Detection of brain tumors using hyperspectral imaging by semi-supervised algorithms combining spectral unmixing and supervised classification

Miguel Tejedor and Gustavo Callicó
Department of Integrated Systems (DSI)
Institute for Applied Microelectronics (IUMA)
Las Palmas de Gran Canaria, Spain

Abstract— **The detection of human brain cancer tissues by the naked eye during neurosurgical operations is one of the current challenges for neurosurgeons in a tumour resection surgery. Hyperspectral imaging provides a large amount of information about the characteristics of the materials captured due to its high spectral resolution. This paper proposes a strategy based on this type of data for brain cancer detection using semi-supervised classification in order to improve the classification results offered by supervised approach. The main goal is to find the best alternative to detect brain tumour samples taken into account the accuracy obtained. For that end, the semi-supervised algorithm proposed combines spectral unmixing techniques with supervised classification. Quantitative and qualitative experimental results have been conducted to analyse the classification results in semi-supervised fashion.**

Keywords-component: Brain cancer detection; Hyperspectral imaging; Semi-supervised classification; Support vector machine; Spectral unmixing

I. INTRODUCTION

Due to the increase of the incidence and mortality from brain tumour in world population in recent decades, cancer has become the leading cause of death worldwide. If detection is early, life expectancy considerably increases. However, these tumours tend to infiltrate into healthy brain tissue, so that surgery is complex and sometimes almost impossible. It is therefore of high interest to investigate new non-invasive techniques that allow early cancer detection, providing the most accurate diagnosis possible. In this sense, the use of hyperspectral images together with a classification process can be a powerful solution to improve diagnosis of diseases and to assist the surgeon in differentiating between healthy and diseased tissues during surgery [1]. In order to properly detect brain tumour samples, semi-supervised algorithm combining spectral unmixing [2] and Support Vector Machine (SVM) [3] has been developed.

This work is framed in the first steps of the HELICoiD (HypErspectraL Imaging Cancer Detection) project, which is a European FET project that has the aim to discriminate between healthy and tumour tissues in the surface of the brain, in real-time, during neurosurgical operations.

II. METHODOLOGY

A. *Database*

The hyperspectral data have been pre-processed following the chain presented in [4]. This chain is composed mainly by four steps: image calibration, noise filtering, band averaging and pixel normalization. In order to perform a classification of the brain hyperspectral images, some pixels have been extracted and labelled from some hypercubes using a methodology based on Spectral Angle Mapper (SAM) presented in [5] to generate the ground truth. TABLE I. summarizes the information about the database used in this study, including four patients and four different classes: normal tissue, blood vessels, tumour tissue and background elements.

TABLE I. SAMPLES DATASET USED IN THIS SET OF EXPERIMENTS

Medical Samples					
Patient ID	***Captures***	***Normal Tissue***	***Tumour Tissue***	***Blood Vessels***	***Background***
Op1	**C1**	2295	1221	1331	630
	C2	2187	138	1000	7444
Op2	**C1**	4516	855	8697	1685
	C2	6553	3139	6041	8731
Op3	**C1**	1251	2046	4089	696
Op4	**C1**	1842	3655	1513	2625

B. *Semi-supervised algorithm*

When all samples are obtained from the same operation is possible to obtain competitive results because these samples are similar to each other. However, classifying a patient using training samples from the other operations is a challenging task because of the great variability among different patients resulting from biological human variability.

In order to address this issue, the semi-supervised algorithm presented in Figure 1. is proposed. Specifically, the developed algorithm classifies a new patient training from the rest of the operations which generally provides poor results. Nevertheless, the classification process generates a set of scores such that each pixel has an associated confidence score. These scores are calculated by the classifier and represent the probability of each pixel belonging to a particular class.

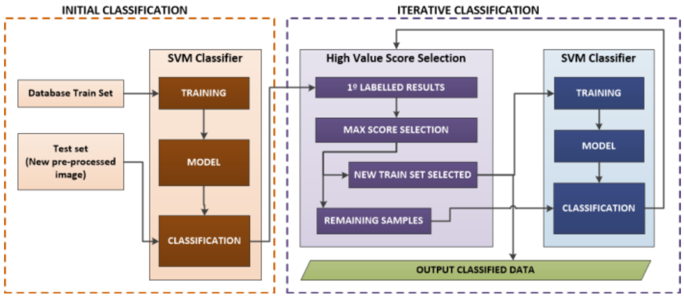

Figure 1. Semi-supervised approach

Then, the scores are used to determine the best pixels from each class, so that a small set of pixels with highest scores in a particular class are chosen as a training samples for that class. The labels of the chosen pixels are given as a solution, while the pixels that were not chosen are classified again but training the classifier with the new training set formed by the chosen pixels. It is noteworthy that this new training set is formed by pixels from the new patient and there are not pixels in the training from other patients. Next, this process is repeated. At first, SVM classifier is used in order to obtain the scores and the classification results. However, it is intended to improve the algorithm including spectral unmixing, which provides an additional source of information in the classification process in order to make the decision on the labels of the samples and a combination of new selection criteria.

C. Evaluation

In order to quantitatively evaluate the performance of the proposed system Overall Accuracy (OA) is used. This metric is the percentage of pixels correctly classified in all classes.

III. Experimental Results And Discussion

The hyperspectral classification experiments have been performed using the three different processes: supervised approach using SVM, semi-supervised approach based on SVM and semi-supervised approach based on a combination of SVM with spectral unmixing. The purpose of this study is to determine the more accurate approach for brain tumour detection. The experimental results are summarized in Figure 2.

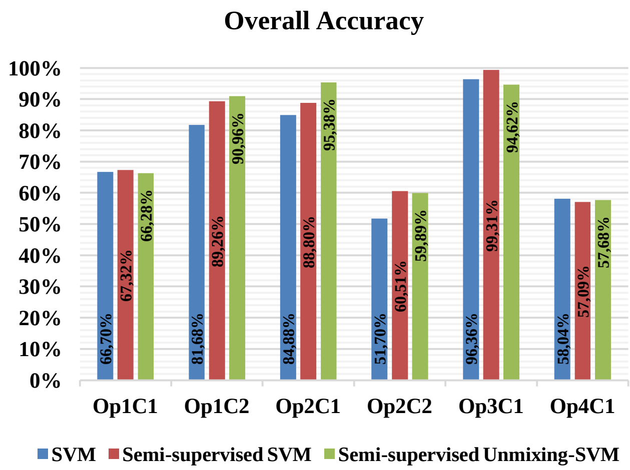

Figure 2. Accuracy comparison between the classification results of the three different processes.

As it is shown in Figure 2. , using a semi-supervised approach based on SVM offers very competitive results and generally improves significantly the accuracy obtained except in the case of patient Op4C1, increasing accuracy even 8%-9% in some patients such as Op1C2 and OpC2 and obtaining up to 99.31% accuracy in patient Op3C1. Moreover, using Unmixing-SVM process generally offers good results, especially in patients Op1C2 and Op2C1, in which a significant increase in accuracy is obtained.

IV. Conclusions

In this research work, an algorithm for brain cancer detection based on semi-supervised approach has been developed. This algorithm offers very competitive results distinguishing brain tumour tissues, solving the issues related the biological human variability and demonstrating that a semi-supervised approach based on SVM can be used for this application. Moreover, it can be concluded that spectral unmixing has certain capacity to distinguish brain tumour tissues and combining these techniques with SVM in the semi-supervised system provides some extra information improving the results obtained in some patients.

Acknowledgment

This work has been supported in part by the European Commission through the FP7 FET Open programme ICT-2011.9.2, European Project HELICoiD "HypErspectral Imaging Cancer Detection" under Grant Agreement 618080.

References

[1] Saima Rathore, Mutawarra Hussain, Ahmad Ali, and Asifullah Khan, "A Recent Survey on Colon Cancer Detection Techniques," Transactions on Computational Biology and Bioinformatics, vol. 10, no. 3, May/June 2013.

[2] José M. Bioucas-Dias, Antonio Plaza, Nicolas Dobigeon, Mario Parente, Qian Du, Paul Gader, and Jocelyn Chanussot, "Hyperspectral Unmixing Overview: Geometrical, Statical, and Sparse Regression-Based Approaches," Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 5, no. 2, April 2012.

[3] Gualtieri J. A. and Chettri S., "Support vector machines for classification of hyperspectral data," Proc. IEEE International Geoscience and Remote Sensing Symposium, vol. 2, IGARSS '00, proceedings, July 2000.

[4] Fabelo H., Ortega S., Guerra R., Callicó G., Szolna A., Piñeiro J., Tejedor M., López S. and Sarmiento R. (2016). A Novel Use of Hyperspectral Images for Human Brain Cancer Detection using in-Vivo Samples. In Proceedings of the 9th International Joint Conference on Biomedical Engineering Systems and Technologies ISBN 978-989-758-170-0, pages 311-320.

[5] S. Kabwama, C. Sosa, S. Ortega, H. Fabelo, A. Szolna, J. F. Piñeiro, D. Bulters, A. J. O'Shanahan, S. Bisshop, G. M. Callicó, "Intra-operative Hyperspectral Imaging for Brain Tumour Detection and Delineation".