today, Soatto maintains. He notes that facial recognition systems require that images be captured under very rigid parameters of lighting, distance and angle. If this framework is disrupted or ignored, the system does not work properly. The goal is to find an invariant property in an object and recognize it despite all variables.

One approach is to store images of an object under all possible conditions of lighting and angles. But this is not practical because the range of variables is almost infinite, he observes. Scientists know how to address certain types of invariances that are geometric in nature and relate them to an object's position and orientation. However, variances relating to illumination levels and qualities are unknown, forcing researchers to make assumptions in their calculations.

Although dynamic vision seeks to understand the mathematical key to extract data from images, Soatto believes the solution must be independent of any specific algorithm or system used to solve it. "Whether it's the eye and the brain or a camera and computer, it doesn't matter because the mathematical properties of the problem are the same," Soatto emphasizes.

The goal of UCLA's laboratory research is to discover or analyze properties of the problem of dynamic vision that are device-independent. Once these properties are discovered, an algorithm can be implemented for a specific device, but "if we have gotten the math right, then any device should work," he points out.

Though other researchers are studying the use of different bands of light, lasers and even acoustic imaging to guide autonomous vehicles and robots, the basic problem remains the same. "No matter how the image is acquired, once it gets into a computer, it's a bunch of zeros and ones. So in a sense, the difficulty is not acquiring an image, it is interpreting it," Soatto maintains.

The U.S. military has been a major contributor to research for autonomous aircraft. Although dynamic vision systems have difficulty in complex environments, such as city streets or a battlefield, they operate reasonably well in the air. Soatto notes that this is a matter of perspective. Although the physical space is the same, when viewed from a high altitude, environments such as city streets become relatively static and structured, he explains.

Soatto believes that a number of dynamic vision systems will be available in the near future, noting that Dickmanns' system is already in commercial use on freightliner trucks. The technology generates a warning if it detects any inconsistencies in highway driving patterns. For example, if a driver were to fall asleep behind the wheel, the system would keep the vehicle in its lane and sound an alert to wake the driver. Vision-based robots are working on factory floors, and the UCLA vision laboratory also is involved in research to provide U.S. Army helicopters with autonomous guidance and landing systems. "These systems are a reality—you don't need to wait five years," he says. *—HSK*

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Additional information on dynamic vision is available on the World Wide Web at ***www.engineer.ucla.edu/stories/vision.htm.***