Bartneck, C., & Okada, M. (2001). Robotic User Interfaces.
Proceedings of the Human and Computer Conference (HC2001), Aizu pp. 130-140.

Robotic User Interfaces

Christoph Bartneck[1,2], Michio Okada[3]

[1]Technical University of Eindhoven
Den Dolech 2, P.O. Box 513
5600 MB Eindhoven
The Netherlands
christoph@bartneck.de

[2]Philips Research Laboratories
Prof. Holstlaan 4
5656 AA Eindhoven
The Netherlands

[3]ATR MIC Research Laboratories
2-2-2 Hikaridai, Seika-cho Soraku-gun
Kyoto 619-0288, Japan
okada@mic.atr.co.jp

Figure 1: My Real Baby

Figure 2: Kuma

Figure 3: Tama

ABSTRACT

Currently, we are experiencing the rise of a new interface paradigm: Robotic User Interfaces (RUI). We give a structured overview of current studies and implementations in the area of RUI and discuss their dis/advantages. In particular we classify the RUIs in terms of tool – toy scale, remote control – autonomy scale, reactive dialogue scale and anthropomorphism scale. Unfortunately, many of the robots currently celebrated in the media are not particular interesting for the area of RUI because they only resemble advanced remote controlled toys.

Next we describe Muu and eMuu, two conversational robotic user interfaces developed at the Media Integration and Communications Group (MIC) of the Advanced Telecommunications Research Institute International (ATR). The research scope of Muu is dialogue coordination in mixed initiative situations with multiple participants and eMuu's scope is the communication of emotions.

We provide a short technical introduction to the robots and describe our research questions. Next we report on an upcoming experiment in which investigate user's interaction with eMuu.

KEYWORDS

Robotic User Interface, Emotions, Dialogue

INTRODUCTION

The Japanese government (Ministry of Economy, Trade and Industry) recently announced a special support program for the development of robotics in Japan. They consider it a key technology for the 21st century. The Robo Festa in Kansai [28] and Kanagawa [27], two robotic fairs, are an early result of this support program. The enormous number of visitors that these events attracted illustrates a high public interest in robotics.

Robots have been used in the production of goods for a long time. They changed the face of car production and many other industries. Another classic application of robots is tele-operations such as hazardous duties (mine rescue and survey, bomb disposal and assessment of the Chernobyl reactor) and planetary exploration, such as Nasa's Pathfinder Mission [20].

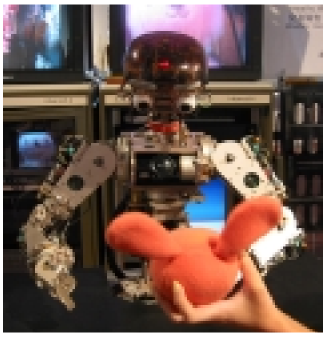

Figure 4: Infanoid

Figure 5: Seal

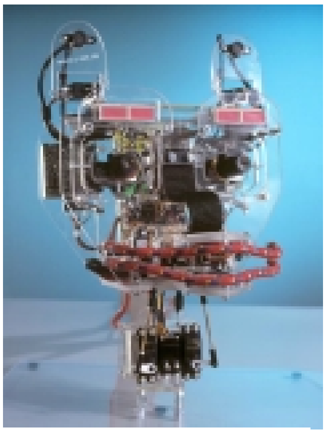

Figure 6: Mexi

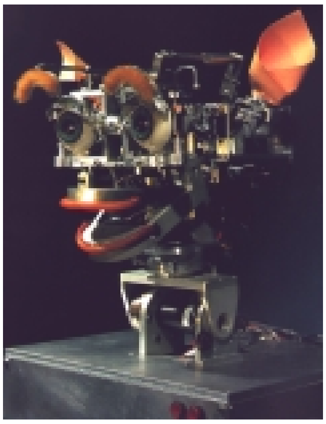

Figure 7: Kismet

Robots also found their way into the worlds of our children in the form of LEGO Mindstorms [17] and My Real Baby [15] (see Figure 1). Several robotic pets are available, such as Aibo [31] (see Figure 12). Kuma & Tama [18] (see Figure 2 and 3) were designed as companions for elderly people.

Researchers build robots to investigate human communication. In particular they investigate Pre-Verbal Communication (Infaniod [11], see Figure 4) and emotional communication (Seal Robot [33] see Figure 5, Mexi [7] see Figure 6, and Kismet [5] see Figure 7).

More recent developments are in the area of tele-presence, such as iRobot's iRobot-LE [15] (see Figure 8) and the work of Paulus and Canny [25]. The basic idea is to enable humans to participate in an event through a robotic avatar. This way you can participate in the Christmas celebration with your parents even if you are on a different continent.

Creating artificial life forms, in particular artificial humans has been a vision of human kind for ages. Honda's Asimo [12] (see Figure 9) and Sony's SDR-3X [32] (see Figure 10) bring us one step closer, at least from an engineering point of view. Making a 2 legged robot walk like a human has been a major achievement and even though these robots might not turn out to be commercially successful products, they certainly have taught us a lot about engineering and contributed to the expansion of our knowledge. Whenever we find a useful application for a robot we will know how to make it walk.

Another recent development is Robotic User Interfaces (RUI), which are the main focus of this paper. With RUI we do not mean the interface to a robot which then executes a certain action but the robot being the interface to another system. This only makes sense if the RUI is a good interface to the system in the first place. The question what systems might benefit from having an interface character (robot or screen character) in general is still ongoing and is not the focus of this paper. There are, however, studies [8, 16, 26] that suggest that the educational and entertainment domain is appropriate for interface characters. We consider the home as a promising application domain for a robotic user interface. The robot could become the "home character" and function as the interface between the user and the home. The user could instruct the character to switch on the TV in the same manner as requesting to raise the temperature in the room. NEC already offers such a robot called Personal Robot R100 [21] (see Figure 19).

We are sometimes missing a discussion of the underlying assumptions of some of these robotics applications. In the case of Kuma & Tama we wonder if it is a good idea to sell a robotic pet to lonely elderly people instead of providing them with real social contact or technology that enables them to build up relationships with real people.

Now that we have an overview of the general application fields of robots we will first describe properties which will help us to classify certain robots, then perform a survey on several robots and last describe our own research.

Figure 8: iRobot-LE

PROPERTIES OF ROBOTIC USER INTERFACES

Since the systems that the robot can be an interface to are numerous we shall rather try to categorize the robots by the following 4 properties:

Toy – Tool Scale
Remote Control – Autnonomous Scale
Reactive – Dialogue Scale
Anthropomorphism Scale

Tool - Toy Scale

The robot can either help humans to solve a certain problem effectively and efficiently or be toy to play with. In that case, the interaction might be very inefficient, but very effective in terms of its entertainment value. Using a spoon to carry an egg a certain distance might be a very inefficient way of transporting eggs, but it is very effective in entertaining us.

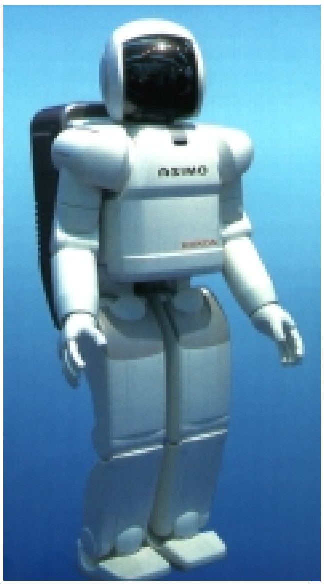

Figure 9: Asimo

Remote Control – Autonomous Scale

Many robots are remotely controlled by humans and are not able to do anything by themselves. Even so their functions may be fairly complex, they still remain only remote controlled machines and are not necessarily usable as a RUI.

Other robots are able to control their functions by themselves and do not require humans to tell them what to do. This often comes hand in hand with development of artificial life forms.

Reactive – Dialogue Scale

Some RUIs rely on reactive loops to interact with humans. A certain event, such as touching the robot creates a certain reaction, like turning around. The following interaction often follows strict turn taking patterns in which either the robot or the human fills in the role of the dialogue manager.

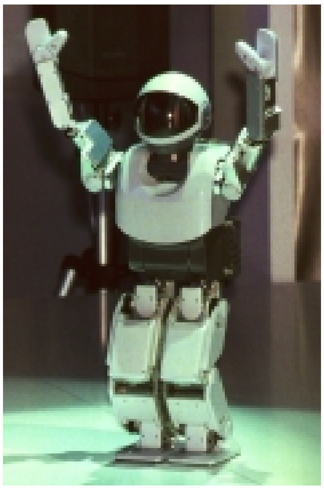

Figure 10: SDR-3X

On the other hand, dialogue systems are based on mixed initiative. Both, the user and the robot can initiate interaction and turn taking might vary through the course of the interaction. It is not bound to strict turn taking patterns. This scale can only be applied to robots that have control over their communication and do not simply have a human in the background to communicate with the user.

Anthropomorphism Scale

A robot can be more or less shaped like a human. Industrial robots look very little like humans and at the other end of the scale, Asimo [12] (see Figure 9) is shaped almost like a human.

SURVEY OF ROBOTIC USER INTERFACES

Bellow we give an overview of current robots that are often referred to as Robotic User Interfaces.

Tmsuk IV

Figure 11: TMSUK IV

This is a good example of a highly anthropomorphic and completely remote controlled robot [36] (see Figure 11). It can not be considered a RUI since only the actions of the user are mapped directly to the robot. Even though the user input device is very advanced this robot remains a novelty, since it lacks skills for industrial applications, such as hazardous duties or rescue missions. Its main application seems in the entertainment business and it has already been featured in several Japanese talk shows.

Aibo

Figure 12: Aibo

Aibo [31] (see Figure 12) was the first commercially available robotic pet. Besides entertaining the user with its behavior it can also read out webpages and emails and can therefore be considered a RUI. It is highly autonomous and with the additional "Aibo Life" program it also develops its own character and behaviors. Its interaction with humans is highly reactive. The user can initiate the interaction by giving a voice command or touching the robot, to which Aibo will react with a set behavior.

Robovie

Figure 13: Robovie

Robovie [19] (see Figure 13) is another example of an autonomous anthropomorphic robot that interacts with humans. It does not execute particular tasks but is supposed to exist as a partner in human society. It has a variety of communications skills to do so, but lacks useful functionality. Robovie cannot be considered a RUI because it does not control another system. The interaction pattern is rather reactive. Even though Robovie and the user can initiate interaction, the resulting interaction is strictly sequential.

Redbeard's Pirate Quest

Figure 14: Zowie

Zowie Intertainment developed a toy set [38] (see Figure 14), which connects the model of a pirate ship and its figures to a PC. By moving characters and objects around the playset, children experience the pirate world on the computer screen, navigating the dangers of the sea, exploring uncharted territories and battling rival pirates and sea monsters. The active parts of the playset, including the captain's wheel, telescope and cannons, are mapped to the functions of the virtual pirate ship on the screen.

Even so this set might not be a robot in the classical sense, the ship and its characters can be considered a robotic user interface to the virtual pirate world on the computer. The interaction is very much like a dialogue. Both parties can initiate interaction and the turn taking itself, such as the battle with another ship, can change very quickly.

The ship has sensors but no actuators. Therefore it is not possible to apply the Remote Control – Autonomous Scale. The characters of the ship, such as the captain, are of course highly anthropomorphic, but only the whole ship with all of its part can be considered the RUI. Therefore it is also very difficult to apply the anthropomorphic scale.

Figure 15: Gladion

Gladion

Takara developed a toy series called Web Diver [35] (see Figure 15), based on a popular Japanese TV series. Its main character Gladion, is a fearsome battle robot. By connecting the Gladion figure to a television set, the same Gladion appears on screen, and as the Gladion figure is transformed by the user, the on screen Gladion also makes the same transformation simultaneously. Depending on the transformation mode of the Gladion, various television games can be played, such as a shooting battle game and a train racing game. Moving and touching the figure controls the Gladion in the game.

Gladion is not a robot in the classical sense because it cannot move, but it has the shape of a robot. We consider Gladion a RUI, because the figure controls the actions of the TV character. The figure has sensors but no actuators. Therefore it is not possible to apply the Remote Control – Autonomous Scale. The figure itself is rather anthropomorphic and the interaction between the user and the robot is much like a dialogue, just as you would expect from a television game.

Figure 16: Sensor Doll

Sensor-Doll

ATR MIC Research developed a context aware Sensor-Doll [37] (see Figure 16) in form of a teddy. The various sensors of the doll, such as touch sensor, bending sensor and accelerometer, are mapped to a midi sound and music synthesis generator running on an external computer. This doll has sensors but no actuators. Therefore it is not possible to apply the Remote Control – Autonomous Scale. The form of the doll is on the level of a pet and the interaction is highly reactive. The doll itself cannot initiate interaction.

Figure 17: QB

QB

The Tokyo Research Laboratory of IBM created a robot named QB [14] (see Figure 17), which is based on an earlier robot named Pong [13] (see Figure 18). QB has several touch sensors and is able to drive around, move his arms and express emotions on his face. It has and a microphone and speaker including speech recognition and synthesis skills. QB acts as an intermediate between the user and the internet. It can read our emails and search for content on the internet, such as weather news, which it then reads out upon request.

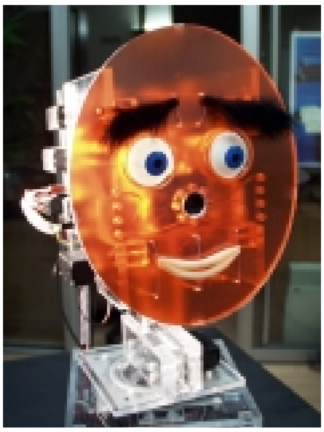

Figure 18: Pong

Since QB is also able to play games with the user it is somewhere in the middle of the toy-tool scale. It is autonomous and only needs to return to its house to recharge its batteries. The interaction is in form of a dialogue, since the user and QB can initiate interaction and flexible change roles of listener and speaker. The form of QB is anthropomorphic on the level cartoon characters.

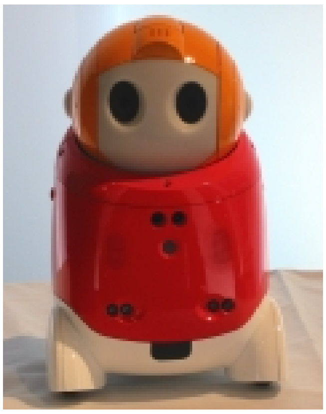

Figure 19: R100

R100

NEC developed a house robot called R100 [21] (see Figure 19), which is based on the more widely know PaPeRo robot. This robot is the most advanced commercially available RUI at this point in time. It has two cameras, microphones, and sensors for distance, touch, light and temperature. It can drive around, rotate its head, talk, listen and control household appliances, such as TVs and Video recorders. Moreover it can deliver emails and messages among the members of the household.

Since the R100 is also able to play games with the user it is somewhere in the middle of the toy-tool scale. It is highly autonomous and only needs to be recharge every 2 hours. The interaction is in form of a dialogue, since the user and the R100 can initiate interaction and flexible change roles of listener and speaker. The form of R100 is anthropomorphic on the level cartoon characters.

MUU2 AND EMUU, TWO RUI DEVELOPMENTS AT ATR

Figure 20:eMuu

eMuu (see Figure 20)

Many studies have been performed to integrate emotions into machines. Already products and studies are available which use emotions. Products range from computer games (The Sims [9]), to toys (Tamagotchi, [1]), software agents (Microsoft's Persona Project [4]) and robots (Aibo [31]). Studies covered poker playing agents [16], multi agent worlds [10, 23, 6] and robots [5, 13].

As mentioned earlier, we consider the home as a promising application domain for a robotic user interface. In our experiment, we would like to imitate such an interaction between a user and a home character. Therefore we study a negotiation task, which is a good abstraction of such an interaction. The negotiation situation is set up to allow for an integrative solution [3] and hence promote co-operation.

Though, speech is the most natural modality of interaction with such a robotic home character it is not necessary that the robotic character talks to the user. It is more important that the character listens to the user.

An important aspect of the implementation of emotional characters is not the character itself, but the technology behind it. A character based on speech technology might be very emotional, but it will still not lead to a higher user satisfaction if the speech recognition does not work properly. Therefore it is important to match the appearance and interaction of the character with the technical abilities of its host system.

We will perform an experiment with users to investigate:

- Will the user perceive the negotiation with a character more enjoyable than without a character?
- Will the user perceive the interaction with a physical character more enjoyable than with an screen character?

- Will the user perceive the interaction with a character that uses affective expression more enjoyable than with a character that does not use affective expressions?
- Does the cultural background of a user influence his/her negotiation behavior?
- Will the interaction with a character, which uses a Western European negotiation style, be perceived more enjoyable by Western Europeans than by Japanese users?

Implementation

The eMuu software consists of 3 components (see figure 22). The game engine, which implements the negotiation task, and the character engine, which controls the behavior of the character, are running on a PC using JAVA (see figure 22). The emotional reasoning is based on the OCC model [24].

The emotion engine, which controls the emotional state and the facial expression, is running on 2 LEGO Mindstorms RCX [17] inside of the robot and communicates with the PC via infrared. Since infrared communication is rather slow we limited the communication to the exchange of emotional states and behavior control. The software for the RCX is written in JAVA and runs on the leJos [30] firmware, a Java Virtual Machine for the RCX.

This architecture builds on Sloman's [29] evolutionary approach of the mind. The emotions and sensor-motoric control are in the lower part of the conscious (the processor inside the RCX) and the reasoning in the higher conscious (the PC). The outer shell of eMuu (see figure 20) is based on Muu [22] and the facial expression are based on previous work by Bartneck [2].

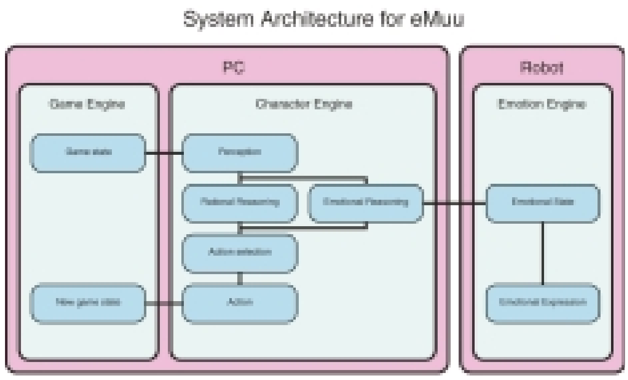

Figure 22: System Architecture of eMuu

Muu2

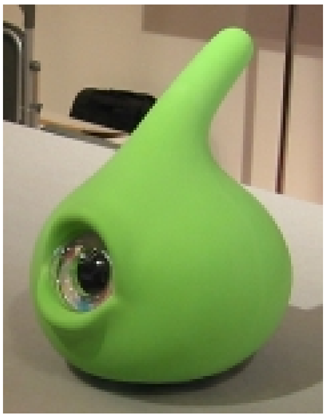

Figure 21: Muu2

Muu2 (see Figure 21) focuses on a constructive approach to the dialogue phenomena. Turn taking, social bonding and the organization of conversational sequences are of particular interest. Previous circles of modeling and evaluation include The Talking Eye Project [33]. Another area of interest is the conveyance of social presence by connecting two sets of Muu2s over a network. User A interacts with his set of Muu2s, which are mapped to the actions of User B's set of Muu2s. By observing his set of Muu2s, user B can feel the presence of User A.

A possible business application for Muu2 is foreign language learning. A student can converse with multiple Muu2s and not only learns the language, but also the appropriate turn taking and social behavior. Learning the English vocabulary and grammar, for example, is not necessarily enough for a Japanese speaker to communicate successfully in the USA.

Actuators

- Muu2 has 4 degrees of freedom. It can pan and tilt its head and control 2 wheels independently to drive around.
- 1 speaker for speech synthesis.

Sensors

- 8 optical distance sensors that operate at a range from 10-0 cm from the robot. The sensors are arranged in equal angles of 45 degree around the body of the robot.
- 1 CCD camera, which tracks the position of a human face by tracking the skin color.
- 4 touch sensors at the upper half of the robot to detect patting.
- 2 microphones for speech recognition and spatial location of the sound source.

Hardware

- The shell of Muu2 is very soft and made of ploy-urethane.
- The batteries of Muu2 enable it to operate autonomously for 1 hour.
- It uses radio waves to communicate with a PC and other Muu2s.
- The vision system and the motor control is based on a Hitachi SH4 board and the speech engine (recognition and synthesis) is based on a 2nd Hitachi SH4.

Software

The robots are able to learn communication skills by using a learning corsswire system with a genetic algorithm. All the software is written in C. The Hitachi SH4 boards run the iTron operating system.

REFERENCES

1. Bandai, 2000, 'Tamagotchi'. http://www.bandai.com
2. Bartneck, C.: 2000, 'Affective expresions of machines'. Stan Ackerman Institute, Eindhoven.
3. Beach, L.R., 1997, 'The psychology of decision making: people in organizations'. London, Sage.
4. Bell, G.; Ling, d.; Kurlander, D.; Miller, j.; Pugh, D.; Skelly, T.; Stankosky, A.; Thiel, D.; Dantzich, M.v.; Wax, T.: 1997, 'Lifelike Computer Characters: The Persona Project at Microsoft Research'. In: Jeffrey M. Bradshaw (ed): Software agents, London, AAAI Press, pp. 191-222.
5. Breazeal, C.: 1999, 'Robot in Society: Friend or Appliance?'. In Agents99 workshop on emotion-based agent architectures, Seattle, pp. 18-26
6. Cañamero, D.: 1997, 'Modelling motivations and emotions as a basis for intelligent behavior'. Proceedings of the first international conference on Autonomous agents , Marina del Rey, CA, pp. 148-155.
7. C-Lab (Siemens & University of Paderborn), 2001, Mexi - machine with emotionally extended intelligence. http://www.c-lab.de/home/de/news/2001/01-02-21-emotional_engine_lang.html
8. Doyle, P.: 1999, 'When is a Communicative Agent a Good Idea?'. In Workshop on Communicative Agents of the Third International Conference on Autonomous Agents, Seattle.
9. Electronic Arts, 2000, 'The Sims'. http://thesims.ea.com/us/
10. Elliott, C.D.: 1992, 'The Affective Reasoner: A Process model of emotions in a multi-agent system'. Ph.D. Thesis at The Institute for the Learning Sciences, Northwestern University, Evanston, Illinois.
11. Hideki Kozima: Infanoid: An Experimental Tool for Developmental Psycho-Robotics, 2000, International Workshop on Developmental Study, Tokyo
12. Honda, 2001, Asimo, http://www.honda.co.jp/ASIMO/
13. IBM, 2000, 'Pong'. http://www.almaden.ibm.com/ almaden/media/image_pong.html
14. IBM, 2001, QB, http://www.edu.t.soka.ac.jp/~toguma/qb/
15. iRobot, 2001, My Real Baby and iRobot-LE, http://www.irobot.com/
16. Koda, T.: 1996, 'Agents with Faces: A Study on the Effect of Personification of Software Agents'. Master Thesis, MIT Media Lab, Cambridge.
17. LEGO, 2001: LEGO Mindstroms website at http://www.legomindstorms.com
18. Matsushita, 1999, Tama & Kuma, http://www.matsushita.co.jp/corp/news/official.data/data.dir/en990324-2/en990324-2.html
19. Michita Imai, 2001, Robovie, http://www.mic.atr.co.jp/~michita/everyday-e/
20. Nasa, 1991, Mars Pathfinder Mission, http://mars.jpl.nasa.gov/MPF/
21. NEC, 2001, Personal Robot R100, http://www.incx.nec.co.jp/robot/english/index.html

22. Okada, M.: Muu: Artificial Creatures as an Embodied Interface, Proceedings of the ACM Siggraph 2000, New Orleans, pp. 91
23. O'Reilly, W.S.N.: 1996, 'Believable Social and Emotional Agents'. Ph.D. Thesis at the Carnegie Mellon University, Pittsburgh, PA.
24. Ortony, A.; Clore, G.; Collins, A., 1988, 'The Cognitive Structure of Emotions'. Cambridge, Cambridge University Press.
25. Paulos, E.; Canny, J., 2001, Social Tele-Embodiement: Understanding Presence, Autonomous Robots, 11, pp. 87-95.
26. Rizzo, P.: 1999, 'Emotional Agents for User Entertainment: Discussing the Underlying Assumptions'. In Proceedings of the International Workshop on Affect in Interactions held in conjunction with the AC'99, Annual Conference of the EC I3 Programme, Siena.
27. Robe Festa Kanagawa, 2001, http://www.pref.kanagawa.jp/osirase/robo/, Kanagawa
28. Robe Festa Kansai, 2001, http://www.robokansai.gr.jp/, Osaka.
29. Sloman, A.: 1999, 'Architectural requirements for human-like agents both natural and artificial '. In: K. Dautenhahn, (ed): Human Cognition And Social Agent Technology, Advances in Consciousness Research, 19, Amsterdam, John Benjamins Publishing Company.
30. Solorzano, Jose: leJOS: Java based OS for Lego RCX at http://lejos.sourceforge.net/
31. Sony, 1999, 'Aibo'. http://www.aibo.co.jp
32. Sony, 2000, SDR-3X, http://www.sony.co.jp/en/SonyInfo/News/Press/200011/00-057E2/
33. Suzuki, N.; Takeuchi, Y; Ishii, K.; Okada, M., 2000, Talinging Eye: Autonomous creatures for augmented chatting. Robotic and Autonomous Systems, 31, pp. 171-187
34. Takanori Shibata, 2001, http://www.mel.go.jp/soshiki/robot/biorobo/shibata/shibata.html
35. Takara, 2001, W-Diver Press Release, http://www.takaratoys.co.jp/company/english/PR/CyberAdventure.pdf
36. Tmsuk, 2001, TMSUK IV, http://www.tmsuk.co.jp/
37. Tomoko Yonezawa, Brian Clarkson, Michiaki Yasumura, Kenji Mase, 2001, Context-aware Sensor-Doll as a Music Expression Device, Proceedings of the CHI2001 Conference (Short Talks), Seattle, pp. 307-308
38. Zowie, 2000, Redbeard's Pirate Quest, http:// www.zowie.com