Fuzzy Logic for Grasping Type Classification of Human Hand Based on Myoelectric Signal Parameter

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Abstract. This research aim to classify grasping types between power grip and precision grip based on myoelectric signal parameters. Ten healthy male with normal grasping strengths, and ideal body mass index (BMI) were choosen as subject and asked to perform several grasping types, i.e. spherical, cylindrical, lateral, hook and tip. Myoelectric signal were captured by AD620 based circuits from subjects' lower arms, both in fresh and fatigue condition and output were processed by using TRUE RTA (Real Time Analyzer) software to get their frequency based form. After that, there were calculations to determine their frequency base parameter of Mean Frequency (MNP), Median Frequency (MDF), Mean Power (MNP), Total Power (TTP) and Spectral Moment (SM). Based on our researh MNF, MDF, TTP, MNP and SM are found to be parameters with high robustness caracteristic which can be proposed as a fuzzy logic control input parameter. Based on our trial, this logic control model can already distinguish power grip and precission grip within the input range.

Keyword* : *AD620, Fuzzy Logic, Myoelectric Signal Parameters, Grasping Type

1. Introduction

Fuzzy logic is a control system that has been successfully used in many fields. In this research, fuzzy logic was used to recognize the myoelectric signals and classify them into basic grasping types of human hand. The basic grasping types of the human hand are divided into power grip and precision grip consisting of spherical grasp, cylindrical grasp, lateral grasp, hook grasp, tip grasp, and palmar grasp (Martel and Gini, 2007) (see ., [10]). The control system is considered good if it can recognize a wide variety of basic grasping types (i.e. spherical, cylindrical, lateral, hook and tip). According to Phinyomark (2012) some myoelectric signal parameters can be used to analyze the myoelectric signal, i.e. Median Frequency (MDF), Mean Frequency (MNF), Mean Power (MNP), Total Power (TTP), and Spectral Moment (SM) (see ., [11]).

Research about control system with fuzzy logic has been researched by Chan et.all., (2000). (see ., [2]). Beside that, research about the control system prosthetic hand, and captured the myoelectric signal with surface electrode, and the technique about classification the signal and human hand with comprehensive grasp taxonomy has been researched over the past 8 years. (see ., [3], [4],[5], and [6]).

In this research the signals which have been analyzed can be used as input parameters in the making of fuzzy logic. However, before the signal was processed by using fuzzy logic, the parameters should be tested whether they have good robustness so that they are not affected by the fatigue factor. Types of control systems available are very diverse, however, the control system used in this research was fuzzy logic. The reason is the decision-making in fuzzy logic is using a rule that was created earlier without being bound by previous decision historical data. The myoelectric signal is a dynamic signal depending on the size of the muscle grip strength, so it is more appropriate to use fuzzy logic. More over, fuzzy logic is applied generally to the problem issues which contain elements of uncertainty, inaccuracy (imprecision), noise, and so on (see .,[8])..

The purpose of this research was to determine a reliable myoelectric signal parameters for a fuzzy logic development, in order to classify the 5 basic types of human grasping: spherical grasp, cylindrical grasp, lateral grasp, tip grasp, and hook grasp.

2. Research Methodology

This research is described in methodology as follows:

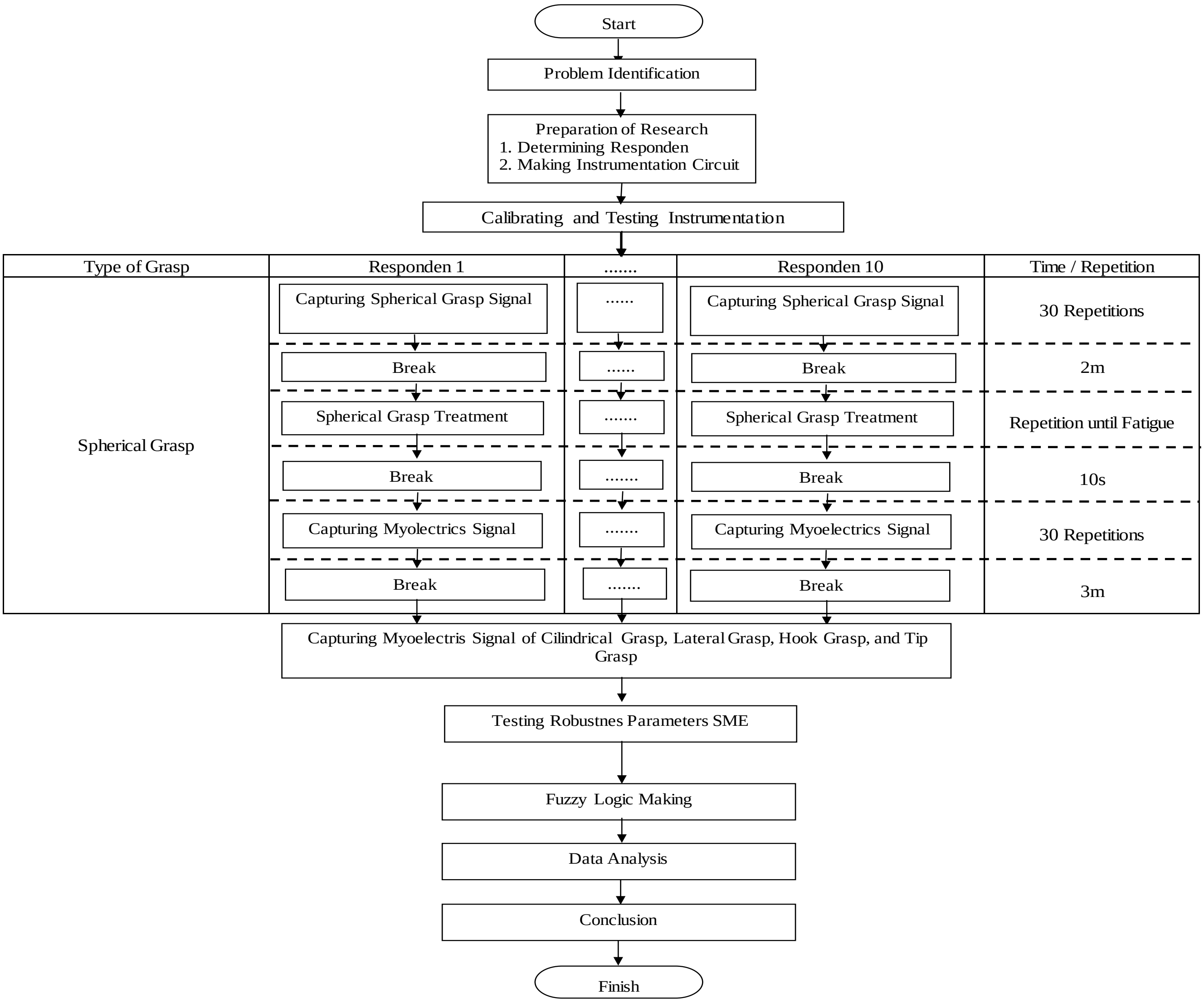


Figure 1. Research methodology

2.1 Research Preparation

The research preparation was consisted of respondent determination step and instrumentation assembly step. Respondents in this research were determined by several criteria: male, has maximum lower arm circumference so as to show muscle strength, has normal muscle grip strength at least 36.8 N, and has ideal weight proportion based on calculation of body mass index.

As for instrumentation assembly step, it is required several electronic components such as AD620 circuit, trimpot, capacitor, resistor, input-output cable, oscilloscope, and function generator. AD620 circuit is used as a magnifyer i.e. enlarging myoelectric signal amplitude captured by the electrode on skin surface. This tool is a magnification instrument with high accuracy which only requires one potentiometer with resistant magnification of 1-10000 Ω. The circuit is used to detect myoelectric signal with 3-channel i.e. thumb, index finger and other three fingers myoelectric signals. The schematics of AD620 circuit is presented by the following figure:

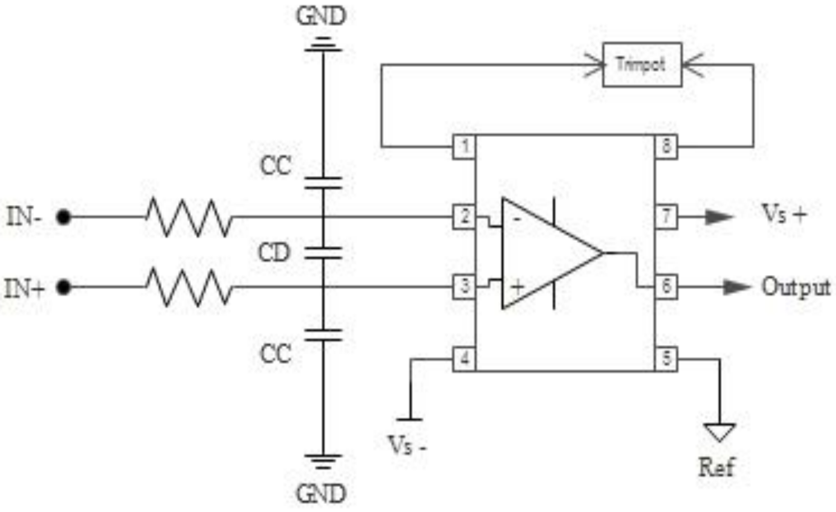


Figure 2. AD620 circuit instrumentation schematic

2.2 Instrumentation Calibration

Calibration step was performed to determine whether the incoming input signal was equal to the signal captured at the output. Calibration was used to calibrate the signal generated from the function generator and captured by using an oscilloscope. The input signal generated by the function generator is a sine signal with characteristic of 10 mV and 70 Hz. To obtain a magnification of 100 times, resistance on the potentiometer was set to ± 500 Ω. To avoid noise, signal receiver circuit was placed as far as possible from the noise source. Output signals from signal captor then checked by using an oscilloscope. The oscilloscope was set to display signal with scale of 0.1 V / Div and the lower peak of the sine signal generated was placed precisely on x-axis of the oscilloscope. If the instrumentation circuit was working properly then the output value captured by the oscilloscope woud be a signal with characteristic of 1 V and 70 Hz. It was determined by captured signal in the range of 0-5 divisions on the oscilloscope. The schematics of instrument calibration is presented by the following figure:

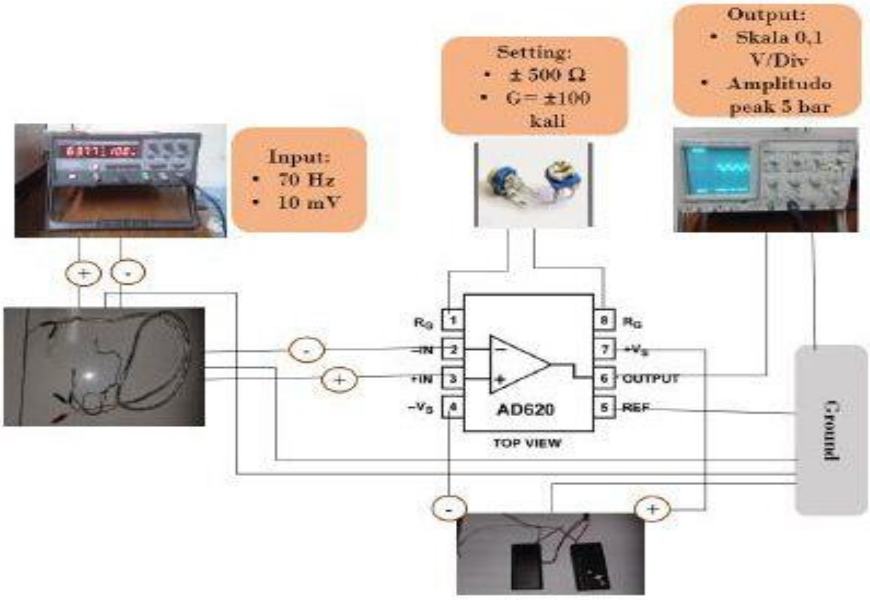


Figure 3. Instrumentation calibration schematics

2.3 Myoelectric Signal Capture

Myoelectric signal capture, in accordance with signal capture schematics, was to connect the electrode installed at the respondents' hands with instrumentation circuit, function generator and oscillloscope. Then the respondents were asked to perform basic grasping types of power grip and precision grip i.e. spherical grasp, cylindrical grasp, lateral grasp, tip grasp, and hook grasp. (This research develop based on Ardian 2016) (see., [1]).

Spherical grasp was conducted in which respondents grasped on a sphere with diameter of 4.5 cm. Cylindrical grasp, respondents were asked to perform grasping of cylindrical object, in this researh was grasping on iron pipes with diameter of 3 cm. Lateral grasp is grasping conducted for thin-sized objects, to perform this kind of grasping, respondents were asked to grasp on objects with dimension of 70x50x3 mm^3. Tip grasp is a type of precision grip, respondents were asked to pick up small objects with dimensions of 3x5x5 mm^3. The last grasping type is the hook grasp, respondents were asked to perform grasping such as the movement to put the brakes on a motorcycle, to simulate this case respondents were asked to perform grasping object with diameter of 2 cm.

Each type of grasping was performed by 30 repetitions, after which respondents took a break for two minutes, then respondents were asked to perform grasping until fatigue. After that, the respondents were given time off for ten seconds for power grip and five seconds for precision grip. Furthermore, respondents performed grasping for another 30 repetitions. Respondents then took a rest for three minutes before performing measurements for next grasping types.

2.4 SME Parameters Robustness Test

At this step, robustness test was conducted for obtained signals. Myoelectric signal selected should not be affected by fatigue. Robustness test can be conducted by observing the captured signal amplitude i.e. by observing the amplitude height or width. Indications of muscle fatigue can be seen by observing shrinking amplitude height and growing amplitude width. However, in this research, robustness test was assisted by Paired T-test. Paired T-test was performed to determine whether there were significant differences between before and after treatment (see., [9]).. Here is a recapitulation of robust myoelectrics signal parameter by Paired T-test:

Table 1. Recapitulation of robust myoelectric signal parameters

Responden	Cilindrical	Spherical	Lateral	Hook	Tip
1	TTP, MDF, MNP	MNF			
2					
3	MNF			MDF	MDF
4	TTP,MDF,MNF,MNP		MNF	MNF	TTP,MDF,MNF
5		MNF		TTP,MDF,MNP	
6			TTP,MDF,MNF,MNP		
7		SM	MNF	MNF	MNF
8	TTP,MDF,MNF,MNP			MNF	
9					MNF
10		SM	MNF,TTP,SM	TTP,MDF,MNF,MNP	

Table 1 shows robust parameters of respondents 1-10 in each basic grasping type of human hand. based on table above, it can be seen on respondent 2 that there are no robust parameters in each grasping type, respondent 1 does not have robust parameter on lateral grasp, hook grasp and tip grasp, etc. While the recapitulation of myoelectris signal parameter value of grasping type of human hand is presented in table 2.

Table 2. Recapitulation value myoelectric signal parameters

GERAKAN DASAR	TTP	MDF	MNF	MNP	SM
CILINDRICAL	-21717,65	-10858,825	4094,568959	-90,11473029	
	-17879,39	-8939,695	4727,098349	-74,18834025	
SPHERICAL			4085,176762		-99385969,47
			4659,771812		-84771336,15
LATERAL	-23262,16	-10970,305	3900,223747	-91,03987552	-90792351,25
	-17235,16	-9987,96	5069,39974	-82,88763485	-87371915,63
HOOK	-21747,27	-10873,635	4042,389628	-90,0733195	
	-18816,3	-9408,15	4750,382657	-78,07593361	
TIP	-21853,82	-11376,615	4318,68848		
	-20347,76	-10173,88	4378,228587		

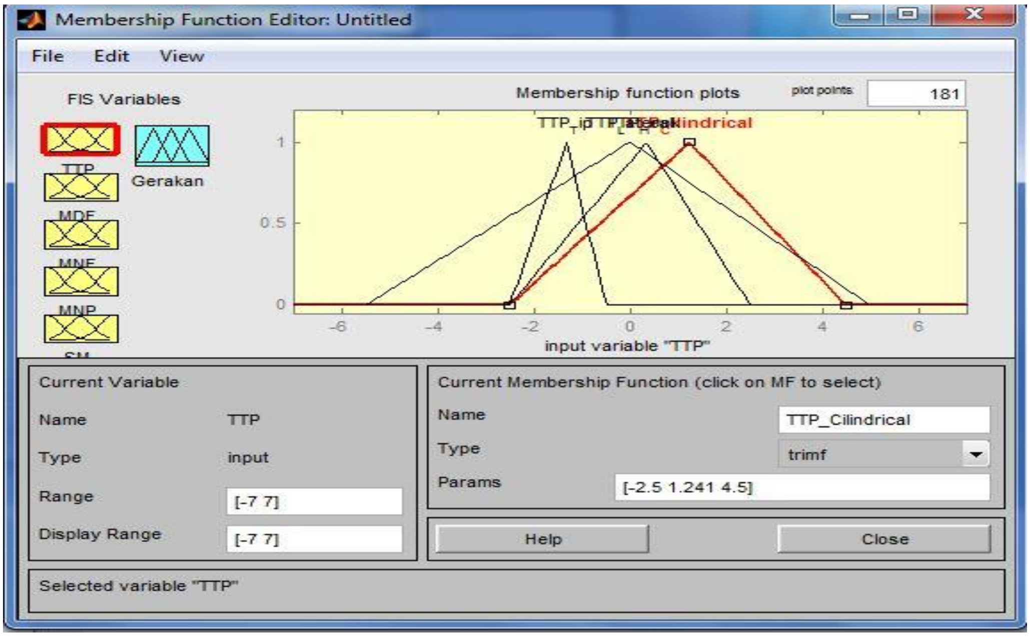
2.5 Fuzzy Logic Making

Fuzzy logic was made based on robustness test parameters value. Robust MDF, MNF, MNP, TTP, and SM parameters would serve as membership function input error, and the basic type grasping i.e. spherical, cylindrical, lateral, hook and tip would serve as membership fuction output (see ., [7]). Based on the recapitulation of robust parameter values and input parameter adjustment then normalized level was made as follows:

Table 3. Normalized level

TTP	MDF	MNF	MNP	SM	Normalized Level
3900,223747	-99,68	-108,53	-10970,305	-100,4677593	-5
4017,141346	-98,709	-106,188	-10767,244	-97,57250207	-4
4134,058945	-97,738	-103,846	-10564,183	-94,67724481	-3
4250,976545	-96,767	-101,504	-10361,122	-91,78198755	-2
4367,894144	-95,796	-99,162	-10158,061	-88,88673029	-1
4484,811744	-94,825	-96,82	-9955	-85,99147303	0
4601,729343	-93,854	-94,478	-9751,939	-83,09621577	1
4718,646942	-92,883	-92,136	-9548,878	-80,20095851	2
4835,564542	-91,912	-89,794	-9345,817	-77,30570124	3
4952,482141	-90,941	-87,452	-9142,756	-74,41044398	4
5069,39974	-89,97	-85,11	-8939,695	-71,51518672	5

The normalized level was made in range of -5 until 5, and then the parameter value at each grasp type range was divided by range of -5 until 5, so the value could serve as input in the membership function in range of -5 to 5. The membership function is presented in the following figure:



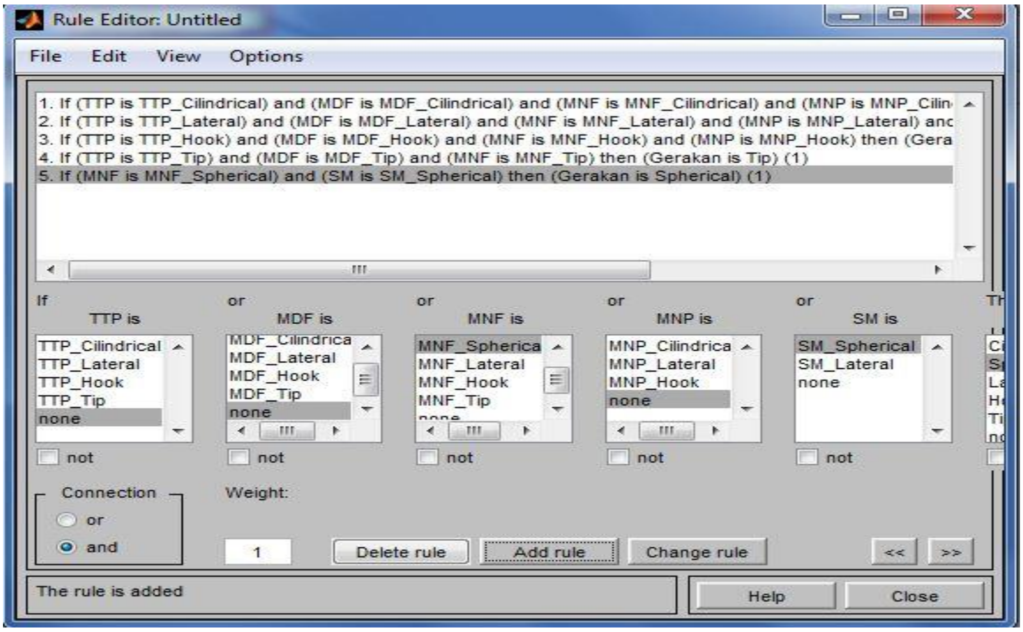
Current Variable
Name TTP
Type input
Range [-7 7]
Display Range [-7 7]

Current Membership Function (click on MF to select)
Name TTP_Cilindrical
Type trimf
Params [-2.5 1.241 4.5]

Selected variable "TTP"

Figure 4. Membership function parameters

The next step was to determine the rule that would be used in decision-making on fuzzy logic. In this step, the rule was created by selecting myoelectric signal parameters as input variables and grasping types as output variables. Decision was made based on the value of the parameters inputted into the model. The fuzzy logic rule is presented by the following figure. And the results of the fuzzy logic model is presented in Figure 6 in surface graphical form.



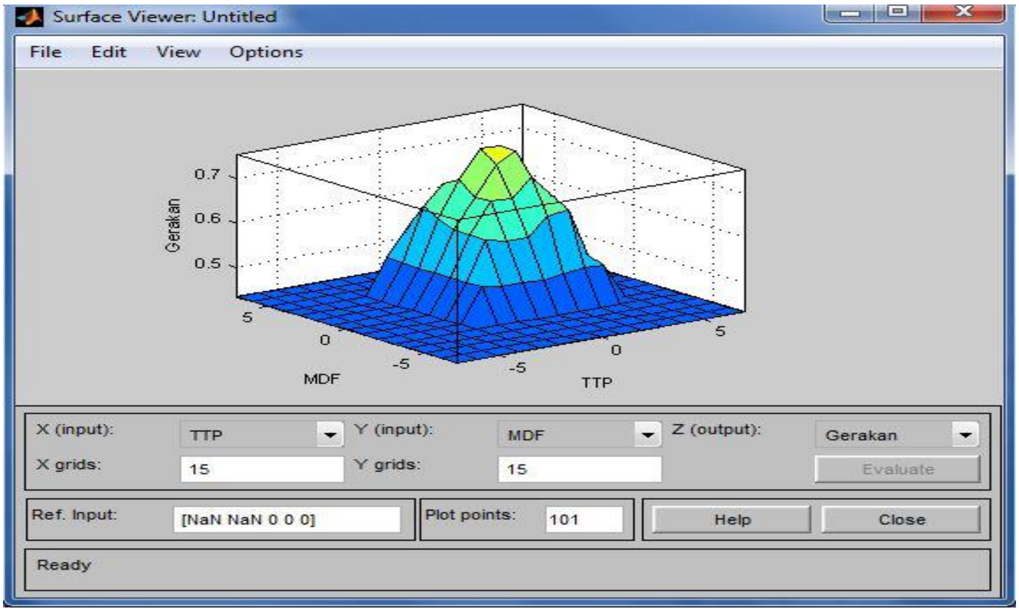
1. If (TTP is TTP_Cilindrical) and (MDF is MDF_Cilindrical) and (MNF is MNF_Cilindrical) and (MNP is MNP_Cilin
2. If (TTP is TTP_Lateral) and (MDF is MDF_Lateral) and (MNF is MNF_Lateral) and (MNP is MNP_Lateral) anc
3. If (TTP is TTP_Hook) and (MDF is MDF_Hook) and (MNF is MNF_Hook) and (MNP is MNP_Hook) then (Gera
4. If (TTP is TTP_Tip) and (MDF is MDF_Tip) and (MNF is MNF_Tip) then (Gerakan is Tip) (1)
5. If (MNF is MNF_Spherical) and (SM is SM_Spherical) then (Gerakan is Spherical) (1)

Connection
○ or
● and

Weight: 1

The rule is added

Figure 5. Fuzzy logic rule

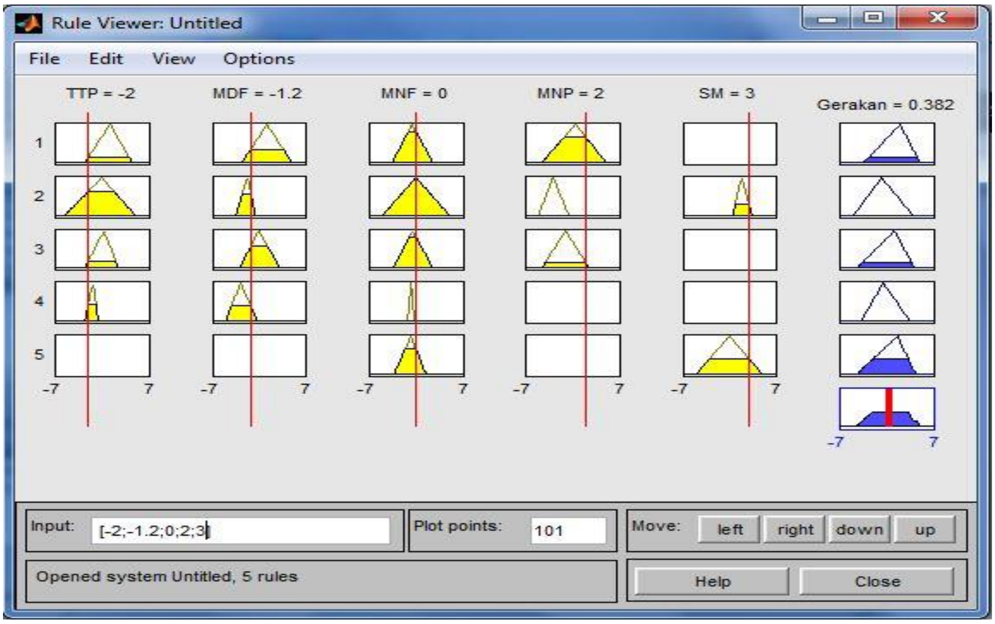


X (input): TTP
Y (input): MDF
Z (output): Gerakan
X grids: 15
Y grids: 15
Ref. Input: [NaN NaN 0 0 0]
Plot points: 101
Ready

Figure 6. Fuzzy logic surface graphics

3. Main Results

Fuzzy logic were made as a control system for classifying myoelectric signal parameters input and classifying those signals into basic grasping types. The grasping types could be determined by inputting signal parameters value obtained in the fuzzy logic model that has been created. Fuzzy logic model would then made a decision based on fuzzy logic rule and membership function on input variables and membership functions on output variable, so the model could classify the incoming signal parameters into the grasping types i.e. spherical, cylindrical, laeral, hook, or tip. The model testing is presented in the following figure:



Input: [-2;-1.2;0;2;3]
Plot points: 101
Opened system Untitled, 5 rules

Figure 7. Fuzzy logic rule viewer

Based on the figure above, the testing were conducted by inputting parameters with TTP parameter value of 2, MDF of 1.2, MNF of 0, MNP of 2, and SM of 3, then the model made a decision with value of 0.382. By observing the membership function on basic grasping could be determined that the value was classified as spherical, cylindrical, laeral, hook, or tip. However, the model still had difficulty in classifying the input signal parameters, because the parameter values on the membership function were still biased, so that the output results given by the model could not make a definite decision

4. Fuzzy Logic Testing

Testing is done by re-selecting as many as 12 respondents to the same criteria as the choice of respondents when collecting data. Respondents were asked to perform gripe cylindrical, spherical, hook, lateral and tip each move 6 times for each respondent. The data obtained is then converted in the form myoelectric signal parameters prior to the tests by using fuzzy logic model. Data parameters obtained encrypted and entered into a variable input on the control logic, the percentage of successful model of control logic is measured by how many times the model can recognize the input signal and mengklasifikasin into gripe types corresponding to the input value. Based on testing showed that of 360 times of testing, the model can only identify and classify types gripe as much as 60 times. So the success of the model in recognizing and classifying new types penggenggman 15-20%. Fuzzy logic testis is shown in table :

Table 4. Output results of model testing fuzzy logic control

Responden	TTP	MDF	MNF	MNP	SM	SM2	SM 3	Outout	Persentase (%)
Cilindrical	-3,5	1,5	1,5	0,5	4,5	-3,5	-4,5	Cilindrical	45:35:10:5:5
	-3,5	1,5	1,5	1,5	3,5	-4,5	-4,5	Spherical	45:35:10:5:5
	-0,5	1,5	1,5	0,5	2,5	-4,5	-4,5	Spherical	45:35:10:5:5
	-0,5	1,5	1,5	4,5	2,5	-4,5	-4,5	Spherical	45:35:10:5:5
	0,5	1,5	1,5	3,5	1,5	-4,5	-4,5	Spherical	45:35:10:5:5
	-3,5	1,5	1,5	2,5	2,5	-4,5	3,0	Spherical	45:35:10:5:5
Spherical	-2,5	-4,5	-5,0	-5,0	-2,5	-5,0	-5,0	Spherical	45:35:10:5:5
	-2,0	-4,5	-5,0	-5,0	-2,5	-5,0	-5,0	Spherical	45:35:10:5:5
	-2,5	-4,5	-5,0	-4,5	-2,5	-5,0	-5,0	Spherical	45:35:10:5:5
	-3,5	-4,5	-5,0	-4,5	-2,5	-5,0	-5,0	Spherical	45:35:10:5:5
	-3,5	-4,5	-5,0	-4,5	-3,0	-5,0	-5,0	Spherical	45:35:10:5:5
	-4,0	-4,5	-5,0	-4,0	-3,5	-5,0	-5,0	Spherical	45:35:10:5:5
Lateral	-2,5	-5,0	-5,0	-2,5	-3,0	-5,0	-5,0	Spherical	45:35:10:5:5
	-2,5	-5,0	-5,0	-2,5	-1,5	-5,0	-5,0	Spherical	45:35:10:5:5
	-2,0	-5,0	-5,0	-2,5	-2,0	-5,0	-5,0	Spherical	45:35:10:5:5
	-2,5	-5,0	-5,0	-2,5	-3,5	-5,0	-5,0	Spherical	45:35:10:5:5
	-3,0	-5,0	-5,0	-2,5	-3,0	-5,0	-5,0	Spherical	45:35:10:5:5
	-2,5	-5,0	-5,0	-2,5	-3,0	-5,0	-5,0	Spherical	45:35:10:5:5
Hook	-2,5	-5,0	-5,0	-2,0	-4,0	-5,0	-5,0	Spherical	45:35:10:5:5
	-2,5	-5,0	-5,0	-2,0	-3,5	-5,0	-5,0	Spherical	45:35:10:5:5
	-3,0	-5,0	-5,0	-3,0	-1,0	-5,0	-5,0	Spherical	45:35:10:5:5
	-2,5	-5,0	-5,0	-3,5	-1,5	-5,0	-5,0	Spherical	45:35:10:5:5
	0,5	-5,0	-5,0	-4,0	-3,5	-5,0	-5,0	Spherical	45:35:10:5:5
	-0,5	-5,0	-5,0	-4,0	-3,0	-5,0	-5,0	Spherical	45:35:10:5:5
Tip	-4,5	1,5	1,5	0,5	1,5	-4,5	-4,5	Spherical	45:35:10:5:5
	-4,5	2,5	1,5	0,5	1,5	-4,5	-4,5	Spherical	45:35:10:5:5
	-4,5	2,5	1,5	0,5	1,5	-4,5	-4,5	Spherical	45:35:10:5:5
	-4,5	2,5	1,5	0,5	1,5	-4,5	-4,5	Spherical	45:35:10:5:5
	-4,5	2,5	1,5	0,5	1,5	-4,5	-4,5	Spherical	45:35:10:5:5
	-4,5	2,5	1,5	0,5	1,5	-4,5	-4,5	Spherical	45:35:10:5:5

5. Conclusions

After analyzing the fuzzy logic that has been created, it can be concluded that:

1. Fuzzy logic is used in classifying types gripe at low cost anthropomorphic prosthetic hand has a ± 20% success rate in identifying mioelektrik signals and classifies them into motion cyilindrical, spherical, hook, lateral and tip.
2. Parameters used in the modeling were not enough, there should be additional parameters to repair the fuzzy logic model

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