal then Stats = Not Healthy
[R9] = IF Age = Old and Oxygen Saturation = Serious then Stats = Not Healthy
[R10] = IF Age = Old and Oxygen Saturation = Moderate then Stats = Not Healthy
[R12] = IF Age = Old and Oxygen Saturation = Mild then Stats = Unwell
[R13] = IF Age = Old and Oxygen Saturation = Normal then Stats = Not Healthy

Table 4. Rules for body temperature health condition.

| Body Temperature | Age      |
|------------------|----------|
|                  | Teenager | Adult  | Old    |
| Cold             | Unwell   | Unwell | Unwell |
| Normal Hot       | Healthy  | Healthy | Healthy |
|                  | Not healthy | Not healthy | Not healthy |

Table 4 shows Design the rules of body temperature health condition using fuzzy logic. The rules are:
[R1] = IF Age = Teenager and Body Temperature = Cold then Stats = Unwell
[R2] = IF Age = Teenager and Body Temperature = Normal then Stats = Healthy
[R3] = IF Age = Teenager and Body Temperature = Hot then Stats = Not healthy
[R4] = IF Age = Adult and Body Temperature = Cold then Stats = Unwell
[R5] = IF Age = Adult and Body Temperature = Normal then Stats = Healthy
[R6] = IF Age = Adult and Body Temperature = Hot then Stats = Not healthy
[R7] = IF Age = Old and Body Temperature = Cold then Stats = Unwell
[R8] = IF Age = Old and Body Temperature = Normal then Stats = Healthy
[R9] = IF Age = Old and Body Temperature = Hot then Stats = Not healthy.

3.3. Defuzzification

The fuzzy quantity change process that is presented in the form of a fuzzy set with membership function to regain its strict form (crispy) [2]. Figure 6 shows the design of output defuzzification to health condition using by Centroid Method.

![Defuzzification of health condition](image)

This membership has three value not healthy (<20), unwell (30-50) and healthy (≥60). Defuzzification of health condition has the following characteristics:

\[
\text{Not Healthy} = \begin{cases} 
1, & x \leq 20 \\
(30-x)/(30-20), & 20 < x < 30 \\
0, & x \geq 30 
\end{cases} 
\]  \quad (15)

\[
\text{Unwell} = \begin{cases} 
1, & 30 \leq x \leq 50 \\
(x-20)/(30-20), & 20 < x < 30 \\
(60-x)/(60-50), & 60 > x > 50 \\
0, & 20 \geq x \text{ or } x \geq 60 
\end{cases} 
\]  \quad (16)

\[
\text{Healthy} = \begin{cases} 
1, & x \geq 60 \\
(x-50)/(60-50), & 50 > x > 60 \\
0, & 50 \geq x 
\end{cases} 
\]  \quad (17)

3.4. Example

The age of user is 26\textsuperscript{th} y.o and his body temperature is 35.7 \textdegree C

3.4.1. Fuzzification.

\[
\mu_{\text{Teenager}} = (30-26)/(30-25) = 0.8 
\]  \quad (18)
\[ \mu_{\text{Adult}} = \frac{(26-25)}{(30-25)} = 0.2 \]  
\[ \mu_{\text{Cold}} = \frac{(36-35.7)}{(36-34)} = 0.15 \]  
\[ \mu_{\text{Normal}} = \frac{(35.7-34)}{(36-34)} = 0.85 \]

3.4.2. **Inference.**

In this section, to determine the value of the membership function used operation AND (Minimum).

If age is teenager (0.8) AND Body Temperature is cold (0.15) THEN output Unwell (0.15).

If age is teenager (0.8) AND Body Temperature is normal (0.85) THEN output Healthy (0.8).

If age is adult (0.2) AND Body Temperature is cold (0.15) THEN output Unwell (0.15).

If age is adult (0.2) AND Body Temperature is normal (0.85) THEN output Healthy (0.2).

Operation OR (Maximum).

Unwell (0.15) OR Unwell (0.15) THEN Unwell (0.15).

Healthy (0.8) OR Healthy (0.2) Then Healthy (0.8)

3.4.3. **Defuzzification.**

\[ \text{Output} = \frac{(0.5 \times 25) + (0.15 \times 200) + (0.5 \times 55) + (0.8 \times 720)}{1 + 0.75 + 7.2} = 72.17877 \]  
Value of defuzzification is 72.17877 and in this case his health status is Healthy.

3.4.4. **Application interface**

Application is created to display the value of pulse rate, oxygen saturation and body temperature. This application can notify the user's health condition based on data received and processed by fuzzy logic and then the results can be seen directly by the user.

3.4.5. **Biodata interface.**

Figure 7 below get displays the biodata interface. In order to monitor the health condition, users first entering a combination of name, age, and profession. The data entered will be used fuzzy logic in the application. The age user will be used in fuzzy calculations.
3.4.6. Measuring Menu. After the user successfully entering the biodata, the user can monitor his health condition. Figure 8 measuring menu interface. This menu serves as a menu to get data from devices via Bluetooth sent to the application used. In display of application can be seen data from the results of the measurement of conditions pulse rate, oxygen saturation and body temperature which will determine the health status of the user.

3.4.7. Result Menu. After the user get data from devices, fuzzy logic will process the data that has been received, then conclude the results of health conditions. The result of health condition can be seen data in display application. This tab serves to display health conditions based on data obtained using fuzzy logic shown in figure 9.
4. Experiment Result

After design of system is complete, a testing stage is needed to measure the feasibility and functional level of the application. This stage includes test scenarios and test results. The scenario used to test this system using compare the calculation between application and real.

In this design for fuzzy logic is for health monitoring. Application will be tested inference rules, there are rules inference which is the key of this system to run well. This application is expected to function properly.

| Testing | Pulse Rate | Application | Real |
|---------|------------|-------------|------|
| 1.      | 85         | Healthy     | Healthy |
| 2.      | 84         | Healthy     | Healthy |
| 3.      | 84         | Healthy     | Healthy |
| 4.      | 74         | Healthy     | Healthy |
| 5.      | 90         | Healthy     | Healthy |
| 6.      | 80         | Healthy     | Healthy |
| 7.      | 89         | Healthy     | Healthy |
| .       | .          | .           | .     |
| .       | .          | .           | .     |
| 64.     | 54         | Not Healthy | Not Healthy |

In table 5, the result of testing health condition by 32 users, each of whom tested twice as much. It can be seen that the conditions obtained are in accordance with the rules that are determined using fuzzy logic and compared with the health conditions, the percentage of accuracy is obtained pulse rate \((51/64)*100\% = 79.688\%\).

| Testing | Pulse Rate | Application | Real |
|---------|------------|-------------|------|
| 1.      | 94         | Unwell      | Healthy |
| 2.      | 95         | Healthy     | Healthy |
| 3.      | 94         | Unwell      | Healthy |
| 4.      | 95         | Healthy     | Healthy |
| 5.      | 97         | Healthy     | Healthy |
| 6.      | 96         | Healthy     | Healthy |
| 7.      | 95         | Healthy     | Healthy |
| .       | .          | .           | .     |
| .       | .          | .           | .     |
| 64.     | 96         | Healthy     | Healthy |

In table 6, the result of testing health condition by 32 users, each of whom tested twice as much. It can be seen that the conditions obtained are in accordance with the rules that are determined using fuzzy logic and compared with the actual conditions, the percentage of accuracy is obtained oxygen saturation \((46/64)*100\% = 71.875\%\).
Table 7. Experiment result for body temperature.

| Testing | Pulse Rate | Application | Real |
|---------|------------|-------------|------|
| 1.      | 34.7       | Healthy     | Healthy |
| 2.      | 34.7       | Healthy     | Healthy |
| 3.      | 34.7       | Healthy     | Healthy |
| 4.      | 35.2       | Healthy     | Healthy |
| 5.      | 32.2       | Unwell      | Healthy |
| 6.      | 33.2       | Unwell      | Healthy |
| 7.      | 34.2       | Unwell      | Unwell |
| ...     | ...        | ...         | ...   |
| 64.     | 36.4       | Healthy     | Healthy |

In the table 7, the result of testing health condition by 32 users, each of whom tested twice as much. It can be seen that the conditions obtained are in accordance with the rules that are determined using fuzzy logic and compared with the actual conditions, the percentage of accuracy is obtained body temperature (32/64)*100% = 50%.

5. Conclusion
In this paper, the result of experiments, it can be concluded that the application can run well as desired and, the fuzzy logic works well to conclude health condition, this application using fuzzy logic with successful accuracy are pulse rate (79.688%), oxygen saturation (71.875%), and body temperature (50%).

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