Developing Fuzzy Inference System of the Observed Albireo Star's Trail using Surface Meteorological Parameter over ITERA Astronomical Observatory (IAO)

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Abstract

This study aims to develop Fuzzy Inference System (FIS) trail of star seeing over ITERA Astronomical Observatory (IAO) using surface meteorological parameter during site selection to develop observatory. The one-day surface meteorological observation such as Pressure (P), Temperature (T), and Humidity (H) and trail of Albireo (β Cyg) star seeing value was taken from Mt. Betung, Lampung, Indonesia. The surface meteorological data are analyzed to obtain Albireo (β Cyg) star seeing value in 3 to 4 August 2017. By using statistical method obtained the seeing value in daily variation of Albireo (β Cyg) star trail with surface meteorological as a predictor parameter. The standard error of estimate (S-Value) between predictor parameter (pressure and humidity) with Albireo star seeing are reached 0.0027543 in two days variation. Based on the result, the three Membership Functions (MFs) with Gaussian function was proposed in this study to develop FIS trail of star. The result shows that the configuration analysis from input parameter FIS with 15 role bases from surface meteorological parameter has successful to target with Albireo (β Cyg) star trail. The 15 role bases from FIS was used to estimate seeing value from meteorological parameter in near future.

Keywords: fuzzy inference system (FIS), surface meteorological parameter, and trail of albireo star

1. Introduction

Today, Fuzzy Inference System (FIS) was designed to support observatory site selection over ITERA Astronomical Observatory (IAO) Lampung, Sumatera in near future. IAO located in national park area over Taman Hutan Raya–Wan Abdurrahman (TAHURA-WAR) Mt. Betung, Lampung, Sumatera to capture trail of star. During observatory site selection, many observers had obstacles to capture trail of star such as wheather condition, beast, and observation facilities. Mountain forest area over Ancient Babylonian observational was choosen to reduce obstacles during observation trail of star [1]. Here, the observer could be safe during obtain the star trail from extreme weather. However, the surface meteorological parameter such as Pressure (P), Temperature (T), and Humidity (H) were reduced telescope performance during extreme weather [2, 3]. Thus, Skynet Robotic Telescope Network (SRTN) is recommended to capture trail of stars during extreme weather to improve performace astronomical conventional telescope [4, 5, 6]. In addition, the observation star trails cannot capture by robotic telescope during sky pollution [7, 8, 9]. The higest cost and risk to observe trail of star during sky pollution will be worthless. Furthermore, the statistical method to minimizing obstacle, cost, and risk during observatory site selection [10]. However, the statistical method cannot to minimizing obstacle, cost, and risk. To improve statistical method during minimizing obstacle, cost, and risk we use surface meteorological data. Here, the meteorological data e.g. P, T, and H data are used to minimize the obstacle, cost, and risk during observatory site selection. Thus, in this study we develop Fuzzy Inference System (FIS) as a tool to configure trail of star using P, T, and H data to minimize the obstacle, cost, and risk during observatory site selection.

Many researchers were used FIS application to controlling quadcopter in dynamical movement and optimization of tank irrigation System to improve conventional irrigation system [11, 12] due to FIS have the capability to develop the model with the highest accuracy [13, 14]. Thus, in this study the FIS development of trail Albireo (β Cyg) star using meteorological data were combined with Artificial Neural Network (ANN) in near future.

2. Metodology
2.1. Data and Location

ITERA Astronomical Observatory (IAO) located in Taman Hutan Raya–Wan Abdurrahman (TAHURA-WAR), Mt. Betung, Lampung, Sumatera, Indonesia with geographic coordinate 5.27°S, 105.09°E over 1030 mdpl. The surface topographyin Mt. Betung condition is good for observation activity to see star trails in 1030 mdpl due to clear of sky and near equatorial area. The star trails with highest resolution over Mt. Betung area could be obtain by many professional and amateur astronomer using conventional and digital telescope in near future. In order to develop Fuzzy Inference System (FIS), the surface meteorological data and trail of star was used as a predictor and targeted parameter, respectively. During observatory site selection, we use double star namely Albireo (β Cyg) star as an object to capture trail value. The Albireo (β Cyg) star have five characteristics function to obtain trail value (see Table 1). In this study, the Albireo (β Cyg) star was selected as a pointer to assess observatorium site selection during observatory site selection over Mt. Betung. This star Albireo (β Cyg) located over Cygnus astrological sign.

Table 1. Albireo (β Cyg) star characteristics function

No.	Parameter	Value
1.	RA	$19^h\ 31^m\ 26.8^s$
2.	Dec	27° 57' 34.7"
3.	m_v	3.35
4.	(B-V)	0.82
5.	Class Spectral	K2II

2.2 Data Processing

During observation activity, the trail of Albireo (β Cyg) star located in the North of horizon over Mt. Betung. The trail value or seeing function Albireo (β Cyg) is aperture telescope to be seen on various altitude in the sky over Albireo (β Cyg) star [15]. Here, the Albireo (β Cyg) star seeing function are configured with surface meteorological data to obtain S-Value. Table 2 shows configuration between Albireo (β Cyg) star seeing function and P, T, and H parameter [16].

Table 2. Configuration Albireo (β Cyg) Star Seeing Function and P, T, and H Parameter

No.	Predictor Parameter	Target parameter
1.	P	
2.	T	
3.	H	
4.	P and T	Albireo star seeing
5.	P and H	
6.	T and H	
7.	$P, T,$ and H	

After configured with seven input parameters and one output, the best S-value result from paired parameter (predictor and target parameter) was chosen to develop Membership Functions (MFs) using gaussian function. Here, we choose three MFs condition over Gaussian function based on characteristics for each predictor and target parameter. Table 3 shows configuration MFs predictor and target parameter using Gaussian function over FIS Albireo (β Cyg) star seeing.

Table 3. Configuration MFs Predictor and Target Parameter over FIS
Albireo (β Cyg) Star Seeing

No.	Parameter	MFs FIS
1.	*P*	Low
		Normal
		High
2.	*T*	Cold
		Warm
		Hot
3.	*H*	Dry
		Dampy
		Moist
4	Albireo star seeing	Low
		Normal
		High

As can be seen in Table 3, the three condition MFs FIS of Albireo (β Cyg) star seeing was applied in this study. The three condition MFs FIS of Albireo (β Cyg) star seeing based on turbulace over atmosphere [17, 18]. The turbulence event over atmosphere are caused by climate area (cloud system) and surface meteorological parameter [19]. Thus, during develop MFs FIS Albireo (β Cyg) star seeing using *P*, *T*, and *H* parameter, we have four steps to obtain the result such as preparation step, processing data (P, T, H and tail seeing value), integrated parameter data, and validation (see Figure 3).
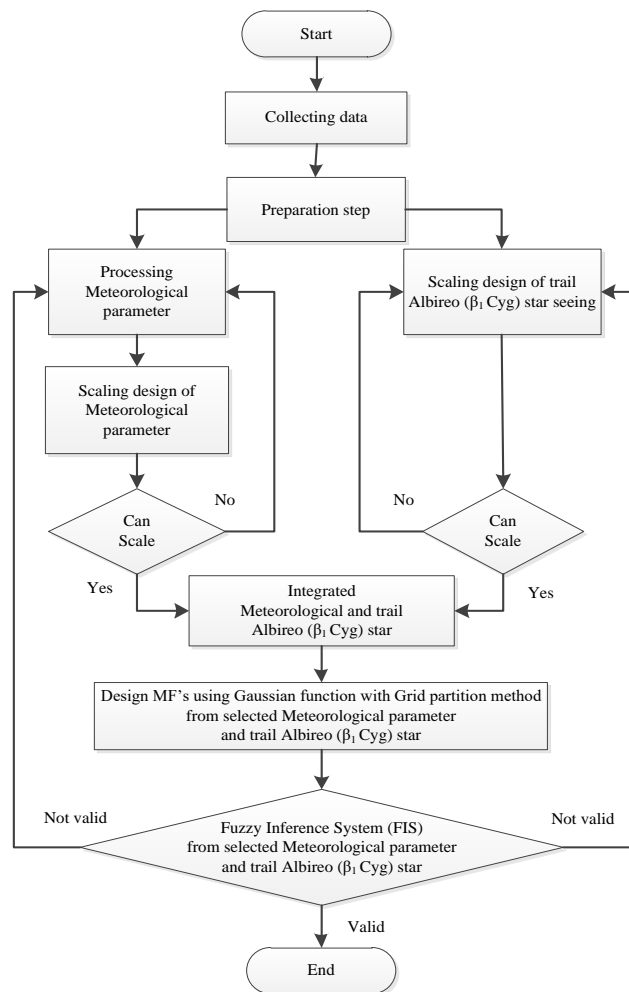

Figure 3. Flowchart developing MFs FIS Albireo (β Cyg) star seeing
using *P*, *T*, and *H* parameter.

3. Results and Discussion

In order to achieve the objective, we analyse all the parameter taken from observation over Taman Hutan Raya–Wan Abdurrahman (TAHURA-WAR), Mt. Betung, Lampung, Indonesia. During trail observation Albireo (β Cyg) star seeing, the Albireo (β Cyg) star trail is captured using Meade atlitude azimuth telescope over 3 to 4 August 2017 while local surface condition is cloudy. Figure 4 shows the trail observation of Albireo (β Cyg) star seeing using Meade atlitude azimuth telescope.

Figure 4. The trail of Albireo (β Cyg) star seeing using Meade atlitude azimuth telescope in 3 to 4 August 2017 over IAO, Lampung, Sumatera, Indonesia.

Figure 4, the first and second line of Albireo is β_1 and β_2 Cyg observation star, respectively. During observation site selection, we use Albireo star β_1 Cyg as a star pointer to analyze the best seeing value. In this study, the processing star image analysis called Image Reduction and Analysis Facilities (IRAF) was used to reduce noise from meade telescope (RC telescope) [20]. We use IRAF software in Fortran to analyze star image over Ubuntu, Linux platform. The Gocherman method is used to obtain trail direction in x-axis or seeing value in the Albireo star [21]. Figure 5 shows the result of third order polynomial curve fitting seeing value.
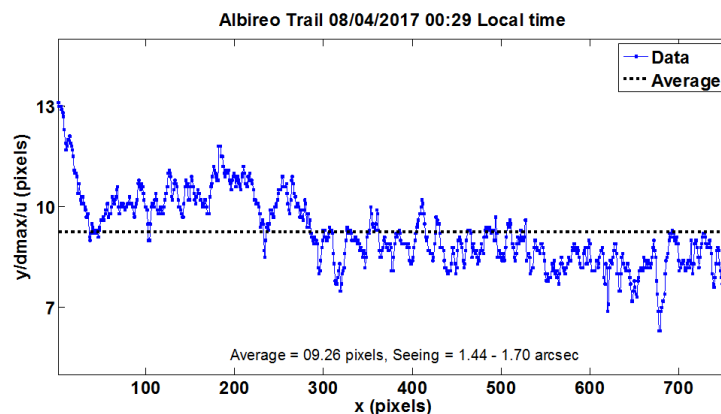

Figure 5. The result of processing trail of Albireo (β_1Cyg) star seeing observation using IRAF software in Fortran platform.

Based on the result, we obtain average pixel 9.26 with seeing value of trail Albireo (β_1 Cyg) star 1.44 to 1.70 arcsec in processing data session. In order to support Membership Functions (MFs) trail Albireo (β_1Cyg) star development, we use P, T, and H parameter data in two days observation from TAHURA-WAR, Mt. Betung, Lampung, Indonesia. Here, a

per-minute resolution data was performed in this study during collecting P, T, and H parameter over TAHURA-WAR, Mt. Betung, Lampung, Indonesia (see Figure 6).
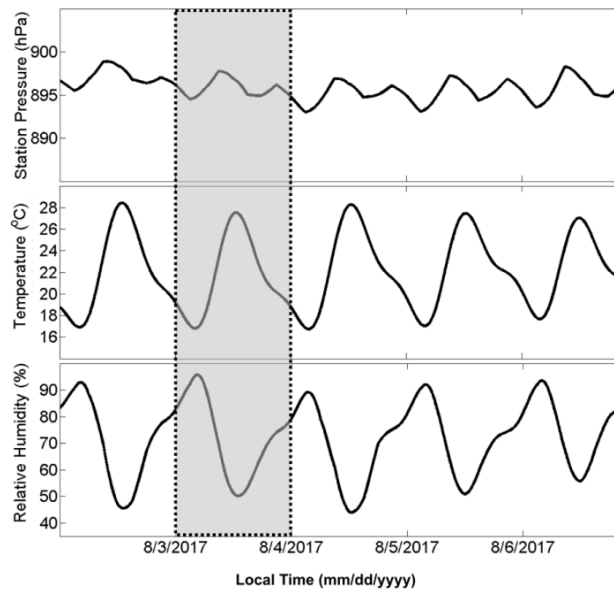

Figure 6. Daily variation of P, T, and H parameter over TAHURA-WAR, Mt. Betung, Lampung, Indonesia over 3 to 6 August 2017.

As can be seen in Figure 6, the daily variation of P, T, and H parameter taken from the nearest ground station over TAHURA-WAR, Mt. Betung, Lampung, Indonesia (elevation 1030 mdpl) is used in this study. The grey mark shows the surface meteorology condition during observation trail Albireo (β_1 Cyg) star. Here, the surface meteorology condition during observation trail Albireo (β_1 Cyg) star are mist and cloudly with P, T, and H parameter 897 hPa, 18°C, and 89%. After all the P, T, and H parameter obtained, we develop FIS using Gaussian function from selected parameter [22, 23]. Here, we assess seven-predictor parameters to obtain S-Value (see Table 4).

Table 4. Assessment S-Value between Predictor and Target Parameter

S-Value	Predictor Parameter	Target parameter
0.0029120	P	
0.0029821	T	
0.0030357	H	
N/A	P and T	Albireo star seeing
0.0027543	P and H	
N/A	T and H	
N/A	P, T, and H	

As can be seen in Table 4, the assessment result from S-Value between predictor and target parameter was performed in this study. Based on the result, we found N/A value from three configurations due to temperature parameter cannot calculate to obtain S-Value. However, pressure and relative humidity parameters have a good predictor parameter with 0.0027543S-Value while the single configuration (*P*, *T*, and *H*) have poor result as a predictor parameter. Based on the result, we choose pressure and relative humidity (configuration five) as a predictior parameter and targeted with trail Albireo (β_1Cyg) star. In order to design FIS from MFs we use scalling method [24, 25]. Table 5 shows the lowest and higest seeing parameter was assesed based on reference from specific point over Mt. Wilson observatory, Canada.

Table 5. Seeing Value, MFs Status, and Visual Reference over
Mt. Betung, IAO, Lampung, Sumatera, Indonesia.

Seeing (arcsec)	MFs status	Visual reference
0.1818	Low	Image sharp
0.2424		and motionless
0.3029		
0.3635		
0.4241		
0.4847		
0.5453	Normal	Image sharp
0.6059		and sight motion
1.2118		
1.8176		
2.4235	High	Image soft
3.0294		and blurred
3.6353		

As can be seen in Table 5, the three MFs status trail Albireo (β_1 Cyg) seeing stars are used in this study. The blue, gray, and red marking color of MFs status is represented the trail Albireo (β_1 Cyg) seeing stars condition. Furthermore, the selected configuration (pressure and relative humidity parameter) was scalled based on characteristic Mt. Betung, IAO, Lampung, Sumatera, Indonesia to evaluate trail Albireo (β_1 Cyg) seeing stars condition (see Table 6).

Table 6. Scale of Characteristic Surface Meteorological Parameter
over Mt. Betung, IAO Sumatera, Indonesia.

Parameter	MFs status	Value
P	Low	< 900
	Normal	800 ~ 750
	High	> 750 hPa
H	Dry	< 70%
	Dampy	70 ~ 80%
	Moist	> 90%

As can be seen in Table 6, the characteristic surface meteorological parameter has scaled become to three conditions. Here, the three MFs status of pressure and relative humidity parameter was scaled during FIS development over Mt. Betung, IAO, Lampung, Sumatera, Indonesia. Furthermore, the selected configuration parameter pressure, relative humidity, and trailAlbireo (β_1 Cyg) star parameter over Mt. Betung, IAO, Lampung, Sumatera, Indonesia. In addition, the MFs structure of pressure, relative humidity, and seeing parameter over Mt. Betung, IAO, Lampung, Sumatera, Indonesia is showed in Figure 7.
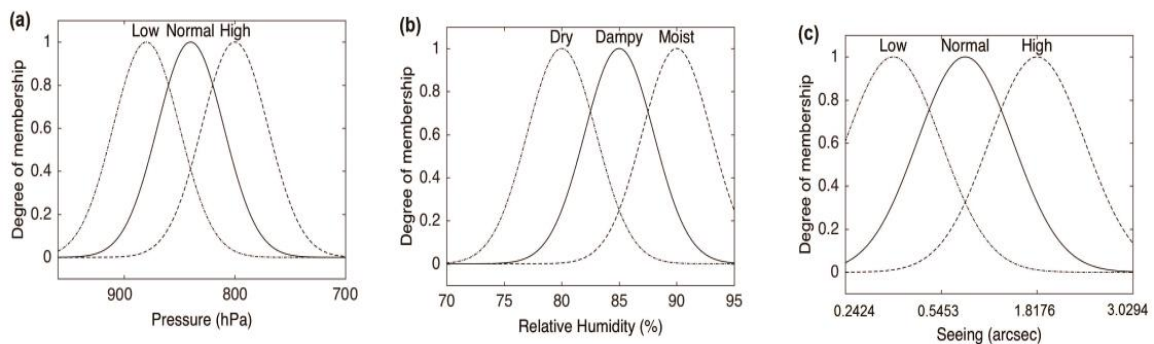

Figure 7. MFs structure of (a) pressure, (b) relative humidity, and
(c) seeing over Mt. Betung, IAO, Lampung, Sumatera, Indonesia.

Figure 7 shows the degree of membership function pressure, relative humidity, and seeing was constructed using Gaussian function. This function was choosed based on data characteristic pressure, relative humidity, and seeing each parameter status. In order to obtain seeing value, we develop role base between input and target parameter based on supervision astronomers and meteorologist experience. This supervision will be embedded over role base fuzzy logic in the next studies by ITERA Astronomical Observatory (IAO) reseach group. Around 15 role bases with two input parameter and one target parameter was developed to obtain potential seeing parameter from pressure and relative humidity parameter. In validation process, seeing parameter from Fuzzy Logic will be compared by local observation. Thus, we can minimize the obstacle, cost, and risk during observatory site selection in near future. Finally, we successful developing FIS seeing value from surface meteorology parameter to support observatory site selection.

4. Conclusion

The development Fuzzy Inference System (FIS) using sugeno type was successfully carried out to support observatory site selection over over Mt. Betung, IAO, Lampung, Sumatera, Indonesia. The configuration method was successful performed in this study to obtain pairing data between input and target parameter on FIS development. In this study we found the configuration of surface meteorological data e.g. pressure and relative humidity and Albireo (β_1 Cyg) trail data as a input and target parameter, respectively. By using observation data, we obtained the data to design FIS. During development FIS, we have 15 role bases to assess seeing value based on pressure and relative humidity with trail Albireo (β_1 Cyg) star 1.44 to 1.70 arcsec (Image resolution is sharp and sight motion). Finally, the FIS seeing value was developed to support observation site selection and we suggested the FIS seeing value as a seeing model using surface meteorological in the next studies.

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