Megapixel Cameras in Security Applications: Are They Ready For Prime Time?

This paper provides an overview of the benefits and limitations of current megapixel technology.

Introduction

Headlines in every security publication shout terms like "High Definition Video" and "Megapixel Cameras," followed by stories that claim greater detail and more coverage with fewer cameras. It's easy to see that the future of video surveillance belongs to higher definition cameras. However, as with most emerging technologies, the devil is in the detail, making it important to look at the story behind the latest video surveillance headlines. This paper will take a detailed look at the very real benefits gained by using high definition video as well as the potential drawbacks security system designers must be aware of.

Due to the limited amount of area that standard video cameras can cover while providing a sufficient level of detail, the current model for security system design relies on the use of large numbers of cameras.

Today's Standard

The role of video surveillance has changed dramatically over its short history. CCTV security started with one or two fixed cameras in critical areas watched by a security officer. The advent of moveable cameras expanded the possible area of coverage that could be viewed. Recording added a new twist, allowing many more cameras to be "viewed" after the fact. And, as cameras became increasingly affordable, recorded video surveillance systems proliferated.

The current design model for most small to medium size systems is the deployment of many cameras that are unattended but constantly recording. Typically, these systems are not used to identify a crime in progress, but they are valuable in providing "forensic" evidence after the fact, providing the ability to retrieve video corresponding to a given time or event. Newer tools such as integrated video analytics have helped to make the process of searching the recorded video much more efficient, while better compression methods have helped to reduce necessary storage space. However, until now, with the introduction of higher resolution video, the need for large numbers of cameras has remained constant, as standard VGA resolution cameras are limited in the amount of area they can cover while providing a sufficient level of recorded detail. Higher resolution cameras offer the possibility of lowering the camera count.

The security world is pointing to the transition we've witnessed in consumer camera technology as a model for reshaping the parameters of security video technology.

What's Taken So Long?

The much faster adaptation of Megapixel technology within consumer point-and-shoot cameras as compared to security video cameras may be attributed to the far more simple design of low-cost still digital cameras as well as to a much greater overall market demand.

High quality photography is at everyone's fingertips. Low-cost digital cameras are everywhere, even integrated into cell phones and music players, and without the need for film, the cost of a digital photo has been reduced to the insignificant price of storage. This low cost, high quality and convenience causes much confusion in the video surveillance field. Security practitioners are often asked, "Why is my security camera lower in quality than my cell phone camera?" It's a good question with a not-so-simple answer.

Comparing digital consumer cameras to security video cameras is not an apples-to-apples comparison. These devices are different in many fundamental ways. Digital still cameras are low-use devices. They take one image at a time and record it to internal memory, often requiring a several second delay between taking each photo. These cameras make use of inexpensive sensors and mechanical shutters to control exposure and time. By contrast, surveillance cameras must be on continuous duty, requiring high-speed electronic shutters and the ability to transmit images to a remote location. These expensive design features, combined with the need for a highly reliable power supply and a long expected time-to-failure, all contribute to making video surveillance cameras a far different animal than your simple, hand-held "point-and shoot" device.

Compounding the situation is the fact that the market for video surveillance cameras is dwarfed by the market for cell phones and consumer-grade digital cameras. When one considers the much higher cost and complexity of surveillance cameras, combined with the economies-of-scale benefiting the consumer electronics market, it is not surprising that higher resolution technology has been embraced by digital camera manufacturers at a much quicker pace. Fortunately, the security market has, at last, begun its own transition to the newer technology, and higher resolution cameras are now readily available.

However, before making the decision to incorporate higher resolution cameras into your own security installations, it is important to understand the technology. While these cameras can deliver many tangible benefits, there are also some inherent drawbacks that must be considered. These cameras are terrific when used appropriately but are not the best choices for every situation.

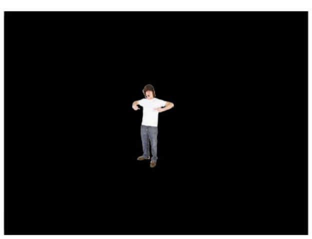
A New Technology Brings New Thinking

Megapixel cameras offer a way to increase the amount of detail captured within an image without sacrificing the area that the camera can cover. This redefines the equation used to determine how many cameras are required to provide sufficient surveillance coverage.

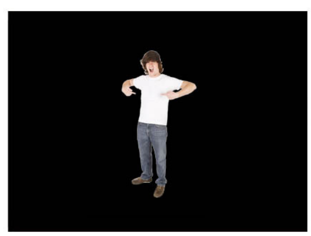
In planning a system, security designers are trained to think about what a camera will "see" and whether that view will satisfy the pre-established goals or objectives for that camera. These are typically defined as one of three possibilities: Detection, Recognition or Identification. Placement of the camera and focal length of the lens must be carefully calibrated to ensure that the camera does, in fact, "see" a level of detail that supports the intended goal.

The following example demonstrates how these objectives are translated into a real application using today's most common technology, VGA-quality cameras and varifocal lenses.

EXAMPLE: *A car park measures 100 feet wide x 175 feet deep and is located fifty feet away from the camera. The camera is focused on a 6 foot tall man in the middle of the car park. Using a lens calculator, the pictures below define what type of lenses would be needed to achieve the three objectives of video surveillance, detection, recognition and identification.*



Purpose: Detection
Object Distance: 131 ft.
Lens Focal Length: 6.8 mm



Purpose: Recognition
Object Distance: 131 ft.
Lens Focal Length: 34 mm

Purpose: Identification
Object Distance: 131 ft.
Lens Focal Length: 81 mm

As shown in the first image, a camera covering an area approximately 20 feet wide is capable of showing the man in the car park at a size and level of detail that is sufficient for providing "detection." Five cameras would be necessary in order to provide "detection" surveillance of the entire car park. But for recognition and identification, *many more cameras would be required. In fact, providing an "identification" level of coverage of the entire car park would be completely impractical, as it would require in excess of 700 cameras! But the fact is, using standard VGA cameras, there is no way to capture detail without getting close to your subject, and getting close sacrifices the area of coverage.*

Megapixel cameras reduce this constraint, offering a way to increase the picture quality and reduce the camera count. More pixels within the recorded image provide the ability to use electronic zoom to a greater extent before the visible detail within the image begins to break up or "pixelate." So, when using megapixel technology, the alternative to moving closer to the targeted object is to choose a camera that records the images with a higher number of megapixels.

Compared to standard video, a 1.3 megapixel camera records more than four times the number of pixels within each video frame.

The standard VGA resolution camera supplies a pixel array of 640 X 480 (307,200 pixels or about 0.3 megapixels.) An entry level SXGA megapixel camera for security delivers a resolution of 1280 X1024. The resulting pixel count is 1,310,720 pixels or 1.3 megapixels. That is over 4 times greater than standard VGA. A 3 megapixel camera, with a resolution of 2048 x 1536, contains 10 times more pixels than standard VGA. The disparity becomes even greater with higher megapixel count cameras.

Practical Applications for Megapixel Technology

There are many different ways to benefit from megapixel technology.

The most obvious is to take advantage of the higher resolution to capture a wider viewing area. In a facial recognition application, today's VGA cameras are capable of covering only a five foot field-of-view. By contrast, a 2-megapixel camera can cover a field of 11 feet and a 3-megapixel camera covers almost 15 feet. This means that in the previous car park example, seven 3-megapixel cameras could provide the level of coverage that has traditionally required 20 cameras.

A variation of this theme is to use a single megapixel camera to provide the function of multiple "virtual cameras." A megapixel image can be divided into several different sections, with each section focusing on a different area of interest. These sections can be enlarged electronically and then viewed by separate operators watching on separate monitors.

EXAMPLE: The adjacent image shows a three megapixel view of a station, captured from high above. The image is comprised of 2048 x 1536 pixels.

Complete View from One 3 Megapixel Camera

There are three areas of interest within this view that require monitoring; two banks of turnstiles and two ticket machines located between them. Using a traditional VGA PTZ camera with strong zoom capability, it would be possible for the three areas to be viewed and recorded by a single device. However, it would be unable to capture and record all three areas simultaneously and would require a live operator to determine which area requires attention at any given time. While zooming into one of the three areas, the other two would temporarily be left unmonitored.

An installation can use fewer megapixel cameras than would be required using standard video cameras and still capture the same level of detail. This includes the possibility of splitting the video from one megapixel camera into multiple "virtual cameras."

Using electronic zoom capabilities of the fixed megapixel camera, the three areas can each be focused on simultaneously as three "virtual cameras," with each image viewed and recorded separately.

Views from Virtual Cameras

The level of detail provided by each "virtual camera" is comparable to that offered by standard VGA cameras. This is because the megapixel camera is constantly capturing 2048 pixels across the width of the entire station image. Since a single bank of turnstiles, for example, takes up 1/3 the width of the entire image, then that section is comprised of 2048/3 pixels, or 682 pixels, across. This is similar to the 640 horizontal pixels displayed in a standard VGA image.

Another practical use for megapixel cameras involves taking advantage of models that feature a widescreen aspect ratio, which provide for more efficient viewing and storage. As the image on the following page shows, a traditional 4:3 aspect ratio provides much unneeded viewing of the distant skyscrapers, whereas the widescreen perspective uses a larger percentage of the screen for viewing the relevant car park vicinity.

The widescreen resolution of many megapixel cameras provides for more efficient viewing and storage.

Along the same lines, much valuable storage is wasted saving imagery of the skyscrapers when any future video playback will almost certainly be the result of investigating events that occurred at street level. Common widescreen megapixel resolutions include 1366 x 768 (1 megapixel), 1440 x 900 (1.3 megapixels) and 1600 x 900 (1.4 megapixels).

There are two advantages that pertain not just to megapixel cameras but to many digital IP cameras that record at VGA resolution.

Due to a "progressive scan" design, many digital IP and all megapixel cameras have the ability to display fast moving objects without any of the motion artifacts that are prevalent when using traditional cameras. Traditional video uses a series of odd and even lines (called interlacing) to display each video frame, resulting in the blurred or jagged edges of moving objects that do not line up exactly with the two sets of lines. By contrast, each megapixel frame is a complete image, eliminating this effect.

Many megapixel cameras, as well as lower-resolution IP cameras, offer the convenience of "Power over Ethernet" and a clearer view of moving objects due to "progressive scanning."

Finally, many IP cameras, including almost all megapixel cameras, use CMOS sensors that require a low operating current. This allows the cameras to be supported by a single Cat-6 cable that enables both the transfer of data to and from the network and also brings power to the camera. This one cable installation not only lowers installation cost but also allows the video to interface with a number of other technologies.

The availability of bidirectional digital transmission reduces the need for separate cables for PTZ-control of cameras, firmware updates and the use of other peripheral devices. These advantages are becoming increasingly apparent to system designers, IT management and end-users, as they reap the cost benefit of using standard switches, routers and existing network cabling for the installation process. Leveraging fibre and wireless solutions also add to the savings.

Considerations Beyond Resolution

The ability to cover more area with fewer cameras is a major advantage of megapixel cameras, but there are other issues that must be considered when planning the use of these cameras within a video security system.

The CMOS sensors used in megapixel cameras are not as light sensitive as CCD sensors but offer other benefits, such as low power consumption and faster processing speed.

As previously mentioned, most megapixel cameras use a CMOS type light capture sensor. (CMOS stands for Complementary Metal Oxide Semiconductor.) This is a different type of sensor, with different light-sensing characteristics, than the CCD (Charge-Coupled Device) type that has been developed for use in most analog cameras. CCD sensors provide high quality, low-noise pictures over a wide range of light conditions. However, despite their superior light sensitivity and wide dynamic range, they are not typically used in megapixel cameras. Instead, CMOS sensors are used due to their low power consumption that enables "powering over Ethernet," a faster processing speed and comparatively low cost. As a result, megapixel cameras often deliver images with more picture noise and colour.

Another difference between CMOS and CCD sensors is that CMOS sensors do not cause colour blooming in bright lighting conditions. Autoiris lenses are used in traditional cameras with CCD sensors in order to eliminate color blooming. Since this effect does not occur in megapixel cameras, many megapixel cameras feature a manual iris.

Megapixel cameras do not require Autoiris lenses.

A third difference between the two sensor types is the manner in which each frame of video is exposed. In CCD sensors, the entire frame is exposed at once in a manner that is referred to as "global shutter." In CMOS cameras, each frame is exposed from top to bottom in a "rolling" motion. When capturing video in a space that is lit by older, low-refresh fluorescent lighting, the slow rate at which the fluorescent lights flicker may cause inconsistencies in exposure within each video frame, from top to bottom.

Megapixel cameras may not perform well under low-refresh fluorescent lighting.

Separate from the issue of sensor type, megapixel cameras also face light sensitivity challenges due to the smaller size of the pixels that comprise their video. Many megapixel cameras are designed around the common, 1/3 inch analog chip. Compared to standard video cameras, megapixel cameras need to fit upwards of three times the number of pixels on the same 1/3 square inch, making each individual pixel significantly smaller. Smaller pixels are much less sensitive to light. This means that megapixel cameras often deliver poor quality images in low light conditions, and the automatic gain control used to compensate for the low light adds additional noise. This

Until megapixel cameras offer a larger, 1/2-inch imager and compatible 1/2 inch lenses become readily available, it is best to use megapixel cameras in well-lit areas.

may cause concern to system designers on two fronts. Most obviously, critical visual information may not be captured and, equally important but less obvious, noise within the video will increase file size, leading to storage concerns. Some megapixel camera manufacturers are beginning to use 1/2 square inch imagers to allow for larger pixels that offer greater light sensitivity, but compatible lenses for use with these imagers are currently expensive and not readily available. For now, it is best to use megapixel cameras in well-lit areas.

Using a megapixel compatible lens will guarantee the best performance, particularly when viewing enlarged, recorded video.

Camera optics should not be overlooked when striving for the best performance and value from high resolution cameras. A megapixel-compatible lens should be used to ensure that images provide consistently high contrast and high resolution from the centre of the lens all the way to the edge. While the difference in lens performance may not be that obvious when viewing live video, the value of the higher quality lens becomes evident when stored images are enlarged for investigation. Without use of the proper lens, the benefit of the higher resolution camera will be lost in situations that most require megapixel performance.

Megapixel cameras currently transmit between 2 and 12 frames-per-second, which may be too low for some applications.

Finally, no discussion on megapixel cameras would be complete without addressing the issue of "frame rate," the number of pictures captured per second by the camera. By nature, high resolution cameras transmit greater amounts of data and this additional data takes longer for the camera to process. As a result, most megapixel cameras are not capable of transmitting the 25 frames-per-second that is standard for traditional analogue video. Instead, megapixel cameras transmit between 2 and 15 frames-per-second, usually providing users with ability to select the desired rate. System designers would be remiss not to consider the risk of missing key evidence due to a low frame rate. Some surveillance targets, such as a car park, can be adequately covered using a low frame rate, as even the fastest moving car will still be captured. However, events that occur within a split second, such as a shoplifter quickly concealing an object or a person being assaulted, may be missed if corresponding video is recorded at low frame rates.

Storage and Bandwidth Considerations

This white paper began with a discussion of why consumer-level digital cameras and professional security video cameras should not be thought to represent similar technologies. However, the evolution of point-and-shoot digital cameras does yield one apt analogy to the world of security video, and that is in the area of bandwidth and storage.

Initially, digital cameras could only provide low resolution images — so low, in fact, that they could only provide printed pictures as large as 4” x 5” before pixelisation occurred. File sizes were relatively small, transferring images from camera to computer was often done via the now extinct “floppy disc” or slow, version 1.0 USB ports, and photo storage on the PC was not a real concern. However, as technology improved and picture resolution increased, image transfer and storage became more challenging. Today’s megapixel cameras often have at least a gigabyte of storage, provide highly compressed JPEG files for emailing, and PC owners use huge hard drives or external drives to store their photos (along with their music and videos).

Megapixel video cameras will impact the need for network bandwidth and storage in the same way that megapixel still cameras, along with other consumer electronic devices, have increased consumer needs for high-speed transmission and ample storage of digital content.

The same increasing demands for bandwidth and storage are now being seen in the world of security video. When digital video started to make inroads within surveillance technology several years back, a 40 GB hard drive was considered big. Now, terabyte drives and gigabyte networks are commonplace. Megapixel cameras, with so much more data in every single frame, have the potential to increase this demand exponentially. Right now, the lower frame rates provided by megapixel cameras are somewhat mitigating the full effect, but it is likely that in the future, megapixel cameras will offer the same frame rates we’ve come to expect from standard video and our systems will need to support them.

It is imperative that system designers make use of the tools provided by camera manufactures so that they fully understand the impact any given megapixel camera will have on file sizes and bandwidth. Some manufactures, like Vicon, offer megapixel cameras that provide the designer with flexible frame rates and constant bit rate options, affording a way to calculate bandwidth and storage with greater accuracy.

Summary

Megapixel cameras will bring major changes to the video security industry. More recorded picture detail will make post-incident analysis far more effective in many applications. And, increased demand for the technology will lead to continued improvements in performance and lower per-unit camera costs. However, like any

Megapixel technology is quickly making headway into the video security market. With a proper understanding of its benefits and current limitations, security professionals can begin making use of it today and expect even greater things from it in the years ahead.

tool, it is only beneficial when used correctly and in the proper settings.

Security design is about analysing risks and deciding what actions would most effectively minimise or remove them, all within the constraints of the project's budget. Already, there are plenty of applications in which megapixel cameras can contribute to increased post-event forensic capabilities, lower overall system cost due to the need for fewer cameras, or both. And, as technology continues to improve, appropriate applications for these cameras will continue to grow.

For now, high-quality, time-tested, traditional video cameras are not dead. Their low cost and highly developed functionality in extreme lighting conditions are still needed for many applications. The next decade will undoubtedly witness a transition toward higher resolution cameras becoming the industry standard, but not until issues of light sensitivity, file size and cost are more thoroughly addressed.