



**HACETTEPE UNIVERSITY  
ENGINEERING FACULTY  
DEPARTMENT OF COMPUTER ENGINEERING**

# **BBM 407 - Fuzzy Logic**

## **Mamdani Style Fuzzy Inference System**

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# Libraries

I imported os and glob libraries to access all .csv files I have in the file, pandas library to do the most operations with the dataset, missingno library to do feature selection based on missing values, seaborn library to do feature selection based on heatmap, numpy library mostly for the mathematical operations like arange that used to determine variable ranges, sklearn.metrics library to print out the membership functions and skfuzzy library for all the fuzzy operations.

```
import os
import glob
import numpy as np
import pandas as pd
import matplotlib as mpl
import matplotlib.pyplot as plt
import missingno as msno
import seaborn as sns
import skfuzzy as fuzz
import skfuzzy.membership as mf
import sklearn.metrics
```

# Data Set

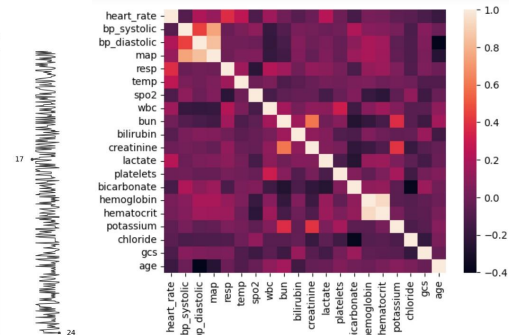
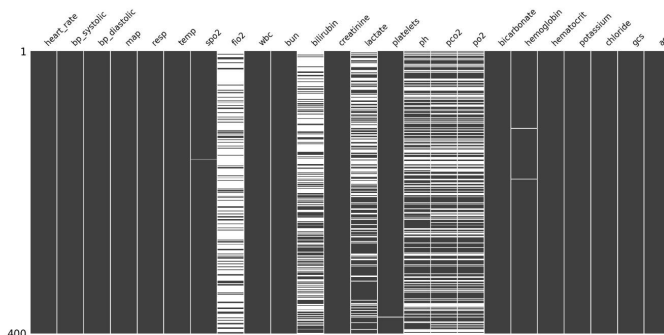
I took 200 person datasets from the sepsis file and 200 person datasets from the no sepsis file, then took mean in every column for all person datasets and combined them in a single dataset with 400 rows.

	heart_rate	bp_systolic	bp_diastolic	map	resp	temp	spo2	fio2	wbc	bun	bicarbonate	hemoglobin	hematocrit	potassium	chloride	gcs	age	sirs	qsofa	sepsis_lcd			
0	84.608696	116.478261	50.608696	66.434783	15.521739	36.946860	96.347826	NaN	12.475000	11.000000	28.000000	8.975000	28.375000	5.000000	108.000000	11.826087	83.72	0.304348	0.043478	0.0			
1	92.363636	111.409091	60.363636	72.136364	27.272727	36.145503	96.045455	NaN	15.600000	19.000000	40.000000	13.000000	40.700000	4.700000	67.000000	15.000000	74.57	0.908091	0.136364	0.0			
2	73.086567	124.086567	52.043478	79.347826	15.173913	36.345503	96.304348	NaN	7.333333	12.888889	28.111111	11.222222	33.788889	3.837500	109.222222	13.857143	80.03	0.043478	0.000000	0.0			
3	79.250000	116.416667	45.208333	68.944445	19.083333	37.371212	98.208333	NaN	9.400000	13.000000	24.000000	11.600000	33.500000	3.800000	103.000000	11.458333	81.40	0.125000	0.541667	0.0			
4	91.238095	127.476190	50.190476	73.238095	17.272727	36.965608	98.190476	51.428571	10.890000	21.700000	24.300000	9.940000	29.100000	5.981904	108.700000	8.095238	75.10	0.227273	0.272727	0.0			
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...			
395	126.217391	101.996022	59.996022	68.913043	28.798130	37.536232	99.069597	NaN	0.423529	21.352941	21.823529	7.576471	20.911765	1.890896	105.000000	14.173913	48.51	1.000000	0.869565	1.0			
396	73.811887	91.791887	58.833333	68.083333	20.870000	37.737969	95.883333	NaN	4.900000	6.000000	22.000000	11.950000	34.400000	1.883833	110.500000	3.700000	110.500000	0.5396	0.050000	0.498333	1.0		
397	117.727273	109.913043	61.965217	72.089567	22.222723	37.889569	95.618182	NaN	31.004545	11.636864	26.272727	9.904545	30.977273	1.859182	9.904545	30.977273	3.400000	96.318182	14.545455	83.53	0.666667	0.991304	1.0
398	78.772727	116.500000	78.909091	91.772727	21.363636	36.919192	94.818182	40.909091	14.236842	19.947368	22.884211	11.721053	36.747368	4.505263	105.631579	8.347826	88.32	0.565217	0.608964	1.0			
399	72.900000	102.350000	44.900000	67.500000	17.800000	37.855556	98.350000	42.222222	14.600000	26.000000	24.000000	9.800000	30.100000	1.883500	42.222222	14.600000	26.000000	24.000000	9.800000	30.100000	0.450000	1.0	

400 rows × 21 columns

# Feature Selection

For input features, first I checked their missing values and eliminated fio2, ph, pco2, po2 features since they have too many null values that will prevent it from checking their effect on the output. Then looked at the heatmap of their correlations and eliminated bp\_systolic, bp\_diastolic, resp, temp, spo2, wbc, bun, bicarbonate, hemoglobin, hematocrit, potassium, chloride, age features.

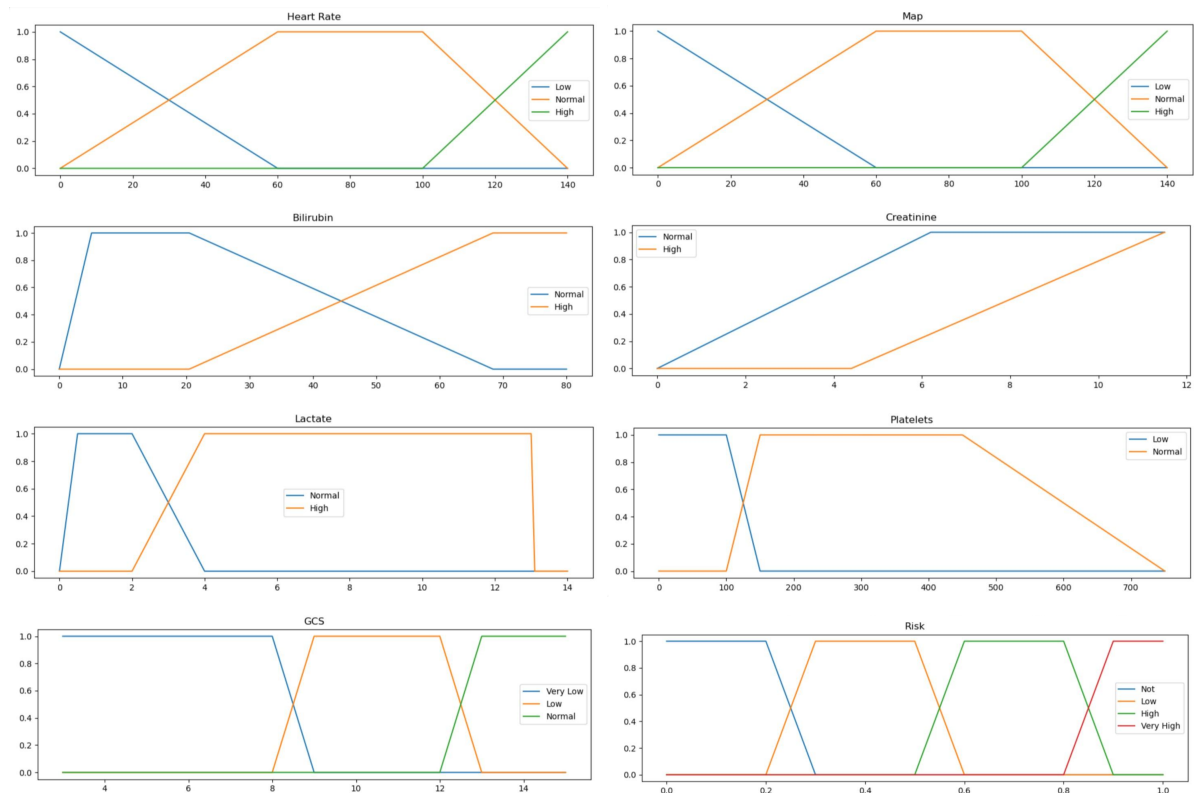


# Variable Ranges

I determined ranges for input variables mostly from their ranges in the dataset but also their normal ranges. I determined a range between 0 and 1 with 0.1 spacing for risk variables.

## Membership Functions

For the heart rate feature, I used 3 sets and determined their range values by internet[1]. For the map feature, I used 3 sets and determined their range values by internet[2]. For the bilirubin feature, I used 2 sets and determined their range values by internet[3]. For the creatinine feature, I used 2 sets and determined their range values by internet[4]. For the lactate feature, I used 2 sets and determined their range values by internet[5]. For the platelets feature, I used 2 sets and determined their range values by internet[6]. For the gcs feature, I used 3 sets and determined their range values by internet[7]. For the risk output I used 4 sets for not sepsis, low risk, high risk and very high risk.



## Rules

I determined rules by result of my research of the sepsis and septic shock definitions that I attached under[8,9,10].

	1992* Sepsis Consensus Definitions Conference <sup>1</sup>	2003* Sepsis Consensus Definitions Conference <sup>2</sup>	2016* Sepsis Consensus Definitions Conference <sup>3</sup>
Infection without systemic inflammation	Infection	Infection	Infection
Infection with systemic inflammation without organ dysfunction	Sepsis**	Sepsis***	Infection
Infection with systemic inflammation and presence of organ dysfunction	Severe sepsis	Severe sepsis	Sepsis
Infection-induced hypotension not responding to fluid administration and requiring vasopressors	Septic shock	Septic shock	Septic shock****

\* Date of publication

\*\* SIRS criteria were the only criteria for systemic inflammation

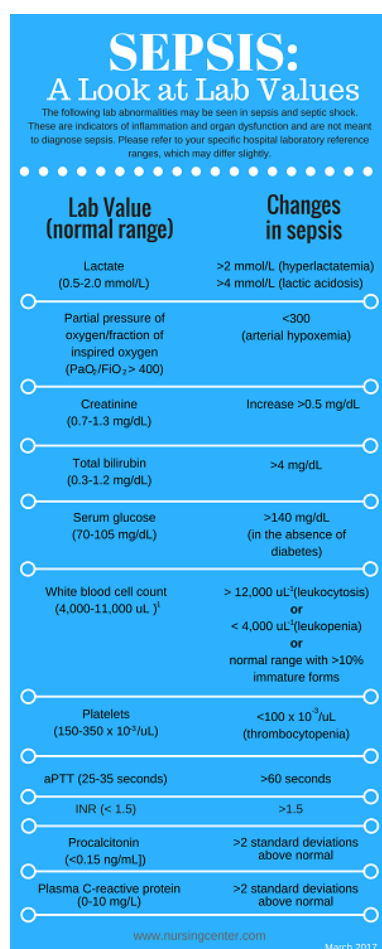
\*\*\* Added to SIRS criteria several other general, hemodynamic, inflammatory, organ dysfunction, and tissue hypoperfusion variables which, if abnormal, might support systemic inflammation

\*\*\*\* Also requires an elevated lactate

<sup>1</sup>1992 publication (Bone *et al.*)

<sup>2</sup>2003 publication (Levy *et al.*)

<sup>3</sup>2016 publication (Singer *et al.*)



Systemic Inflammatory Response Syndrome (SIRS) criteria Patients are diagnosed with SIRS if they meet two of the four criteria

Criteria	Metric	Comment
Temperature	>100.4° F (>38.0°C) or <96.8°F (<36.0°C)	Either hyperthermia or hypothermia is a SIRS criteria
Heart rate	>90 beats per minute	Only tachycardia
Respiratory rate	>20 breaths per minute	If the patient is mechanically ventilated, PaCO <sub>2</sub> <32 mm Hg
White blood count	>12,000/mm <sup>3</sup> or <4,000/mm <sup>3</sup> or >10% immature forms	Any one of these parameters is sufficient for this category

### The SOFA Score\*

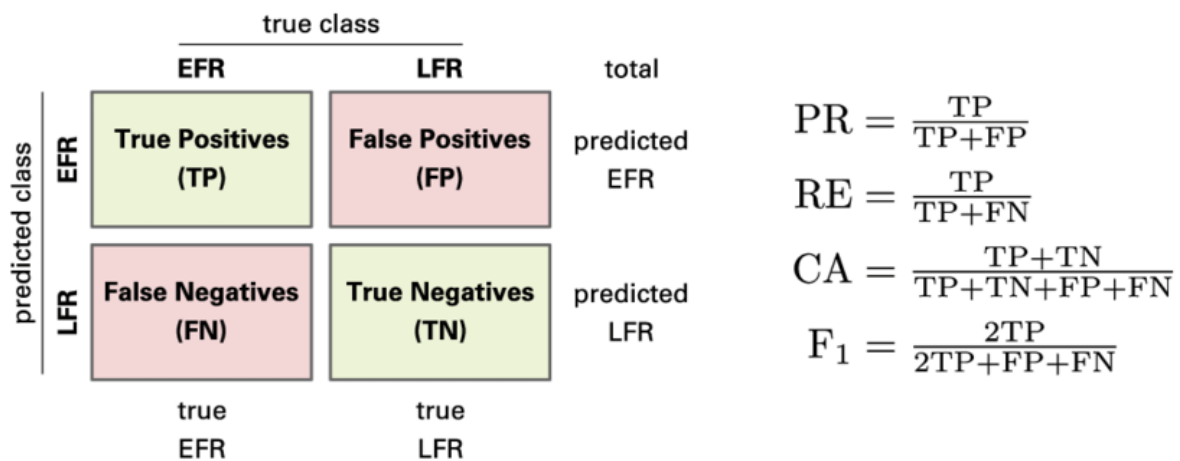
Organ System, Measurement	SOFA Score				
	0	1	2	3	4
<b>Respiration</b> PaO <sub>2</sub> /FIO <sub>2</sub> , mmHg	Normal	<400	<300	<200 (with respiratory support)	<100 (with respiratory support)
<b>Coagulation</b> Platelets x10 <sup>3</sup> /mm <sup>3</sup>	Normal	<150	<100	<50	<20
<b>Liver</b> Bilirubin, mg/dL (μmol/l)	Normal	1.2-1.9 (20-32)	2.0-5.9 (33-101)	6.0-11.9 (102-204)	>12.0 (>204)
<b>Cardiovascular</b> Hypotension	Normal	MAP<70 mmHg	Dopamine ≤5 or dobutamine (any dose)**	Dopamine >5 or epinephrine ≤0.1 or norepinephrine ≤0.1	Dopamine >15 or epinephrine >0.1 or norepinephrine >0.1
<b>Central Nervous System</b> Glasgow Coma Score	Normal	13-14	10-12	6-9	<6
<b>Renal</b> Creatinine, mg/dL (μmol/l) or Urine output	Normal	1.2-1.9 (110-170)	2.0-3.4 (171-299)	3.5-4.9 (300-440) or <500 mL/day	>5.0 (>440) or <200 mL/day

\* Source: Vincent *et al.*, 1996.

\*\*Adrenergic agents administered for at least 1 hour (doses given are in mcg/kg/min).

	Heart Rate			MAP			Bilirubin		Creatinine		Lactate		Platelets		GCS			Risk			
	Low	Normal	High	Low	Normal	High	Normal	High	Normal	High	Normal	High	Low	Normal	Very Low	Low	Normal	Not	Low	High	Very High
Rule0																					
Rule1																					
Rule2																					
Rule3																					
Rule4																					
Rule5																					
Rule6																					
Rule7																					
Rule8																					
Rule9																					
Rule10																					
Rule11																					
Rule12																					
Rule13																					
Rule14																					
Rule15																					
Rule16																					
Rule17																					
Rule18																					
Rule19																					
Rule20																					
Rule21																					

## Results



## Confusion Matrix

```
sklearn.metrics.confusion_matrix(Y, Y_result)
array([[194,  6],
       [185, 15]], dtype=int64)
```

## Accuracy Score

```
sklearn.metrics.accuracy_score(Y, Y_result)
0.5225
```

## F1 Score

```
sklearn.metrics.f1_score(Y, Y_result)
0.13574660633484162
```

## ROC(AUC) Score

```
sklearn.metrics.roc_auc_score(Y, Y_result)
0.5225
```

## References

- [1] "Heart Rate Normal Range". <https://www.healthline.com/health/dangerous-heart-rate>.
- [2] "MAP Normal Range". <https://www.healthline.com/health/mean-arterial-pressure>.
- [3] "Bilirubin Normal Range".  
<https://www.mountsinai.org/health-library/tests/bilirubin-blood-test>.
- [4] "Creatinine Normal Range".  
<https://www.mayoclinic.org/tests-procedures/creatinine-test/about/pac-20384646>.
- [5] "Lactate Normal Range". <https://www.ucsfhealth.org/medical-tests/lactic-acid-test>.
- [6] "Platelets Normal Range". <https://www.nhlbi.nih.gov/health/thrombocytopenia>.
- [7] "GCS Normal Range". <https://medictests.com/units/glasgow-coma-score>.
- [8] "Laboratory Signs of Sepsis".  
<https://www.nursingcenter.com/ncblog/march-2017/laboratory-signs-of-sepsis>.
- [9] "Diagnosing Sepsis". <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4980259/>.
- [10] "SOFA Score in Relation to Sepsis".  
<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9385349/>.