Smart Line Scan Measurement Systems

All you need for image acquisition and analysis

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Fig. 1 The Smart Control Box SK91USB3-SC100 is the heart of a smart line scan camera system. Connected to a USB 3.0 line scan camera it provides standalone image acquisition and analysis capabilities to downstream PLC devices or process control computers.

Current industrial machine vision applications mostly rely on PC-based image processing. Smart camera systems, which incorporate an image sensor and computing capabilities, were initially restricted to very simple tasks like barcode reading and interpretation. But as the computing capabilities of embedded systems increased, smart cameras are now able to handle a wide range of applications.

Especially when machine vision has to be integrated into an existing automation system, this is often more easily done with a smart camera solution than with a PC-based vision system. Smart camera solutions are smaller, they generally generate less heat, and, therefore, can be a better choice if localized sorting tasks pass / fail decision making or process control is requested.

Line scan cameras

Unlike consumer cameras which use a two-dimensional matrix of photosensitive pixels for image acquisition, line scan cameras have a single sensor line. They are used for one-dimensional measurements, e.g. to determine the width of a gap or the diameter of a cable, or for two-dimensional image acquisition of moving objects.

Many industrial processes require the products to be moved from one production stage to the next. With a matrix camera, image acquisition of moving objects needs much effort. The results are often better if the moving object is scanned by a line scan camera.

High optical resolution, high speed, synchronization of individual line scans, and simplified illumination requirements are other advantages of line scan cameras.

A modular smart line scan camera system based on ARM-platforms

Most smart line scan systems incorporate the processor into the camera housing. While this all-in-one solution has its advantages, it tends to require rather large camera housings. But often space is limited and it is then more convenient to have a small camera combined with a small separate computing unit. This is also more flexible, because camera and computing unit can be exchanged independently.

This prompted Schäfter+Kirchhoff to develop the Smart Control Box which connects to any of the monochrome series USB 3.0 line scan cameras [1] via a rugged industrial-grade interface. To-

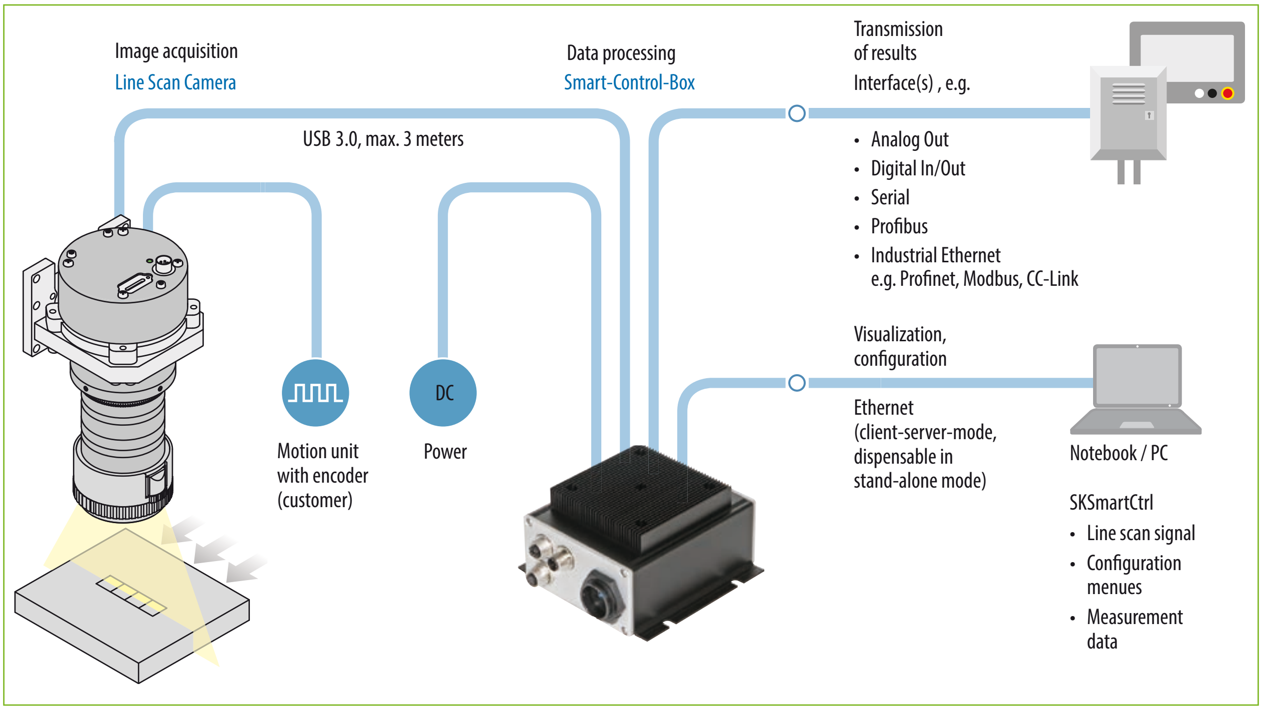

Fig. 2 System components of a smart line scan measurement system. The line scan camera uses the encoder signals of the motion unit for synchronization. The line scans are transferred to the Smart Control Box via a USB 3.0 connection for evaluation. The Smart Control Box operates either in client-server mode, or stand-alone. In stand-alone mode, only a temporary connection to a control computer is required for configuration and set up.

gether they perform as autonomous measuring units directly attached to the machine or in close contact to the object. They can measure widths, diameters, distances, edge or peak positions and many more values. Good-bad decisions are made according to adjustable tolerances. Measurement results and decisions are transferred via standard industrial interfaces to a higher-level control unit like a PLC or a process control computer.

The heart of the Smart Control Box is a high-performing ARM 8-core 64-bit processor well suited for signal and image processing. The rugged and compact box has an IP65 rating for easy integration in rough environments.

The box is configured via its LAN connection. Thereafter, it can operate stand-alone or in client-server mode, where system commands and requests are sent from a client computer via Ethernet and the measurement results are returned to the client accordingly. For operation a comfortable MS Windows user interface is available. To facilitate the setup and adjustment of the sensor the server can provide complete line signals to the client in real time. This is very helpful when checking the correct alignment of the camera with the measurement object and with the illumination used.

Company

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Schäfter+Kirchhoff has accumulated substantial experience in the development of opto-mechanical and opto-electronic systems for use in research, aviation, and in space, as well as for demanding medical and industrial applications. Schäfter+Kirchhoff designs and manufactures their line scan camera systems, laser sources, beam-shaping optics, and fiber-optic components, including laser beam couplers, fiber collimators, and fiber port clusters for customers worldwide.

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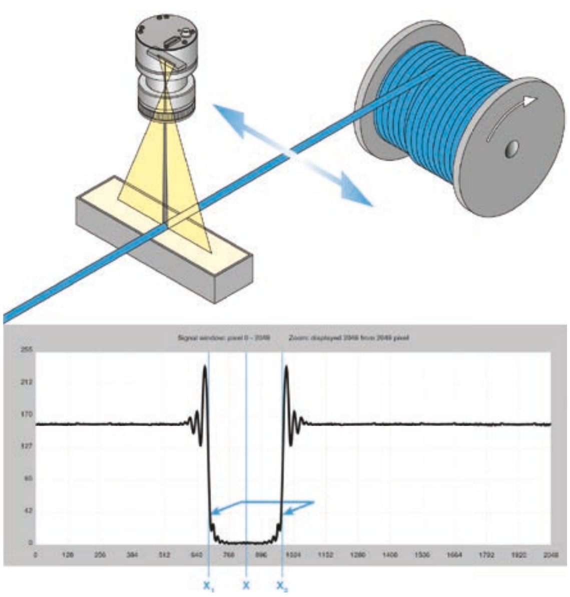
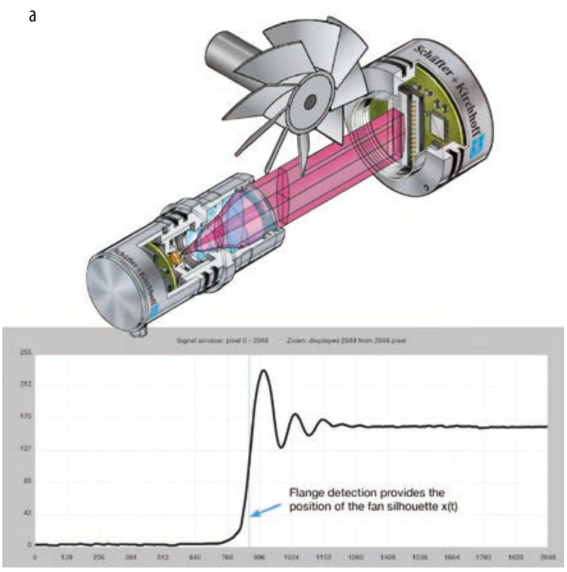


Fig. 3 Spooling inspection of a reel. The light is blocked by the cable, creating a shadow on the sensor. The position of the cable is given by the edges of the shadow. The position measurement is used to check for the correct lateral pendulum movement during spooling.

a



b

Fig. 4a Measuring the concentric run out of a fan: The collimated laser beam directed onto the line scan camera is tangentially interrupted by the rotating fan, creating a shadow edge in the line signal. The concentricity of the rotation is calculated from the variation of the edge position.
Fig. 4b The Flatbeam laser source series 91CM-M60 generate a beam with minimum divergence (max. 0.02 mrad). The measurement accuracy is increased due to their reduced power noise and speckle contrast.

In client-server mode, the maximum distance between client and server is one hundred meters. Up to eight smart line scan camera systems can be handled and controlled by a single client.

In stand-alone mode, output from the smart line scan system is also possible via Profibus, RS232, digital I/O or two analog outputs with 16 bit resolution (Fig. 2).

The line scan camera can be operated in free-run mode, where it takes line scans at a user-defined fixed frequency. In case of a constant movement velocity, this is sufficient. For varying velocities, the motion unit has to be equipped with an encoder. The encoder signals are evaluated by the camera itself, which has inputs for both line and frame synchronization. Optionally, the external trigger frequency is divided down by the internal programmable frequency divider of the camera.

Application examples

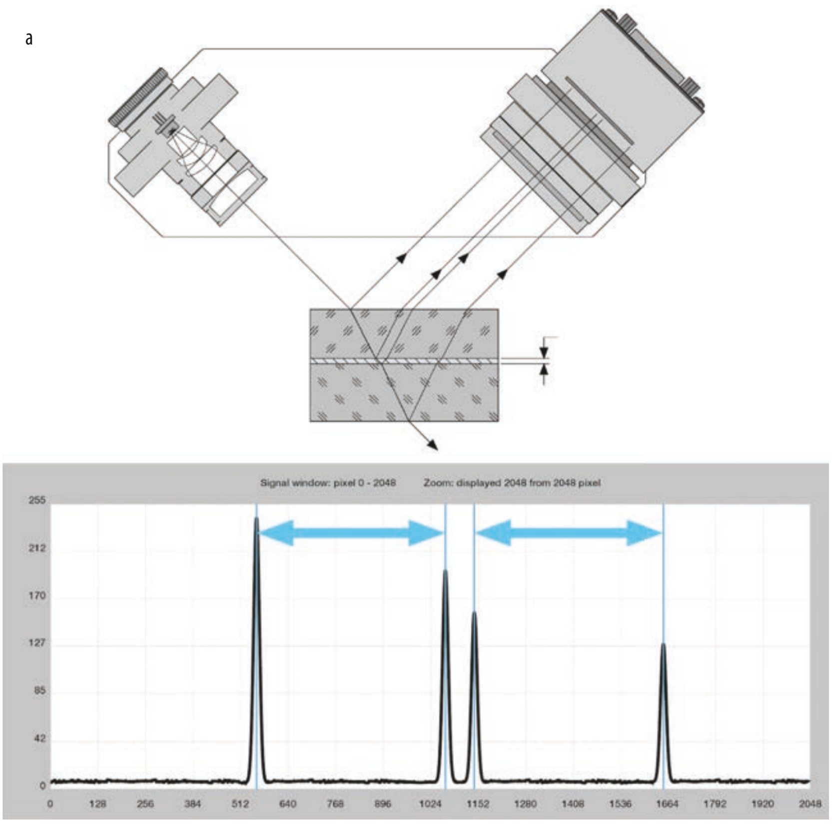
Especially in stand-alone mode, smart line scan camera systems are predestined for one-dimensional measurement tasks, where they determine the position and width of an object, or the position of an edge or a signal peak. This results in a continuous stream of measurement results which can be directed directly to a programmable logic controller (PLC) or a process controlling computer.

Examples of one-dimensional measurements are shown in Figs. 3 – 5.

Fig. 3 shows how the position of a cable is determined during spooling. The cable is placed in front of a uniform LED backlight illumination. It is imaged onto the line sensor by a camera lens. It appears as a dark object in the line signal. The result returned by the smart camera system is the position of the center of the dark object.

Fig. 4 shows an application where a wide and collimated laser beam is directed onto the line sensor. Objects placed into the beam, like the fan wings in Fig. 4, then create a characteristic diffraction pattern, the so-called Fresnel diffraction pattern, which is used for accurate measurement of the rotation concentricity.

a



b

Fig. 5a Detecting the reflex peaks from optical boundary layers for measuring glass thickness. The light is blocked by the cable, creating a shadow on the sensor. The position of the cable is given by the edges of the shadow. The position measurement is used to check for the correct lateral pendulum movement during spooling.
Fig. 5b The semi-telecentric laser lines series 13LT generate a laser beam which is collimated in one and focussed in the other direction. This kind of lasers is often used in reflex sensors.

Schäfter+Kirchhoff offers special low-noise and low-speckle laser sources for this task. An example is the 91CM-M90 series of Flatbeam lasers for measurement ranges up to 32 mm. These lasers have a typical divergence less than 0.02 mrad, i.e., their deviation from parallelism is about 0.001 degrees (Fig. 4b).

The last example shown here (Fig. 5) also uses the combination of a line scan camera and a laser beam, without any camera lens. But here, the laser is not collimated but focussed onto the sensor line after it has been reflected by several layers of glass. Each layer interface, including the final glass-air interface, causes a reflex. These reflexes appear as peaks in the line signal. The Smart Control Box calculates the layer thicknesses from the peak distances.

For measurement tasks like this it is appropriate to use a line laser rather than a focussed spot, with the laser line oriented perpendicular to the sensor line. Even a small tilt of the glass layers perpendicular to the plane of measurement would otherwise cause the spot to fall off the sensor.

The laser series 13LTM is offered by Schäfter+Kirchhoff for these kind of reflex measurements (Fig. 5b). These are semi-telecentric laser lines with extended depth of focus. Semi-telecentric means that the beam is focused in one direction, and collimated in the other. This together with the extended depth of focus ensures that all reflexes are focused on the sensor with sufficient signal amplitude, despite their differences in optical path length.

Summary and conclusions

The use of a smart line scan camera system should be considered especially when machine vision has to be integrated into an existing application. A modular system consisting of a line scan camera and the Smart Control Box presented in this article has advantages regarding space requirements and offers greater flexibility compared with an all-in-one solution. Smart line scan camera systems are predestined for continuous one-dimensional measurements, providing a continuous stream of measuring results. Three examples of such measuring tasks are presented in the article.

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[1] Table, listing the charcteristics of Schäfter+Kirchhoff's monochrome series USB 3.0 line scan cameras which connect to the Smart Control Box http://www.SuKHamburg.com/table

Authors

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Ulrich Oechsner studied physics before completing his doctoral thesis at the University of Hamburg. After research in the fields of electrophysiology and physiological optics, he joined Schäfter+Kirchhoff in 2000 as senior optical designer. He became managing director in 2015.

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