

# Toyota Partner Robots

By Takagi Soya

## 1. Introduction

The Toyota Group Pavilion at the 2005 World Exposition in Aichi Prefecture, Japan, featured robot performances based on the theme “The Dream, Joy and Inspiration of Mobility in the 21st Century.” The personal mobility concept vehicle “i-unit” and the Toyota Partner Robots took center stage during the live shows. Introduced here are the musical instrument-playing robot band “Concerto” (*Photo 1*) and the bipedal passenger robot “i-foot” (*Photo 2*) which routinely amazed capacity crowds for 2,550 shows over the course of 180 days.

## 2. Robot Band “Concerto”

The virtuoso robot band “Concerto” consists of both wheeled and bipedal robots. The bipedal model can easily maneuver in a human environment to assist in a variety of tasks. Wheeled robots are beneficial in environments where high speeds and the ability to

rapidly change direction are desirable. A total of eight robots performed during EXPO 2005, playing many different instruments, including the trumpet, the French horn and the tuba.

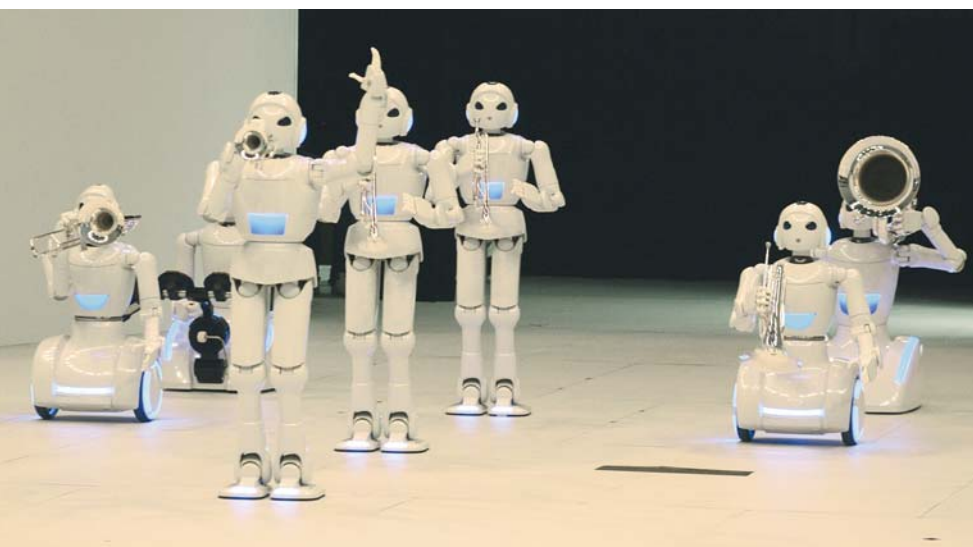
A management system was developed to monitor and control the robots during the performance shows. This system facilitated pre-show preparations such as standby mode software, battery and position control checks. The lighting, music and other stage controls were also fully integrated into the robot management system. After signaling the robots to initiate the programmed tasks, this system allowed the show’s engineers to wirelessly monitor the location and condition of each unit during the performance.

Suspension control technology utilized in the automobile industry to minimize vibration and improve riding comfort was adopted for use with the Toyota Partner Robots for stabilization control. In order to achieve reliable and stable motion control, it was necessary to detect the robots’ posture as

well as angular velocity and acceleration. A high-accuracy inertial force sensor was developed for this purpose, based on the human semicircular canal—the part of the inner ear responsible for maintaining balance. The result is a high-efficiency, compact and inexpensive sensor that is integrated into each of the Toyota Partner Robots used throughout EXPO 2005, including the wire-driven model that was on display at the Toyota Group Pavilion exhibit.

Another innovation unique to “Concerto” is the artificial lips essential for performance with the brass instruments. A diaphragm was used to reproduce the vibration of human lips; when coupled with the robots’ finger dexterity, the instrument produced a delicate timbre tone. Bearing in mind that the ultimate goal of the Toyota Partner Robots is to assist in various aspects of daily life, the ability to manipulate tools with the same ease of a human is paramount. Therefore, great emphasis was placed on the

Photo 1



Robot band “Concerto”

Photo 2



Bipedal passenger robot “i-foot”

development of lithe arm and hand movements (*Photo 3*). Consequently, the success of the Toyota Partner Robots to perform at a concert level is considered a milestone in robot advancement.

### 3. Bipedal Passenger Robot “i-foot”

The two-legged “i-foot” is a personal-use passenger robot that can move seamlessly between indoor and outdoor settings, an attribute Toyota calls “3-D mobility.” The robot has a peculiar knee joint assembly that causes the legs to rotate opposite that of humans, similar to the legs of a bird. As a result, the passenger seat can be lowered close to the ground for added stability, and thus facilitates mounting and dismounting of the robot (*Photo 4*). Interestingly, “i-foot” was not originally part of the Partner Robot development plan; instead, it evolved as a pet project of the younger engineers on the team. Part of the “Gundam generation,” these engineers were inspired by a long-running animation series from the 1970s starring human pilot-controlled robotic exoskeletons. The

mechanisms seen throughout the series definitely had an influence on the concept and design behind the robot that would later be known as “i-foot”.

The ability to ascend and descend stairs—a feat that had long presented a challenge to mobile robotics—was added to the revolutionary walking technology already implemented on the other Toyota Partner Robots. Mounted on the right armrest is an innovative joystick-style Human Machine Interface (HMI) that allows the user to intuitively control the speed and direction of “i-foot”.

Dedicated to promoting “safety first,” “i-foot” is loaded with numerous safety features to protect the passenger and others in the robot’s vicinity. A rear camera analogous to those found in automobiles checks for the presence of people, cars or other obstacles when walking in reverse (*Photo 5*). In the unlikely event that the robot was to collapse, the eggshell-shaped frame has been engineered to significantly reduce the impact to the passenger. This “Shell-on-Legs” design was verified through rigorous computer-aided engineering (CAE) simulations and real-world crash analyses.

### 4. Summary

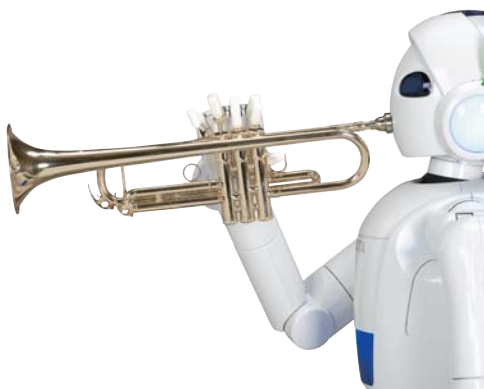
From the motors, amplifiers, sensors and other hardware components to the walking control, performance algorithms and robot management software, the Toyota Partner Robots represent the synthesis of the diverse technological strengths of the Toyota Group.

For Japan, a declining birthrate coupled with an aging population is expected to result in a dangerously low labor force and shortage of proper welfare and nursing for the elderly in the surprisingly near future. Consequently, robots are expected to help reduce the burden on a strained society. Toyota anticipates that robots will be integrated into many aspects of daily life, contributing in such areas as personal assistance, manufacturing, welfare and mobility.

Driven by the dream to help usher in a new society in which humans and robots will coexist, Toyota remains dedicated to continued development of the Partner Robots. **JS**

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*Photo 3*



*The hand of a partner robot, holding a trumpet*

*Photo 4*



*Bird-like legs of “i-foot”*

*Photo 5*

*Photos: Toyota Motor Corp.*



*“i-foot” Human Machine Interface (HMI)*