Part 2

Humanoid Robotics I
Session Summary

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For a long time, the human-shaped robot has been considered the ultimate goal of robotic system development. One of the earliest humanoids was developed by Professor Kato and his group at Waseda University. Many other groups also attempted to build biped walking robots during the 1980s. In 1996, the announcement of a complete humanoid model “P2” by Honda opened a new era for humanoid R&D. Its well-designed appearance and stable walk gave a kind of shock to researchers who had attempted to build similar walking machines, and discouraged them to compete with Honda. However, at the same time, new challenges of humanoid R&D began. Japanese METI launched the Humanoid Robotics Project to provide technical infrastructures for developing a new humanoid platform and to seek practical applications of humanoid robots. Universities have joined in developing humanoid robots for fundamental research, while companies are introducing humanoid or home robots into the marketplace. Now, robots are not only objects to be built, but also tools to be used for studying humans and robots. We can view a humanoid as a human-shaped robot, but also, we can recognize the humanoid as novel computing machinery, which can not only compute, but also behave. We are obtaining a powerful new tool for the experimental study of behavior of humans and robots.

This session focuses on recent development of human-shaped robots and includes the following four papers. Kuniyoshi presents the ETL-Humanoid: a research vehicle for open-ended action imitation. Kagami introduces the University of Tokyo’s humanoid H6 and explains its low-level autonomy. Hirukawa reveals the software of the HRP project: “OpenHRP”, which was developed as an open architecture for humanoid robotics platforms. Lastly, Inaba reports a novel approach to humanoid hardware design that includes a spine structure as a backbone, and tendon drive actuation.

Imitation is a very familiar phenomenon to all of us humans. Children often imitate the behavior of their parents or the figures shown on TV. Adults also imitate others in more subtle ways. For example, when we attend a fancy dinner, we often take a glance at attendees sitting nearby, and imitate their manner so as not to offend the others. We also occasionally acquire the styles or habits of someone we respect or love, without being aware of it. Currently, the study of imitation is growing in a variety of fields, since imitation is related to, and binds together, the fundamental issues in human intelligence such as sensory-motor integration, category generation, contextual information processes, memory, learning, understanding of self and other agents, and social intelligence. The capability of action imitation constitutes a fundamental basis of higher human intelligence. Kuniyoshi first analyzes the concept.
of imitation and discusses the essential problems underlying imitation. He takes a synthetic approach to understanding imitation capabilities, which requires a versatile humanoid robot platform. An overview of his group’s full-body humanoid robot system is presented, along with their early experiments on behavior imitation with the humanoid. The robot can continuously interact with humans through visual, auditory and motion modalities in an unmodified everyday environment. For example, when a person approaches the robot showing a dual-arm motion, the robot spontaneously begins to copy it.

Kagami presents the low-level autonomy of the humanoid robots H6 and H7, which were developed by a group at The University of Tokyo. The low-level autonomy of a humanoid is divided into the following three categories: 1) walking functions such as online compensation of dynamic balance and online generation of walking trajectories, 2) manipulation functions such as arm motion planning and 3D vision based interactive planning, and 3) human interaction such as human identification and tracking, face recognition, voice recognition, and speech synthesis. For bipedal locomotion, an overview of an autonomous walking system is explained using a log-scale cycle-layered design. The layers include, online ZMP compensation, dynamically-stable walking trajectory generation with self-collision checking, and footstep sequence planning. For object manipulation, three software modules are discussed. They are: the auto-balancer for dynamically-stable standing motion generation, collision-free arm motion planning based on RRT (Rapidly-exploring Random Tree) method, and full-body dynamically-stable motion planning. For autonomy in human interaction, an experimental implementation of 3D-vision based human identification, face recognition software, and a natural language interface are explained. Integrating all of the above components, several interesting experiments are introduced.

Hirukawa presents an open architecture humanoid robotics software platform (OpenHRP for short) upon which various building blocks of humanoid robotics can be investigated. OpenHRP is a virtual humanoid robot platform with a compatible humanoid robot, and consists of a simulator of humanoid robots and a motion control library. OpenHRP also has a view simulator for humanoid robots with which humanoid vision software can be studied. The simulator is built on CORBA, which is a standard, interoperability software architecture. The real-time controller of the robot is run using ART-Linux, which is a real-time extension of Linux. Because of the unification of the controllers, and the consistency realized between the simulated and real robots, OpenHRP is a useful virtual platform for humanoid robotics on which various fundamental technologies can be developed. The virtualization of the platform is very important in order to inherit the software resources from one hardware instance to another very efficiently. Hirukawa stresses that OpenHRP will be a common software basis and is expected to become a standard software platform for humanoid research and development.

Inaba reports his novel challenge to build a humanoid with very complex physical structure and a massive parallel information network. The basic idea offers a new design scheme to realize whole-body limberness in a humanoid body. The de-
developed humanoid “Kenta” has a flexible spine consisting of nine vertebrae, which form an S-curve spine like that of humans. The torso form is controlled by 40 motor-driven wires with tension sensors. The arm consists of two ball joints at its shoulder, an elbow joint, and a wrist ball joint, which are controlled by 14 wire-muscles. The leg consists of a hip ball joint, a knee joint, and an ankle ball joint, and is controlled by 10 wires. The neck is controlled by 6 wires. In order to sense and control a whole-body humanoid, 45 microprocessors (28 for 94 wire-muscles with tension sensors, 13 for 60 tactile sensors, 2 for acceleration sensors, 2 for communication hubs) are networked inside the body. Inaba stresses the importance of brain research for whole-body limberness of physically complex structures. Thus, he developed Kenta to implement evolitional humanoid software on a massive parallel sensor-motor system like a human body.