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Blurred Images Bring Surveillance Into Sharper Focus

Computational imaging processes data from images even as the camera collects them.

The average shutterbug does not return home from vacation excited to find that his sightseeing snapshots are all out of focus and that his video travelogue consists of one frozen image. Researchers in MITRE's Computational Imaging and Sensing Group, however, might celebrate such mangled mementos as results of technological breakthroughs in digital imaging, rather than of klutzy camerawork.

Michael Stenner, lead researcher in the group's Computational Imaging for Persistent Pervasive Surveillance project, begins to explain why he might have a more positive reaction to blurry photos than expected. "The digital camera in your pocket for the most part works exactly the same way as the very first film cameras two centuries ago. That's because cameras are designed to capture what humans see. To do so, they mimic the human eye."

But the eye can be easily fooled. And overwhelmed. When you're designing cameras for surveillance work, those are not features you want to mimic.

Take for instance the age old practice of camouflage. "Camouflage mimics the colors and patterns the human eye takes in when we look at real foliage," says Stenner. "But if you construct a camera that works differently from the human eye—one that doesn't focus solely on the red-green-blue color bands that human sight perceives—then the camera can more easily tell the difference between camouflage and real foliage."

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Too Much to See

But in surveillance, designing a camera that sees what the human eye might not is only one of the challenges. The goal of large-area surveillance is basically to determine who went where. To figure that out requires analyzing the countless images the cameras capture. In a typical large-area surveillance mission, a plane outfitted with cameras will fly over a targeted zone. The collected images, often comprising terabytes of information, are stored on banks of hard drives onboard the plane.

When the plane lands, the hard drives are shipped to processing centers sometimes thousands of miles away where the images are downloaded and analyzed. By the time the data from that analysis makes its way back to those charged with monitoring the target area, the data has lost much of its utility. A solution MITRE's researchers are pursuing is to design a camera that can process the data from images even as it collects them. This is, in essence, what computational imaging means.

Thinking with Light

"These days," says Stenner, "even though every digital camera has a computer built into it that processes the raw image data so as to produce the best possible final image, most lenses are still designed so that the raw image is already as sharp and perfect as possible. But there are sometimes advantages to having a not-so-sharp-and-perfect raw image. So when you're designing a camera, you should be jointly designing the optical components and digital processing. This gives you the freedom to manipulate the image data at either the optical end or the processing end, depending on your needs."

For instance, when designing a camera for large-area surveillance, you can craft the optical system so that it manipulates light in such a way to make the data the camera collects easier to process. Surprisingly, one such way to manipulate visual data is to blur it.

(continued...)

Seeing Clearly through Blurs

MITRE is currently expanding upon a technique, developed by Ramesh Raskar of MIT Media Lab, called coded exposure or "flutter shutter." Normally, when a camera collects an image, it opens its shutter for a set period of time. The longer the shutter is open, the more light it can collect, but the more likely the scene is to change while being collected, causing blur. That's why a long shutter exposure is preferred for shooting in low light, so that the camera can collect enough light. A short shutter opening is preferred for capturing a moving object, so that the scene doesn't "change" or blur. The dilemma comes when both problems occur simultaneously, a low-light scene with moving objects.

The technique of coded exposure avoids having to trade off between too little light and too much change. The amount an object blurs in a photo is a mathematical result of its movement. By "flutter shuttering"—repeatedly and rapidly opening and closing its shutter in a precisely defined sequence, the coded exposure camera deliberately allows motion blur to occur in the images it collects and encodes that blur with a predetermined formula. Now the camera can collect as much light as it needs because it knows the exact code to deblur any images that might become marred.

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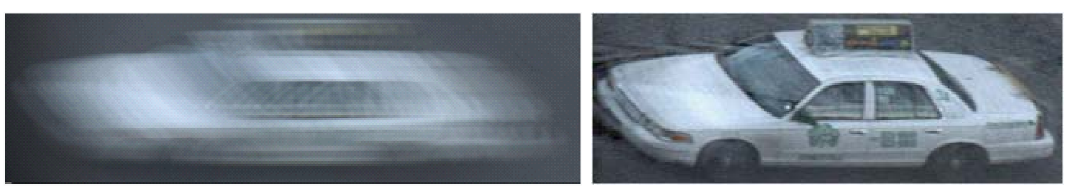
By using coded exposure in the design of surveillance cameras, MITRE can expand the hours and conditions under which surveillance can take place, while reducing the loss of vital information.

The flipside of coded exposure is also useful in analyzing surveillance imagery. Where the flutter shutter technique deliberately imposes a mathematically determined blur to the images it collects, MITRE is designing techniques to recognize those "blur codes" in images. Simply take a picture with a coded exposure, find the blurry object, and analyze the blur code to reveal how fast the object is moving and in what direction. As blurry images will no longer be a mystery and a concern, a single long-exposure image can capture the same amount of surveillance information as several video frames while presenting considerably less data to store and transmit.

Practical Vision

Computational imaging is a relatively new discipline, but MITRE's investment in emerging technologies has given the company a head start in the field. The number of MITRE researchers engaged in computational imaging rivals that employed by major centers of academia. However, says Stenner, MITRE's interest in computational imaging remains as pragmatic as its sponsors' needs. "We don't want our sponsors to have to indiscriminately measure billions of pixels of data and then wade through it all. We want to find the most efficient ways for them to directly measure, extract, and analyze the most useful information from a scene."

While coded exposure imaging is certainly on the cutting edge of optical technology, related techniques are already being used in cell phone cameras to provide greater depth of field in the photos with a minimum of focusing. So don't worry if your vacation photos start out blurry; it's just the first step to making them crystal clear.



This example of deblurring (right) uses the "flutter-shutter" technique developed by Ramesh Raskar, MIT Media Lab.

—by Christopher Lockheardt

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