Surgical Fluorescence Imaging with Computational Single Photon Cameras

Abstract: Our cameras usually measure light as an analog flux that varies as a function of space and time. This approximation ignores the quantum nature of light which is actually made of discrete photons each of which is collected at a sensor pixel at an instant in time. Single photon cameras have pixels that can detect photons and the timing of their arrival resulting in cameras with unprecedented capabilities. Concepts like motion blur, exposure time, and dynamic range that are essential to conventional cameras do not really apply to single photon sensors. In this presentation I will cover computational imaging capabilities enabled by single photon cameras and their application in surgical fluorescence imaging.

These enhanced imaging capabilities are particularly interesting in applications with extreme demands, such as Fluorescence Guided Surgery (FGS). FGS methods make use of fluorescent markers that selectively attach to and label different anatomical structures in the human body to make them visible during surgery. Labels for vasculature, tumors, and nerves are under investigation. Imaging systems need to work with weak signals in moving scenes covered by bright ambient light. We are applying a series of computational imaging improvements to allow our cameras to produce image qualities during surgery that used to only be achievable in static scenes in a dark laboratory.

This high signal quality and the exceptional time resolution of our cameras may further enhance future FGS methods by capturing fluorescence lifetime. The nanosecond scale fluorescence lifetime of a fluorescent marker is related to the markers surroundings and molecular binding partners. By measuring lifetime we may better differentiate between marker molecules that are actually bound to the target site and those that are floating freely. It may even be possible to perform label free FGS by making use of fluorescent molecules that are naturally present in human cells.