WHITE PAPER

Optimal Vision Using Cameras for Intelligent Transportation Systems

Intelligent Transportation Systems (ITS) require intelligent vision solutions. Modern camera technologies can help in a multitude of traffic situations – from monitoring traffic flows to toll collection, from identifying violations to enforcement. This white paper describes how industrial (machine vision) cameras and network (IP) cameras give intelligent transportation systems the power of vision.

Traffic volumes are rising constantly around the world, driving the development of a vast range of different mobility options. As transportation systems grow increasingly complex, they must also meet demands for increased speed and safety. Systems for organizing and monitoring traffic flows must deliver efficiency coupled with the lowest possible personnel overhead. Cameras are the key factor in satisfying these requirements. Today's high-performance cameras are the "optimized eye" for Intelligent Transportation Systems (ITS), supplying high-resolution images even under challenging conditions. Cameras give modern transportation systems the power of vision – from identifying traffic violations to traffic monitoring and toll collection systems. The camera technologies used for these purposes fall into two groups: industrial cameras (machine vision) and network cameras (IP).

Two Systems and Always the Right Solution: Industrial and Network Cameras

Because they contribute different functional strengths, both network cameras and industrial cameras have a role in intelligent transportation systems. Industrial cameras were originally designed for use in machine vision applications, such as merchandise inspections and process controlling. Their images are sent directly in uncompressed form to a PC, meaning that a relatively large volume of data must be processed. The benefit of this methodology is that no image data is lost through compression. Network cameras, by contrast, compress the images they record. This has the benefit that the data volumes are significantly reduced, allowing the data to be stored in the camera and made available to as many users as desired via the network. Network cameras are frequently used for video surveillance.

Both camera technologies offer different functions beyond their original areas of application, making them compatible with a wide variety of transportation projects. They can: monitor speeding drivers, illegal lane changes and red light violations, identify and check vehicles that must pay tolls, and monitor traffic flows, streets, tunnels or weather conditions, as well as detect accidents and other traffic incidents.

What Are the Key Aspects of Intelligent Transportation Systems?

Real-time Capability

Real-time capability in cameras is especially relevant for applications where speed is crucial, such as monitoring driving speeds or toll systems, or when the camera must synchronize its exposure settings with the images being collected. For these applications, the camera is in waiting position and starts gathering images when it receives either an external trigger signal or one via the network. This trigger signal can be set off, for example, when a contact threshold is tripped or a light barrier or radar device is triggered. The key factor for a high-quality image is the lowest possible latency, which refers to the delay between the receipt of the trigger signal and the start of collection of images; industrial cameras in particular are designed for this characteristic. Some network cameras, including the IP cameras from Basler, also feature a trigger mode. In this case the key question when selecting a system is how much information the image must contain. Will the compressed image from a network camera (MJPEG/MPEG-4/H.264), which requires less bandwidth, be sufficient, or is the detail-rich image information (BMP) as delivered by an industrial camera necessary?

Sequencer Acquisition Mode

One frequent issue for documenting speeding and red light violations as well as the identification of vehicles by toll systems is changing light conditions and strong reflections on license plates, which often contrast sharply with the dark section of the images where the driver can be seen. The use of a sequencer acquisition mode can solve this problem. The camera shoots a series of images at different settings in just fractions of a second. These are configured to various exposure settings and/or excerpts from the image, the so-called Area of Interest (AOI). In the latter case, one specific area of the sensor is selected for exposure alongside the overall image. This area might, for example, be set to the height of the license plate on vehicles. This has the benefit that less data needs to be transmitted, which means the sensors can work much more quickly.

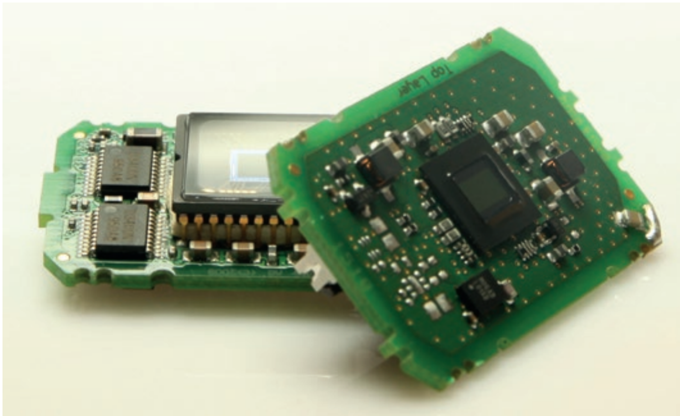
Image-No.	Expo.	Gain	AOI Size	AOI Pos	...
1	2ms	10	1000 x 800	0 x 0	...
2	12ms	55	250 x 250	0 x 333	...
...	...	...	...	...	...
64	2ms	55	100 x 500	444 x 555	...

Example serial image sequence in the Sequencer Acquisition Mode (SAM): unlike the single image acquisition mode, the SAM executes a series of images in which every single one of a maximum of 64 images could follow a different set of parameters (such as gain, AOI or exposure time).

Sensors

Several factors play a role when selecting the sensors for intelligent traffic systems. The first is the resolution of the sensor; it determines the ease of identifying details from a given excerpt from the image. If, as with toll collection systems and speed measurement devices, only the license plates for individual vehicles, or the flow of traffic into a tunnel must be recorded, then a relatively low resolution (VGA to 2 megapixel) is sufficient. If, however, a toll collection system or a traffic violation monitoring system must record several lanes of traffic at once, then a high-resolution sensor with a high pixel count would be required (e.g. 2 MP for two lanes, 5 MP for three lanes).

Another criterion for selecting a sensor is the technology being used. The two major technology types are CCD and CMOS sensors, which are differentiated by the processes used to produce them. CCD sensors are more expensive to produce than CMOS sensors and have long been used in digital cameras. They are known for large pixel dimensions that can absorb more light, exhibit less dark noise and feature a so-called global shutter. This last feature controls the exposure of the sensor by opening all pixels at once and closing them again simultaneously after a specific exposure time. CMOS sensors, originally produced for use in memory chip manufacturing and significantly cheaper to produce than CCD sensors, have so far only rarely had large pixels. They control exposure of the pixels primarily through a rolling shutter, which opens the pixels one row after another and then closes them again after a specific delay. This creates a disadvantage when moving objects are being recorded from the side, since they will be recorded with distortion. Newer generations of this sensor technology, including those from CMOSIS, now feature large pixel sizes and global shutter technology.



CMOS and CCD Sensors: identical task, different technology

The third selection criterion for sensors is the pixel size. It is decisive for determining how much light a camera can record, since the larger the pixel, the more light it can absorb and thus the greater its sensitivity in low-light situations. If a traffic system must work in twilight and foggy conditions, for example, and weaker supplemental lighting sources are in place, then a sensor with larger pixels capable of generating a strong signal even from little light should be used. In this case CCD sensors, with pixels roughly double the size of CMOS sensors (2 to 8 µm vs. 2 µm) are the better choice, as they present a larger surface space and thus four times the ability to gather photons.

High Sensitivity

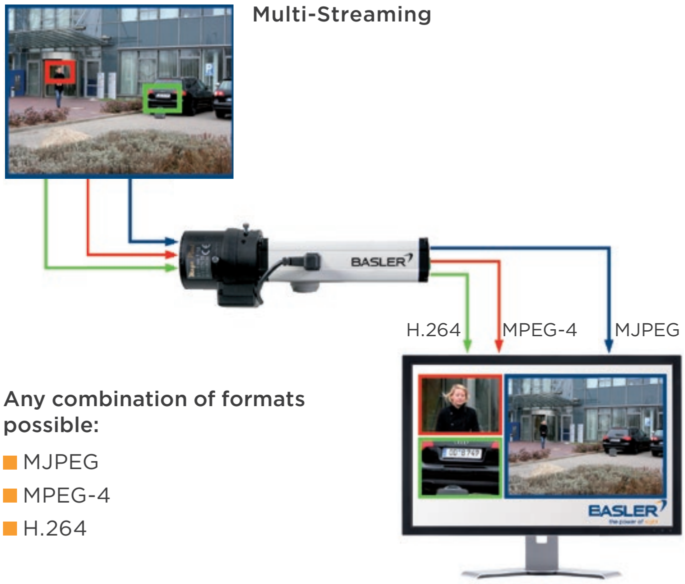
Applications that involve recording fast-moving objects such as cars require a high-sensitivity sensor, which is capable of working with extremely short exposure times. This type of sensor can generate a good signal even in low light conditions by collecting as many photons as possible, which are then converted very efficiently into electrons and detected (quantum efficiency/QE). For this type of application, it's also important to have the lowest possible dark noise, meaning the lowest levels of disruption during the gathering process, a feature usually associated with CCD sensors. Low dark noise values ensure that image quality remains good even in poor lighting conditions without an external flash, or when capturing fast-driving vehicles that are moving during the exposure window. The newer generation of CMOS sensors stacks up relatively well with the significantly more expensive CCD sensors in terms of sensitivity.

Compression Processes

Compression processes are important if, for example, multi-camera systems or long-term storage of the image data dictate that bandwidth and storage space be maximized. Network cameras handle this effortlessly, since their MJPEG, MPEG-4 and H.264 compression technology allows them to transmit images at a quality comparable with industrial cameras, but at a significantly reduced data volume (1/40 to 1/100 the data volumes). This compression process, while particularly well suited to traffic flow monitoring and the detection of traffic accidents and other traffic incidents (incident detection systems), can also be used in combination with multi-streaming.

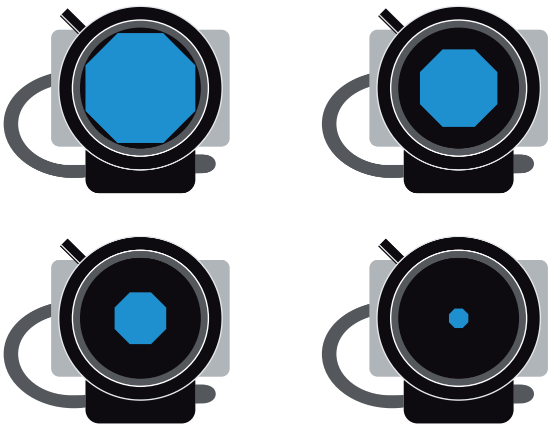
Multi-Streaming

Traffic monitoring often requires observation of various aspects of a scene, as well as the ability to document the recording. For this application, an industrial camera solution would require multiple cameras generating an enormous volume of data. Thanks to their various compression processes (MJPEG/MPEG-4/H.264), network cameras can capture multiple video streams at once for different Areas of Interest (AOIs), each in the necessary optimal image quality. This makes it possible, for example, to record a general overview of a monitored area in one stream, while another stream records a specific vehicle at a correspondingly high frame rate and low compression. At the same time, yet another stream can record at a relatively low frame rate and strong compression levels, to achieve a low data volume that makes it suitable for long-term archiving. This setup keeps data volumes as low as possible, saving on both storage space and bandwidth.



DC Iris

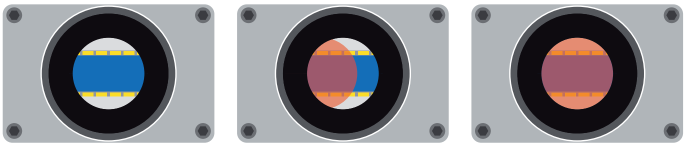
One very helpful function for applications like traffic monitoring is the DC iris, featured in all network cameras from Basler. It adjusts the camera's iris automatically — using not just exposure settings but exposure time and amplification factor (gain) as well — to fit the lighting conditions, allowing for more flexible reaction to the lighting conditions that occur in traffic-related applications. The DC iris lens involves a motor capable of opening or closing the iris, and a small cable connected to the camera, whereby a set of intelligent analytical electronics sends out the control signal based on the ambient light levels. If low light is sensed, the iris opens completely; if strong light reaches the sensor, such as from intense sunlight, the iris opening is reduced to prevent the sensor from becoming overexposed.



DC iris: adjusts the camera's iris automatically depending on changing light conditions.

Day/Night Functionality

The day/night functionality of network cameras is helpful for traffic monitoring, since it delivers high-contrast images even in low-light conditions. Network cameras with day/night functionality include an automatically-pivoting infrared (IR)-blocking filter that is positioned in front of the sensor when in day mode, and away from the sensor when in night mode. The filter ensures that the camera correctly depicts colors during daylight while allowing for high-quality black-and-white shots using infrared illumination at night.



Day/night functionality: an automatically-pivoting IR-blocking filter provides for accurate 24/7-color and black/white-rendering.

Cable Length

Another aspect when selecting between camera technologies is the cable length. This is rarely an issue for IP cameras (Ethernet port), since the maximum cable length of 100 m (109 yds.) offers plenty of room for deployment. When selecting an industrial camera technology, however, the choice (USB, GigE, Camera Link, etc.) depends significantly on the technical setup. A distant processing unit (such as a PC on the edge of the street) requires a longer cable, and lends itself to GigE. A compact, integrated solution with the camera close to the processing unit (such as an embedded PC) can frequently make do with a short cable, allowing for any number of different interface technologies. When cost efficiency is a priority, however, GigE is usually the first choice.

Cameras for all Situations

Basler cameras are outstandingly well suited for applications in the field of intelligent transportation systems, since they always deliver high image quality, a large dynamic range, high levels of sensitivity, and an outstanding price/performance ratio; they also work with cables up to 100 m (109 yds).

We recommend the following Basler camera series for various ITS applications:

For documentation of traffic violations, including speed traps, red light violations and monitoring of illegal lane changes, cameras with real-time compatibility and sequencer acquisition mode are the ideal choice. The sensors must offer at least 1.4 to 5 MP of resolution and high levels of sensitivity. For this reason we recommend the ace, aviator, pilot and scout from Basler. They deliver uncompressed images as required in cases such as documentation of traffic violations. Basler network cameras support video streaming.

For toll collection systems, including free-flow tolling and monitoring of toll evasion, the high speeds of the vehicles require real-time-compatible cameras, as well as high resolution and high sensitivity sensors. For this reason the ace, aviator, pilot and scout from Basler are particularly good choices here.

Cameras for use in traffic monitoring, such as for monitoring the flow of traffic in tunnels and on streets, and for monitoring weather conditions and detecting accidents and other traffic incidents, should have DC iris control and a day/night functionality. In particular, if limited bandwidth is available and/or the monitoring data is to be stored, or transmitted to far-away command centers, a Basler network camera is the best choice.

Author

Enzio Schneider is Basler's Product Line Manager ITS, and manages the vertical ITS market covering all kinds of traffic applications. He is a graduate geophysicist and joined Basler in 2004 as part of the former flat panel display business for Project Engineering and Sales. In his current role, Enzio manages Basler's ITS customers in the broad camera portfolio, and in upcoming developments.

About Basler

Basler is a leading global manufacturer of digital cameras for industrial and video surveillance applications, medical devices, and traffic systems. Product designs are driven by industry requirements and offer easy integration, compact size, excellent image quality, and a very strong price/performance ratio. Founded in 1988, Basler has 25 years of experience in vision technologies and has designed and manufactured high quality digital cameras for 15 years. The company employs around 300 people at its headquarters in Ahrensburg, Germany, as well as at international subsidiaries and offices in the U.S., Singapore, Taiwan, and Korea.

Contact

Enzio Schneider – Product Line Manager ITS

Tel. +49 4102 463 346
Fax +49 4102 463 46346
E-Mail enzio.schneider@baslerweb.com

Basler AG
An der Strusbek 60-62
22926 Ahrensburg
Germany