HDTV System for Parkinson's Disease Diagnosis

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***Abstract*—Health care is facing major challenges and information technologies play an important role in disease management. Cost issues raised by many medical problems that society has to face involve a superior approach to the diagnosis of the diseases that characterize the modern world. In this paper, we suggest the implementation of a high definition video system in the early management of Parkinson's disease. The High-Definition Television Video System (HDTV) is designed to record suspicious patients, on their inhabitancy, in order to detect tremor and analyze its evolution. Also, after testing HDTV system functionality, an alternative method is proposed for video sequences assessing in order to eliminate uncertainty and provide an adequate telediagnosis.**

***Index Terms*—HDTV, video recording, image analysis, medical diagnosis, fuzzy systems.**

I. INTRODUCTION

Population health is a matter of national, European and global utmost importance. Public health is extensively influenced by the quality of healthcare services, the interventions promptness, but also by the possibility of medically examining a greater number of patients simultaneously or in a short time. The medical system has been confronted with the insufficiency of public financial resources, as well as a high lack of specialists in the field. Notwithstanding, the health system has been forced to offer quality medical services able to bring clinical benefits. In this way, the need for patient's residence treatment is ever-growing, especially in the diagnosis or treatment of neurological diseases.

Neurological diseases are disorders of the brain, spinal cord and nerves throughout the entire human body. As illustrated by the National Institute of Neurological Disorders and Stroke, the neurological affections include: epilepsy, Alzheimer's disease and other types of dementia, cerebral-vascular disease, including stroke, multiple sclerosis, Parkinson's disease, neurological infections, cerebral tumors and traumatic disorders of the nervous system [1].

EU member states and the European Commission have undertaken actions in order to build confidence and acceptance of telemonitoring and telediagnosis services. Solving the technical problems of the applications in this domain is expanding, also due to the possibility of video systems usage, interactive or not, which prove high definition facilities, storage and data transmission.

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Of the neurological disorders mentioned above, in this paper we study Parkinson's disease, this being a chronic neurodegenerative disease of the brain, due to the slow and progressive destruction of the nerve cells placed in the brain's center, in the so called area substantia nigra [2-3]. The loss of these nerve cells that produce the neurotransmitter dopamine remains unclear, the literature indicating an association between environmental and genetic factors [4].

Generally, the disease affects people over the age of 50 years, but lately, the first signs of the disease occurred after the age of 40 years. Parkinson's disease which was first described by James Parkinson in 1817 is not fatal, but is progressive and incurable, thus affecting severely the quality of life [5].

Symptoms of Parkinson's disease include tremor, muscle rigidity, difficulty in initiating/performing certain movements (akinesia), problems with balance and coordination, difficulty in articulating sounds or syllables (dysarthria) [5-7].

Despite recent medical breakthroughs, there is currently no Parkinson's disease cure. Thus, drug therapy is aimed at correcting the symptoms, especially of the motor symptoms, as well as attenuation of their consequences on the patient's daily and social life [8-10].

Also, to eliminate lesions occurring on the surface of the brain, the surgical intervention might be an option, by Deep Brain Stimulation method (DBS) on patients with advanced forms of the disease. Since the disease cannot be stopped, symptoms will be eliminated for only short time periods.

Statistics show that in Europe there are over 1.2 million Parkinson's patients [11], and in Romania there are about 72,000 patients, for which 1 billion Euros/ year are spent for treatment. Therefore, the high costs on Parkinson management disease, which should be managed by the society, involve a superior approach, where the inter- and multi-disciplines have become compulsory factors.

Currently, the social impact of the individual on the society and vice versa should be minimized, their relation basing mainly on reasons of cost and efficiency. The management of medical information on patients with Parkinson's is considering, at different times, the cooptation and deployment in the therapeutic approach of methods that provide support for decision making, in order to provide a correct medical diagnosis and optimization of all response times from the neurologist, and thus optimize the disease's management outcomes.

II. Parkinson Disease Management HDTV System

Parkinson's disease can be difficult to diagnose because many other disorders have similar symptoms to those seen in Parkinson's (tremor, rigidity, akinesia, problems with balance, dysarthria). Also, certain types of medication such as antipsychotics and some medicines used to treat high blood pressure can lead to symptoms similar to those of Parkinson's disease.

Currently, the specialty consultations are initially carried out by the general practitioner, which often involves moving the patient to the medical center. In this case, two issues may arise, since there is no standard diagnosis test available in order to detect the Parkinson's disease [12-14]. One of the issues is related to the "fear of a white coat" syndrome (such situation might determine high blood pressure and tremor) [15-16], and the other issue is related to the idea, according to which the disease diagnosis cannot be carried out in one single consultation (in this situation, the patient discomfort will increase, due to extensive medical visits). The financial inconvenient shouldn't be neglected either, as regards the repeated visits to the medical center.

However, after the occurrence of tremor, it should be carefully watched and the patient should discuss with the neurologist, within thorough medical checks. An accurate description can help the doctor provide an accurate diagnosis [17]. Though, some patients might not describe accurately the symptoms and might not answer correctly to the physician's questions. Under these circumstances, we suggest the use of advanced video systems for the diagnosis of Parkinson's disease, so that preliminary tests might be carried out on patient's residence, thus avoiding the above mentioned issues. These systems can be used by both the general practitioners and the neurologists, as well.

Until recently, it was thought that video systems can be used to determine the amplitude and frequency of tremor by means of video sequences, but Uhrikova et al. [18-19] proved that automated analysis of tremor frequency, provided by video sequences with a duration of at least 5 seconds, will lead to results at least comparable to those obtained from the analysis of tremor signals, obtained using accelerometer sensor-based systems, respectively, optical.

We propose an advanced video system which contains a HD camcorder, an HD media player, an HDTV set and a PC (Fig. 1). The need for high definition equipment derives from the need of high quality video sequences recorded on patient's residence.

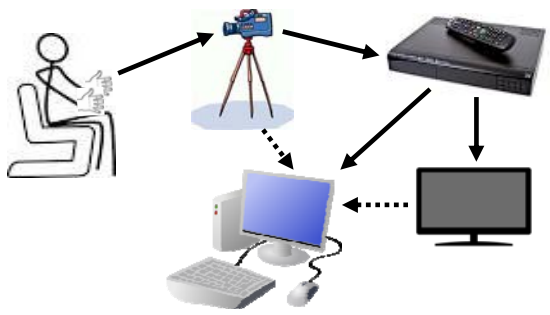

Figure 1. The proposed advanced video system

The advantages of an HD system over a classical video system are: the undeniable superiority and related characteristics that define image quality: resolution (temporal, spatial and tonal), sharpness, brightness, contrast, image contour, geometric accuracy and color rendering fidelity [20-23].

The HD camcorder must be equipped with a hard disk drive (or / and memory card) to record video maximum bit rate in order to increase sharpness and video sequences details. Also, CMOS camera sensor must have high sensitivity in order to capture high-quality images even in low light conditions [24].

The HD media player allows playback in the doctor's office at a high quality definition of the video sequences recorded at the patient's home through a high definition TV set. The use of the media player video system proposed is imposed by the high quality required on replaying video sequences (the studio quality has become necessary in order to maintain the details). This is not possible without video processing for image enhancement: correction techniques of the outlines on images details, techniques of eliminating the noise artifacts, interpolation techniques that support HD signals and image processing techniques supporting 10-bit.

The doctor's office should be equipped with a high definition TV set, allowing the replay on its screen of progressive explored images, in order to integrally display the 50 Hz frames. It is preferable a LCD TV with a 6-8 ms response time in order to eliminate the ghosting effect that occurs when viewing fast moving images. A major advantage is represented by the LCD display, which does not reflect the light, neither natural nor artificial light sources. The image displayed is characterized by two main features of image quality: fidelity (basically small differences between the rendered image and the original image displayed by the TV set) [25] and intelligibility (feature indicating the doctor's skill or the computer of extracting relevant information from image) [26].

The computer has the part of analysis, interpretation and using of images on the achieved information. The analysis result, represented mainly by the information quantity extracted from image is strongly depending upon the image quality submitted to the analysis. The high quality of an analyzed image will determine the adequate setting of a diagnosis, and respectively, the time on setting the diagnosis, by the doctor that views the medical image [27].

III. Hardware and Software Design

Starting from the basic processes chain, which an image runs over and from where the main ways on increasing the images quality result (Fig. 2), the following equipment was used on carrying out experiments: a Sony HDR-CX360VE/TC HD video camera, Popcorn Hour C-300 media player, LG 32LS570S TV set and the Storm 3400 Intel i5-3470 500GB 8GB computing system.

During video sequences recording, the camcorder was installed on a tripod, even if this camera type has a tremor correction technology of optical stabilization SteadyShot active mode. The installation of the camera on a tripod excludes patient's emotion and stress related to the video operator, the camera being easily manipulated by a family member. The Sony HDR-CX360VE/TC camcorder is equipped with a high resolution CMOS Exmor RTM sensor, which makes the video sequences of excellent brightness

and contrast, without the granular aspect, even for the poorly illuminated rooms.

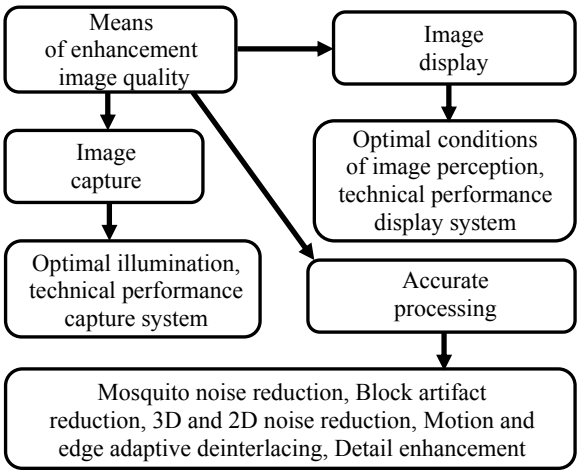

Figure 2. Means of image quality enhancement

The video sequences were made with the optical zoom, which was adjusted so that the video clips render the same perspective as the Human Visual System (HVS). In this case, the objective calculation derives from the fact that the focal length is equal to the image diagonal (film / sensor). That is, for the 35 mm film (24 x 36 mm), the normal lens size is given by:

$$Objective = \sqrt{24^2 + 36^2} = 43{,}26\,mm \quad (1)$$

Thus, the objective was set to 43 mm, in order to obtain video scenes as real as possible. The used camcorder was equipped with a Global Positioning System (GPS), being able to record the exact location where the videos were filmed. Therefore, if the situation requires the movement to the generalist practitioner to the patient's residence, such activity will be accurately and easily carried out.

The camcorder allows the direct compression and MPEG-4 format saving, but the immediate transfer on computer (the simple files copying) signifies a method that assumes data losses. For this reason, the media player method will be used. In order to maintain the original digital signal, and therefore on maintaining the quality of images or sound of the materials recorded, the need of digital/analog conversion was eliminated, thus connecting the video camera to the media player device, by means of a HDMI 1.3 cable, which has a bandwidth of 340MHz and a maximum bit rate of 10.2Gbps.

The Popcorn Hour C-300 media player is a video processing equipment, based on the System-on-Chip (SoC) architecture, by a Sigma Designs 8646 processor on 800MHz and a GF 9452 (Gennum Corporation) video processor, which ensures the high definition image enhancement, due to a high precision measurement function and of the VXP^{TM} technology. The VXP^{TM} technology offers a package of interlacing, scaling, image enhancement and frame rate conversion processing algorithms. The central aim of the image improvement techniques consists in increasing the ability on interpreting the data included within the image, by increasing the dynamic of the chosen features.

The media player is used practically, without taking into account any information over the original image or over the degradation process. In accordance to this theory, even an original (not altered) image can be somehow improved, thus achieving a "falsified" image, but subjectively preferred [28]. In fact, the pictures from the digital video camera are affected by noise due to variable sensitivity of the CMOS sensor elements, sensor's resolution and timing errors in the digitization process. The images can be also affected by the blurring effect, due to the distortions of the lens system and smoothing operations in the spatial domain.

The mathematical model of an image degradation process is illustrated by (2):

$$g(x,y) = h(x,y) * f(x,y) + n(x,y) \quad (2)$$

where $g(x, y)$ – the altered image, $f(x, y)$ – the original image, $n(x, y)$ – the additive noise applied to the image, and $h(x, y)$ – the function that defines the linear filter of image alteration.

The convolution operation achieved in relationship (2) is defined by:

$$h(x,y) * f(x,y) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} h(x',y') \cdot f(x-x', y-y')dx'dy' \quad (3)$$

As regards the numerical images, defined by samples taken in (i, j) spatial coordinates, where $0<i<M-1$, $0<j<N-1$, the alteration relationship (2) will become:

$$g(i,j) = h(i,j) * f(i,j) + n(i,j = \\ = \sum_{p=0}^{M-1}\sum_{q=0}^{N-1} h(p,q) \cdot f(i-p, j-q) + n(i,j) \quad (4)$$

As regards the spectral range of the Fourier transform, relation (4) becomes:

$$G(u,v) = F(u,v) \cdot H(u,v) + N(u,v) \quad (5)$$

The issue related to image enhancement consists in a filter operation $I(u, v)$ over the altered image $G(u, v)$ and carrying out a good estimation of the original function, in accordance to equation (6):

$$\hat{F}(u,v) = G(u,v) \cdot I(u,v) \quad (6)$$

Among the algorithms used on image enhancement, one might illustrate the operation principle of the edges outlining, which is compulsory on achieving an image submitted to evaluation. In the situation of continuous video sequences, the information related to local luminance variations will focus on the gradient vector:

$$\Delta f(x,y) = \frac{\partial f(x,y)}{\partial x^2}\bar{i} + \frac{\partial f(x,y)}{\partial y^2}\bar{j} \quad (7)$$

As a second order differentiation operator, for the continuous situation, the Laplacian included in relation (7) will be used:

$$\nabla f(x,y) = \frac{\partial f(x,y)}{\partial x^2} + \frac{\partial f(x,y)}{\partial y^2} \quad (8)$$

where $\nabla = \Delta^2$.

In this way, the outlining of the edges will be carried out in accordance to relation (8):

$$\bar{f}(x,y) = f(x,y) - \nabla f(x,y) \quad (9)$$

The TV set used during the experiments, and foreseen with an LCD display on LED backlight, will be connected to the media player by means of the high speed HDMI cable on CEC type (Consumer Electronics Control), which has the no. 13 pin connected, for information exchange between

devices [24]. The (HDMI 1) external input will be selected from the input list. SIMPLINK will be selected, editing the name of the external device connected to the TV set terminal. SIMPLINK is a feature that enables the control of the multimedia devices, including the media player.

Then in the AV operating mode, the THX Cinema option is selected. Thomlinson Holman's Experiment (THX) is an audio and video certification standard developed by George Lucas and Thomlinson Holman, guaranteeing quality image playback, as specified playing standard. Adjustments are also set from the Picture/Picture Mode/Advanced Control /Expert Control activating Super Resolution option (to provide improved detail in regions where the image is blurred or shaded) and Edge Enhancer (edges outlining for the elements present in the video sequences). In the situation of image noise presence, optimal adjustments will be carried out from the Picture/Picture Mode/Picture Options/Noise Reduction/MPEG Noise Reduction (reduces noise caused by compressing digital video).

The PC used in such application will be endowed with a MSI GeForce GTX 650 Ti Cyclone II OC Power Edition 1GB DDR5 128-bit video board, foreseen with a HDMI connector, and which will support the high definition images of the video sequences that are to be evaluated.

IV. Evaluating the HD Video Sequences

One of the most reliable and rapid assessment of the HD video sequences is represented by the subjective assessment conducted by the human observer, in this case the physician (general practitioner or neurologist). On initiating the video sequences visualizing, and in order to subjectively calibrate the quality, the doctor can be informed by a set of standard video sequences. However, the subjective evaluation of videos with suspicious patients, the doctor relies on previous experiences.

In order to eliminate uncertainty in the evaluation of patients suspected of Parkinson's disease tremor, an alternative method for assessing the video sequences is proposed, which is based on the successive visualization of a video series pairs X and Y, where X is the sequence of reference with a clinically healthy person and a suspicious patient sequence Y. In this respect, the doctor will be able to carry out a comparative assessment of a video consisting of a stringing set of images that will determine an initial telediagnostic. Normally, assessments should be repeated, and could collect a series of images daily, or several times of the day. Fig. 3 shows the slide sequence and corresponding times displayed. The proposed method assumes that the doctor will know from the start the order of the displayed images.

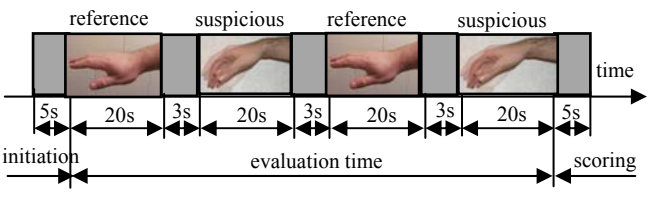

Figure 3. Images sequence and display time

After evaluating the video sequences, the doctor will rate tremor on a scale ranging from 0 to 100 corresponding to the variation from imperceptible to powerful. It will keep daily records aiming to change the time of day, or daily variation. In Fig. 4 the tremor variation is illustrated within 20 days for a "suspicious" patient.

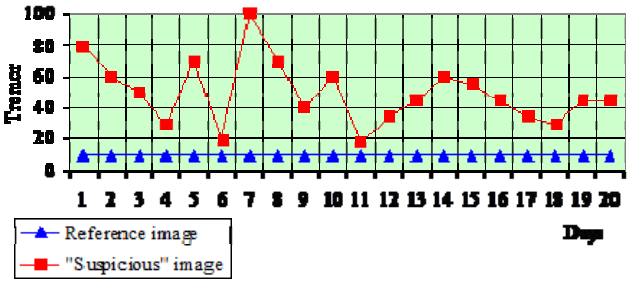

Figure 4. Variation of tremor during 20 days for a suspicious PD patient

When the doctor has reservations from declaring a diagnosis or wishes another type of evaluation, an objective evaluation will be used, by means of the computing system. In this situation, the AForge.Net Framework was used, meaning the C# framework designed for developers and researchers in of Computer Vision and Artificial Intelligence field [29]. A set of libraries on *AForge.Imaging* and *AForge.Video* was used on the preprocessing, filtering action, images processing and images visualization [28]. AForge.Net Framework was published under GNU Lesser General Public License v3.

The hand tremor detection procedure from a video sequence is based on comparing the current image with the previous image by backing grayscale of the current image (*currentFrame*) and the previous image (*backgroundFrame*). Afterwards, the *Difference* and *Threshold* filters were used, in order to identify the regions where the two images are differentiated by one bit. In this current stage, a picture of white pixels will be achieved, in the regions where the two images are different. The white pixels will be counted, thus analyzing the *changedPixel* variable; if their number exceeds in percentage the level established initially, a message of movement detection will be generated. As regards the real detection of the hands movement from the images that are accompanied by noise, the *Erosion* filter will be used [29].

However, this algorithm has the disadvantage that for slow and steady tremor, the changes will be very small from image to image, thus not detecting hand movements. It will be implemented an algorithm for detecting hand movements (tremor), based on the analysis of two histograms - horizontal and vertical - which can be calculated using two classes:

- *HorizontalIntensityStatistics*;
- *VerticalIntensityStatistics*.

In this way, the position of the hand will be analyzed, if this is placed in horizontal position, by observing the horizontal histogram and identifying in percentage the surfaces related to hands, lower than the person trunk area (Fig. 5). The histogram that corresponds to an image of L gray levels is given by the discrete function:

$$P_k = N_k \cdot N \tag{10}$$

where N_k is the number of pixels that shows the gray level $k \in \{0, 1, 2, \ldots, L-1\}$, and N signifies the total number of pixels included in the image.

Using the *Aforge.Math* library, with the *Min* and *Max* features of *Histogram* class, the aria occupied by the hand in histogram will be determined, and the *HandPosition* class will provide the hand position at any moment, depending on the fix position of the trunk.

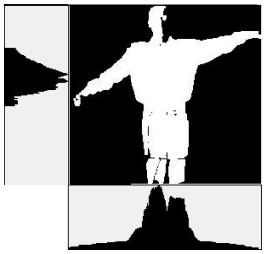

Figure 5. Horizontal and vertical histograms

A. The Fuzzy Logic System Used on Images Contrast Emphasis

For this stage of the study a fuzzy logic system was implemented, able to accomplish the contrast emphasis of the image. For this stage, the first step consists in describing the necessary processing, under linguistic form (by means of processing rules expressed in human language), taking into account the following work steps that are in accordance to the methodologies drawn up in the literature [30-31].

The first processing by which the pixels quite bright in the original image should become very bright in the processed image; afterwards, the quite dark pixels in the original image should become very dark in the processed image; a processing phase by which the pixels have a mean gray level in the original image should maintain a level of mean gray. In accordance to the linguistic description of the processing in view, one should define three fuzzy sets over the input variable universe, able to describe the concepts: *Bright enough*, *Medium*, *Dark enough*.

In accordance to the methodology [32], the fuzzy logic system uses, the following:

- Singleton fuzzyfication;
- Product implication;
- Aggregation of partial conclusions;
- Centroid defuzzification.

By using MATLAB, Fig. 6 illustrates the fuzzy sets of input, as regards the image drawn up in Fig. 5 histograms.

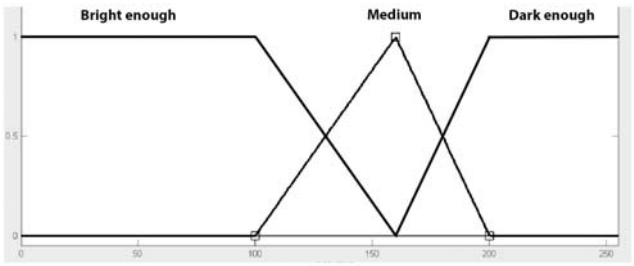

Figure 6. Input fuzzy sets relative to histograms image included in Fig. 5

B. Tremor Database and Partial Results

A database with affected patients has been provided by County Emergency Hospital of Suceava (The Neurology Clinic) [17],[32-33]. This dataset is composed of a range of tremor measurements for 82 people, among which 28 have *Parkinson's Disease* (PD). Each column drawn up in the table is a particular trembling measure, and each row corresponds to one of the 5500 trembling recordings from these individuals [32]. The essential aim of this dataset consists in differentiating the healthy people from those suffering of Parkinson's disease; in the status column, the values are set within *0* for the healthy and *1* for PD or *Suspicious Parkinson's Disease* (SPD). All patients under analysis suffer from moderate to severe postural tremor. Such postural tremor cannot be distinguished by means of clinical features (such as the frequency or amplitude). The average duration of disease (meantime the disease installs), age and sex of PD patients were compared to those on SPD or *Normal Tremor* (NT) in Table I.

TABLE I. DATA-SIZE, AGE, GENDER AND DISEASE DURATION DISTRIBUTION OF PD, SPD, AND NT SUBJECTS

	PD	**SPD**	**NT**
Number of patients	28	24	30
Mean age (range in years)	64.54 (40-90)	63.24 (27-94)	64.52 (24-86)
Gender (male/female)	18/10	16/8	19/11
Mean disease duration	16.4	15.3	

One might notice in Table I that the mean age of PD, SPD and NT people is similar, though the age intervals are different. This issue can be seen as an indicator specific to the PD installment steps before the current diagnosis.

The *VerticalIntensityStatistics* class was applied for only the hand image, and in this way the entire subject image was not necessary anymore (Fig. 7).

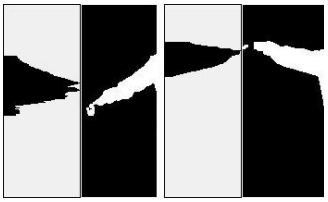

Figure 7. Vertical histogram (PD tremor vs. NT tremor)

As Fig. 7 illustrates, one might identify major differences between NT and PD medical cases, by using the system proposed and emphasized in this paper.

V. CONCLUSION

The management of medical information on patients with Parkinson's disease is considering, at different times, the cooptation and deployment in the therapeutic approach of methods that provide support for decision making, in order to provide a correct medical diagnosis and optimization of all response times from the neurologist, and thus optimize the disease's management outcomes.

Using the video advanced systems within the Parkinson's disease management will determine the achievement of essential benefits, for both the medical system and patients, such as: increased autonomy of patients, improved clinical treatment, research progress in the medical field and supervising the health public system.

The Parkinson's disease has proven pre-symptomatic and clinical stages and these do not yet allow a clear diagnose of the disease in early forms, but the establishment of an amending evolution could significantly improve patient's life quality. Therefore we try to find ways to provide a more

accurate diagnosis. PD tremor frequency is 4-6 Hz but may increase in frequency and amplitude, and can be triggered by mental and emotional stress. The proposed system relieves the patient of face to face with the physician stress. This system can be installed in the neurologist waiting room, so that the doctor can watch in real time the motor reactions of the patients.

The video recordings of suspected patients of Parkinson's disease used for detecting the tremor and the video systems are really qualitative and quantitative methods used in the diagnosis and management of Parkinson's disease [34-35], but we propose to use the management system described above on other neurological disorders, such as such as Alzheimer's disease.

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