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To cite this article: A Wantoro *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **857** 012027

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Implementation of fuzzy-profile matching in determining drug suitability for hypertensive patients

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Abstract. Treatments of patients with hypertension can be done in two ways, namely modifying lifestyle and antihypertensive drugs. Generally giving hypertensive drugs depends on age, history of illness, smoking habits, obesity and on diseases such as diabetes, kidney failure, heart failure and ischemic heart disease. Inappropriate use of antihypertensive drugs often causes complaints such as fever, diarrhea, diabetes, mouth breathing, nerve disorders, radiation to the neck and head area. In providing hypertensive drugs that are appropriate to the patient's condition, doctor and medical personnels are required to have high pharmacological knowledge. Not all hospitals have pharmacology experts, therefore this study was conducted to develop a model that can be used as a drug suitability model based on the patient's condition. The method used in this study is Weight Matching Using Fuzzy Logic. Based on the results of comparisons with expert 1 and expert 2, the results of the average system testing are obtained with a value of 100% precision, recall 96.6% and accuracy 96.5%. Tests show that the application with a fuzzy logic approach can increase the efficiency of 9.5% compared to the interpolation weighting method.

Keywords: fuzzy logic, drug suitability, hypertensive patients, weight matching.

1. Introduction

Hypertension is a condition where blood pressure is >140/90 millimeters of mercury mmHG [1]. Hypertension is still the number one killer disease in Indonesia and hypertensive sufferers always experience an increase from 2013-2018 [2]. Hypertension is a very common medical condition, affecting roughly 20% of the world population [3]. Handling of patients with hypertension can be done in two ways, namely by modifying lifestyle and using antihypertensive drugs [4]. Anti-hypertensive drugs given usually are related to age, history of illness, smoking habits, obesity, and considering existing diseases such as diabetes, kidney, heart failure and ischemic heart [5].

The parameters used for the administration of hypertension drugs are age, weight, kidney health, lung health, sugar levels, blood circulation levels, heart health, depression levels, uric acid levels and the level of sexuality [5]. The use of anti-hypertensive drugs that are not appropriate can cause complaints or side effects such as fever, diarrhea, diabetes, kidney failure, stress, mouth breathing, nerve abnormalities, radiation to the neck and head area and local disorders of the salivary glands, therefore it is very important to know and know the type antihypertensive drugs [6]. Medications are



the most common cause of reduced saliva. Antihypertensive drugs include one class of drugs that can cause side effects such as xerostomia. Data shows that around 770,000 patients in the hospital suffered injuries or even died from drug side effects. The primary source of error is prescribing errors [7].

Selection of the appropriate antihypertensive drug, the right dose, is a complex problem that requires a greater understanding of pharmacological options [8]. Based on data from the National Patient Safety Map Report 12th medication errors were ranked first at 24.8% of 10 cases. The results of an expert evaluation found a relationship between the types of hypertension drugs with the patient's health condition. There are 5 (five) types of hypertension drugs that have been identified, namely Diuretics, Beta Blockers, Ace Inhibitors, Calcium Channel Blockers (CCB) and Potential Receptor Blockers (ARBs) [5]. Even though various treatments have been carried out quite well, the level of uncontrolled hypertension remains high. Most patients need more than one drug because the recommendations in treatment are heterogeneous and no one has been able to identify optimal dosing strategies or drug combinations [9].

Research shows that 34% of anti-hypertensive drugs given by medical personnel are not the right dose [10]. In the United States, medication errors are estimated to harm 1.5 million patients per year. Not all hospitals have pharmacology experts. Therefore, this study was conducted to develop a model that can be used as a match for drugs based on the patient's condition. The study [5] conducted a drug evaluation using the Profile Matching method by weighting interpolation. The results showed an accuracy of 87%. This result is not optimal because of making inaccurate curves and domains. In weight parameters (BMI) if the patient weighs 13 bmi, the result of the value is 1.33 on a scale of 5. If calculated using an ideal table, then the membership value is 0. Therefore, this study will be developed using a fuzzy logic approach to calculate weights to improve accuracy results.

The medical record data are used as input parameters of the patient's condition. Pharmacologist knowledge and drug parameters are used as input to determine the suitability of the drug using Profile Matching and Fuzzy Logic methods using curves and membership functions. The use of triangular and trapezoidal curves can provide smaller computational time [11]. The results of this study are in the form of a model of suitability of hypertension drugs with a better level of accuracy that can be used by doctors or medical personnel as a recommendation in providing medications for patients with hypertension.

2. The Proposed Method

The drug suitability model with the patient's health condition is developed by describing the proposed prototype architecture of the drug model. The prototype model consists of 2 (two) main parts, namely the development environment and consultation environment (Fig. 1).

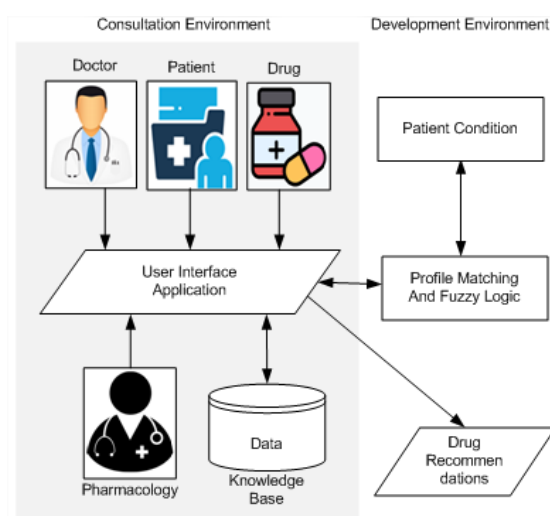


Figure 1. The suitability model of hypertension drugs is based on the patient's condition

2.1. Model Development Stages

The stages of development consist of creating knowledge base involving input data from hospitals, expert knowledge and knowledge from literature studies. The method used is Profile Matching method which is combined with fuzzy approach. Fuzzy logic is used to calculate the suitability of patients with the type of anti-hypertensive drug. The accuracy of the system is tested by experts using Confusion Matrix table to get the values of accuracy, precision and recall, as presented on Fig. 2.

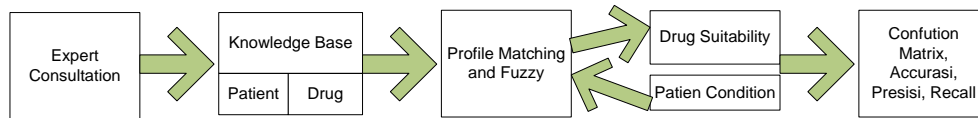


Figure 2. The stages of developing a conformity model for hypertension drugs

2.2. Knowledge Base Creation Stage

The stage of creating knowledge base is done by involving doctors/experts in the field of hypertension, considering the patient's condition data and antihypertensive drugs obtained from the patient's medical record, and the criteria used as a reference for the type of medicine that is appropriate to the patient's health condition.

2.3. Determination of Patient Parameters

The results of the consultation with the expert doctor indicated that there were 10 (ten) parameters that determined the administration of antihypertensive drugs in hypertensive patients. These criteria are age, weight, kidney health level, lung health level, sugar level, blood circulation level, heart health level, depression level, uric acid level and level of sexuality (table 1).

Table 1. Parameters of the patient condition that influence Hypertension drug administration[5]

K1	K2	K3	K4	K5	K6	K7	K8	K9	K10
Age	Weight	health kidney level	Health lung level	Grade sugar level	Circulation level blood	Heart health level	Level depression	Uric acid levels (K9)	Sexuality level
year	BMI	mg/dl	ppm	mg/dl	liter	pulse/mi nute	Hamilton	mg/dl	ordinal

2.4. Suitabilty of Condition of Patients with Types of Hypertension Medication

To find out the suitability of the patient's condition with the type of Hypertension drug, it is necessary to have ideal data from 10 parameters with the suitability of certain types of hypertensive drugs, as well as other types of drugs such as those in show in table 2.

Table 2. Value of ideal criteria with types of antihypertensive drugs [5]

Type of drug	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10
Diuretic	≤ 65	18,5-24,9	0,6-1,2	< 4	60-139	> 6	> 100	≥ 35	2-7,5	Up Normal
Beta B	≤ 65	18,5-24,9	> 1,2	< 4	60-139	> 6	60-100	≤ 35	> 7,5	Normal
ACE-I	> 65	≥ 25	> 1,2	≥ 4	≥ 140	> 6	> 100	> 35	> 7,5	Normal
CCB	≤ 65	≥ 25	> 1,2	≥ 4	≥ 200	5 – 6	> 100	≥ 35	> 7,5	Up Normal
ARB	≤ 65	≥ 25	0,6-1,2	≥ 4	≥ 200	> 6	> 100	≥ 35	> 7,5	Up Normal

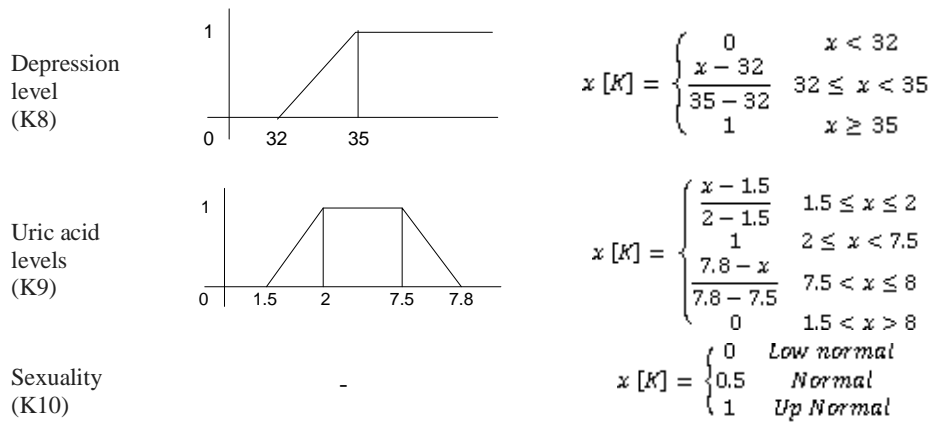
Furthermore, this table is used as an ideal value to determine the weight value of each parameter that has matches the condition of the patient with the type of hypertension drug using Matching and Fuzzy logic methods.

2.5. Making Ideal Membership Curves and Functions of Drug Types

Forming curves based on patient parameters for each type of drug is carried out based on the ideal profile value of each parameter that has been verified by a specialist. Giving amounts formulated using fuzzy logic, as presented on table 3.

Table 3. Curves and membership functions are ideal for types of Diuretic drugs

Parameter	Curve	Membership Function
Age (K1)		$x [K] = \begin{cases} 1 & x \leq 65 \\ \frac{65-x}{65-60} & 65 < x \leq 67 \\ 0 & x > 67 \end{cases}$
Weight (K2)		$x [K] = \begin{cases} \frac{x-16}{18.5-16} & 16 \leq x \leq 18.5 \\ 1 & 18.5 \leq x \leq 24.9 \\ \frac{25-x}{25.9-24.9} & 24.9 < x \leq 25.9 \\ 0 & 16 < x > 25.9 \end{cases}$
Health Kidney level (K3)		$x [K] = \begin{cases} \frac{x-0.45}{0.6-0.45} & 0.45 \leq x \leq 0.6 \\ 1 & 0.6 \leq x \leq 1.2 \\ \frac{1.4-x}{1.4-1.2} & 1.2 < x \leq 1.35 \\ 0 & 0.45 < x > 1.35 \end{cases}$
Health lung level (K4)		$x [K] = \begin{cases} 1 & x \leq 4 \\ \frac{5-x}{5-4} & 4 \leq x \leq 5 \\ 0 & x > 5 \end{cases}$
Level of sugar (K5)		$x [K] = \begin{cases} \frac{x-55}{60-55} & 55 \leq x \leq 60 \\ 1 & 60 \leq x < 139 \\ \frac{143-x}{143-139} & 139 < x \leq 143 \\ 0 & 55 < x > 143 \end{cases}$
Circulation blood level (K6)		$x [K] = \begin{cases} 0 & x < 5 \\ \frac{6-x}{6-5} & 5 \leq x \leq 6 \\ 1 & x > 6 \end{cases}$
Health heart level (K7)		$x [K] = \begin{cases} 0 & x < 90 \\ \frac{x-90}{100-90} & 90 \leq x \leq 100 \\ 1 & x > 100 \end{cases}$



Also, the ideal curves for Beta Blocker type drugs, Ace Inhibitors, CCB and ARB is performed as on table 4 and 5, where the calculation of membership weights for Patient "P-001" on the suitability of the Diuretic drug.

Table 4. Calculation of the value of W (x) of the patient "P-001" with the Type of Diuretic Drug

P-001	Data	Membership Function
Age	76	$W(x) = (>67) = 0$
Weight	17	$W(x) = (17-16)/(18.5-16) = 0.4$
Health kidney level	1.5	$W(x) = (>1.35) = 0$
Health Lung level	7.3	$W(x) = (>5) = 0$
Sugar level	95	$W(x) = (60 \leq x \leq 139) = 1$
Circulation blood level	11	$W(x) = (x > 6) = 1$
Health heart level	114	$W(x) = (x > 100) = 1$
Depression level	19	$W(x) = (x < 32) = 0$
Uric acid levels	6	$W(x) = (2 \leq x \leq 7.5) = 1$
Sexuality	Low normal	$W(x) = 0$

Table 5. Calculation of weights for types of Diuretic drugs

Patient	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10
P-001	76	17	1,5	7,3	95	11	114	19	6	Up normal
Value	0	0.4	0	0	1	1	1	0	1	0

2.6. Determination of Core Factor (NCF) and Secondary Factor (NSF) Value

The next stage is grouping patient parameters into core factors and secondary factors. Core factors are the leading parameter group where the determination of the type of drug given is very dependent on the parameters in this group while the secondary factor is a parameter group that does not have a strong influence on the determination of the type of drug given to hypertensive patients (table 6).

Table 6. Parameters of core factors and secondary factors

Core Factor (CF)	Secondary Factor (SF)
1. Kidney health level (K3)	1. Age (K1)
2. Level of sugar (K5)	2. Weight (K2)
3. Blood circulation level (K6)	3. Lung health level (K4)
4. Heart health level (K7)	4. Depression level (K8)
5. Uric acid level (K9)	5. Sexuality (K10)

The calculation of the weight value is regarded as the average weight value of the core factor parameters (level of kidney health, sugar level, arterial blood circulation level, heart health level, level of uric acid level) and secondary core factors (age, weight, level of lung health, Level of depression, sexuality) as below:

Average weight of core factor parameters (NCF)

$$\text{NCF} = \frac{(0+1+1+1+1)}{5} = 0.8$$

Average weight of secondary factor parameters (NSF)

$$\text{NSF} = \frac{(0+0.4+0+0+0)}{5} = 0.08$$

The value of suitability evaluation of patients with diuretic drugs was calculated by taking into account the influence of core factors and secondary factors as follows:

$$\begin{aligned} \text{Match value} &= (0.60 * \text{NCF}) + (0.4 * \text{NSF}) \\ &= (0.60 * 0.8) + (0.4 * 0.08) \\ &= 0.48 + 0.032 \\ &= 0.512 \end{aligned}$$

The result value of 0.512 indicates that patient "P-001" with the conditions shown in the patient data table, if given a type of Diuretic anti-hypertension drug, shows a match $(0.512 / 1) \times 100\% = 51.2\%$. By using the same method the match value of patient "P-001" with other types of drugs can be obtained (table 7).

Table 7. Results of patient match rates for each type of antihypertensive drug

Patient	Diuretic	Beta B	ACE-i	CCB	ARB
P-001	51.2%	47.2%	52%	32%	32%

Thus, the model can calculate the suitability of the patient's condition with the type of antihypertensive drug with different drug matches.

2.7. Determination of recommendations for drug administration

The total value of the calculation of the suitability of the type of drug and the patient's health parameters are then sorted from the largest to the smallest. The type of drug with the first order of suitability or the largest total value is recommended to be given to the patient because the drug is best suited to the patient's health condition. However, all calculation results are displayed so that doctors and medical personnel can determine based on their level of expertise and experience.

3. Testing and Results

The test conducted includes calculating the value of accuracy, precision and recall to show the value of accuracy. Tests were carried out in 2 (two) stages involving different experts. Each experiment used the same 100 patient data in previous studies. The test results produced an average value of 100% precision, 94.7% recall and 95% accuracy (table 8).

Table 8. Confusion matrix with the first expert

Actual Table	Type of Drug	ARB	ACE	Beta	CCB	Diuretic
	ARB	6	0	0	0	0
	ACE	0	28	0	0	1
	Beta	0	0	29	0	1
	CCB	0	0	0	6	1
	Diuretic	0	1	0	1	31

The second test conducted by different experts showed better accuracy with 100% precision, 98.5 recall and 98% accuracy. This means that the proposed model can provide good drug recommendations (table 9).

Table 9. Confusion matrix with the second expert

Actual Table	Type of Drug	ARB	ACE	Beta	CCB	Diuretic
	ARB	6	0	0	0	0
	ACE	0	28	0	0	0
	Beta	0	0	28	0	1
	CCB	0	0	0	5	0
	Diuretic	0	0	1	0	31

Based on the values of accuracy, precision and recall in table 8 and table 9, the average value is calculated with a value of 100% precision, 96.6% recall and 96.5% accuracy. This value indicates that fuzzy logic approach can increase the value of accuracy by 9.5% when compared to interpolation approach. The system can provide recommendations for drug administration correctly.

3.1. Comparison of Fuzzy Weighting, Interpolation and Ordinal

In the previous studies, an ordinal weighting and interpolation method were proposed, so to see the accuracy with fuzzy approach a comparison with ordinal methods and interpolation was needed. Figure 3 presents the results of a comparison of the values of accuracy, precision and recall of the three (3) methods (Fig. 3).

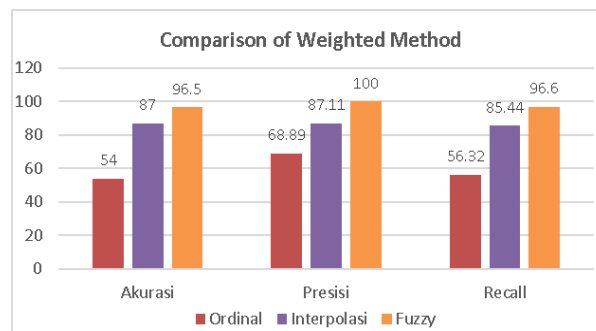


Figure 3. Comparison of weighted *Ordinal, Interpolation* and *Fuzzy*

4. Conclusion

Based on the description, explanation and testing that have been carried out, some conclusions have been drawn that this study produced a model of suitability of drug administration based on the patient's health conditions using Profile Matching and fuzzy logic approach. Based on the results of comparisons with expert 1 and expert 2, the results of the average system testing are obtained with a

value of 100% precision, recall 96.6% and accuracy 95%. Tests show that the application with fuzzy logic approach can increase the accuracy of 9% compared to the interpolation weighting method. However, this research still needs to be continued, considering that it still has several weaknesses and disadvantages. Creating knowledge base to be continually updated and adapted to the patient's condition for different sexes is essential.

Acknowledgments

The author would like to thank the University of Teknokrat Indonesia who has provided support, to the Promoter and Co-Promoter for his guidance and to the IC-STAR 2019 Committee thank you for giving this opportunity.

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