Proceedings of the 28th IEEE
EMBS Annual International Conference
New York City, USA, Aug 30-Sept 3, 2006

Quantitative Tool Design using Tomographic Brain Image Processing from SPECT to support Psychiatric Diagnosis

M. Vidal, J. Piñeyro, R. Alvarado and R. Callupe

E-BIO *Bioengineering Applications*

Pontificia Universidad Católica del Perú

***Abstract*— Considering the advance in the knowledge of the psychiatric disease's physiopathology and its treatment, it becomes necessary the use of image processing algorithms in order to help the psychiatric diagnosis and to monitor the therapy. It is not but until the appearance of neuroimaging equipment that this branch of medicine "counts on" a support in engineering, emphasizing the technique of functional brain imaging in the neurological and psychiatric analysis. The purpose of this investigation is to create a tool composed by an image processing system, a dynamic information database and algorithms of comparative analysis, based on SPECT technology. The use of this tool allows to identify and compare common patterns and to obtain incidence levels in a quantitative form.**

I. INTRODUCTION

In order to achieve a diagnosis of the psychiatric pathology, the specialist employs the images generated by SPECT (Single-Photon Emission Computed Tomography), the treatment record of the patient and the nuclear medicine report. The use of the SPECT in psychiatry using neuropsychological tests is increasing due to its capability to show changes that take place by the consumption of addictive substances. For example, currently applications of SPECT are: the detection of ischemic stroke (that requires SPECT of Urgencies), the detection of epilepsy (being used ictus SPECT in the pre-surgical detection of the center), the support to the clinical diagnosis of the DTA, the diagnosis of cerebral death, the detection of vasoconstriction after subarachnoid hemorrhage, the determination of the subtype of ictus and the location of the epileptogenic center [1].

The qualitative analysis of these images sometimes defers among specialists, since it is based on the observation of the colors red, blue, yellow and orange. These colors indicate hemodynamic changes at cerebral level, being located the areas of greater or smaller perfusion in function to the intensity and type of the color at cortical and subcortical levels [1], [2]. It is in this stage of the analysis where the experience of the specialist is key to the final diagnosis but also makes it a subjective one.

As this analysis tends to be a subjective and not a quantitative one, it does not allow having a real appreciation of the evolution of the nosological process over time. The objective of this research is to create a tool composed by an image processing system, a dynamic data base of information and algorithms of comparative analysis based on SPECT technology. The use of this tool helps to identify common patterns, to compare them and to consider their levels of incidence in a quantitative form. The output of the system gives support information to the specialist for a better diagnosis by measuring brain perfusion percentages [3].

The latest models of SPECT equipments such as TruePoint Symbia (Siemens Medical [4]), Infinia Hawkeye (General Electric Medical [5]) and Precedence (Philips Medical [6]), have highly specialized systems for image brain processing. However, their technologies are 'closed' and proprietary.

The proposed tool has advantages of low cost, integral compatibility, and easy handling. It is designed to help the medical needs formulated by psychiatrists and nuclear medicine specialists. This tool requires only the image generated by the SPECT in any format.

The following specialized databases in the area of Functional Brain Imaging applied to psychiatry were reviewed:

- ✓ Brain SPECT Information and Resources
- ✓ OHBM Organization for Human Brain Mapping
- ✓ Society for Neuroscience
- ✓ Johns Hopkins University: Center for Imaging Science
- ✓ Institute of Neurology, Queen Square from University College London

II. METHODOLOGY

A. Image Processing

The goal of image processing algorithms in tomographic brain images is to identify the areas with brain perfusion by analyzing its color. This process constitutes the main source for the detection of psychiatric diseases [7]-[9]. These regions are mainly different from one to another by their color and dimensions, being these two parameters the most related to the state of the cerebral functions of the patient.

According to their form, they are classified in two types: Compact regions that show the inner parts of the brain and Surrounding regions that show the outer parts like the cortex. For the specialist, to distinguish and to classify them is not a complicated task, but it requires time and much training. It is here where the experience of the specialist is key. Automating this process requires to understand and to imitate the used mechanism [10], [11].

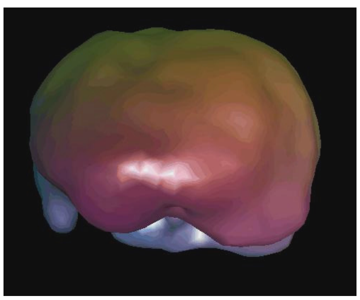

Fig. 1. A 3D SPECT Brain Image from a drug dependent patient. This image was generated by the SPECT PICKER model located in Guillermo Almenara, Hospital Lima-Perú.

B. Characteristics of the Images of the SPECT

The 3D image generated by the SPECT (Fig. 1) is cut in 3 sections: sagittal, transverse and coronal, which are stored in a 1280x1024 image in JPEG format. There is also a section with information of the patient.

Each of the three sections contains 16 takings of the brain as well (Fig.2). These takings are separated to analyze them individually. These images show the following characteristics [12]:

- ✓ Few distinguishable elements
- ✓ Limited number of colors
- ✓ Compact and surrounding regions of simple geometry
- ✓ Smooth gradient of intensities

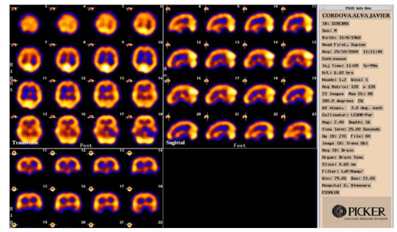

Fig. 2. Tomographic Image showing the 3 planes (Coronal, Sagittal and Transverse) of the brain. Additionally, it shows the information of the patient.

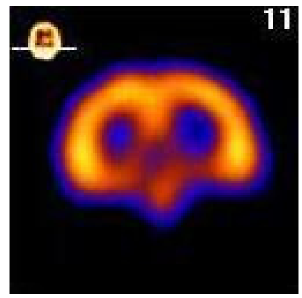

Fig. 3. Coronal Image. This will be used to explain the developed algorithm.

These characteristics are desirable for image processing and analysis because they reduce the number of parameters to be taken into account. A small number of distinguishable elements reduce the analysis of the number of regions, a limited amount of colors allows us to obtain excellent results by means of colorimetry and a simple geometry allows the use of simple algorithms. Whereas a smooth gradient makes the algorithms of detection of edges and areas be difficult. These characteristics make the process of colorimetry, morphological operations, segmentation, thresholding, and detection of areas, be appropriate to deal with this type images.

C. Algorithm

For each image of each plane (16 x 3 images) (Fig.3) of the SPECT, the analysis begins with morphological operations [13].

Morphological Operations

Morphological Operations such as dilation and erosion are applied to each of the 48 images generated per tomography (Fig. 4), to obtain the area of interest and to eliminate pixels that could affect the measure of the brain perfusion areas.

$$A \bullet B = \cup\{ (B)_Z \mid (B)_Z \subseteq A \}$$

Morphological operations of A by B, denoted $A \bullet B$ is simply erosion of A by B, followed by dilation of the result by B.

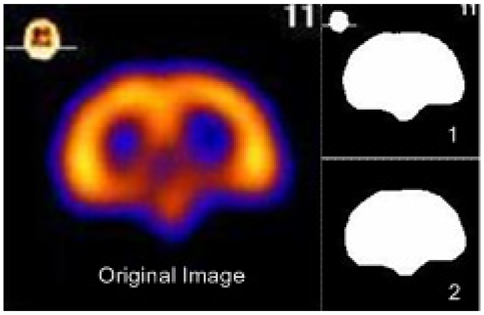

Fig. 4. (1) Image in gray scale of Figure 3 after evaluating the histogram to obtain the interest area, (2). Same Image after applying erosion and dilation with an 11th order.

Colorimetry

Because of the analyzed colors determine the brain perfusion areas in each plane (sagittal, coronal, and transverse) and these colors let specialists do the diagnosis in each lobe. A colorimetry algorithm is used.

$$F_\theta(x,y)=\left\{\frac{1}{2}\left[(g_{xx}+g_{yy})+(g_{xx}-g_{yy})\cos 2\theta+2g_{xy}\sin 2\theta\right]\right\}^{1/2}$$

Rate of color change (magnitude of the gradient), $F_\theta(x,y)$ images of the same size as the input image

For each type of cut was found the borders of color for the four specific colors in 24 bits format (Table 1).

Table 1. This table shows the thresholds for each specific colors using Colorimetry in 24 bits RGB format. Blue: bone structures, Orange: Normal perfusion, Red: Hyporperfusion, Yellow: Hyperperfusion.

		R	R	G	G	B	B
	Color	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
	Blue	0	84	0	255	94	255
	Orange	140	255	89	161	0	255
	Red	102	255	0	71	0	51
	Yellow	140	255	159	255	0	255

Segmentation

One type of segmentation is used: Thresholding. A thresholding is made in each plane of color obtaining three binary images that are combined to form one compound image that shows the regions that agree with a specific color (Fig 5) [14].

$$g(x,y)=\begin{cases}1 & if\ f(x,y)\geq T\\ 0 & if\ f(x,y)<T\end{cases}$$

Pixels labeled 1 correspond to objects, whereas pixels labeled 0 correspond to the background. T is a defined constant for the thresholding.

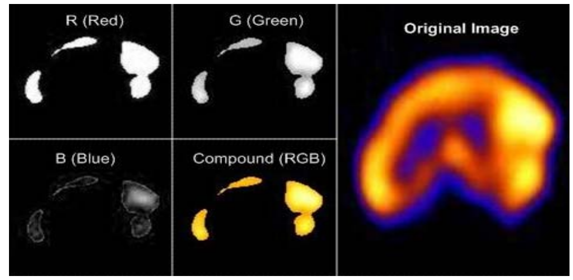

Fig. 5. A thresholded Image in RGB: R (Red), B (Blue), G (Green) and result of combine the 3 thresholds.

In this way, it is possible to segment the tomographic images separating the regions according to a specific color. The quality of the results is influenced mainly by the dispersion in the colorimetry stage, that is why it is necessary to make a compilation of many samples to reach a reliable interval of thresholding (Fig. 6) [15]-[17].

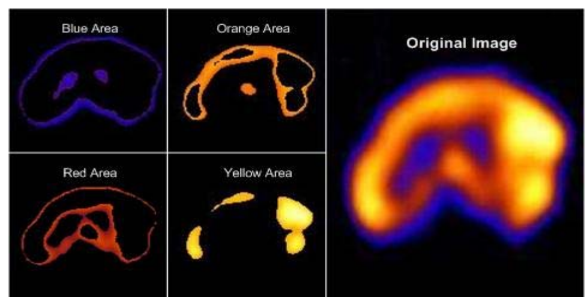

Fig. 6. Segmented Image showing the four colors of interest in the analysis of the brain image.

Measurement of Areas

The area of each analyzed color was determinated after thresholding and segmentation processes [18], [19]. Techniques for counting pixels and connecting neighborhoods were used. Finally, percentages with respect to the total area of interest were generated.

III. Results

Table 2 shows the comparison between the diagnosis tool and the specialist. It shows the brain perfusion areas in percentages. The designed tool was tested in the Drug Dependency Department from Guillermo Almenara Hospital in Lima-Perú.

The factors analyzed in each image were the percentage by color in zone of interest, the percentage by areas and the location of the zone of interest according to the cerebral lobes (Table 2).

Table 2. This table shows the results of the comparison between the Tool Diagnosis (T.D.) and the Specialist Diagnosis (S.D.), showing the validation rate (V.R.).

Patient N° 1		Cut 1…	…Cut 16	T.D	S.D.	V.R.
Sagital	%Blue	36.58	31.7	Base	Hypoperfusion of the Left Temporal Lobe and Base Ganglia System	
	%Orange	21.84	24.31	Ganglia		85%
	%Red	33.38	31.92	Hypoperfusion		
	%Yellow	8.2	12.08			
Coronal	%Blue	29.07	29.51	Orbito		
	%Orange	21.99	23.12	Frontal		67%
	%Red	32.89	32.4	Hypoperfusion		
	%Yellow	16.06	14.97			
Transverse	%Blue	27.6	21.35	Left		
	%Orange	32.63	33.56	Temporal		78%
	%Red	26.49	29	Hypoperfusion		
	%Yellow	13.28	16.09			

IV. Discussion

- The Quantification of the percentage of the cases like the transient ischemic pathology lets to measure the evolution of the process surpassing the contribution made by the Functional Magnetic Resonance [1], [2].
- The importance of the quantification and the possibility of counting on objective parameters and indicators are emphasized. It facilitates the evaluation of the diseases and its application not only in psychiatry, but in neurology and even in studies of problems of development [20].
- The importance of the creation of a database is also emphasized. It facilitates the comparative study of the mental health problem from its structural and functional principles.

V. Conclusion

- A system that allows to identify and compare common patterns and to obtain incidence levels in a quantitative form for psychiatric diseases was developed.
- The developed system was tested in a database of 10 patients showing a validation rate of 78%. It allowed to improve the quality of diagnosis.
- The hemodynamic changes in the nosological processes were quantified. It will make it possible to monitor objectively the treatments and the processes through indicators or factors of evaluation.
- This tool will allow the specialists to count on programs based on image processing for each region needs. It is important to mention that Peru has only 5 SPECT equipments which in their majority do not have specialized software for the quantitative analysis of the images.

References

[1] Gansler DA, Harris GJ, Oscar-Berman M, Streeter C, Lewis RF, Ahmed I and Achong "Hyperfusion of inferior frontal brain regions in abstinent alcoholiscs: a pilot SPECT study," Department of Psychiatry, Tufts University School of Medicine, New England Medical Center, Boston, Massachusetts, USA 2005

[2] Ernst T, Chang L, Lautentitti and Speck Oliver "Correlation of Regional Cerebral Blood Flow from Perfusion MRI and SPECT in normal subjects," Departments of Radiology and Neurology, Harbor UCLA Medical Center, Torrance, CA, USA-Magnetic Resonance Imaging, Vol 17, Nro. 3 pp. 349-354 1999

[3] "Role of radiology in psychiatry: a review," Department of Behavioural Sciences, College of Medicine, University of Ilorin, Ilorin, Nigeria-East Africa Medicine Journal 2005 May;82(5):260-6

[4] Siemens Medical. Available: www.medical.siemens.com/

[5] Philips Medical. Available: www.medical.philips.com

[6] General Electric Medical. Available: www.gehealthcare.com

[7] Andreasen, N "The role of in vivo neuroimaging in psychiatry." C.European Journal of Nuclear Medicine; 2000 Supplement, Vol. 27 Issue 13, ps37, 2p

[8] Talbot P and Laruelle P "The role of in vivo molecular imaging with PET and SPECT in the elucidation of psychiatric drug action and new drug development," European Neuropsychopharmacology; Dec2002, Vol. 12 Issue 6, p503, 9p

[9] Boas G, " Noninvasive Imaging of the Brain," New England Medical Center, Boston, Massachusetts, USA 2005 2004

[10] Proakis J, Digital Signal Processing: principles, algorithms and applications 3rd ed. Upper saddle river N.J.: Prentice Hall, 1996.

[11] Gonzales R and Woods R Digital Image Processing using MATLAB US, 2003

[12] Jovan G. Brankov, Yongyi Yang, Miles N. Wernick, and Manoj V. Narayanan, "Motion compensated reconstruction of gated SPECT data," Conference Record of the 2002 IEEE Nuclear Science Symposium & Medical Imaging Conference, 2002.

[13] Pollak I, Willsky A and Krim H "Image Segmentation and Edge Enhancement via Stabilized Inverse Diffusion Equations," , IEEE Transaction on Image Processing, 1997

[14] Fitzpatrick J.M. and Sonka M *Morphological Methods for Biomedical Image Analysis* Handbook of Medical Imaging: Volume 3, Progress in Medical Image Processing and Analysis, SPIE Optical Engineering Press, III, 2000

[15] Jovan G. Brankov, Nikolas P. Galatsanos, Yongyi Yang, and Miles N. Wernick, "Segmentation of dynamic PET or fMRI images based on a similarity metric," IEEE Transactions on Nuclear Science, vol. 50, pp. 2152-2156, 2003.

[16] Davatzikos C.A. and Prince J.L "Segmentation and Mapping of Highly-Convoluted Contours with Applications to Medical Images", Proceedings of the Conference on Acoustics, Speech and Signal Processing , IEEE Catalog #92CH3103-9, pp. III-569-572, San Francisco, 1992

[17] Cooper M and Miller M.I. "Information Measures for Object Recognition," SPIE Conference on Algorithms for Synthetic Aperture Radar Imagery V

[18] Haller J, Christensen G.E., Joshi S.C., Gado M., Miller M.I., and Vannier M.W., "Functional and structural mapping of human cerebral cortex: Solutions are in the surfaces", In Y. Bizais, C. Braillot, and R. Di Paola, editors, Information Processing in Medical Imaging.

[19] Davatzikos C.A. and Prince J.L "An Active Contour Model for Mapping the Cortex", IEEE Transactions on Medical Imaging, 14(1):65--80, 1995.

[20] E. Galli, **"**Depresion: Psychopathology and Brain Perfusion**,"** http://www.alasbimnjournal.cl/revistas/2/enrique_galli_total.htm