Medical Robotics and Computer-Integrated Surgery
Russell H. Taylor
The Johns Hopkins University, United States of America

The impact of Computer-Integrated Surgery (CIS) on medicine in the next 20 years will be as great as that of Computer-Integrated Manufacturing on industrial production over the past 20 years. A novel partnership between human surgeons and machines, made possible by advances in computing and engineering technology, will overcome many of the limitations of traditional surgery. By extending human surgeons’ ability to plan and carry out surgical interventions more accurately and less invasively, CIS systems will address a vital national need to greatly reduce costs, improve clinical outcomes, and improve the efficiency of health care delivery. As CIS systems evolve, we expect to see the emergence of two dominant and complementary paradigms: Surgical CAD/CAM systems will integrate accurate patient-specific models, surgical plan optimization, and a variety of execution environments permitting the plans to be carried out accurately, safely, and with minimal invasiveness. Surgical Assistant systems will work cooperatively with human surgeons in carrying out precise and minimally invasive surgical procedures. Over time, these will merge into a broader family of systems that couple information to action in interventional medicine.

The overall information flow associated with CIS systems is illustrated in Figure 1. These systems combine images and other information about an individual patient with “atlas” information about human anatomy to help clinicians plan how to treat the patient. In the operating room, the patient-specific plan and model are updated using images and other real-time information. The system has a variety of means, including robots and “augmented reality” displays to assist the surgeon in carrying out the procedure safely and accurately. The same technology will be used to assist in subsequent patient follow-up and in enabling statistical quality control to help improve the overall efficacy and safety of surgery and interventions.

CIS research inherently involves three synergistic areas: a) modeling and analysis of patients & surgical procedures in order to support more effective planning, execution assistance, and follow-up of surgical procedures; b) interface technology, including robots & sensors, connecting the “virtual reality” of computer models and surgical plans to the “actual reality” of the operating room, patients, and surgeons; and c) systems science to develop improved techniques for ensuring the safety and reliability of systems, for characterizing expected performance in the presence of uncertainty, for analysis of how subsystems and components will interact, and for system performance validation. Examples are shown in Figure 2.

This talk will explore these themes, with examples drawn from our own research and elsewhere.
Speaker Biography: Russell H. Taylor

Russell H. Taylor received a B.E.S. degree from The Johns Hopkins University in 1970 and a Ph.D. in Computer Science from Stanford in 1976. He joined IBM Research in 1976, where he developed the AML robot language. Following a two-year assignment in Boca Raton, he managed robotics and automation technology research activities at IBM Research from 1982 until returning to full time technical work in late 1988. From March 1990 to September 1995, he was manager of Computer Assisted Surgery. In September 1995, Dr. Taylor moved to Johns Hopkins University as a Professor of Computer Science, with joint appointments in Radiology, Surgery and Mechanical Engineering. He is also Director of the NSF Engineering Research Center for Computer-Integrated Surgical Systems and Technology. Dr. Taylor has a long history of research in computer-integrated surgery and related fields. In 1988-9, he led the team that developed the first prototype for the ROBODOC® system for robotic hip replacement surgery and is currently on the Scientific Advisory Board of Integrated Surgical Systems. At IBM he subsequently developed novel systems for computer-assisted craniofacial surgery and robotically-augmented endoscopic surgery. At Johns Hopkins, he has worked on all aspects of CIS systems, including modeling, registration, and robotics in areas including percutaneous local therapy, microsurgery, and computer-assisted bone cancer surgery. He is Editor Emeritus of the IEEE Transactions on Robotics and Automation, a Fellow of the IEEE and the AIMBE, and a member of various honorary societies, panels, editorial boards, and program committees. In February, 2000 he received the Maurice Müller award for excellence in computer-assisted orthopaedic surgery.