Inexpensive infrared color video using commercial off the shelf technology

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Introduction

Color infrared photography using multi-layer silver halide film has been widely exploited to measure vegetation health and vegetation type, determine the condition and makeup of soils, differentiate vegetation from man-made camouflage, perform forensic analysis of crime scenes and to analyze artwork and writing samples. Color IR (CIR) film has sensitivity to near infrared (out to ~820nm) in one band and to red and green in the other two film layers. (see attached spectral response curves of Kodak Aerochrome 1443 CIR film) In these applications the extension of the sensitive spectral region of the film to ~ 825 nm allows spectral signature analysis and unique recognition of objects that is otherwise impossible using conventional photometrically matched color film. CIR film has been widely used so photo-interpreters are familiar and comfortable performing analysis with images with this spectral response.

Silicon image sensors usually have high responsivity out to wavelengths of 800 - 900nm. The possibility of an electronic camera with spectral response equivalent to CIR film is exciting and has been exploited commercially in the past (Kodak DCS460CIR). However, these previous commercial CIR electronic cameras have been very expensive (~US$45K) and out of the reach of small laboratories. We propose a CIR electronic camera that uses inexpensive video cameras, readily available commercial electronics and portable computers to provide modest resolution near real-time video imagery with spectral sensitivity equivalent to CIR film. The extension to other wavelength sensitivities to observe other spectral features is obvious and straightforward.

Objectives

This project has the following near-term objectives:

1. Develop proof-of-principle hardware and software for a low cost multi-band medium resolution (640 X 480 pixels) electronic camera with spectral sensitivity similar to CIR film. This system will use 3 inexpensive black and white video cameras (with suitable bandpass filters) or, equivalently, a color ('RGB') camera and a IR-filtered monochrome camera with commercial video combining and capture electronics to record images on a portable computer. Post-acquisition near real-time software on the computer will combine the images into a color infrared image. (see Figure 1)
2. Develop a straw man design for a programmable gate array device (FPGA) to allow real time acquisition of images from the 4-camera system described above. The components will be specified and detail at the schematic level will be produced.
3. Perform performance testing and analysis to show the utility of the prototype camera system using suitable test targets and outside scenes.

This work is an extension of an undergraduate senior research project and builds upon lessons learned during that work.

Method

In concept, a color IR camera system can be built using either two cameras (a conventional color RGB camera and an IR filtered monochrome camera) or three cameras (3 monochrome cameras with filters to select bandpass for IR, green and red). Hardware will be constructed using commercial video cameras, commercial lenses and readily obtainable 'colored glass' filters. Filters are available inexpensively to allow spectral tailoring to practically any bandpass (from 3 nm FWHM to 500 nm FWHM) and any wavelength in the visible-near infrared region. Initially filters will be selected to reproduce the spectral response of CIR film.

The output from the two or three video cameras will be combined using a video multiplexer that combines up to four video fields from up to four cameras into a single frame. This single frame will be captured by a frame grabber, the composite image segmented, and then overlayed to produce a multi-plane image with the proper geometric and amplitude adjustments. All of the components, except for the personal computer, can be purchased for under $200 each (see budget for a cost breakdown), producing a system cost of less than $500. (less software)

Deliverables

1. A detail report that describes the system, measurements and performance checks, software listings and descriptions.
2. An analysis of the spectral sensitivity of the camera system and a comparison with Kodak 1443 CIR film.
3. Completed images from indoor and outdoor scenes.
4. The camera system comprised of:
    a. Two or three video cameras
    b. Filters for the cameras for the desired bandpass
    c. Lenses
    d. Frame multiplexer
    e. Frame grabber
    f. Power supplies and cables
    g. MS Windows compatible software for combination and adjustment.

Budget

Hardware:

Three Camera System:	
3 X Monochrome video cameras	$275
3 X 12.5 mm FL 'C' mount lenses	$125
3 X colored glass filters, 25 mm dia.	$90
Video multiplexer	$100
Cables, power supplies	$40
USB Frame grabber	$60
Mounting plates, asst'd hardware	$100
MS Visual Basic compiler	$100
Total Hardware:	$890

Labor:

Undergraduate Student,	
10 hr /week, 20 weeks + 35 hr/week 10 weeks @ $10	$5500
Sr. Research Scientist,	
40 hr/week, 2 weeks	$3400
Total	**$9790**

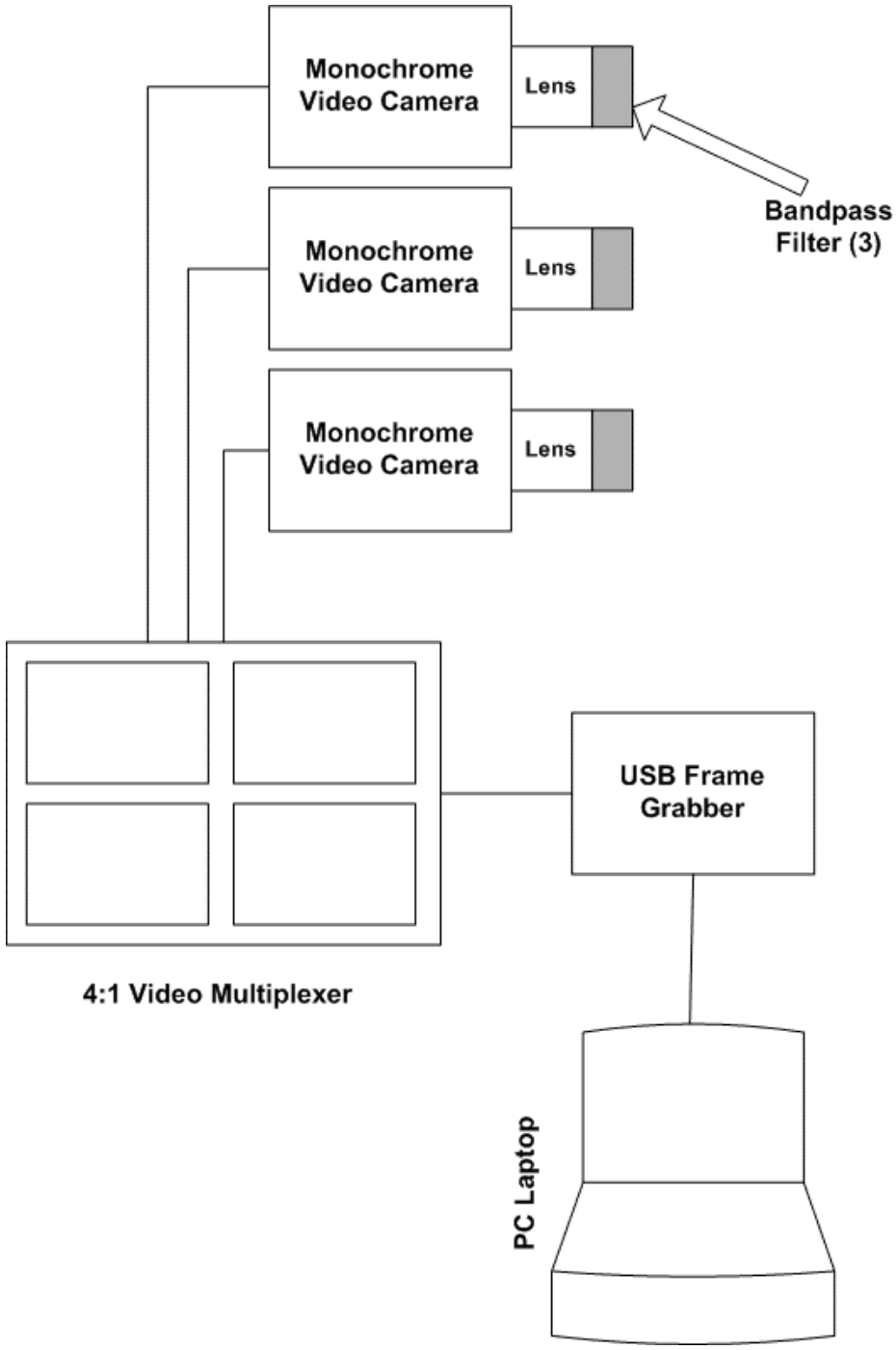

Figure 1 - Optical and electronic system for an inexpensive 3-band CIR camera. All the components are commercially available. The filters are chosen to match the response of CIR film. The cameras are co-sighted to observe the same point at a known distance. Software resident on the Laptop PC aligns the images and adjusts the responses of each band to produce a finished CIR image.

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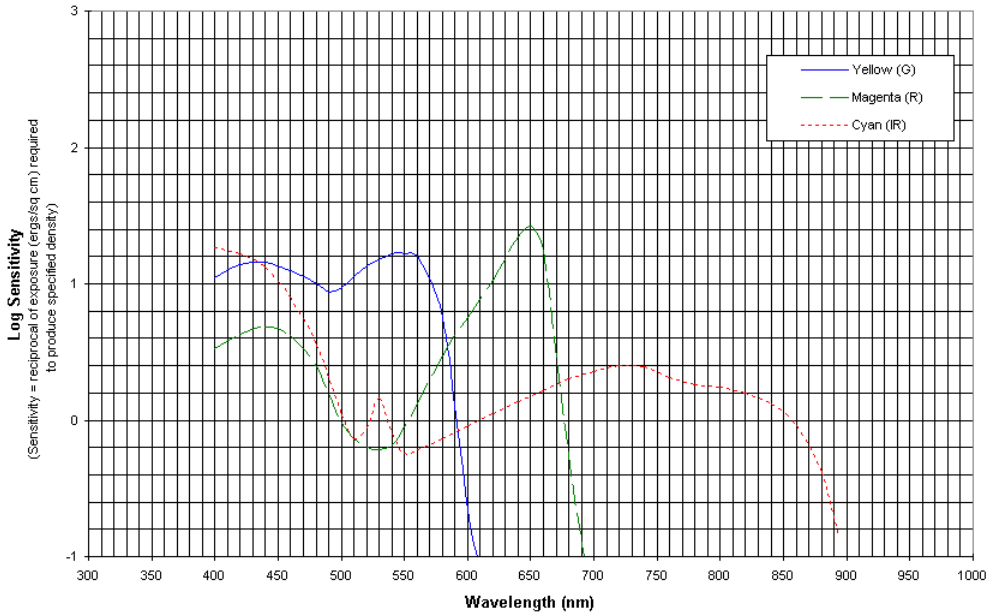
SPECTRAL SENSITIVITY, For Publication

KODAK AEROCHROME III Infrared Film 1443
KODAK AEROCHROME III Infrared NP Film SO-734
Normalized to 1/50 sec; Process AR-5; Density=1.0, Equivalent Neutral Density (END)
(G = Green sensitive, R = Red sensitive, IR = Infrared Sensitive)



Notice: While the data presented are typical of production coatings, they do not represent standards which must be met by Eastman Kodak Company. Varying storage, exposure and processing conditions will affect results. The company reserves the right to change and improve product characteristics at any time.

Spectral Response of KODAK CIR film