



## Voice Analysis at Massachusetts General Hospital Using Digital Kymography and Xcitex Software

Date Published: October 2011

### Abstract

Digital kymography is a high-speed medical imaging technique used to visualize human vocal cord vibration. Before this technique was created, doctors studying vocal cords and their vibratory characteristics faced major challenges in capturing vocal cord motion for analysis and diagnosis. Assisted by Xcitex engineers, researchers at Massachusetts General Hospital have developed a solution using Xcitex's ProAnalyst® and MiDAS software.

*"The combination of High-Speed Videoendoscopy with Digital Kymography capability, then followed by powerful analysis methods providing to the clinician all relevant information at a glance, in visual, graphical, and numerical form, is likely to be the best approach [to Voice Analysis]."*

-Dimitar Deliyski, Ph.D. and  
Pencho Petrushev, Ph.D.

Department of Communication  
Sciences and Disorders and  
Department of Mathematics at the  
University of South Carolina, from their  
article, *"Methods for Objective  
Assessment of High-Speed  
Videoendoscopy"*

When a person speaks, sings, or shouts, vocal cords in the larynx vibrate in excess of 100 times per second, faster than the blink of an eye. This incredible speed combined with the difficulty of accessing vocal cords deep in the throat create complex problems for audiologists and doctors who study diseases and disorders of the larynx.

*Strobe laryngoscopy*, or stroboscopy, is the traditional technology for studying the motion of vocal cords. An endoscope, a long probe consisting of lenses with a video camera at the back end, is inserted into the patient's throat. A series of strobe pulses, externally timed to correlate with the beat frequency of the vocal cord, create an artificial movie of the vocal cords opening and closing. By presenting these images along a timeline, movies of the motion can be created using a process known as *kymography*. However, stroboscopy only provides valuable imagery if the vocal cord motion is periodic or cyclically "regular."

Dr. Robert Hillman and Dr. Daryush Mehta at Massachusetts General Hospital Voice Center in Boston have developed a solution that holds promise for the millions who suffer with voice disorders. Partnered with Xcitex engineers, Drs. Hillman and Mehta designed and built a state-of-the-art patient laboratory utilizing Xcitex technologies for high-speed imaging.

A new analysis technique called *digital video kymography* replaces the strobe source and analog video camera with a digital high-speed video camera. High-speed video, which captures frames of videos more than 150 times faster than traditional video, provides the temporal resolution to capture both periodic and aperiodic (irregular) vocal-cord dynamics.

Mass General doctors and Xcitex engineers have developed a novel hardware setup consisting of a PCI digital acquisition board (6259 M Series from National Instruments), a PCB Piezotronics microphone and accelerometer, a laryngeal impedance sensor called an electroglottograph, an intraoral air pressure transducer, an oral airflow airtransducer, an endoscope, a high-speed camera (Vision Research v7.3 Phantom), and a powerful light attached to the endoscope with fiber optics. The researchers insert the endoscope into the throat of the patient, who performs a series of vocal exercises. Xcitex software then gathers data and images from the exam.

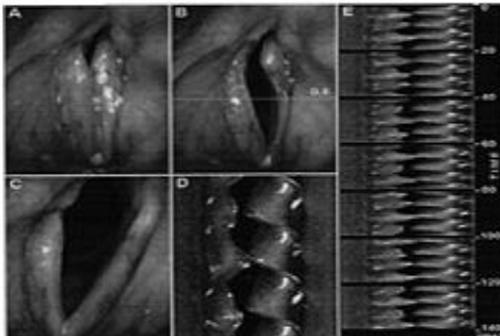


*MGH doctors using digital video kymography*

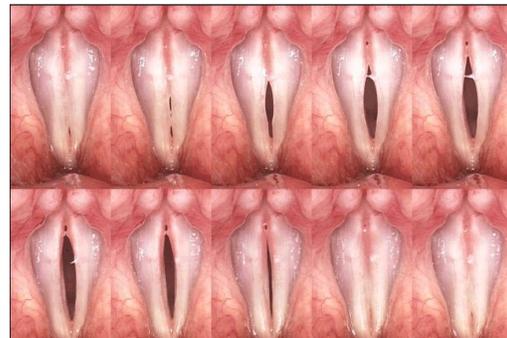
Drs. Hillman and Mehta typically record video at 4000 fps, 6250 fps, or 8000 fps and record synchronized data at 100 kHz or 160 kHz. They use MiDAS DA to precisely synchronize the video with the data from the external sensors. This combination of video and data enables analysis of laryngoscopic factors such as acoustic microphone signals, electrical conductance of the larynx, neck skin acceleration, and air pressures and flows in the mouth.

After MiDAS DA consolidates the video collection with all the pertinent data, ProAnalyst provides information about the vocal cords in the video. The doctors track the motion of layers of vibrating tissue on the surface of the vocal cords, using ProAnalyst to observe segments of vocal cord tissue and the air space in between (the glottis). Several ProAnalyst features facilitate this process:

- **Contrast modification** manually changes color, intensity, gamma, and contrast.
- **Image stabilization** removes unwanted camera motion and isolates an object for calculating relative motion.
- **Thresholding** modifies the intensity of individual pixels in an image for optimal tracking.
- **1-D Line Summary** tracks lateral motion of the vocal cords and provides a useful visual aid for assessing vibratory patterns such as periodicity and asymmetry.
- **2-D Feature Tracking** monitors the modulation of the glottal area over time.



*Digital video kymographic images and data*



*Segments of vocal cord tissue and glottis*

Drs. Hillman and Mehta use the motion analysis tools from ProAnalyst to prototype image processing algorithms for further optimization in MATLAB, gaining valuable information about their patients and techniques for developing bio-implants to restore normal voice and speech capability to damaged vocal cords. Xcitex engineer Eli Brown notes, "We were able to leverage several Xcitex core technologies to bring a powerful customized system to the laboratory. Our MiDAS technology captures data from their clinical sensors and tightly synchronizes it with their high-speed endoscopic video stream. Post-acquisition, they apply our analysis tools to extract the meaningful data they need for their research."

Peter Carellas, President of Xcitex adds, "The Xcitex-MGH partnership started with a simple workshop visit and evolved into this valuable project. Drs. Hillman and Mehta were quick to imagine the utility of Xcitex products in an untraditional market, and to articulate their specifications to us. With equal resourcefulness, the Xcitex engineering team was able to create a solution resulting in this life-enhancing product that we intend to market to medical research centers and high-end hospitals worldwide."

According to Mehta, MiDAS DA's ability to play back audio immediately after recording has been critically important in the clinical setting. With the addition of ProAnalyst's rapid prototype creation capabilities, Xcitex software dramatically improves Hillman and Mehta's efficiency when conducting exams. After acquiring data and video from their patients in the lab, Drs. Hillman and Mehta enter the information into a database that serves a community of researchers working to characterize the patterns exhibited during vocal-cord vibration, specifically those related to vibratory asymmetries and irregularities. Beyond Mass General, the data benefits a multidisciplinary team of surgeons, speech-language pathologists, and research scientists seeking to better understand trauma and diseases of the vocal cords, and to evaluate the efficacy of current surgical repair techniques.

Hillman and Mehta's work is directed by Dr. Dimitar Deliyski and Dr. Pencho Petrushev, renowned professors in the Department of Communications Sciences and Disorders and the Department of Mathematics at the University of South Carolina. In their article *Methods for Objective Assessment of High-Speed Videoendoscopy*, Deliyski and Petrushev laud the value of new technologies, including digital video kymography.

High-speed video combined with data collection from air pressure gauges and audio signals and rapid post-processing holds great promise for the future of laryngoscopic vocal cord analysis. With Xcitex software and technology as a foundation, the expertise of these pioneering researchers will be able to assist a wider range of patients affected by voice disorders and diseases.

## Technology Profile

Xcitex ProAnalyst® motion analysis software  
Xcitex MiDAS DA data collection software  
National Instruments PCI digital acquisition  
Piezotronics microphone and accelerometer  
Vision Research Phantom high-speed camera

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