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DLP® Products DMD-Based Hyperspectral Imager Makes Surgery Easier

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Novel hyperspectral imager aids surgeons

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Illuminating bodily tissues with a digital micromirror device enables non-invasive characterization of living tissue based on chemistry and morphology.

When performing open or endoscopic surgery, it is often difficult to differentiate between neighboring tissues. For example, when removing the gallbladder, it is important not to damage the common bile duct. If we could non-invasively distinguish the bile duct from surrounding arteries, the surgeon would know better where to cut.

Spectroscopy has been used for decades to characterize chemical and biological molecules based on their spectral signatures, that is, the way they reflect or absorb different wavelengths of light. It is well-documented that oxygenated tissue reflects different wavelengths of light at different intensities than deoxygenated tissue.[1] In the same way, gallbladder and bile duct tissue has a different spectral signature than surrounding anatomical structures such as the liver and blood vessels.[2] In hyperspectral imaging, we capture a series of images while scanning through wavelengths of light. Each processed image pixel corresponds to the spectrum for that point on the image. We then compare each spectrum to known spectral signatures to determine which tissue they match, or their level of oxygenation. Liquid crystal tunable filters (LCTF) have been used previously to scan through the wavelengths of light, generating only one processed image every 30s. We have developed a new hyperspectral imager which uses a programmable digital micromirror device (DMD) from Texas Instruments DLP® Products group to generate over three processed images per second.

The primary limitation of the previous LCTF system is that only single bandpasses of narrow bandwidth light can be filtered at a time.[3] The new system has a DLP DMD-based spectral illumination light source (OL 490, Optronic Labs).[4] In the DMD source, broadband light is diffracted through a slit, reflected from a grid of digitally-controlled programmable micromirrors, and optically directed to a focal plane array (FPA, or digital camera) through a liquid light guide (LLG), similar to an optical fiber that has an increased capacity for transmitting light. Figure 1 shows the experimental setup. By controlling the state of each mirror individually, the source illuminates tissue with a programmed selection of wavelengths of light and the camera measures the reflection of that spectrum. The programmed spectrum may simply be a single bandpass—similar to the LCTF output—or a more complex combination of wavelengths that cannot be duplicated by the LCTF. Since the DMD hyperspectral imager

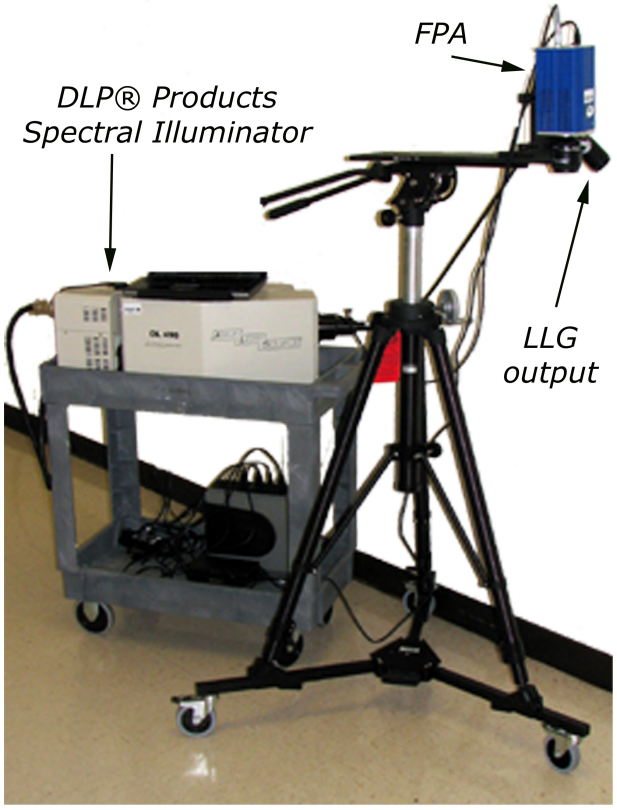

Figure 1. *DMD-based hyperspectral imager for medical imaging.*

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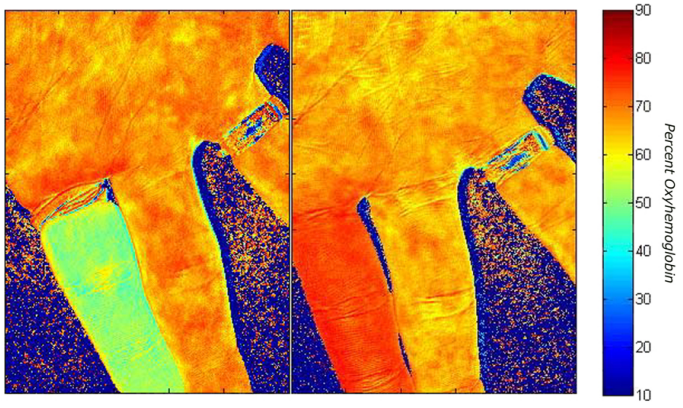

Figure 2. *An initial proof of principle of the hyperspectral imager's ability to show oxygenation. (left) A subject's index finger was temporarily bound with a rubber band to restrict blood flow. (right) When the rubber band is removed, a surge of blood returns to the finger causing hyperfusion.*

uses mirrors instead of liquid crystals, the tuning time is faster and the wavelength range is broader. Using a micromirror array and DLP technology lets the user program the source illumination using predetermined complex spectra or color mixtures of light.

Figure 2 shows how the percentage of oxyhemoglobin in the blood can be detected. The pixel color illustrates the percentage of oxyhemoglobin. Red relates to high levels of oxyhemoglobin while yellow, green, and blue represent decreasing levels of oxyhemoglobin, respectively. The DMD hyperspectral imager is currently operated in two illumination modes to assess tissue oxygenation: 'Sweep' and '3shot'. Examples of both types of image are shown in Figure 3. In 'Sweep' mode, we scan 126 discrete wavelengths with 10nm bandwidth, which is similar to filtering broadband white light with our LCTF system. After acquiring the hyperspectral data (126 images), we separate out known spectral signatures of oxyhemoglobin (HbO_2) and deoxyhemoglobin (deoxy-Hb) to color-code each pixel. One color-coded image is generated every 20s. Our '3shot' method uses the DLP source to illuminate the tissue with color mixtures of light chosen to reveal differences between the known spectral signatures of HbO_2 and deoxy-Hb.

The DMD hyperspectral imager can be used for real-time imaging in a wide variety of surgical and clinical applications. Because the light source is programmable and has a spectral range of 380–1600nm, any chemical or biological components with differing spectral signatures can be contrasted with this system. Currently, the system is used in animal studies during partial kidney removals to monitor the restricted blood supply

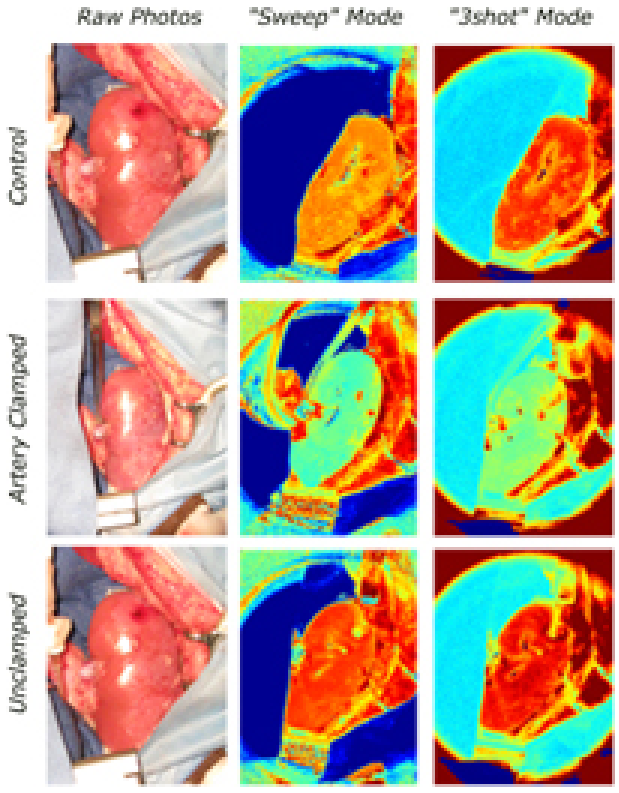

Figure 3. *Raw and processed images from animal study of kidney clamping. 'Sweep' and '3shot' images are color-coded according to the color bar shown in Figure 2, where red indicates high oxygenation, green indicates medium oxygenation, and blue indicates low oxygenation.*

in the kidney after arterial clamping (see Figure 3 and online video[5]). We expect to fine tune the system for use with standard medical equipment, such as endoscopes, so that it can be used in human surgery.

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5. Video of pig kidney surgery on October 6th 2008. *Credit: Jack Smith* with special thanks to the surgeons Chad Tracy and Jeffrey Cadeddu http://spie.org/documents/newsroom/videos/1394/HSI-UTSW-Oct-6-08-rev2-silent.mov