Institute for High-Dimensional Medical Imaging

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General Summary

The goal of our research is to develop new imaging systems that can be applied to clinical medicine now and in the future. High-dimensional, i.e., 3-dimensional (3D) and 4-dimensional (4D), imaging techniques have enabled noninvasive, realistic, uninhibited, and accurate observations of human spatial structures and their dynamics. The availability of real-time imaging using high-performance computers and medical virtual reality systems has expanded the possibilities for diagnosis, treatment, surgery, and medical education. The Institute for High-Dimensional Medical Imaging has therefore has established a system that facilitates cooperative research and development with international researchers and organizations.

Research Activities

Clinical application of high-dimensional medical imaging with real-time imaging techniques

The purpose of this project was to develop and clinically apply high-dimensional medical imaging with noninvasively obtained functional and morphological data of a living human. In this project, research was focused on developing an analysis system for real-time 4D ultrasonic images and a 4D dynamic visualization system for cardiovascular medicine. Clinically applicable methods of high-dimensional imaging were developed in collaboration with various departments of The Jikei University School of Medicine and with the Mayo Clinic (Rochester, MN, USA).

Development of a data-fusion system for image-guided surgery

A data-fusion system that enables surgeons to observe the inner structures of the surgical field during operations and data-fusion systems for laparoscopic surgery and robotic surgery have been developed with this project. A "video see-through" navigation system with a C-arm-mounted computed tomography scanner has been developed for a high-tech navigation operating room at Daisan Hospital. This year, the video see-through navigation system was applied to 2 liver operations and 1 vascular surgery operation in collaboration with the Department of Surgery.

Development of a temporal-spatial human motion-analysis system based on measurements of unrestrained whole-body movement

The research focused on temporal-spatial measurements of the whole human body in motion and the temporal-spatial quantitative analysis of motion. The whole-body movements of a subject were measured and volumetrically rendered with 3D models that were reconstructed from magnetic resonance data by means of a dynamic spatial video camera developed by the High-Tech Research Center Project. A new technique was developed to visualize the dynamics of a patient-specific 4D skeletal system using a standardized human skeletal model and a 4D patient-specific body-surface model. We are aiming to improve the speed and accuracy of analysis for efficient application of the system for orthopedics, rehabilitation, and sports medicine.

Development of an endoscopic robot system

An endoscopic robot has been developed to overcome difficulties that occur during endoscopic mucosal resection: limited degrees of freedom, wound-closure area, and forceps-permitted torque. The robot was also built to extend the operative field for at-once safe resection of a lesion and closure of the mucosal wound within a broad area. In addition to endoscopic mucosal resection, natural orifice transluminal endoscopic surgery (NOTES), a new surgical method that penetrates the stomach wall for access to abdominal organs, was attempted. The robot consists of a stereoscopic endoscope and two manipulators. We also attempted to use the robot for vascular surgery. Several new mechanisms were developed to ensure a clear view within blood vessels, and intraoperative navigation with 4D ultrasonography was achieved this year.

Development of a surgery-simulation system and its use for laparoscopic surgery

A surgery-simulation system for laparoscopically assisted colorectal surgery has been developed in collaboration with the Department of Surgery. The system allows the spatial distribution of blood vessels to be visualized and their positions relative to other organs to be recognized. We intend to use this system for surgical training and for the preoperative planning of surgical procedures. With this system, the surgeon can manipulate patient-specific organs as elastic models and can perform simulations interactively in real-time. This year, the system was applied to the preoperative simulation of laparoscopically assisted colorectal surgery with the consent of our university's ethics committee. With this system, the range of lymph node removal and the vessels that should be processed could be decided preoperatively. We believe this system will improve the safety of surgical procedures.

Development of real-time visualization and motion-analysis system for implanted artificial joints

A real-time imaging system that can visualize the 3D location of hip joints and the skeletal system of patients and analyze their motion has been developed. This year, we developed an intraoperative pressure-measurement system for estimating postoperative hip dislocation after total hip arthroplasty. The system can be used to measure the pressure distribution of the hip joint surface during surgery. With this system, the surgeon can estimate the risk of dislocation and select the most suitable implant for each patient. This research is a collaborative study with the Graduate School of Medicine, Osaka University.

Development of a 4D human model, "Virtual Anatomia"

A 4D human model that contains the dynamics of the inner structure of the heart or the skeletal structure as well as the detailed anatomical structure of the "living human" has been developed as a collaborative work with a software company. The human model was constructed with the whole-body magnetic resonance data set of a healthy volunteer and contains 421 parts, including the skeletal system, internal organs, and the vascular system. The model enables the structure of the entire body to be interactively visualized and analyzed in the virtual environment from any point of view. Furthermore, this 4D models allows the real-time observation of the inner structure of the beating heart and the analysis of the dynamics of the whole-body skeletal system.

Publications

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