AN OVERVIEW: NIR IMAGING SYSTEM FOR MEDICAL PHOTOGRAMMETRY APPLICATIONS

M. Farid M. Ariff[1], **Halim Setan**[1] & **Albert K. Chong**[2]

[1]Medical Imaging Research Group, Fakulti Kejuruteraan & Sains Geoinformasi, Universiti Teknologi Malaysia, 81310 Skudai, Johor.

[2]School of Surveying, University of Otago, 310 Castle Street, Dunedin, New Zealand.

Email: mohdfarid@fksg.utm.my, halim@fksg.utm.my & chonga@albers.otago.ac.nz

ABSTRACT

To this day, the NIR (Near-Infrared) remains one of the most useful extra-visible bands in the EM (electromagnetic) spectrum. Aerial photogrammetry have long relied on NIR imagery to capture the landscape with the greatest possible clarity over a wide range of atmospheric conditions including some quite unsuitable for visible light photography. But today, with features like low-cost, higher-resolution and hand-held digital cameras with near-infrared (NIR) capability are now readily available for close-range photogframmetry applications. The NIR spectrum (700 to 1000 nanometers) is a tiny part of the overall electro-magnetic spectrum. It is just outside the spectrum seen by the human eye. While it is not possible to see NIR radiation it can be recorded on NIR films or CCDs with special filters. Digital NIR image of vegetations, living things, rocks and man-made objects have a number of positive features over the traditional color or black and white photography. In the past, NIR images were strategically used only because of the expensive and hard-to-find NIR films and high-cost CCDs. However, present CCD cameras require only inexpensive NIR filters to take good NIR images. The paper highlights the current applications and potential of NIR images in photogrammetry for the purpose of medical applications.

Key words and phrases: Near-Infrared photograph, 3D spatial data, camera calibration, human tissue

1.0 INTRODUCTION

1.1 What Is Infrared?

All objects emit infrared radiation. Infrared energy is generated by the vibration & rotation of atoms & molecules within a substance. As an object becomes hotter, it's molecular activity increases & causes that object to generate more energy. Actually we can only see a very small part of the entire range of radiation called the electromagnetic spectrum. The only difference between these different types of radiation is their wavelength or frequency. Infrared radiation lies between the visible and microwave portions of the electromagnetic spectrum (**Figure 1**).

Infrared waves have wavelengths longer than visible and shorter than microwaves and have frequencies which are lower than visible and higher than microwaves. Infrared is broken into three categories: near, mid and far-infrared. Near-infrared refers to the part of the infrared spectrum that is closest to visible light and far-infrared refers to the part that is closer to the microwave region. Mid-infrared is the region between these two (**Figure 2**).

Figure 1 : The electromagnetic spectrum

Figure 2 : Infrared spectrum

1.2 NIR Spectrum

The NIR spectrum (700 to 1000 nanometers) is a tiny part of the overall electro-magnetic spectrum. It's just outside the spectrum seen by the human eye. While it is not possible to see NIR radiation it can be recorded on NIR films or CCDs with special filters. By and large, most photographed NIR radiations are reflected from the photographed objects. The original radiations sources are the sun, artificial lights or artificial emitters or a combination of these sources. To provide a uniform illumination of the object in a room, a NIR light source is built into the flash unit in digital cameras. In the past NIR images were strategically used only because of the expensive and hard-to-find NIR films. However, CCDs has created a low-cost and user-friendly approach of getting high-resolution NIR images.

Low-cost nigh-shot cameras are capable of taking good NIR photographs up to 1.1 µm without any complicated setup. Generally, the NIR cut-off filters are removed to increase the sensitivity under dark conditions. To remove the visible bands (up to 840 nm from NIR photograph IR filters are mounted in front of the camera lens. The photography is similar to Moderate Resolution Imaging Spectroradiometer (MODIS) band 2 (841-876 nm) (Kinoshita, et al 2003). For proper daylight aerial photography of terrain neutral density (ND) filters are also needed to reduce solar reflection. The photographs are similar to satellite imagery. In general, NIR photographs are digital processed to highlight the underlying features. Off-the-shelf image processing software may be used to produce good composite photograph. For an example it is possible to highlight both colour and NIR photographs by editing the channels so that a less important channel such as the blue in the colour photograph would be replaced by the NIR image. A display of all the channels of the new colour composite reviews the old red, the old green and the new NIR features.

The paper provides a summary of the current applications of small-format NIR images in photogrammetric mapping of the environmental and medical fields.

1.3 NIR Applications

Infrared energy plays an important role in our everyday live. For example, infrared cameras permit us to see in the dark, plot weather condition from satellites, detect breast cancer, remotely measure temperature, analyze the chemical composition of distant object and etc (**Figure 3**).

Figure 3 : NIR applications

1.3.1 Environmental Applications

Application of small-format CCD in this very broad discipline is probably the most noteworthy. Generally, the photogrammetrists are requested to map and study the vegetation, water quality and soil or rock characteristic of the terrestrial and the marine environment. NIR aerial photography is an important tool in the study of changes to the environment; the pollution of the air and water; the health of crops, forests, wetlands and the sea; and the condition of the soil (Jackson 1986; Kinoshita et al 2003; Wright et al 2003; Kodak 2004). The advantage of NIR is its ability to penetrate aerial haze (*ibid)* (**Figure 4**).

Figure 4 : NIR photographs (aerial)

Most documentation of the terrestrial environment involves the use of CCD cameras and aerial photography. In a routine practice, both colour and NIR photographs are captured at a suitable altitude. The mapping entails either digital mapping or digital orthophoto production or both from the aerial photos. The convenience of CCD for NIR photography has resulted in the extensive use of the invisible light radiant.

1.3.2 Biomedical Applications

Near Infra-Red (NIR) is known for its ability to penetrate the human skin. Reported findings show that the penetration depth is roughly 2 mm for normal skin condition. Research shows that penetration depth depend on the intensity and wave-length used as the NIR source. Research also shows that the depth of penetration is dependent on the absorption and reflection rate of the skin tissue. Recent advances in electronic technology have allowed NIR source and NIR sensor to be fine-tuned to narrow-band of wave-lengths of 5 nano-metres (nm). NIR electronic spectrum ranges from 7000 to 1000 nm. The capability is crucial for the study of skin condition because the absorption and reflection can be computed mathematically by taking the ratio of the intensity and wave-length. Consequently, the association of skin condition and the depth of penetration can be studied accurately (**Figure 5**).

Figure 5 : Photographic penetration (lesion skin)

Eggert (1935) was among the first scientists to discover that oxy and carboxyhaemoglobin could be differentiated with NIR photographs. His research showed that oxyhaemoglobin reflects more while carboxyhaemoglobin absorbs more NIR radiation than the surrounding tissues (Nieuwenhuis 1991). Nieuwenhui (1991) and Cotton et al (1999) showed that in the epidermis or the upper layer of the skin the NIR radiation is absorbed by the pigment melanin. In other words, any abnormality of the skin could be detected without any invasive intervention. Recently, NIR spectroscopy have been researched to determine the optimum wavelength(s) and the most appropriate technique for the study of the concentration of oxyhemoglobin (HbO2) and deoxyhemoglobin (HbR) in blood vessels (Strangman et al 2003). The potential of the studies includes non-evasive study of the characteristic of blood circulation (flow pressure, flow volume) and vascular condition which includes obstruction and congestion (**Figure 6**).

Figure 6 : Photographic penetration (blood circulation)

1.3.2.1 Diagnosis Breast / Skin Cancer & Tumor

<u>Infrared Photography Method</u>

- Presents the first infrared photographs (infrared film) for the detection of cancer in the female breast. The photographs showed an asymmetrical pattern in cancerous breasts (Gibson 1945).

- Described use of standardized serial photography (infrared film) in assessment and treatment of advanced breast cancer. As part of overall methodology they used infrared techniques (Gilson & Parbhoo 1981).

- Cited examples of lupus being recorded using this technique in Copenhagen and that the photographs distinguished between dead skin and living skin with lupus nodules in it. Noted that caucasian skin appeared chalky, red lips recorded light and that all lines of the face were exaggerated. Also noted that Negro skin tended to photograph light. He repeated these findings in his later articles in 1937 and 1939 (Clark 1934; Clark 1937; Clark 1939b).

- Found the technique was useful for showing changes in the deep layers of the skin in such conditions as lupus, angioma, pigmented naevi; whereas ordinary photography was superior to infrared in superficial lesions of the skin such as psoriasis, macular and papular syphilis and lichen planus (Haxthausen 1933).

- Showed that infrared photography (infrared film) could delineate the engorged blood vessels draining the breast and necrotic areas could be differentiated. Diseased breast absorbed infrared more strongly than the normal tissue. Showed that malignant melanoma absorbed infrared (Marshall 1977) (**Figure 7**).

Figure 7 : Diseased breast (right) absorbed infrared more strongly than the normal tissue

<u>Normal Method</u>

- **Palpation**. The doctor can tell a lot about a lump - its size, its texture, and whether it moves easily by palpation, carefully feeling the lump and the tissue around it. Benign lumps often feel different from cancerous ones.

- **Mammography**. X-rays of the breast can give the doctor important information about a breast lump. If an area on the mammogram looks suspicious or is not clear, additional x-rays may be needed.

- **Ultrasonography**. Using high-frequency sound waves, ultrasonography can often show whether a lump is solid or filled with fluid.

- Other method : **MRI** & **PET Scanning**

1.3.2.2 Diagnosis Blood & Vascular

<u>Infrared Photography Method</u>

- Used infrared photography (infrared film) to penetrate burn eschar and establish whether a good blood supply existed beneath the burn's slough (Anselmo & Zawacki 1973).

- Showed the infrared record to be useful for delineating superficial veins in cases of thrombosis of the axillary veins (Kaplan 1938).

- Described penetration of burn eschar with infrared to examine underlying blood supply. Concluded that the assessment of burn depth could be greatly enhanced and that further work should be done in the area (Stevenson 1981).

- Also suggested that colour infrared (infrared film) could detect hemosiderin and that melanin could be distinguished from venous blood (Gibson 1962).

- Showed infrared photographs (infrared film) delineating varicose veins (Feldman 1936).

Figure 8 : Dilated veins due to inferior vena cava obstruction

Normal Method

- Ateriograms (angiograms)
- CT or CAT scans
- Doppler Testing or Duplex/Doppler Ultrasound Exam
- Magnetic Resonance Angiography (MRA) or Magnetic Resonance Imaging (MRI)
- Transcutaneous Oximetry (TCOM) & more…

1.4 NIR Cameras & Images

One of the most beautiful and unexpected kinds of photographs can be produced using digital infrared photography techniques. Infrared photography has been around for a long, long time, but using film, it was expensive, very difficult to do and the results were extremely unpredictable, and frequently disappointing. But now with digital cameras (CCD) becoming more affordable, just about anyone has access to the hidden world of invisible light photography. This means, we must attach an infrared filter at the camera (hold one in front of the lens).

Using the conventional cameras and IR film, the most useful 35mm equipment is a single-lens reflex (SLR) camera with an automatic diaphragm. It is well suited to hand-held operation with infrared color film. Also, when opaque, infared-transmitting filters are placed over the lights instead of over the lens, this camera can also be hand-held for black & white infrared photography.

Thermal IR Camera

Digital SLR (like) with IR Mode

Thermal SLR IR Camera

SLR Camera – Support IR Film

Figure 8 : NIR cameras

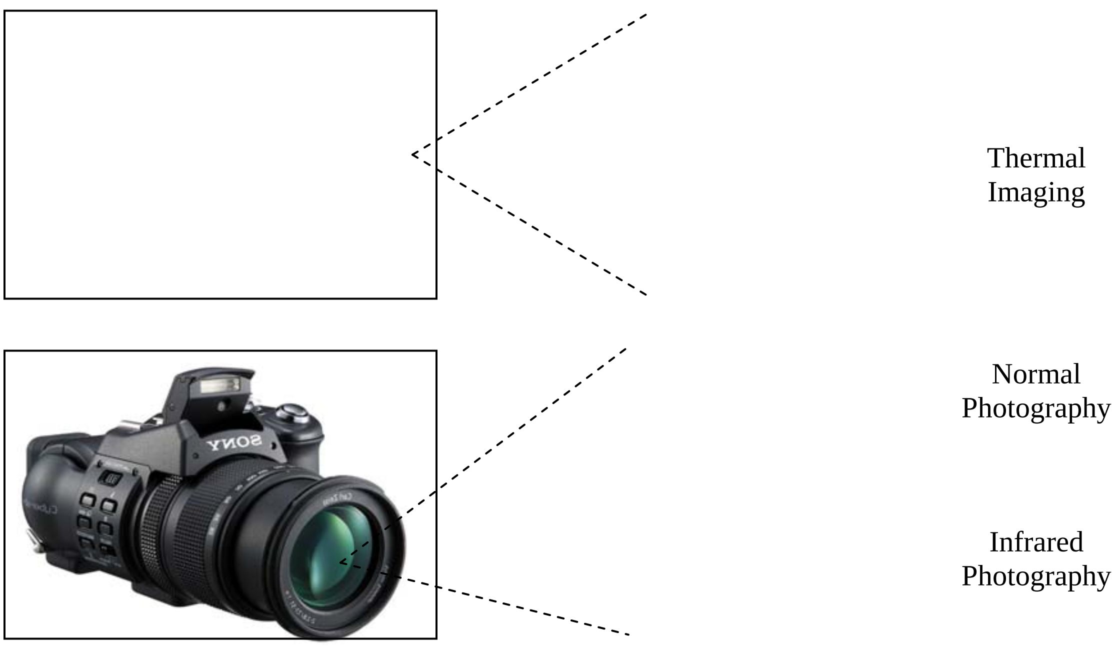

Figure 9 : NIR images

2.0 OBJECTIVES

1) To evaluate the characterizations of **NIR** imaging system for **Medical Photogrammetry** applications.

    - To determine the correlation between NIR wave-length and tissue absorption and reflection based on skin-depth penetration.
    - To determine the correlation of NIR wave-length and skin-depth penetration.
    - To study the correlation between skin lesion and skin-depth penetration.

2) To determine the optimum of a **NIR** camera calibration for **Medical Photogrammetry** data acquisition system.

    Research Scope : Human Skin (normal, lesion, cancer & tumor) & blood vessel

3.0 METHODOLOGY

1) NIR Camera Lens Calibration Tests.

2) Depth Of NIR Penetration Test.

    - Use fresh animal skin tissue to study depth of various NIR wave-length and intensity.
    - Use skin tissue and spectrometer to study absorption and reflection (*).
    - Use five sets of optimal wave-length and intensity to study depth penetration (**).
    - Analyse the correlation of (*) and (**).
    - Use optimal wave-length and intensity to study human skin (normal, lesion, cancer & tumor) & blood vessel.

3) 3D Mapping (Stereo)

4) Results & Analysis

3.1 NIR Camera Lens Calibration Tests

For ultra-high precision 3D spatial data capture using images the cameras must be calibrated. Standard non-metric camera calibration is well documented (Fryer, 1989; Beyer 1992; Peterson *et al*. 1993; Fraser and Edmundson 1996). This process includes the determination of the principal point of autocollimation (PPA), the principal distance (PD), the radial lens distortion parameters (k1, k2 and k3), and in some instances the dynamic fluctuation.

3.2 Depth Of NIR Penetration Tests

For the majority of NIR applications in the medical field involves the penetration of NIR radiation in human tissue. As discussed earlier NIR is known to penetrate skin to a depth exceeding 3mm. However the correct wave-band and image processing techniques must be used to obtain the optimum results. The objective of the exercise is to establish the correct procedure

4.0 EXPECTED OUTCOME

1) NIR imaging system for **Medical Photogrammetry** applications (e.g. tumor studies, breast cancer & etc).

    - An set of optimal wave-length and intensity for various skin tissue conditions.

    - New understanding on the depth penetration of NIR electromagnetic Energy for various skin lesions.

2) New technique or method (optimum) to calibrate the **NIR** cameras.

3) Can find out the others current applications and potential of NIR images in **Medical Photogrammetry** fields.

5.0 RESULTS & CONCLUSIONS

Only preliminary study and finding are available at this stage. It is because this research already begins and still on going. It is the first step toward the understanding of NIR for the study of skin tissue condition. The next phase of the research is to do NIR camera lens calibration tests, depth of NIR penetration test and map skin tissue condition in the form of three-dimensional contour map. The research may provide new understanding of skin lesion (wound and skin cancer) using NIR imaging technique.

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