all unknown. All of these things influence your measurements in the sense that if you change any of them, your images—the values between zero and 255 recorded in the computer—are completely different," he says.

The key ideas behind dynamic vision date back to the 1940s, but Soatto believes the first person to demonstrate working systems based on the theory is Ernst Dickmanns, a professor at Universitaet der Bundeswehr, Munich, Germany. Between the late 1970s and 1994, Dickmanns developed passenger cars that drove autonomously on European highways at speeds of up to 111 miles per hour, reading speed signs and passing slower vehicles.

Dickmanns used a structured environment to make his system work. Highways are not arbitrary objects, but rather slabs of concrete with stripes painted on them and populated with cars, trucks and motorcycles. Soatto describes this as a very simple environment because many of its properties are known. "If you took Dickmanns' car and put it on the streets of Los Angeles, it wouldn't go anywhere because the complexity of the environment is infinitely superior. On the streets you have pedestrians, buildings, dogs—all sorts of things. It is very difficult to embed these [variables]," he maintains.

Dickmanns used this model and attempted to enrich it by augmenting the system. Soatto chose to approach the issue from another angle. "Suppose you know nothing about the environment. If you put me in a building I know nothing about, I can still get around. So I came in from that end, the so-called unstructured environment, and one of the questions that I posed was, 'What exactly can I do in an environment I know nothing about?'" Soatto explains.

Called structure from motion, this theory asks the question, Can the three-dimensional properties of a scene be reconstructed by using only images of an object? To solve this problem—which Soatto describes as one of the central issues of dynamic vision—UCLA researchers are measuring light, which represents images and arrays of positive numbers. This data is converted into estimates of the particular properties of objects, such as shape and motion. A framework is then created based on stochastic process estimation, statistical modeling and optimization. The resulting structure can be posed in mathematical terms as a very complex optimization problem. "We use techniques from stochastic optimization and systems theory to address this problem by devising algorithms to do the estimation and analysis—for instance, to prove that a solution to this problem exists and that it is unique," he says.

The difficulty of designing dynamic vision is in determining the best way to collect this highly variable data and extract the properties of a specific scene. "How can I recognize friends' faces regardless of whether they are in bright sunlight, shade, wearing wigs, smiling, in different poses or orientations? I still manage to recognize them," he notes.

But extracting this data and coalescing it into an algorithm is extremely difficult. No efficient system for handling variations in illumination exists