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## Chapter 1 : Lighting & Imaging - Sensors, Metrology & Control - Industrial | SCHOTT AG

*Lighting for the control room of MRI/imaging suites requires the combination of even ambient and non-glare task illumination with the added flexibility of dimmable control.*

Principle[ edit ] Projecting a narrow band of light onto a three-dimensionally shaped surface produces a line of illumination that appears distorted from other perspectives than that of the projector, and can be used for geometric reconstruction of the surface shape light section. A faster and more versatile method is the projection of patterns consisting of many stripes at once, or of arbitrary fringes, as this allows for the acquisition of a multitude of samples simultaneously. Seen from different viewpoints, the pattern appears geometrically distorted due to the surface shape of the object. Although many other variants of structured light projection are possible, patterns of parallel stripes are widely used. The picture shows the geometrical deformation of a single stripe projected onto a simple 3D surface. Generation of light patterns[ edit ] Fringe pattern recording system with 2 cameras avoiding obstructions Two major methods of stripe pattern generation have been established: Laser interference and projection. The laser interference method works with two wide planar laser beam fronts. Their interference results in regular, equidistant line patterns. Different pattern sizes can be obtained by changing the angle between these beams. The method allows for the exact and easy generation of very fine patterns with unlimited depth of field. Disadvantages are high cost of implementation, difficulties providing the ideal beam geometry, and laser typical effects like speckle noise and the possible self interference with beam parts reflected from objects. Typically, there is no means of modulating individual stripes, such as with Gray codes. The projection method uses incoherent light and basically works like a video projector. Patterns are usually generated by passing light through a digital spatial light modulator , typically based on one of the three currently most widespread digital projection technologies, transmissive liquid crystal , reflective liquid crystal on silicon LCOS or digital light processing DLP; moving micro mirror modulators, which have various comparative advantages and disadvantages for this application. Other methods of projection could be and have been used, however. Patterns generated by digital display projectors have small discontinuities due to the pixel boundaries in the displays. Sufficiently small boundaries however can practically be neglected as they are evened out by the slightest defocus. A typical measuring assembly consists of one projector and at least one camera. For many applications, two cameras on opposite sides of the projector have been established as useful. Invisible or imperceptible structured light uses structured light without interfering with other computer vision tasks for which the projected pattern will be confusing. Example methods include the use of infrared light or of extremely high framerates alternating between two exact opposite patterns. A mathematical model is used for describing the imaging properties of projector and cameras. Essentially based on the simple geometric properties of a pinhole camera , the model also has to take into account the geometric distortions and optical aberration of projector and camera lenses. The parameters of the camera as well as its orientation in space can be determined by a series of calibration measurements, using photogrammetric bundle adjustment. Analysis of stripe patterns[ edit ] There are several depth cues contained in the observed stripe patterns. The displacement of any single stripe can directly be converted into 3D coordinates. For this purpose, the individual stripe has to be identified, which can for example be accomplished by tracing or counting stripes pattern recognition method. Another common method projects alternating stripe patterns, resulting in binary Gray code sequences identifying the number of each individual stripe hitting the object. An important depth cue also results from the varying stripe widths along the object surface. Stripe width is a function of the steepness of a surface part, i. Stripe frequency and phase deliver similar cues and can be analyzed by a Fourier transform. Finally, the wavelet transform has recently been discussed for the same purpose. In many practical implementations, series of measurements combining pattern recognition, Gray codes and Fourier transform are obtained for a complete and unambiguous reconstruction of shapes. Another method also belonging to the area of fringe projection has been demonstrated, utilizing the depth of field of the camera. Precision and range[ edit ] The optical resolution of fringe projection methods depends on the width of the stripes used and their optical quality. It is also limited

by the wavelength of light. An extreme reduction of stripe width proves inefficient due to limitations in depth of field, camera resolution and display resolution. Therefore, the phase shift method has been widely established: A number of at least 3, typically about 10 exposures are taken with slightly shifted stripes. The first theoretical deductions of this method relied on stripes with a sine wave shaped intensity modulation, but the methods work with "rectangular" modulated stripes, as delivered from LCD or DLP displays as well. By phase shifting, surface detail of e. Current optical stripe pattern profilometry hence allows for detail resolutions down to the wavelength of light, below 1 micrometer in practice or, with larger stripe patterns, to approx. Arbitrarily large objects can be measured with accordingly large stripe patterns and setups. Practical applications are documented involving objects several meters in size. Typical accuracy figures are: Planarity of a 2-foot 0. Shape of a motor combustion chamber to 2 micrometres 7. This can be accomplished by attaching marker points to the object and combining perspectives afterwards by matching these markers. The process can be automated, by mounting the object on a motorized turntable or CNC positioning device. Markers can as well be applied on a positioning device instead of the object itself. The 3D data gathered can be used to retrieve CAD computer aided design data and models from existing components reverse engineering , hand formed samples or sculptures, natural objects or artifacts. Challenges[ edit ] As with all optical methods, reflective or transparent surfaces raise difficulties. Reflections cause light to be reflected either away from the camera or right into its optics. In both cases, the dynamic range of the camera can be exceeded. Transparent or semi-transparent surfaces also cause major difficulties. In these cases, coating the surfaces with a thin opaque lacquer just for measuring purposes is a common practice. A recent method handles highly reflective and specular objects by inserting a 1-dimensional diffuser between the light source e. Reflective cavities and concave objects are therefore difficult to handle. It is also hard to handle translucent materials, such as skin, marble, wax, plants and human tissue because of the phenomenon of sub-surface scattering. Recently, there has been an effort in the computer vision community to handle such optically complex scenes by re-designing the illumination patterns. Inline precision inspection of components during the production process. Health care applications, such as live measuring of human body shapes or the micro structures of human skin. Motion picture applications have been proposed, for example the acquisition of spatial scene data for three-dimensional television. These systems feature self-monitoring for calibration status, transformation accuracy, environmental changes, and part movement to ensure high-quality measuring data. A technology by PrimeSense , used in an early version of Microsoft Kinect , used a pattern of projected infrared points to generate a dense 3D image. Later on, the Microsoft Kinect switched to using a time-of-flight camera instead of structured light. Occipital Structure Sensor uses a pattern of projected infrared points, calibrated to minimize distortion to generate a dense 3D image. Structure Core uses a stereo camera that matches against a random pattern of projected infrared points to generate a dense 3D image. Intel RealSense camera projects a series of infrared patterns to obtain the 3D structure. Face ID system works by projecting more than 30, infrared dots onto a face and producing a 3D facial map. VicoVR sensor uses a pattern of infrared points for skeletal tracking. Chiaro Technologies uses a single engineered pattern of infrared points called Symbolic Light to stream 3D point clouds for industrial applications.

## Chapter 2 : Medical Imaging Lighting

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This section does not cite any sources. Please help improve this section by adding citations to reliable sources. Unsourced material may be challenged and removed. November Learn how and when to remove this template message Infrared radiation can be used as a deliberate heating source. For example, it is used in infrared saunas to heat the occupants. It may also be used in other heating applications, such as to remove ice from the wings of aircraft de-icing. Infrared heating is also becoming more popular in industrial manufacturing processes, e. In these applications, infrared heaters replace convection ovens and contact heating. Efficiency is achieved by matching the wavelength of the infrared heater to the absorption characteristics of the material. Radiative cooling A variety of technologies or proposed technologies take advantage of infrared emissions to cool buildings or other systems. Consumer IR IR data transmission is also employed in short-range communication among computer peripherals and personal digital assistants. Remote controls and IrDA devices use infrared light-emitting diodes LEDs to emit infrared radiation that is focused by a plastic lens into a narrow beam. The beam is modulated , i. The receiver uses a silicon photodiode to convert the infrared radiation to an electric current. It responds only to the rapidly pulsing signal created by the transmitter, and filters out slowly changing infrared radiation from ambient light. Infrared communications are useful for indoor use in areas of high population density. IR does not penetrate walls and so does not interfere with other devices in adjoining rooms. Infrared is the most common way for remote controls to command appliances. IR data transmission of encoded audio versions of printed signs is being researched as an aid for visually impaired people through the RIAS Remote Infrared Audible Signage project. Transmitting IR data from one device to another is sometimes referred to as beaming. Spectroscopy[ edit ] Infrared vibrational spectroscopy see also near-infrared spectroscopy is a technique that can be used to identify molecules by analysis of their constituent bonds. Each chemical bond in a molecule vibrates at a frequency characteristic of that bond. A group of atoms in a molecule e. If an oscillation leads to a change in dipole in the molecule then it will absorb a photon that has the same frequency. The vibrational frequencies of most molecules correspond to the frequencies of infrared light. A spectrum of all the frequencies of absorption in a sample is recorded. Thin film metrology[ edit ] In the semiconductor industry, infrared light can be used to characterize materials such as thin films and periodic trench structures. By measuring the reflectance of light from the surface of a semiconductor wafer, the index of refraction n and the extinction Coefficient k can be determined via the Forouhi-Bloomer dispersion equations. The reflectance from the infrared light can also be used to determine the critical dimension, depth, and sidewall angle of high aspect ratio trench structures. A frontal system can be seen in the Gulf of Mexico with embedded Cumulonimbus cloud. Shallower Cumulus and Stratocumulus can be seen off the Eastern Seaboard. Weather satellites equipped with scanning radiometers produce thermal or infrared images, which can then enable a trained analyst to determine cloud heights and types, to calculate land and surface water temperatures, and to locate ocean surface features. The scanning is typically in the range  High, cold ice clouds such as Cirrus or Cumulonimbus show up bright white, lower warmer clouds such as Stratus or Stratocumulus show up as grey with intermediate clouds shaded accordingly. Hot land surfaces will show up as dark-grey or black. One disadvantage of infrared imagery is that low cloud such as stratus or fog can be a similar temperature to the surrounding land or sea surface and does not show up. However, using the difference in brightness of the IR4 channel  The main advantage of infrared is that images can be produced at night, allowing a continuous sequence of weather to be studied. These infrared pictures can depict ocean eddies or vortices and map currents such as the Gulf Stream, which are valuable to the shipping industry. Fishermen and farmers are interested in knowing land and water temperatures to protect their crops against frost or increase their catch from the sea. Using color-digitized techniques, the gray-shaded thermal images can be converted to color for easier identification of desired information. The main water vapour channel at 6. Climatology[ edit ] In the field of climatology, atmospheric infrared radiation is monitored to detect trends in

the energy exchange between the earth and the atmosphere. It is one of the primary parameters studied in research into global warming , together with solar radiation. Schematic of the greenhouse effect A pyrgeometer is utilized in this field of research to perform continuous outdoor measurements. This is a broadband infrared radiometer with sensitivity for infrared radiation between approximately 4. Infrared astronomy and far-infrared astronomy Beta Pictoris with its planet Beta Pictoris b, the light-blue dot off-center, as seen in infrared. It combines two images, the inner disc is at 3. Astronomers observe objects in the infrared portion of the electromagnetic spectrum using optical components, including mirrors, lenses and solid state digital detectors. For this reason it is classified as part of optical astronomy. To form an image, the components of an infrared telescope need to be carefully shielded from heat sources, and the detectors are chilled using liquid helium. The sensitivity of Earth-based infrared telescopes is significantly limited by water vapor in the atmosphere, which absorbs a portion of the infrared radiation arriving from space outside of selected atmospheric windows. This limitation can be partially alleviated by placing the telescope observatory at a high altitude, or by carrying the telescope aloft with a balloon or an aircraft. Space telescopes do not suffer from this handicap, and so outer space is considered the ideal location for infrared astronomy. The infrared portion of the spectrum has several useful benefits for astronomers. Cold, dark molecular clouds of gas and dust in our galaxy will glow with radiated heat as they are irradiated by imbedded stars. Infrared can also be used to detect protostars before they begin to emit visible light. Stars emit a smaller portion of their energy in the infrared spectrum, so nearby cool objects such as planets can be more readily detected. In the visible light spectrum, the glare from the star will drown out the reflected light from a planet. Infrared light is also useful for observing the cores of active galaxies , which are often cloaked in gas and dust. Distant galaxies with a high redshift will have the peak portion of their spectrum shifted toward longer wavelengths, so they are more readily observed in the infrared. It works by collecting an additional infrared channel from the scan at the same position and resolution as the three visible color channels red, green, and blue. The infrared channel, in combination with the other channels, is used to detect the location of scratches and dust. Once located, those defects can be corrected by scaling or replaced by inpainting. Art conservators are looking to see whether the visible layers of paint differ from the underdrawing or layers in between â€” such alterations are called pentimenti when made by the original artist. This is very useful information in deciding whether a painting is the prime version by the original artist or a copy, and whether it has been altered by over-enthusiastic restoration work. In general, the more pentimenti the more likely a painting is to be the prime version. It also gives useful insights into working practices. Each of his feet was underdrawn in one position, painted in another, and then overpainted in a third. These alterations are seen in infrared reflectograms. Similar uses of infrared are made by conservators and scientists on various types of objects, especially very old written documents such as the Dead Sea Scrolls , the Roman works in the Villa of the Papyri , and the Silk Road texts found in the Dunhuang Caves. Infrared sensing in snakes Thermographic image of a snake eating a mouse The pit viper has a pair of infrared sensory pits on its head. There is uncertainty regarding the exact thermal sensitivity of this biological infrared detection system. There is some work relating to anti-herpes virus treatment. Since the radiation is invisible, special IR-proof goggles must be worn in such places. Please help improve this article by adding citations to reliable sources. July Learn how and when to remove this template message The discovery of infrared radiation is ascribed to William Herschel , the astronomer , in the early 19th century. Herschel published his results in before the Royal Society of London. Herschel used a prism to refract light from the sun and detected the infrared, beyond the red part of the spectrum, through an increase in the temperature recorded on a thermometer. He was surprised at the result and called them "Calorific Rays".

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