QRIO: A Small Bipedal Entertainment Robot

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Human beings tend to be stimulated by seeing and having contact with human-like figures. Therefore a humanoid robot, which has a human-like form and behaves autonomously like a human being, can attract people's attention more than any other previous products and is beginning to create new values in the fields of art and entertainment. The SDR (Sony Dream Robot) project developed a small bipedal entertainment robot, QRIO, and has been working on exploiting this new field of robotics from two key points of view: "motion entertainment" and "communication entertainment." Regarding motion entertainment, we have been developing QRIO's ability to perform a variety of dynamic human-like motions to entertain us. As for communication entertainment, we have been working on the technology for giving it a personality through increasing its recognition and interaction abilities.

The SDR project started in 1997, and SDR-3X, the prototype of Sony's humanoid robot, was released in November 2000. It introduced the integrated robot actuator ISA (Intelligent Servo Actuator), which was newly developed to enable a high power/weight ratio and integration of a motor, reduction gears, and controllers into one module. We achieved dynamic bipedal walking using motion patterns calculated off-line based on a ZMP (Zero Moment Point) stability criteria, some gymnastic motions on the floor, para-para dances (Japanese modern dance with quick steps), football performances using monaural vision, and operations via simple voice commands.

SDR-4X, which was released in March 2002, is an advanced model that can adapt its performance to its environment and situations found in the home. Richer communication with people was also achieved by a variety of sensor systems and recognition technologies. While improving the output performance of ISA, a newly developed "Real-time Integrated Adaptive Control System" controls the joints based on information from various sensors including accelerometers, gyros, and force sensors. It enables a stable biped walk on irregular terrain and posture retention under external pressures. In addition, it can also achieve more flexible walking by real-time production of walking patterns in accordance with various situations. A micro-stereo vision system in its head can measure the distance to an object by processing the parallax of two cameras. It allows the robot to automatically produce a route in order to avoid obstacles. The SDR-4X can also recognize individuals by frontal facial images captured by these cameras. It can detect sound sources and recognize an individual speaking by utilizing seven microphones in its head. By inputting music and lyrics data into the robot, it can also produce a singing voice with vibrato through voice synthesis.

SDR-4X11, which is an enhanced version of SDR-4X, was released in March 2003, and its safety capabilities were improved. It can cope with one of the most important issues in biped walking robots—falling over. In case it is faced with a fall-over situation, it detects the fall-over direction, takes a protective posture depending on the direction while making its joints flexible to reduce damage. If something gets trapped in the moving parts, touch sensors distributed over the body can detect the situation, powering down the torque of actuators to a safe level. In the same way, touch sensors on the grip at the collar of the robot detect if it is lifted. SDR-4X11 is also equipped with recovery functions from these irregular situations. As

for intelligent capabilities, functions for map-building, identifying its location, and onboard recognition of large vocabularies were introduced.

In September 2003, SDR-4X11 was renamed QRIO, which stands for "Quest for Curiosity." QRIO was introduced to the public as Sony's Corporate Ambassador and symbolizes Sony's continuous quest and curiosity for technological innovation.

In December 2003, an enhanced QRIO capable of integrated motion control for walking, jumping, and running was announced. Control theory beyond the standard ZMP stability criteria was developed to cope with motions including flight phases, which make QRIO the world's first running humanoid robot as recorded in the *Guinness Book of World Records* 2005. At the same time, its hands are redesigned to grasp objects.

In September 2004, an enhanced control system for a biped walk called "Natural Gait Control" was announced, which allows QRIO to walk using the edges of its soles to achieve more natural and human-like gaits with a wider stride and a faster pace. At the same time, the path planning ability was improved to cope with 2.5D maps, which enabled going up and down stairs autonomously. In October 2004, the control system for roller skating was also announced.

QRIO has been performing a significant role as a corporate ambassador at innumerable events. QRIO is also serving as UNESCO's science messenger and promotes curiosity about science and a love of peace in children all over the world. Through these activities, there has been a tremendous public response to our entertainment humanoid robots. Although we have no business plan for commercializing it at this moment, we'll continue to consider the possibility.

Keywords:

ZMP (Zero Moment Point): That point on the ground at which the moments generated around the horizontal axes by the robot motion are zero.

Support Polygon: A minimum convex polygon that includes all the contact points of the robot with the ground.

ZMP Stability Criteria: A theorem that a motion pattern becomes dynamically consistent with the equation of motion when the ZMP calculated from it exists inside the support polygon.