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NEAR-INFRARED CAMERA FOR NIGHT SURVEILLANCE APPLICATIONS

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ABSTRACT

Mostly today, illegal activities occur in the darkness of night. So how does one observe an area looking for lawbreakers at night when no means of visual sight is available? Using spotlights to see what is happening modifies the very behaviour that is being witnessed. Infrared cameras allow surveillance personnel to set back at a safe and unnoticeable distance and record the activity as it occurs, with minimal or no artificial lighting. The most popular and well known method of performing night surveillance is based on the use of night vision technique. In particular, near-infrared (NIR) cameras operate well in low light environments because the system provide their own NIR light sources. Consequently, this research was carried out to determine the suitability of NIR camera for night surveillance applications. The paper provides a discussion on the laboratory testing, data analysis and results of the use of NIR camera for 3D spatial data capture in low light conditions. Various NIR filter are used in this research. The result shows that the measurement accuracy is different for each NIR filter (715 nm, 780 nm, 830 nm and 850 nm) and similar for NIR filter-850nm and colour photographs. Consequently, the research suggests that the NIR camera and filter could be used as an alternative to colour photographs for night surveillance applications.

Key words: NIR camera, NIR filters, night surveillance, camera calibration.

1.0 INTRODUCTION

Infrared technology has been used in surveillance activities particularly for night time surveillance. Infrared technology is currently divided into two types which are thermal camera and infrared photography camera. Thermal cameras use heat sensor concept while infrared photography cameras uses NIR sensor such as night vision technology.

Night vision is extremely sensitive to infrared source (undetectable by human eye) which shows visuals in dark areas. Infrared filters help in enhancing night vision (Derrick, 2004) and designed for photographic effect with various size and wavelengths (700-925 nm) (Gibson, 1978; Chong, 2004). Every wavelength has different reactions to certain light (Hinkle *et al*. 2001). In night surveillance, light disturbance, fog and dampness have certain effects on the image and may be subjected to poor imaging. This will affect the visual image of the system. The use of infrared filter can help in reducing and optimise the effect of these disturbances (Gibson, 1978).

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Night vision is commonly used in night surveillance at low-light security or condition involving totally darkness. Infrared cameras with night vision function are ideal device for anyone needs to monitor in the dark for work or pleasure. Infrared cameras use infrared light (illuminator) instead of the regular lighting spectrum in order to produce better images in complete darkness or low light condition. Today, many surveillance systems consist of day and night version cameras. It mean that cameras can automatically or manually switch between day mode with colour video and night mode with black and white low light image.

This research was required to determine the suitability of NIR camera for night surveillance applications. The paper provides a discussion of the laboratory testing of the use of NIR camera for 3D data captured in low light condition based on various NIR filters. The results of NIR photography for each NIR filter and conventional colour photography are compared in order to evaluate the potential of NIR for further research (e.g. forensic mapping). Camera calibration for colour and NIR data-sets is reported. Tests were conducted on mannequins.

2.0 METHODOLOGY

The research entails two stages. First stages involves the calibration of the Sony HC-5E HDV cameras to determine their principal distances for colour and NIR imaging. The next comprises the testing of the colour and NIR photographs using mannequins (**Figure 1**). Initially, mannequins were used to avoid any error due to movement in order to determine the potential accuracy.

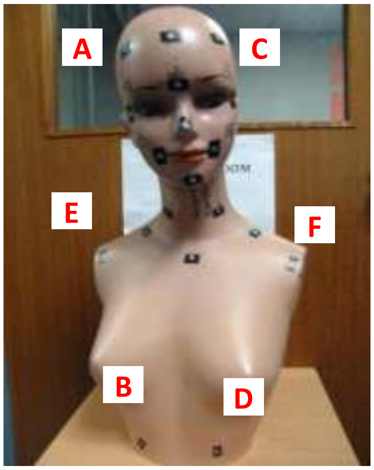

Figure 1: Mannequin

2.1 Equipment and Software

One Sony HC-5E HDV camera (6 megapixels) was used in the research (**Figure 2**). The camera is capable of taking colour and NIR photographs. A built-in NIR light source (700 to 930 nm) which is located at about 10 mm below the lens was used to illuminate the target while NIR photographs were taken. **Figure 3** shows a set of four NIR filters were used in the research. Each filter is designed with a specific range of wavelength (715 nm, 780 nm, 830 nm and 850 nm).

Figure 2: Sony HDV (HC-5E) and Infrared Illuminator

Figure 3: NIR Filters

Figure 4 shows a portable calibration frame that used in the research. Retro-targets were placed on the frame and on the bracing at three level of depth (0 mm, 75 mm and 150 mm). Retro-targets are highly reflective targets, which are specially made for precise automated digitizing (Atkinson, 1996). The coordinates of the retro-targets on the portable control frame were obtained photogrammetrically.

Figure 4: A Portable Calibration Frame

Australis photogrammetric bundle adjustment software (Version 6.04, 2002) was used to obtain high precision image coordinates from the digital images (Fraser and Edmundson 2000). The software was used to carry out photogrammetric computations, which included relative orientation, space resection, triangulation, bundle adjustment and measurement.

2.2 Calibrating the Camera

For ultra-high precision 3D spatial data capture 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 (k_1, k_2 and k_3), and in some instances the dynamic fluctuation.

The HDV cameras were calibrated based on colour and NIR photographs. The HDV was mounted on a tripod. The position of the HDV mount and the calibration frame were adjusted so that the object distance of 3.0 m would be similar to the object distance of the mannequin subject stereo photography. The 3.0 m object distance was found to be suitable for the chosen video and further research (e.g. forensic mapping). The PD was set to a wide-angle setting of 5.1 mm.

Convergent imagery of the portable calibration frame was taken by tilting the calibration frame through four different rotations (Karara, 1989) (**Figure 5**). These rotations simulated a set of four convergent image of the set-up. Each set-up was repeated four times. The colour imaging technique of the HDV was used first and this was followed by the NIR imaging technique. All the convergent photographs were digitized in auto mode using Australis. A self-calibration technique was used because this technique does not require a set of known object-space coordinates of the targets photographed (Cooper and Robson, 1996).

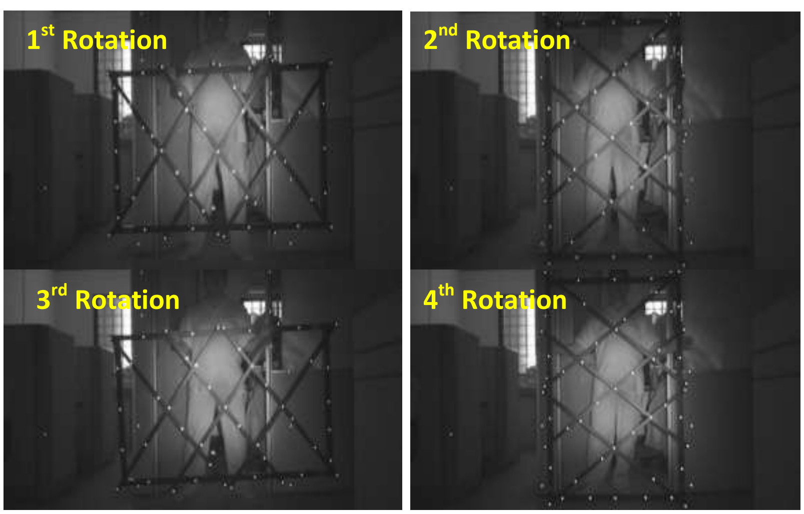

Figure 5: Four Different Rotations

2.3 Stereoscopic Photography

Again, HDV camera was used to capture stereo convergent imagery of the mannequin. The PD camera was set to a wide-angle setting of 5.1 mm and other electronic settings such as ISO, aperture, metering mode, exposure value and colour tones were set to default and the shutter speed was set to auto. Initially, the tests were performed on mannequin to determine whether colour and NIR photography would have an effect on the measurement always of the same subject. Each test was repeated four times. A total of twenty sets of stereopair were obtained for colour (four sets) and NIR photography (sixteen sets). For each type of NIR photography, four tests were carried out which consist of four NIR wavelengths study: (i) 715 nm, (ii) 780 nm, (iii) 830 nm and (iv) 850 nm. **Figure 6** shows example of the data.

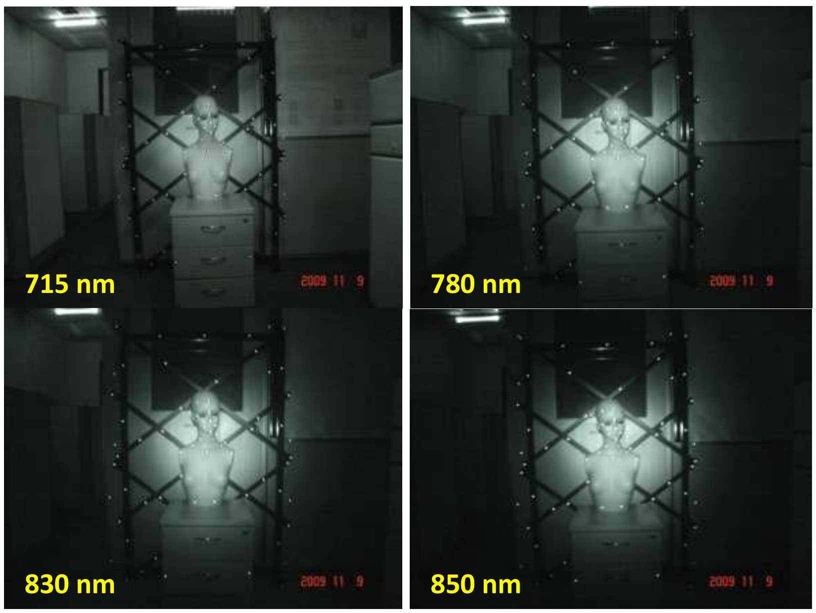

Figure 6: Effect of Different Wavelength on NIR photography

3.0 RESULTS AND ANALYSIS

The results of four sets of camera calibration for each set-up are shown in **Table 1**.

Table 1: Camera Focal Length Results

Set-up	Focal Length '*c*' (Means from four set data)
Colour Photography	5.118 mm
NIR Photography	
Filter-715 nm	5.168 mm
Filter-780 nm	5.175 mm
Filter-830 nm	5.175 mm
Filter-850 nm	5.183 mm

Table 1 shows the '*c*' for colour photography is shorter than the '*c*' for NIR photography by about 50 micron (filter-715 nm), 57 micron (filter-780 nm), 56 micron (filter-830 nm) and 64 micron (filter-850 nm). A student's *t*-test (*t*α (0.05)) shows that different between the means (colour photography vs. each NIR filter) is significant (H_0: μ1-μ2=0 was rejected). Based on analysis of variance (Anova), the standard deviation of the computed '*c*' of the colour photography is larger than the NIR photography (**Table 2**).

Table 2: Mean and Std. Dev. of the Computed '*c*' (Focal Length)

Mean	n	Std. Dev	
5.11816	4	0.020286	Colour
5.16761	4	0.002456	NIR-715
5.17523	4	0.005802	NIR-780
5.17463	4	0.009557	NIR-830
5.18248	4	0.017064	NIR-850
5.16362	20	0.026436	Total

Consequently, it implied that both NIR and colour photography have a different focal length '*c*'. For NIR photography it has demonstrated that focal lengths '*c*' for each NIR filter are slightly different with the very small values (**Figure 7**). As the object distance was set to the same value for both types of photography no errors are expected from changes in the distance from this source.

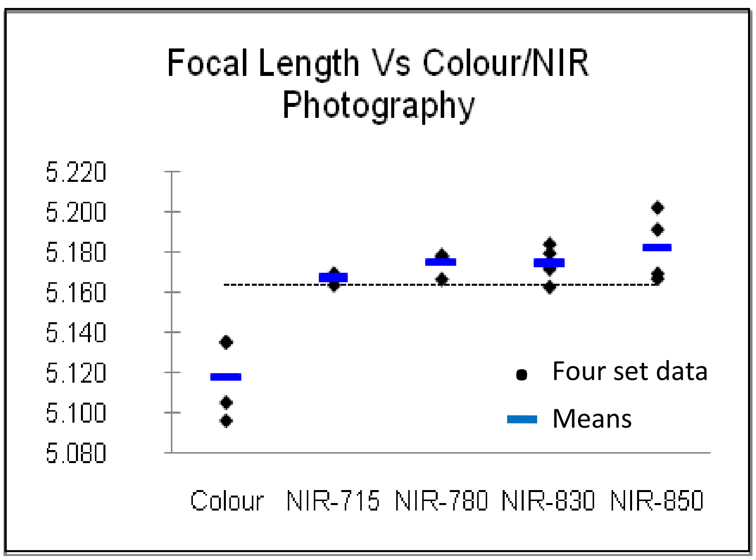

Figure 7: Chart - Focal Length Vs Colour/NIR Photography

3.2 Photographic Measurement

Stage 2 involves the measurements obtained from the mannequins. Three-dimensional distances (3Ds) between targeted landmarks were used to compare the computed object-space dimensional accuracy between NIR and colour photographs. The 3Ds were used instead of object-space coordinates to avoid any potential errors originating from slight displacements of the mannequin in between sets of stereo photography. The distances which were regarded as true were determined by a set of eight convergent photographs, two scale bars and photogrammetric bundle adjustments. The six longest 3Ds distances from the six targeted landmarks (**Figure 1**) were used in the comparison. Each test consisted of five sets and each set generated six 3D distances. Accordingly, 30 3Ds distance were used in each of the tests.

The results of the tests performed on mannequins are presented in **Tables 3**. The mean and standard deviation of the stereodigitising results of the colour and NIR photography are presented. Considering the whole data-set, most of the mean accuracy values are lower than or close to the 1.0 mm. The mean accuracy values of the NIR filter-850 nm photographs are of similar magnitude (less than 0.6 mm) to the mean accuracy values of the colour photographs.

Table 3: Difference between the true and measured 3Ds versus colour/NIR photography

Point/ Test	**A-B** (mm)		**C-D** (mm)	
	Mean	Std Dev	Mean	Std Dev
Colour	*0.4*	0.4	*0.4*	0.4
NIR				
715 nm	*0.9*	0.5	*0.8*	0.4
780 nm	*0.7*	0.5	*0.8*	0.5
830 nm	*-0.8*	0.4	*0.7*	0.5
850 nm	*0.3*	0.2	*0.4*	0.3
Point/ Test	**E-D** (mm)		**F-B** (mm)	
	Mean	Std Dev	Mean	Std Dev
Colour	*0.4*	0.5	*0.5*	0.4
NIR				
715 nm	*0.8*	0.5	*0.8*	0.4
780 nm	*0.7*	0.4	*-0.7*	0.4
830 nm	*-0.7*	0.5	*-0.8*	0.4
850 nm	*0.4*	0.2	*0.3*	0.2
Point/ Test	**E-F** (mm)		**B-D** (mm)	
	Mean	Std Dev	Mean	Std Dev
Colour	*0.5*	0.4	*0.4*	0.5
NIR				
715 nm	*0.9*	0.4	*0.9*	0.5
780 nm	*0.9*	0.4	*-0.7*	0.4
830 nm	*0.8*	0.5	*-0.8*	0.4
850 nm	*0.4*	0.3	*0.4*	0.2

This suggests that NIR filter-850 nm photography has the potential to be used to acquire 3D spatial data and measurements in low light condition. The standard deviation for all data was consistently in a range of 0.4 to 0.5 mm except for NIR filter-850 nm which shows a standard deviation less than or close to 0.3 mm. A statistical Student's *t*-test (tα (0.05)) shows that the differences between the means and standard deviations (all data vs. colour) are significant (H_0: μ1-μ2=0 was rejected).

4.0 CONCLUSIONS

This project attempted to determine whether digital NIR photography could be used for photogrammetric mapping of human features (based on mannequin) as an alternative to traditional colour photography. The results show that the accuracies of measurement on the mannequin are similar for both colour and NIR photography (especially filter-850 nm). Most of the mean accuracy values for all photography setup are lower than or close to the 1.0 mm.

The standard deviation for all data was consistently in a range of 0.4 to 0.5 mm except for NIR filter-850 nm provides standard deviation less than or close to 0.3 mm. Consequently, the results showed that NIR photography (filter-850 nm) constitutes a potential alternative for 3D spatial data capture in low light condition.

Further research will investigate the suitability of NIR images for forensic measurement of night surveillance images. There are several advantages of using NIR photography for mapping human features, especially for forensic mapping. Firstly, NIR photography requires less lighting resources and can be used in low light conditions. Many NIR/night surveillance images today are greatly enhanced with the use of NIR filters. Secondly, the stereo-images seemed to present fewer glares to the human eye, thus making stereodigitising less of a strain on the eyes (Chong and Mathiew, 2006). Certainly, there is potential for NIR imaging techniques in close range photogrammetric applications.

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