3D Optical Shape Sensing for Medical Applications

All surgical procedures performed in the medical industry may be classified as being non-invasive, minimally invasive, or invasive. These classifications generally refer to the degree to which medical instruments are introduced into the body. While a great number of ailments may be treated non-invasively with various medical procedures, physicians must still rely on minimally invasive and invasive procedures to treat some conditions. Doctors and medical researchers are therefore constantly searching for ways to make such procedures safer, repeatable, and more cost-effective.

The greatest breakthroughs in minimally invasive surgery include the development of medical endoscopes and the subsequent introduction of modern imaging methods based on catheters, such as angiography and intravascular ultrasound (IVUS). These instruments give an indirect view of the heart, blood vessels, internal organs, and other parts of the anatomy to doctors, thus providing them with a wealth of information to establish a more reliable diagnosis. In addition, these devices can be equipped to remove blockages, deliver medicines, remove foreign objects, and in some cases, perform minor surgeries. A key benefit of catheters and endoscopes is that they require only a small incision, often small enough to be sealed with a simple Band-Aid rather than staples or stitches. This significantly decreases healing and rehabilitation times, and it minimizes both functional and cosmetic damage to the body. Some such procedures, including colonoscopies, are even performed on an outpatient basis. This capability can reduce the cost of installed implants by showing where a problem is located, for example, and limit mistakes by enabling surgeons to investigate organs or internal tracts prior to performing more involved and risky invasive surgeries. While endoscopes and imaging catheters open a new landscape for better diagnosis and treatment, there are several drawbacks which limit their success. First, they pose a significant risk to the patients as physicians manually guide the instruments through the digestive, pulmonary, or cardiovascular system. There is limited technology to aid physicians in this process, and, particularly with endoscopy, knowledge of human anatomy must be relied upon. While the physicians who perform these procedures are highly- trained, every patient is different and may represent a new challenge. Complications in invasive procedures often cause internal bleeding, adhesions, infections, as well as vessel wall and organ punctures. There are several common techniques used to help mitigate these risks. The first and most familiar is the use of an endoscope featuring a light and lens or camera. The instrument is guided through known internal tracts until a foreign object or tract wall damage, for example, is discovered visually. However, knowledge of what path the endoscope is following within the body, whether it is sharply bent at any point along its length, or even its precise location may be unknown. The physician can only see what is in front of the device and know only the general location of the instrument.

Physicians viewing an image from medical endoscope.

> 'For minimally invasive surgical procedures, optical shape sensors enable higher resolution instrument tracking while minimizing the complexity associated with traditional ultrasonic and fluoroscopic

The second most widely used minimally invasive surgical imaging technique is angiography, which involves the use of catheters to navigate the body. Coronary catheterization, for example, relies on radiocontrast agents paired with X-ray radiation to produce images of the cardiac system as the instrument is guided along. On the way to the target location, the technician or physician must stop periodically to release a small amount of agent and take an X-ray image to determine the catheter's location. This method complicates the procedure and extends its duration. It also increases the amount of foreign material injected into a patient's body and the doses of radiation a patient must be exposed to. Additionally, the radiocontrast agent is quickly washed away, leaving technicians with limited time to determine the position of the instrument and decide whether to proceed or backtrack. These risks and limitations remain undesirable to many.

A third but less utilized method is intravascular ultrasound (IVUS) imaging which provides the location of the entire catheter or endoscope nearly in real-time. However, this method's reliance on the reflection of high-frequency sound pulses from interfaces within the body has several drawbacks. These interfaces, such as those between blood and vessel or fat and organ, do not produce sufficient reflections to enable consistently clear imaging. The contrast and resolution of the images generated by ultrasonic transducers are therefore often difficult to interpret. This creates a tradeoff between spatial resolution and signal penetration depth. Because endoscopes and imaging catheters are very thin and follow complex paths, multiple transducers, or sensors, must be used and constantly adjusted to obtain a meaningful image of the instrument. This adds to the complexity and duration of the procedure.

Medical Endoscope.

Sensuron's RTS125 Fiber Optic Sensing System

The advent and development of continuous fiber optic sensors based on Fiber Bragg Gratings (FBG) can aid in navigating and positioning endoscopes and catheters by overcoming several of the shortcomings of traditional methods. Optical shape sensors are very small in diameter (280 microns) and chemically inert, which allows them to be integrated with existing minimally invasive technologies. These sensors are unique in that they can sense in a spatially continuous manner, providing information about the location of the entire length of the instrument without the use of X-rays or ultrasound. The data they generate can be plotted in real-time and displayed visually on a monitor to show the position of the instrument. This image can also be compared to known coordinates of locations within the body, enabling physicians to pair the visual reference from the tip of an endoscope with knowledge of how and where the rest of the instrument is positioned. This improved positional awareness can help with real-time guidance of the instrument, eliminate the injection of foreign chemicals into a patient's body, and do away with radiation.

Improving medical techniques while also driving down costs and reducing risks are all key metrics in the testing and adoption of new medical technologies. This is exactly what is attractive about medical instruments equipped with optical shape sensors. For minimally invasive surgical procedures, optical shape sensors enable higher-resolution instrument tracking while minimizing the complexity associated with traditional ultrasonic and fluoroscopic methods. This equates to reduced risk of complication during procedures, quicker recovery, and thus better long-term health for patients. Meanwhile, physicians and technicians will see improvement in the quality of their diagnoses when using optical shape sensing instruments, providing higher fidelity real-time information. New instruments and procedures utilizing fiber optic shape sensors will ensure that skilled physicians