Optical Metrology in Manufacturing

Latest technological advances open new opportunities with the right approach and the right equipment

BACKGROUND

Optical Metrology is a crucial tool used in industrial automation to increase productivity and quality levels via 100% inspection rates. Thanks to the latest leaps towards higher resolution and frame rates of image sensors accompanied by mature high-bandwidth camera interfaces like USB 3.0, optical metrology today allows for very fast analysis of 2D and 3D objects with unprecedented accuracy. This solution sheet provides considerations and reasoning on how to select the right key system components, especially cameras for different metrology applications.

SYSTEM PARAMETERS

The designs of Optical Metrology systems vary widely, depending on the application. However, lens, image sensor, and camera play key roles in all classic systems. Each component influences the performance of the system in quantitative and qualitative aspects.

Accuracy: Quantitative parameters are the measurement accuracy in the 2D image plane and in the third dimension, the depth, as well as the time required to capture and measure an object. Furthermore, one needs to take into account whether the target object is stationary or in motion (e.g. on a conveyor belt or handled by a robot). A qualitative parameter is the reliability of a measurement system. Despite varying environmental conditions, like temperature and lighting, measurement results shall be consistent and reproducible. Also the failure rate of measurement operations itself, e.g. due to issues in camera electronics or software is critical.

Global Shutter Sensor: Regarding image sensor resolution, it is obvious that the number of pixels is directly proportional to the spatial resolution and accurate representation of the object. Unless one can ensure that the object and the camera are absolutely still during the exposure time of the sensor, a global shutter sensor is mandatory so that all pixels are captured and read out at the same time after the exposure is finished.

With global shutter technology, no distortion is

introduced by movements during the exposure. The standard approach of classic industrial camera design is to take a good sensor with CCD or CMOS global shutter technology, add various image enhancement features and capture modes, and implement the camera in a low-cost design.

Precise Results: Camera selection is often based on resolution, frame rate, minimum exposure time, and price criteria, which works well for applications in general inspection and presence detection like food and print quality verification or normal factory automation. New innovations in image sensor designs and data interfaces are enabling camera manufacturers to produce cameras with increased resolutions coupled with higher frame rates. These innovations are increasing the range of applications that can leverage the new technologies for more precise inspection results.

APPLICATIONS AND REQUIREMENTS

High Frame Rates: In 2D Geometrical Metrology, a single camera is mounted orthogonally to the surface that shall be captured. When it comes to the analysis of the dimension, e.g., of flat metal sheets after cutting, milling, drilling and further processing steps, the sheets are moving on a conveyor. On top typical range for the intended accuracy is 0.1mm. In such scenarios, the production output is often cameras. Even more critical, all frames from up to 4 limited by the inspection capacities rather than by the production machines itself. Thus, cameras should be able to capture and measure the objects when they are moving at high speed (e.g. 2 meters per second). This requires the camera to be very sensitive in order to allow for short exposure times. Furthermore, since multiple objects per second are passing by the camera, a high frame rate needs to interface with high bandwidth is required.

be the industry standard before USB 3.0 became common in consumer and industrial PCs. While USB 3.0 is considered to be wide spread and mature, the good pixels in the surrounding of the defects.



careful design of the camera chipset, the camera firmware, image buffers inside the camera, the software driver, as well as the selection of the host chipset are crucial to make sure that all frames captured by the camera are actually delivered and retained by the PC; otherwise, parts may slip through the inspection process. This is a core aspect of the "qualitative performance" parameters of a metrology system mentioned above.

Zero Frame Loss: Zero frame loss is critical when moving objects are measured by several cameras in order to obtain a 3D model. For a correct 3D representation, all cameras need to capture an image of the object at the same point in time. This of the belt, a metrology camera is mounted and a can be accomplished via external trigger signals linked to the general purpose I/O port of the industrial cameras have to be delivered reliably to a single host PC where all images are then combined. If a frame from just one camera is lost, the whole measurement operation will fail.

Superior Image Quality: Beyond a reliable video and control interface, metrology sets major requirements on the image quality of a camera. The advantages of larger sensor resolutions of latest CCD be delivered to the processing unit. Thus, a camera and global shutter CMOS image sensors come with several challenges since no component is perfect. Qualitative Performance: CameraLink used to Often these sensors come with clusters of defective pixels. The correction of these defects is done in the manufacturing process by interpolating between the

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Since in metrology, the sharp edges of objects need to be detected and measured, large clusters of defect pixels reduce the consistently achievable accuracy. Most high-end camera manufacturers grade incoming sensors and reserve the best devices with few defective pixels for cameras that go into metrology applications.

Sensor Tap-Balancing: Another challenge of high resolution sensors and a major differentiator is the quality of the sensor tap-balancing. High resolution CCD sensors are divided in taps in order to allow for a faster readout. However, each tap has its own processing pipeline with analog-digital conversion and amplifiers. Again, each of these components is unique, which usually results in different levels of brightness between the 2 or even 4 taps. The differences in brightness lead to artificial edges in the image and can mislead measurement algorithms.

The balancing of the taps is done in the FPGA of the camera and requires the calibration of numerous parameters during manufacturing of the camera. Theses parameters depend on exposure time, gain and sensor temperature. Only with an elaborate calibration method can cameras deliver optimal image quality with uniformity and linearity under most operation conditions.

Reliability: In metrology systems for industrial automation and quality inspection, higher camera resolution increases accuracy, high sensitivity allows for faster travel of the inspected objects and faster frame rates increase the throughput. The latest sensor technologies and interface standards allow metrology systems to meet these expectations. Aside from these improvements, the real differentiating factors for metrology cameras are the image quality, mechanical stability and reliability of the sensors, the read-out electronics, the camera interface, and software drivers. These are some of the critical aspects to be considered when it comes to the selection of system components for optical metrology applications. Most of them are not covered on datasheets and price lists but need the involvement of a trusted expert in the field so that the right components are selected to meet the application requirements.



Image 1: Quad Tap Mismatch



Image 2: Quad Tap Matched

FEATURED CAMERA

INFINITY3-3URM

The INFINITY3-3URM is a high-speed, high sensitivity, research-grade monochrome camera with a resolution of 2.8 megapixel. The research-grade designation is a testament to the low noise electronics, high-grade components and unique thermal management techniques.

This camera is well suited for applications such as metrology, where extreme sensitivity, increased resolution and high speed are required. It builds on leading edge ExView HAD II Quad Tap sensor technology to deliver high quality imaging and high sensitivity in a compact camera rich in features. Lumenera's advanced tap matching process ensures seamless images across large temperature and gain ranges.

ORDERING OPTIONS:

INFINITYY3-3URC 2.8 Megapixel, color CCD, uncooled USB 3.0 camera INFINITY3-3URM 2.8 Megapixel, monochrome CCD, uncooled USB 3.0 camera

LUMENERA MICROSCOPY CAMERAS:

To view Lumenera's full INFINITY product line, visit us online: www.lumenera.com/products/microscopy-cameras



Highlights

- 53 fps at full resolution, 66 fps at full HD
- 2.8 megapixel uncooled CCD sensor
- ROI support for even higher frame rates
- Selectable 8 or 14-bit pixel data
- Full image analysis software included
- High sensitivity and dynamic range
- Plug and Play USB 3.0
- Sony EXview HAD II Quad Tap Performance



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