

The EndoTester™ – A LabVIEW-Based Automated Test System for Fiber-Optic Endoscopes

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The Challenge: Assessing the optical performance of fiber-optic endoscopes and video systems in a clinical setting.

The Solution: Using LabVIEW and IMAQ™ products to build an integrated test bench suitable for use by the clinical staff to measure parameters such as light loss, symmetry, and distortion.

Introduction

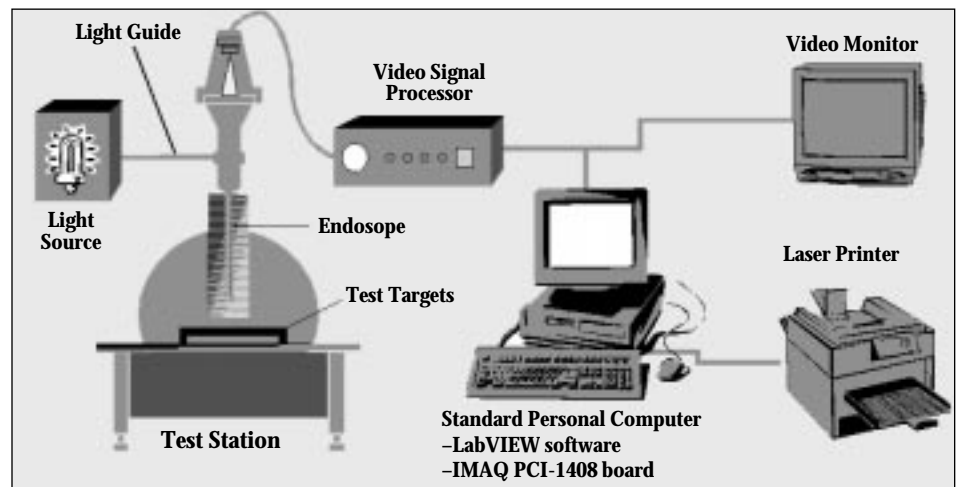
The popularity of endoscopic surgery is growing, in large part because it is generally safer and less expensive than conventional surgery. As endoscopic surgery becomes more common, accurately evaluating the performance of endoscopes and their peripheral components becomes essential.

Assessing the optical performance of endoscopes and video systems is often difficult in the clinical setting. The surgeon depends on a high-quality image to perform minimally invasive surgery, yet assurance of proper function of the equipment by biomedical engineering

By leveraging off standard PCs and IMAQ image acquisition plug-in boards, this LabVIEW-based system is highly versatile and affordable.

staff is not always straightforward. Poor images can result from many variables, such as optical problems with the rigid endoscope, damaged fibers in the light cable, video camera malfunctions, and cleanliness of the equipment, especially lens surfaces on both ends of the endoscope.

We developed the EndoTester evaluation system in response to worldwide demand for an affordable, accurate, and highly versatile test system for assessing the performance characteristics



The EndoTester System Configuration

of endoscopes and video systems in the clinical setting.

The EndoTester Evaluation System

The EndoTester (patents pending) is an easy-to-use, "plug and play" endoscope QA system to assess and accurately quantify the optical characteristics of fiber-optic endoscopes. The system, which we designed from its conception for ease of use, accommodates virtually any type of fiber-optic endoscope. Multimedia features and on-line help and instructions provide support for biomedical engineering staff, nurses, and physicians. By leveraging off standard PCs and an IMAQ image acquisition board, this LabVIEW-based system is highly versatile and affordable.

The figure illustrates the fundamental components of the EndoTester. The variable light source and fiber-optic cable deliver light through the endoscope to the target test patterns or a photometer. A charge-coupled device (CCD) video camera is attached to the eyepiece of the endoscope and the video signal processor processes images. These video signals are then passed to a standard PC containing custom LabVIEW software and the IMAQ PCI-1408 image acquisition board, which digitizes the video signal. We rapidly developed the image acquisition

and image analysis algorithms using LabVIEW and IMAQ Vision software. An optional video monitor is also useful for aligning the test patterns. The system prints final reports (including image profiles) on a high-quality laser printer or digital printer.

Using the optical test bench and specialized software, the user performs a series of tests on the endoscope and its peripheral devices. Specifically, these tests include:

- Relative light loss
- Geometric distortion
- Modulation transfer function (MTF)
- Reflective symmetry
- Percent of lighted (good) fibers

Each series of tests is associated with a specific endoscope so the staff can observe trends and easily compare successive measurements. Specific information about each endoscope (i.e., manufacturer, diameter, length, tip angle, department/unit, control number and operator), the reason for the test (such as quality control or pre/post repair), and any problems associated with the scope are also documented through the electronic record. In addition, all the quantitative measurements from each test are automatically appended to the electronic record.

Relative light loss measurements quantify the degree of light loss from the

light source to the distal tip of the endoscope. The relative light loss is a measure of fiber-optic damage. The geometric distortion test quantifies the optical distortion of the rod-lens system. To perform this test, the image acquisition board captures the image of a square grid pattern. The modulation transfer function (MTF), a measure of contrast, has long been considered a "gold standard" in

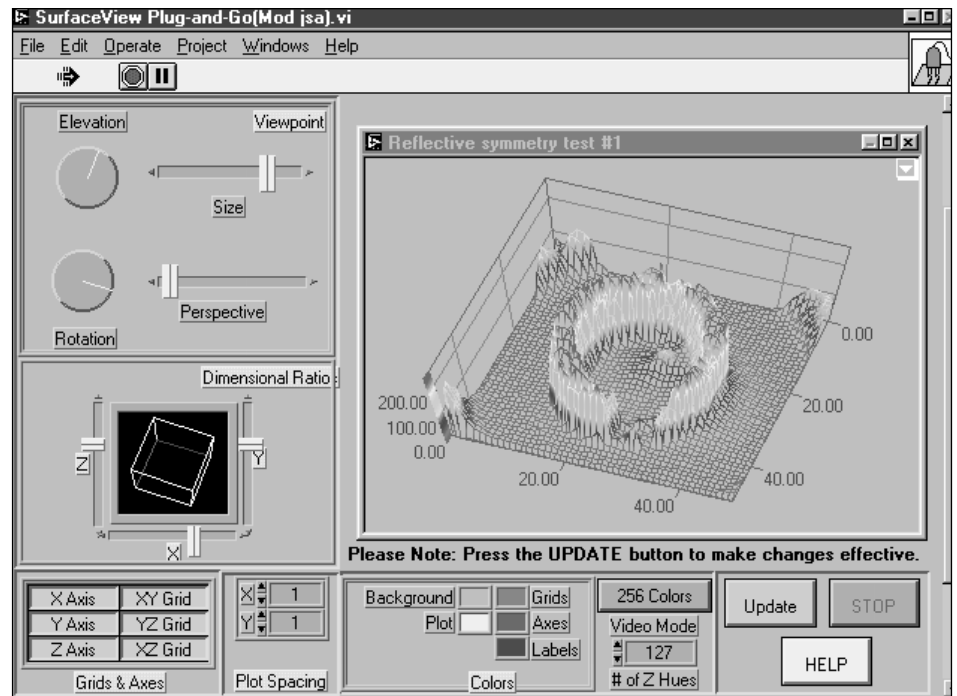
... an equivalent test system is now available at less cost than a single endoscope repair, thanks to the benefits of virtual instrumentation.

measuring optical performance. Studies have shown that a user's perception of image quality correlates with high MTF.

Reflective symmetry is a measure of light amplitude in the field of view of the endoscope. This value is important because it quantifies the effective distribution of light. By employing five magnitude comparators built into LabVIEW, it is possible to transform the continuous illumination pattern into five annular rings of decreasing gray scales. A histogram graphs the number of pixels from each comparator output (light intensity). For each ring displayed in the filtered image, the user can observe how many pixels exist from each band of intensity.

We can also display the pattern of lighted optical fibers for the endoscope under test. The operator can actually see the broken fibers (dark areas), which do not carry any light, and then identify fiber damage by comparison of successive tests.

In addition to the two-dimensional profile of lighted fibers, we can also display this pattern (and all other image patterns) in the form of a three-dimensional contour plot. Broken fibers are clearly indicated in the figure by



Contour Profile of the Endoscope Tip Reflection (Lighted Fibers) Test. Three-dimensional display and analysis were done with SurfaceView™ from Metric Systems (Cedar Park, TX).

depressions or valleys. The operator can observe this interactive graph from a variety of viewpoints by varying the elevation, rotation, size, and perspective controls.

Summary

With the EndoTester, an easy-to-use optical evaluation system for endoscopes, you can objectively measure performance prior to equipment purchase to verify specifications, and in routine clinical use for preventive maintenance. The need for repair can be better defined and the repairs verified when service is completed.

The explosive growth of minimally invasive surgery has created a significant market for endoscope repairs and service. Endoscope repairs cost from \$500 to \$1,500 or more. Inadequate repairs can result in extended surgical time while the

surgeon to switches scopes (often several times) during a procedure.

Although commercially available endoscope evaluation systems (for original equipment manufacturers) cost more than \$40,000, clinical institutions can now have an affordable, accurate test system thanks to virtual instrumentation. We believe that the EndoTester can play an important role in reducing unnecessary costs while improving the quality of the endoscopic equipment and the outcome of its use. This technology can "level the playing field" to the benefit of health care providers, ethical service providers, manufacturers of quality products, payers, and patients.

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