

Figure 1: Membership Functions of Gait Speed

2) **Stride Interval (Sec)** : Stride refers that the distance between two left steps. The time taken for the stride is called stride interval. This consists of three fuzzy sets for identification viz., control group ranges, Parkinson’s disease group ranges, Huntington’s disease group ranges. Membership function of this fuzzy set is trapezoidal and triangular. The table 2 shows the fuzzy set and ranges of stride interval and figure 2 shows the membership functions.

Table 2: Fuzzy Set and Ranges of Stride Interval

Input Field	Classification of Diseases	
	Ranges	Fuzzy Set
Stride Interval (sec)	< 1.146	Low
	1.08 – 1.22	Mid
	> 1.146	High

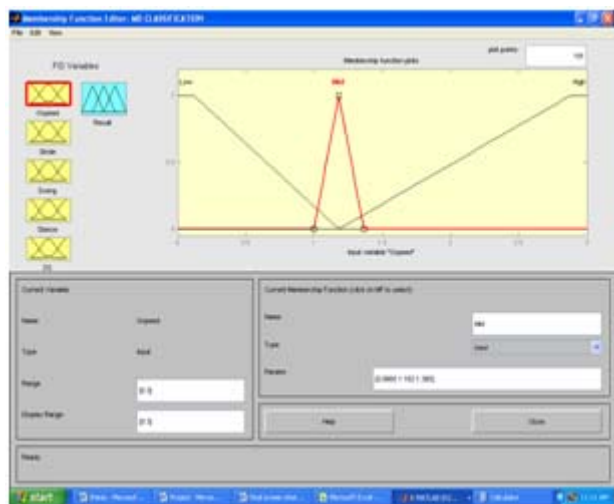


Figure 2: Membership Functions of Stride Interval

3) **Swing Interval (%stride)** : This is also similar to the swing interval. But, it is measured based on percentage of stride. This consists of three fuzzy sets for identification viz., control group ranges, Parkinson’s disease group ranges, Huntington’s disease group ranges. Membership function of this fuzzy set is triangular and trapezoidal. The table 3 shows the fuzzy set and ranges of swing interval and figure 3 shows the membership functions.

Table 3: Fuzzy Set and Ranges of Swing Interval

Input Field	Classification of Diseases	
	Ranges	Fuzzy Set
Swing Interval (% stride)	< 35.59	Low
	34.92 – 36.26	Mid
	> 35.59	High

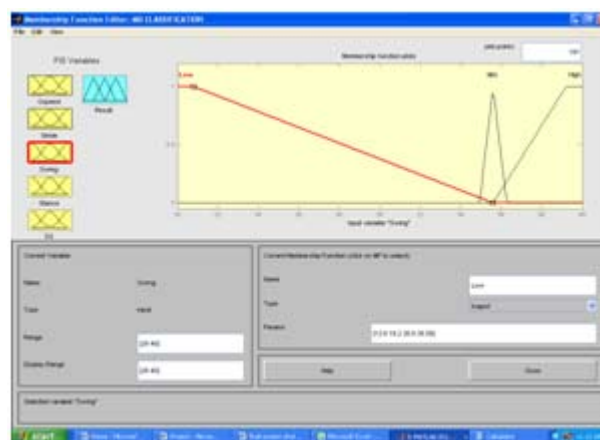


Figure 3: Membership Functions of Swing Interval

4) **Stance interval (%stride)**: This is also similar to the stance interval. But, it is measured based on percentage of stride. This consists of three fuzzy sets for identification viz., control group ranges, Parkinson’s disease group ranges, and Huntington’s disease group ranges. Membership function of this fuzzy set is triangular and trapezoidal. The table 4 shows the fuzzy set and ranges of stance interval and figure 4 shows its membership functions.

Table 4: Fuzzy Set and Ranges of Stance Interval

Input Field	Classification of Diseases	
	Ranges	Fuzzy Set
Stance Interval (% stride)	< 65.78	Low
	63.74 – 67.52	Mid
	> 65.78	High



Figure 4: Membership Functions of Stance Interval

5) **Double Support (DS) Interval (% Stride)** : This is similar to the DS interval but it is based on percentage of stride. This consists of three fuzzy sets for identification viz., control group ranges, Parkinson’s disease group ranges, Huntington’s disease group ranges. Membership function of this fuzzy set is triangular and trapezoidal. The table 5

shows the fuzzy set and ranges of DS interval and figure 5 shows its membership functions.

**Table 5:** Fuzzy Set and Ranges of Double Support

Input Field	Classification of Diseases	
	Ranges	Fuzzy Set
Double Support Interval (% Stride)	< 31.48	Low
	28.82 – 34.15	Mid
	> 31.48	High



**Figure 5:** Membership Functions of DS

**Output Variable:**

It is the goal variable. This variable depicts whether the subject suffers by Parkinson’s disease or Huntington’s Disease or healthy subject. These ranges are also mentioned in the membership functions. Membership function of this fuzzy set is triangular and trapezoidal. The table 6 shows the fuzzy set and ranges of result field and figure 6 shows the membership functions.

**Table 6:** Fuzzy Set and Ranges of Result Field

Output Field	Classification of Diseases	
	Ranges	Fuzzy Set
Result	< 1	Healthy
	0 – 2	PD
	> 1	HD



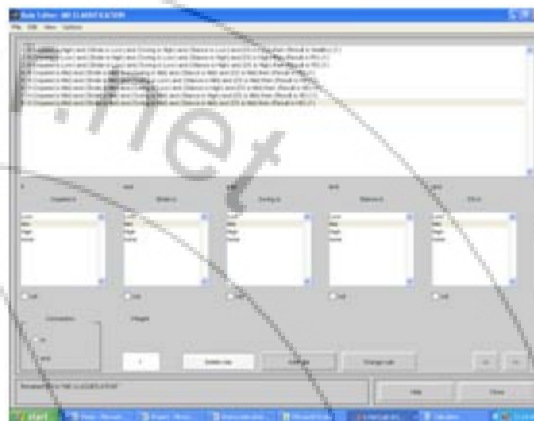
**Figure 6:** Membership Functions of Result

**3.2 Fuzzy Rule Editor**

Rule Editor is the important one in Fuzzy Inference System. The rules are set in the rule editor. The disease identification

system has 8 rules. Figure 7 shows the rule editor. Some Fuzzy Rules are as follows:

1. If (Gspeed is high) and (Stride is low) and (Swing is high) and (Stance is low) and (DS is low) then the (Result is healthy (1))
2. If (Gspeed is low) and (Stride is high) and (Swing is low) and (Stance is high) and ( DS is High) then the (Result is PD (1))
3. If (Gspeed is mid) and (Stride is mid) and (Swing is mid) and (Stance is mid) and ( DS is mid) then the (Result is HD (1))



**Figure 7:** Rule Editor

**3.3 Fuzzification and Defuzzification**

This is the Mamdani approach fuzzy system. In this system, the inputs are used AND operators. So, it gives the correct result. Hence, the antecedent section has combination of some inputs to form rules in the rule editor. For aggregation, the system is used maximum of validity degree. These maximum degrees is calculated as follows:

$$A = \max(\text{all rules})$$

For defuzzification, the system is used ‘centroid’ method.

$$z_{COA} = \frac{\int z \mu_A(z) dz}{\int \mu_A(z) dz}$$

Through this formula, the defuzzification is calculated. It displays the answer.

**4. Results**

In the experiment, the following defuzzification values are derived to identify the diseases.

**Table 7:** Defuzzification Values

Defuzzification Values	Nature Of Disease
<1	Control subject
=1	Parkinson’s Disease
>1	Huntington’s Disease

**4.1 Experimental Result**

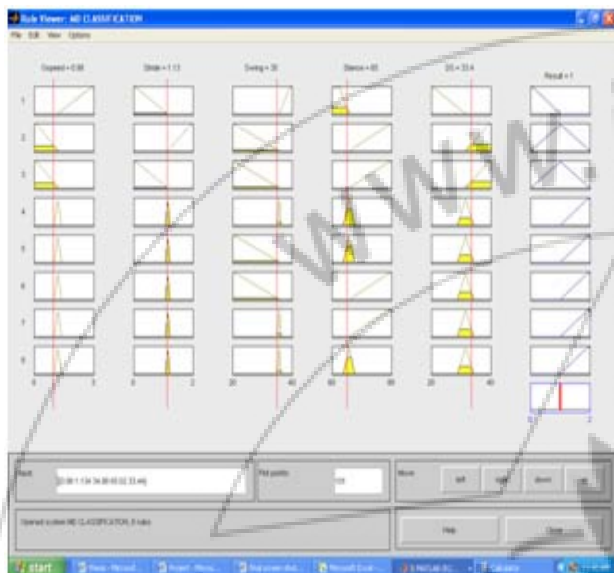
**Experiment No.1:**

The data are extracted from physionet.org. The table 8 shows the inputs of the proposed system and its result.

**Table 8:** Gait Parameter Inputs for Experiment No.1

Gait Speed	Stride	Swing	Stance	DS	Result
0.98	1.134138	34.98461	65.01539	33.43861	1 (PD)

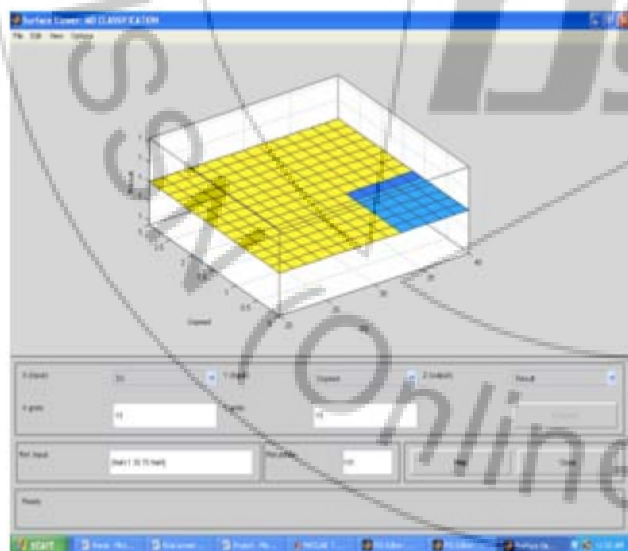
The proposed system gives the result is 1 based on the given inputs. So, that given subject is suffering from Parkinson’s disease. Figure 8 shows the output of the above input parameters.



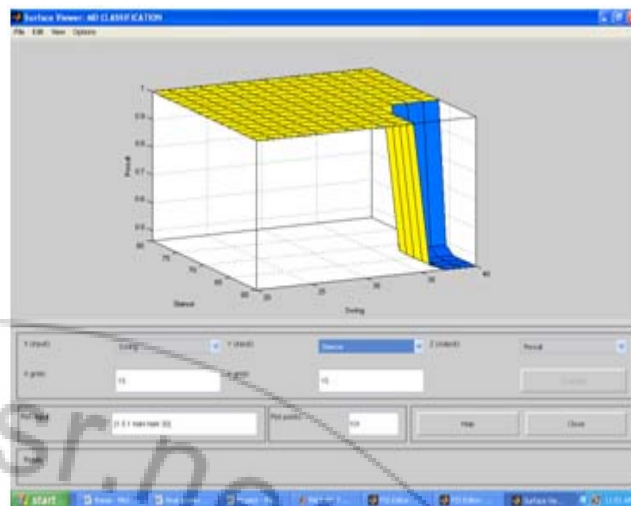
**Figure 8:** Output – PD people

**4.2 Surface View of input vs output**

This shows the graphical representation of different inputs and output. The following are some of the surface views.



**Figure 9:** Surface view of DS and Gait speed vs Result



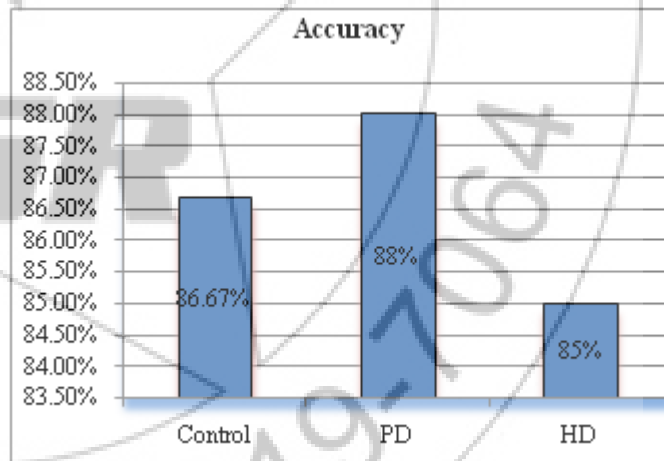
**Figure 10:** Surface view of Swing and Stride Interval vs Result

**5. Analysis**

The analysis covers 100 subject. The accuracy percentage is calculated as follows:

**Table 9:** Accuracy of Each Group

Subject	Total Number In the group	Number of Positive Results	Number of Negative Results	Positive Results %	Negative Results %
Control	30	26	4	86.67	13.33
PD	50	46	6	88.00	12.00
HD	20	17	3	85.00	15.00



**Figure 11:** Each Group Accuracy

**6. Conclusions and Scope for Future Work**

Centroid method is used for defuzzification calculations. Testing data are also used to test the results. It gives the expected output. This system has been proved to give results with better accuracy. Again, the system is trained to identify only two similar disorders viz. PD and HD with similar symptoms. Hence, there is further scope to analyse some other similar movement disorders like Progressive Supranuclear Palsy, ALS, dementia.



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