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Solid State Technology

(Peer-reviewed monthly online journal)

Acceptance Letter

17/October/2020

Dear Agus Wantoro, Admi Syarif, Khairun Nisa Berawi & Lukman Pura,

We are pleased to accept your manuscript entitled **"Application-Based on Fuzzy Tsukamoto And Profile Matching for Combination Drugs Recommendations in Patients Hypertension with Complications"** The paper is tentatively scheduled for publication in the **"October- November"** 2020 in regular issue.

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Sincerely

Elias K. Stefanakos

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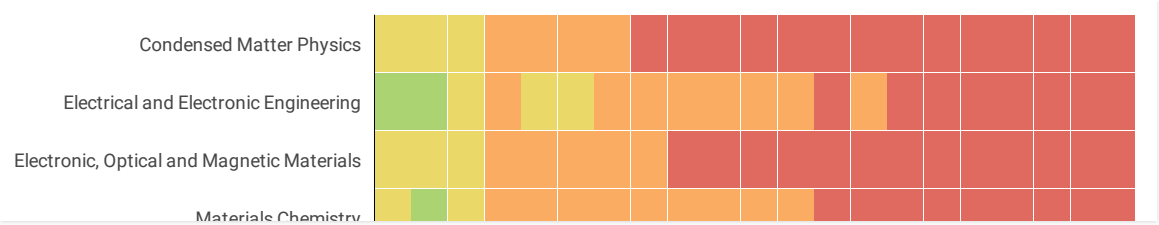

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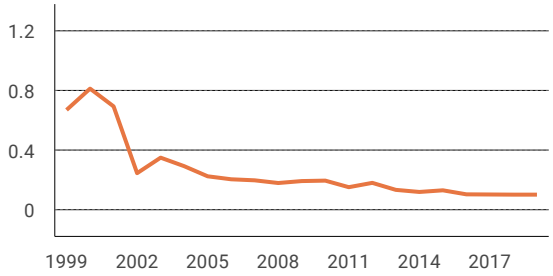

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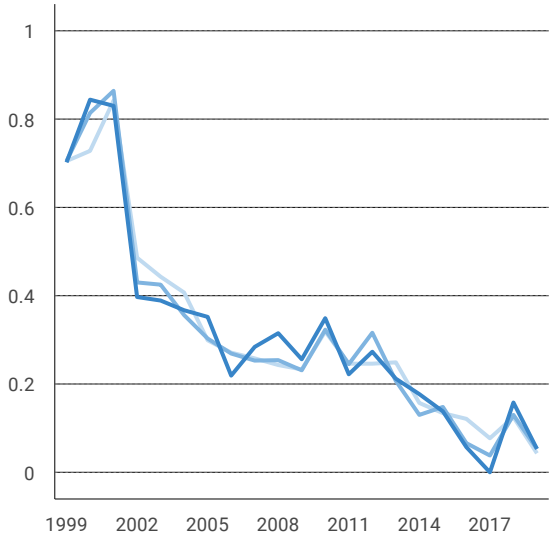

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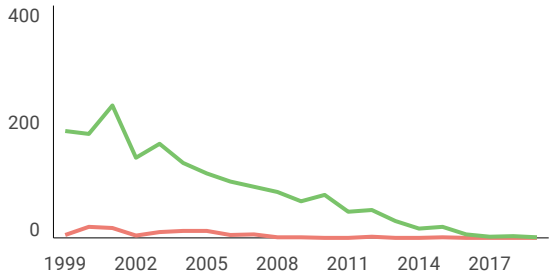

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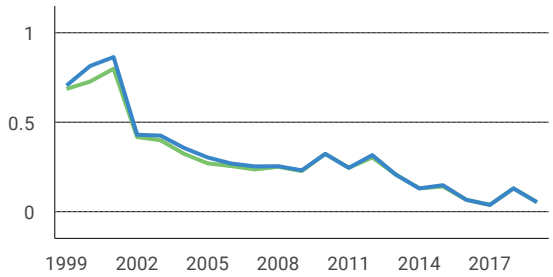

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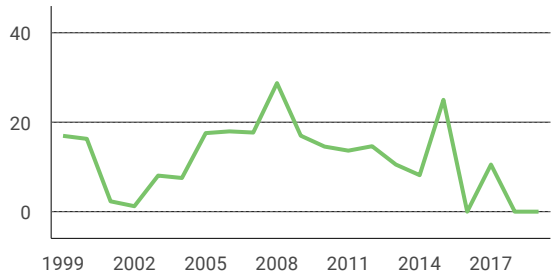

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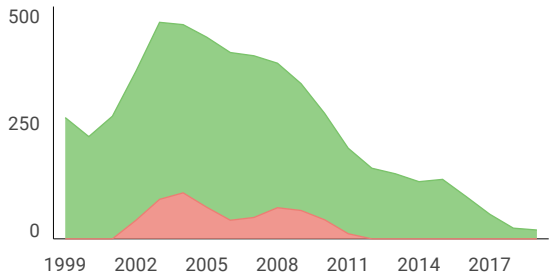

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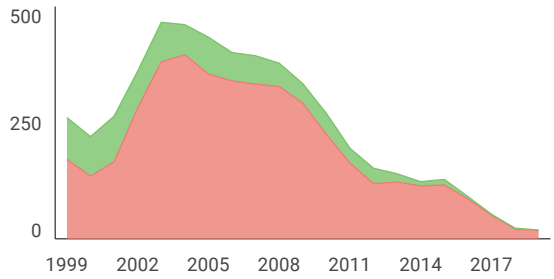

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Application-Based on Fuzzy Tsukamoto And Profile Matching for Combination Drugs Recommendations in Patients Hypertension with Complications

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Abstract- *Hypertension is still the number one killer disease in Indonesia, and hypertension sufferers have increased by 8.3% per year from 2013-2018. In 2018 the prevalence of hypertension in Indonesia reached 34.1% and affected about 20% of the world's population. Handling of hypertension sufferers can be done in two ways, namely modifying lifestyle and using drugs. Antihypertensive drugs that are given pay attention to age, history of the disease, smoking habits, obesity, and consider diseases such as diabetes, kidney, heart failure, and ischemic heart. Improper use of antihypertensive drugs often causes fever, diarrhea, diabetes, kidney failure, stress, breathing through the mouth, neurological disorders, radiation to the neck and head area, and localized disorders of the salivary glands. Doctors or medical personnel in providing antihypertensive drugs require good pharmacological knowledge. In general, not all hospitals have someone who is an expert in pharmacology. Therefore this study aims to develop a model based on Fuzzy Tsukamoto and Profile Matching for a recommendation of drug combinations, the suitability of dosage, and frequency in hypertensive patients. The results of the model evaluation show an accuracy of 97.5%*

Keywords: *Hypertension, Profile Matching, Fuzzy Tsukamoto, Drugs*

1 INTRODUCTION

Hypertension is a condition when systolic blood pressure (BP)>140/90. The rate of 140 mmHg when the heart pumps blood throughout the body, and the number 90 mmHG refers to diastolic reading when the heart is relaxed (James et al., 2014). Hypertension becomes the worlds' health problem; the increasing prevalence of hypertension, accompanied by other diseases that accompany it, will increase cardiovascular events. In developed countries, the cardiovascular disease becomes the disease that often causes death. This is due to the modern lifestyle done in an instant and relaxed way (Rumagit, Pojoh, & Manampiring, 2012). One of the cardiovascular disease that often causes death is hypertension (Viera, Cohen, Mitchell, & Sloane, 2008). Hypertension is the number one deadly disease globally and has always increased by an average of 8.3% from 2013 (Indonesia Ministry of Health, 2014).

Doctors and paramedics often see patients with high blood pressure, especially systolic, without proper treatment and eventually end up in a hospital with a heart attack, kidney failure, and stroke. Hypertension usually does not cause specific symptoms, which caused there are many untreated hypertension patients. It is

about 10-20% of hypertension patients who receive treatment could achieve blood pressure control targets. It is predicted that the prevalence of hypertension will increase and impact public health (James et al., 2014). Hypertension intervention in the form of lifestyle modification can inhibit hypertension progression (Kandarini, 2017). Suppose the treatment with lifestyle changes such as consuming low-salt foods, exercising, maintaining ideal body weight, stopping smoking, limiting the consumption of alcoholic beverages, and controlling stress have not significantly reduced hypertension. In that case, the patient needs anti-hypertension drugs (Medications & Changes, 2014). The goal of treating hypertension is to reduce cardiovascular morbidity and mortality due to high blood pressure in the least possible way to disrupt the quality of a patient's life(Anonim, 2006). Drugs use one of the treatment therapy given the patients. The goal of drug use therapy is to improve patients' quality of life and minimize risk(BPOM, 2015). The treatment process can occur in inappropriate ways, such as medication errors and improper dosage(Soetanto, Hartati, Wardoyo, & Wibowo, 2018). Giving the appropriate antihypertensive drugs and the right dosage becomes a complex problem that requires a greater understanding of pharmacology(Germino, 2008). Inadequate and ineffective administration of drugs and improper dosage become problems for health services. The negative effects of irrational drug use can be detrimental in many ways. In addition to economic dissipation, it can decrease the treatment services quality, for example, increased side effects, treatment failure, and increased anti-microbial resistance(Puput Puspitawati, 2009). Based on the National Patient Safety Report data, drug administration errors become first ranked in 24.8% of 10 cases(Persi, 2007). Problems can occur when writing recipes using hands, which shows a reasonably high error compared to using computers (Iqbal, Nadeem, Khan, Akhtar, & Waraich, 2001).

Research shows that 34% of the administration of antihypertensive drugs by medical personnel is inappropriate(Supadmi, 2011). Which causes incomplete hypertension treatment results, and contraindications occur in patients. Giving of antihypertensive drugs can cause side effects such as fever, increased sugar content, resulting in kidney failure, indigestion (diarrhea), stressful, nerve disorders, difficulty breathing normally or can be through the mouth, radiation to the neck and head area, and diseases of the salivary glands (Soetanto et al., 2018). Hypertension medication usually only requires one type of drug with a low dosage; if it has not been successful, it requires a combination of more than one medicine (Kandarini, 2017). The latest clinical trial results show that most hypertensive patients successfully control their blood pressure after taking two or more antihypertensive drugs(Carolina & Brunton, 2014). Treatment with healthy lifestyle changes and drug consumption has been shown to reduce blood pressure and cardiovascular complications(Meric-Bernstam et al., 2015). This condition underlies types of antihypertensive drugs circulating in health clinics. On the other hand, this creates complexity for the clinician in determining the most effective and appropriate antihypertensive medication given based on the patient's specific conditions. Clinicians are required to have the ability to determine the indications of starting pharmacological therapy, blood pressure control targets, and type of anti-hypertension that must be selected.

Providing antihypertensive drugs, doctors, and medical personnel requires standard knowledge of pharmacological doctors. Not all health clinics or hospitals have an expert in the field of pharmacology. Therefore, this study was conducted to develop a model using Fuzzy Logic and Profile Matching methods to calculate drug suitability and dosage for hypertension sufferers. Fuzzy logic was chosen because it has more flexible values when compared to Ordinal weighting(Soetanto et al., 2018). The Fuzzy-Profile Matching (FPM) method has been widely used in research in various fields. Research in drug recommendations using the Profile Matching method can provide a level of accuracy between the system and experts at 87% (Soetanto et al., 2018). Previous studies applying the FPM method were used for Embedded Ethnic Inference DNA. The system can calculate DNA compatibility from ethnic differences (Hartono, Widyanto, & Soedarsono, 2010).

In addition to DNA matching, the PM method is used to calculate poor house selection. This method's application results in a decision-making process for poor housing beneficiaries following the standards set by Baitul Mal to be fast and accurate(Afijal, Iqbal, Najmuddin, & Iskandar, 2014). The application of fuzzy logic has been used for research, one of which is cardiovascular risk classification. Fuzzy logic can map cardiovascular risk in the form of geometric dots of tubular shapes on the hypercube in the form of gradients for disease level (Barini, Ngoo, & Mwangi, 2019). A fuzzy application can diagnose more quickly and accurately in coronary heart diagnosis compared to the classical system (Alqudah, 2017).

Based on several studies that have been done, the use of Fuzzy Logic and Profile Matching has been successful in solving several problems. In this study, Fuzzy and Profile Matching methods will be used to calculate the value of drug compatibility and dosage with hypertension patients who are dissertated by other diseases such as kidney, glucose, and heart problems. This study's results are in the form of models and applications that will be used by paramedics and doctors to assist in recommending hypertension drugs, dosages, and frequency of drug administration.

2 RESEARCH METHOD

The antihypertensive drugs' application suitability to the patient's health condition was developed by describing the proposed prototype architecture. This prototype consists of two main parts, the development knowledge base and the development environment. This model was developed from Soetanto's, 2018, as Figure 2.

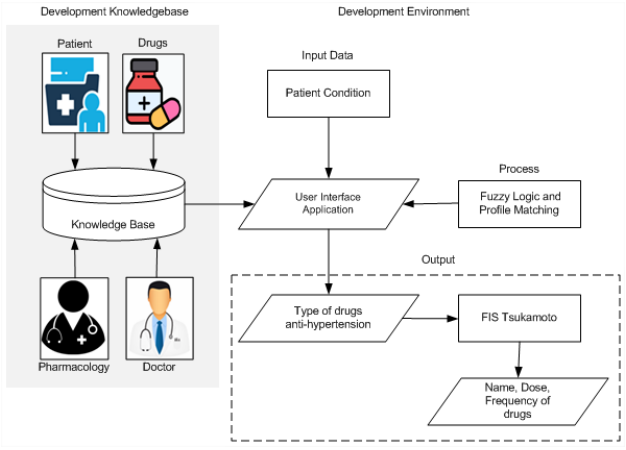


Figure 1. Development of antihypertensive drug suitability models

2.1 The stages of model development

The development starts with base-making using expert knowledge and literature. Figure 2 explains the steps of the research that began with expert consultation through system testing. The method used is Fuzzy Logic using curves and membership functions. Next, the match result was calculated by the core and secondary factors using the Profile Matching method. The system and experts' accuracy results were tested using the Confusion Matrix table to get the value of precision, accuracy, and recall.

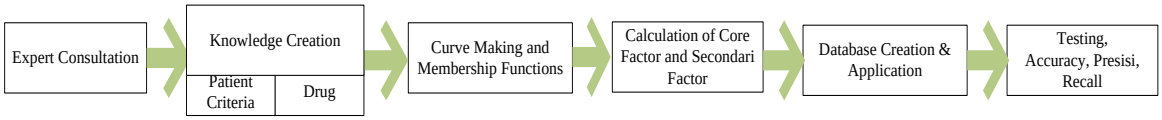


Figure 2. The phase of developing a hypertension drug suitability

2.2 Criteria Input for determining drugs

Based on the consultations with the expert's results and some literature reviews, the criteria used to determine the type of hypertension medication are blood pressure, age, BMI, kidney creatinine health, blood sugar levels, and a patient's history of heart disease.

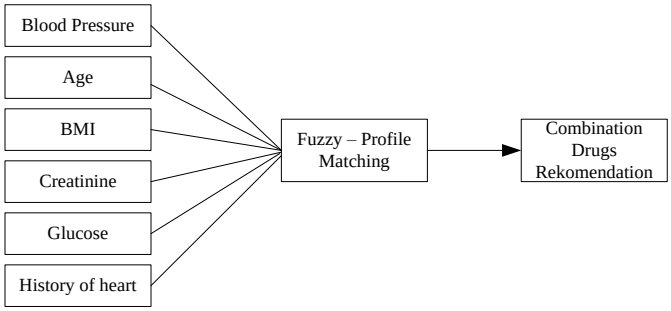


Figure 3. Criteria input for determining hypertension drugs recommendations

2.3 Determination of Hypertension Medication Based on Patient Criteria

The consultation with experts results and references indicate that are 6 (six) criteria that determine the administration of antihypertensive drugs to patients with complications.

Table 1. Criteria health of patients

C1	C2	C3	C4	C5	C6
Blood pressure	Age	Body mass index	Kidney creatinine levels	Glucose Level	Heart history
mm/Hg	year	BMI	mg/dl	mg/dl	Yes/No

Following is a brief explanation of each patient's health criteria used in recommending the hypertension medication type:

a. Blood pressure (C1). The amount of blood pressure in mm/hg will determine the antihypertensive medicines to be given. Blood pressure is obtained from measurements using a sphygmomanometer placed on the arm in a sitting and relaxed position. BP has several levels, hypertension I (140-159), level II (160-179), level III (≥180) (Subias, 2016)
b. Age (C2) is obtained based on the patient's date of birth in years. Patient age is one of the criteria that can affect the drug administration for hypertension [9]. The analysis turns outpatients with age 60 years and has a greater risk of developing hypertension (Medications & Changes, 2014).
c. Body Mass Index (BMI) (C3) calculation uses the formula: BMI = Weight / (Height * Height). BMI standards used are bodyweight (<18.5), Normal (18.5 - 24.9), Overweight (25.0 - 29.9), Fat (≥30), and ≥35 overweight(Guilherme et al., 2015). Research on this subject has been carried out for 44 years with the results of research that overweight and obesity contribute as a cause of 26% of cases of hypertension in men and 28% in women (Ho, Pinsky, Kannel, & Levy, 1993)
d. Kidney creatinine (C4) in mg/dl. Kidney health is known to be one of the diseases caused by hypertension patients and is a consideration in recommending drugs (Soetanto et al., 2018). The level

of kidney creatinine is obtained based on laboratory tests with the Enzymatic method (Pendidikan, Spesialis, Klinik, Sakit, & Sadikin, 2016)

e. Glucose level (C5) mg/dl. This data was obtained from the results of laboratory tests using a tool with the Hexokinase (Baharuddin, Nurulita, & Arif, 2015)
f. History of the heart (C6) is obtained from the patient's health data has a history of heart

2.4 Knowledge Base of Drugs Compatibility with Patient Criteria

There are 5 (five) types of antihypertensive drugs commonly used by doctors, namely Ace Inhibitors (ACE-I), Diuretics, Beta-Blockers (BB), Calcium Channel Blockers (CCB), and Angiotensin Receptor Blockers (ARB) (Medications & Changes, 2014). The results of consultations with expert cardiovascular and hypertension found the ideal values for each type of drug shown in Table 3.

Table 2. Criteria and ideal values for the patient's condition with type of drugs

Type of drugs	C1 (mm/Hg)	C2 (year)	C3 (BMI)	C4 (mg/dl)	C5 (mg/dl)	C6 (yes/no)
ACE-Inhibitor	>180	55 - 60	≥35	≥4.2 (m) ≥4.1 (w)	≥200	Yes
ARB	170 – 180	≤55	30 - 34.9	1.2 - 4.2 (m) 1.1 - 4.1 (w)	≥200	No
Beta-Blocker	160 – 170	≥70	25 - 29.9	0.4 – 0.8 (m) 0.3 – 0.7 (w)	≤200	Yes
Diuretic	150 – 160	65 - 70	18.5 - 24.9	≤0.4 (m) ≤0.3 (w)	≤200	Yes
CCB	<150	60 - 65	<18.5	0.9 - 1.2 (m) 0.8 - 1.1 (w)	≤200	No

Table 3 is then made as a fuzzy set domain as an ideal value on the membership curve to determine each criterion's weight that is compatible with the condition of patients with anti-hypertension drugs. The fuzzy set domain can be seen in several Table 3.

Table 3. Membership of domain input criteria of C1-C6

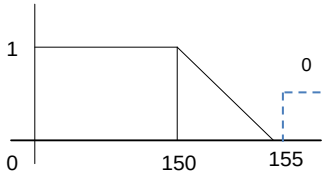
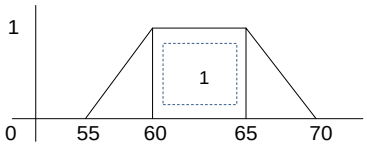
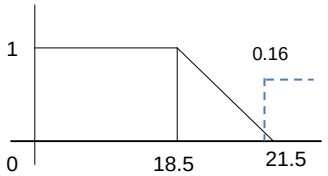
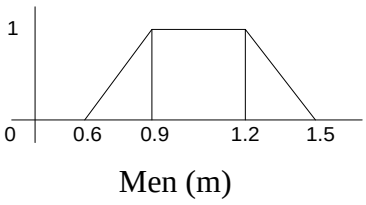
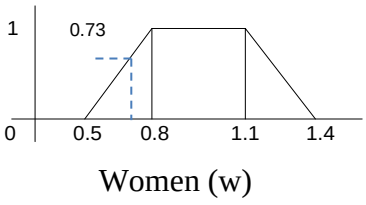
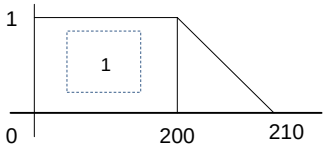
Field Input	Domain	Type of drugs
Blood Pressure (BP)	175 – 200	Ace Inhibitor
	165 - 185	ARB
	155 - 175	Beta-Blocker
	145 -165	Diuretic
	140 – 155	CCB
Age	50 – 65	Ace Inhibitor
	17 - 60	ARB
	65 - 100	Beta-Blocker
	60 - 75	Diuretic
	55 – 70	CCB
Body Mass Index (BMI)	32 – 40	Ace Inhibitor
	27 - 37.9	ARB
	22 - 31.2	Beta-Blocker
	15.5 - 27.9	Diuretic
	0 - 21.5	CCB

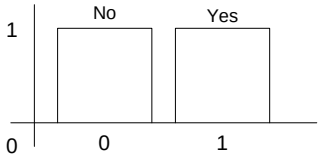
Field Input	Domain	Type of drugs
Kidney Creatinine Levels	3.8 – 9	Ace Inhibitor
	0.8 – 4.4	ARB
	0.1 – 0.9	Beta-Blocker
	0 – 0.6	Diuretic
	0.5 – 1.4	CCB
Glucose Level	140 - 200	Ace Inhibitor
	140 - 200	ARB
	0 - 210	Beta-Blocker
	0 - 210	Diuretic
	0 - 210	CCB
History of Heart	Yes [1]	Ace Inhibitor
	No [0]	ARB
	Yes [1]	Beta-Blocker
	Yes [1]	Diuretic
	No [0]	CCB

2.5 Making Curves and Membership Functions for Type of Drug

Based on Tables 4, a curve and membership function are then made using fuzzy logic. The curve depicted the ideal criterion for CCB drug types.

Table 4. Curves and membership functions for types of CCB drug types

Criteria	Curves	Memberships function
Blood pressure (C1)		$\mu[x] = \begin{cases} 1 & x \le 150 \\ \frac{155 - x}{155 - 150} & 150 \le x \le 155 \\ 0 & x > 155 \end{cases}$
Age (C2)		$\mu[x] = \begin{cases} 0 & 55 \le x > 70 \\ \frac{70 - x}{70 - 65} & 65 \le x \le 70 \\ 1 & 60 \le x \le 65 \\ \frac{x - 55}{60 - 55} & 55 < x < 60 \end{cases}$
Body mass index (BMI) (C3)		$\mu[x] = \begin{cases} 1 & x \le 18.5 \\ \frac{21.5 - x}{21.5 - 18.5} & 18.5 \le x \le 21.5 \\ 0 & x > 21.5 \end{cases}$
Kidney creatinine level (C4)	 Men (m)  Women (w)	$\mu[x] = \begin{cases} 0 & 0.6 \le x > 1.5 \\ \frac{1.5 - x}{1.5 - 1.2} & 1.2 \le x > 1.5 \\ 1 & 0.9 < x \le 1.2 \\ \frac{x - 0.6}{0.9 - 0.6} & 0.6 < x \le 0.9 \end{cases}$ $\mu[x] = \begin{cases} 0 & 0.5 \le x > 1.4 \\ \frac{1.4 - x}{1.4 - 1.1} & x \ge 1.1 \\ 1 & 0.8 < x \le 1.1 \\ \frac{x - 0.5}{0.8 - 0.5} & 0.5 < x \le 0.8 \end{cases}$
Glucose level (C5)		$\mu[x] = \begin{cases} 1 & x \le 200 \\ \frac{200 - x}{210 - 200} & 200 \le x \le 210 \\ 0 & x > 210 \end{cases}$

History of the heart (C6)		$\mu[x] = \begin{cases} 1 & ACEI, Beta, Diuretic \\ 0 & ARB, CCB \end{cases}$

Furthermore, curve and membership function for the types of drugs ACE-I, Beta-Blocker, ARB, and Beta Blocker is made. Based on the curve and membership function, then calculated the fuzzy weights of each patient's criteria. Fuzzy weighting values can see in Table 5.

Table 5. Calculation of membership value "P-001" with types of CCB drug types

Criteria	Data	Value of membership
Blood pressure (C1)	168	($x \geq 155$) = 0
Age (C2)	64	($60 \leq x \leq 65$) = 1
Body mass index (BMI) (C3)	21	($18.5 \leq x \leq 21.5$) = 0.16
Kidney creatinine level (C4)	0.72	($0.5 < x \leq 0.8$) = 0.73
Level of glucose (C5)	139	($x \leq 200$) = 1
History of the heart(C6)	No	CCB = 1

2.6 Determination Criteria of Core Factor (CF) and Secondary Factor (SF)

The next stage is grouping patient criteria into core factors and secondary factors. Core factors are the leading Criteria group, whereas the second factor is a group of criteria that do not have a strong influence on determining the type of drug. The grouping is presented in Table 6.

Table 6. Classifying core and secondary factor

Core Factor (CF)	Secondary Factor (SF)
1. Blood pressure (C1) 2. Age (C2) 3. History of the heart (C6)	1. Body mass index (BMI) (C3) 2. Kidney creatinine level (C4) 3. Level of glucose (C5)

Based on the grouping of core factors and the subsequent factors calculated the average value

1. The value of the average core factor criteria

   $CF = \frac{(0+1+1)}{3} = 0.66$

2. The value average secondary factor criteria

   $SF = \frac{(0.16+0.73+1)}{3} = 0.63$

The grouping core factor's value average value multiplied the weight of 75%, and the secondary factor multiplied with a weight of 25%. The result of the core factor and secondary factor weights are then added to get a matching value

Total = (0.75 * CF) + (0.25 * SF)
= (0.75 * 0.66) + (0.25 * 0.63)
= 0.495 + 0.157
= 0.65

The results calculate of the value 0.567 indicate that the patient "P-001" if given the type of antihypertensive drug CCB has suitable (0.65 / 1) x 100% = 65% and for the second drug 40.8% that Beta-Blocker, the medications are given can be combined, as shown in Table 8.

Table 7. The results of matching patients with each type of drugs types

Patient	Ace Inhibitor	ARB	Beta-Blocker	Diuretic	CCB
P-001	5%	40%	**40.8%**	36%	**65%**
Level	*5*	*3*	*2*	*4*	*1*

2.7 Criteria for Determination of Drug Dosage and Frequency

The criteria used to determine the dosage are Blood Pressure, Age, and BMI. These criteria will be used as input to the system and calculate the dosage using Fuzzy Logic and FIS Tsukamoto, as shown in Figure 4.

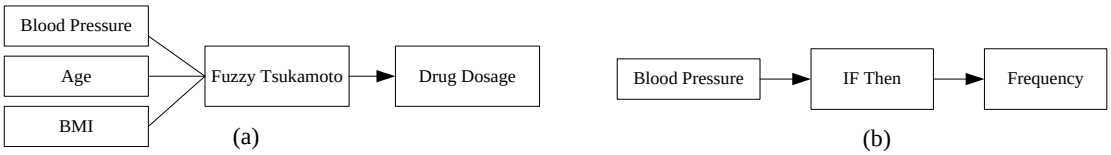


Figure 4. (a) Criteria for determining recommendations (b) Criteria for determining drug frequency

The management of antihypertensive medications starts with low dosages then slowly increases according to age, needs, and body weight. The optimal therapy must be useful for 24 hours, usually by giving a single drug. Patient compliance is a significant factor in the treatment because it can reduce treatment costs and control hypertension. Giving the right dosage can protect patients from various risks of sudden death, such as heart attack or stroke (Puput Puspitawati, 2009). Based on how it works, antihypertensive drugs are divided into several groups (Herlambang, 2013). These drug groups have different drugs, which are shown in Table 8.

Table 8. Types, dosage, and frequency of drugs

Types of drug	Drug	Dosage (Mg)	Frequentation (Ones/Day)
ACE-Inhibitor	Captopril	25 - 100	2x - 3x
	Benazepril	10 - 40	1x - 2x
ARB	Losartan	25 - 100	1x - 2x
	Valsartan	80 - 320	1x
Beta-Blocker	Sebutolol	200 - 800	2x
	Atenolol	25 - 100	2x

Diuretic	Hidroclorotiazid	12,5 - 25	1x
	Klortalidon	12,5 - 25	1x
CCB	Nefedipine	30 - 60	3x - 4x
	Verapamil	80 - 320	2x - 3x

2.8 The domain of Drug Dosage

Making the domain for drug dosages is divided into 2 (two), namely low and high. The sample used in this calculation is the CCB type with the name drug is Atenolol, which is presented in Table 9.

Table 9. The domain of drug dosage

Type of drug	Drug	Dosage (mg)	Domain (mg)	
			Low	High
CCB	Nefedipine	30 - 60	30 - 50	40 - 60

2.9 Set of Drug Dosage

People with age ≥65 years sensitive to drugs and side effects due to physiological changes; therefore, it is recommended for lower dosages. The ratio between the number of medications used and body size affects the body's concentration. In the Lancet medical journal, the dosage of antibiotics should be adjusted to the patient's body weight. High dosages of medication are given for obese patients (Falagas & Kompoti, 2006)

Table 10. Fuzzy set for drug dosage

Variable Input	Linguistic representation	Domain	Output (Dosage)
Blood pressure (mm/Hg)	Very high	[165 - 200]	High [40-60]
	High	[153 – 167]	
	Medium high	[0 - 155]	Low [30-50]
Age (year)	Young	[≤50]	High [40-60]
	Middle	[50 – 60]	
	Old	[≥60]	Low [30-50]
BMI	Over	[≥26]	High [40-60]
	Normal	[20 – 26]	
	Underweight	[≥20]	Low [30-50]

Domain there is Table 10, next step make in curve and membership function for Figures 6 and 9.

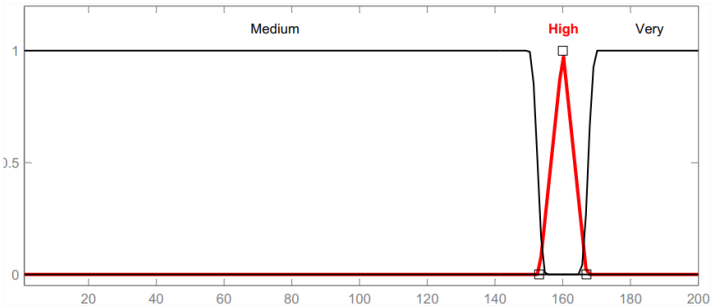


Figure 5. The curve of membership blood pressure

Membership function for blood pressure set curves:

$$e[i] = \begin{cases} 1 & i \le 150 \\ \dfrac{155 - i}{155 - 150} & 150 \le i \le 155 \\ 0 & i \ge 155 \end{cases} \quad h[i] = \begin{cases} 0 & 167 \le i \le 150 \\ \dfrac{i - 153}{160 - 153} & 153 \le i \le 167 \\ \dfrac{167 - i}{167 - 160} & 160 \le i \le 167 \end{cases} \quad e[i] = \begin{cases} 0 & i \le 165 \\ \dfrac{i - 165}{170 - 165} & 165 \le i \le 170 \\ 0 & i \ge 170 \end{cases}$$

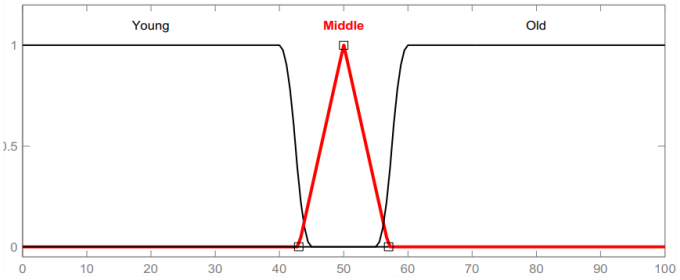


Figure 6. The curve of membership age

Membership function for the age set curve:

$$e[i] = \begin{cases} 1 & i \le 40 \\ \dfrac{45 - i}{45 - 40} & 40 \le i \le 45 \\ 0 & i \ge 45 \end{cases} \quad h[i] = \begin{cases} 0 & 43 \le i \le 57 \\ \dfrac{i - 43}{50 - 43} & 43 \le i \le 50 \\ \dfrac{57 - i}{57 - 50} & 50 \le i \le 57 \end{cases} \quad e[i] = \begin{cases} 0 & i \le 55 \\ \dfrac{i - 55}{60 - 55} & 55 \le i \le 60 \\ 1 & i \ge 60 \end{cases}$$

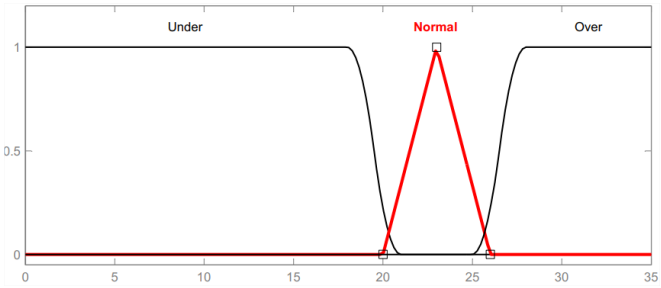


Figure 7. The curve of membership BMI

Membership function for BMI set curves:

$$e[i] = \begin{cases} 1 & i \le 18 \\ \frac{21-i}{21-18} & 18 \le i \le 21 \\ 0 & i \ge 21 \end{cases} \quad h[i] = \begin{cases} 0 & 26 \le i \le 20 \\ \frac{i-20}{23-20} & 20 \le i \le 23 \\ \frac{26-i}{26-23} & 23 \le i \le 26 \end{cases} \quad e[i] = \begin{cases} 0 & i \le 25 \\ \frac{i-25}{28-25} & 25 \le i \le 28 \\ 1 & i \ge 28 \end{cases}$$

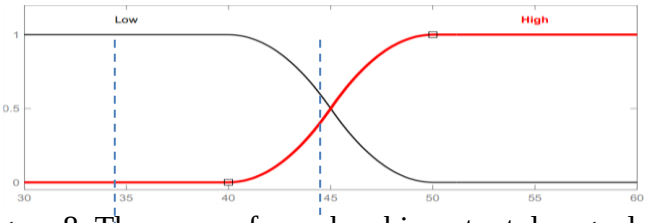


Figure 8. The curve of membership output dosage drug

Membership function for the set of output curves:

$$e[i] = \begin{cases} 1 & 30 \le i \le 40 \\ \frac{50-i}{50-40} & 40 \le i \le 50 \\ 0 & 30 \ge i \ge 50 \end{cases} \quad h[i] = \begin{cases} 0 & 40 \ge i \ge 60 \\ \frac{i-40}{50-40} & 40 \le i \le 50 \\ 1 & 50 \le i \le 60 \end{cases}$$

Furthermore, the curves and membership functions are made for medium and low dosages. Based on the curve and membership function, then calculate the fuzzy weights of each patient's criteria.

Table 11. Calculation of blood pressure membership values

Criteria	Data	Linguistic Variables		
		Medium-High	High	Very high
Blood pressure (BP)	168	0	0	0.6

Table 12. Calculation of age membership values

Criteria	Data	Linguistic Variables		
		Young	Middle	Old
Age (year)	64	0	0	1

Table 13.Calculation of BMI membership values

Criteria	Data	Linguistic Variables		
		Underweight	Normal	Over Weight
Body mass index (BMI)	21	0	0.33	0

2.10 Fuzzy Implication Rules

Monotonous fuzzy rules are used as a basis for fuzzy implication techniques. Rules using the formula of the criteria number raised by the number of sub-criteria. The criteria used are 3 (three), namely blood pressure, age, BMI, and sub-criteria of each criterion are 3 (three), so the number of rules used is $3^3 = 27$ rules.

"[R1] If Blood Pressure Very High and Age-Old and BMI Over Then High dosage;"
"[R2] If Blood Pressure Very High and Age-Old and BMI Normal Then High dosage;"
"[R3] If Blood Pressure Very High and Age-Old and BMI Low Then Low dosage;"
"[R4] If Blood Pressure Very High and Age Middle and BMI Over Then High dosage;"
"[R5] If Blood Pressure Very High and Age Middle and BMI Normal Then High dosage;"
"[R6] If Blood Pressure Very High and Age Middle and BMI Under Weight Then Low dosage;"
"[R7] If Blood Pressure Very High and Age Young and BMI Over Then High dosage;"
"[R8] If Blood Pressure Very High and Age Young and BMI Normal Then High dosage;"
"[R9] If Blood Pressure Very High and Age Young and BMI Under Weight Then High dosage;"
"[R10] If Blood Pressure High and Age-Old and BMI Over Then Low dosage;"
"[R11] If Blood Pressure High and Age-Old and BMI Normal Then Low dosage;"
"[R12] If Blood Pressure High and Age-Old and BMI Under Weight Then Low dosage;"
"[R13] If Blood Pressure High and Age Middle and BMI Over Then High dosage;"
"[R14] If Blood Pressure High and Age Middle and BMI Normal Then Low dosage;"
"[R15] If Blood Pressure High and Age Middle and BMI Under Weight Then Low dosage;"
"[R16] If Blood Pressure High and Age Young and BMI Over Then High dosage;"
"[R17] If Blood Pressure High and Age Young and BMI Normal Then High dosage;"
"[R18] If Blood Pressure High and Age Young and BMI Under Weight Then Low dosage;"
"[R19] If Blood Pressure Medium High and Age-Old and BMI Over Then Low dosage;"
"[R20] If Blood Pressure Medium High and Age-Old and BMI Normal Then Low dosage;"
"[R21] If Blood Pressure Medium High and Age-Old and BMI Under Weight Then Low dosage;"
"[R22] If Blood Pressure Medium High and Age Middle and BMI Over Then Low dosage;"
"[R23] If Blood Pressure Medium High and Age Middle and BMI Normal Then Low dosage;"
"[R24] If Blood Pressure Medium High and Age Middle and BMI Under Weight Then Low dosage;"
"[R25] If Blood Pressure Medium High and Age Young and BMI Over Then High dosage;"
"[R26] If Blood Pressure Medium High and Age Young and BMI Normal Then Low dosage;"
"[R27] If Blood Pressure Medium High and Age Young and BMI Under Weight Then Low dosage;"

Then value z calculation will be performed to look for output using FIS Tsukamoto from each rule given explicitly (crisp) based on α-predicate (fire strength). In this calculation, not all R1-R27 rules are displayed. The final result is obtained using a weighted average

$\alpha\text{-predicat}_1$ = μBP Very High ∩ μAge Old ∩ μBMI Over Then High dosage;
= Min (0.6; 1; 0)
= 0
z1 = α1 * (High-Low) + Low
= 0 * (60 – 300) + 30
= 30

Results of all calculations $\alpha\text{-predikat}_{1\text{-}27}$ and value z will show Table 14.

Table 14. Value of α-predicate and z

ID	BP	Age	BMI	Min ($\alpha_{1\text{-}27}$)	$Z_{1\text{-}27}$

1	0.6	1	0	0	30
2	0.6	1	0.33	0.33	50
3	0.6	1	0	0	60
4	0.6	0	0	0	30
5	0.6	0	0.33	0	30
6	0.6	0	0	0	50
7	0.6	0	0	0	30
8	0.6	0	0.33	0	30
9	0.6	0	0	0	30
10	0	1	0	0	60
11	0	1	0.33	0	60
12	0	1	0	0	60
13	0	0	0	0	30
14	0	0	0.33	0	60
15	0	0	0	0	60
16	0	0	0	0	30
17	0	0	0.33	0	30
18	0	0	0	0	60
19	0	1	0	0	60
20	0	1	0.33	0	60
21	0	1	0	0	60
22	0	0	0	0	60
23	0	0	0.33	0	60
24	0	0	0	0	30
25	0	0	0	0	30
26	0	0	0.33	0	60
27	0	0	0	0	60

2.11 Deffuzyfication

After a combination of forming rules, the next step is doing a calculation to get the value of defuzzification by adding the rules to rules 27 to get the weighted average value *(Weight Average)*

$$\text{z (Dosage)} = \frac{(a1 * z1) + (a2 * z2) + (a3 * z3) + (a4 * z4) + \cdots (a64 * z27) +}{a1 + a2 + a3 + a4 \ldots a27}$$

z (Dosage) = 50 mg

The results of calculations using a weighted average produce a value of 20.8 mg, then patients with blood pressure (TD) of 168, age 64 years, and BMI 21; based on calculations, the system recommends a dosage of 50mg. Frequency of drug /day use [IF-Then] function with the calculation in Table 15.

Table 15. Determining the frequency of drug administration

Types of drug	Drugs	Blood pressure	Frequentation (Ones/Day)
ACE-Inhibitor	Captopril	≥165	3
		≥140	2
	Bernzanepril	≥165	2
		≥140	1
ARB	Losartan	≥165	2
		≥140	1
	Valsartan	≥140	1
Beta-Blocker	Betaxolol	≥140	2
	Atenolol	≥140	2
Diuretic	Hidroclorotiazid	≥140	1
	Klortalidon	≥140	1
CCB	Nifedipine	≥165	4
		≥140	3
	Verapamil	≥165	3
		≥140	2

2.12 Application for Medication of Hypertension

Based on the results of the hypertension drug match, the right medicine for the patient is with the condition of Blood Pressure 168, Age 64 years, BMI 21, kidney health 0.72, blood sugar 139, blood circulation 6.2, and heart rate 86, the best results of calculations which has the most excellent compatibility for the condition of this patient is the type of CCB drug with the name of the drug, Nifedipine dosage 50 mg consumed 4 (four) ones/day. This calculation was developed using the Pascal programming language with Borland Delphi

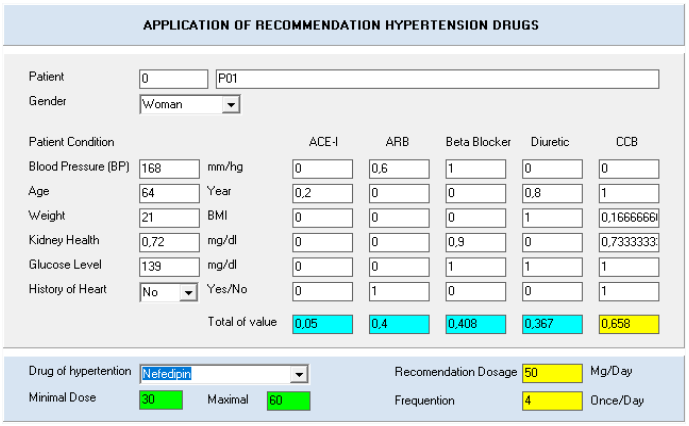


Figure 9. The developed interface primary system recommendations type of drugs, drug, dosage, and frequency

2.13 Determination of Drug Administration

Values from the calculation results using the application are sorted from the first largest and second-largest. The drug types with the first and second-largest match values are chosen to be combined, given to the patient, because it is considered the most appropriate for the patient's health. However, the entire calculation of the drug's value is still displayed so that doctors can choose based on ability and experience.

2.14 Comparison with Existing Systems

Table 17 shows the differences between previous research and this study. The difference lies in the number of input criteria, drug name, dose, and drug administration frequency.

Table 16. Comparison with existing systems

Author	Year	Method	Number Criteria	Type of Drugs	Accuracy (%)	Name of Drugs/ Combination	Dosage	Frequency
Soetanto *et al.*	2018	Interpolation and Profile Matching	10	5	87	No	No	No
This paper	2020	Fuzzy and Profile Matching	7	5	97.5	Yes	Yes	Yes

3 RESULTS AND DISCUSSION

The test uses 20 (twenty) medical records of male and female patients taken from the Abdoel Moeloek general hospital in 2019. The medical data record, tests were conducted between the system with hypertension and internal medicine experts by dr. Lukman Pura, Sp. PD-KGH., MHSM., FINASIM.

Table 17. Data on medical records of hypertensive patients with complications

ID	Patient	BP	Age	Gender	BMI	Creatinine	Glucose	History Heart	Expert		System	
									Drug 1	Drugs 2	Drug 1	Drugs 2
1	P-001	168	64	W	21	0,72	139	86	CCB	ARB	CCB	ARB
2	P-002	155	56	W	30,6	5,64	161	105	ACEI	Diuretic	ACEI	Diuretic
3	P-003	170	54	W	34,3	0,71	100	100	ARB	Beta B	ARB	Beta B
4	P-004	145	56	W	32,2	0,9	314	110	ACEI	ARB	ACEI	ARB
5	P-005	147	49	W	20,8	1,19	99	98	CCB	Beta B	CCB	Diuretic
6	P-006	169	66	W	22,6	5,4	43	108	Beta B	Diuretic	Beta B	Diuretic
7	P-007	185	54	W	19,7	5,64	161	99	ACEI	ARB	ACEI	ARB
8	P-008	150	36	M	34,2	9,52	109	124	ARB	Beta B	Diuretic	Beta B
9	P-009	165	64	M	21,5	6,35	105	100	CCB	ACEI	CCB	ACEI
10	P-010	160	61	M	20	14,8	98	113	Diuretic	Beta B	Diuretic	Beta B
11	P-011	172	69	M	18,9	2,88	75	99	ARB	Beta B	ARB	Beta B
12	P-012	166	57	M	26,4	0,47	73	102	Beta B	ACEI	Beta B	ACEI
13	P-013	158	22	M	28,1	3,61	103	98	ARB	Beta B	ARB	Beta B
14	P-014	175	43	M	33	3,14	92	107	ARB	Beta B	ARB	Beta B
15	P-015	163	80	M	19,5	0,82	75	109	Beta B	Diuretic	Beta B	Diuretic
16	P-016	186	63	M	29,3	2,25	141	119	ACEI	Diuretic	ACEI	Diuretic
17	P-017	158	55	M	27	1,59	113	110	Diuretic	Beta B	Diuretic	Beta B
18	P-018	177	18	M	24,1	0,61	102	112	ARB	CCB	ARB	CCB
19	P-019	181	42	M	34,3	9,2	109	120	ACEI	ARB	ACEI	ARB
20	P-020	160	61	M	30,2	2,6	130	113	Diuretic	Beta B	Diuretic	Beta B

Source: Data on poly medical records of diseases in Abdoel Moleok Hospital 2019

Results from expert testing with 6 (six) types of ARB drugs and the system recommends as many as 5. Experts and systems provide recommendations for the same type of drug ACE-I as many 5. Types of Beta Blocker drugs experts and systems provide the same amount of three. For CCB type, experts, and systems, recommend the same is 3. Types of Diuretic drugs experts recommend 3 (tree), and the system is 4. The results of this comparison are shown in the confusion matrix in Table 18.

Table 18. The result of comparing the confusion matrix between expert and system

Type of drug	ACE-I	ARB	Beta-B	Diuretic	CCB
ACE-I	5	0	0	0	0
ARB	0	5	0	1	0
Beta-B	0	0	3	0	0
Diuretic	0	1	0	3	0
CCB	1	0	0	0	3

(a)

Type of drug	ACE-I	ARB	Beta-B	Diuretic	CCB
ACE-I	2	0	0	0	0
ARB	0	4	0	1	0
Beta-B	0	0	8	1	0
Diuretic	0	0	1	4	0
CCB	0	0	0	0	1

(b)

The test includes a calculation value of precision, accuracy, and recalls to show the value of accuracy. Testing is done by involving experts in hypertension and internal medicine. The test used 20 medical records of patients with hypertension complications. (a) Average value of 95% precision, 96.6% recall, and accuracy 98% (b) values for the precision of 96%, recall 97.76%, and accuracy 97%.

Table 19. Average Precision, Recall, and Accuracy

Expert and System	Precision	Recall	Accuracy
Drug recommendation 1	95%	96.6%	98%
Drug Recommendation 2	96%	97.7%	97%
Average	**95.5%**	**97.15%**	**97.5%**

Based on the testing results for the types of drugs to 1 (one) and 2 (two), the average value of precision obtained is 95.5%, 97.15% recall, and 97.5% accuracy. The results of calculations in the confusion matrix tables 19 are presented in graphical form in Figure 10.

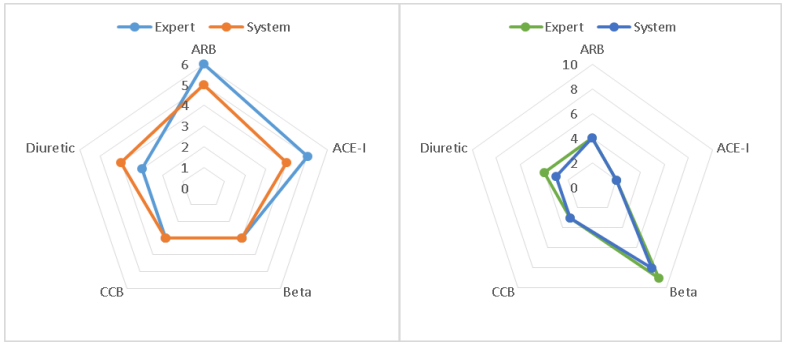


Figure 10. Graph comparison of drug recommendations between systems and experts

4 CONCLUSION

Based on the results of the test that have been carried out between experts and the system, it can be concluded that this study produced a model and application using Fuzzy Logic and Profile Matching methods for the suitability of the type of drug, drug name, dosage, and frequency based on patient health. It includes the value calculation of precision, accuracy, and recall, which shows pretty good results, which means this application can be used by doctors to recommend appropriate antihypertensive drugs. However, this research still needs to be developed because there are still some shortcomings and weaknesses. Creation of a knowledge base that is always updated and adapted to the condition of white and black patients

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