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Multispectral Imaging Systems for Space, Military and Commercial Applications

Multiphoton imaging techniques and camera systems are serving industries with immediate definition improvements for a wide range of applications. Advanced devices utilize multi-spectrum cameras able to sense multiple frequencies of light selected from the electromagnetic spectrum. This new technology is being applied across multiple industries and applications. Satellites in space offer amazing views of earth's surface, as well as providing both physical analysis and chemical information to the users. Defense industries are building data bases for navigation and precise positioning control using geospatial imaging maps that help reduce dependency on GPS, (global positioning satellites). Medical instruments are offering disease detection information by sensing cellular image changes during infections. The agricultural and food industries have designed imaging systems to detect maturity of plant fertilization, product ripeness and even quality analysis prior to product distribution to the consumer. Ecologists are using spectral image tracking in coordination with the North Atlantic University in Artic Norway to monitor and plot global warming trends.

Spectral image analysis goes beyond the classical RGB, (red, green and blue), frequency cameras to include and utilize advantages of light beyond the human visible spectrum. Variations in camera designs can include frequencies such as x-ray, infrared, and ultraviolet image analysis capturing and analysis. Modern image systems have borrowed methods from early spectrum analysis machines that used various light frequencies and material refractions during illumination to define elements within materials. Spectral light frequencies most often considered are based on application and fit into wavelengths listed here:

- Light frequencies used include:
- Ultra Violet from 200 to 400 nanometers
- Visible ranging from 400 to 780 nanometers
- Infrared ranges from 780 to 2500 nanometers
- Mid-range Infrared from 2500 to 25,000 nanometers.

Leveraging the understanding of each material element offers a different refractive index to light many different applications exist. A unique example of spectral material analysis is underway with the collection of Mars surface materials for shipment back to earth for analysis. Defense surveillance systems have spectral analysis devices that look down through highly camouflaged target areas. In some cases, buried devices, such as land mines can be mapped from above, prior to battle troops incursion into the area. Medical applications have embraced hyperspectral imaging in areas including automated surgery and image controlled surgery procedures. Some tissue disease analysis methods are significantly reducing lab analysis cost and time by using a selected line-scanner on the camera to compare concerning areas to the overall scan of the body tissue in that area. New narrow band sensors are being added to fit other specific applications from those useful in detecting chemical data such as in chlorophyll content and percent of moisture in plant-life. Highly reflective surface materials are regularly searched near potential petroleum and mining zones.

Spatial analysis includes the process of planning the size, and sections, of images being processed within the image collection. Camera and Lens design begins with planning based upon desired frequency of refractions within minute sections of the image. Lens and filters are also designed for various different wavelengths able to be placed in an addressable matrix on the lens to match the technology.

“Combining Spectral imaging with Spatial technologies and Angular views off-Nadir for highest resolution from a distance”

Terrain Surveillance
from Drone

Designs are extending surveillance data analysis by switching from overall image scans to picking data from sections of a variety of individual pixels.

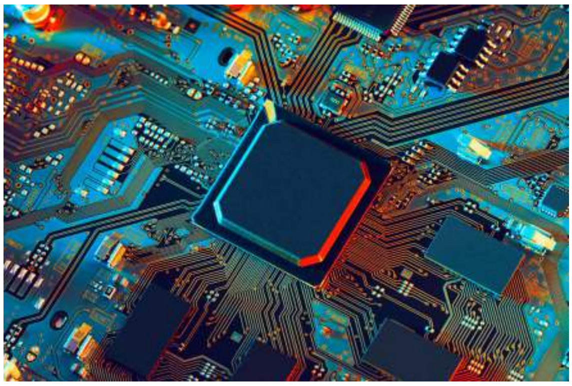
Heights from a camera can be analyzed to build details in elevation of the terrain below. The U.S. Army ERDC, (Engineering Research and Development Center), is considering the need for highly interactive geospatial mapping and control for use in battlespace planning and tactics. Today, many ground based defense tactics require highly controlled positioning to communicate direction and distance within an area that may involve close proximity of both friend and foe. High quality spatial image data can allow for precise positioning and placement of critical troops and elements. Spatial image matrix lenses are available that can allow a parallel image to the overall spectral images and support highly controlled focus on specific elements or frequencies within the overall photo for best resolution and analysis. By sampling details of data from across a broad spectrum of the electromagnetic field, data can be presented in various colored images that fit within the human eye and add details such as elevation, various colored image reflection and even chemical composition through environmental conditions.

Viewing angles while imaging from drones to space cameras has added to the evolution of spectral imaging in a number of ways. Images from earth are rarely taken vertically downward, but are taken at 15 degrees off nadir, (Nadir – directly below an object in space.). This offers an oblique angle for resolution that is easily exhibited in photos such as looking straight down over a city. The angular image exhibits varying heights of each building next to each other. While perfectly vertical images of that same city show tops of buildings but not the relative heights from street level to each building.

Industry examples can be found for many applications on line and in the literature. Multispectral detection for night vision and defense has continued to evolve with companies such as FLIR corporations focus on early helicopter search systems. Extensive literature is also ava liable from SPIE, (International society for optics and photonics.) See their digital library with sections focused on Hyperspectral Imaging.

Coordinating design for both mechanical and electrical performance with complex circuitry becomes critical with density, signal speed, and potential ruggedness. In some cases, the camera imaging system is mounted inside a mobile instrument and can be exposed to high shock, vibration and environmental conditions. Sensors are often extended beyond the inner frame or portion of the main operating system. Fortunately, CCD type spectral camera sensors can be mounted to coordinate with existing design methods. Rather than connecting multiple systems into a complex printed circuit stack or

Hyperspectral Satellite



CCD type Hyper Spectral Chip

module, designers have chip and sensor devices available that offer total circuit functions on one chip. The benefits of circuit size and weight reduction are combined with increases in data processing and storage. (New signal modulation and anti-jamming methods are more easily employed as well.) DROIC, (digital-read out I.C.) chips can also reduce noise and increase digital signal integrity, all within a single-chip module. In addition, higher speed digital read and processing with CMOS, and GaN, (Gallium Nitride), materials help increase satellite to satellite signal integrity up in the 10 Gbit/sec. ranges. Military satellite designers are coordinating LEO, (low elevation orbiting), small satellite constellations with highly referenced satellites at medium to higher orbits. Multi-spectral circuits on LEO satellites are closer to earth surface and benefit with high signal levels on the ground, and coordinate with higher-level units for best position accuracy.

Spectral data management and routing to other circuitry within the system is often accomplished using Nano-D connectors and miniature wiring. Nano-D connectors are designed for high reliability and to remain working in portable activities and extreme environments. (The larger Micro-D connector design helped establish reliability and performance standards and are used for higher current levels on physically larger circuits.) The Nano-connector design employs a 17,200 KSI beryllium copper "spring pin-to-solid-socket" designed to insure signal integrity during use. Higher speed Nano interconnections can easily handle the increased speeds with lower voltages. As signal speed increases and the wave-length of each signal is shorter, vibration and circuit noise is suppressed inside the Nano-metal shell and back-shell system connected to a shielded cable.

Virtual design and integration of high-density interconnection cable and connectors is readily available for spectral imaging. Instrument designers can work on-line with experienced connector designers using solid-models to fit high density application images into their circuits. Established standard connectors may fit the solid-model of a current connector and is overlaid or inserted into the system image to insure it fits. If new shapes, pin configurations, or sizes are needed they can be quickly addressed. Variations can include mixed signals to include power and signal within one connector, as well. A rapid build of the 3-d model is then shipped to the system engineer for prototype assurance. Hyper spectral imaging is here and being used routinely. Interconnections and signal routing is readily designed to the system requirements by collaborating with the connector manufacturer.

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