Wireless health monitoring with fuzzy decision tree for the community patients of chronic hypertension

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Abstract. Health is an important factor needed by humans. There are many facilities for indicators of human health learning, including through the internet. Health monitoring that can be seen anywhere, in this case, a clinic or hospital with internet technology is one way to monitor the patient's condition and is presented in the form of real-time data. One device that can be online is digital tensimeter, especially for patients in the hypertension community. Health indicator data such as systole, diastole, and heart rate values, are obtained easily so that they can be used to analyze the patient's condition. The method as used is to use the hardware device ESP 8266 from an offline tensimeter device so that the data on the real condition of the patient can be read anywhere. In addition, this device saves the number of computer network nodes to connect to the internet. After the data is read, the data is processed using Fuzzy decision tree to analyze which patients need immediate care. The result is that from 150 measured data, the value of decision tree accuracy with Fuzzy process is obtained at 95%.

1. Introduction
Blood pressure is an important indicator in human life. High blood pressure is second-ranked as 10 causes of death in Indonesia. Hypertension can cause heart attacks through hardening and thickening of arterial walls or atherosclerosis, strokes because there are blockages or ruptured blood vessels, aneurysms that are blood vessels weakened and protruding like balloons, kidney problems because the kidney blood vessels narrow and weaken, the eyes begin blurred vision until blindness, metabolic syndrome or metabolic abnormalities of the body and difficulty remembering or focusing while speaking [1, 2]. Clinical staff and nurses will always test the patient's condition through a tensimeter device to determine the patient's health both at the beginning of the meeting and in the recovery process. Certain diseases are characterized by an increase or decrease in the value of systole and diastole [2][3]. Normal blood pressure is taken using two sizes and is usually measured as the value of systole and diastole for example 120/80 mmHg. The upper number (120) shows the upper arterial blood pressure due to the heartbeat and is called systolic pressure. While the lower blood pressure number (80) shows blood pressure when the heart rests between pumping processes and is called diastolic pressure[4, 5].

However, the research conducted by (Gijon-Conde, 2015) conducted outpatient blood pressure monitoring (ABPM) in hypertensive control patients of 720 patients suffering from hypertension (the average age of patients was 72.3 ± 6.3 years; 51.3%, men), 64.4% had conventional blood pressure ≥ 140/90 mm Hg, and from this 39, 9% of patients were not treated, 49.5% of patients were treated, and 10.6% of patients changed to patients who were resistant to treatment [6, 7].
Whereas research (Crittenden et al, 2017) shows that health coaching is a promising approach to the management of hypertension (HTN), indicated by a reduction in systolic and diastolic blood pressure. The obstacles faced during the research process indicate that patient participation in managing hypertension depends on the tools needed, the level of education, and a holistic approach. A holistic approach is a concept that looks at all potential factors that can have an effect on a patient's health during a health check. From these two studies, the importance of monitoring the value of systole and diastole in community patients with hypertension [8, 9].

The brief structure of this paper as follows: Firstly, Introduction section consists of background prospective hypertension, wireless monitoring research, purpose and contribution of the research as well as the structure of this paper. Secondly, literature reviews capture ESP 8266 and fuzzy decision tree. Thirdly, material and methods section covers research methods, hardware infrastructure, and tree structure. Fourthly, result and discussion section explain system implementation, the advantage of using ESP8266, and fuzzy decision tree. Fifthly, Conclusion section captures the results of hypertensive classification of community patients based on the values and patient's condition using Fuzzy Decision Tree and further research.

2. Literature Review

In this literature review, we discuss the symptoms of hypertension, esp8266 wireless module, internet of thing, Graph Structure and Fuzzy decision tree.

2.1. Symptoms of hypertension

People with hypertension usually do not show any characteristics or only experience mild symptoms. However, in general, the symptoms of hypertension are a severe headache, dizziness, blurred vision, nausea, ringing in the ears, confusion, irregular heartbeat, fatigue, chest pain, difficulty breathing, blood in the urine, a tickling sensation in the chest, neck, or ears. Most cases of high blood pressure in adolescents are classified as primary hypertension. Like adults, the cause of primary hypertension is not fully understood. Some teenagers seem to inherit the tendency to get high blood pressure from their parents, while others fall victim to bad lifestyles, which results in obesity and body shape that is not ideal, which the term is referred to by doctors as "decreased cardiovascular fitness". In some cases, hypertension in adolescents is based on certain medical conditions that have already been suffered, such as heart and kidney disease. But in general, several factors that can increase a person's risk of developing hypertension are Fatigue, Diabetes, Gout, Obesity, high cholesterol, kidney disease, alcoholism, women who take birth control pills and people who basically have high blood pressure [10, 11].

High blood pressure or hypertension is a permanent condition where continuous high blood pressure or more than 140/90 mmHg. Hypertension cannot feel. Many people don't even realize they have high blood pressure. Hypertension can occur without any physical symptoms that follow. This disease secretly damages blood vessels and causes serious health threats. Because hypertension is not a stand-alone disease, but a syndrome or collection of symptoms of disease in the body. Hypertension can also be caused by other diseases, such as heart disease or kidney disease. If patients who have high blood pressure caused by other diseases, hypertension can be cured by treating the previous underlying disease and the disease is indeed possible to be cured [12, 13].

However, most cases of high blood pressure (around 85% to 90%) in the world are classified as primary hypertension. In most cases, the condition of primary hypertension suffered by most people is influenced by heredity (genetic) or unhealthy lifestyle/environment. For some cases, the cause of primary hypertension cannot be determined. This type of hypertension cannot be cured, it can only be controlled with high blood pressure drugs. Thus, if blood pressure drops, it does not mean complete recovery from hypertension. The potential risk of disease complications caused by hypertension if the symptoms are not managed and blood pressure rises again [14, 15].
2.2. **ESP 8266 wireless module**

ESP8266 is a WiFi module that is already SoC (System on Chip), so we can do programming directly to ESP8266 without the need for additional microcontrollers. Another plus, ESP8266 can run the role of ad-hoc access points and clients at once. In general, ESP8266 can be programmed by via AT command via UART serial communication, and programming to a microcontroller on ESP8266 using Arduino IDE with Core already installed ESP8266. Another advantage of ESP8266 is having a deep sleep mode so that the use of power will be relatively much more efficient than the WiFi module. An important note that must be underlined is, ESP8266 operates at a voltage of 3.3V\[16, 17]\.

2.3. **Internet of thing**

Casagras (An Institution of Coordinators and action support for activities and standardization related to the use of global RFID) defines IoT as a global network infrastructure, which connects physical objects and virtual objects in this case the internet through the process of exploitation by data retrieval and communication capabilities between computers. Infrastructure is the relationship between existing networks and the internet together with network development. This will offer object identification, sensor use, and capability of connection capacity as the basis for independent stand-alone service development and applications that work together. This can be characterized by autonomous high-level data retrieval, transfer of events or events, network connectivity, and interoperability between devices used\[18, 19]\.

2.4. **Graph for Structure Tree**

A graph is a collection of points (vertices) in a two-dimensional plane connected by a series of lines. Graphs can be used to represent discrete objects and relationships between objects. The visual representation of a graph is to declare an object as a point, circle, or point (Vertex), while the relationship between objects on an object is expressed as a line (Edge) [20]. In graph theory, Network-flow is a directed graph where each side has a capacity or value and each side has a flow. The value of the flow at the edge cannot exceed the edge capacity [21, 22].

![Graph for Structure Tree](image)

Figure 1. Decision Tree Construction.

The linkages between attributes in each class are shown in Figure 1. Network Flow of each attribute has a weight connected through the edge. Furthermore, after determining attribute relations can be used to compile the tree[23].
Table 1. Relations between attributes at the initial stage

| Graph | a->a | a->b | a->c | a->d | b->a | b->b | b->c | b->d | c->b | c->c | d->a | d->b | d->c |
|-------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 1 (Class A) | 1    | 1    | 0    | 1    | 0    | 0    | 0    | 0    | 1    | 0    | 0    | 0    | 1    |
| 2 (Class B) | 1    | 1    | 1    | 0    | 0    | 0    | 0    | 0    | 1    | 1    | 1    | 0    |      |
| 3 (Class A) | 1    | 0    | 0    | 1    | 1    | 1    | 0    | 0    | 0    | 0    | 1    | 0    |      |
| 4 (Class C) | 0    | 1    | 0    | 0    | 1    | 1    | 0    | 1    | 0    | 0    | 0    | 0    |      |

2.5. Fuzzy Decision Tree
The concept of Decision Tree is to convert data into a tree of decisions and rules. The Decision Tree method is used to estimate the discrete value of the target function. Decision trees are a set of IF, THEN, and ELSE rules, where each path in a tree is associated with a rule, where the premise consists of a set of nodes that will be encountered during the data insertion process. The conclusion of the rules themselves consists of classes connected with leaves from each path. In the decision tree, each leaf node is labeled a different class. Furthermore, the benefits of fuzzy set theory in decision trees are simplifying nodes and increasing the ability of decision trees when using quantitative attributes[24, 25].

3. Methodology

![Figure 2. Research methodology](image_url)

The methodology in this research is the patient's offline tensimeter data sent wirelessly to the server. This research is a follow-up study wherein the previous research a system was made to be able to send tensimeter data to a server using the ESP8266 device which can save the number of nodes used by ZigBee, namely 9 nodes to 5 nodes to connect to the internet because ZigBee requires a transmit-receive module.

As seen in infrastructure, Figure 2, if in the previous research the user connected through an access point or room wifi, in this research there were additions, namely modules that could be used outside the room connection such as users in parks or locations where there was no wifi signal. Users can connect and send data using a mobile device. So the device can be used outdoors such as open space. By utilizing the Public IP feature on the Indi home telecom service, the server IP is used as the
destination address on the telecom service IP forwarding facility, so that the public IP can recognize
the local server for further translation to receive data. Hardware configuration as shown in Figure 3.
The graph matrix of network topology can be arranged into an adjacency table as shown in Table 2.

![Network Topology Wireless Health Monitoring](image)

**Figure 3.** Network Topology Wireless Health Monitoring

| Class | Connection | a->b | c->d | f->g | b->e | d->e | g->h | h->i | i->j | j->e | e->k | k->n | k->m | k->l |
|-------|------------|------|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Room 01 | 1 1 0 1 0 0 0 0 0 0 0 0 0 0 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Room 02 | 0 0 0 0 1 1 0 0 0 0 1 1 1 1 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Outside | 0 0 1 0 0 0 1 1 1 1 1 1 1 1 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Next, a table of relationships between nodes can be arranged as shown in Table 3.

| node | a | b | c | d | e | f | g | h | i | j | k | l | m | n |
|------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a    | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| b    | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| c    | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| d    | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| e    | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| f    | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| g    | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| h    | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| i    | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| j    | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| k    | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| l    | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| m    | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| n    | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |

Both tables are used to analyze network conditions using machine learning. Where table 1 is used
to get the desired class through the training and testing process while table 2 is used to determine the
adjacency of the proximity matrix between nodes in the network topology.

The implementation of the system to get results is after getting blood pressure data through the
patient's tensile device sent by ESP8266 from each device, the data is received on the server device
using a socket server. The tensimeter device that has been installed ESP8266 is shown in figure 4 and 5.
ESP8266 and Access Point sets as Client Server

data tensimeter send to the internet (ISP)

IP Public telkom (dynamic) sets as forwarding IP

Data receives as server listener

Data process with Fuzzy decision tree

Figure 4. ESP8266 inside tensimeter

Figure 5. Connection to Access point and free DNS

4. Research and Discussion

In this study, the first advantage is to use ESP8266 wireless besides functioning as a microcontroller, this device has a mini form so that it is easy to pin on hardware. In addition, for outside connections WIFI area using Port forwarding is very helpful for capturing data from an offline device to the server. DNS is used to facilitate the naming of data IP Address in the cloud so that it does not need a public IP that is dynamic. Data sent by ESP8266 via ISP to web dynamic DNS is sent and received by the server socket listener. In addition to the value of systole, diastole, and heart, parameters of the patient's physical condition were also used.

This is needed as a material consideration for building trees. Hence, there are 4 main attributes in the database with the expected output class results are Fuzzy Sets with each class membership namely Very urgent, Urgent, Medium, Low and Very Low. J.48 Decision Tree can be formed as follows:

J48 pruned tree

Diastole <= 89
  |  Sistole <= 119
  |  |  Diastole <= 69: Very_Low (33.0)
  |  |  Diastole > 69
  |  |  |  Diastole <= 78: Low (14.0)
  |  |  |  Diastole > 78: Very_Low (3.0)
  |  |  Sistole > 119: Medium (50.0)
  |  Diastole > 89
  |  |  Fisik <= 47
  |  |  |  Sistole <= 159: urgent (5.0)
  |  |  |  Sistole > 159: very_urgent (14.0)
  |  |  Fisik > 47: urgent (31.0)

Number of Leaves : 7
Size of the tree : 13

The results by using fuzzy decision tree J.48 and Random Forest, from 150 data records obtained a result of a virtual machine the classification process 150 data is correct (96.6667%), the Virtual Machine mentions the Classification process, there are 5 incorrect (3.333%). The Kappa statistic
states 0.9556, the absolute error average is 0.0837, the error of the average square is 0.1487, the absolute error is 27.6192%, the error of the relative square root is 38.224%. The total amount of data used is 150, so the accuracy value in compiling trees uses decision tree J.48 with this Fuzzy algorithm is 95% as shown in Table 4 below.

### Table 4. Fuzzy Decision Tree Accuracy Measurement J.48 and random forest

| Class       | TP Rate | FP Rate | Precision | Recall | F-Measure | ROC Area |
|-------------|---------|---------|-----------|--------|-----------|----------|
| very_urgent | 0.6451  | 0.0070  | 0.6451    | 0.6451 | 0.6681    | 0.6903   |
| urgent      | 0.6750  | 0.0090  | 0.6750    | 0.6750 | 0.6750    | 0.6903   |
| Medium      | 1.0000  | 0.0007  | 0.0681    | 1.0000 | 0.0688    | 1.0000   |
| Low         | 0.6451  | -       | 1.0000    | 0.6451 | 0.6688    | 0.6924   |
| Very_Low    | 1.0000  | -       | 1.0000    | 1.0000 | 1.0000    | 1.0000   |

5. Conclusion
The results of this study are the implementation of the internet on offline tensimeter devices using ESP8266 successfully performed. The number of nodes needed is shorter than using a ZigBee device to connect to the internet. Classification of hypertension of community patients based on systole-diastole value, heart rate and patient condition using Fuzzy Decision Tree J.48 with 95% accurate results.

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References
[1] Aslanger E, M Sezer and S Umman, High blood pressure: An obscuring misnomer? Anatolian journal of cardiology 16 9 pp 713-719.
[2] Fukuta H and W C Little, Heart failure clinics, The cardiac cycle and the physiologic basis of left ventricular contraction, ejection, relaxation, and filling 4 1 pp 1-11.
[3] Franklin S S and N D Wong 2013 Global Heart, Hypertension and Cardiovascular Disease: Contributions of the Framingham Heart Study 8 1 pp 49-57.
[4] Ogedegbe G and T Pickering, Cardiology clinics, Principles and techniques of blood pressure measurement 28 4 pp 571-586.
[5] McEvoy J W, Y Chen, A Rawlings, R C Hoogeveen, C M Ballantyne, R S Blumenthal, J Coresh and E Selvin 2016 Journal of the American College of Cardiology, Diastolic Blood Pressure, Subclinical Myocardial Damage, and Cardiac Events: Implications for Blood Pressure Control 68 16 pp 1713-1722.
[6] Gijón-Conde T, A Graciani, E.López-Garcia, P Guallar-Castillón, F Rodríguez-Artalejo and J R Banegas 2015 Journal of the American Medical Directors Association, Impact of Ambulatory Blood Pressure Monitoring on Control of Untreated, Untreated, and Resistant Hypertension in Older People in Spain 16 8 pp 668-673.
[7] Turchin A, S I Goldberg, M Shubina, J S Einbinder and P R Conlin, Hypertension 1979 Encounter frequency and blood pressure in hypertensive patients with diabetes mellitus 56 1 pp 68-74.
[8] Crittenden D, S Seibenhenner and B Hamilton 2017 The Journal for Nurse Practitioners, Health Coaching and the Management of Hypertension 13 5 pp e237-e239.
[9] Drevenhorn E 2018 International journal of hypertension, A Proposed Middle-Range Theory of Nursing in Hypertension Care pp 2858253-2858253.
[10] Kazancioğlu R, Kidney international supplements, Risk factors for chronic kidney disease: an update 3 4 pp 368-371.
[11] Volpe M, G Gallo and G Tocci 2018 International Journal of Cardiology, Is early and fast blood pressure control important in hypertension management? 254 pp 328-332.
[12] Schultz M G and J E Sharman, Pulse (Basel, Switzerland), Exercise Hypertension 1 3-4 pp 161-176.
[13] Tracey, Kevin J 2014 Immunity, Hypertension: An Immune Disorder? 41 5 pp 673-674.
[14] Southerland J H, D G Gill, P R Gangula, L R Halpern, C Y Cardona and C P Mouton, Clinical, cosmetic and investigational dentistry, Dental management in patients with hypertension: challenges and solutions 8 pp 111-120.
[15] Bolivar J J 2013 International journal of hypertension, Essential hypertension: an approach to its etiology and neurogenic pathophysiology pp 547809-547809.
[16] Abdel-Basset M, G Manogaran and M Mohamed 2018 Future Generation Computer Systems, Internet of Things (IoT) and its impact on supply chain: A framework for building smart, secure and efficient systems.
[17] Civerchia F, S Bocchino, C Salvadori, E Rossi, L Maggiani and M Petracca 2017 Journal of Industrial Information Integration, Industrial Internet of Things monitoring solution for advanced predictive maintenance applications 7 pp 4-12.
[18] Gil D, A Ferrández, H Mora-Mora and J Peral, Sensors (Basel, Switzerland), Internet of Things: A Review of Surveys Based on Context Aware Intelligent Services 16 7 pp 1069.
[19] Mehta R, J Sahni and K Khanna 2018 Procedia Computer Science, Internet of Things: Vision, Applications and Challenges 132 pp 1263-1269.
[20] Schmidt F, P Spröte and R W Fleming 2016 Vision Research, Perception of shape and space across rigid transformations 126 pp 318-329.
[21] Schmidt M and M Skutella 2014 Discrete Applied Mathematics, Earliest arrival flows in networks with multiple sinks 164 pp 320-327.
[22] Zhang X, E Miller-Hooks and K Denny 2015 Journal of Transport Geography, Assessing the role of network topology in transportation network resilience 46 pp 35-45.
[23] Jia Y, Y Qi, H Shang, R Jiang and A Li 2018 Engineering, A Practical Approach to Constructing a Knowledge Graph for Cybersecurity 4 1 pp 53-60.
[24] Wang X, X Liu, W Pedrycz and L Zhang 2015 Pattern Recognition, Fuzzy rule based decision trees 48 1 pp 50-59.
[25] Liu X, X Feng and W Pedrycz 2013 Data & Knowledge Engineering, Extraction of fuzzy rules from fuzzy decision trees: An axiomatic fuzzy sets (AFS) approach 84 pp 1-25.