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A METHOD FOR ASSESSING MAMMARY TUMOURS BASED ON HYPERSPECTRAL IMAGING

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Abstract. Mammary tumours often present in unspayed female dogs and cats are frequently assessed in clinical practice by physical inspection and histopathological examination, and in some special situations by chest X-rays and abdominal ultrasound imaging. In this paper, we propose a new non-invasive method for assessing mammary tumours in dogs using hyperspectral imaging. This method provides spatial and spectral information about tumour tissues as coloured maps from which size, type and severity of mammary tumour can be further derived. These results are very important and can help the surgeon in the treatment planning. In conclusion, the proposed method could play an important role in the future assessment of mammary tumours.

Key words: mammary tumour, k-means classification, hyperspectral imaging, non-invasive assessment, medical imaging.

1. INTRODUCTION

Mammary tumours represent one of the most frequent neoplastic diseases encountered in intact female dogs and cats. Therefore, early and accurate diagnosis of mammary tumours is of considerable importance in establishing an appropriate therapeutic approach leading to the best outcomes. A number of methods are currently used in veterinary medicine for diagnosis of mammary tumours in dogs such as: physical examination [1, 2], biochemical and haematological examinations [3], histopathological and cytological examinations [2, 4, 5] radiological evaluation of the thorax [6], abdominal ultrasound evaluation [7] and computed tomography evaluation [6]. Although these methods are frequently applied in clinical practice with all their advantages and disadvantages, the development of new methods for the quantitative assessment of mammary tumours, more practical and precise, is considered by veterinarian doctors to be of great importance for both animal and human medicine.

In this paper we propose a new method for quantitative assessment of canine mammary tumour based on hyperspectral imaging (HSI). This imaging method

was recently introduced in human medicine with significant results in the detection of cancer, diabetic foot ulcers, and peripheral vascular disease and for the assessment of tissue blood oxygenation levels during surgery [8]. The preliminary results reported in the oncological field have proved its ability to detect the gastric cancer [9], tongue cancer [10], melanoma [11, 12], prostate cancer [13], cancerous lung tissue [14], and cancerous lymph node tissue [14].

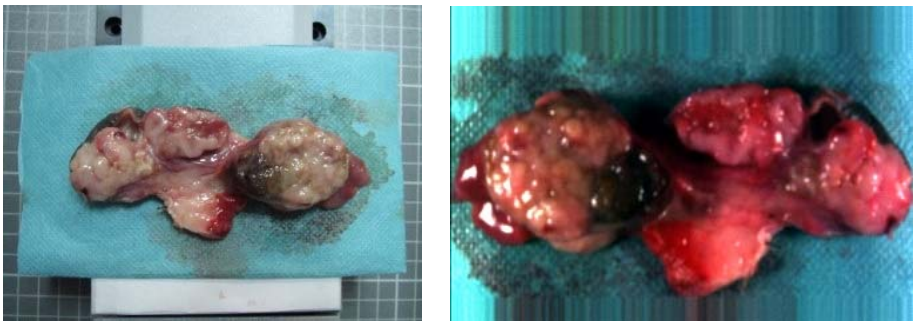
Hyperspectral imaging (HIS) consist in acquiring hundreds of images in many adjacent narrow spectral bands and compressing them into a single file called hypercube [15]. In every pixel of the hyperspectral image a reflectance spectrum can be obtain. Thus the spectral and spatial information are combined and more knowledge about the studied object or scene can be obtained.

The way in which HIS method could be used in veterinary medicine for quantitative assessment of mammary tumours in dogs was investigated in this paper. The main objectives of the work were: (a) identification of all the tissue types in the area affected by the tumour, (b) generating a map to represent the different types of tissue, (c) the analysis of this map, (d) evaluation of the apparent area of each identifiable tissue type.

2. MATERIALS AND METHODS

2.1. MAMMARY TUMOUR

The study was performed on a adenocarcinoma mammary extracted from a 12 years-old dog female from German Sheppard breed (Fig. 1).



a) b)

Fig. 1 – Mammary tumour in dog; a) RGB image; b) HSI image.

2.2. HYPERSPECTRAL IMAGE AQUISITION

Hyperspectral image of the tumour was acquired using a line-scan hyperspectral system (Fig. 2) consisting of a V8E spectrograph (Specim, Oulu, Finland), a DX4 charge couple device (CCD) (Kappa, Gleichen, Germany) and

17 mm Xenoplan lens (Schneider Optics, Bad Kreuznach, Germany). The system has acquisition speed of 11 frames per second (fps) and a spectral range of 400–800 nm with a resolution of 1390 × 1040.

The images were acquired at a 4 × 4 binning so that the spectral and spatial resolution has a value of ¼ from the maximum resolution.

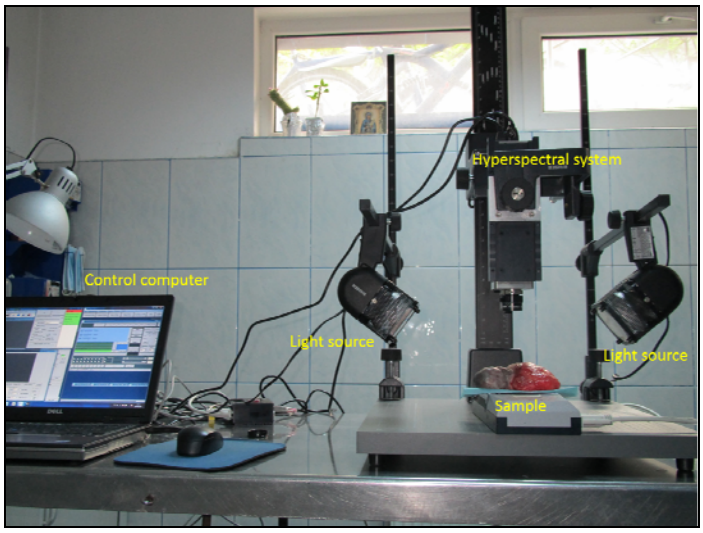


Fig. 2 – Experimental set-up.

2.3. MAMMARY TUMOURS ASSESSING METHOD

The proposed method for assessing mammary tumour consist in the following steps (Fig. 3).

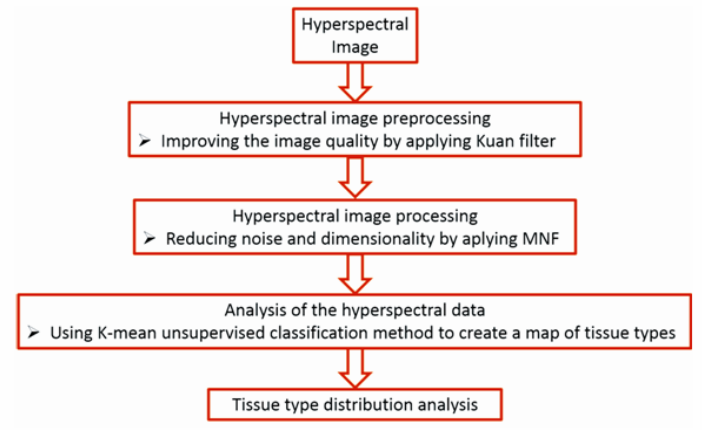


Fig. 3 – Work flow of the method for assessing mammary tumours.

(1) *Hyperspectral data pre-processing.* As a first step of the method, a reduction of the noise that affect hyperspectral data was performed by using a Kuan filter. The Kuan filter is an adaptive filter that uses the standard deviation of those pixels within a local box surrounding each pixel to calculate a new pixel value. Typically, the original pixel value is replaced with a new value calculated based on the surrounding valid pixels (those that satisfy the standard deviation criteria) [16]. By applying this filter a considerable reduction in the noise is obtained (Fig. 4).

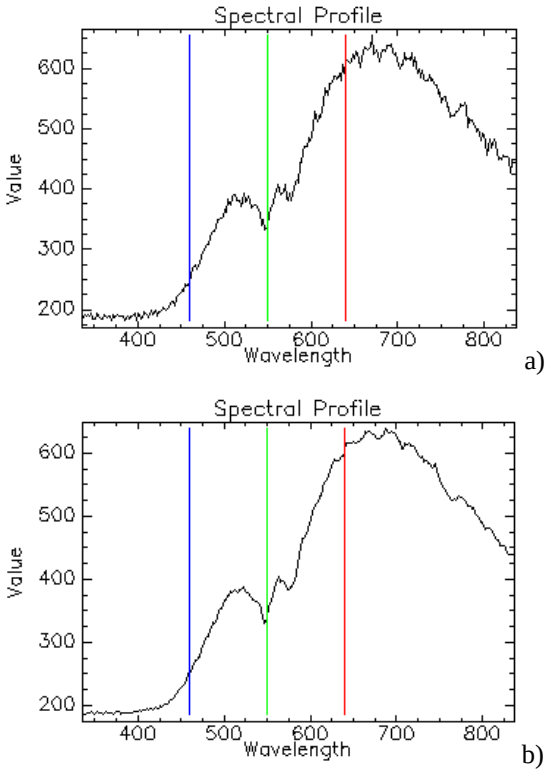
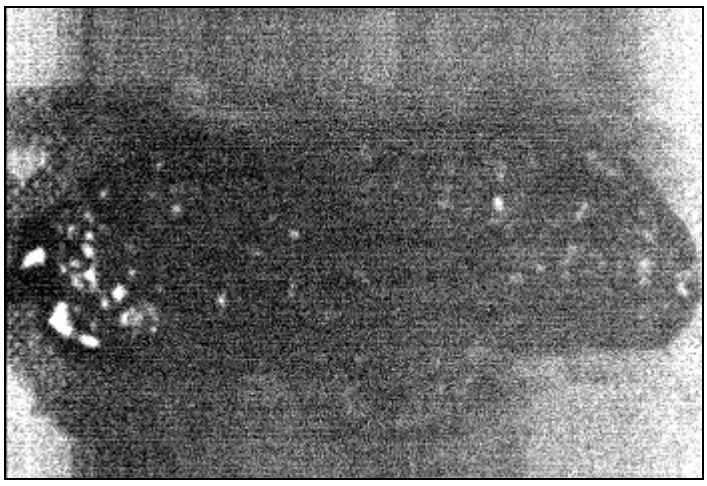


Fig. 4 – De-noising results after Kuan filtering of the pixel (85 × 123) from the hyperspectral image of canine tumour; a) before Kuan filtering; b) after Kuan filtering.

(2) *Hyperspectral data processing.* Given the large volume data contained in the hyperspectral image of canine mammary tumour, an image processing step was necessary in order to reduce its dimensionality and redundant noise. Minimum has not been considered. The second operation accounts for the original correlations, and noise fraction (MNF) transformation was chosen to perform these data corrections. The MNF transform is an algorithm consisting of two consecutive data reduction operations [17]. The first is based on an estimation of noise in the data as

represented by a correlation matrix. This transformation decorrelates and rescales the noise in the data, by variance. At this stage, the information about band noise creates a set of components that contain weighted information about the variance across all bands in the raw data set. The algorithm retains specific band information because all original bands contribute to the weight of each component (Fig. 5) [18].


a)

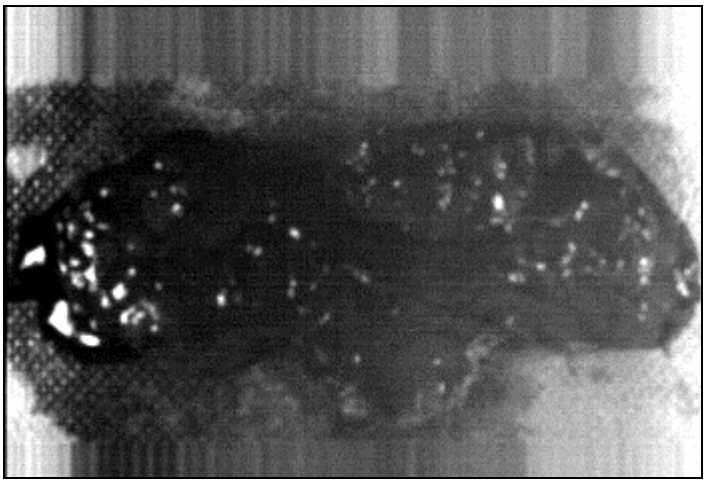

b)

Fig. 5 – Hyperspectral data processing using MNF transformation a) HSI 401 nm; b) MNF 401 nm.

(3) *Hyperspectral data analysis*. In order to extract the most meaningful features from hyperspectral image of canine mammary tumour, K-means unsupervised classification method was used. We chose this method of hyperspectral data analysis as being an appropriate classification method for

clinical practice because it allows the reduction of the computation time without losing any information. It is well known that the analysis of a high volume of data requires a large amount of time or a very powerful workstation.

K-Means method calculates the initial class means uniform distributed in the hyperspectral data image then iteratively clusters the pixels into the nearest class using a minimum distance technique. At each iteration the class means are recalculated and the pixels are reclassified with respect to the new means. The pixels are classified to the nearest class unless a standard deviation or distance threshold is specified, in which case some pixels may be unclassified if they do not meet the selected criteria. This process continues until the number of pixels in each class changes by less than the selected pixel change threshold or the maximum number of iterations is reached [19].

3. RESULTS AND DISCUSSIONS

Figure 6 shows the map of tissue types identified in tumour and adjacent areas as generated by K-means classification.

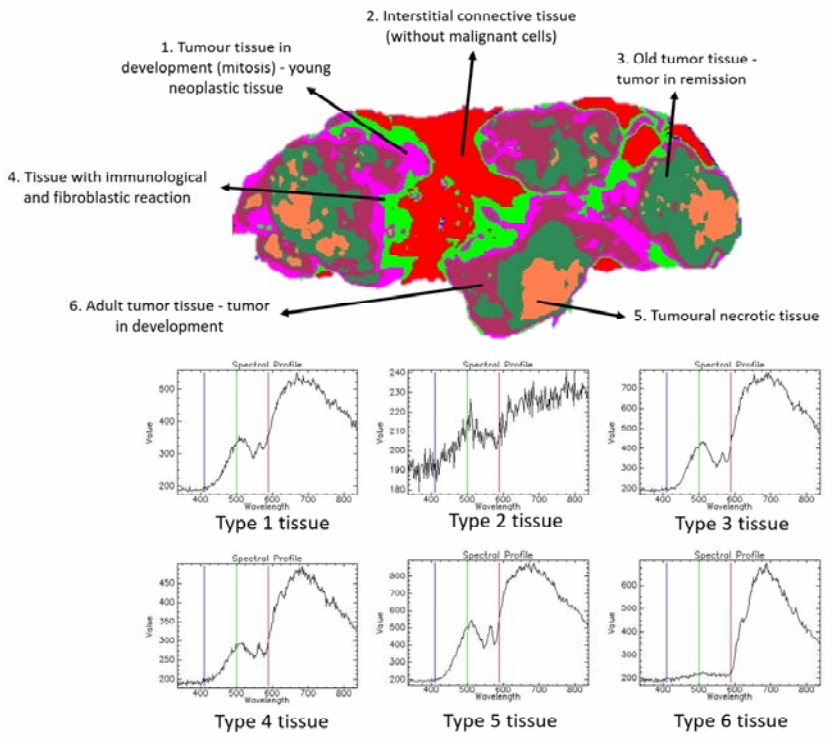


Fig. 6 – Tissue types identified in tumour and adjacent areas and their representative spectra.

As we can see in Fig. 6 six tissue types were identified based on their representative spectra. These tissue types were confirmed by histopathological exam as being: tumour tissue in development (mitosis) – young neoplastic tissue (type 1), interstitial connective tissue (without malignant cells) (type 2), old tumour tissue – tumour in remission (type 3), tissue with immunological and fibroblastic reaction (type 4), necrotic tumour tissue (type 5) and adult tumour tissue – tumour in development (type 6). The CCD sensor of the hyperspectral camera digitizes the intensity of the light incident on each pixel in a 12-bit format, *i.e.* taking values from 0 to 4095. These intensity values (digitized) are displayed on y-axis of the above spectra. Tissue types can be distinguished by these intensity values at 510 nm and 567 nm.

Necrotic tumour tissue has the highest value of 600. The second highest value it is 470 and it is old tumour in remission. The 3rd highest value belongs to young tumour tissue and it has a value of 370. The tissue with immunological and fibroblastic reaction has a value of 300 in the 510–567 nm spectral range while the unaffected tissue has a value of 260 and the adult tumour tissue has a value of 200. As it can be seen the tumour tissue types can be differentiated by the spectral properties especially in the 500–570 nm spectral range.

Other than the spectral characteristics which were presented above, each tumour type has different spatial characteristic and they are presented in Table 1.

Table 1

Tissue type relative area

Tissue type	**Type tissue**	**Colour**	**Relative area** (pixels)
1	Tumour tissue in development (mitosis) – young neoplastic tissue	Magenta	3613
2	Interstitial connective tissue (without malignant cells)	Red	6790
3	Old tumour tissue – tumour in remission	Dark green	7650
4	Tissue with immunological and fibroblastic reaction	Green	4110
5	Necrotic tumour tissue	Orange	3520
6	Adult tumour tissue – tumour in development	Purple	6911

The severity of the mammary adenocarcinoma was established as being reduced based on the 3 predominant tissue types, which they are:

– old tumour tissue – tumour in remission (7650 pixels) represented by dark green;
– adult tumour tissue – tumour in development (6911 pixels) represented by purple;

– interstitial connective tissue (without malignant cells) (6790 pixels) represented by red.

The classifications shows a clear demarcation between the tumour types thus can be a useful tool in surgery, more precise removal of the tumour. Also determining the size is important for deciding if it needs surgical intervention or it can be treated.

4. CONCLUSIONS

The method proposed by us proved its ability to identify all the tissue types in the tumour area, generate the tissue types map in order to analyse the tissue types map and evaluate the relative area of each identifiable tissue type.

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