Medicine over the past decades has undergone significant changes. In particular, surgery has become increasingly more technology based due to advances and rapid developments in device technology and computer graphics. Minimally invasive surgery (MIS) has revolutionized surgery introducing optical systems and small surgical instruments. In computer graphics Virtual Reality (VR) allows a more intuitive interaction with three-dimensional (3-D) computer generated environments. Furthermore, Augmented Reality (AR) provides a real-time overlay of reality with digital information. This transformation opens up new opportunities for diagnostics, medical education, preoperative planning and intraoperative support. The traditional see one, do one, teach one educational environment has now changed to simulation-based training where sophisticated surgical procedures can be planned and rehearsed in a safe virtual environment before the patient enters the operating room (OR). In the operating theatre the surgeon's abilities can be enhanced by superimposing computer generated information on the real patient resulting in better navigation and higher precision of the surgical intervention. With the increasing role of quality management and certification in the health care system, medical simulation can lead to improved quality of care and patient outcomes becoming an integral element finally.

Rapid developments over the last 20 years have significantly influenced surgery. More changes will inevitably emerge in the coming years. Surgery will become increasingly technology based. Two essential developments which have occurred in different domains, namely computer graphics and surgery, form the basis for the topic of this chapter.

In computer graphics, virtual reality (VR) techniques introduced a new dimension in the man–machine interface. VR allows more intuitive interaction with the computer and an immersive and realistic presentation of three-dimensional (3-D) computer-generated worlds using novel input and output devices. This paradigm shift has the potential to simulate processes in such a way that the user has the feeling that he is interacting with the real world.

In surgery, the paradigm shift happened through the transition from open surgery to minimally invasive surgery (MIS), which has revolutionized surgery. MIS has developed into an indispensable diagnostic and thera-
Minimally invasive surgery includes surgical techniques that use optical systems to inspect cavities of the human body and small instruments to perform surgical procedures. An endoscope, with optics and light source, and other miniaturized instruments are inserted into the operative field through small incisions. With the surgeon holding the optical system with the video camera in one hand and watching the operative field on the monitor, the other hand is free to guide either a probe or a small surgical instrument.

### 63.1 Virtual Reality

Whereas traditional surgery allows guidance of instruments through direct visual control (one axis, eye to hand, and instrument to patient), endoscopic techniques require the coordination of two axes (eye to monitor and hand, instrument to patient). This coordination technique is called triangulation. Besides this triangulation, endoscopy requires further skills; most surgical procedures can be performed with one dominant hand performing the critical parts of the procedure, but endoscopy requires true ambidextrous activity. A further feature of minimally invasive surgical procedures is the loss of direct contact between the surgeon’s hand and the actual operative field. The surgeon does not directly touch the anatomical structures. Rather, he/she manipulates these via various surgical instruments.

### 63.2 Medical Applications

The use of computer graphics has opened up new possibilities in medicine. At the beginning of the 1990s, Satava envisioned a paradigm shift in surgical training due to emerging virtual-reality-based medical simulators [63.1–3] (Fig. 63.1). Surgical education is not about training surgeons over a specific time span. Surgical