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An ethological and emotional basis for human–robot interaction

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Abstract

This paper presents the role of ethological and emotional models as the basis for an architecture in support of entertainment robotic systems. Specific examples for Sony's AIBO are presented as well as extensions related to a new humanoid robot, SDR.

Keywords: Robot architecture; Entertainment robot; Emotion; Ethology

1. Introduction

Human–robot interaction is of critical importance in the entertainment robotics sector. In order to produce a desirable end product that can be enjoyed over extended periods of time, it is essential that an understanding of not only robotics but also human psychology be brought to bear. In this paper we describe two aspects of a software architecture that addresses several of the fundamental needs posed by this domain:

1. Incorporation of high-fidelity ethological models of behavior as a basis for providing the ability for people to relate in predictable ways to a robotic artifact.
2. Generation of motivational behavior (e.g., emotions) that supports human conceptions of living creatures, and thus encourages a natural bonding between the human and the robotic artifact.

Fig. 1 shows the range of products that Sony currently produces for the entertainment robotic sector. They include various versions of dog-like robots (AIBOs) and the newer humanoid robot (SDR). Fortunately the entertainment robotics domain is highly tolerant of outside-the-norm behavior and performance as it does not require high precision nor repeatability as required for more standard robotic applications [1].

Ethology refers to the study of animals in their natural setting and was largely founded in the early 1900s by Lorenz [2] and Tinbergen [3]. Our work seeks to extract from observational behavior (not neuroscientific models) suitable descriptions of animal activity that can be effectively mapped onto robotic systems to provide the appearance of life-like activity.

Studies of the manifestation of emotions in humans and their similar occurrence as motivational behavior in animals can also provide support for effective interactivity between a robot and a human [4,5,19]. By incorporating aspects of emotional and instinctive behavior into a robotic architecture we contend that a greater ability to relate to the end-user is provided.

2. Ethological basis

The study of canine behavior has provided fertile ground for the creation of a novel architecture for AIBO. In particular, the extensive body of research

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Fig. 1. Sony's entertainment robots (top and lower left) AIBO variants, (bottom right) SDR.

conducted by Scott and Fuller [6] and Fox [7], among others has provided a rich ethogram (categorization of behavioral patterns) that spans the range of animal activities (see Table 1). The play and maladaptive subsystems are treated as separate behavioral subsystems for pragmatic reasons within the architecture.

Using Timberlake's behavioral systems approach [8], drawn from psychology, these canine behaviors can be further organized into various subsystems, modes, and modules, and then mapped onto a typical behavior-based architecture [9]. Figs. 2–5 illustrate some representative organizational examples within the design, focusing particularly on aspects of the agonistic subsystem.

Table 1
Main behavioral subsystems of the dog

Investigative (searching/seeking)
Sexual
Epimeletic (care and attention giving)
Eliminative (excretion and urination)
Et-epimeletic (attention getting or care soliciting)
Ingestive (food and liquids)
Allelomimetic (doing what others in group do)
Comfort-seeking (shelter-seeking)
Agonistic (associated with conflict)
Miscellaneous motor
Play
Maladaptive

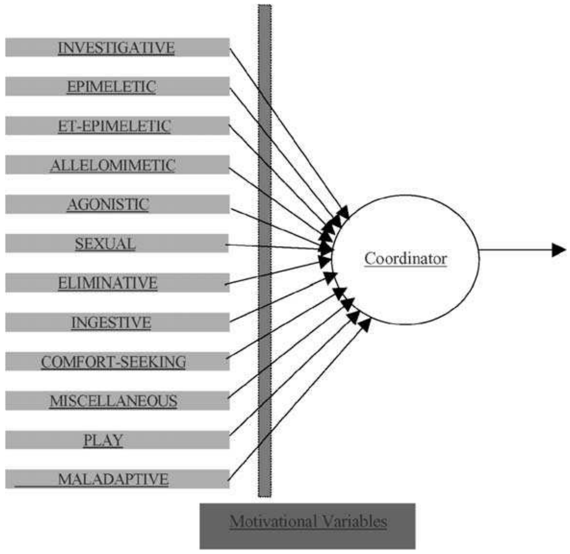

Fig. 2. Complete set of subsystems.

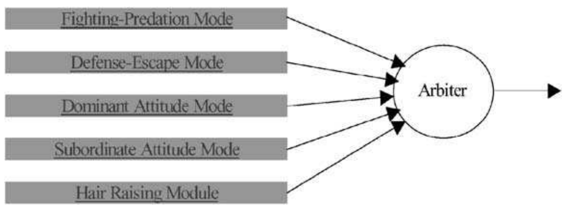

Fig. 3. Modes comprising agonistic subsystem.

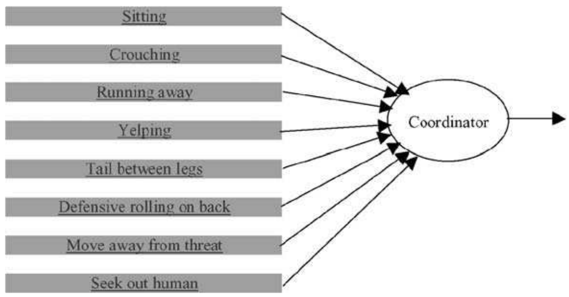

Fig. 4. Modules within defense-escape mode.

Stimulus = threat or dominant animal present + attack
+ escape route/area present + high fear
(the escape areas may include corners of rooms)

Response = run(fast, towards escape route/area)
+ ear-position(both, back)

Fig. 5. Example: run-away module.

From a design perspective, a least-commitment strategy is taken regarding the coordination mechanisms, with a preference towards MacFarland's motivational space methods [10], but for computational reasons using variations of the lateral inhibition methods described first by Ludlow [11] and later by Blumberg [12].

3. Emotional basis

Although an ethological model provides a basis for the kinds of behavior we should realize within the robot, a particular specific behavior must be selected in a given situation. The basic mechanism of action selection of our ethological model is to evaluate both external stimuli and ongoing internal drives. We employ the "homeostasis regulation rule" for action selection [13]. Namely, internal variables are specified that must be regulated and maintained within proper ranges. Behavioral actions and changes within the environment produce change in these internal variables. The basic rule for action selection is to use the regulation of the internal variables as a motivational "drive" signal for the behavior modules (Fig. 6).

Another motivation to introduce an internal state model is to incorporate emotional expression behaviors. There are many proposals for emotional models. Ekman and Davidson [14] proposed six basic emotional states: happiness, anger, sadness, fear, surprise, and disgust. In addition, some researchers propose the reduction of an "emotional basis dimension" into only two or three dimensions. We employ Takanishi's model [15], which is three-dimensional: pleasant, arousal, and confidence. The six basic emotional states are located within this three-dimensional space. We further combine the internal variables with "pleasantness". Namely, if the robot's variables are within the regulated range, the pleasantness is high. The arousal axis is controlled by both circadian rhythm and unexpected stimuli. Confidence is controlled by the confidence (certainty) of recognized external stimuli. As shown in Fig. 7, the internal state model generates "drive signals" and the "emotional signals" to the behaviors.

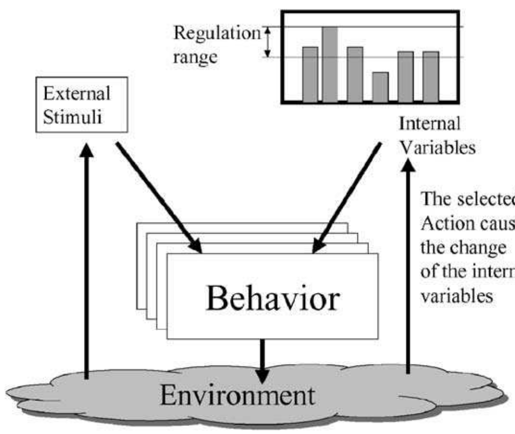

Fig. 6. Role of drives in behavior selection.

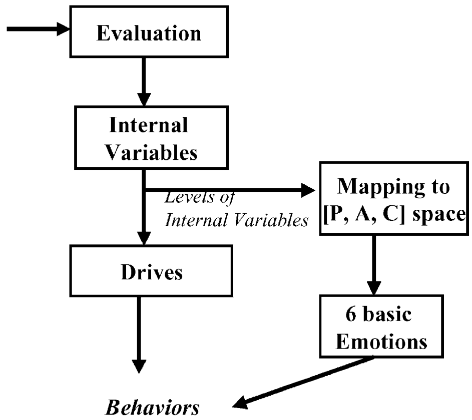

Fig. 7. Relationship of drives and emotions to behaviors.

4. AIBO architectural implementation

In order to verify the advantages of the ethological approach, the model described in the previous sections was implemented, focusing on checking if the following features can be validated in an actual robot.

(1) The fusion of internal motivations and external stimuli.
(2) The coordination of behaviors via lateral inhibition.
(3) Computational efficiency with a layered architecture.

In order to simplify and shorten development time, we implemented a subset of the overall model with limited perception (recognition targets) as follows:

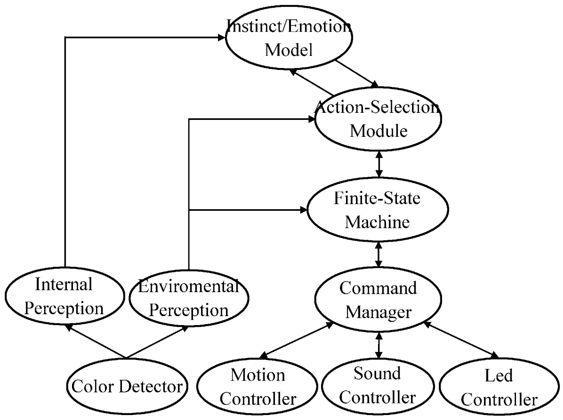

Fig. 8. Software architecture.

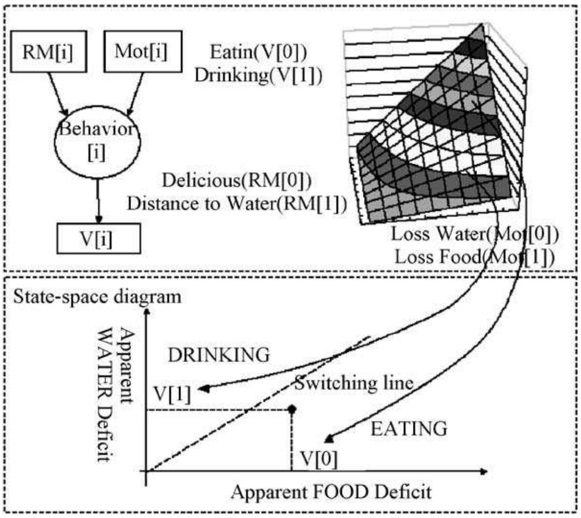

Fig. 9. State-space diagram.

- Only three partial subsystems, as shown in Fig. 11, are realized.
- Only three environmental objects, WATER, FOOD, and MASTER, can be discerned using visual color classification.

Fig. 8 shows the implemented software architecture on the robot AIBO. Regarding the behavior control part, roughly speaking, there are three principal components: Releasing Mechanism (environmental perception), Motivation Creator (instinct/emotion model), and the Action Selection Module.

The Releasing Mechanism component computes its output RM[I] (Fig. 9) using environmental perceptual results, such as the distance to a recognized object. As itemized above, we only use the color camera signal for this purpose and only three objects can currently be detected.

The Motivation Creator computes its output Mot[I] (Fig. 9) using an Instinct and Emotional Model, which has six internal variables: nourishment, moisture, bladder distension, tiredness, curiosity, and affection. Furthermore, another six variables act to keep the six internal variables within some bounded values. These are called instinct variables, which include hunger, thirst, elimination, tiredness, curiosity, and affection. The output of the Motivation Creator Mot[I] is computed using these instinct variables.

In the Action Selection Module, a behavior variable V[I] is computed using a function of RM[I] and Mot[I] as shown in the graph of Fig. 9. This computation is carried out from behaviors in a higher organization level (e.g., subsystem, mode). Lateral inhibition is used to avoid behavioral dithering (thrashing between behaviors) and is also carried out by the Action Selection module so that the system can select a single behavior for execution. From the highest organizational layer (subsystems) to the lowest layer (primitive modules), the computations are performed to select a proper action command, which is then sent to a Finite State Machine where the specific sequences on how to achieve the behavior are described.

Thus, the action to be executed is selected based on the value V[I], which is affected by both Mot[I] related to the internal variables and RM[I] related to the external stimuli. For example, even if the robot has high motivation for ingestive behavior, without the relevant external stimuli (e.g., a food object), then the robot does not select the ingestive behavior, and vice versa.

Fig. 10 shows a layered and tree structured architecture for subsystems, modes, and primitive modules. Fig. 11 shows the implemented behavior tree, where three subsystems, investigative, ingestive, and play, are housed. Investigative refers to exploratory behaviors such as walking around (locomotion), ingestive means consummatory behaviors such as eating or drinking, and play means interactive behaviors with a human such as giving/offering a paw. In this simplified implementation, there is a single mode per subsystem.

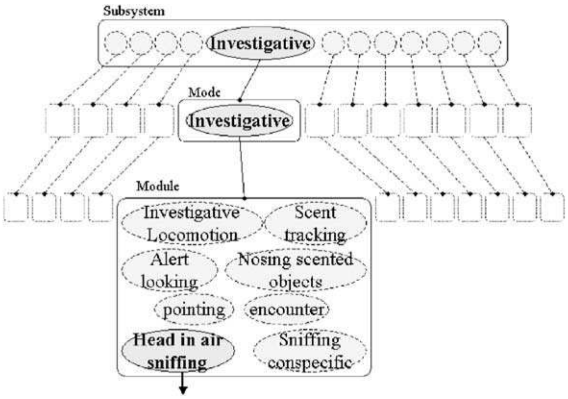

Fig. 10. Behavioral tree (whole).

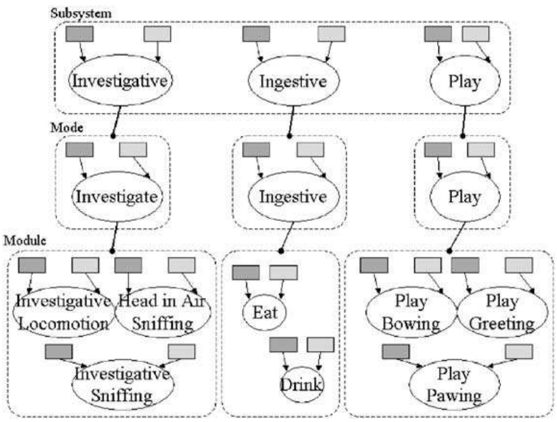

Fig. 11. Behavioral tree (implemented).

5. Experiments and results

In order to verify if the advantages of this approach are achieved, we built a test field as shown in Fig. 12.

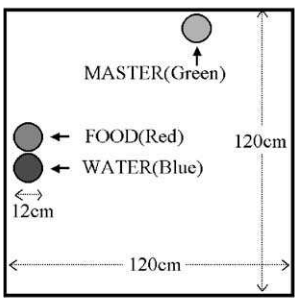

Fig. 12. Field.

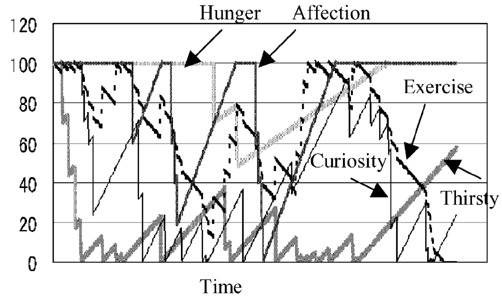

Fig. 13. Time–Instinct graph.

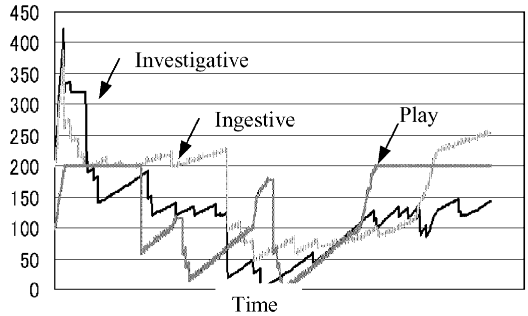

Fig. 14. Time–Motivation graph for subsystem.

For easy recognition, red, blue, and green circles with 12 cm diameter are used, which correspond to FOOD, WATER, and MASTER, respectively. The field is 120 cm square and is surrounded by walls. The robot described in the previous section is placed on the field and determines the RM[I], Mot[I], V[I], selected behavior, during a time course of activity.

Figs. 13–17 show various time sequences for some relevant measurements. Fig. 13 shows the

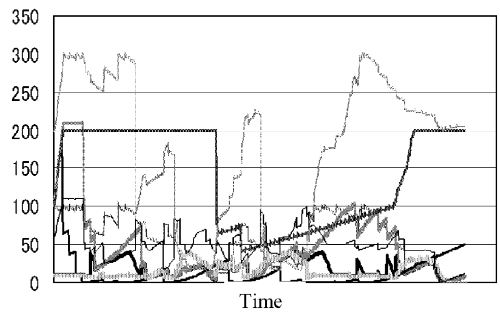

Fig. 15. Time–Motivation graph for modules.

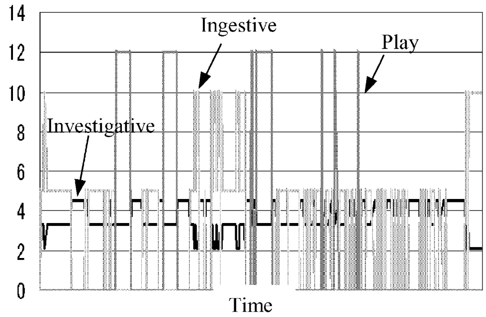

Fig. 16. Time–Release Mechanism graph.

Time–Instinct variable graph. Time axis is from 0 to 5 min for Figs. 13–17. Figs. 14 and 15 show Time–Motivation variable graphs corresponding to Mot[I] of the subsystems and modules. Fig. 16 shows a Time–Release Mechanism (RM[I]) variable graph, and Fig. 17 shows the time sequence of selected behaviors. Here, the five internal variables decrease as time passes but increase when the corresponding behavior is executed. Roughly speaking, Hunger and Thirsty are for Ingestive behavior, Affection and Exercise are for Play behavior, and Curiosity and Exercise are for Investigative behavior. Each instinct has a value from 0 to 100. Thus, the vertical axis in Fig. 13 shows the instinct value. Vertical axes in Figs. 14–17 show dimensionless values of Motivation, Release signals and Behaviors.

Comparing Fig. 13 with Fig. 17, we can observe an increase in the value of the instinct variables as well as their decrease when the corresponding behavioral action is selected. Moreover, comparing Figs. 14 and 15 with Fig. 17, we observe that the corresponding action is not selected (as expected) even when higher Motivation variable Mot[I] is present during some time intervals. Comparing Figs. 16 and 17, for this same period, the Release Mechanism value RM[I] is small, so not enough external stimuli is presented within that period to evoke the corresponding behavior.

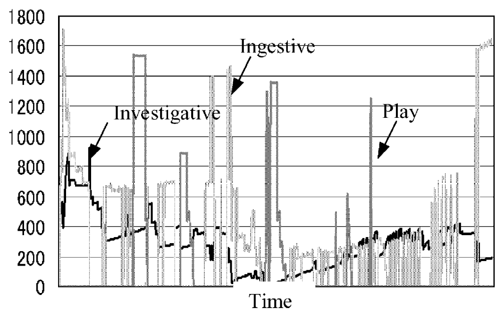

Fig. 17. Time–Behavior graph.

During such a period, the system selected "investigative" behavior. Thus, the motivation variables or the internal variables combined with the external stimuli affect the action selection mechanism in this system, as anticipated.

In the current implementation, we found one problem, which occurred within the ingestive branch of the behavioral tree. Since we integrate an eating behavior and a drinking behavior as the possible outcomes of the ingestive behavior, both "hunger" and "thirsty" are the input signal to the motivation and both "food" and "water" are the input to the release signals. For example, when the "hunger" motivation is large, and WATER exists, then the highest layer selects "ingestive" behavior correctly. Because WATER does not produce a large Release Mechanism value for the eating behavior, there is no action that has both large RM[I] and Mot[I] in the lowest layer of the selected ingestive subsystem. This can be avoided by designing a proper tree structure.

6. Emotionally grounded symbols

Although our goal is to implement "dog-like" behavior based on ethological studies, when we implemented symbol acquisition behavior, we need to learn the meanings of the acquired symbols in terms of the robot's needs [16,17].

Symbol grounding is a basic challenge in artificial intelligence, as discussed by Harnard [18] among others. From a pattern recognition point of view, if we treat the classified categories as symbols, we can say they are physically grounded through the perceptual channel. However, when we design behaviors with objects that can be treated as physically grounded symbols, we realize that we cannot assign proper behavioral responses to all objects encountered in advance.

For example, using visual and audio pattern classification technologies, a robot can recognize a new object with a "red" color and associate its name with the audio pronunciation as "tomato". Thus, the robot

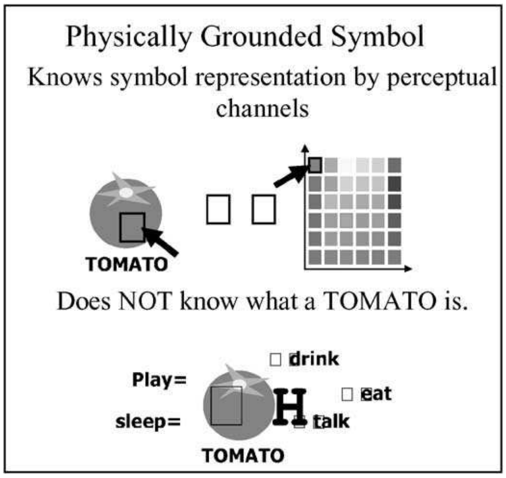

Fig. 18. Behavioral symbol grounding problem.

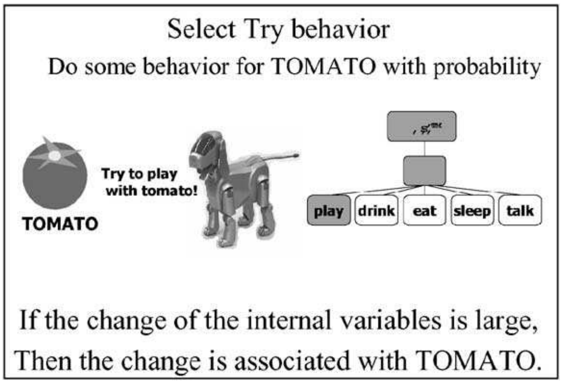

Fig. 19. "Try" behavior for experimentation with new environmental objects.

acquires the physically grounded symbol of tomato (Fig. 18). However, it does not know what to do with the tomato (i.e., what is the correct behavioral response to an tomato). This is because the robot does not learn the meaning of the tomato.

While evolution in nature permits the learned association of specific symbols with appropriate behaviors, and indeed suitable design in robotic systems can also provide many of these associations, clearly new and unforeseen objects must be dealt with, and thus permitting user interaction via teaching to occur. To solve the problem, we proposed a concept of an "emotionally grounded symbol", where the physically grounded symbol is associated with the change of internal variables when the robot applies a behavior in response to the object (Fig. 19). Then, when the robot sees or hears the symbol (tomato), it knows which associated behavior causes the change of its internal variables. Thus, we say the robot now knows the meaning of the symbol (e.g., the tomato is associated with an increase of the internal variable "nourishment" and the robot knows and stores the correct behavioral response when it sees or hears the symbol "tomato").

Fig. 20 shows the extended architecture for the emotionally grounded symbol system, which we call the Emotionally GrOunded architecture, or EGO architecture. In this system, both physically grounded symbol acquisition and emotionally grounded acquisition are achieved.

In Fig. 21 the basis for the physically grounded symbol acquisition is depicted. Assume that there are two perceptual channels, the visual perception channel and the auditory perception channel. The visual perceptual channel outputs visual events (VEs), which are category IDs of the visual perception module. The auditory perceptual channel outputs auditory events (AEs), which are also category IDs of the auditory perception module. These VEs and AEs can be considered as grounding to the physical world through the perceptual channels. For example, a particular VE (VE-1) is a color segmentation event, which indicates a "red" object in the visual input of the robot. An AE (AE-1) is a phoneme sequence [red]. If these two events occur simultaneously, these two are first stored in a Short-Term-Memory (STM), and then memorized in an associative memory or a Long-Term-Memory (LTM) (Fig. 21(a)). The actual robot implementation

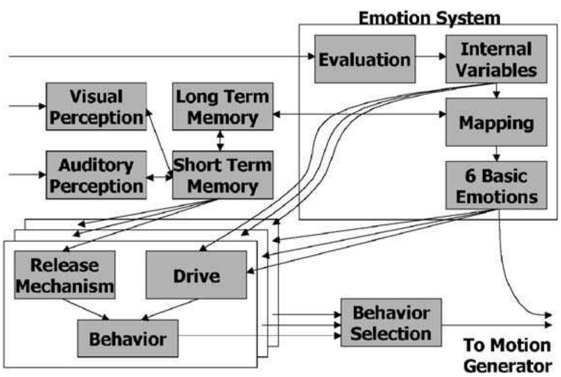

Fig. 20. EGO architecture.

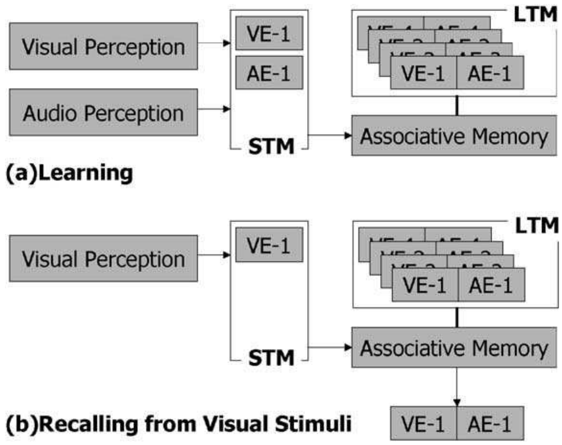

Fig. 21. Physically grounded symbol acquisition: (a) associative learning of visual event and audio event, (b) recalling its name from the visual event.

includes dialogue with the human to learn the object name from the human.

After the learning episode is over, if only one event, e.g., the AE-1 (phoneme sequence [red]), is input to associative memory, then the memorized VE-1 is output from the associative memory, which is the category indication of "red" object. Thus, the symbol is grounded to both the visual and audio perceptual channels. Of course if only the VE-1 ("red" object) is presented, then the associative memory can recall AE_1 (phoneme sequence [red]).

In addition to the associative memory capability of the visual and audio events, the EGO architecture can memorize the emotional experience, which is a basic concept of the emotionally grounded symbol acquisition. For example, after the physically grounded symbol (e.g., tomato) is acquired, the robot may try to apply several behaviors, such as eating and kicking. Then, the internal variables related to the applied behaviors associated with the "tomato" receive a big change for the internal variables related to eating, but not kicking. Now the symbol is associated with the change of the internal variables, so that when the robot perceives the symbol, the change of internal variables is also recalled. This change of internal variables can now be used to generate the drive signals for behaviors so that the eating behavior is highly activated.

The change of the internal variables is also input to the emotional system and can virtually generate the emotional state by the associated change of the internal variables. Thus, the robot can recall its previous emotional experience with the symbol.

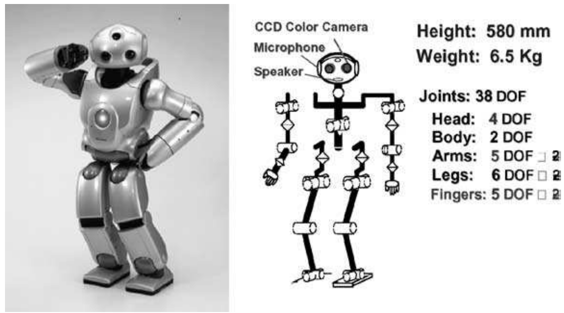

Fig. 22. SDR-4X.

7. SDR humanoid architectural overview

We are now in the process of extending our research on the ethological architecture for use in the humanoid robot SDR-4X (Fig. 22). The research hypothesis is that human behavior can also be effectively captured using ethological modeling. Unfortunately, the ethological literature for humans is nowhere near as rich as it is for dogs, principally due to privacy issues. Nonetheless, child behavior is reasonably well documented due to security and welfare issues for children and can serve as a basis for ethological models of young children. It is recognized that a purely behavioral approach cannot account for all levels of human competence; so incorporating deliberation into reactivity also requires architectural modification. In addition, speech-processing capabilities further increases both the competency and the complexity of the system. Our current architectural thinking for the humanoid is shown in Fig. 23.

This SDR-4X architecture is based on the EGO architecture shown earlier in Fig. 20. It possesses perception, memory, ISM (Internal State Model), and behavior generation components. The main difference from the EGO architecture is that there is now a deliberative layer on top of Situated Behavior Layer.

The technical targets of SDR-4X are to implement a humanoid robot, which can walk on various floor conditions (a soft carpet, a hard wooden floor, and a slippery tatami floor), and can deal with obstacles

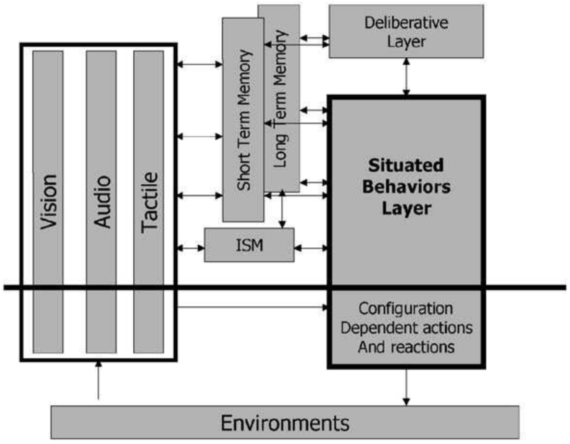

Fig. 23. Preliminary design for humanoid architecture.

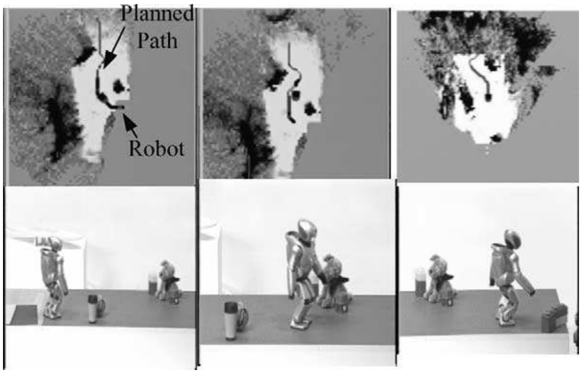

Fig. 24. Obstacle avoidance and path planning using a micro stereo-vision. Above the generated occupancy grid, below the behavior during execution.

without falling down. Even if it falls down by accident, it can recover and resume its behavior. Then, it can also search for a human to interact with via speech and motion. To achieve these goals, SDR-4X has the following features:

(1) Real-time adaptive motion control.
(2) Real-time gait pattern generation.
(3) Real-time and real world space perception capability.
(4) Multi-modal human–robot interaction.

Regarding the real-time and real-world space perception, a micro-stereo-vision system with obstacle detection is implemented. On top of the detection system, we further implement a path planner so that SDR-4X can walk toward the target place while avoiding obstacles. Fig. 24 shows the obstacle avoidance behavior. The upper three figures show the occupancy grids corresponding to the lower three situations shown in the photos. Obstacles are shown in black areas, and flat spaces which SDR can walk through are in white areas in the figure.

Another feature for spatial perception involves sound localization with multiple microphones. SDR-4X has seven microphones in its head to detect the sound direction in both the horizontal and vertical directions.

Regarding the multi-modal human interaction technologies, we have implemented multi-face detection and multi-face identification (Fig. 25), a large vocabulary continuous speech recognizer, a speaker identification system, and unknown word acquisition with unknown face learning. In addition, a text-to-speech synthesizer has been implemented.

Using these technologies, a simple dialogue system with a tree structure has been implemented as described in the previous section, to acquire and associate a new face with a new name. During the interaction with a human, the EGO architecture remembers the emotional experience with that person, so that the robot can have different interactions with different people depending on the associated emotion with each individual.

In addition, SDR-4X has two significant entertainment abilities, which are dancing and singing.

Fig. 25. Multiple face detection and identification.

Fig. 26. SDR-4X with emotional expression.

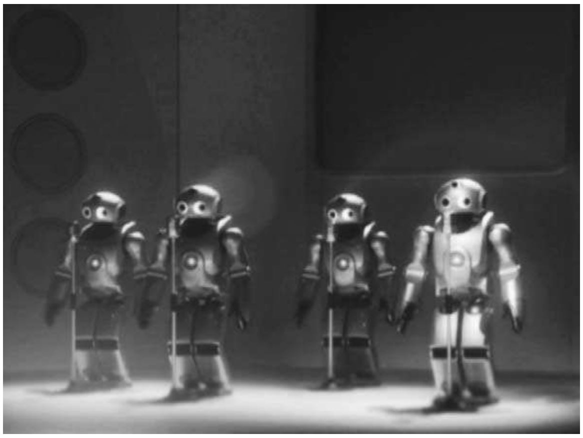

Fig. 27. Singing a song performance with dancing.

SDR-4X especially uses its speech synthesis technology for changing the tone of its voice. Namely, with either a musical score or text data, SDR-4X can sing a song with emotional expression (Figs. 26 and 27).

In March 2002 in Japan, we presented an exhibition at RoboDex, where we gave demonstrations of these performances in public. Parts of these demonstrations were conducted using the architecture described in Fig. 22.

8. Summary and conclusions

An ethological model and emotional model for autonomous dog-like behavior has been presented. This is then extended into an emotionally grounded architecture (EGO architecture) for learning new objects by associating their effect on internal motivational and emotional variables that generate how to behave in the presence of these objects. The EGO architecture is naturally extended to the behavior control architecture for a small humanoid, SDR-4X, which has real-time and real-world perception and mobile capability with multi-modal human interaction capability. Several technologies such as face detection, identification, and stereo-vision with obstacle avoidance behavior are described.

In the future, we are going to realize even more natural human interaction with dialogue. The emotionally grounded concept is a key to understanding the meaning of the user's uttered words in relation to the robot's perceptions, behaviors, capabilities, and needs.

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References

[1] M. Fujita, AIBO: towards the era of digital creatures, International Journal of Robotics Research 20 (10) (2001) 781–794.
[2] K. Lorenz, The Foundations of Ethology, Springer, New York, 1981.
[3] N. Tinbergen, Social Behavior in Animals, Methuen, London, 1953.
[4] C. Breazeal, Designing Sociable Robots, MIT Press, Cambridge, MA, 2002.
[5] K. Dautenhahn, A. Billard, Bringing up robots or psychology of socially intelligent robots: from theory to implementation, in: Proceedings of the Third International Conference on Autonomous Agents, Seattle, WA, May 1999.
[6] J.P. Scott, J.L. Fuller, Genetics and the Social Behavior of the Dog, University of Chicago Press, Chicago, IL, 1965.
[7] M. Fox, The Dog: Its Domestication and Behavior, Garland, New York, 1978.
[8] W. Timberlake, G. Lucas, Behavior systems and learning: from misbehavior to general principles, in: S. Klein, R. Mowrer (Eds.), Contemporary Learning Theories: Instrumental Conditioning Theory and the Impacts of Biological Constraints on Learning, Lawrence Erlbaum, Hillsdale, NJ, 1989.
[9] R.C. Arkin, Behavior-based Robotics, MIT Press, Cambridge, MA, 1998.

[10] D. MacFarland (Ed.), Motivational Control Systems Analysis, Academic Press, London, 1974.
[11] A. Ludlow, The behaviour of a model animal, Behaviour LVIII (1–2) (1976) 131–172.
[12] B. Blumberg, Action–selection in Hamsterdam: lessons from ethology, in: Cliff, et al. (Ed.), From Animals to Animats 3, MIT Press, Cambridge, MA, 1994, pp. 108–117.
[13] R.C. Arkin, Homeostatic control for a mobile robot, dynamic replanning in hazardous environments, in: Proceedings of the SPIE Conference on Mobile Robots, Cambridge, MA, 1988, pp. 240–249.
[14] P. Ekman, R.J. Davidson, The Nature of Emotion, Oxford University Press, Oxford, 1994.
[15] A. Takanishi, An anthropromorphic robot head having autonomous facial expression function for natural communication with human, in: Proceedings of the Ninth International Symposium on Robotics Research (ISRR99), 1999, pp. 197–304.
[16] M. Fujita, R. Hasegawa, T. Takagi, J. Yokono, H. Shiomura, An autonomous robot that eats information via interaction with human and environment, in: Proceedings of the IEEE ROMAN-01, 2001, pp. 383–389.
[17] M. Fujita, et al., Physically and emotionally grounded symbol acquisition for autonomous robots, in: Proceedings of the AAAI Fall Symposium: Emotional and Intelligent II, 2001, pp. 43–46.
[18] S. Harnard, The symbol grounding problem, Physica D 42 (1990) 335–346.
[19] F. Michaud, EMIB: computational architecture based on emotion and motivation for intentional selection and configuration of behavior-producing modules, Cognitive Science Quarterly, in press (Special Issue on Desires, Goals, Intentions, and Values: Computational Architectures).

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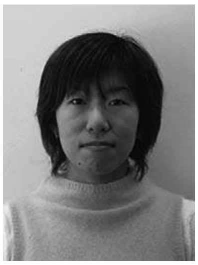

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