A Twelve-Band Airborne Digital Video Imaging System (ADVIS)

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This article describes an airborne digital video imaging system (ADVIS) and presents multispectral imagery to illustrate its potential use as a remote sensing research tool. The system was primarily designed to acquire multiband images for ascertaining spectral bands and/or band combinations to better characterize and assess natural resources. The ADVIS is comprised of 12 charge coupled device (CCD) analog video cameras and a computer equipped with a single multichannel digitizing board. The system cameras are equipped with various narrowband (6.5–12.6 nm bandwidths) interference filters to acquire images within the visible/near-infrared (NIR) (400–1000 nm) spectral waveband. The ADVIS multichannel capturing board is capable of obtaining 12 analog video inputs that are readily converted into digital images having 640 by 480 pixels resolution. The digitizing board has four RGB banks which have the capability of generating four synchronized real-time false color composite images from any selectable three-band combination among the 12 cameras, as keyed by the RGB inputs of the digitizing board. The computer system has a two GB storage capacity hard drive that can store 2000 RGB 24-bit color images. The system is unique because the quad real-time color composite imagery it provides is of adequate quality for assessing scenes of interest and there is no need for post-processing band registration immediately after the flight mission in order to evaluate the imagery. Also, the display of the quad images readily depicts which composite image(s) provides better differences among land-use cover types in the scene. This imagery, however, needs to be registered for image processing and analysis. The display of the black-and-white (B&W) image components (spectral bands) of the composite images provide basic information to assist in the interpretation of the color composites and to qualitatively understand the interaction of ecological parameters with the electromagnetic spectrum. The ADVIS multispectral image acquisition may determine the best band(s) for characterizing and/or detecting problems of the various natural resources. ©Elsevier Science Inc., 1998

INTRODUCTION

Airborne digital video imaging systems have become versatile data-gathering tools because of their high spatial resolution, near real-time image availability and computer compatibility. Current video and digital camera systems that are widely used for many commercial applications and research purposes are the three- and/or four-camera systems. These systems have cameras equipped with narrowband interference filters and the image signals are digitized in a frame grabber and/or recorded on video cassette recorders (Benkelman and Behrent, 1992; Honey, 1993; Mao et al., 1994; Everitt, et al., 1995; Sun et al., 1996). Many of these systems have been developed generally to acquire imagery in the visible green, red, and near-infrared (NIR) spectral regions to obtain color-infrared (CIR) imagery to simulate CIR film which has been the chosen medium for assessing natural resources.

Other video and digital camera systems that have been used for the same purpose are the band-sequential, filter wheel systems (Niedrauer and Paul, 1985; Fouche and Booyse, 1994; King, 1995). These cameras have a rotating filter wheel in front of the camera lens which is capable of obtaining six to eight spectral image bands. Imaging spectrometers, which are a different kind of imaging systems in comparison to multispectral video and
digital systems, have also been used commercially and in research applications. These systems [i.e., Airborne Visible/Infrared Spectrometer (AVIRIS), Compact Airborne Spectrographic Imager (CASI)] have the capability of collecting image data in a 100 or more of very narrow and contiguous spectral bands throughout the visible and near-infrared regions of the electromagnetic spectrum. (CASI can collect up to 288 bands within the 0.4–1.0 \( \mu m \) waveband). These remarkable and sophisticated systems, however, are costly (200,000–plus price range) in comparison to video and digital systems ($30,000±80,000 quired at low altitudes, compensating for high altitude interference filters to acquire imagery of specific spectral bands. With these lenses, maximum coverage can be acquired at low altitudes, compensating for high altitude image acquisition. Figure 2 shows some of the filters being used on the ADVIS cameras. The arrows indicate the filters’ center wavelengths. Table 1 shows the filters’ bandwidths and their respective peak transmission. Hence, any 12 user-selectable filters can be used to obtain maximum enhancement of features within an area of interest. In addition, the camera frame mount permits the substitution of other cameras/sensors with a wide range of spectral sensitivity (i.e., ultraviolet, mid-infrared, thermal), thus making this system versatile.

A prototype 12-camera digital video/computer system was developed by the USDA-ARS at Weslaco, Texas for use as a remote sensing research tool (Escober et al., 1995). The system cameras were equipped with visible/NIR (400–1000 nm) narrowband (6.5–12.6 nm bandwidths) interference filters. The system incorporated a computer that had four RGB frame grabbers with 512 by 512 pixel format having the capability of generating four synchronized real-time RGB false color digital composite images simultaneously. Testing trials of the system showed its potential as a research tool for ascertaining spectral bands for use in characterizing and assessing natural resources and for understanding the interaction of ecological parameters within the 400–1000 nm spectral waveband.

With the improvements in videographic and computer hardware/software technology, this system has been upgraded, featuring better image quality (640 by 480 pixels resolution) and data acquisition capability similar to many multispectral scanners, but with the simplicity in approach of photography. This system was primarily designed to acquire multispectral imagery for ascertaining spectral bands or band combinations for characterizing and assessing natural resources. The objective of this paper is to describe this improved 12-band airborne digital video imaging system and present multispectral imagery to illustrate its potential use as a research tool.

**ADVIS Description**

Figure 1 shows the airborne digital video imaging system (ADVIS). It is comprised of a 12 CCD analog video camera system mounted on a lightweight aluminum frame (A) and a rack-mount having four 10-cm B&W monitors (B), a computer equipped with a built-in color monitor and a digitizing board (C), a video routing switcher (D), a power distributor (E), and an Omni frame modular signal chasis (F). The camera system consists of 12 (four three-camera clusters) interlaced B&W, high resolution, visible/NIR light sensitive (400–1100 nm) COHU\(^1\) (Model 4800 series) cameras that have better than 550 horizontal line resolution. These cameras are equipped with 2/3-inch format CCD image sensors which have 754(H) by 488(V) picture element. The cameras have 12.5 mm fixed lenses and are equipped with various narrowband interference filters to acquire imagery of specific spectral bands. With these lenses, maximum coverage can be acquired at low altitudes, compensating for high altitude image acquisition. Figure 2 shows some of the filters being used on the ADVIS cameras. The arrows indicate the filters’ center wavelengths. Table 1 shows the filters’ bandwidths and their respective peak transmission. Hence, any 12 user-selectable filters can be used to obtain maximum enhancement of features within an area of interest. In addition, the camera frame mount permits the substitution of other cameras/sensors with a wide range of spectral sensitivity (i.e., ultraviolet, mid-infrared, thermal), thus making this system versatile.

The cameras are equipped with genlock input connectors to sync/genlock the cameras. The Omni frame module signal chassis has three VideoTek distribution amplifier modules and a VideoTek sync generator module to synchronize all cameras simultaneously.

The computer is a Bi-Link Pentium 150-MHz system that has a 22.5-cm built-in S-VGA color monitor. It is equipped with a SNAPPER-24 single multichannel digitizing board having 640×480 pixel resolution. The ADVIS, therefore, acquires analog video that is readily converted into digital format. The digitizing board has four RGB banks which have the capability of generating sequentially (one camera cluster-at-a-time) four synchronized false-color composite images from any selectable three-band combination among the 12 cameras, as keyed by the RGB inputs of the digitizing board. The sequential image acquisition of this system takes less than 2 s and requires approximately 12 s to download the TIFF-formatted images into the hard drive. The ADVIS, therefore, can obtain only one quad image of a specific site at a time; however, many sites can be acquired since the computer system has a 2 GB storage capacity hard drive that can store 2000 RGB 24-bit color images. The computer mouse serves as the capturing image device rather than the use of the computer keyboard. Image registration to acquire real-time color composite imagery with a multicamera system has been previously described by Everitt et al. (1991). With this imaging system, the camera clusters are fastened to the camera mount in a slight offset position to compensate for the movement of the

\(^1\) Trade names are included for the benefit of the reader and do not imply an endorsement of or a preference for the product listed by the U.S. Department of Agriculture
airplane. In addition, at the time of capturing an image the pilot slows the airplane.

The ADVIS also has the optional capability of obtaining the same imagery that the Pentium computer system digitizes in analog format. By keying the RGB inputs of four FORA (Model ENC-110) color encoders to those of the SNAPPER-24 digitizing board, four NTSC analog false color composites can be recorded on four Panasonic (Model AG-7400) S-VHS recorders. Therefore, the analog composite imagery can be obtained simultaneously with the digital image acquisition, serving as backup data in the event the ADVIS computer system malfunctions during the mission.

During image acquisition, false color composites and their respective B&W image band components are simultaneously viewed on the computer 22.5-cm built-in S-VGA color monitor and on the 10-cm Sony quad rack-mounted (Model PVM-411) monitors, respectively. Hence, prior
to digitizing data, the imagery is displayed (one camera cluster-at-a-time basis) on the monitors using the video routing switcher to adjust camera apertures for best contrast in each B&W band and for the color balance of the generated color composite. Target areas are flown several times to adjust all camera apertures. Also, images scenes being digitally acquired are readily viewed to ensure the digitized image and the area of interest are correctly obtained.

The power source for the ADVIS is provided by the aircraft’s 24-V battery. The cameras’ power is rendered by means of a converter that reduces the 24–12 V DC, whereas the computer system, TV monitors, video switcher, and Omni frame chassis are powered by an inverter that changes the 24 V DC to 110 V AC.

The ADVIS digital imagery presented here was obtained with an Aero Commander 680S aircraft at altitudes above ground level of 457–914 m (1500–3000 ft) giving a ground pixel resolution of 0.49–0.98 m (1.62–3.23 ft), respectively. At the time of image acquisition, the aircraft speed was 100 knots/h while the video camera frame rate was 1/30 of a second. All imagery was acquired between 1100 h and 1400 h under sunny conditions. Illustrated images presented in this article were printed (300 dpi) on a Fargo Primera Pro Color printer, using Image Pro and Adobe Photoshop software (version 3.0).

### ADVIS MULTISPECTRAL IMAGERY EXAMPLE

Image acquisition with the ADVIS has shown its potential use as a research tool for ascertaining spectral bands to detect or discriminate among a variety of ecologi-
Figure 2. Narrowband filters currently being used on the ADVIS cameras. The arrows indicate the filters’ center wavelength.

Figure 3. Example of the ADVIS capabilities of generating four synchronized near real-time RGB false color digital composite images. The scene shows the detection of an effluent discharge directly into a river.
cal variables, including, plant species/communities, plant stress, saline soils, water pollution, etc. Figure 3 shows an example of the ADVIS capabilities of generating four synchronized near real-time RGB false color digital composite images from any selectable three-band combination among the 12 cameras, as keyed by the RGB inputs of the single multi-channel digitizing board. The scene shows the detection of an effluent discharge directly into a river. The data acquisition capability of this system is similar to that of a multispectral scanner, but with the simplicity in approach of photography in that the capture of these real-time color composite images is accomplished by just pressing the computer mouse. Even though the real-time composite imagery provided by the ADVIS may be one or two pixels off, the system is unique because the imagery is of adequate quality for assessing scenes of interest and there is no need for post-processing and analysis, however, the imagery needs to be corrected and registered to obtain accurate and reliable digital data.

The color composite images display information about the scene in terms of the various color renditions resulting from different land cover features. These composite images, however, do not provide the required information that is necessary to help explain the observed differences on the images. The color composites serve as images for visual interpretation, while each of the B&W image components provide information about the differences displayed in the composite images.

Figure 4 shows an illustration of the ADVIS false color composite images and their respective B&W image components (spectral bands). This illustration depicts the role of the ADVIS as a research tool. The scene is an area comprised predominantly of natural vegetation. As has been indicated, the ADVIS color composite imagery readily depicts which composite image(s) provides better differences among land-use cover types in the scenes. For image processing and analysis, however, the imagery needs to be corrected and registered to obtain accurate and reliable digital data.

The plant species interactions with the NIR 820 and the reflective visible 720, 700, 600, 560, 550, and 530 B&W bands show more differences than with the visible absorption 660, 640, 630, 488, and 450 bands. Furthermore, these images reveal that the visible 720, 560, 550, and 530 band interactions were greater than the 820 band, with the exception of the interaction that occurred with the whitish-gray tree areas. The interaction result of each of these visible bands also contributed more to the information and color tonal renditions of its respective composite image than the other image components.

Understanding the association between the land cover features reflectivity and the color tonal renditions produced on color imagery is important to the interpretation of the resulting imagery. Interpreting briefly the CIR composite image (A), for example, the composite B&W image components reveal that the visible 550 band showed more distinct gray scale differences (greater interactions) among the woody plant species than the visible 640 and NIR 820 bands. The light pinkish to reddish-rust magenta trees are mostly attributed to the variable gray tone combinations of the visible 640 and 550 bands; however, the red color differences among the plants were mostly affected by the 550 band. In the 550 image band, which represents the reflectance peak in the visible region (see Fig. 2), the trees produced a lighter gray tonal response. In comparison to the other spectral bands, there were greater interactions (more gray scale differences) between the 550 spectral light and the tree species which caused this band to depict better differences among them. In the 640 band, trees with dark green foliage had dark gray tonal responses. These dark tonal responses may also have been attributed to in-canopy shadowing (Richardson et al., 1975). Conversely, trees with green and light green foliage absorbed less light, causing them to render a gray tonal response in the image. The tree species in this spectral band, however, were not as distinguishable as in the 550 image band.

Of the three bands, the 820 band contributed less to the tonal colors in the composite image. With the exception of the trees in the upper center and a few trees on the left side of the image which gave a whitish response, most of the trees produced a moderate gray to dull gray tonal response, causing them to be less conspicuous. The bright and dull red magenta trees in the composite, therefore, generally resulted from the variable whitish-gray, dull gray and dark gray tonal responses in all three spectral image bands, but the combination of both the 640 and 550 visible bands contributed the most to the image color tones.
As a research tool, therefore, the ADVIS multispectral imagery provides basic information for understanding and relating how vegetation conditions and/or changes interact with a particular wavelength or wavebands and how these interactions affect the appearance of vegetation on color imagery. In addition, this multiband imagery may also yield information that may ultimately determine the best bands for detecting problems or characterizing various natural resource parameters.

**CONCLUSIONS**

This article describes the ADVIS and presented multispectral imagery to illustrate its potential use as a research tool. This system can be assembled for approximately $35,000. The system is unique because of the quad real-time color composite imagery it provides. The display of the imagery readily depicts which composite image(s) provide better differences among land-use cover types in the scenes. For image processing and analysis, however, the imagery needs to be corrected and registered. The display of the B&W image components (spectral bands) of the composite images provide basic information to assist in the interpretation of the color composite imagery and to qualitatively understand the interaction of ecological parameters with the electromagnetic spectrum. While the current three- and/or four-camera systems provide one or two composite images (three or four spectral bands) and filter wheel systems provide six to eight B&W images, the ADVIS captures four color composite images (12 spectral bands) which can be readily displayed and assessed immediately after the flight mission. This kind of multispectral image acquisition clearly shows that the ADVIS has promise as
a research tool. In future research studies, the ADVIS multispectral imagery will be subjected to various image processing techniques and analysis to determine optimal spectral bands for applications and/or to better characterize and assess natural resources.

REFERENCES


