# Discussion

## Satoshi Kagami

**Q:** If you put a lot of efforts into constructing a human hand, it could walk and could do everything what your humanoids were intended to design for manipulation and locomotion. It reminds me of the hand in the Adams family movie. The hand but can walk, climb, manipulate objects, and so on. What do you think about this?
**A:** Yes, I see your point. For example, mechanical engineers in the robotics field are working on a simpler mechanism that can walk and manipulate objects. Humanoid robots tend to have more than 30 DOFs, but their proposed mechanism has only 14 DOFs. Even wheels are the most efficient way of moving in many cases, and specialized tools are the most efficient way of handling special purpose objects. Functionally, such a design will work for exploring other planets or other nonhuman environment. However, I believe human shape is one of the keys to adapting in a human environment. In that case nothing should be changed for robots, so robots can move and manipulate any object that is designed for human beings. Thinner and lighter is better in terms of safety, but smaller doesn't make sense for this purpose.
By the way, designing and developing a hand equivalent to the human hand is the most challenging and difficult problem in my opinion. The human hand has 28 DOFs together with millions of tactile sensors in a small space. It can do very precise task, yet it can hold a hanging human body by itself. Current technology can't achieve this. As I said, humanoid robots have about 40 DOFs, so I can build a 1.5m size hand with tactile sensors, but a 20cm hand is really challenging. It'll take another 10-20 years to reach that stage.

**Q:** It takes a long time for children to learn something -- they must do it ten or a hundred times. However, they grow by learning about the environment. Do humanoid robots have this ability?
**A:** There is no concept of conceptual learning in my robots; it's completely programmed. For example, in kicking a ball, only the right leg is programmed to kick a ball. That is not a limitation of the robot but just that the programmer was lazy. There are many automatic parameter tuning programs working, and they are necessary to adapt to the environment and changes of the body in that space. However general purpose learning has not yet been achieved. The search space of the real world is too huge, and there is no good way to explore that space efficiently. That is very difficult. Professor Schaal, who is the next speaker, is a specialist in learning, so perhaps he can answer this question.

**Q:** You mentioned humanoid robots that work in the human environment. For example, handling some object may require some specific action, otherwise it can be very strange. What do you consider the model and intelligence required for that purpose?
**A:** Very good question. If a robot tries to carry a cup of glass filled with water, it must know that the cup should not turn over or it should walk very carefully. Such knowledge is quite important. Some knowledge such as dropping, colliding or such can be estimated by a physics simulator. That technology is dramatically improving. However, it is also important to model what the human world consists of and how humans handle objects. The more challenging task is directly handling a human being itself -- where to pull or push and how to lift, etc. We need a good model about the human world and human beings.

**Q:** You mentioned that your humanoid robot uses Intel Pentium processors. Is this the ultimate controller of humanoid robots? You mentioned that you are building a processor, which is quite surprising. Why aren't you satisfied with the Pentium processor for humanoid robots?
**A:** I'm afraid the detailed slide is written in Japanese. So why not Pentium? First of all it consumes too much electricity. Human being tend to consume about 100W even sleeping or walking slowly. However our humanoid robot consumes about 350W in total, but more than 100W is consumed by Pentium processors, which is too much because the battery is heavy and takes up space. Second, sensing and planning still requires more power than currently available. For example, the vision system need about 10 times or more resolution to reach what we humans have, but it requires more than 10,000 times the processing power. Fortunately, those procedures can be parallelized. Therefore, we decided to design a processor that has a high parallel computation function with a high speed network link.
The picture shows our 3rd generation system. It uses 0.13 micrometer design rule. We also are developing a real-time Linux system to work with it.

## Ken'ichiro Nagasaka

**Q:** How many people are working on QRIO? How can QRIO identify people in conducting an orchestra ?
**A:** We can't disclose the precise figure. While conducting an orchestra, QRIO doesn't recognize people. They just follow his motions.

**Q:** What kind of functions are required in addition to the current ones?
**A:** There are still a lot of issues to be solved. For example, developing a head that shows a lot of facial expressions will be important to achieve richer communications with humans.

**Q:** What's the difference between the three kinds of ISA?
**A:** ISA-MH is for high-torque and low-frequency applications. ISA-S is for low-torque and high-frequency applications. ISA-M is for an intermediate use.

**Q:** What applications other than entertainment are you considering?
**A:** For the time being, we aren't thinking of any other applications.

**Q:** Why don't you use an ASIC instead of a FPGA for image processing?
**A:** There's the possibility of changing the stereo vision algorithm because QRIO is just a prototype and still in the development phase.

**Q:** How easily scalable are robots?
**A:** There are a lot of difficulties in terms of hardware design to make robots scalable. The applications themselves also seem to be different between large and small humanoid robots.

**Q:** Are you thinking of commercializing QRIO?
**A:** QRIO is a prototype and not a product. For the time being, there are no plans for it to be commercialized. We will continue to focus on its appeal as Sony's symbol of technology.

**Q:** Are the devices used for QRIO SONY's original devices?
**A:** Basically, core devices are made at SONY. However, standard devices available on the market are also included in QRIO.

**Q:** What is your opinion of cell processors?
**A:** This is a fascinating topic. We need more computational power and concurrency for more sophisticated controls and intelligence. Cell processors may be a good solution.

**Q:** What are the critical issues in manufacturing QRIO?
**A:** Sorry, we can't disclose manufacturing matters.

**Q:** What is needed to make QRIO more attractive?
**A:** Technology that maintains excitement and interest is important. To realize this, learning ability or strategies to enrich content for robotic applications, e.g., free SDKs, will be effective.