Fuzzy Logic Application to Brain Diseases Diagnosis

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ABSTRACT

The primary aim of this research is to design a Fuzzy Inference System for diagnosing brain diseases. The design was carried out with MATLAB software using the Mamdani inference method. The scope of the work is extended to five brain diseases, namely Alzheimer’s disease, Creutzfeldt - Jakob disease, Huntington’s disease, Multiple Sclerosis and Parkinson’s disease. The system has four input variables and one output variable while three membership functions are used which are low, medium and high. The results seem promising as compared to earlier studies being conducted.

Keywords: Fuzzy Logic, Membership Functions, Brain Disease, Diagnosis, Neurodegenerative

1. INTRODUCTION

Physiologically, the brain is responsible for the centralized control of other organs of the body. The brain controls the rest of the body both by generating patterns of muscle activity and by driving the secretion of chemicals called hormones. This centralized control allows rapid and coordinated responses to changes in the environment.

Once the brain is injured, other parts of the body will malfunction. These other parts may affect movement, memory, personality, reasoning ability and the behavior of the victim. Examples of brain diseases are Head trauma, Stroke, Migraine etc. But in this research, we will be diagnosing the Neurodegenerative diseases. The Neurodegenerative diseases include Alzheimer’s disease, Parkinson’s disease, Huntington’s disease, Multiple Sclerosis and Creutzfeldt - Jakob disease. These are motor neuron diseases which are caused by the gradual death of individual neurons, leading to diminution in movement control, memory, and cognition.

Alzheimer’s disease is a progressive disease that destroys memory and other important mental functions. Parkinson’s disease is a progressive disorder of the nervous system that affects one’s movement. It develops gradually, sometimes starting with a barely noticeable tremor in just one hand. But while a tremor may be the most well-known sign of Parkinson’s disease, the disorder also commonly causes stiffness or slowing of movement.

Huntington’s disease is an inherited disease that causes the progressive breakdown (degeneration) of nerve cells in the brain. Huntington’s disease has a broad impact on a person’s functional abilities and usually results in movement, thinking (cognitive) and psychiatric disorders. Creutzfeldt-Jakob disease is a degenerative brain disorder that leads to dementia and, ultimately, death. Symptoms of Creutzfeldt-Jakob disease (CJD) sometimes resemble those of other dementia-like brain disorders, such as Alzheimer’s, but Creutzfeldt-Jakob disease usually progresses much more rapidly. Multiple sclerosis (MS) on the other hand is a disease in which the immune system attacks the protective sheath (myelin) that covers the nerves. Myelin damage disrupts communication between the brain and the rest of the body. Ultimately, the nerves themselves may deteriorate a process that’s currently irreversible.

However, memory loss is a problem common to people with these diseases. Whether it’s occasional forgetfulness or loss of short-term memory that interferes with daily life. It can be caused by other symptoms like moodiness, sleep disturbances and depression. Both quantity and quality of sleep are important to memory. Getting inadequate sleep at night or waking frequently can lead to tiredness, which interferes with the ability to consolidate and retrieve information. Also paying attention and being able to focus can be a difficult task if one is depressed which can affect memory. Also Stress and anxiety can hinder concentration. When you are disturbed and distracted, you will be unable to remember things. Stress caused by an emotional trauma can also lead to memory loss.

Another common symptom is uncoordinated movement which is due to a muscle control problem that causes an inability to coordinate movements. It leads to a jerky, unsteady, to-and-fro motion of the middle of the body (trunk) and an unsteady gait (walking style). This jerky involuntary movement can also affect the limbs [7,8,9].

2. LITERATURE REVIEW

Fuzzy logic has two different meanings. In a narrow sense, fuzzy logic is a logical system, which is an extension of multivalve logic. In a wider sense fuzzy logic (FL) is almost synonymous with the theory of fuzzy sets - a theory which relates to classes of objects with unsharp boundaries in which membership is a matter of degree. Even in its more narrow definition, fuzzy logic differs both in concept and substance from traditional multivalve logical systems.

However, a fuzzy expert system is simply an expert system that uses a variety of fuzzy membership functions and rules, instead of Boolean logic, to reason about data [1]. Decision support systems for diagnostics purposes of human diseases has really helped patients and experts to an extent. In [2], the authors explained the important roles of fuzzy expert system in medicine for
symptomatic diagnostic remedies. They made it known that fuzzy logic is a method to render precise what is imprecise in the world of medicine. The various medical expert systems in existence include expert system for hypertension, sleep disorder, heart diseases, breast cancer, prostate cancer and several other diseases.

In [3], using fuzzy inference system in developing the expert system, the author made it clear that having so many factors to analyze to diagnose the heart disease of a patient makes the physician’s job difficult. Hence the need for an accurate tool which considers the risk factors and show certain result in uncertain term. The system was implemented using the Mamdani model. Mamdani’s fuzzy inference method is the most commonly seen fuzzy methodology. The system made use of eleven (11) Input variables and only one (1) Output variable. The input fields are the type of chest pain, the blood pressure, cholesterol level, age, sex and other variables. The output variable refers to the presence of heart disease in the patient.

Also in [4], a fuzzy inference approach was implemented for the diagnosis of sleep disorders with symptoms by classifying the symptoms into groups using three membership functions. This system was able to diagnose four (4) forms of sleep disorders namely, sleep apnea, insomnia, parasomnia, and snoring.

### Table 1: Diseases and the symptoms

<table>
<thead>
<tr>
<th>Diseases</th>
<th>Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alzheimer’s Disease</td>
<td>Forgetfulness(FG), Memory Problem(MP), Impaired judgment(IJ), Hallucinations (HL), Speech Difficulties (SPD), Sleep disturbances (SD), Moodiness/Depression (MD)</td>
</tr>
<tr>
<td>Creutzfeldt–Jakob</td>
<td>Memory Problem (MP), Confusion(CO), Involuntary Jerky Movements (IJM), Difficulty in Walking (DW), Muscle Stiffness (MS), Moodiness/Depression (MD)</td>
</tr>
<tr>
<td>Huntington’s Disease</td>
<td>Memory Problem (MP), Impaired judgment (IJ), Lack of Muscle Control (LMC), Involuntary Jerky Movements (IJM), Difficulty in Walking (DW), Moodiness/Depression</td>
</tr>
<tr>
<td>Multiple Sclerosis</td>
<td>Memory Problem (MP), Lack of Muscle Control (LMC), Speech Difficulties, Urinary Problem (UP), Tiredness (TD)</td>
</tr>
<tr>
<td>Parkinson’s Disease</td>
<td>Lack of Muscle Control (LMC), Difficulty in Walking, Muscle Stiffness (MS), Skin Problems (SP), Urinary Problem, Sleep disturbances (SD), Moodiness/Depression (MD)</td>
</tr>
</tbody>
</table>

### Table 2: Diseases and the grouped symptoms

<table>
<thead>
<tr>
<th>Diseases</th>
<th>Cognitive Symptoms</th>
<th>Motor-Function Symptoms</th>
<th>Physical Symptoms</th>
<th>Psychological Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FG</td>
<td>MP</td>
<td>CO</td>
<td>IJ</td>
</tr>
<tr>
<td>Alzheimer’s Disease</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>Creutzfeldt-Jakob</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Huntington’s Disease</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>Multiple Sclerosis</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>Parkinson’s Disease</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
</tbody>
</table>
Table 3: Ranges of fuzzy values

<table>
<thead>
<tr>
<th>Membership functions</th>
<th>Fuzzy Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>$0 &lt; x &lt; 0.3$</td>
</tr>
<tr>
<td>Medium</td>
<td>$0.3 \leq x &lt; 0.6$</td>
</tr>
<tr>
<td>High</td>
<td>$0.6 \leq x &lt; 1$</td>
</tr>
</tbody>
</table>

From Table 2, a cell with “YES” indicates that the symptom is related to the disease. So to get the membership function of the grouped symptoms,

\[
\text{Membership function} = \frac{\text{No of "YES"}}{\text{Total no of symptoms in a group}}
\]

Therefore, for Alzheimer’s disease,

\[
\text{Membership function of Cognitive Symptoms} = \frac{\text{No of "YES"}}{\text{Total no of symptoms in a group}} = 0.75
\]

Comparing the value with values in Table 3, the membership function of cognitive symptoms for Alzheimer’s disease will be high. This is how the membership functions used in the rule base was generated.

4. RESULT

This inference system accepts four input variables which are the cognitive symptoms, motor-function symptoms, physical symptoms, psychological symptoms and the output given out is the disease. The inference system compares the input to its rules and gives out the disease. Fig 2 shows the structure of the fuzzy inference system.

Fig 2: Outline of the proposed system

Fig 3: Developed fuzzy rules

Defuzzification is the process of converting the aggregated output membership function into crisp form. It must be performed in order to derive an appropriate representative value for the final output. [10] The conversion is done using the Centroid defuzzification technique given in equation 1:

\[
x_c = \frac{\int x \mu(x) dx}{\int \mu(x) dx}
\]

Where

- $x_c$ is the defuzzified output,
- $\mu(x)$ is the aggregated output membership function and
- $x$ is the output variable i.e. center of membership function.

The Centroid technique is the most commonly used defuzzification technique and is very accurate. Though dealing with complex membership functions can be computationally difficult.

Fig 4 shows the result when the cognitive symptoms are medium, the motor-function symptoms are medium, physical symptoms are medium and the psychological symptoms are medium; the disease is Creutzfeldt – Jakob disease. The triangular membership function is shown in figure 5.
Fig 4: Result Rule viewer

Fig 5: Results of the fuzzy inference system

Fig 6: Surface view of the fuzzy expert system

Fig 6 shows the surface view which is the output of Motor-Function Symptoms against cognitive symptoms. This surface view is a three-dimensional curve that represents the mapping from Cognitive symptoms and Motor-function symptoms to disease. Because this curve represents a two-input one-output case, you can see the entire mapping in one plot. When we move beyond three dimensions overall, we start to encounter trouble displaying the results.

Accordingly, the Surface Viewer is equipped with drop-down menus X (input), Y (input), and Z (output): that let you select any two inputs and any one output for plotting. Below these menus are two input fields X grids: and Y grids: that let you specify how many x-axis and y-axis grid lines you want to include.

5. CONCLUSION

Fuzzy inference system is one of the best approaches because it simulates an expert’s behavior in diagnosing diseases. For this research, the cognitive symptoms, motor-function symptoms, physical symptoms and the psychological symptoms are the input variables while the disease is the output. The system was developed using three trapezoidal membership functions which are low, medium and high. The membership function for the output variable is triangular. The system was tested and the accuracy is very good.

REFERENCES


AUTHORS’ PROFILES

Ayangbekun Oluwafemi J. received his Master of Science (MSc) degree in Computer Science in 2007 from University of Ibadan Nigeria and his Bachelor of Technology (B.Tech) in Computer Engineering in 2003 from Ladoke Akintola University of Technology Ogbomoso, Nigeria. He is presently a PhD researcher in the Department of Information Systems, University of Cape Town, South Africa. He has published several research Papers in an International Journals and also presented research papers in Learned Conferences.

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