MONASH University
Engineering

Assessment cover sheet

Unit and student details					
Unit code	TRC 4901	**Unit title**	Artificial Intelligence		
If this is a group assignment, each student must include their name and ID number and sign the student statement.					
Student ID	29392004	**Surname**	Ranjan	**Given names**	Rivyesch
Student ID		**Surname**		**Given names**	
Student ID		**Surname**		**Given names**	
Student ID		**Surname**		**Given names**	

Assessment details			
Title of assignment /lab	Lab 1 - Experiment on weather forecasting using fuzzy logic system	**Authorised group assignment**	Yes ☐ No ☑
Lecturer/tutor	Dr. Parasuraman	**Tutorial day and time**	Wednesday 8 am
Due date	31/03/2021	**Date submitted**	27/03/2021
Has any part of this assessment been previously submitted as part of another unit/course?			Yes ☐ No ☑

Submission date and extensions

All work must be submitted by the due date. If an extension of work is required, please complete and submit a Special Consideration application (in-semester assessment task) form to your examiner/lecturer/tutor.

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Student signature	Rivyesch Ranjan	**Date**	22/03/2021
Student signature		**Date**	
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1.0 Introduction

Weather forecasting is the application of science and modern-day tools to predict the ever-changing state of the atmosphere for a future time at a specific location. Its goal is to reduce weather-related losses and enhance social benefits. With the information that is provides to people and organisations, protection of life and property, safety, and support of economic prosperity and quality of life is significantly improved [1].

With the advancement of technology and greater availability of data in recent years, there have been increased interest in artificial intelligence models. These techniques have enormous potential and have been proven through various research studies to have significantly improved performance capabilities. A research conducted estimates the annual benefit of reliable and accurate weather forecast model is about $31.5 billion, compared to the $5.1 billion cost of generating the information [2].

The objective of this lab is to understand the working of a fuzzy logic system and become proficient in designing a fuzzy logic system for a weather forecast application. This simulation is to be done using the Fuzzy Logic Toolbox on Matlab with the help of its GUI tools. For this lab study, the simulation for both cases uses the weather data of Chicago O'hare in August 1989. The data used has a resolution of one hour, hence the data set has 744 rows consisting of three columns with the variables of interest.

2.0 Preliminary Studies

The data in the dataset of interest is plotted in the figure below to visualise the trends and extract important information. The plot indicates that the dew point and relative humidity are directly proportional whereas the dew point has an inversely proportional relationship with relative humidity. The theory is that when both dew point temperature and dry bulb temperature are relatively close to each other in values then the relative humidity is relatively high [3]. As the temperature difference between the dew point and dry bulb increases, the relative humidity decreases. This theory is supported by the figure 1 below.

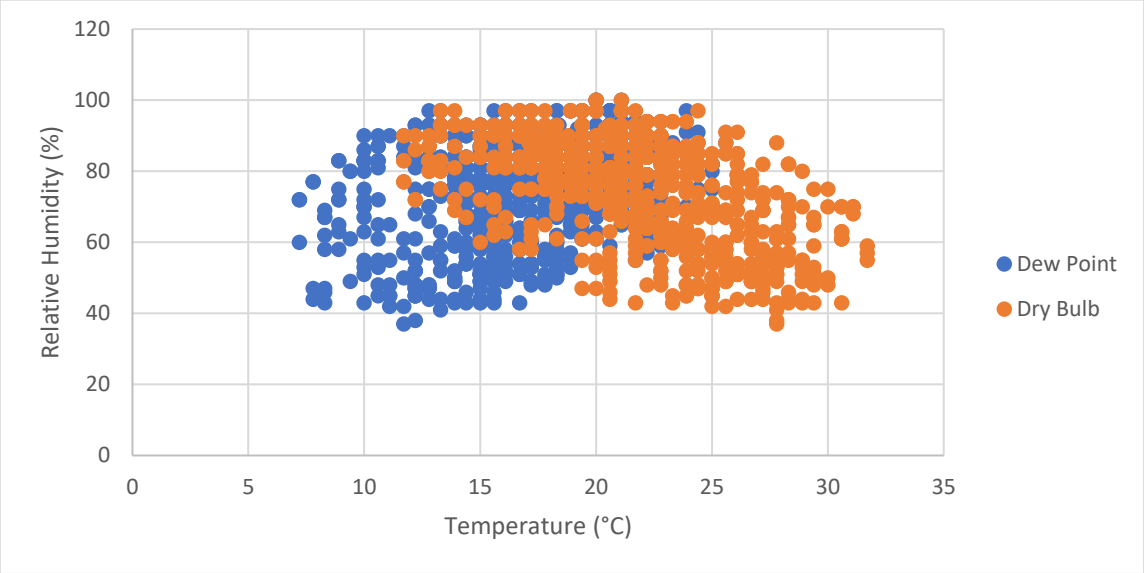

Figure 1: Plot of Relative Humidity against Temperature for August 1989

Table 1: Important Statistical Information from Dataset

	Min	Max
Dry Bulb Temperature (°C)	11.7	31.7
Dew Point Temperature (°C)	7.2	25.6
Relative Humidity (%)	37	100

3.0 Methodology

Each input and output use five membership functions to achieve an acceptable mapping between the inputs and output. All membership functions were of triangular type and the parameters which are shown below for each input and output have been tuned through a trial-and-error iteration process until a desirable accuracy is achieved.

After the membership functions are specified, the next step is to define the fuzzy rules for the Fuzzy Inference System (FIS). Since each input consisted of five unique membership functions a maximum of 25 possible rules can be created to define the FIS. However, due to the nature of the data not all relationships are valid and realistic. Hence, a total of 23 rules are used to fully define the system for both case A and case B.

The rules are defined base on the trends observed from the plotted data in figure 1. Based on the theory mentioned in section 2.0 above, a unique Karnaugh table is constructed for each case to better visualise the rules and the relationships between the inputs and output. Then a 3D surface plot is generated which shows a representation of all the rules defined to create the fuzzy system.

There are various defuzzification methods that are available for use in the toolbox. For this lab all simulations make use of the centroid technique for defuzzification, which happens to be one of the most popular technique. This technique returns the centre of gravity (COG) of the fuzzy set along the x-axis. At the COG point found the fuzzy set would balance.

The MATLAB code written to simulate the data using fuzzy logic system can be found in appendix 8.5.

4.0 Case Study A

The first case study takes in historical data of the dew point temperature and dry bulb temperature as the two inputs and relative humidity as an output for the training of the model. The model's performance is then evaluated by comparing the simulated output with the real output from the dataset.

4.1 Rule Evaluation

The rules defined for the simulation of Case A has been summarised in table 5 below. The reasoning behind the choices made for the rules have been briefly discussed in section 3.0 above. These rules seen are the optimal choices that has been determined through a trial-and-error basis.

The rules in table 2 can also be viewed in the form of a surface plot. On careful inspection of figure 2, the trend of the 3D plot matches that of the theory. The plot is affected by the shapes of the membership functions and the rules of the fuzzy system.

Table 2: Case A Karnaugh Map for Relative Humidity

		Dry Bulb Temperature (°C)				
		Very Cold	Cold	Moderate	Warm	Hot
Dew Point Temperature (°C)	Very Cold			Very Low	Very Low	Very Low
	Cold	Very High	Medium	Low	Very Low	Very Low
	Moderate	Very High	High	Medium	Low	Very Low
	Warm	Very High	Very High	High	Medium	Low
	Hot	Very High	Very High	Very High	High	Medium

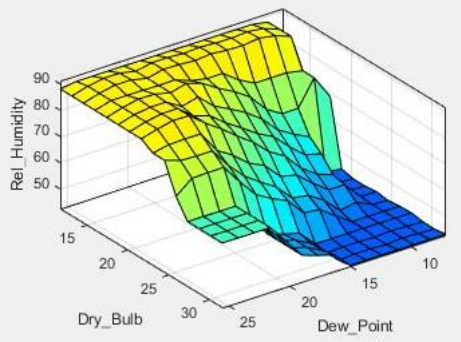

Figure 2: 3D Surface Plot of FIS Rules for Case A

4.2 Results

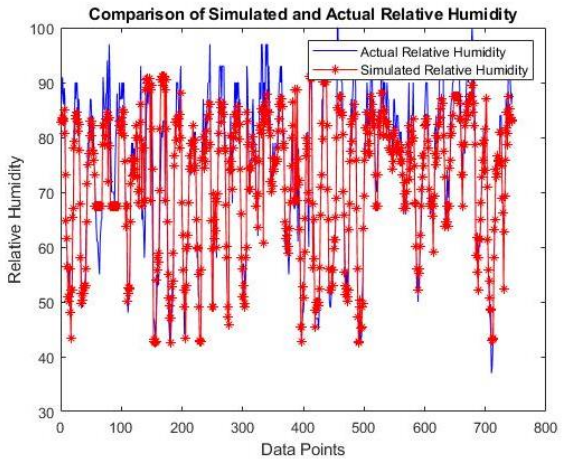

Figure 3: Comparison Graph of Simulated and Actual Relative Humidity for all Data Points

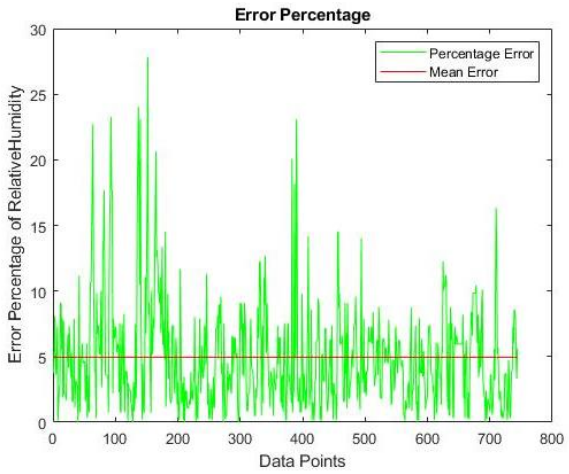

Figure 4: Plot of Error Percentage for all Data Points

4.3 Discussion

Iteratively tuning and optimising all membership function parameters of the inputs and the output, and modifying the rules defined, reduced the average error of the fuzzy logic system. The optimised parameters can be viewed in tables 6 to 8 along with the corresponding membership parameters in figure 8 to 10. This meant that there was less difference between the actual and predicted values of relative humidity. Hence, the accuracy and reliability of the forecasted values of relative humidity is improved.

The system designed has an average error of 4.9471 and is capable of making fairly accurate predictions. Figure 4 shows the error percentage of output for every data point used in the simulations. Majority of the high spikes correspond to the rows of data with high relative humidity values. The maximum error of the fuzzy system is determined to be 27.8489 while the smallest error is a mere 0.00033335.

Figure 3 above illustrates the simulated and actual data of relative humidity. This figure provides evidence of the accuracy of the system as it can be seen that the simulated curves follow the trend of the actual curve. The difference between the simulated relative humidity and actual relative humidity is especially accurate for low to high relative humidity data values. The reason for the error of 4.9471 is mainly due to the systems failure to make accurate predictions at extremely high relative humidity values. Figure 3 reinforces this statement where it can be clearly seen that the fuzzy logic system consistently underestimates the relative humidity. Nevertheless, an accuracy of more than 95% is more than acceptable for weather applications as it is almost impossible to create a perfect model since weather is highly stochastic in nature and dependent on a wide variety of variables.

4.4 Case Study Investigation

The following data points were randomly selected from the data set. The dry bulb temperature and dew point temperature were entered into the Fuzzy Inference Simulation as inputs to generate and determine the corresponding relative humidity. The rule viewer for each of these three cases can be viewed in the appendix under section 8.1 in figure 12 to figure 14.

Table 3: Comparison between Actual and Predicted Relative Humidity for Random Rows of the Dataset

Case No.	Row	Actual Relative Humidity (%)	Simulated Relative Humidity (%)	Percentage Difference (%)
Case 1	94	76	75.8	0.263
Case 2	183	45	47.2	4.889
Case 3	354	88	67.5	23.295

5.0 Case Study B

The methodology used is exactly the same as that discussed in section 3.0. The only major difference is that here the two inputs used are relative humidity and dry bulb temperature, and the output is the dew point temperature. Tables 9 to 11 and figures 15 to 17 in the appendix correspond to the optimised model.

5.1 Rule Evaluation

The rules used here are summarised in table 4. They were determined by examining the dataset and then making slight modifications until a satisfactory error is obtained. Figure 5 shows the combination of the rules and the membership functions in a visual form.

Table 4: Case B Karnaugh Map for Relative Humidity

		Dry Bulb Temperature (°C)				
		Very Cold	Cold	Moderate	Warm	Hot
Relative Humidity (%)	Very Low	Very Cold	Very Cold	Very Cold	Cold	Moderate
	Low	Very Cold	Very Cold	Cold	Moderate	Warm
	Medium	Very Cold	Cold	Moderate	Warm	Hot
	High	Very Cold	Moderate	Warm	Hot	
	Very High	Very Cold	Moderate	Warm	Hot	

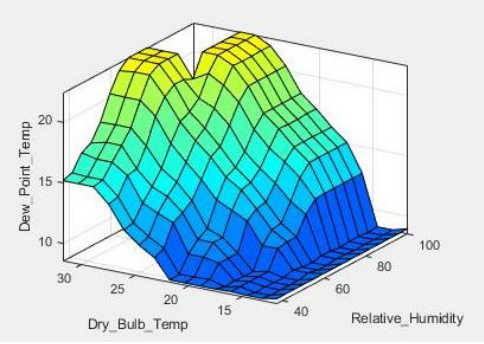

Figure 5: 3D Surface Plot of FIS Rules for Case B

5.2 Results

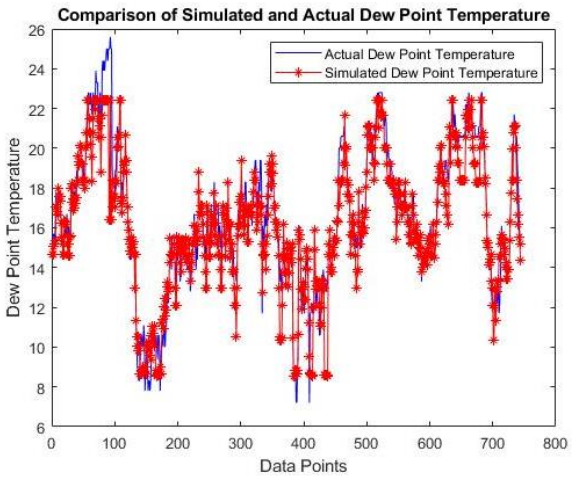

Figure 6: Comparison Graph of Simulated and Actual Dew Point Temperature for all Data Points

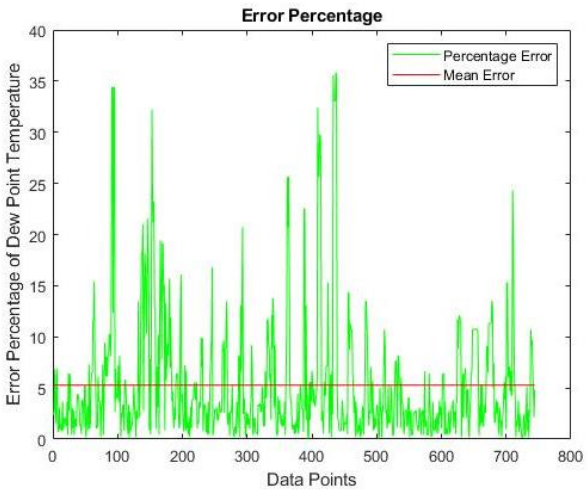

Figure 7: Plot of Error Percentage for all Data Points

5.3 Discussion

Numerous trial-and-error iterations were done to tune and optimise the overall fuzzy logic system. After optimisation the average error was 5.2706. The maximum error read is 35.8329 while the smallest error is only 0.0530. This average error was deemed satisfactory to the point that the system can reliably provide accurate predictions most of the time. The accuracy of this system for Case B is more than 94 % accurate.

Referring to figure 6 it is clear that the simulated plot closely follows the trend of the actual data. In fact, for most ranges of dew point temperatures the simulation is able to provide an accurate prediction. It is only at the extremities at either end that the simulation tends to underestimate the value of dew point temperature and these are represented by the sharp spiked in figure 7.

5.4 Case Study Investigation

The following data points were randomly selected from the data set. The rule viewer for each of these three cases can be viewed in the appendix under section 8.2 in figure 20 to figure 22. Also, a sample calculation of the percentage difference can be found in the appendix under section 8.4.

Table 5: Comparison between Actual and Predicted Dew Point Temperature for Random Rows of the Dataset

Case No.	Row	Actual Dew Point Temperature (°C)	Simulated Relative Humidity (°C)	Percentage Difference (%)
Case 1	388	8.9	8.84	0.674
Case 2	232	14.4	15.8	9.722
Case 3	67	22.8	21.5	5.702

6.0 Conclusion

In conclusion, the weather was successfully used to train two separate fuzzy logic systems to predict the relative humidity and dew point temperature respectively. The mean error of both systems was of a satisfactory level, with the first and second system having an error of 4.9471 and 5.2706 respectively. These systems have both been optimised by adjusting each of the five membership functions belong to each input and output through a trial-and-error method. An improvement in the accuracy of both systems could be achieved through the introduction of more membership function to define the data of the input and output. Finally, weather is usually dependent on many factors beyond just the relative humidity, dew point temperature and dry bulb temperature which have been used as historical data in the two systems [4]. Using additional variables that have strong correlation might very well improve the forecasting accuracy even more.

7.0 References

[1] *Satellite observations of the Earth's environment*. Washington, D.C.: National Academies Press, 2003, p. 29.

[2] When weather matters. Washington, D.C.: National Academies Press, 2010, p. 1.

[3] Dry bulb -, wet bulb - and dew point temperatures", engineeringtoolbox.com, 2017. [online]. available: http://www.engineeringtoolbox.com/dry-wet-bulb-dew-point-air-d_682.html.

[4] N. Society, "weather", *National Geographic Society*, 2021. [Online]. Available: https://www.nationalgeographic.org/encyclopedia/weather/. [Accessed: 25- Mar- 2021].

8.0 Appendix

8.1 Case A

Table 6: Parameters for Input 1

Linguistic Variable	Linguistic Value	Numerical Range
Dry Bulb Temp	Very Cold	10.95°C-17.45°C [10.95 13.95 17.45]
	Cold	14.69°C-21.19°C [14.69 17.69 21.19]
	Moderate	18°C-25°C [18 21 25]
	Warm	21.83°C-27.1°C [21.83 24.9 27.1]
	Hot	25.59°C-33.1°C [25.59 29.9 33.1]

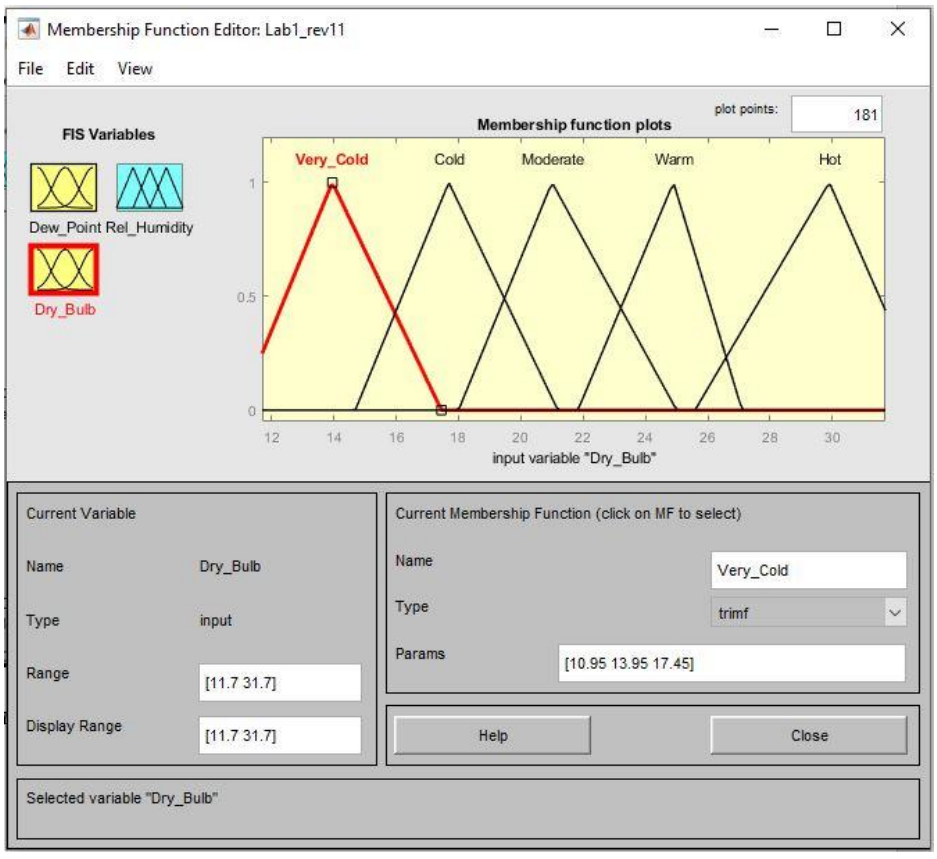

Figure 8: Membership Functions for Dry Bulb Temperature

Table 7: Parameters for Input 2

Linguistic Variable	Linguistic Value	Numerical Range
Dew Point Temp	Very Cold	0°C-11°C [0 7 11]
	Cold	8.5°C-14.38°C [8.5 11.1 14.38]
	Moderate	11.8°C-18.66°C [11.8 15 18.66]
	Warm	15.1°C-21.49°C [15.1 18.6 21.49]
	Hot	19.1°C-25.8°C [19.1 22.4 25.8]

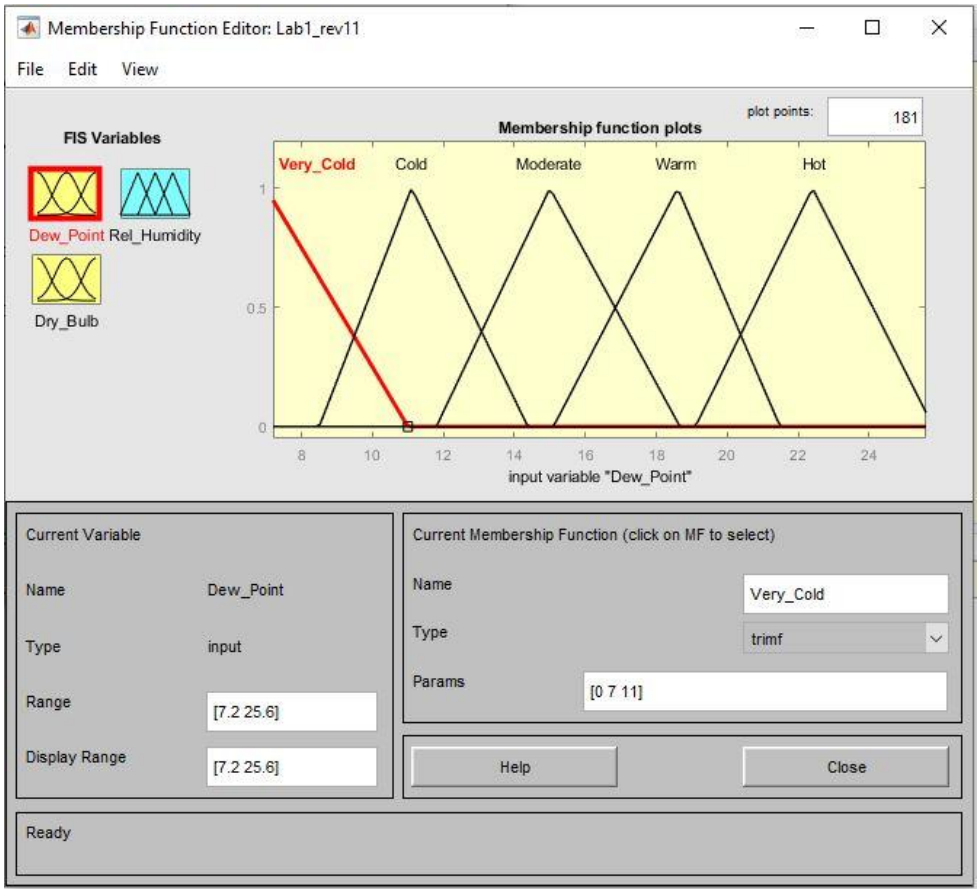

Figure 9: Membership Functions for Dew Point Temperature

Table 8: Parameters for Output

Linguistic Variable	Linguistic Value	Numerical Range
Relative Humidity	Very Low	30%-52% [30 41 52]
	Low	41%-65% [41 53 65]
	Medium	55%-80% [55 67.5 80]
	High	70%-93.8% [70.3 82.42 93.8]
	Very High	75.42%-110% [75.42 95.6 110]

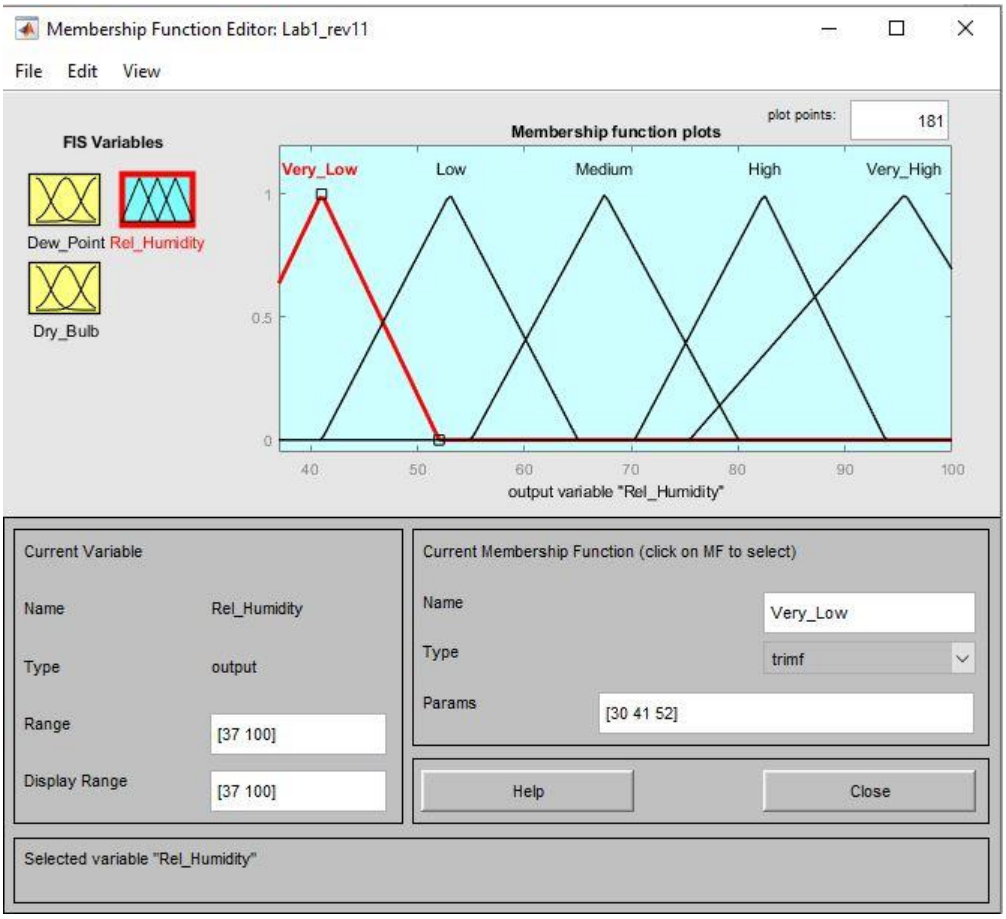

Figure 10: Membership Functions for Relative Humidity

Figure 11: Membership Function Rules

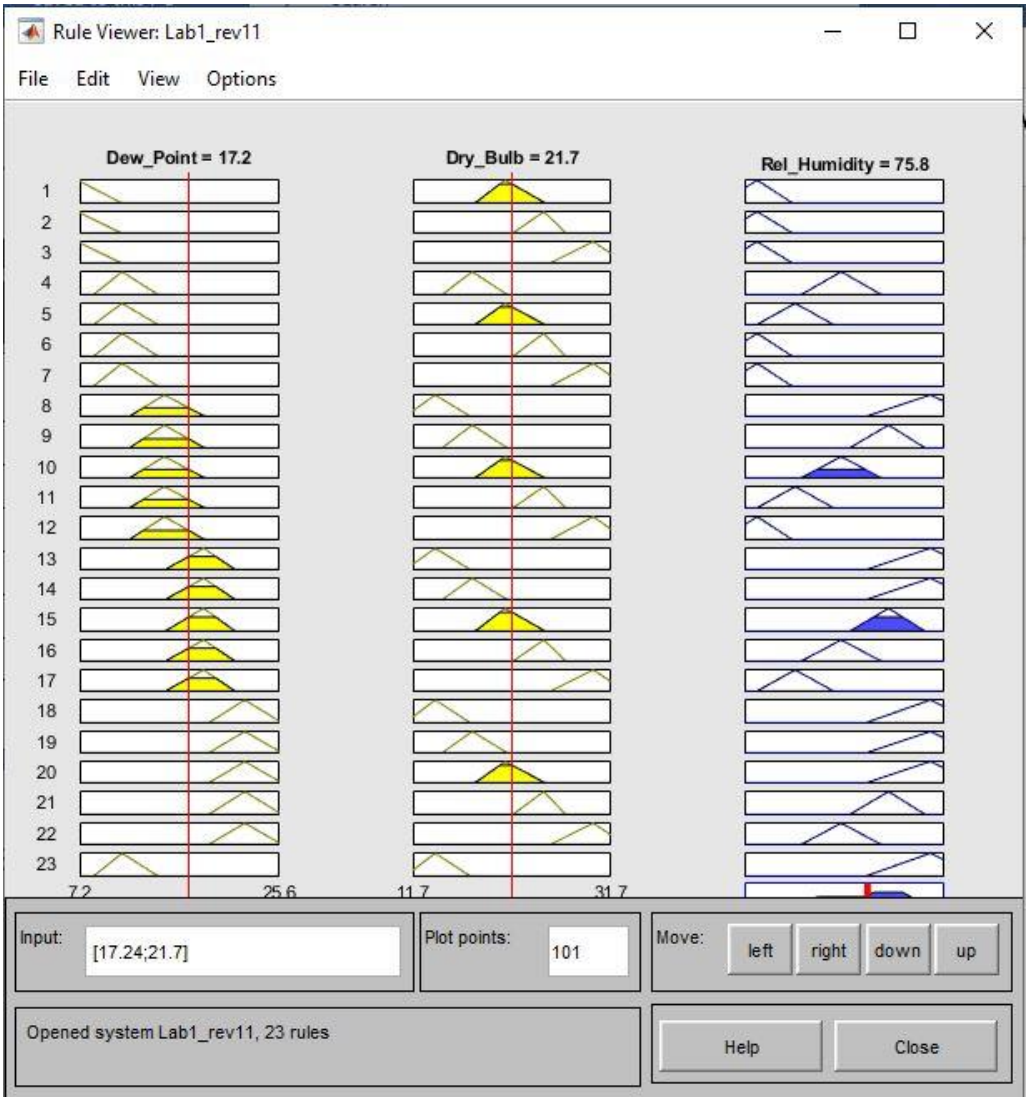

Figure 12: Rule Viewer Results for Case Study 1

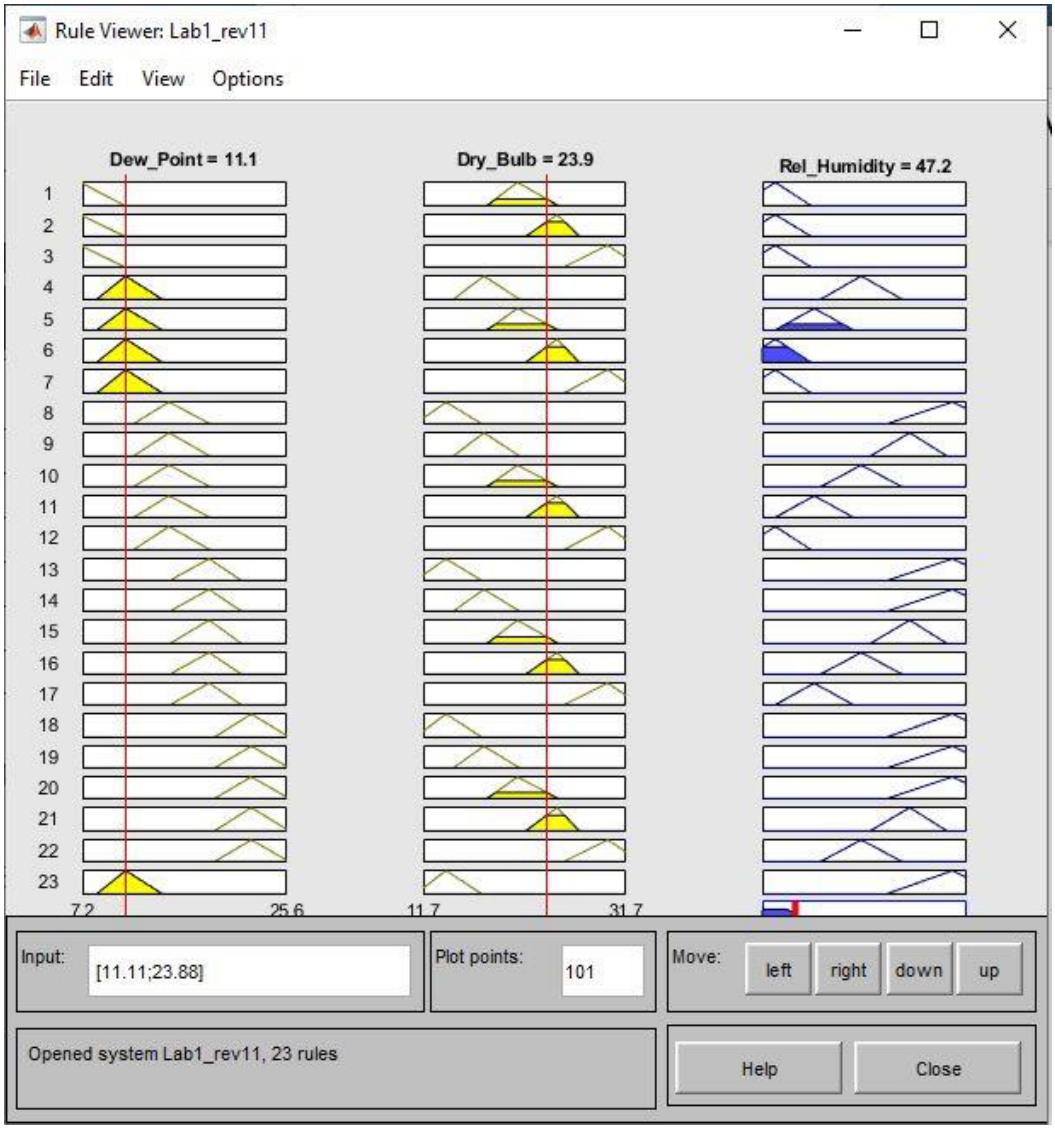

Figure 13: Rule Viewer Results for Case Study 2

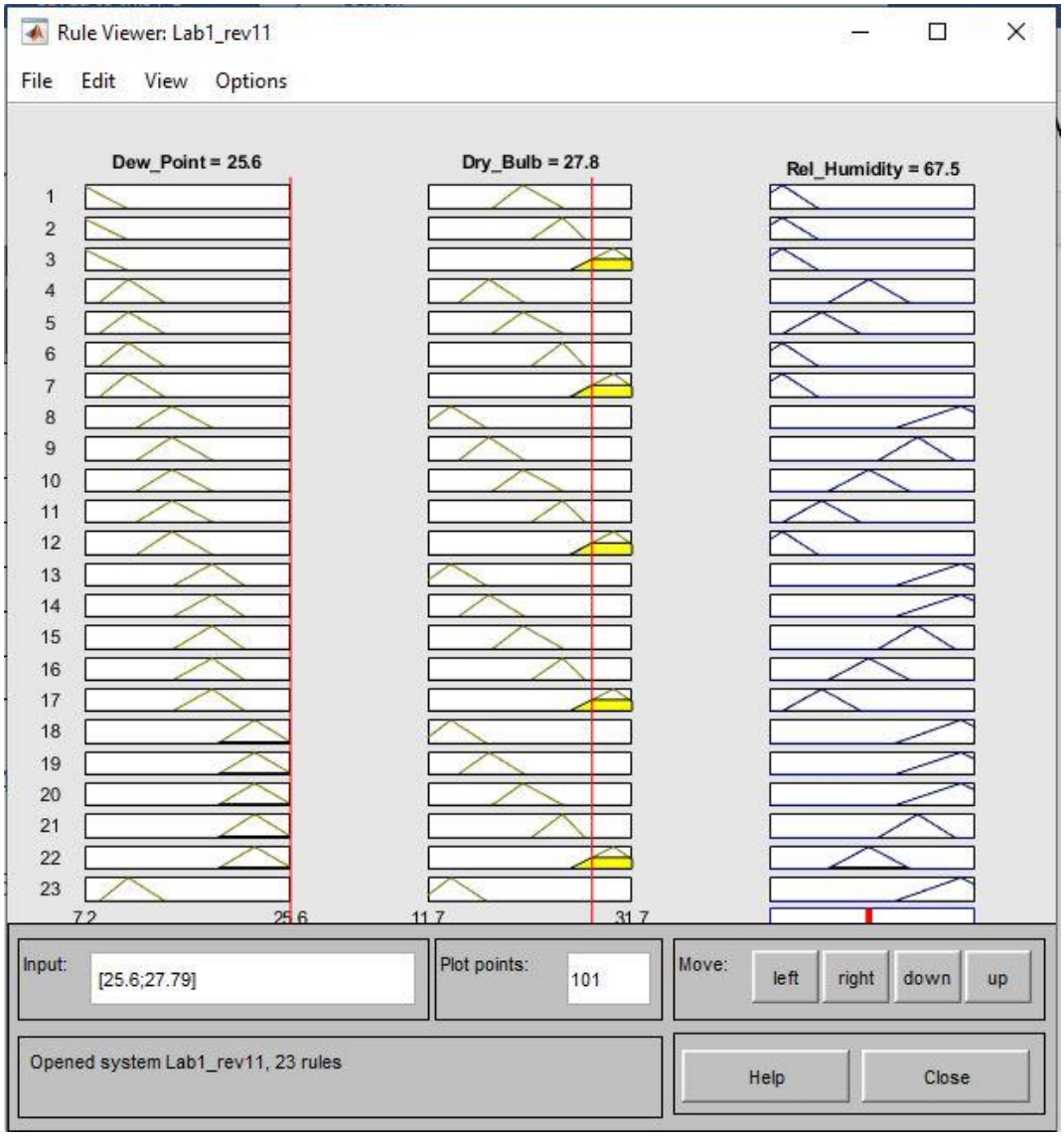

Figure 14: Rule Viewer Results for Case Study 3

8.2 Case B

Table 9: Parameters for Input 1

Input 1		
Linguistic Variable	Linguistic Value	Numerical Range
Dry Bulb Temp	Very Cold	10.95°C-17.45°C [10.95 13.95 17.45]
	Cold	14.69°C-21.19°C [14.69 17.69 21.19]
	Moderate	18°C-25°C [18 21 25]
	Warm	21.8°C-28.18°C [21.8 24.9 28.18]
	Hot	25.59°C-33.1°C [25.59 29.9 33.1]

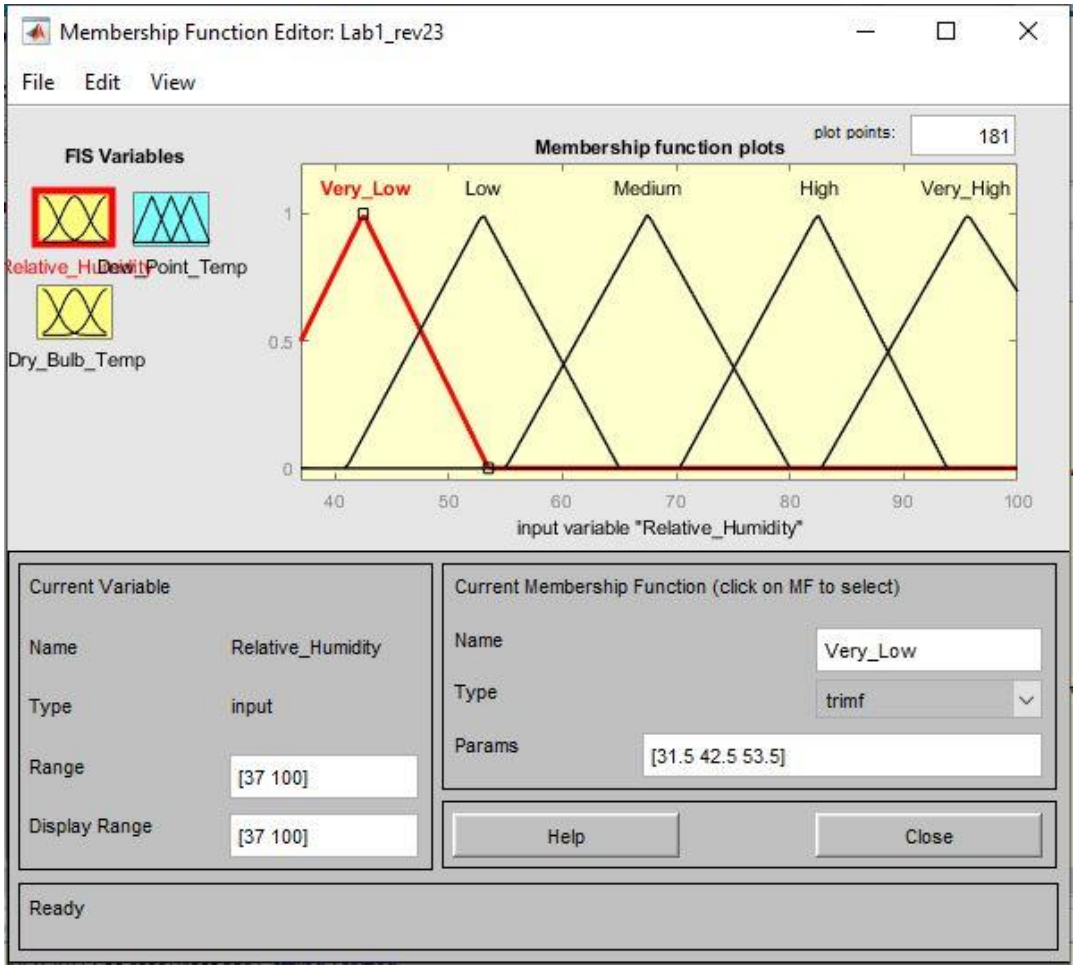

Figure 15: Membership Function for Relative Humidity

Table 10: Parameters for Input 2

Input 2		
Linguistic Variable	Linguistic Value	Numerical Range
Relative Humidity	Very Low	31.5%-53.5% [31.5 42.5 53.5]
	Low	41%-65% [41 53 65]
	Medium	55%-80% [55 67.5 80]
	High	70%-93.8% [70.3 82.42 93.8]
	Very High	75.42%-110% [75.42 95.6 110]

Figure 16: Membership Function for Dry Bulb Temperature

Table 11: Parameters for Output

Output		
Linguistic Variable	Linguistic Value	Numerical Range
Dew Point Temp	Very Cold	0°C-11.36°C [0 7 11.36]
	Cold	8.5°C-14.38°C [8.5 11.1 14.38]
	Moderate	11.8°C-18.66°C [11.8 15 18.66]
	Warm	15.1°C-21.49°C [15.1 18.6 21.49]
	Hot	19.1°C-25.8°C [19.1 22.4 25.8]

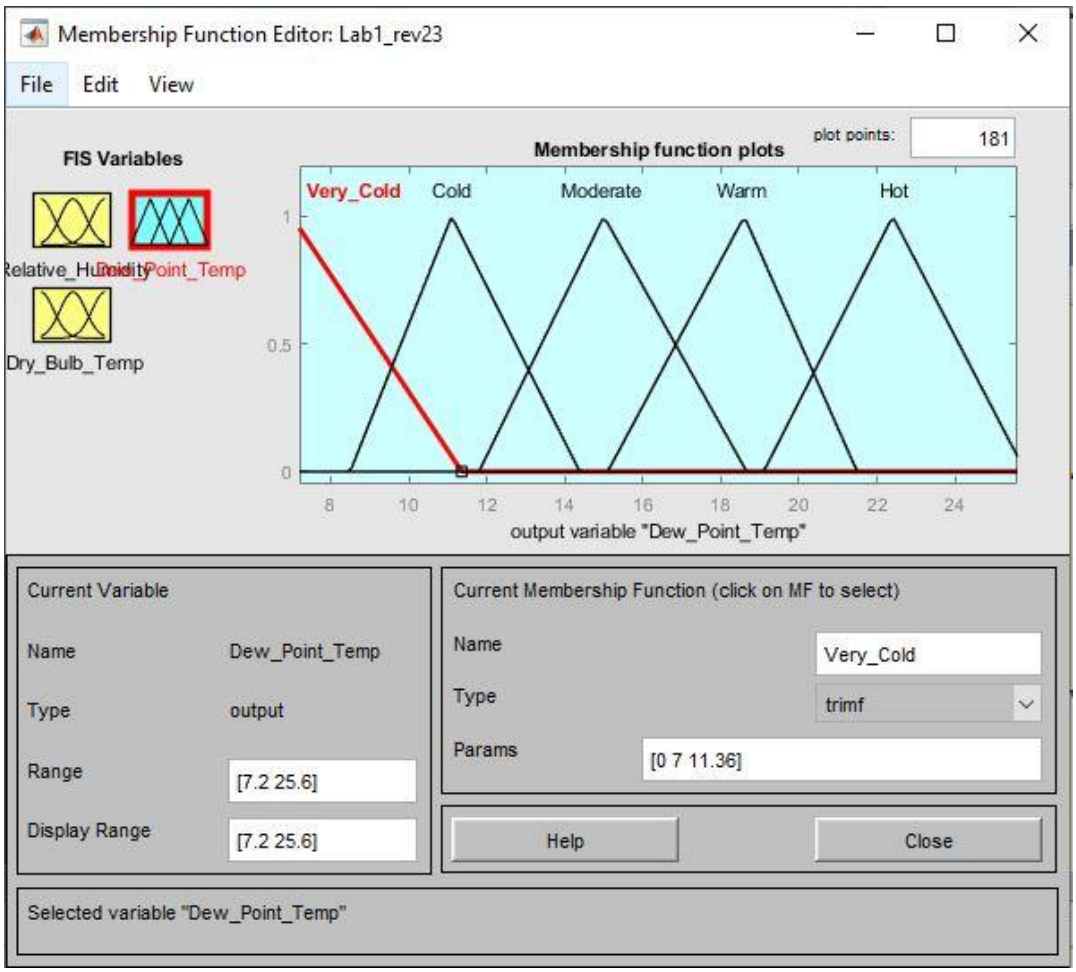

Figure 17: Membership Function for Dew Point Temperature

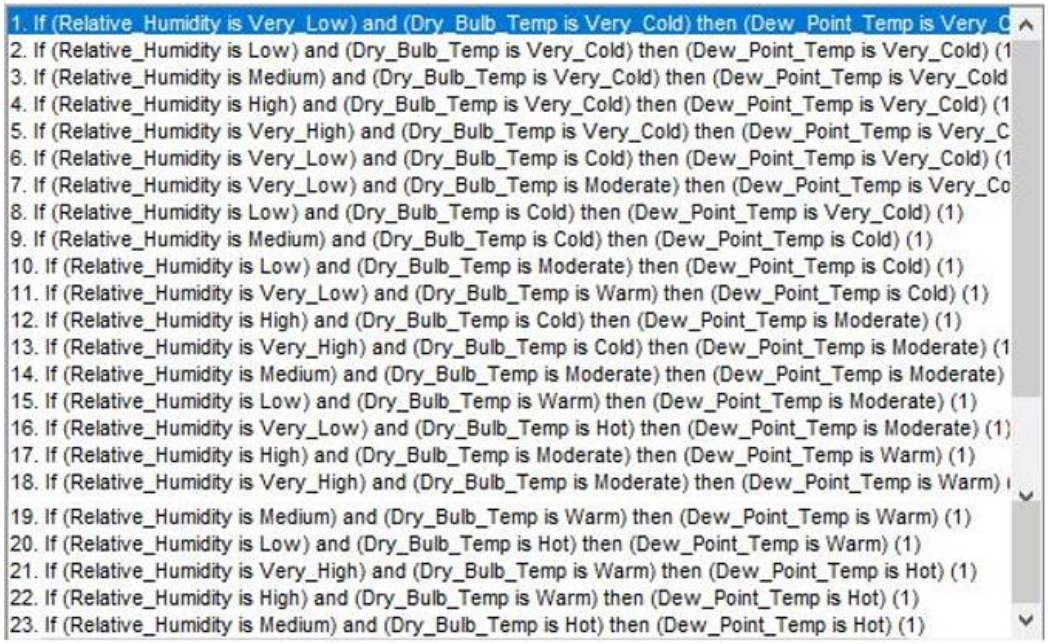

Figure 18: Membership Function Rules

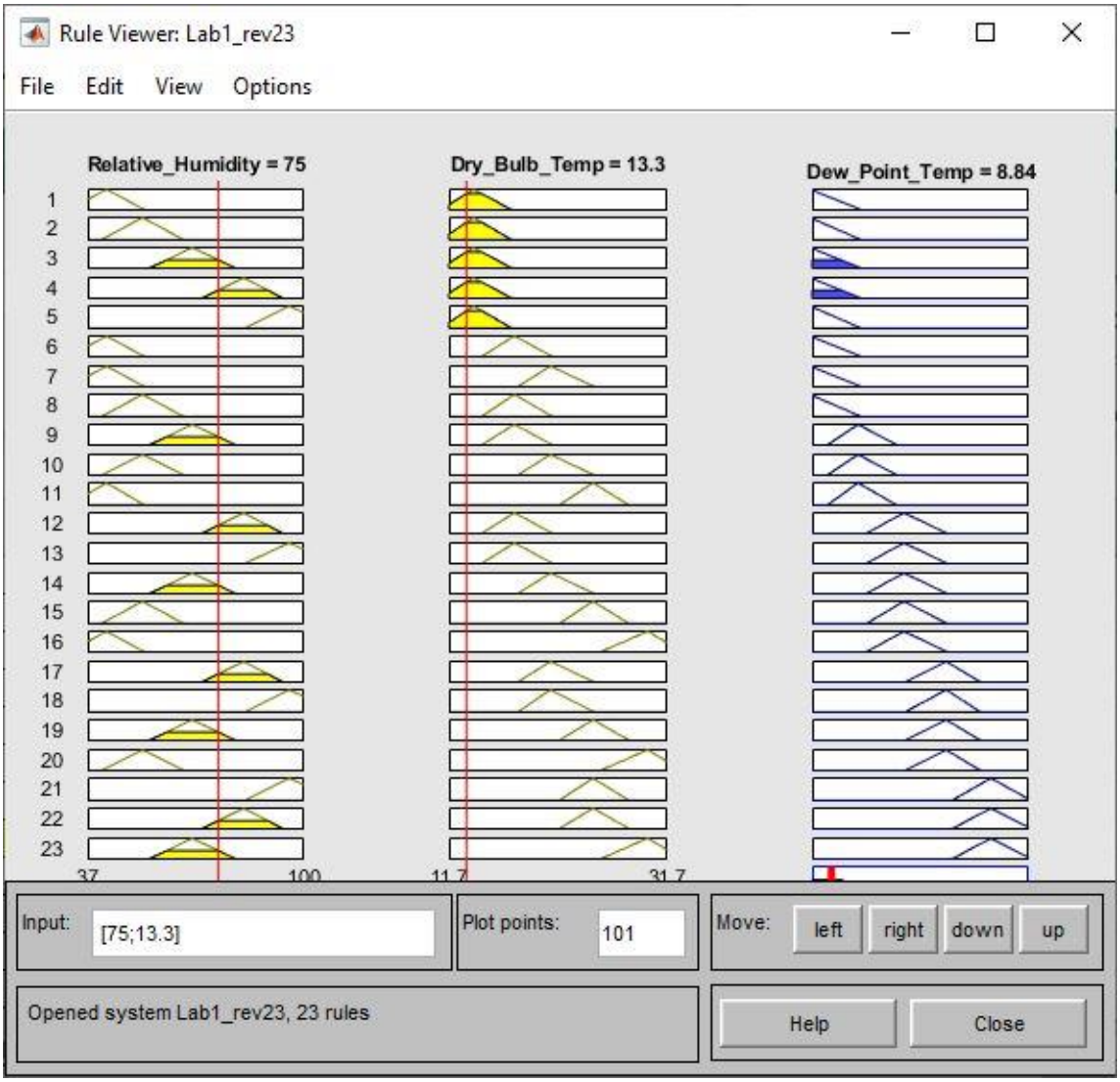

Figure 19: Rule Viewer Results for Case Study 1

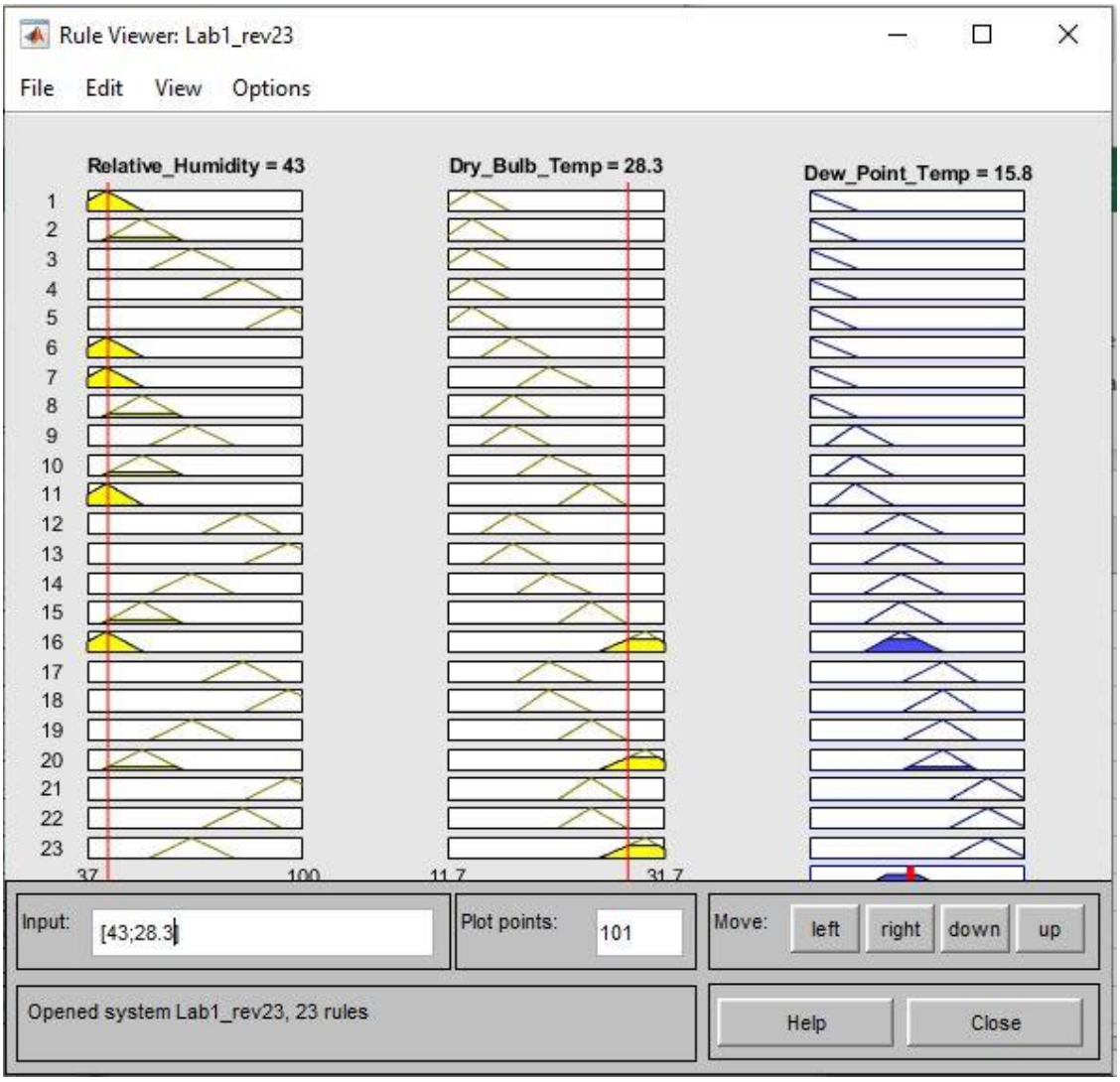

Figure 20: Rule Viewer Results for Case Study 2

Figure 21: Rule Viewer Results for Case Study 3

8.3 Data Set: Chicago O'hare (August 1989)

Table 12: Complete Dataset Selected for the Training of the Fuzzy Logic System

Row No.	Dry Bulb Temperature (°C)	Dew Point Temperature (°C)	Relative Humidity (%)
1	17.2	15	86
2	17.4	15.5	88
3	17.2	15.7	91
4	17.5	15.6	88
5	17.6	15.4	86
6	18.1	16.5	89
7	20	17.8	87
8	22.2	17.2	73
9	23.9	16.7	64
10	25.6	17.2	60
11	26.7	17.8	58
12	27.2	17.8	56
13	27.2	17.8	56
14	27.8	17.2	53
15	26.7	16.1	52
16	27.8	16.1	49
17	27.2	15	47
18	26.1	15	51
19	26.1	15	51
20	23.3	16.1	64
21	22.8	16.1	66
22	18.9	15.6	81
23	18.9	16.1	84
24	18.3	16.7	90
25	17.8	15.6	87
26	17.2	15.6	90
27	17.8	16.1	90
28	17.2	15	87
29	18.3	15.6	84
30	18.3	16.1	87
31	21.7	17.8	79
32	23.9	17.8	69
33	26.7	18.3	60
34	27.2	17.2	54
35	28.9	17.8	51
36	28.9	17.2	49
37	29.4	17.8	50
38	29.4	18.3	51
39	29.4	18.3	51

40	29.4	18.9	53
41	28.9	18.9	55
42	27.2	19.4	63
43	26.1	18.9	65
44	24.4	19.4	74
45	23.3	19.4	79
46	23.3	19.4	79
47	22.8	19.4	82
48	22.2	19.4	84
49	21.7	19.4	87
50	21.7	19.4	87
51	21.1	18.3	84
52	21.7	17.8	79
53	21.7	18.9	84
54	22.8	19.4	82
55	25	20.6	76
56	26.7	21.7	74
57	28.3	22.2	70
58	29.4	22.8	67
59	30.6	22.8	63
60	30.6	22.2	61
61	30.6	22.2	61
62	31.7	22.8	59
63	31.7	22.2	57
64	31.7	21.7	55
65	30.6	22.2	61
66	30.6	22.8	63
67	29.4	22.2	65
68	29.4	22.2	65
69	26.1	22.2	79
70	25.6	23.9	91
71	25.6	23.3	88
72	26.1	23.3	85
73	26.1	23.3	85
74	23.3	20.6	85
75	24.4	22.2	88
76	24.4	22.2	88
77	23.9	22.8	94
78	23.9	18.9	74
79	23.3	21.1	87
80	24.4	23.9	97
81	26.1	24.4	91
82	27.2	23.9	82
83	29.4	24.4	75

84	30	23.9	70
85	30.6	24.4	70
86	30.6	24.4	70
87	31.1	25	70
88	31.1	25	70
89	31.1	24.4	68
90	30	25	75
91	28.9	25	80
92	28.3	25	82
93	27.8	25.6	88
94	28.3	25	82
95	28.3	25	82
96	21.7	18.9	84
97	20	18.3	90
98	20.6	18.3	87
99	20.6	18.3	87
100	20	17.8	87
101	20.6	18.9	90
102	21.1	18.9	87
103	21.7	20	90
104	22.8	21.1	90
105	23.3	20.6	85
106	25.6	20.6	74
107	27.2	21.1	69
108	28.3	21.7	67
109	28.3	21.7	67
110	27.8	17.2	53
111	30	17.8	48
112	30	18.3	50
113	29.4	18.3	51
114	27.8	18.3	57
115	26.1	18.9	65
116	24.4	19.4	74
117	23.9	20	79
118	23.9	19.4	76
119	22.2	18.3	79
120	22.2	17.2	73
121	20	16.1	78
122	20	15.6	76
123	19.4	15.6	78
124	18.3	14.4	78
125	17.8	14.4	81
126	18.3	15	81
127	20	15	73

128	21.1	15	68
129	21.7	15.6	68
130	21.1	15.6	71
131	17.2	14.4	84
132	16.1	15	93
133	17.2	13.9	81
134	17.8	11.1	65
135	16.1	10	67
136	15.6	8.9	65
137	16.1	8.9	63
138	16.7	8.3	58
139	15.6	8.3	62
140	13.9	8.9	72
141	12.8	10	83
142	12.8	10.6	87
143	12.2	10.6	90
144	12.2	10	86
145	11.7	10	90
146	12.8	11.1	90
147	12.8	10.6	87
148	11.7	7.8	77
149	11.7	8.9	83
150	12.8	9.4	80
151	15.6	10	70
152	17.2	8.9	58
153	19.4	7.8	47
154	20	8.3	47
155	20.6	8.3	46
156	20.6	7.8	44
157	21.7	8.3	43
158	20.6	9.4	49
159	20.6	10.6	53
160	20	10.6	55
161	20	10	53
162	19.4	10	55
163	17.2	10	63
164	15.6	10	70
165	14.4	10	75
166	13.9	10.6	81
167	13.3	10	80
168	12.8	9.4	80
169	13.3	10.6	83
170	13.3	10.6	83
171	12.8	10	83

172	11.7	7.8	77
173	11.7	8.9	83
174	12.8	10	83
175	15.6	10.6	72
176	18.3	10.6	61
177	20.6	10	51
178	22.8	11.1	48
179	23.9	11.1	45
180	23.3	10	43
181	25	11.1	42
182	23.9	11.1	45
183	23.9	12.2	48
184	24.4	12.8	48
185	22.8	12.2	52
186	22.8	13.3	55
187	19.4	14.4	73
188	18.9	15	78
189	17.2	14.4	84
190	17.2	13.9	81
191	17.2	15.6	90
192	17.2	15.6	90
193	17.2	15.6	90
194	17.8	15.6	87
195	17.8	15	84
196	16.1	12.8	81
197	15.6	13.9	90
198	15.6	14.4	93
199	18.3	15	81
200	21.1	14.4	66
201	22.8	15	62
202	25	15.6	56
203	26.1	15	51
204	26.7	13.3	44
205	25.6	13.9	49
206	27.2	13.9	44
207	25	15	54
208	24.4	15.6	58
209	23.3	15	60
210	22.8	14.4	60
211	21.1	15	68
212	20	15.6	76
213	18.9	15	78
214	19.4	14.4	73
215	17.8	13.9	78

216	17.8	13.9	78
217	17.8	13.9	78
218	17.8	14.4	81
219	17.2	13.9	81
220	17.2	12.8	75
221	16.7	13.3	81
222	17.2	13.9	81
223	19.4	14.4	73
224	22.2	15	64
225	24.4	15.6	58
226	25.6	16.7	58
227	26.7	15.6	51
228	27.2	16.1	51
229	27.8	13.9	43
230	28.3	15	44
231	28.3	14.4	43
232	25	15.6	56
233	22.2	18.3	79
234	21.1	17.2	79
235	19.4	17.2	87
236	20	16.7	81
237	21.1	16.7	76
238	20.6	16.7	79
239	19.4	16.7	84
240	18.9	15.6	81
241	18.3	15.6	84
242	17.8	15.6	87
243	17.2	15.6	90
244	16.7	15	90
245	16.1	14.4	90
246	16.1	15.6	97
247	20	17.2	84
248	23.9	16.7	64
249	24.4	15.6	58
250	26.7	15	49
251	26.7	15	49
252	22.2	16.1	69
253	25.6	17.2	60
254	22.2	15	64
255	22.8	16.7	69
256	24.4	16.7	62
257	25.6	16.7	58
258	24.4	18.3	69
259	22.2	16.1	69

260	20	16.7	81
261	18.9	16.7	87
262	17.8	16.7	93
263	17.8	16.7	93
264	18.3	17.2	93
265	17.2	15	87
266	17.2	16.1	93
267	17.2	16.1	93
268	16.1	15	93
269	16.7	15.6	93
270	16.1	12.8	81
271	20	16.7	81
272	23.3	17.2	69
273	25	16.7	60
274	26.1	16.1	54
275	27.2	15.6	49
276	26.7	15	49
277	28.3	15.6	46
278	21.7	17.2	76
279	20.6	16.1	76
280	21.1	18.3	84
281	20	15.6	76
282	20	16.1	78
283	20.6	14.4	68
284	18.9	15.6	81
285	18.3	14.4	78
286	17.8	15	84
287	16.7	15	90
288	16.7	15	90
289	16.7	13.9	84
290	15.6	13.9	90
291	16.1	13.9	87
292	15.6	13.9	90
293	15	13.3	90
294	16.1	13.3	84
295	18.3	16.1	87
296	21.7	16.7	73
297	23.9	17.2	66
298	25	16.1	58
299	26.7	16.7	54
300	27.2	17.8	56
301	28.3	18.9	57
302	27.2	17.8	56
303	27.2	17.2	54

304	27.8	16.7	51
305	26.1	16.1	54
306	25.6	16.7	58
307	19.4	18.3	93
308	20	18.3	90
309	20	17.2	84
310	21.1	16.7	76
311	21.1	15.6	71
312	21.1	15.6	71
313	21.1	16.7	76
314	21.1	16.7	76
315	21.1	16.7	76
316	20	17.2	84
317	19.4	17.2	87
318	19.4	16.1	81
319	21.1	17.2	79
320	21.1	17.2	79
321	22.2	18.3	79
322	25	18.9	69
323	25.6	19.4	69
324	25.6	19.4	69
325	23.9	16.1	62
326	23.3	17.8	71
327	20	16.1	78
328	19.4	17.8	90
329	20.6	18.3	87
330	20	17.8	87
331	20	19.4	97
332	20	19.4	97
333	19.4	18.3	93
334	19.4	11.7	61
335	17.8	16.1	90
336	17.2	15.6	90
337	17.2	14.4	84
338	17.2	16.7	97
339	17.2	16.1	93
340	16.7	16.1	97
341	17.8	17.2	97
342	18.3	16.1	87
343	19.4	18.3	93
344	20.6	18.3	87
345	22.2	19.4	84
346	23.9	18.9	74
347	23.9	18.9	74

348	24.4	18.9	71
349	22.8	17.8	74
350	22.8	18.9	79
351	22.8	18.3	76
352	23.3	18.9	76
353	21.7	17.2	76
354	20.6	16.7	79
355	20	16.1	78
356	20	16.1	78
357	19.4	15.6	78
358	18.9	15.6	81
359	18.3	15.6	84
360	17.2	15.6	90
361	16.1	14.4	90
362	15	13.9	93
363	15	13.3	90
364	15	13.9	93
365	15	12.8	87
366	15.6	12.8	84
367	17.8	13.9	78
368	18.9	15.6	81
369	20.6	15	71
370	21.7	13.9	61
371	22.2	13.9	59
372	21.7	13.3	59
373	23.3	15	60
374	22.8	15	62
375	23.3	14.4	58
376	22.8	13.3	55
377	22.2	13.9	59
378	21.1	14.4	66
379	20.6	14.4	68
380	19.4	14.4	73
381	18.3	14.4	78
382	17.8	14.4	81
383	15	10	72
384	13.9	8.3	69
385	14.4	8.3	67
386	14.4	8.3	67
387	13.3	8.9	75
388	12.2	7.2	72
389	12.2	7.2	72
390	13.9	8.9	72
391	17.2	9.4	61

392	19.4	15.6	78
393	21.7	16.1	71
394	23.3	15.6	62
395	23.9	14.4	56
396	25	12.2	45
397	25.6	11.7	42
398	25	12.2	45
399	24.4	12.8	48
400	23.9	12.2	48
401	22.8	11.7	50
402	21.7	12.8	57
403	20.6	13.3	63
404	18.9	14.4	76
405	18.3	14.4	78
406	17.8	13.9	78
407	16.7	13.3	81
408	17.2	10.6	65
409	15	7.2	60
410	13.9	11.7	87
411	13.3	11.7	90
412	13.3	12.2	93
413	13.3	12.2	93
414	14.4	11.7	84
415	18.3	12.2	68
416	20.6	11.7	57
417	22.8	15.6	64
418	23.9	15	58
419	25	12.2	45
420	25	12.8	47
421	25	12.8	47
422	24.4	12.2	47
423	24.4	12.2	47
424	24.4	12.2	47
425	23.3	10.6	45
426	22.2	10.6	48
427	20.6	11.1	55
428	19.4	12.8	66
429	18.3	12.8	70
430	18.3	13.3	73
431	16.1	13.9	87
432	16.1	13.3	84
433	14.4	13.3	93
434	13.9	12.8	93
435	13.9	12.8	93

436	13.3	12.8	97
437	13.9	13.3	97
438	14.4	13.3	93
439	17.8	14.4	81
440	20.6	15	71
441	22.8	15.6	64
442	24.4	14.4	54
443	25	13.9	50
444	25.6	13.9	49
445	25.6	13.9	49
446	26.1	15	51
447	26.1	15.6	52
448	25.6	15	52
449	25	15.6	56
450	24.4	15.6	58
451	23.9	15.6	60
452	23.9	15.6	60
453	23.3	16.1	64
454	22.8	16.7	69
455	21.7	18.3	81
456	20	20	100
457	20	20	100
458	21.1	20	93
459	21.1	20.6	97
460	21.7	20.6	93
461	21.7	20.6	93
462	21.7	20.6	93
463	22.2	20.6	90
464	22.8	21.1	90
465	24.4	21.1	82
466	26.1	20	69
467	26.7	20	67
468	27.8	19.4	61
469	28.9	18.9	55
470	27.8	17.8	55
471	28.9	18.3	53
472	27.2	17.8	56
473	27.8	17.2	53
474	26.1	15	51
475	23.3	15.6	62
476	22.2	15.6	66
477	20	16.1	78
478	19.4	16.1	81
479	18.3	16.1	87

480	18.9	16.1	84
481	17.8	15.6	87
482	17.2	15.6	90
483	16.1	15	93
484	16.1	15	93
485	16.7	15.6	93
486	16.7	15	90
487	21.1	17.2	79
488	22.8	16.1	66
489	25.6	15.6	54
490	27.2	15.6	49
491	28.3	15	44
492	28.9	15	43
493	29.4	17.2	48
494	30.6	16.7	43
495	29.4	15.6	43
496	28.9	15.6	44
497	27.8	16.7	51
498	27.2	17.2	54
499	26.1	18.3	62
500	25	19.4	71
501	23.9	20	79
502	24.4	20.6	79
503	23.9	21.1	85
504	23.9	21.1	85
505	22.8	21.1	90
506	22.8	20.6	87
507	23.3	20	82
508	22.8	20	84
509	22.8	19.4	82
510	22.8	20.6	87
511	22.2	20.6	90
512	21.7	20.6	93
513	22.2	21.1	94
514	23.3	21.1	87
515	23.9	21.7	87
516	25	22.2	85
517	25.6	22.8	85
518	26.7	22.2	77
519	28.3	22.8	72
520	28.3	22.8	72
521	28.9	22.8	70
522	27.8	22.8	74
523	26.7	22.8	79

524	25.6	22.8	85
525	24.4	21.7	85
526	24.4	21.7	85
527	24.4	21.1	82
528	22.8	21.1	90
529	22.8	21.7	94
530	22.8	21.7	94
531	22.8	21.1	90
532	22.2	19.4	84
533	21.7	20	90
534	21.7	20	90
535	21.7	19.4	87
536	21.7	19.4	87
537	22.2	19.4	84
538	21.1	19.4	90
539	21.1	18.9	87
540	21.1	18.9	87
541	21.1	17.8	81
542	21.7	18.3	81
543	21.7	17.8	79
544	20.6	17.2	81
545	20.6	17.2	81
546	20.6	17.2	81
547	20	15.6	76
548	20	16.1	78
549	20	17.8	87
550	20.6	18.3	87
551	21.1	18.3	84
552	21.1	17.8	81
553	20.6	17.2	81
554	20	17.2	84
555	20	17.2	84
556	19.4	16.7	84
557	20	16.7	81
558	20	16.7	81
559	20.6	16.7	79
560	20.6	17.2	81
561	21.1	17.8	81
562	21.7	17.2	76
563	21.7	17.2	76
564	22.2	17.2	73
565	22.8	16.1	66
566	22.2	16.7	71
567	22.2	16.1	69

568	22.8	16.1	66
569	22.2	15.6	66
570	21.7	15.6	68
571	20.6	15.6	73
572	20.6	17.2	81
573	20	17.2	84
574	19.4	17.8	90
575	21.1	16.1	73
576	20	15.6	76
577	19.4	15.6	78
578	18.3	15.6	84
579	18.9	16.1	84
580	18.9	16.1	84
581	17.2	15.6	90
582	18.3	15	81
583	19.4	15	76
584	21.1	15	68
585	22.2	15.6	66
586	23.3	15	60
587	23.9	13.3	52
588	24.4	14.4	54
589	25	13.9	50
590	24.4	14.4	54
591	24.4	13.9	52
592	23.3	14.4	58
593	22.8	14.4	60
594	21.7	14.4	64
595	20.6	14.4	68
596	20	14.4	71
597	18.9	14.4	76
598	19.4	15	76
599	18.9	15	78
600	17.8	15	84
601	18.3	16.1	87
602	17.2	15.6	90
603	17.2	15.6	90
604	17.2	15.6	90
605	18.9	16.1	84
606	18.9	15.6	81
607	20.6	14.4	68
608	20.6	14.4	68
609	21.7	15	66
610	22.2	15.6	66
611	22.8	16.7	69

612	23.9	17.8	69
613	25	18.3	67
614	26.7	18.9	63
615	25.6	18.9	67
616	25	19.4	71
617	22.8	19.4	82
618	23.3	19.4	79
619	22.2	19.4	84
620	22.2	18.3	79
621	22.2	18.3	79
622	21.7	18.3	81
623	21.1	18.9	87
624	21.1	18.9	87
625	20	19.4	97
626	20.6	19.4	93
627	19.4	18.9	97
628	19.4	18.9	97
629	18.9	18.3	97
630	18.9	18.3	97
631	23.3	20.6	85
632	24.4	20.6	79
633	26.1	20.6	72
634	27.2	21.1	69
635	28.3	21.1	65
636	28.3	21.1	65
637	27.2	22.2	74
638	27.2	21.7	72
639	27.2	21.1	69
640	27.2	21.7	72
641	26.1	21.1	74
642	25	20.6	76
643	23.3	20.6	85
644	22.8	20.6	87
645	22.2	20	87
646	22.2	20.6	90
647	22.2	20.6	90
648	21.7	20.6	93
649	21.7	20.6	93
650	21.7	20.6	93
651	21.7	20.6	93
652	21.7	20.6	93
653	21.7	20.6	93
654	21.7	20.6	93
655	21.7	20.6	93

656	21.7	20.6	93
657	23.3	22.2	94
658	24.4	21.7	85
659	24.4	22.2	88
660	26.1	22.2	79
661	26.7	22.2	77
662	28.3	22.8	72
663	26.7	22.2	77
664	26.1	22.2	79
665	26.1	22.2	79
666	26.1	21.7	77
667	25	21.7	82
668	23.3	21.1	87
669	22.8	21.1	90
670	22.2	21.1	94
671	22.2	21.1	94
672	22.2	20.6	90
673	21.1	20.6	97
674	21.1	20.6	97
675	21.1	20.6	97
676	21.1	20.6	97
677	21.1	20.6	97
678	21.1	21.1	100
679	21.7	21.1	97
680	22.8	21.1	90
681	23.3	22.2	94
682	25.6	22.8	85
683	26.1	22.8	82
684	27.8	20	63
685	28.3	20	61
686	29.4	20.6	59
687	27.8	19.4	61
688	27.2	18.3	58
689	26.7	18.3	60
690	25.6	17.2	60
691	23.9	15.6	60
692	22.2	15	64
693	21.1	15	68
694	20	14.4	71
695	18.3	13.9	76
696	17.8	13.9	78
697	17.2	13.9	81
698	17.2	12.8	75
699	16.7	12.2	75

700	15.6	12.2	81
701	15	12.2	84
702	15	12.2	84
703	18.3	12.8	70
704	20	12.2	61
705	21.7	12.2	55
706	22.8	12.2	52
707	23.9	12.2	48
708	25	12.8	47
709	26.1	12.8	44
710	27.8	11.7	37
711	27.8	12.2	38
712	27.8	13.3	41
713	27.2	14.4	46
714	25.6	16.1	56
715	23.3	15.6	62
716	22.2	15	64
717	20	15.6	76
718	20	15	73
719	18.9	14.4	76
720	18.9	13.9	73
721	18.3	13.9	76
722	17.8	13.3	75
723	17.8	13.3	75
724	16.7	13.9	84
725	16.7	13.9	84
726	16.7	13.9	84
727	19.4	15	76
728	22.8	16.7	69
729	24.4	17.8	67
730	28.3	18.3	55
731	26.7	19.4	65
732	25.6	19.4	69
733	25	20.6	76
734	23.9	21.7	87
735	23.9	21.1	85
736	23.9	20.6	82
737	22.8	20.6	87
738	21.7	20.6	93
739	20.4	19.2	92
740	19.4	18.4	93
741	18.8	17.3	90
742	18.2	16.3	88
743	17.7	15.5	86

744	17.1	15.1	88

8.4 Sample Calculation

$$Percentage\ Error\ (\%) = \left|\frac{Actual\ Output - Simulated\ Output}{Actual\ Output}\right| \times 100$$

Demonstrating the calculation for Case B Case 2

$$Percentage\ Error\ = \left|\frac{14.4\ - 15.8}{14.4}\right| \times 100$$

$$Percentage\ Error\ = 9.722\ \%$$

8.5 MATLAB Code

```
%Name: Rivyesch Ranjan
%ID: 29392004
%Date: 17/03/2021

%Tidying up the workplace
clc;
clear all;
close all;

%Importing the relevant data from the data sheet provided
chicago_Ohare='data_Chicago1989.xlsx'; %Importing data from the excel file
Dry_Bulb_Temp = xlsread(chicago_Ohare,'A:A');
Dew_Point_Temp = xlsread(chicago_Ohare,'B:B');
Relative_Humidity=xlsread(chicago_Ohare,'C:C');

%% Developing a Fuzzy Logic Controller for Weather Prediction (Case A)
% input 1 : Dew Point Temperature
% input 2 : Dry Bulb Temperature
% output : relative humidity

fuzzy_set_A= readfis('Lab1_rev11.fis');

%Using fuzzy logic to simulate data
Output_A=evalfis([Dew_Point_Temp Dry_Bulb_Temp],fuzzy_set_A);
deviation_A=abs(Output_A-Relative_Humidity);
max_deviation_A=max(deviation_A);
error_A= deviation_A./Relative_Humidity*100;
min_error_A=min(error_A)
max_error_A=max(error_A)
average_error_A=mean(error_A)

%Graph plotted to compare Actual and Simulated Relative Humidity
figure(1)
```

```
plot(1:length(Relative_Humidity),Relative_Humidity,'b',1:length(Relative_Humidity
),Output_A,'r*-')
title('Comparison of Simulated and Actual Relative Humidity')
xlabel('Data Points')
ylabel('Relative Humidity')
legend('Actual Relative Humidity','Simulated Relative Humidity')
%Graph plotted for percentage error and mean error
figure(2)
plot(1:length(Relative_Humidity),error_A,'g', [1,length(Relative_Humidity)],
[average_error_A,average_error_A], 'r')
title('Error Percentage')
xlabel('Data Points')
ylabel('Error Percentage of RelativeHumidity')
legend ('Percentage Error', 'Mean Error')


%% Developing a Fuzzy Logic Controller for Weather Prediction (Case B)
% input 1 : Relative Humidity
% input 2 : Dry Bulb Temperature
% output : Dew Point Temperature

fuzzy_set_B= readfis('Lab1_rev23.fis');

%Using fuzzy logic to simulate data
Output_B=evalfis([Relative_Humidity Dry_Bulb_Temp],fuzzy_set_B);
deviation_B=abs(Output_B-Dew_Point_Temp);
max_deviation_A=max(deviation_B);
error_B= deviation_B./Dew_Point_Temp*100;
min_error_B=min(error_B)
max_error_B=max(error_B)
average_error_B=mean(error_B)

%Graph plotted to compare Actual and Simulated Dew Point Temperature
figure(3)
plot(1:length(Dew_Point_Temp),Dew_Point_Temp,'b',1:length(Dew_Point_Temp),Output_
B,'r*-')
title('Comparison of Simulated and Actual Dew Point Temperature')
xlabel('Data Points')
ylabel('Dew Point Temperature')
legend('Actual Dew Point Temperature','Simulated Dew Point Temperature')
%Graph plotted for percentage error and mean error
figure(4)
plot(1:length(Dew_Point_Temp),error_B,'g', [1,length(Dew_Point_Temp)],
[average_error_B,average_error_B], 'r')
title('Error Percentage')
xlabel('Data Points')
ylabel('Error Percentage of Dew Point Temperature')
legend ('Percentage Error', 'Mean Error')
```