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A Infrared hyperspectral imaging technique for non-invasive cancer detection.

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Abstract:- Hyperspectral imaging(HI) is an emerging technology in the field of biomedical engineering which may be used as a non-invasive modality for cancer characterization. In this project, we propose to investigate hyperspectral imaging for the characterization of gastric cancer. The hyperspectral imaging has been used for the detection of various kinds of human cancer; breast, gastric, prostate and tongue. A research group has also investigated the use of reflectance imaging to detect canine cancer using fluorescent dyes. The use of hyperspectral imaging, however, has been limited for the characterization of cancer. In this project, we have already acquired many hyperspectral images of tumors. The malignant tissue has relatively low reflectance intensity compared to the benign tissue. The decreased reflectance intensity observed for malignant tumors is due to the increased microvasculature and therefore higher blood content of cancerous tissue relative to benign tissue. In the future, we will normalize and preprocess the spectral dataset. We propose to apply various algorithms such as Support Vector Machine, Linear Discriminant Analysis and Principal Component Analysis on the spectral data to discern the malignant and benign tumors. The advantage of cancer detection using hyperspectral imaging is that it is non-invasive, highly efficient and less time consuming than traditional methods like biopsy.

Keywords:- spectral imaging; spectroscopy; hyper spectral; multispectral. Gastric cancer.

I. INTRODUCTION

This Research aims to explain the technology of gastric cancer detection using hyperspectral imaging technique. This technique was developed by A.H.Goetz in 1980 Standard rules lay down the operation of hyperspectral technique. This is demonstrated by acquiring an image of diagnostic patient followed by normalization, filtering and windowing. However its application in detection of cancer is still under development mode [1].

Conventional color cameras acquire intensity information from the visible electromagnetic spectrum, that is, red, green and blue. Hyperspectral imaging measures and collects intensity information over more than hundred spectral bands across the electromagnetic spectrum. So it extends invisible wavelength regions to human vision range. Hyperspectral images are acquired by 'hyperspectral sensors' and these sensors have a variety of applications in the fields of agriculture, physics, remote sensing and surveillance. This technique was used originally for the purpose of remote sensing, and that project was initiated and developed by NASA. But recently, hyperspectral imaging is also being used in the field of medicine, particularly cancer detection. This is because this kind of novel technology can quantify several biomarkers found in tissue, and thereby can be used for non-invasive tissue analysis.

During hyperspectral imaging, the data produced by the sensor consists of a collection of images. This set of images can be represented by a three dimensional cube of image, where the first two coordinates represent the spatial coordinate of a pixel and the third coordinate gives the wavelength of a particular spectral band. Thus it gives both the spectral and spatial information at the same time. The accuracy of these sensors is measured in terms of two parameters: spatial resolution and spectral resolution. Spectral resolution is the width of each band of the spectrum and is given by $\Delta\lambda$, where $\Delta\lambda$ is the minimum wavelength difference that can be distinguished at a wavelength λ. Spatial resolution is the measure of how closely we can resolve lines in an image, and is given by the number of pixel values per unit length.

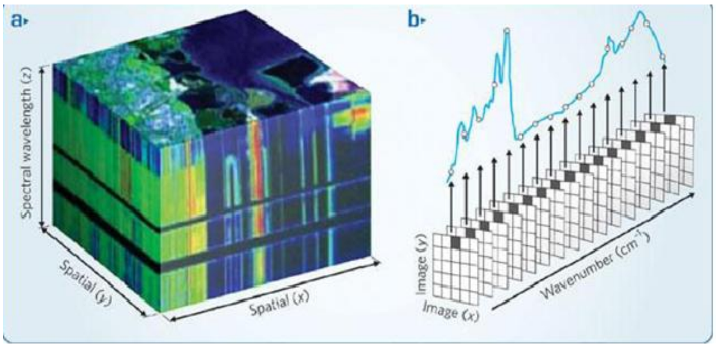


Figure 1.1: A hyperspectral three dimensional imaging cube where the three coordinates represent the horizontal axis, vertical axis and the wavelength respectively.

Grating as the dispersive medium in the optical system, the second class uses band pass filter, which can be tunable or fixed, and the third class implements a technique called the Fourier Transform Spectroscopy[2]. In this technique, Fourier Transform is applied to obtain the spectral decomposition of the light entering the hyperspectral sensor. In this project, the second class of hyperspectral imaging technique will be used. Our hyperspectral camera consists of a liquid crystal tunable filter, which scans the spectrum in increment of 10 nm. Hyperspectral Imaging has a wide array of applications in many fields. Primarily, it was developed by NASA for the purpose of remote sensing, geology mining and space exploration. Recently, it is also being used in agriculture, mineralogy, surveillance, physics, chemical imaging and non-invasive tissue analysis for detection of cancer and other diseases. In agriculture, this technology is used to monitor the health of crops and to detect chemical composition, nutrient and water status and disease outbreak for plants.

In this research work, we will focus on the use of hyperspectral imaging for non-invasive canine cancer detection. Near-infrared hyperspectral imaging has been used for the detection of various kinds of cancer; breast, gastric, prostate, tongue. In this project, we focus on the near-infrared region (NIR) that extends from 650nm to 1100nm. This is because NIR light is absorbed by certain chromophores that are biochemically significant, namely, hemoglobin, water and lipid. Thus using NIR spectroscopy, we can quantify the concentration of these important biomarkers. Literature shows that NIR light penetrates into tissue farther than light in any other spectrum, because tissue has low absorptivity in this region.[3] Thus weakly absorbed NIR light that can penetrate several centimeters is used for the hyperspectral imaging of thick tissue such as brain, breast and muscle. Literature shows some favorable results in the detection of breast cancer using NIR spectroscopy. Since canine mammary tumor is physiologically similar to human breast tumor, we use NIR spectral range (650-1100nm) as the light transmission range for our project. When a spectrometer is used in an imaging sensor, the resulting images record a reflectance spectrum for each pixel in the image.

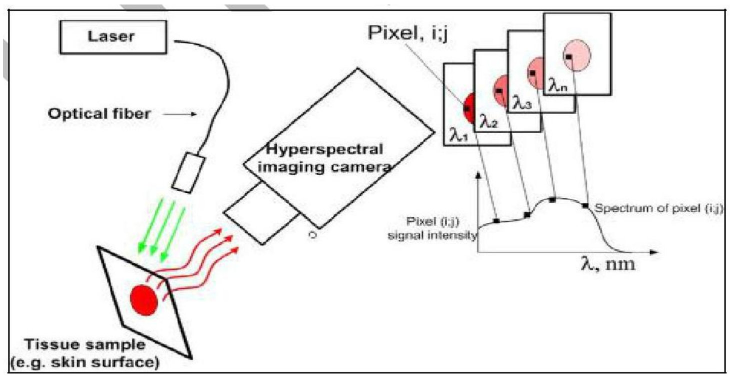


Fig.1.2: Ahyperspectral imaging setup for tissue analysis.

II. WORKING PRINCIPLE

Hyperspectral imaging is a remote sensing technique that enables the acquisition of spectral and spatial information of an object or parts of it without getting directly in contact with its surface. For an example, when digital image is acquired by a standard digital camera, the result is generally a color image composed of three overlapping images that are obtained in three discrete spectral channels (RGB).therefore, digital camera acts as a three channel multispectral camera, being able o simultaneously acquire all the spectral information in certain scene in three specific portions of the electromagnetic spectrum. If more than three channels are used, potentially more information about the recorded scene can be obtained.

On the basis of the number of channels used in the recording, their contiguity, and their spectral separation, it is possible to define the difference between multispectral and hyperspectral imaging techniques. In a multispectral imaging system the number of independent spectral channels is typically not more than ten, and they are not necessarily contiguously distributed. The amount of spectral information acquired with such systems is therefore limited and the classification of certain materials is only possible if significant spectral differences occur.

As compared to multispectral imagers, a hyperspectral imaging system provides a much greater number of spectral channels, which cover the spectral range in a contiguous way, and therefore provide much more complete spectral information. Basically every individual pixel of a hyperspectral imaging recording carries the information of an entire spectral curve, which enables a more efficient target discrimination and further analysis (Grahn and Geladi 2007).Reflectance is the percentage of the light hitting a material that is then reflected by that material (as opposed to being absorbed or transmitted). A reflectance spectrum shows the reflectance of a material measured across a range of wavelengths[4].Some materials will reflect certain wavelengths of light, while other materials will absorb the same wavelengths. These patterns of reflectance and absorption across wavelengths can uniquely identify certain materials. Field and laboratory spectrometers usually measure reflectance at many narrow, closely spaced wavelength bands, so that the resulting spectra appear to be continuous curves.

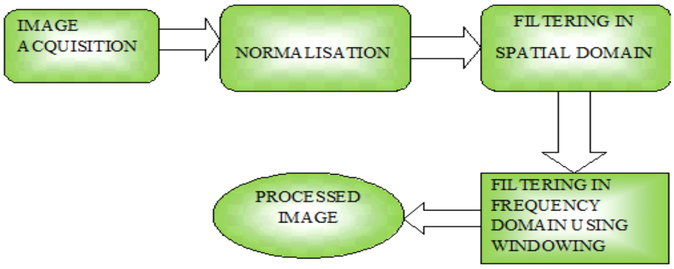


Fig 2.1: Block Diagram Of The Software Developed

Hyperspectral imaging is part of a class of techniques commonly referred to as spectral imaging or spectral analysis. Hyperspectral imaging is related to multispectral imaging. The distinction between hyper- and multi-spectral is sometimes based on an arbitrary "number of bands" or on the type of measurement, depending on what is appropriate to the purpose.

Multispectral imaging deals with several images at discrete and somewhat narrow bands. Being "discrete and somewhat narrow" is what distinguishes multispectral in the visible from color photography. A multispectral sensor may have many bands covering the spectrum from the visible to the longwave infrared. Multispectral images do not produce the "spectrum" of an object. Landsat is an excellent example of multispectral imaging. Hyperspectral deals with imaging narrow spectral bands over a continuous spectral range, and produce the spectra of all pixels in the scene. So a sensor with only 20 bands can also be hyperspectral when it covers the range from 500 to 700 nm with 20 bands each 10 nm wide. (While a sensor with 20 discrete bands covering the VIS, NIR, SWIR, MWIR, and LWIR would be considered multispectral. Ultraspectral' could be reserved for interferometer type imaging sensors with a very fine spectral resolution. These sensors often have (but not necessarily) a low spatial resolution of several pixels only, a restriction imposed by the high data rate. Fifteen years ago only spectral remote sensing experts had access to hyperspectral images or software tools to take advantage of such images[5]. Over the past decade hyperspectral image analysis has matured into one of the most powerful and fastest growing technologies in the field of remote sensing. The “hyper” in hyperspectral means “over” as in “too many” and refers to the large number of measured wavelength bands. Hyperspectral images are spectrally over determined, which means that they provide ample spectral information to identify and distinguish spectrally unique materials. Hyperspectral imagery provides the potential for more accurate and detailed information extraction than possible with any other type of remotely sensed data.

III. DIFFERENT HI TECHNOLOGIES:

There are basically three different techniques used to realize a hyperspectral image: scanning an image spatially, capturing full spectral data sequentially, Scanning an image spectrally, capturing full spatial information sequentially; Taking a "snapshot," capturing all the spectral and spatial information at once. The first type of hyperspectral imaging (HSI) devices obtain images by integrating a dispersive means (a prism or a grating) in an optical system, and has the drawback of having the image analyzed per lines (push broom scan) and also having some mechanical parts integrated into the optical train.

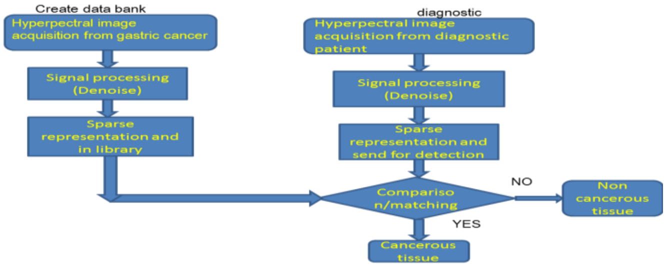
The second type of HSI devices are based on optical band-pass filters (either tunable or fixed) and the spectrum has to be scanned in steps. Both HSI techniques lead to good quality results but have low efficiency in term of light gathering power and traditionally long integration times are necessary to obtain a full HSI cube.

Line-scan systems, where the spatial dimension is collected through platform movement or scanning, require stabilized mounts or accurate pointing information to 'reconstruct' the image. In wavelength scanning systems, spectral smearing can occur if there is movement within the scene, invalidating spectral correlation/detection. Newer full motion video spectral imaging systems can simultaneously captures and processes all three dimensions of a spectral cube at video rates[6]. These systems are more efficient for detection and tracking applications because unlike line-scanning cameras and spatially invariant systems, the spectral information is focused on collecting the application specific data, not extraneous detail

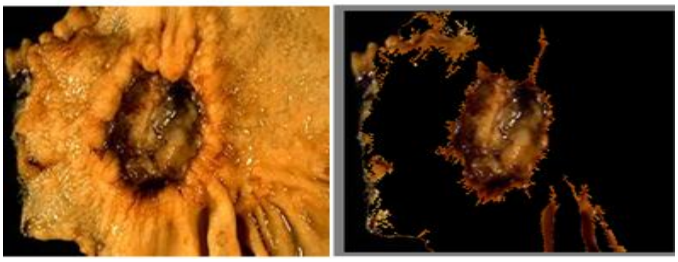
The third type of HSI devices obtain the spectrum of a light source using so-called Fourier transform (FT) spectroscopy; in this technique the FT is applied to the interferogram acquired by a scanning interferometer in order to calculate the spectral composition of the light entering in the interferometer[7,8].

IV. RESULTS

Steps which have to be followed necessarily before executing the software are called execution sequence. Such sequence is executed by using commands which implemented as shown in the subsequent topics.



INPUT IMAGE OUTPUT IMAGE



Filter 1- Mean filter

MSE = 0.0040

PSNR = 72.1350

Filter2-Median filter

MSE = 0 0.0055

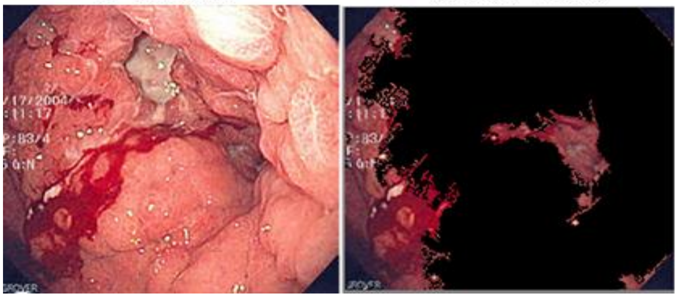
PSNR = 72.1350 70.7381

Filter3-Weiner filter

MSE = 0 0 0.0017

PSNR = 72.1350 70.7381 75.8307

INPUT IMAGE OUTPUT IMAGE



Filter1-Mean filter

MSE = 0.0053

PSNR = 70.8591

Filter2-Median filter

MSE = 0 0.0073

PSNR = 70.8591 69.4718

Filter3-Weiner filter

MSE = 0 0 0.0028

PSNR = 70.8591 69.4718 73.6490

MULTI SPECTRAL	ULTRA SPECRTAL	HYPER SPECRTAL
Requires multiple sensors	Requires single sensors	Requires single sensors
Less bands, wider bandwidth	More bands, very narrow bandwidth	More bands, narrow bandwidth
Less spectral resolution	Very high spectral resolution	High spectral resolution
Requires more sample preparation	Requires less sample preparation	Requires less sample preparation

Table1: Comparison between Multispectral, Ultra spectral & Hyperspectral Technique

Hyperspectral deals with imaging narrow spectral bands over a continuous spectral range, and produce the spectra of all pixels in the scene. Multispectral imaging deals with several images at discrete and somewhat narrow bands[9,10]. Ultraspectral deals with interferometer type imaging sensors with a very fine spectral resolution. Hence hyperspectral imaging has wider range of application and gives better throughput.

V. CONCLUSION

This research involves the concept of gastric cancer detection using hyper spectral technique. The initialization of such a system therefore requires the programming the software and gives the wider opportunity to create greater scope and wide range of applications. The applications may range from agriculture, military, physics, astronomy, food processing and mineralogy etc [11]. The research therefore satisfies the basic requirement of the commercial product,1)Technical Ability2)Highly Efficient And 3)Medical Aid.

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