Development of Entertainment Robot and Its Future

Kohtaro Sabe
Sony Intelligence Dynamics Laboratories, Inc.
Takanawa Muse Building 4F, 3-14-13 Higashigotanda, Shinagawa-ku,
Tokyo, Japan
sabe@idl.sony.co.jp

Abstract

We have proposed the robot entertainment as an application for intelligent robotics. In order to raise this application as a new industry, the platform technology called OPEN-R has been developed at first. On this platform, Sony has developed various types of robots such as quadruped robot, AIBO and humanoid robot, QRIO. In this paper, we describe the technologies used in OPEN-R, then show what has been achieved on AIBO and QRIO. (Keywords: entertainment robot, artificial intelligence)

1. Introduction

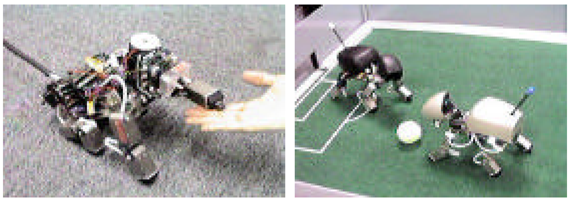
Conventional autonomous robots have been proposed for use in service and dangerous work, however major technological hurdles must be overcome before robots are viable for mission-critical operations. We have noticed that these problems are less severe for use in entertainment thus decided to make entertainment robots.

In the following sections, we describe the technologies of platform called OPEN-R, in which robot entertainment and its technical requirements are also stated. Then, technologies in AIBO are explained especially focused on behavior control methods. Then, the capabilities of humanoid robot, QRIO are described. New research activity called Intelligence Dynamics is introduced at the very end of this paper and summarized.

2. OPEN-R

The purpose of proposing OPEN-R is two-fold. First, we wish to promote research in the intelligent robotics community by providing off-the-shelf components and basic robot systems. These robots should be highly reliable and flexible, so that researchers can concentrate on the aspect of intelligence

Second, we would like to establish a new industry based on entertainment robots. To achieve these goals, OPEN-R provides a standard which can incorporate sophisticated component technologies with advanced software technology.



Pet-type robot   Game-type robot

Fig.1 Robot entertainment

2.1. Robot Entertainment

In Robot Entertainment, robots can be used for various games, as well as serve as a pet. It is unlikely that only one configuration of the robot can cope with a broad range of situations and needs. When people enjoy it as a pet, a possible configuration may be a legged robot with a head, just like the one we have already developed (Fig.1, [4]). However, if children want to play a fast-moving soccer game or a driving game, a wheel-based robot may be preferred. Flexibility in style is essential in the entertainment industry, where software development by third parties play an essential role.

2.2. Reconfigurable Robot Platform

In order to accumulate technologies while improving the cost performance for manufacturing robots, it is necessary to design platform as a basis, and use it for long time with patience. Through the experience of re-designing various proto-type robots from scratch, we felt that platform which is independent of robot's shape and changes in hardware specification is indispensable.

The requirements for these platform technologies beside ordinary computer architecture are listed as follows.

Style Flexibility

Style Flexibility ensures that various kinds of robots can be designed. These robots may have various sensors, such as cameras, infrared sensors, and touch sensors, as well as various motor controllers.

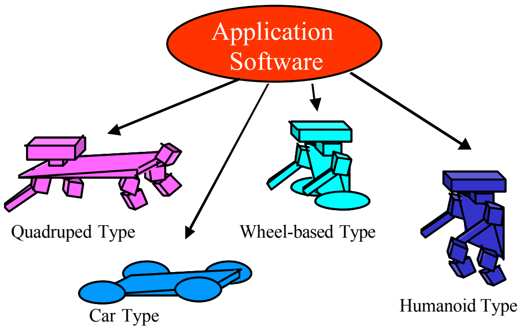


Fig.2 Style Flexibility

Fig.3 Reconfigurable physical component

Software Portability

It should be possible to build application software that runs on various styles of robots. Part of software should also be able to exchange so that combination of different algorithms from different developers can be combined to build a whole system.

The standard for the entertainment robot named OPEN-R was announced in 1998, in which features described bellow are included.

- As interfaces to the sensors and motors, OPEN-R bus was adopted.
- "Memory Stick" is adopted as memory card IF.
- PC card IF is adopted for future enhancement.
- Aperios was used for Operating System.
- Software component and communication among them are defined as well as software layers and API between them.

OPEN-R Bus is serial bus that enables installing sensors and actuators freely. The host controller of the bus handles the composition information of these devices, thus plug-in and plug-out of robotic hardware modules are supported. For OPEN-R, to change configuration of robot freely means attaching various kinds of devices on this serial bus. It is also beneficial to adopt serial bus since wiring becomes easier.

Removable medium such as "MemoryStick" is necessary for software and data exchanges. In the case of entertainment robot, size of medium and tolerance to mechanical shock are important factors.

Aperios[1] is object oriented operating system in which system treats processes as loadable components. This enables the changes in software corresponding to newly installed hardware.

As stated in classical robotics composition method,

Software is categoraized into 3 parts, Recognition, Action, and Plan. Recognition and Action parts, which are often dependent of the robot configuration, are defined as middleware layer. Plan part, which is less dependent, is defined as application layer. API is defined between these layers so that software on application layer can be used among different robot configurations.

Communication and connection methods between software processes (objects) are defined so that software can be exchanged even from one object.

We have prepared the robot hardware realizing different styles of robots by exchanging several hardware components(Fig.3). We have implemented OPEN-R system and experimented on running same application program on different configurations by automatically detecting the configuration changes of the robot and reloading parts of the software that are dependent of the robot style[3].

2.3. Wireless network and robot

After the second generation of AIBO, wireless network (IEEE 802.11b) capability was added using PC cared IF.

Since a robot is a computer that moves around, it makes best use of wireless network. Using this capability, new proposals of entertainment can be expected. For example, the application program such as AIBO Navigator that enables remote controlling of AIBO from PC and AIBO Messenger that receives e-mail and reads it using speech synthesis, were designed and sold.

Effective uses of wireless network for robot application are listed below.

Communication between robots

It enables data exchange, conversation and corporation of behaviors among robots.

Data acquisition from network

Robot can download its new behavioral patterns, contents and programs from Internet.

Personal agent

Robot can be a human interface device to control other devices on the network.

Development Environment

Remote Processing Environment

By connecting to high-end servers, robot become free of computational and memory limitations, which was limited in the case of standalone system.

3. AIBO

The first entertainment robot for home use, AIBO (ERS-110), was put on the market by Sony in 1999. All 5000 units are sold in less than no time by the order through the Internet, though they cost 250,000 yen of high price.

In figure 4, basic hardware and software specifications of ERS-110 are described.

The main characteristics of ERS-110 are 1) rich expression of motions using 18 DOF joints, 2) having 4 instincts (Appetite, kinetic drive, affection desire, and curiosity) and 6 emotions (joy, sadness, anger, surprise, fear, and dislike) to reflect their states to autonomous behaviors, and 3) functions of learning and growing.

3.1. Agent architecture on AIBO

Whether they are autonomous behaviors within the home environment or responses to human, it returns how to program mapping between sensor inputs to action outputs. For product software, which will be used for many months, it is very important to produce diversity and complexity of behaviors to avoid users from getting board soon.

In the followings, many of the techniques for the behavior control are described.

Behavior_Based Architecture

As is the case for the behavior control architecture of proto-type pet robot, MUTANT, we employ a behavior-based architecture for AIBO as well. Many different behavior modules are activated and selected by the action selection mechanism.

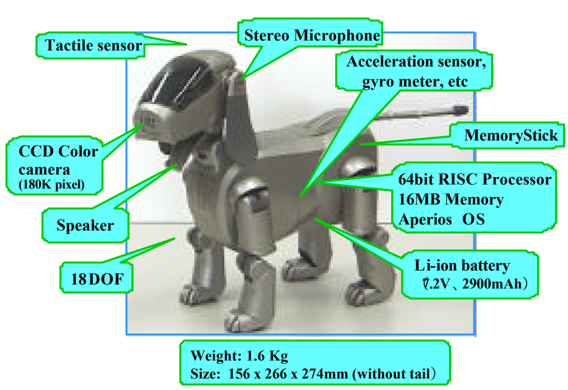


Fig.4 Specification of ERS-110

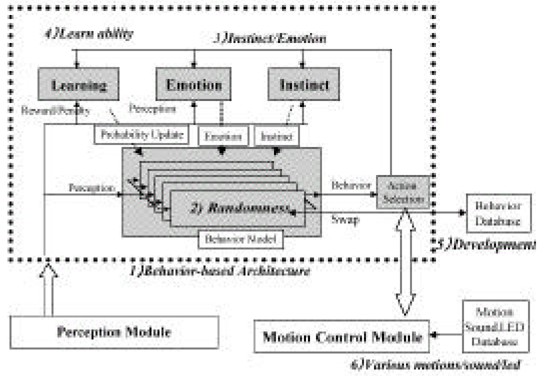


Fig.5 behavior control architecture

Randomness

Each behavior module consists of state-machines to realize a context sensitive response. The state-machine is implemented as a stochastic state-machine, which enables the addition of randomness to action generation. For example, if there is a pink ball, the stochastic state-machine can determine that a kicking behavior is selected with probability 0.4 and a pushing behavior is selected with probability 0.6. Thus, different behaviors can be generated with the same stimuli increasing the complexity of behaviors.

Instincts & Emotions

Simulating instincts and emotions generates motivations for behavior modules. The same stimuli can then generate different behaviors, which again increase the overall complexity of behavior. Of the numerous proposals put forward for emotions, we settled on six fundamental emotions based on the Ekman's model, which is often used in the study of facial expressions. These are joy, sadness, anger, disgust, surprise, and fear. Just as with the instincts, these six values change their values according to equations, which are functions of external stimuli and instincts.

Learning ability

Using the probabilities within the stochastic state-machine, we incorporate reinforcement learning in the architecture. For example, assume that when a hand is presented in front of the robot, there are several possible responses. Let's say, for example, there are 5 possible behaviors. One of the possible behaviors is the "give me a paw" behavior. At the beginning of learning, the probability for each possible behavior being manifested is 0.2. When the "give me a paw" behavior is selected with its initial probability, then the user gives a reward such as petting the robot's head. This causes an increase in the probability of the behavior from 0.2 to 0.4, and the other behaviors' probabilities decrease to 0.15. Then, if again the hand is presented in front of the robot, now the "give me a paw" behavior has a higher probability of being selected. Thus, a user can customize AIBO's response through reinforcement learning. This also increases the complexity of behaviors.

Development

Development can be considered as a slow changing of the robot's behavioral tendencies. Because we implement a behavior using a stochastic state-machine, which can be represented by a graph-structure with probabilities, we can change the graph-structure itself, so that completely different responses can be realized. So a series of discontinuous changes can be observed during the robot's development over its lifetime.

Various Motions

Finally, we implemented many motions, sound patterns, and LED patterns by the contribution of AIBO Motion Editor, the GUI tool for designing these contents. This simply increases the complexity of behaviors.

4. QRIO

Figure 6 shows a basic configuration of QRIO.

Integrated Adaptive Motion Control can be realized in real time for walking on irregular and/or tilted surfaces and retaining posture under external pressure (i.e. when pushed). Gait patterns can also be generated real-time by altering walking pace, cycle and rotating angle in accordance with the situation and environment.

With 2 CCD cameras embedded in its head, QRIO can measure the distance between itself and an object. By estimating a floor plane, QRIO can automatically calculate a route to make its way around the obstacles. 7 microphones equipped in the head make it possible for QRIO to detect the direction of a sound source.

QRIO has abilities to detect face images again a complex background and can memorize up to 10 individuals from face images and tone of voice.

In addition to short-term memory functions to temporary memorize individuals and objects, QRIO is equipped with long-term memory functions to memorize

Height: 580 mm
Weight: 6.5 Kg
DOF: 28 + 10(fingers)
Head: 4 DOF
Body: 4 DOF
Arm: 5 DOF x2
Leg: 6 DOF x2
Hand: 5 DOF x2
Actuator: New ISA
Sensors:
Stereo Camera, Microphones x 6, Speaker
CPU: 64bit processors x3
OS: Aperios
Architecture: OPEN-R

Fig. 6 Basic specification of QRIO

faces and names through more in-depth communications with people. By utilizing both short and long-term memories, the QRIO achieves more complicated conversations.

New voice synthesis engine brings the capability to produce singing voice with vibratos by inputting music and lyric data. Together with motion creation technologies, QRIO can perform beautiful synchronization of singing and dancing.

5. Intelligence Dynamics

Intelligence Dynamics is a newly proposed science that integrates the following two scientific methodologies. 1) A new type of artificial intelligence exploring emergence of intelligence base on physical embodiment. 2) A constructive approach of brain science that verifies a computational model through interaction between a robot and the real world.

To promote this activity, we connect QRIO to the PC cluster system using wireless network as its remote brain

6. Summary

We have described the Sony's development activities in robot entertainment. The progress and the technological accumulation of a past decade in this field were quite large. We started with a single embedded CPU on AIBO, now uses 352 CPU for research activity to seek for better intelligence. The amount of computation for intelligent robots seems to keep growing for a while.

7. References

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