# A Fuzzy Expert Systems Design for Diagnosis of Parkinson's Disease

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*Abstract*-**This paper delineates a model of a fuzzy expert system, dedicated to Parkinson's disease diagnosis. This has been carried out in the view of improving the diagnosis currently established upon basis of subjective scores. Parkinson's disease has proven a high incidence within third age people, signifying the second neurodegenerative disease, after Alzheimer. This paper proposes a new quantitative evaluation and analysis system for patients, in order to diagnose the Parkinson's disease at the incipient stage. The input parameters of the system are represented by amplitude, frequency, the spectral character and trembling localization. The last one signifies the main symptom that occurs in Parkinson's disease, but others can also be mentioned: small handwriting, loss of smell, trouble sleeping, soft or low voice. The proposed system proves to be fast, efficient, and non-invasive and can be used by both physicians and patients at home, as well.**

***Keywords: Parkinson's disease, Fuzzy Logic, Fuzzy Expert Systems***

## I. INTRODUCTION

Parkinson's disease occurs as result of dopamine loss, a chemical mediator that is responsible of body's ability to control the movements. There are also some other factors leading to disease's occurrence, such as: fault of mitochondrial genes, exposure to pesticides, ingestion of drugs (heroine), free radicals, viruses (encephalitis inducers), as well as head shocks [1].

According to the last statistics, one may mention that in Romania, over 75,000 patients suffer of Parkinson, many of them being undiagnosed.

Forwards, the paper is thus structured: Section II underlines background information specific to Parkinson's disease; Section III emphasizes the main scales used by physicians in order to diagnose the Parkinson's disease. Section IV includes the explanation of the new medical method proposed in Parkinson's disease diagnosis. The results achieved are illustrated in Section V. Consequently, Section VI emphasizes the conclusions, making a summary of results and future research proposals.

## II. PARKINSON'S DISEASE BACKGROUND

Parkinson's disease has been occurred in quite different ways from one patient to another, and symptoms have been more and more obvious as the disease advances. In the incipient stage of the disease, the symptoms can be noticed for only half of body [2].

The main signs that appear in the disease's incipient stages are the following:

- trembling of hands, arms, chin and face, when the affected member is non-moving
- the handwriting is small and crowded
- movement difficulties - bradykinesia and akinesia
- postural instability
- disturbance of coordination and equilibrium
- sleep disturbance
- depression
- difficulties in speaking, reducing of voice volume
- sensation of lump in the throat
- Motional blocking, difficulties in executing some simple movements.

The diagnosis is determined by the neurologist, upon basis of expensive imagistic procedures (neuroimagistics, structure imagistics, functional imagistics), as well by using well known subjective scales of evaluation.

The differential diagnosis has been met to various diseases, among which one may mention: the akinetic rigid syndrome, the hyperkinetic syndrome, corticobasal degeneration, insanity with Lewy bodies, medicamentary induced Parkinson, essential trembling, multitudinous systemic atrophy, post-encephalic Parkinson and vascular Parkinson.

Although there is no curative treatment for Parkinson's disease, its symptoms can be attenuated by means of medicines, as well as by modifying the life style. Generally, the symptoms can be successfully controlled if the treatment is adapted to disease's evolution. The treatment's goal consists in controlling the signs and symptoms during a long time duration, as well as reducing the adverse effects. Medicines offer a good symptomatic control within 4 to 6 years.

After such interval, the invalidity progresses in time, despite of treatments, where many patients manifest motional complications on long term.

## III. UNIFIED PARKINSON'S DISEASE RATING SCALE AND OTHER TOOLS FOR PARKINSON'S DISEASE DIAGNOSIS

Starting with 1987, this "universal" scale was introduced in order to evaluate the Parkinson's disease (Unified Parkinson's Disease Rating Scale - UPDRS), thus quantifying signs and symptoms met in Parkinson's disease. It monitors the disabilities, giving individual subscore, at which the Hoen and Yahr's score is added [3].

This is done in the view of setting the disease's stage, Schwab and England Activities of Daily Living (ADL) Scale, which evaluates the daily individual activities of the patient with Parkinson. MMSE evaluates the cognitive disturbances,

PDQ-39 evaluates the quality of patient's life, and the Epworth scales evaluate the sleep disturbances.

The *Unified Parkinson's Disease Rating Scale* (*U*nified *P*arkinson's *D*isease *R*ating **S**cale) is a rating scale used to follow the longitudinal course of Parkinson's disease [3], [4].

It is made up of the following sections:

- *Part I*: evaluation of Mentation, behavior, and mood;
- *Part II*: self evaluation of the activities of daily life (*ADLs*) including speech, swallowing, handwriting, dressing, hygiene, falling, salivating, turning in bed, walking, cutting food;
- *Part III*: clinician-scored motor evaluation;
- *Part IV*: Hoehn and Yahr stating of severity of Parkinson disease.
- *Part V*: Schwab and England ADL scale.

Parts I, II and III contain 44 questions each measured on a 5 point scale (0-4). In monotherapy, a total UPDRS score is the combined sum of I to III, from example, 0 - not affected to 176 - most severely affected. In adjunct therapy, part IV is included. Part IV contains 11 questions and the scale can range from 0 to 23 [5].

Currently, the most common evaluation method to symptoms' gravity for patients with Parkinson's disease (PD) is represented by the scales of clinical evaluation. These assign a score to each present symptom, but the main disadvantage is given by their subjectivism.

Different physicians can assign different scores to the same patient, where no measurements exist in order to be quantified. As concerns the clinical PD diagnosis, UK Parkinson's Disease Society Brain Bank criteria are used, meaning a set of well validated criteria, which help on setting an accurate clinical diagnosis, with a specificity of 98.1% and a sensitivity of 90.4%.

TABLE I
REPRESENTATIVE SAMPLE OF KEY MEASUREMENT FROM THE UPDSR SCALE
TYPE SIZES FOR CAMERA-READY PAPERS

| UPDSR Item | UPDSR Scale | |
|---|---|---|
| | Assessment | Scale Measurement Range |
| Bradykinesia subscale | Body bradykinesia and hypokinesia<br>Left- and right- hand finger taps, opening and closing of hand | 0 – not affected to 36 – most severely affected |
| Tremor subscale | Action tremor of right and left hands<br>Resting tremor in the left and right hand and feet<br>Resting tremor of the face, lips, and chin | 0 – not affected to 32 – most severely affected |
| Rigidity subscale | Rigidity in the neck<br>Rigidity in the left and right upper and lower extremities | 0 – not affected to 20 – most severely affected |
| PIGD (Postural Instability and Gait Disorder) | Falling, freezing, ability to walk<br>Gait, postural stability | 0 – not affected to 20 – most severely affected |

These criteria reunite aspects of anamnesis and clinical examination, where the PD diagnosis has an error rate of 10-20%. Currently, there is no screening test of precocious diagnosis of Parkinson's disease.

## IV. MATERIALS AND METHODS

### A. Previous Research

No data has been identified in the field literature, as concerns finding a system for classifying and evaluating the patients with Parkinson's disease in the incipient stage. Some tests were performed in order to solve some diagnosis issues, by means of classification or fuzzy expert systems in identifying hepatitis, in prostate cancer diagnosis or in the analysis of the umbilical cord blood.

Few data exists in the field literature related coalescence of nonlinear dynamics parameters with the medical parameters. Thus, most of parameters can be characterized by linguistic variables (fuzzy). No report has been seen in the field of appointing the score of Parkinson's Disease Risk and the research is a new work in this field.

### B. The Data

The database used includes 100 records from patients with or without Parkinson's disease, and each record is characterized by seven attributes (age, amplitude of trembling, frequency of trembling, value of Lyapunov exponent, fractal or correlation dimension and UPSDR) [6] - [10].

The main parameters and the corresponding linguistic degrees used in the rule base are presented in TABLE II.

TABLE II
THE MAIN PARAMETERS AND THE CORRESPONDING LINGUISTIC DEGREES

| Parameter | Notation for the linguistic degrees | Remarks |
|---|---|---|
| Age | Very Young, Young, Midle Age, Old | Well understood by physicians/ patient |
| Amplitude | Low, Medium, High | Well understood by physicians |
| Frequency | Low, Medium, High, Very High | Well understood by physicians |
| Lyapunov Exponent | Low, Medium, High | Poorly understood by physicians |
| Correlation Dimension | Low, Medium, High | Poorly understood by physicians |
| Fractal Dimension | Low, Medium, High | Poorly understood by physicians |
| UPDR Score | None, Moderate, Mild, Severe, Extremely Severe | Well understood by physicians |

### C. The Fuzzy Expert System Design

This system is specific to fuzzy expert - hybrid systems. It consists of individual, expert, knowledge engineer, fuzzy rule base, fuzzy inference engine and fuzzification or defuzzification [11]. A Fuzzy Expert System is a collection of membership functions and rules that are used to reason about data. Unlike conventional Expert System, which is mainly symbolic engines, Fuzzy Expert System is oriented toward numerical processing.

With the definition of the rules and membership function we now need to know how to apply this knowledge to specific values of the input variables to compute the values of the output variables. This process is referred to as inferencing. In a Fuzzy Expert System, the inference process

include four subprocesses: fuzzification, inference, composition and defuzzification.

In order to identify the risk score of Parkinson's disease, the FIS tool in software Matlab was used, where FES – Fuzzy Expert System structure is illustrated in the following figure.

*1. The Fuzzification*

In the fuzzification subprocess, the membership functions

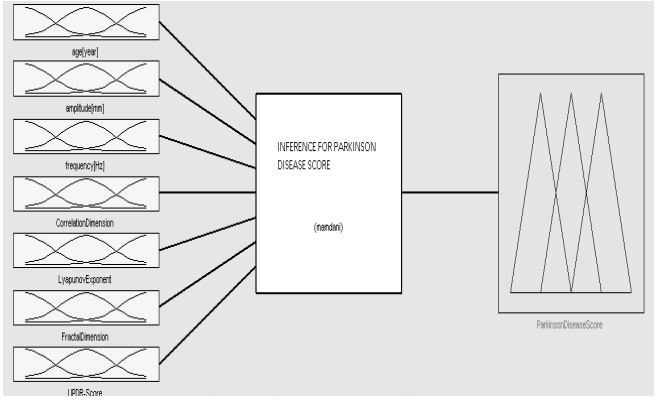


Fig. 1. The structure of the FES

define on the input variables are applied to their actual values, to determine the degree of truth for each rule premise[12] - [16]. The trapezoidal and triangle functions of affiliation were used. The membership functions of the Parkinson's disease fields have been defined as shown below:

The fuzzification of the applied fields has been carried out by some functions, as shown below and that can be used by

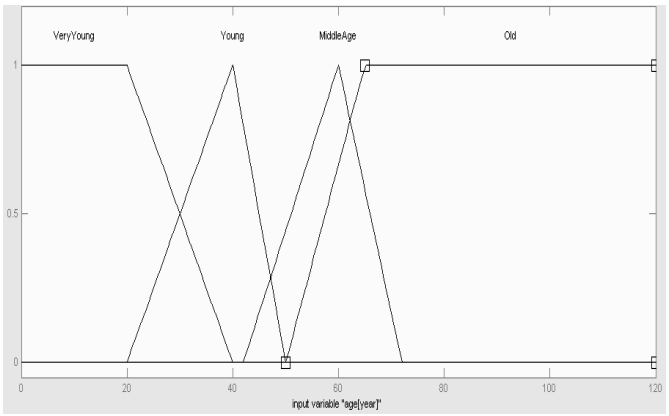


Fig. 2. Membership Function Age[year] (Very Young, Young, Middle Age, Old)

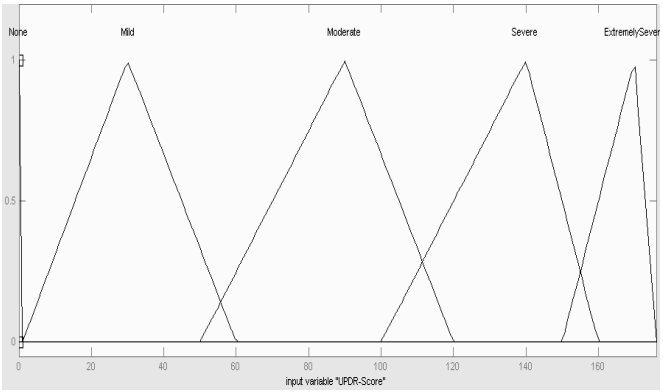


Fig. 3. Membership Function UPDRScore (None, Mild, Moderate, Sever, Extremely Severe)

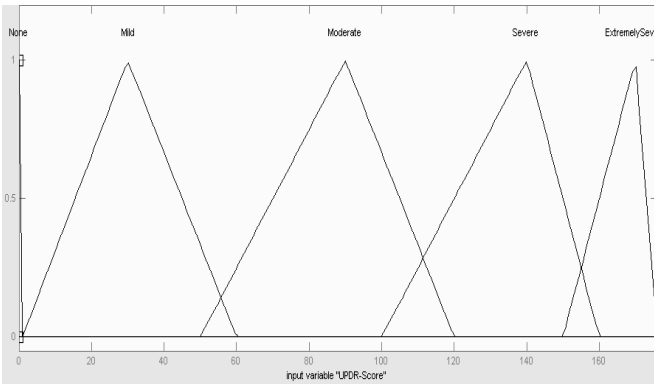


Fig. 4. Output Fuzzy Membership Function Parkinson'S Disease Score (Very Low, Low, Middle, High, Very High)

the specialist cooperation (physicians).

The memberships of the used factors are obtained from formulas (1) – (3):

$$Age(A)=\begin{cases}1; & 65\le a\\ a; & 0<a<65\end{cases} \tag{1}$$

$$Amplitude(\alpha)=\begin{cases}1; & \alpha\ge 10\\ 0; & \alpha\le 1\\ \alpha; & 1<\alpha<10\end{cases} \tag{2}$$

$$PDScore(\lambda)=\begin{cases}\lambda; & 0<\lambda<100\\ 0; & \mu<0\\ 0; & \mu>0\end{cases} \tag{3}$$

*2. The Rule Editor and The Defuzzification*

In the inference subprocess, the truth value for the premise of each rule is computed, and applied to the conclusion part of each rule. This results in one fuzzy subset to be assigned to each output variable for each rule [17]. The Truth Degrees ($\alpha$) of the rules are determined for each rule, by means of the min and max values between working rules. For example, for a 50 years old patient, the values are: 2 mm in Amplitude, 6 Hz in Frequency, 1.4 in Lyapunov Exponent, 1.3 in Fractal Dimension, 3.2 in Correlation Dimension, and 106 UPDRScore. According to the rules 64 and 82, one will obtain:

- $\alpha_{64}$ = min(Middle Age, Medium Amplitude, Medium Frequency, High Lyapunov, High Fractal Dimension, High Correlation Dimension, UPDRScore Severe) = min(0.67,1,1,1,1,1,1) = 0.67.
- $\alpha_{82}$ = min(Old Age, Medium Amplitude, Medium Frequency, High Lyapunov, High Fractal Dimension, High Correlation Dimension, UPDRScore Severe) = min(0.33,1,1,1,1,1,1) = 0.33.

In accordance to Mamdani max-min inference, one will obtain the membership function of the proposed system, meaning: max($\alpha_{64}$, $\alpha_{82}$)=0.67, which is the High PDScore.

Then, the crisp output is calculated, by the centre of gravity defuzzification method, as expressed in the formula (4):

According to the developed rules, and meeting the formulas (1) – (3), for Middle Age, High Amplitude, High Frequency, the membership functions will have the following form:

$$D^{crisp} = \frac{\int D \times \mu_{Middle}(D) dD}{\int D\, \mu_{Middle}(D) dD} \quad (4)$$

For example, the value of PDScore of 62.7, which means that the patient has Parkinson Disease with a probability of 62.7%.

## V. CONCLUSIONS

The proposed fuzzy expert system was designed by using a model of 100 PD tremor time series [18]. This paper delineates a model of a fuzzy expert system, dedicated to Parkinson's disease diagnosis, and which can be used by specialists.

In the proposed research approach, a fuzzy expert system was designed, by using FIS Tools of MATLAB. In the fuzzy expert Systems, the achieved accuracy of diagnosing the Parkinson's disease was of 95.46%.

The Fuzzy Logic Toolbox function that accomplishes the adjustment of membership's function parameter in MATLAB is assigned as ANFIS (Adaptive Neuro-Fuzzy Inference System).

By using a given input or output data set, the ANFIS function creates a fuzzy inference system (FIS), whose Membership Function parameters are adjusted by means of the back propagation algorithm, or in combination with the least squares method.

The neuro-adaptive learning techniques provide a method for the fuzzy modeling procedure to learn information about a data set, in order to compute the membership function parameters that best allow the associated fuzzy inference system to track the given input/output data.

By the help of Matlab software, an ANFIS box was used, in order to create ANFIS (loading the training and testing data, assigning the basic FIS model, assigning the optimization of FIS model parameters, training the system, calculating the errors average probability or testing the systems).

The achieved preliminary results emphasize that the fuzzy relations should be taken into account as an accurate method to handle imprecision of Parkinson's disease diagnostic.

This emphasizes the handling of decision making procedures in the PD treatment, thus encouraging the achievement of future research studies, in order to perfect the proposed model.

Future research proposals include the testing and validation of a screening test, in the view of detecting Parkinson's disease starting with incipient stages.

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