Medical visualization technologies: 3D Endoscope

Dr. Euan Morrison

Taking a deeper dive into some of the specific technologies that have improved medical visualization and as a follow up to my post titled Medical Visualization Technologies [1], here is an overview of how the 3D endoscope in particular has promoted these advances.

The 3D Endoscope:
The development of 3D video endoscopy can be traced back a couple of decades. This began with the emergence of high resolution, high quality video imaging chips enabling 3D visualisation to be achieved by viewing the endoscope image not directly, but via two independent displays. These displays were viewed by the users' left and right eye either through head up displays or other custom designed 3D viewers. At the time, several academic and industrial research groups demonstrated the principle of the technique without much commercial success.The increased cost of these displays, in addition to the dual channel imaging devices and optics, outweighed the benefit of the 3D visualisation. Recently; however, 3D display technology has become widespread with the launch of 3D HD TV, the result being a range of new 3D endoscope products entering the market.

Today, 3D endoscopic visualisation is seen as one of the key enabling technologies for surgical robotic systems, such as the DaVinci robot from Intuitive Surgical. In robotic surgery the surgeon is usually sitting at a workstation remote from the surgical site, manipulating the robotic tools through a computer controlled user-interface. While robotic surgery presents a number of advantages in terms of the precision of control of the surgical instruments and the ability to perform intricate surgery with minimal tissue damage, the electromechanical manipulation of the surgical tool means that the surgeon no longer has a direct physical sensory link between his hand and the surgical tool. This lack of direct sensory feedback is compensated to some extent by introducing 3D visualisation using a specially modified endoscope. The restoration of 3D visualisation in this example enables the surgeon to perform intricate surgical tasks which would prove difficult using a conventional 2D instrument.

How does a 3D endoscope work?

In reality, much in the same way as the human visual system.In the case of the endoscope, rather than using a single optical channel as in a classical 2D system, a pair of parallel optical channels are used to generate two images of the surgical site from two slightly different perspectives. These images can be relayed to an appropriate 3D display – either a pair of conventional 2D displays viewed separately by each of the surgeon's eyes – or a single 3D display viewed by the user through a viewer or pair of 3D glasses. The optical technology used in most 2D and 3D endoscopes is based on a breakthrough developed by the British Physicist, Harold Hopkins, in the 1950's. Hopkins invented the rod lens relay system that allows high quality optical images to be transferred from the main imaging lens at the tip of the endoscope, inside the body of the patient, back to an eyepiece at the proximal end of the endoscope so that it can be viewed comfortably by the surgeon. This imaging system superseded the coherent fibre bundle imaging systems that suffer from poor resolution. The breakthrough Hopkins made was in his use of a series of glass rod relay lenses to transfer the image from the distal to the proximal end of the scope. Using rod lenses, rather than conventional miniature lenses enabled the optical relay to be made from (easy-to-assemble) glass rods which are naturally easier to align and assemble, significantly simplifying manufacture and production. This solution proved so successful that it is still the basis of high quality optical scopes today. Manufacturing stereoscopic pairs of these systems is relatively straightforward and indeed stereo endoscopes for direct visualisation have been on the market for a number of years and are used in microsurgical applications such as transanal endoscopic microsurgery. However, it has been the technological advances in digital imaging and high resolution display technologies, driven by the consumer electronics market, which has seen the recent upsurge in interest in 3D visualisation.

Dr. Euan Morrison is the head of advanced optical & lighting technologies at Sagentia *[2], a technology and product development company. Please stay tuned for his next blog post on the topic of LED surgical lighting.*

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