Full Length Research Paper

Differentiating between nighttime and daytime brain images in cases with restless legs syndrome and studying responsible areas

A. Çakır¹*, T. Aydoğan¹ and H. R. Koyuncuoğlu²

¹Department of Electronics Computer Education, Süleyman Demirel University, 32260, Çünür, Isparta, Turkey.
²Department of Neurology, School of Medicine, Süleyman Demirel University, 32260, Çünür, Isparta, Turkey.

Accepted 13 October, 2010

In this study, a software has been developed to detect the regions that could be responsible for areas in the nervous system of the disorders of cases with Restless Legs Syndrome (RLS). This software produces three distinct results, processing the brain perfusion SPECT image during a time when the patient has no disorders and the brain perfusion image at the time of patient’s disorder, with image-processing algorithms. In this study, the initial image recordings of patients were made with a gamma camera, one at daytime during when the RLS patients had no disorder and at nighttime when the disorder appeared. Then, those recorded images in the format of DICOM were converted into the jpg format. In total, 59 daytime and 59 nighttime images taken from different sections of the patients’ brain were determined by using image processing algorithms. The images were subtracted from one another to obtain the first resulting image belonging to the co-images of the same section of the brains of RLS patients. In order to obtain the second resulting image, Gaussian filter was applied on the co-images and then the images were subtracted. Lastly, after the subtraction of images by histogram matching on the co-images, the final resulting image was obtained. The different regions in the resulting images were marked as coloring blue to be able to assist in easy recognition of which, brain lobes and sections were active during the RLS disorder.

Key words: Image processing, restless legs syndrome, brain perfusion SPECT.

INTRODUCTION

Human central nervous system has the most complicated biological organization known in the universe. Billions of nervous cells and trillions of connections among them form the main structure of the nervous system. Moreover, there are helper cells of up to ten-folds of the nerve cells. This incredibly complex structure, in the light of available knowledge, act as an intermediary unit organizing all livelihood activities and behaviors.

To detect the disease disorders of the nervous system, it is possible to obtain results by imaging the nervous system using various methods and processing these images (aligning, merging, subtracting etc.) with various operations. Today, there are special medical devices using different methods and techniques and software integrated to these devices used for imaging the nervous system and processing the obtained images.

Rapidly developing computer technology resulted in visual quality and gained importance. Visual analysis and evaluation of cases has reached a level of being increasingly accepted by many applications. Naturally, this led to the image processing area to gain an increasing value. As a result of analysis of events by image processing, perfect results can be obtained about the structural and functional properties of organs, any changes in and disorders of the organs, and this saves great time. Many works that were on the shoulders of humans in the past are now being carried out much more...
Restless legs syndrome (RLS)

RLS was first described by Thomas Willis in 1683 and after a long silent time period since then, it was named ‘restless legs syndrome’ by Ekbom Thomas Willis in 1945. He clearly described the classical RLS symptoms now known and emphasized as the abnormal sensations that form the sensorial components of the syndrome, described by patients (Özkayran, 2006).

RLS’s typical clinical property is an irresistible motion motive and motor discomfort associated with dysesthesia particularly in legs preventing patients to fall asleep. Although the symptoms can be unilateral at the beginning of the disease, by time, they affect both lower extremities. That the symptoms are more marked during evening hours and nighttime, emerge and increase at rest, means that they are characteristics of RLS (Benbir et al., 2004). RLS symptoms are generally seen in the legs, rarely in arms, symmetrical on both sides and mostly during nighttime (Yüksel et al., 2006).

Clear symptoms of RLS

Clear symptoms of RLS are:

1. Symptoms generally appear on a single leg by involuntary motion motive. Symptoms generally start by rest and sleep, and are relieved by shaking the legs or by moving.
2. The circadian rhythm of the disorder is generally blamed on striatonigral dopaminergic system disorder and lack of iron in the brain, and a great majority of patients are aided by dopaminergic treatment and iron replacement. In most of the patients, involuntary leg movements are seen during the sleep too and they can be identified by polysomnographic (this is the name given...
to the study used to diagnose sleep disorders like snoring, sleep apnea, periodical leg movement during sleeping and made by measuring the brain waves, eye movements, breathing activities, blood oxygen percentage and muscle activities of the patient throughout the nighttime sleep) records.

(3) A positive family history was found in 20 to 100% of patients, with a consensus that the genetic inheritance is autosomal dominant.

(4) It may be seen as secondary to many diseases of various ranges. Although, if it can be ignored due to non-specific findings, its prevalence is reported at an average of 5 to 15% (Acar and Gencer, 2005).

**RLS Symptoms and Method of Diagnosis**

RLS patients show both sensory and sleep-associated symptoms. Sensory Symptoms constitute a part of the standard diagnosis criteria aimed at RLS, but it can aid the clinical diagnosis of RLS in sleep-associated symptoms. Mild or severe RLS patients with a high percentage reported that they spent more than 30 min to fall asleep while suffering RLS symptoms (a widely used symptom of sleeplessness) and they awake three or more times during nighttime (Hening et al., 2004). Similar results were reported by Montplaisir et al. (1997), who studied 133 patients diagnosed RLS by International RLS Study Group and found that 85% of those patients who complained from difficulties, fell asleep or maintained their sleep. For most RLS patients, the disorder may be associated with sleeping disorder. For example, lack of energy and concentration of the following day, explains the relationship between the effects of the RLS symptoms on sleeping and a weakened overall health condition (Hening et al., 2004).

In 1995, the International Restless Legs Syndrome Study Group (IRLSSG) described the diagnosis criteria of Restless Legs Syndrome. The National Health Institute Conference which was held in May 2002 by specialists including IRLSSG members and authorities on epidemiology and scale design, clarified this criterion. These criteria was revised by IRLSSG and was published in 2003. This panel listed the clinical properties of the syndrome. For a definitive diagnosis, all of the four basic criteria need to be compared. IRLSSG has set the RLS diagnosis criteria (Trenkalert et al., 2005). These are:

(1) Disorder or uncomfortable sensations associated frequently with the motive to move legs.
(2) Start or worsening of uncomfortable sensations or motive to move during periods of no-motion like bleeping or sitting.
(3) Partial or complete remedy of the uncomfortable sensations or motive to move at least as long as the activity continues by motions like walking, bending, stretching etc.
(4) Worse uncomfortable sensations or motive to move at evening or nighttimes compared to daytimes or their emergence during evening/nighttime.

There are supporting criteria in addition to the basic criteria. These are:

(1) Positive response to dopaminergic treatment.
(2) Periodical extremity movements (while awake or asleep).
(3) Restless Legs Syndrome history in the family, bringing into mind, autosomal dominant.

Definitive questions used to define RLS scanning and symptom frequency are:

(1) Have you ever felt any continuous sensation of discomfort while sitting or resting or does this happen from time to time?
(2) Have you ever felt any motive or sensation to move your legs continuously while sitting or resting, or does this happen from time to time?
(3) If yes, does this sensation of discomfort or motive or sensation to move your legs happen worse when you are at rest (sitting or resting) than when you are active or moving?
(4) Does this sensation of discomfort and motive to move get worse during evening or nighttime compared to daytime?
(5) Within the last 12 month time period, have the discomfort sensation in your legs or motive to move your legs while sitting or resting happened one or more time a week in average during nighttime/daytime? (Arslan, 2006; Hening et al., 2004; Allen et al., 2005).

**Image processing**

To determine the difference between different areas of brain images of patients taken during daytime and nighttime, images of the same brain section were first subtracted with no filtering operation. To make the image noises and certain areas of the image more understandable, the images were subjected to Gaussian filtering and histogram matching operations.

None of the image processing techniques can obtain new information which is not available in the image. They can just ensure that available image data will be rendered more useful by various operations. Image improvement is a rendering process of an (available) image, and it’s more understandable in accordance with a specific aim. In this way, specific properties of the image are made more easily understandable for a man’s visual system or they are rendered to be more easily perceived by automatic image analysis systems (Toprak, 2006).

Gaussian filter is a filter that is used to soften images. Image softening operation is used to remove and reduce noise. The formula used for Gaussian filtering is given below (Verim, 2005).

\[ g(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}} \]  

(1)

Gaussian filter can be applied on matrix-size images like 3 x 3, 5 x 5 and 7 x 7 etc. σ is a fixed value (may be taken as 0.1, 0.5 or 1).

The histogram may be named as the table of gray levels of pixels in an image by the number of pixels. When the pixels are frequent in a very narrow area, it may be impossible to see the details. In this case, pixels occasionally can be ensured to distribute more equally by performing histogram matching (Toprak, 2006).

The histogram was described as 0 and P–1 gray levels, and h(i). The total number of pixels in the image is the total of all values in M x N, h(i). Thus, in order to distribute the most unchanging frequency, profile of the
image should have the pixel number of \((M \times N)/P\) of each pixel frequency in the histogram (Toprak, 2006).

The developed application

The interface of the software developed in this study is demonstrated in Figure 1. The developed software can apply the same filters on two images at the same time. Images to be processed by buttons number 1 and 2 are found and opened from the computer's local drivers. Buttons number 5 or 6 is used to subtract the images opened in area number 7 and 8 from one another. The resulting image obtained after the subtraction is opened in another window (in area number 9) and marked with different colours on both images. Gaussian filter may be performed on opened images using button number 3 and histogram matching may be applied using button number 4.

Steps of subtraction of 59 different records and co-image (belonging to the same section of the brain) belonging to RLS patients used in this interface have been taken at different times (daytime and nighttime). These image processing steps are given as a flowchart in Figure 2.

Images seen in Figure 3 have been obtained from a gamma camera at the nuclear medicine laboratory. These images are delivered to the user as DICOM file format. These images are converted into jpg file format with another utility program.

Figure 4 shows images obtained from two different sections. They are converted from the DICOM format into jpg.

In this study, SPECT images were taken from individuals with RLS disorder at two times (in a daytime and in a nighttime). In order that processing be done on 59 brain co-images obtained from the patients, first, the areas to be subtracted from the images must be
Determination of areas to be removed from images

Gaussian filter application on starting images

Subtraction of images from one another

Matching the histograms of starting images

Subtraction of images from one another

Showing the differences to the user

Figure 2. Flowchart of the image processing steps.

Figure 3. White gamma camera taking the images.

Figure 4. View of a sample image taken from different sections in the same person.

Figure 5. The same person’s segmented and scaled images of the same section.

determined. Figure 5 shows the segmented and magnified brain images in the same section of the same person taken at different times.

The first subtraction is made during the next step. The result of this subtraction is shown in Figure 6. As a result
of this subtraction, differing areas were marked by blue color.

Filters are used to reveal certain details in the image or remove unwanted noises in the image. Many losses (or imperfections) resulting from faultiness obtained while the device were recording the images as digitally and poor environmental conditions like lighting can be minimized using image processing filters.

Before doing the second subtraction, a softening operation must be done on the image as applying Gaussian filter on the co-images at the beginning; hence the images given in Figure 7 are obtained.

Subtraction of Gaussian filtered images is seen in Figure 8. In this figure, different areas can be seen with a blue colour.

Before the third subtraction, histogram matching of initial co-images is made and images seen in Figure 9 are obtained. Different areas as a result of histogram matching of images are marked blue as seen in Figure 10.

Three different images were obtained as a result of subtraction using the brain images of a patient at the same section as a result of operation of the image.
processing steps in Figure 2. Some of the processing results of the co-images taken from the different sections of patients are seen in Table 1.

### Table 1. Comparison all image samples.

<table>
<thead>
<tr>
<th>Nighttime image</th>
<th>Daytime image</th>
<th>Result of the first subtraction</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image 1" /></td>
<td><img src="image2.png" alt="Image 2" /></td>
<td><img src="image3.png" alt="Image 3" /></td>
</tr>
<tr>
<td><img src="image4.png" alt="Image 4" /></td>
<td><img src="image5.png" alt="Image 5" /></td>
<td><img src="image6.png" alt="Image 6" /></td>
</tr>
<tr>
<td><img src="image7.png" alt="Image 7" /></td>
<td><img src="image8.png" alt="Image 8" /></td>
<td><img src="image9.png" alt="Image 9" /></td>
</tr>
<tr>
<td><img src="image10.png" alt="Image 10" /></td>
<td><img src="image11.png" alt="Image 11" /></td>
<td><img src="image12.png" alt="Image 12" /></td>
</tr>
<tr>
<td><img src="image13.png" alt="Image 13" /></td>
<td><img src="image14.png" alt="Image 14" /></td>
<td><img src="image15.png" alt="Image 15" /></td>
</tr>
<tr>
<td><img src="image16.png" alt="Image 16" /></td>
<td><img src="image17.png" alt="Image 17" /></td>
<td><img src="image18.png" alt="Image 18" /></td>
</tr>
</tbody>
</table>

### Conclusion

After taking images of the patient in DICOM format by gamma camera, they were later converted into jpg format. Then, they were transferred to the user interface by the developed software. Hence, the image processing algorithms developed are realized.

We obtained three different resulting images from the patient’s brain image at times with no disorder during daytime. According to the brain images taken at the time, it could be interfered that the patient had the disorder as follows:

1. Subtraction of co-images.
2. Subtraction of Gaussian-applied images.

In this study, nighttime and daytime alternative brain images of RLS patient have been obtained by using a gamma camera. They were processed by the help of a software developed, and these activations of the RLS were monitored.

The differences between daytime and nighttime images of the same patient were observed. Different areas on these images were marked as blue for assisting specialists to track easily the effects of RLS disorder on the brain.

### REFERENCES


