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Parkinson Classifier

Project-3

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1. Summary

Parkinson´s disease belongs to a group of conditions called motor system disorders, which are the results of the loss of dopamine-producing brain cells. The four primary symptoms are tremor, rigidity, bradykinesia and postural instability. It is a common world issue as it is the second most prevalent neuropsychiatric neurodegenerative disorders that increases exponentially with aging. It is a non-curable disease, however, if it is detected soon, a treatment can be applied and the time-span and quality life of the patient could be increased [1]. This disorder has 5 phases, in incremental affection order, and each of these phases need a specific approach and treatment to delay the advance of the condition [2]. Due to this fact, we consider vital to classify correctly patients suffering from this condition, in order to understand the progression of the disease and applied the most suitable treatment. There are treatments available that can help at every stage of the disease. However, the earlier the diagnosis, and the earlier the stage at which the disease is diagnosed, the more effective the treatment is at alleviating the symptoms.

The patients are normally classified by a personal doctor appointment that will base their decision following the different scales system used to characterized patients with Parkinson. This diagnostic could be affected by several factors that are not directly related to the disease such as the subjectivity of the medical personal. As the most common scale is related to motor symptoms, we propose a Decision supporting system that standardized the most relevant motor symptoms with their respective scales, and then computes a final reliable score that will detect the different phases of Parkinson disease.

The program will be used mainly by medical stuff such as nurses or doctors, but it could be used as well by trained non-medical stuff that need to be familiar with the different motor scales used in our program. This would facilitate the time of phase detection of the disease by only needing a visual and some survey intervention from the assessor to the patients. Also, the program is capable of giving advice to the medical expert on the treatment the patient could follow, however, the final decision is up to the doctor. This would decrease the medical expenses of consultation as well as the phase detection time of the disorders that directly implies with a faster and a more efficient treatment. It is related to biomedical engineering since it is a health issue that needs to be automatized, it provides support to the decision made by the doctors, as well as it classify patients in a more standard way and provides a treatment recommendation.

2. Parkinson phases

In our supporting Decision Supporting System we follow the Hoehn and Yahr Scale, that is the most known and used scale system to detect severity on Parkinson disorder. It consists of the following 5 phases:

1. **Stage 1**. In this early stage, the symptoms of Parkinson disease are mild and only seen in one side of the body and there are usually minimal or functional impairments [4].

a. The **symptoms** at stage one may include tremor, such as intermittent tremor of one hand, rigidity or impacting expression in one side of the face. This stage is very difficult to diagnose and a physician may wait to see if the symptoms get worse over time before making a formal diagnosis [2].
b. Treatment: Amatadine drug is an early stage drug used to reduce the tremor and rigidity, it is used before Levodopa due to the fact that this last creates immunity. It is also strongly recommended to avoid stressing situations and stay in familiar environments [3].

2. **Stage 2**. It is still considering an early disease and it is characterized by symptoms on both sides of the body without impairment to balance.
    a. **Symptoms** in this stage may include the loss of facial expression on both sides of the face, speech abnormalities, rigidity of the muscles in the trunk, stooped posture and general slowness in all activities of daily living. However, at this stage the individual is still able to perform tasks of daily living [2].
    b. Treatment: If Amatadine does not works to cease the symptoms, an alternate drug are Anticholinergics. It is also strongly recommended to avoid stressing situations and stay in familiar environments [3].

3. **Stage 3**. Stage three is considered mid-stage and is characterized by loss balance and slowness of movement.
    a. Symptoms in this stage is the compromised balance by the inability to make the rapid, automatic and involuntary adjustments necessary to prevent falling. All other symptoms of Parkinson disease are also present at this stage, and generally diagnosis is not in doubt at stage three. An important clarifying factor of stage three is that the patient is still fully independent in their daily living activities, such as dressing, eating and hygiene [2].
    b. Treatment: Levodopa drug relieves bradykinesias, rigidity and may reduce tremor. It is also strongly recommended to avoid stressing situations and stay in familiar environments [3].

4. **Stage 4**. In stage four the disease has progressed to a severely disabling disease. Patients in this stage may be able to walk and stand unassisted, but they are noticeably incapacitated, many use a walker to help them.
    a. Symptoms in this stage unable the patient to live an independent life and needs assistance with some activities of the daily living. The necessity for help with daily living defines this stage. If the patient is still able to live alone, it is still defined as stage three [2].
    b. Treatment: when the drugs does not work, deep brain stimulation [4].

5. Stage 5. Is the most advanced stage and is characterized by an inability to rise from a chair or get out of the bed without help.

a. **Symptoms** in this state totally incapacitate the patient from independent living, it is required around-the-clock assistance to reduce the risk of falling and help the patient with all daily activities [2].
b. **Treatment:** In this stage, the last treatment could be brain surgery [4].

3. Theoretical support of the Questionnaire

Gait

Does the patient limp? (yes or no)

Does the patient walk slowly? (yes or no)

Does the patient fall frequently? (yes or no)

Bradykinesia is one of the most common symptoms of Parkinson, it literally means “Slow movement”. Apart from this, bradykinesia can present incomplete movement, difficulty to initiate movements and sometimes an abrupt termination of movement. Another interesting fact to study about gait is if the patient limps or walks with short gaits. Last but not least, we study if the patient falls frequently [5]. Each of these parameters (Bradykinesia, limp and falls) will have a score of 1 (This makes the metric sub score to be always between 0-3)

Tremor

Classify the tremor of the patient (0 non-existent, 1 mild, 2 moderate, 3 severe)

In the initial stages of the disease, about 70 percent of people experience a slight tremor in the hand or foot, on the side of the body, or less frequently, in the jaw or face. Since Parkinson's tremor usually appears when the muscles are relaxed, it is called "resting" tremor. This means that the affected part of the body trembles when it is not performing an action. Tremor often spreads to the other side of the body as the disease progresses, but usually manifests more strongly on the initially affected side. Usually an increased in the tremor, is associated with an increased impediment and a worsening of the disease. While tremor is the most noticeable external sign of the disease, not all people with PD develop tremor and that is why we need to evaluate other signs of the disease [1, 5].

Posture

Does the patient have retropulsion? (yes or no)

Has the patient failed the pull test? (yes or no)

Is the patient stooped over? (yes or no)

Posture is a characteristic aspect in people with Parkinson's conditions, these are measured by equilibrium tests such as the pull test. The Pull Test (PT) was described by S. Fahn et al and integrated in the Unified Parkinson´s Disease Rating Scale (UPDRS) in 1987 for evaluating the postural. People with postural instability may have a hunched position, with their head bowed and their shoulders dropped [5]. That is why it is important to measure the postural stand of the patient, evaluating if the patient has retropulsion or if it is stooped over.

Daily Activities

Can the patient eat alone? (yes or no)

Can the patient get dressed by himself? (yes or no)

Is the patient not capable of living alone? (yes or no)

We will also study if the patient is able to perform the day-to-day activities such as: Being able to eat alone, get dressed by himself or if he is capable of living alone. We have considered that these activities are the most relevant to study, having a score of 1 point if the patient cannot eat alone or get dressed by himself and 2 points if he can´t live by himself (E.g. Not being able to get out of bed, going to the bathroom or eating alone).

Voice

Does the patient have soft voice? (yes or no)

Is the patient stuttering? (yes or no)

Is the patient speaking fast? (yes or no)

Other symptoms and signals include: Smoothing of the voice (1 point), stuttering (1 point), excess of salivation (not considered as important), and rapid speech (1 point). Taking this into account, the final score can only be between 0 and 3.

4. Structure of the project

With the decision tree and the table score below, we can follow the functioning of the decision support system. If the patient as cited before, only suffers from symptoms in one side of the body, due to literature it is classified as stage 1 of the disease. If symptoms affect both sides, then the number of different possible stages increases and we need a sub-score of the most relevant motor symptoms scales in order to compute the final score. We base our final score in 5 sub-scale systems of the most relevant motor symptoms of Parkinson disease. The given score would be compared to some predefined intervals that correspond each of them to a different stage of the disease,

this would be the model for the structured portion. Dependently from each stage, a suitable treatment would be recommended to the medical expertise. However, as our project is semi-structured we only help doctors to classified the patients with Parkinson and as the unstructured portion, they have the final decision on which treatment the patient should follow. It is a combination of both standard solution procedures and human judgment.

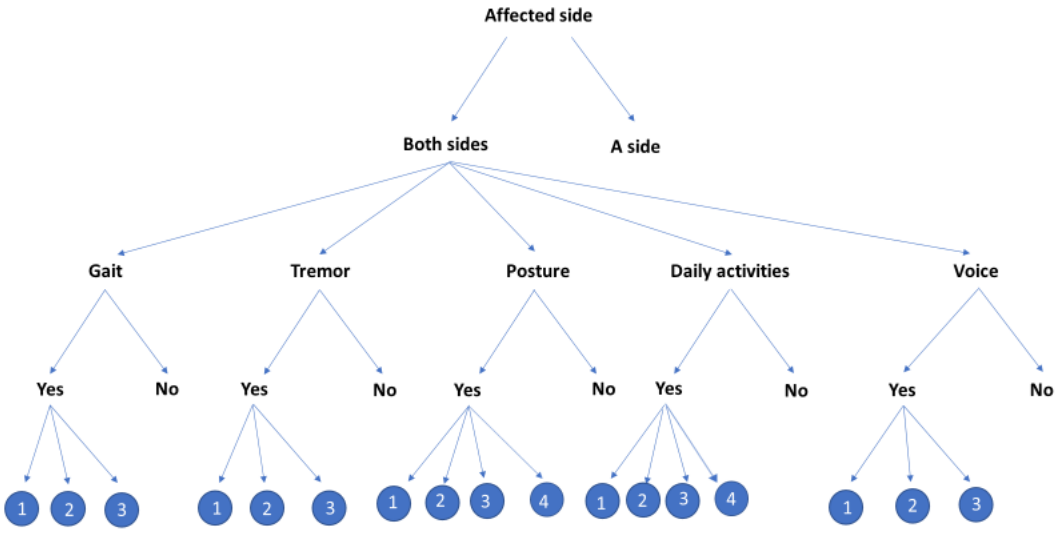

Figure 1. *Decision tree (5 subscale metrics)*

STAGE	SCORE	TREATMENT
1	-1	Amatadine
2	0-4	Anticholinergics
3	5-8	Levodopa
4	9-12	Deep brain stimulation
5	13-17	Brain surgery

Figure 2. *Table of the Parkinson Stage Intervals (5 stages)*

5. Clips

Templates

The template used in the project is the template Patient. It contains several slots that correspond to the answer of specific question regarding each metric. The attributes are divided in 5 subscales: tremor, posture, daily activities, gait and voice. These 5 subscales slots will contain a score deduced from the questions asked in each evaluation metric. Another important attribute is the slot both_sides as it will determine whether the symptoms affect both sides or not. These subscales scores are going to then be sum in

the attribute final_score and with it we will decide the stage of the patient and a recommended treatment. We decided to store all these attributes, as we believe that we will need the stored evidence on how the system make the Parkinson stage classification.

```
(deftemplate Patient (slot name)
        (slot surname)
        (slot age)
        (slot sex)
        (slot both_sides)
        (slot tremor)
        (slot posture)
        (slot daily_activities)
        (slot gait)
        (slot voice)
        (slot final_score)
        (slot stage)
        (slot limp  )
        (slot slow_walking )
        (slot falling_freq )
        (slot eat )
        (slot dress )
        (slot dependency )
        (slot retropulsion )
        (slot pulltest )
        (slot stoopedover )
        (slot softvoice )
        (slot stutter )
        (slot fasttalk )
        (slot diagnosis (default no))
        (slot questions (default no))
        (slot controlsides (default no))
        (slot treatment)
        )
```

The system will only require one patient, this patient will be modified by the GUI and these modifications will trigger the conditions that satisfy a set of rules that follows the path of execution of the program. After the patient is evaluated, Clips will be reset and it will start over by adding an empty patient again.

Rules

In this section, as an explanatory example of our whole subscale metric systems, we would explain the set of rules for the subscale metric system, Posture and Tremor. First, we are going to ask to the doctor/user several yes/no questions related to the symptoms of the metric scale, then we will modify the patient based on those answers. The path of execution would go as follow:

1. **Evaluating if the symptoms affect one side or both sides of the patient:**

```
(defrule Sides1
        (declare (salience 97))
        ?p <- (Patient (both_sides no) (diagnosis no) (questions no))
        =>
        (modify ?p (final_score -1)(stage 1)(questions yes)(controlsides yes))
        )

(defrule Sides2
         (declare (salience 96))
        ?p <- (Patient (both_sides yes) (diagnosis no) (controlsides no))
        =>
        (modify ?p (controlsides yes))
        )
```

With these two rules, our decision-based system will choose two paths of execution. If the patient has symptoms only in one side it will immediately classified the patient as stage 1, it will skip the questionnaire and continue to the evaluation part. On the other hand, if the patient has symptoms in both sides, then, the questionnaire would begin until all the sub-scores are covered.

2. **Evaluating the symptoms of the patient regarding each subscale metric system (eg. Posture and Tremor):**

```
String query = "(modify "+address+" (retropulsion "+retropulsion+")"
        + "(pulltest "+pt+")(stoopedover "+so+")(tremor "+tremor+"))";

Main.clips.eval(query);

Main.clips.run();
```

In the GUI, the program will gather all the yes/no questions related to the symptoms associated to each sub-score. In this case, the code above shows how after compiling all the answer of the sub-score Posture and Tremor, the patient is modified based on those answers. It utilizes a java object Environment to communicate with the decision support system.

3. **Getting the score for the metric scale (eg. Posture):**

```
(defrule GetPosture
        (declare (salience 75))
        ?p <- (Patient (stage nil) (retropulsion ?r) (pulltest ?pu) (stoopedover ?s)
        (diagnosis no))
        (test (numberp ?r))
        (test (numberp ?pu))
        (test (numberp ?s))
```

```
=>
(modify ?p (posture (+ ?r (* ?pu 2) ?s))))
```

After getting all the yes/no questions, we compute the score for this metric. However, as you can observe in the rule, not all the attributes have the same weight in this metric. For example, failing the pull test have the double weight than having retropulsion or being stooped over.

4. Getting the result for the final Score:

After computing all the subscale metrics, the system has to compute the final score, as follows:

```
(defrule GetFinalScore
        (declare (salience 66))
         ?p <- (Patient (tremor ?t) (posture ?po) (daily_activities ?d) (gait ?g)
        (voice ?v) (diagnosis no) (questions no))
         (test (numberp ?t))
        (test (numberp ?po))
        (test (numberp ?d))
        (test (numberp ?g))
         (test (numberp ?v))
         =>
         (modify ?p (final_score (+ ?t ?po ?d ?g ?v)) (questions yes))
         )
```

As you can see, this rule only triggers when all the metric sub-scores were computed and have a numerical value. After this is done, we proceed to continue with the evaluation part by modifying the questions slot.

5. Assigning the stage of the disease:

```
(defrule GetStage2
        (declare (salience 65))
        ?p <- (Patient (final_score ?f) (diagnosis no) (questions yes))
        (test (numberp ?f))
        (test (> ?f 0))
        (test (< ?f 5))
        =>
        (modify ?p (stage 2)))
```

In the evaluation part after we compute the final score, we can classify the patient in 5 different stages, each stage has a score interval as you can see in figure 2. We have a specific rule to detect each stage interval. This is an example of the rule that would be triggered in the case that the patient falls in the stage 2 interval.

6. Recommending a treatment following the patients scales:

```
(defrule AddNewTreatment_Stage2
        (declare (salience 59))
         ?pa <- (Patient (stage 2) (diagnosis no) (treatment nil))
         =>
        (modify ?pa (diagnosis yes) (treatment Anticholinergics))
        )
```

The recommended treatment that the DSS is going to assign, is a treatment based on the stage of the patient. Therefore, we would have one rule for each stage that will assign a different treatment. In this case, this is a rule that would be triggered if the patient corresponds to the stage 2 of the Parkinson disease. Once this is concluded, the patient information is completed and ready to be saved.

7. **Ask the user if he/she wants to evaluate and add another patient:**

   Main.clips.reset();

   If the user decides to add a new patient, it will reset the whole system and a new patient would be asserted at the beginning of the Questionnaire again.

6. Graphic User Interface

The graphic user interface of the program was specially designed to fulfill most of the requirements of an agile and precise Decision Support System. The first step was to connect the .CLP file with the set of rules and the java Application. To do so, we created a java Object Environment, this allow us to interconnect java and Clips through this object. The project will use the same Environment object clips through all the execution of the program, it is important that it is accessible to all the modules of the program and that its value is shared through all the execution, so we declared it as a public static object. The Clips file is in the same folder as the project with the name “project3.CLP”. The GUI was designed to follow the same execution path as the rules in Clips file.

```
Main.clips = new Environment ();
Main.clips.clear();
Main.clips.load("project3.CLP");
Main.clips.reset();
Main.clips.run();
```

The GUI is divided in two different “modules”, the part of the Questionnaire and the Evaluation or Diagnosis Part. In this section, we would like to describe the design of the GUI, its characteristics and its functionalities. In each capture, we would like to describe their different characteristics.

Questionnaire

The Questionnaire part consists of compiling in order all the yes/no questions of each sub-score. In each scene we would evaluate separately each metric, as we don't want to overload the memory of the user or overload the Scene with too much components. In this way we have all the information related together in the same scene.

Sides Affection Evaluation

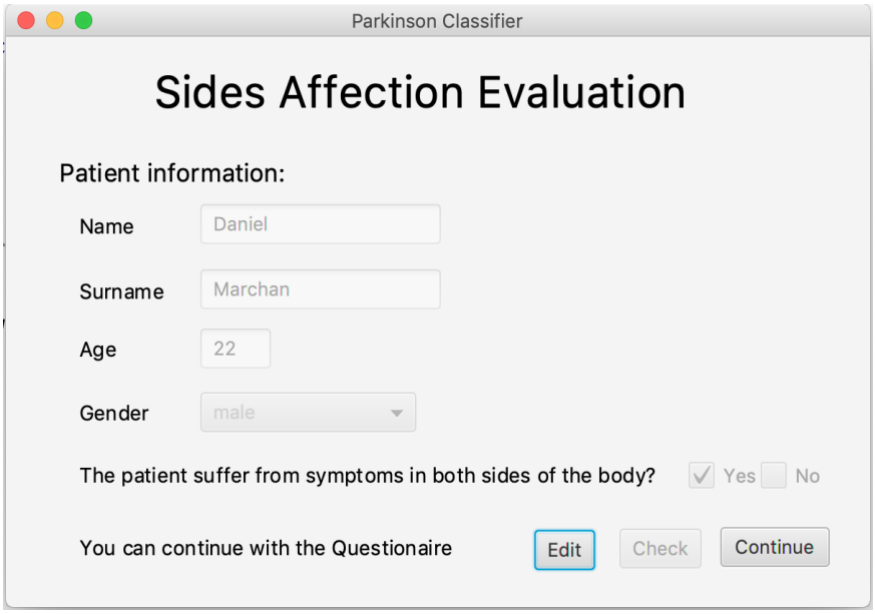

Figure 3. *Sides Affection Evaluation*

This scene corresponds to the beginning of the Questionnaire, in where we obtain all the helpful information of the patient such as the name, surname, age or gender. Then we would ask the first question. This question will condition the path of execution, since we know by literature, that if the patient only shows symptoms in one side of the body then the patients is classified as stage 1. If this happens, we would skip the next scenes of the Questionnaire and go directly to the next module, the Diagnosis part. The GUI is able to guide the user at all moments. The user would only be capable of doing what it is expected of him/her. The buttons, will be activated in an intuitive way, so the user would follow them. This is a good way to prevent user errors.

Gait Evaluation

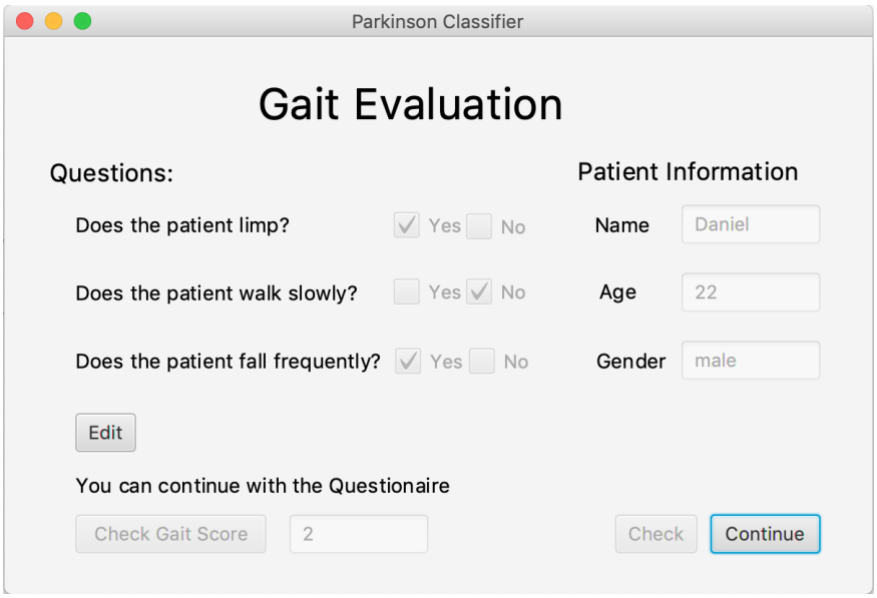

Figure 4. *Gait Evaluation*

This is the first metric to be computed. As you can see we kept the interface simple, three questions related to the symptoms of this metric with an intuitive, efficient and effective way of answering the questions with checkbox. As well, in the right part of this scene we provide the user a feedback information regarding the patient. This is done to improve the user-patient personal relationship. We want that the user that is asking the questions to know some information of the patient, to interact with him/her. Last, the check button is used to revise if all the questions were answered, if not, a friendly warning message would be display informing the user that not all the questions were answered. Only if all the questions were answered you can proceed to the next section.

Daily Activities Evaluation

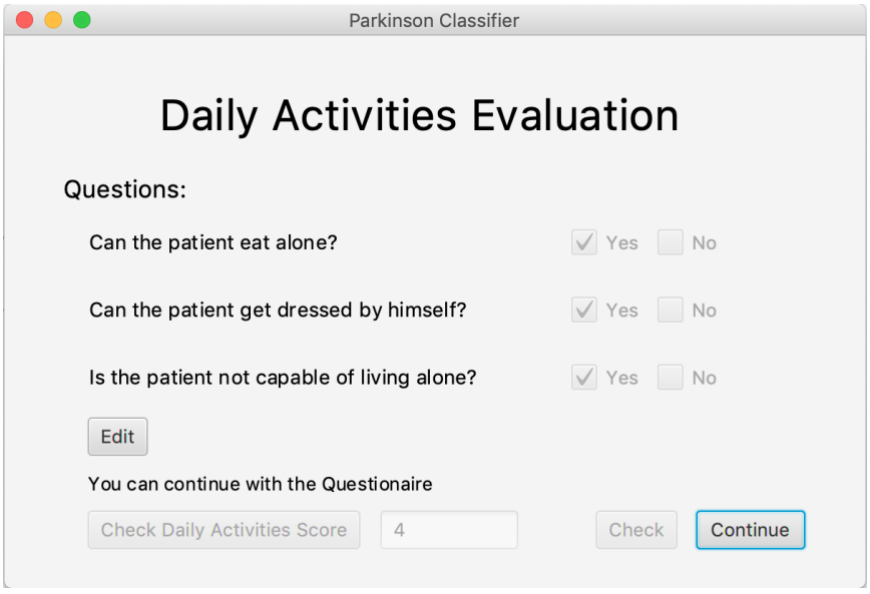

Figure 5. *Daily Activities Evaluation*

This scene is associated with the ability of the patient to manage with basic daily activities. As you can see, the GUI follows as consistent design. The questions and the buttons follow a similar location and have the same actions. This approach was taken to make the interface user friendly and easy to learn. We can observe that in each metric scene, we compute the sub-score of the metric. We display the sub-score, for the user to understand how does the metric is computed based on the questions answered. This is an interactive way to involve the patient via a participatory design.

Posture and Tremor Evaluation

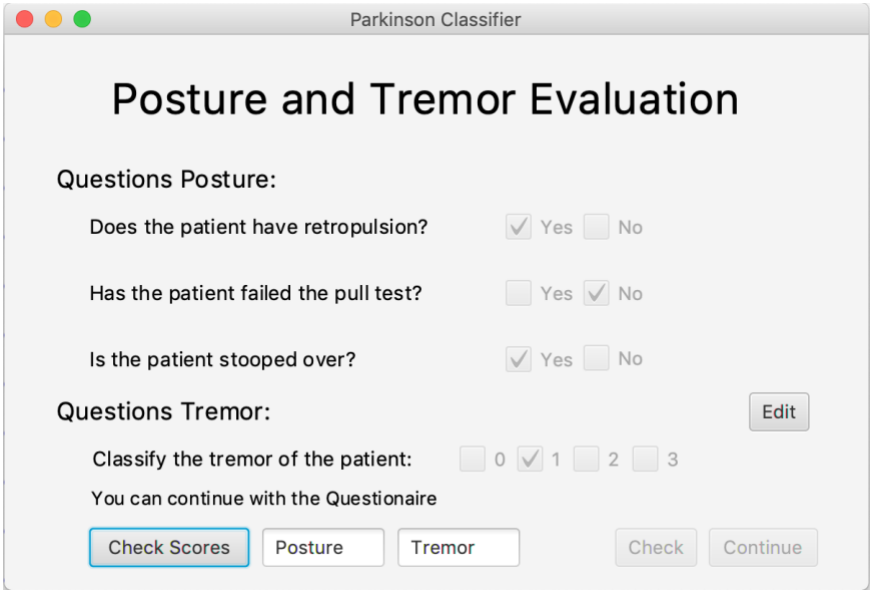

Figure 6. *Posture and Tremor Evaluation*

In this scene we evaluate two metrics, Posture and Tremor. As you can see tremor is assessed in a different but intuitive way, it is based on the magnitude of the tremor. We try to have an interface that is able to make actions easily reversible, that is why we add an edit button in all the Questionnaire scenes. If this button is triggered then you would be able to change all the answers corresponding to this metric.

Vocal Ability Evaluation

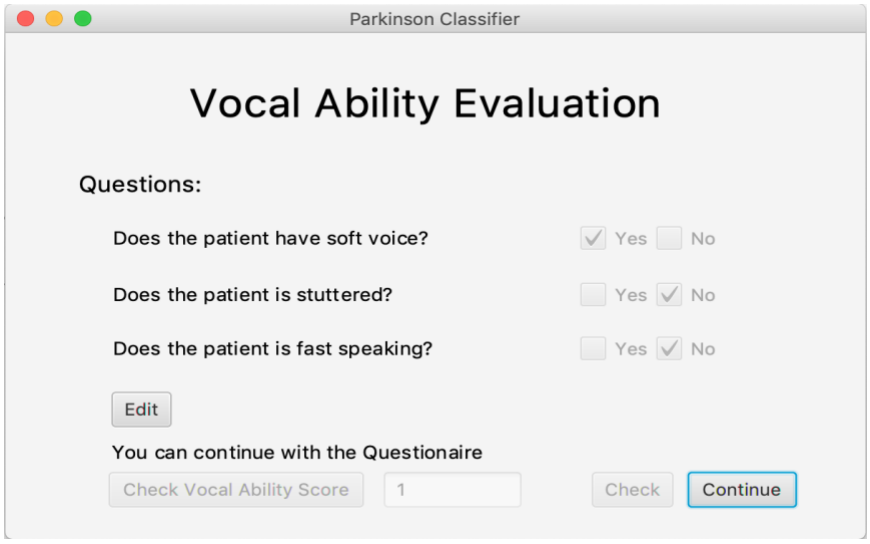

Figure 7. *Vocal Ability Evaluation*

In this scene we evaluate the vocal ability of the patient, it follows the same functionality as the rest of Questionnaire scenes.

Results Evaluation

In this module of the GUI, we would make the diagnosis and classification of the patient based on the final score that is computed from the 5 metrics sub-scores.

Figure 8. *Results Evaluation*

In the left part of the scene, we give feedback to the user by displaying the five metrics sub-scores that were computed during the Questionnaire part. Then the user would be able to compute the final score by pressing the Final score button, this will automatically assign a stage to the patient based on the final score. Then, the user would be recommended with a suggested treatment. Once all the information of the patient is

complete, we can proceed to choose between adding a new patient and making the questionnaire again for other patients or save the patients that you already evaluate and exit the program. Every time a patient is fully evaluated and has all the information needed, it is stored in a PatientsList object that contains a TreeSet that orders the patients alphabetically by the name. If the user finishes evaluating patients, it will have to save the information with the button save. By pressing the Save button, the program will store all the information of the evaluated patients in two files. The first one will store the list of objects Patients (PatientsList) in a binary way and it would contain all the patient information related to the questionnaire and the results of each patient. The second file will contain a text summary of the patients evaluated. The summary contains a readable ordered text with all the relevant information of the patient such as: the name, surname, age, all the metrics sub-scores, the final score, the stage of the patient and the recommended treatment. The names of the files will be associated to the time, day, month and year that they were created and they will be stored in the same folder of the project.

Example

The performance example of our program will be the autogenerated file with the summary of the evaluated patients. This is one of the two files generated and stored in the same folder as the project. In this case this file was generated at 8:03 the 26 of March of 2020, as the name of the file can tell.

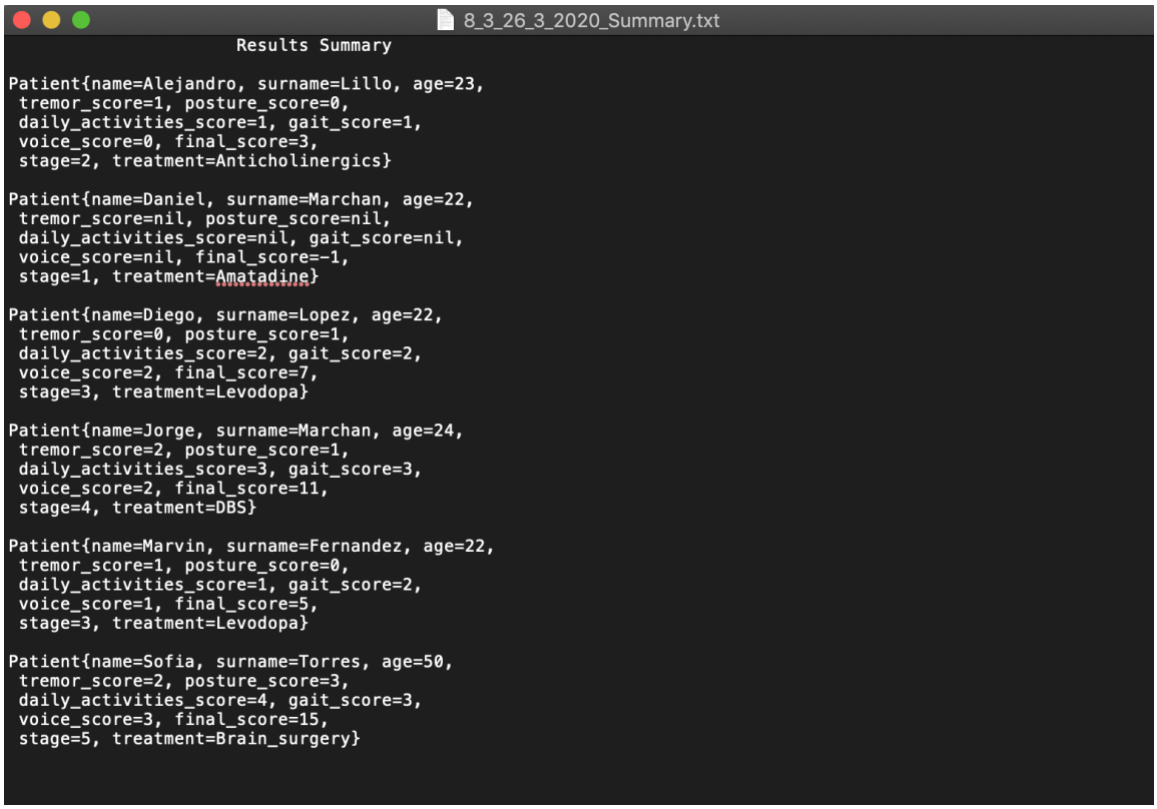

Figure 9. *Summary.txt*

This capture is the result of evaluating 6 different patients. As you can see, the patients are stored by name alphabetic order. We can also appreciate that they have different scores and belong to different stages as well. Therefore, we have the 5 different suggested treatments. This can be very useful as a printable file that is well organized, clear and resumed for a quick assessing of a whole list of patients. This can save the time of evaluation of each patient.

We do not have a capture of the other generated file, since it is stored in binary and it is unreadable. However, this file can be very useful if what you want is to make an analysis of the complete datasets with all the information gathered from the patients with the questionnaire. Different sessions can be easily saved and load again any time. There would be no format problems since they are going to be stored as the same list of objects, therefore the same method to load the data can be used for distinct patients lists. This would return a list of patients and each patient will contain all the information in their different attributes.

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