Computational Optics - Cyber-physical imaging systems to detect disease, see around corners, and visualize the propagation of light

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The process of imaging is a complex interplay between a physical device that collects information through measurements, and an information processing system that converts the collected information into a human-interpretable format - an image - and often further processes the data to obtain a desired piece of information, such as a medical diagnosis. In traditional imaging systems data collection and image formation are performed by optical elements, and computers are used to analyze the resulting human-interpretable images. In this talk I will show different systems that, by changing the way we capture and process imaging data, allow us to see things that are invisible to a regular camera and to human vision. By co-designing data collection and processing we can built cameras that can see around corners, detect disease based on complex spectral information, and study the propagation of light through scattering materials. I will describe two projects in detail:

**Hyperspectral High Speed Microscopy**
Fluorescent spectra provide a powerful source of imaging information in biology and medicine. Fluorescence is naturally present in all living systems, but can also be artificially introduced to mark parts of the organism under study. Fluorescence imaging is used to study the metabolism and functioning of the cell and the structure of living tissue. It can be used to identify tumors during surgery diagnose many diseases. We have developed a hyperspectral swept field confocal microscopy system that constructs images at high speed, together with novel spectral analysis methods to process this data. The added spectral information allows for better analysis of fluorescent spectra.

**Seeing around corners by capturing light in motion**
I will present a camera that composes slow motion videos of light pulses at an effective time resolution of about 0.5 trillion frames per second. http://youtu.be/JWDocXPy-iQ
Using this high speed imaging system we can analyze light paths in a scene and reconstruct images of objects that are not directly visible to the camera. http://youtu.be/9RbLLYCiyGE
We are developing applications for this method in remote sensing and biomedical imaging, for example for the exploration of caves on the moon.