QUALI-QUANTITATIVE ANALYSIS IN THE SPECTROPHOTOMETRIC DIAGNOSIS OF CUTANEOUS MELANOMA

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Abstract: This article presents a set of software tools which are used in conjunction with spectrophotometric technology to support the quali-quantitative analysis of pigmented lesions and their classification as either benign or malignant on the basis of their dominant spectral features. The software components interact with their hardware counterparts to acquire, reduce and analyse spectral images of the lesion directly from the patient's skin. While the system is not intended to replace the specialist's judgment in the diagnosis of melanoma, there is an indication that clearly negative cases can be discriminated against unclear cases requiring further investigation.

Keywords: Spectrophotometry, Principal component analysis, Image processing, Melanoma, Diagnostic methods

1. INTRODUCTION

Considering that early diagnosis represents the established 'gold standard' in the fight against melanoma, the Plastic Surgery Unit of the University of Genova has undertaken a research project named AISPEM, aimed at the spectrophotometric study of pigmented skin lesions. Specifically, this research project, started in December 2004, aims to develop, test, and validate a prototype system as an effective means to support doctors in the analysis of pigmented skin lesions. The system is intended to acquire and display images of such lesions within a spectral range of wave lengths defined between the visible (blu-violet) up to 1000 nm, and the near-infrared (NIR) starting at 400 nm, with a step of 5 nm.
The aim of this article is to present the activities undertaken, the technology implemented, and the results obtained to date as part of the AISPEM project. During the course of this ongoing project a number of solutions have been considered and implemented to address research issues and opportunities as they arose, with the aim of providing a robust and comprehensive support system for the early diagnosis of melanoma, which can be effectively used in the daily medical practice.
suited for the processing of such complex data. As a further objective, the research team worked on the

The activities concerning the hardware instrumentation have been devoted to the development and set-up of two prototypal devices capable of acquiring high spectral resolution images (Raposio et al., 2007).
The first device, which could be considered as pre-prototypal, applies the spectral scanning technology to the acquisition of excised skin tissues. Although the ultimate goal of the project is to perform *in vivo* scans, this first device allowed for a preliminary collection of skin spectra, based on which suitable image processing algorithms could be developed. Meanwhile, the problem of *in vivo* scanning was addressed, resulting in a new prototype, capable of scanning and acquiring images directly from the patient's body.
Parallel work looked at the development of suitable software tools for data processing. In the development of such tools, the research team was faced with significant issues and difficulties linked to the complexity of the spectral acquisitions. However, referring to the study of acquisitions from excised tissues, taken as they became available in the early phases of the project, a joint development and investigative effort has led to the implementation of prototype software tools well-
expansion of the range of informatics tools currently available to clinical staff, with the aim of better

supporting the data filing and diagnostic processes. To this effect, a database was developed to file and store objective data relevant to the cutaneous lesions of each patient, so that these could be monitored over time. The same database could also be used for the management of entire clinical files in electronic format.

As a further development, the integration of these tools with a telemedicine infrastructure has been anticipated and planned for. The idea behind this development is to support data communication and sharing for tele-consultation and *second opinion* purposes among remotely located medical staff.

This article will present the technical features and the intended uses/benefits of the software tools developed within the AISPEM project.

Details about the implemented hardware instrumentation and devices may be found in earlier publications (e.g. Raposio et al., 2007).

2. SPECTRAL ACQUISITION SOFTWARE

The software used for the acquisition of the samples' images is Spectral Scan, a commercial package by DV S.r.l. This user-friendly package supports both image acquisition and storage, and preliminary data analysis.

The user interface (shown in figure 1) provides easy access to acquisition commands and settings for direct interaction with the AISPEM prototypes.

The following sub-sections will analyse in detail the different components of the software package.

3. GENERAL STRUCTURE OF THE SOFTWARE

The image processing software is organized as a set of software components, each one performing a particular step in the data analysis process:

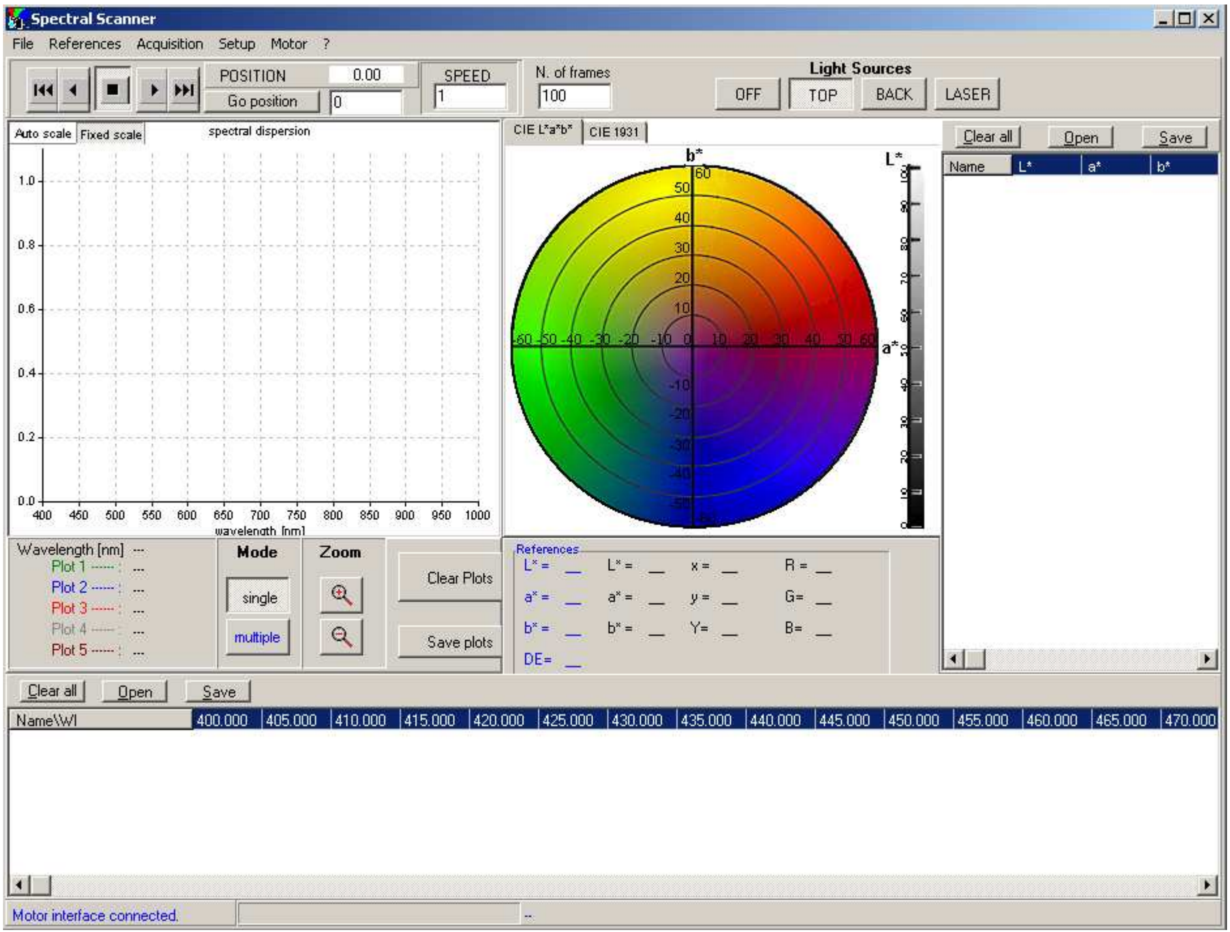

Figure 1: Spectral Scanner – user interface

1. Hyperspectral image acquisition
2. Inclusion of the data in the file system
3. Reduction by exclusion of irrelevant data
4. Isolation of the area relevant to the pigmented lesion
5. Combined analysis of cases.

These different steps/components are discussed in separate sub-sections.

3.1 Acquisition

The acquisition command calls upon the Spectral Scanner programme to begin the scanning of a sample. The acquired image is saved onto a file. The result of a further histological test on the excised sample determines the location within the file system where the corresponding image should be stored.

3.2 Recording

Once the histological test has determined whether the nature of the sample is benign or malignant, and the corresponding image file has been stored in the appropriate location, the acquisition is recorded. This procedure is preliminary to further processing of the spectral image. Specifically, it provides the user with the means to detect the onset of a particular form of image distortion (interlinking of columns), which may randomly occur as images are acquired.

Figure 2 shows a real example of this distortion. The distortion is present in the left image, and the same image is shown on the right after correction. In the figure a particular region is magnified in order to better display this effect.

3.3 Data Reduction

The sizes of the acquired spectral image files may vary considerably. They typically range from 20-30 to 200 MB, depending on the extension of the actual scan (i.e. on the number of lines acquired as part of the image). However, in most cases not the entire image is of interest: in the case of *ex vivo* acquisitions, the portion of the image external to the sample can be excluded from further analysis; in the case of *in vivo* acquisitions, the only portion of interest is the one included in the "target-window".

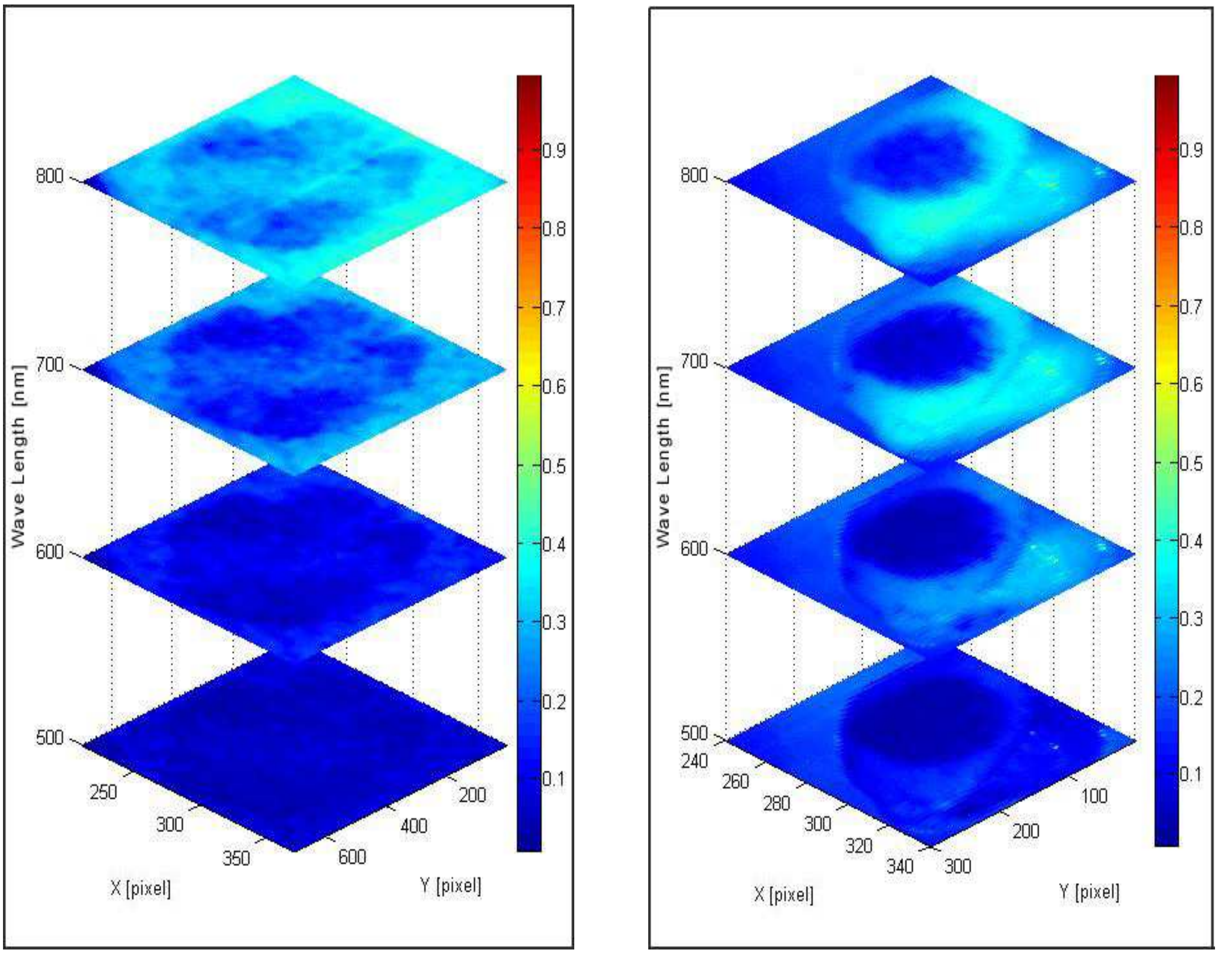

Figure 2: Example of image distortion

The purpose of preliminary data reduction, is to extract from the file the portion of the spectral image that is of actual interest. The process of reduction is based on the analysis of spectral variance: the skin presents a less homogeneous spectrum, therefore the reduction process is based on the identification of the regions characterized by the largest spectral variance, and on the selection of the largest and the most central among them.

3.4 Isolation of Lesions

Once the set of spectral data has been reduced to the sole region of interest, the analysis needs to be focused on the spectrum of the actual lesion. To this effect the lesion needs to be isolated from the surrounding skin. This step needs to be automated in order for the selection of the relevant area to be objective yet complete. In fact, it may be difficult for the human eye to accurately define the boundaries between the lesion and the surrounding skin in the acquired spectral images. There may be multiple reasons for this: occasionally the acquisition is not of high spatial quality (this may be the case especially for *in vivo* acquisitions), in other cases the boundary between the mole and the surrounding skin may be very blurry even when the tissue is directly inspected.

The adopted strategy is based upon the entire spectrum of the acquired image with the aim of extracting its principal component. In other words the process seeks the most characteristic spectral profile, against which the variability of other spectra can be expressed by means of linear combination. A set of coefficients are computed to approximate local spectra, which retain a maximum content of partial information. Principal component analysis relies on data approximations that significantly reduce the dimensionality of the problem. The initial data set typically includes more than 100 variables, representing values of reflectance at different wave lengths). This set is reduced to a single numerical value per pixel without the loss of critical information.

On the basis of the reduced data a histogram of the image is produced, where macroscopic areas can be identified which share common spectral features. The presence of local minima in the histogram identifies threshold values for the definition of such areas.

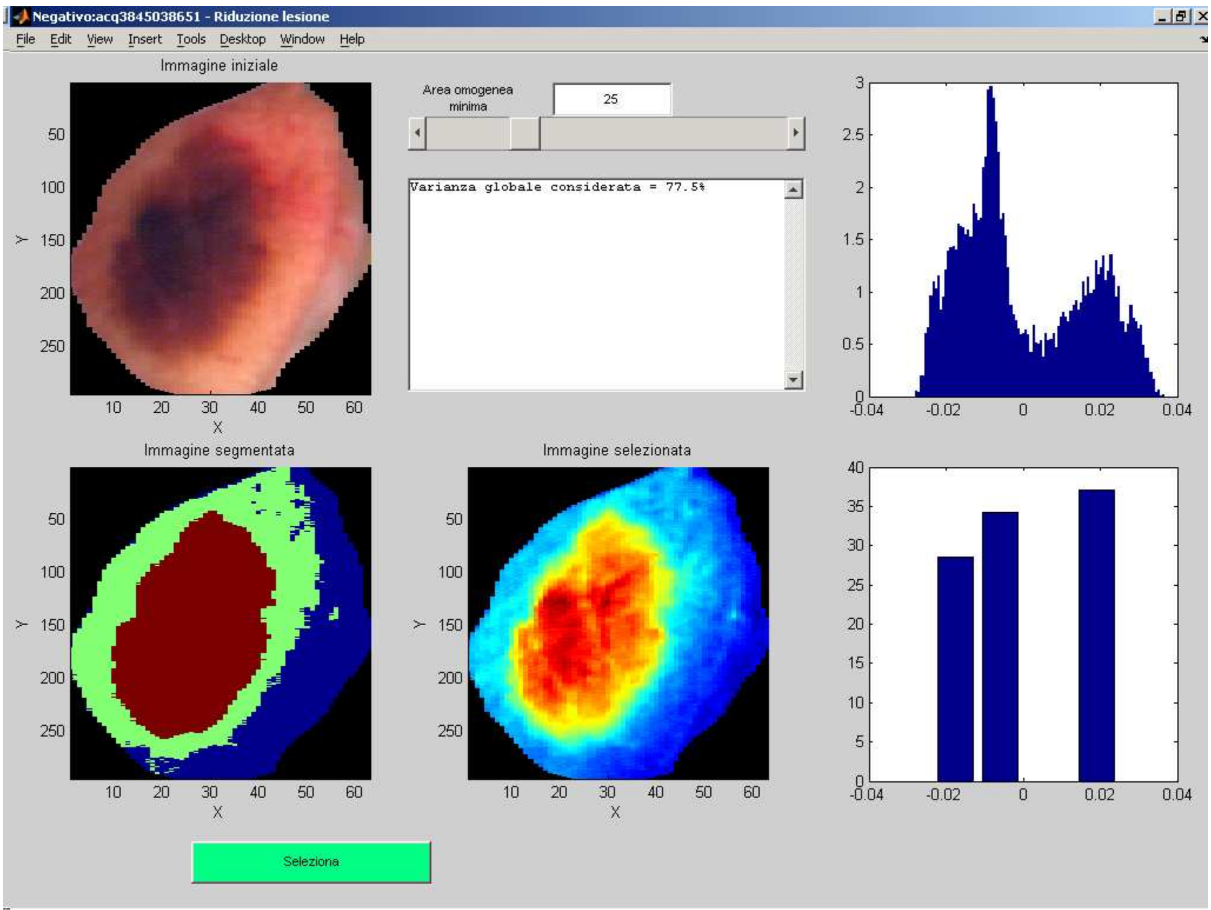

Figure 3: Example of automated isolation of lesions

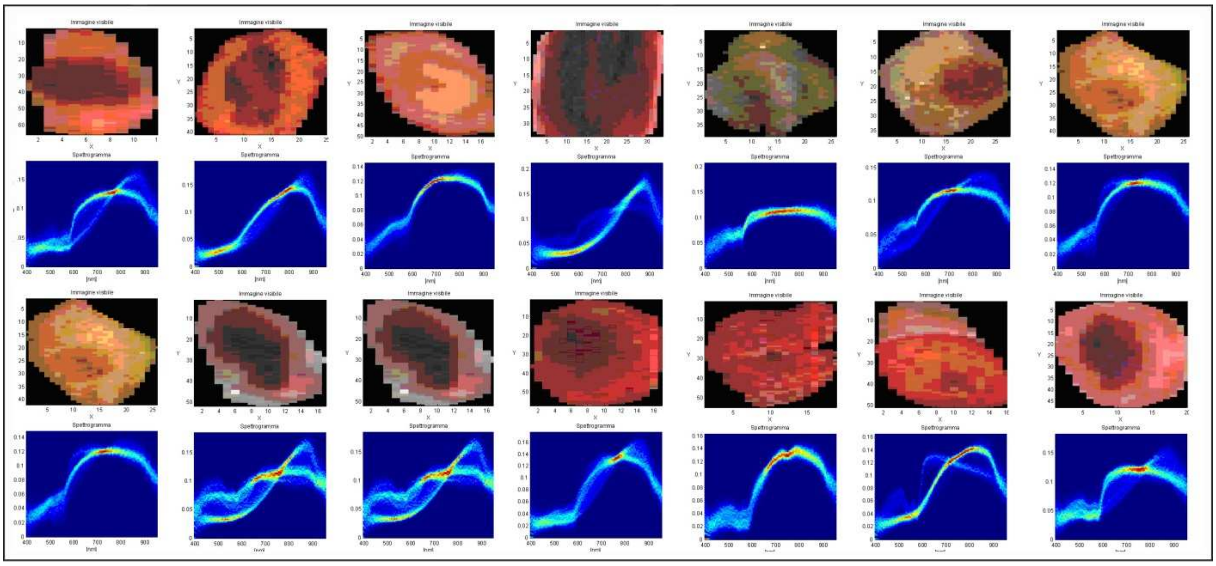

Figure 4: Examples of data reduction

The areas corresponding to the lesion are isolated by the user based on the segmented image, and the corresponding data are extracted and saved onto a file for further analysis.

4. CONCLUSION

This article has proposed an experimental system conceived to support the diagnosis of melanoma by means of objective information about the spectral colours of a pigmented lesion. This type of system is not intended to replace the clinical judgment of the specialist, whose experience will be required for the diagnosis of melanoma. However, a new use is clearly emerging for this diagnostic system as a screening method for GPs to discriminate between cases that are positively benign and uncertain cases requiring further investigation.

This development would carry important benefits to the National Health Services (SSN) by limiting the access to specialistic tests to those patients who actually need them. Secondary benefits include:

Time and cost savings to the patients - given that only a limited number of patients will require access to specialistic centres.

Stress reduction for the patients – given that in the first instance (preliminary screening) they need to deal only with their own GPs

Reduction of wait lists in specialistic structures – thanks to the upstream case-filtering process

Better use of resources in specialistic structures – these will be focused on the cases deemed uncertain by the AISPEM systems available at the local GPs'practices.

Preliminary results from this investigation, still at its early stages, support the validity of this new diagnostic approach. Ultimately, the application of the diagnostic system developed as part of this project, including: the acquisition system, the data processing system, and the database will provide effective support for the early detection of melanoma.

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