Panormo: An Emo-Dramatic Tour Guide

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Abstract

In this paper we present Panormo a tour guide robot for the Botanical Garden of Palermo. Panormo is equipped with an emotional learning system that gives it the ability to learn the emotional evaluation for each incoming stimulus. This evaluation induces robot's emotional states that drive its tour. The robot carries out a dramatization of the tour according to drama's theory and its emotions.
First experiments with the robot show that peoples are pleasantly involved by the robot.

Introduction

Advancements in the field of artificial intelligence and robotic have increased researchers interest in the development of a new range of robotic application domains: domestic, entertainment, health care etc.
The ability for people to naturally communicate with robots in ways inspired by human-human contact is central in these applications. The capability to express and understand emotions for the robot is an important factor to achieve this goal. Recent studies show that emotions encourage a natural interaction between the human and the robot (Breazeal, C. , 2000; Lisetti, C. L., Brown, S. M., Alvarez, K. and Marpaung, A. H. , 2004). Emotions facilitate believable human–robot interaction (Cañamero, L., Fredslund, J., 2001; Ogata, T., Sugano, S., 2000). Moreover it seems that emotions increase the acceptance of the robots (Fong, T., Nourbakhsh, I., Dautenhahn, K., 2003; Breazeal, C. , 2000).
Recent researches have also shown that "if a robot had a compelling personality, people would be more willing to interact with it and to establish a relationship with it" (Fong, T., Nourbakhsh, I., Dautenhahn, K., 2003; Kiesler, S., Goetz, J., 2002). Personality provides humans with a good conceptual model for understanding and interpreting the behavior of the robot (Norman, D.A., 2001).
Different characteristics of a robot contribute to convey it a personality: the robot's physical appearance, its manner of movement and expression (Severinson-Eklund, K., Green, A., Hüttenrauch, H. , 2003; Breazeal, C. , 2000), the tasks a robot performs (Fong, T., Nourbakhsh, I., Dautenhahn, K., 2003), the emotions expression (Yoon, S. Y., Blumberg, B. , Schneider., G., 2000).
In this paper we explore the role of affective factors like emotions and personality to develop a tour guide robot and we present Panormo: an emo-dramatic tour guide that offers a guided tour in the Botanical Garden of Palermo.
In order to allow robots to play a part in our daily life as personal companions to entertain and help us is important that humans feel robots as "life-like" creatures rather than simple "machines".
To address this challenge we take inspiration from drama's theory. Recently drama's theory has been applied in game (Jenkins, H., 2004), virtual agents (Damiano, R., Lombardo, V., Pizzo, A., Nunnari, F. ,2006.), entertainment (Mateas M. and Stern, A., 2005), as methods of exploration and evaluation in user-centered design (Mehto, K., Kantola, V., Tiitta, S.; Kankainen, T., 2006).
In our opinion if the robot puts up a "drama" in which it is the protagonist character and involves users as characters in the drama, the acceptance of the robot as natural partner is increased.
The key features of the proposed system are:

- The robot is provided by an "emotional learning" system that gives it the ability to dynamically learn the emotional value for each stimulus.
- The robot performs the tour according drama's structure.
- Robot emotions drive the dramatization of the tour.

The emotional system and the dramatization of the tour contribute to convey to the robot a "personality".
The paper is organized as follows: first an overview of the system is given; then the emotional system, the dramatization of the tour and the vocal synthesis are presented. Finally the experimental results are exposed.

System Overview

The whole system is built as a collection of concurrently running processes. Each process is able to communicate with each other by message passing. Figure 1 shows the basic processes and the connections involved in the emotional system, the dramatization of the exposition and the emotional vocal synthesis.

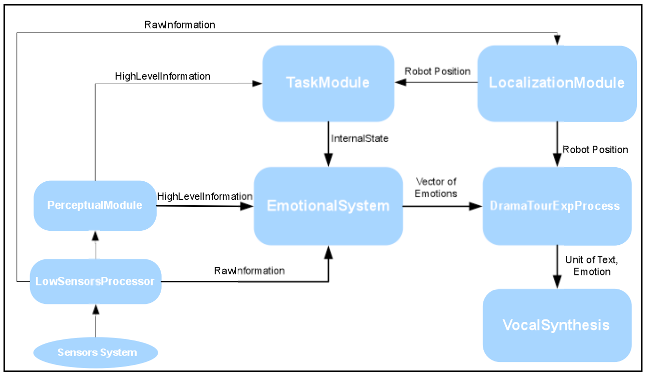

Fig. 1- An overview of the system

LowSensorProcessor is responsible for processing the raw sensors information to extract sensors-based features from the world. The PerceptualModule uses these features to obtain relevant percepts for the robot.
The LocalizationModule estimates the robot position while the TaskModule manages the robot goals

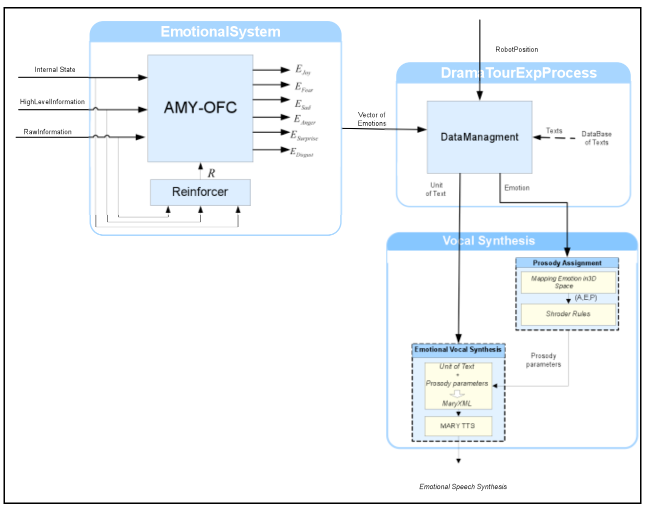

Fig. 2- The proposed system

The EmotionalSystem process (Fig. 2) receives information about environment and about the robot internal status (current action, achieved goals and so on) and gives emotional evaluations for the incoming stimuli. The DramaTourExpProcess receives these emotional evaluations and the current robot position and use these information for the dramatization of the exposition. Finally the VocalSynthesis module vocalizes each unit of text using the appropriate emotional prosody.

Emotional System

Many theories about emotions have been proposed (Plutchik, R., 1991; Ekman P, 1992. ;Ortony, A., Clore, G. & Collins, A., 1988). We refer to "basic emotion" theory. Theorists of basic emotions argue that there are a discrete number of emotions called "basic emotions" that are endowed by evolution. Each emotion is independent of the others in its behavioural, psychological and physiological manifestations and serves a particular function (often biological or social). We refer to the six "basic emotions" proposed by Ekman (Ekman P, 1992.): *Joy, Sad, Surprise, Anger, Fear, Disgust*.
We look also at neurophysiologic basis of emotion to develop an emotional learning system that gives the robot the ability to dynamically learn the emotional value for each stimulus (Fig.3). Nevertheless we don't are interested to low-level models that focus on the anatomical structures that implement neurophysiologic functions. We focus our attention on a computational model that simulates the process of emotional learning.

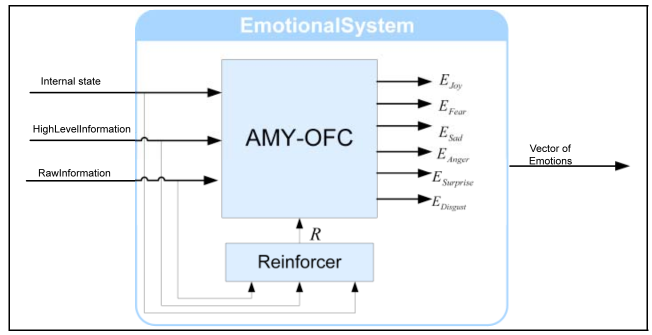

Fig. 3- The EmotionalSystem

Recent neurological findings suggest that the amygdale is the place of the brain where the association between a stimulus and its emotional value takes place (Rolls, E. T, 1995; LeDoux, J. E, 1995). Rolls (Rolls, E. T, 1995) claims that the amygdale assigns an emotional value to each stimulus that is paired with a primary reinforcer.

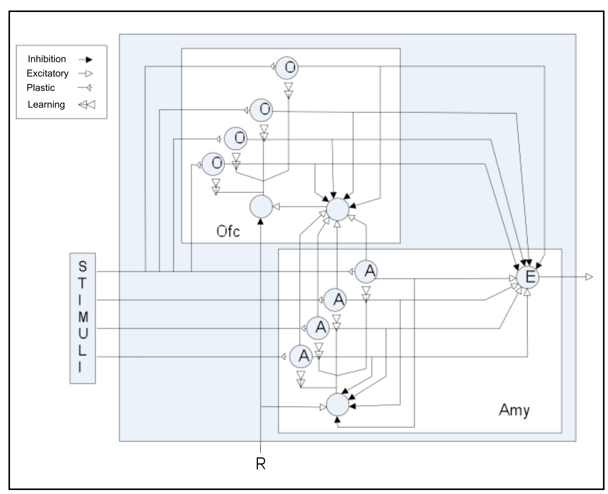

Fig. 4 -. The Amigdala-Orbitofrontal model proposed by J. Moren

Studies show that amigdala hasn't the capability to unlearn an emotional response that it has learned (Rolls, E, 1992; Wilson, F. A. W. and Rolls, E. T., 1993). It is the orbitofrontal cortex that is responsible for inhibiting inappropriate reactions from amygdale. It seems that the

amygdale is responsible for the initial learning of an emotional evaluation of a stimulus while the orbitofrontal cortex is involved in the extinction (Rolls, E. T, 1995).
We use this neurophysiologic evidence for the Emotional learning system. Particularly we refer to amygdale-orbitofrontal computational model proposed by Morèn (Morèn, J. 2002; Balkenius, C. and Morèn, J, 2000). The model is divided in two parts (Fig. 4) conceptually corresponding to the amygdale and the orbitofrontal cortex respectively.
The combined system works at two levels:

- The amygdale learns the emotional response.
- The orbitofrontal system inhibits the system output proportionally to the mismatches between the base system prediction and the actual received reinforcer.

The learning rules of the amygdale and the OFC are shown respectively in formulas (1)-(3) and (4)-(7):

$$E_a = \sum_i A_i; \quad (1)$$

$$A_i = S_i V_i; \quad (2)$$

$$V_i = \alpha S_i [R - \sum_j A_j]^+ \quad (3)$$

$$E_o = \sum_i O_i; \quad (4)$$

$$O_i = S_i W_i; \quad (5)$$

$$W_i = \beta S_i R_0; \quad (6)$$

$$R_o = \begin{cases} [\sum_i A_i - R]^+ - \sum_i O_i & \text{if } R \neq 0, \\ [\sum_i A_i - \sum_i O_i] & \text{otherwise} \end{cases} \quad (7)$$

Where R is the given reinforcer, *Si* are the input stimuli, *Vi* and W_i are the connection weights and α and β are the learning parameters.
The output is the difference between the output from the Amygdala and the inhibitory output from OFC:

$$E = E_a - E_o \quad (3)$$

We have implemented a version of this model with six outputs: one for each Ekman's basic emotion.
Primary reinforcers have been defined for each basic emotion (Table 1).
Environmental stimuli and robot's internal states are inputs for the AMY-OFC (Fig. 3). The appropriate value of emotion is learned for the stimuli that are paired with primary reinforcers.
For example, since the robot is a tour guide one of its goal is to have many peoples that follow its tour. An increasing of people that follow the robot is a primary reinforcer for the joy emotion. If this reinforcer is paired, for example with the robot current action:"tell an anecdote", the value of joy is learned for this action.
As another example if the robot encounters difficult to "reach a position" (robot's goal) because there is an obstacle in front of it the AMY-OFC receives as input a reinforcer for the anger emotion (difficult in achieving a goal) and the environmental input for the presence of the obstacle. The value of anger is then learned for the presence of the obstacle.

Emotions	***Primary Reinforcer***
Joy	The attainment of a goal
Sad	Unsuccessful in achieving goal
Anger	Obstacles for the attainment of goals
Surprise	Unexpected stimulus
Disgust	Something revolting
Fear	Stimulus that hinds the goal of survival

Table 1-Primary Reinforcer for the six basic emotions

The output of AMY-OFC is a vector (*E*) of six emotional values (*E(i)*), one for each basic emotion E_i. The emotion E_i associated with the highest value of *E(i)* is the robot emotional state.
The main advantage of this system is the on-line learning that makes the robot fast in adaptation with dynamic circumstance changes. There isn't a pre-built association between a stimulus and an emotion. The emotional evaluation of each stimulus is dynamically learned according to the received reinforcer. This evaluation isn't permanent: the OFC inhibits inappropriate emotional evaluation (Fig.5).

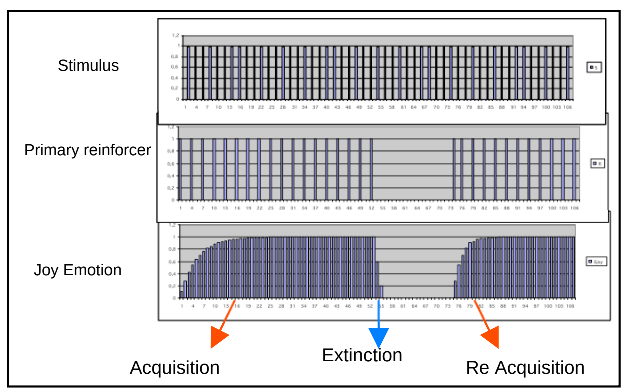

Fig. 5 -. Representation of Acquisition Extinction and Reacquisition process for the joy emotion for one stimulus.

The output of the EmotionalSystem is the input for the DramaTourExpProcess.

Dramatization of the tour

The elements of dramatic structure are:

- The protagonist character that has a goal.
- The antagonist that opposes the protagonist's attempt to reach his goal. There can be different type of antagonist: persons, animals, calamity, inner conflicts of the protagonist etc.

- The tension created by the obstacles that the protagonist encounters.
- The resolution of the conflicts at the end of the drama.

The robot puts up a drama during the tour. It is the protagonist and its goal is to offer a pleasant and playful tour to visitors. The typical dramatic tension is created by:

- The changing of robot emotional states that influences the robot information exposition.
- The presence of an external antagonist: Manlio-Superbike, the curator of the garden that wants to destroy the robot's circuits

According drama's theory and to make the robot more believable we have also created a personal history for the robot that is presented to the visitors by a poster before the tour (Fig.6).

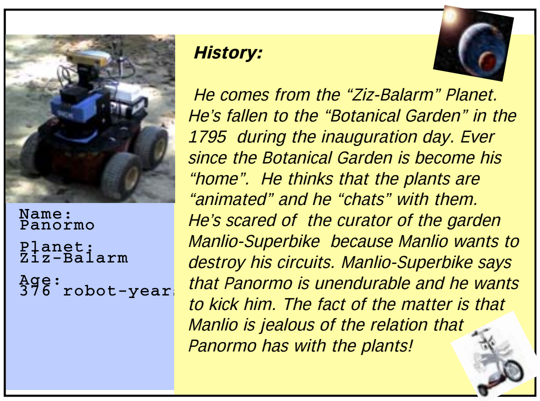

Fig. 6- Panormo's history

The set of information that the robot offers during the tour has been divided into basic unit of text concerning botanical information about plants, the robot personal history, anecdotes about plants and so on. The set of basic unit of text is stored in a database. During the tour the robot dynamically selects unit of text according its position and its emotional state and assembles them in a dramatic coherent form.

Each unit is tagged with the following information tags:

- Informative content: it indicates the content of the text (e.g. a botanical explanation of the plants or anecdote)
- Place: it indicates the location of the garden where the information can be offered. Some texts are description of plants or other objects of interest and then can be exposed only when the robot is near their position. Other texts instead can be offered in any place.
- Length: it indicates the length of the text (short, medium, long).
- Flag: it indicates if the text has just been said by the robot.

For each basic emotion there are some rules that pilot the selection of the elementary unit of text. For example if the robot is Joyful it is more loquacious and it wants to tell anecdotes. The system selects then, for the specified robot position (Place), long texts and texts with an informative content that indicate anecdotes. Instead if the robot is anger it gives only brief and technique explanations about plants.

In the database are also stored editing information that are information necessary for assembling unit of text in a coherent form.

Fig. 7 shows the algorithm:

- The DramaTourExpProcess receives a vector of emotions (*E*) and the current robot position.
- The highest emotional value (*E(k)*) is selected from the vector *E*.
- The emotional rules related to the emotion E_k associated with *E(k)* are applied to select unit of text from Database.
- The units of text are assembled in a coherent form using editing information stored in the database.
- Each unit of text and the emotion E_k are sent to the VocalSynthesis process.

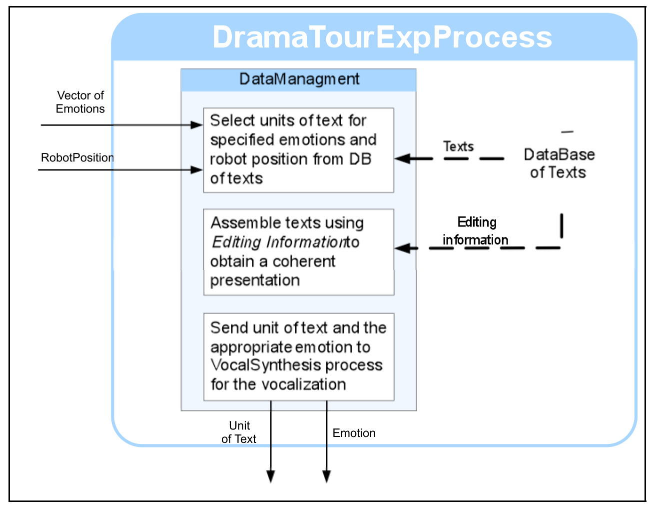

Fig. 7- The DramaTourExpProcess

Emotional Vocal Synthesis

We refer to the emotional prosody speech study carried out by Schröder (Schröder, M. ,2004.). The author formulates prosody rules that link emotional states with their effect on speech prosody. He suggests a representation of emotions for speech in a 3-dimensional space: *activation(A), evaluation(E), power(P)*. He defines some emotional prosody rules that allow mapping speech prosody associated with an emotion in this 3-dimensional space.

Emotion	*A*	*E*	*P*
Neutral	0	0	0
Sad	-8.5	-42.9	-55.3
Anger	34.6	-34.9	-33.7
Fear	31.1	-27.1	-79.4
Joy	28.9	39.8	12.5
Surprise	45.5	15.1	20.3
Disgust	28.2	-40.3	-40.3

Table 2- Values of A, E and P for the six emotions of Ekman

We mapped the six "basic emotions" proposed by Ekman (Ekman P, 1992.) and the absence of emotion (*neutral*) in this space. For five emotions categories, *neutral, sadness, anger, fear* and *joy,* we used the values of A, E and P defined by Schröder et al(Schröder, M., Cowie, R., Douglas-Cowie, E., Westerdijk, M., & Gielen, S, 2001). For the other emotions we experimentally defined the A, E and P values (Table 2).
Fig. 8 shows the basic modules for the emotional vocal synthesis.
The module of "Prosody Assignment" receives from the DramaTourExpProcess the emotion E_i and calculates the point $w(A_{Ei}, E_{Ei}, P_{Ei})$, corresponding to the emotion E_i, in the 3D-space (Table 2). The rules defined by Schröder allow mapping this point with the speech prosody parameter (pitch, intensity, duration and so on). These values and the "unit of text" are input for the "Emotional Vocal Synthesis" module (Fig. 8) that uses them to create a MaryXML document. This document contains the information for the emotional vocal synthesis. It is sent to the MARY Text-To-Speech System (Schröder, M. & Trouvain, J, 2003) for the emotional vocalization of the excerpt.

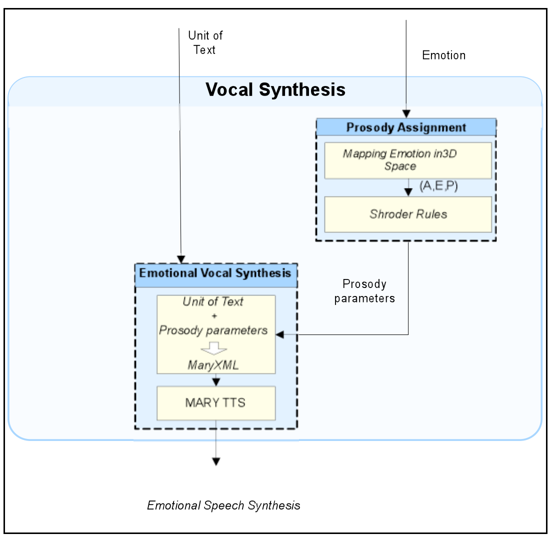

Fig. 8- Emotional Vocal Synthesis

A tour with the robot

To test the effectiveness of our approach we have realized an application for the robot Pioneer 3 (Fig. 9) offering a tour at the Botanical Garden of Palermo.
The real test-bed for the proposed system was during an international conference held at the botanical Garden of Palermo. The robot performed several roundtrips. Figure 11 shows some snapshots taken during the tour. The route was composed by the fixed points showed in figure (Fig. 10). The robot goal was to stop and offer an explanation about the plants or the other objects of interest located near the fixed points.

The robot started in front of the Gymnasium introducing itself and the building, while being in a joyful state. Then it moved towards the second location (Fig. 10).

Fig. 9-The robot Pioneer 3

There were not inputs that made changes in the robot emotional state. The robot was still joyful and according to this emotion it was loquacious. The robot spoke while it was walking: it told an anecdote about its life.
The robot reached the second position. It was still in a joy state and so in this place offered an exposition according to this state. At the end of the speaking it started again toward the third assigned position.
It happened that a person was repeatedly obstructing its path. The robot told the person to move away but he did not move. The robot had no free space in front of it, forcing it to invert its direction. This process induced Anger in the robot. According to this emotion the robot stopped speaking and when it reached the third position it gave only a brief botanical explanation about the near plants. At the end of the speaking the robot started again towards the next position.
The robot had to turn 90° to get from third node ("Plaza") to the fourth node ("Greenhouse"). It took in one case 3 trials to get the right way. This "unsuccessful in achieving a goal" induced sadness. The prosody used by the robot for the speaking shows this emotional state.

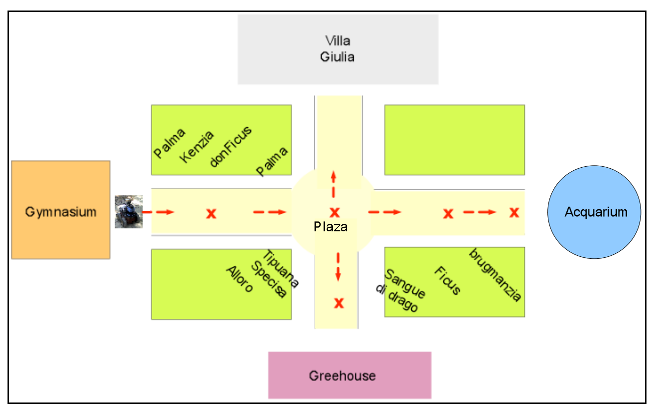

Fig. 10 – A representation of the robot's tour

During its tour the robot switched between a loquacious and playful explanation of the plants and a more serious information presentation creating a tension.
Visitors became "characters" of the drama inducing changes in the robot's emotional states.

During the tour there was another element that created tension: the curator of the garden. At the time of writing the robot recognized the curator using a colorful marker.
When the robot met the curator it became afraid and told anecdotes about its fear.
At the end of the tour the robot was in a joyful state because it has achieved a goal: to complete its tour (conflict resolution).

Fig. 11 –Snapshots of the robot's tour

Conclusions

In this paper we have presented Panormo an emotional robot that offers a "dramatic" guided tour.
First experiments with Panormo show that peoples find pleasing the robot information exposition. Moreover it seems that the manner in which the robot communicates and its capability to express emotions contribute to convey to it a personality. Future works will concern the collection of visitors' opinions gathered through interviews and questionnaires and the analysis of the data with the supervision of psychologists to verify the acceptability of the robot and the visitors' satisfaction.

References

Schröder, M. ,2004. Dimensional emotion representation as a basis for speech synthesis with non-extreme emotions. *Proc. Workshop on Affective Dialogue Systems: Lecture Notes in Computer Science*, Kloster Irsee, Germany, 2004, pp. 209–220.

Schröder, M., Cowie, R., Douglas-Cowie, E., Westerdijk, M., & Gielen, S, 2001 Acoustic correlates of emotion dimensions in view of speech synthesis. *Proceedings of Eurospeech 2001* Aalborg, Denmark, , pp. 87–90

Schröder, M. & Trouvain, J, 2003 The German Text-to-Speech Synthesis System MARY: A Tool for Research, Development and Teaching, *International Journal of Speech Technology*, 6, pp. 365-377.

Ekman P, 1992. Are there basic emotions? Psychological Review. 99, pp. 550-553.

Rolls, E. T, 1995,. A theory if emotion and consciousness, and its application to understanding the neural basis of emotion" *The cognitive neurosciences,*. MIT Press, Cambridge, MA, pages 1091-1106

LeDoux, J. E, 1995. , In search of an emotional system in the brain: leaping from fear to emotion and consciousness. *The cognitive neurosciences*, MIT Press, Cambridge, MA, pages 1049–1061

Rolls, E, 1992, Neurophysiology and functions of the primate amygdale. *The Amygdala: Neurobiological Aspects of Emotion, Memory and Mental Dysfunction*, In Aggleton, J., editor, New York. Wiley-Liss. pages 143–165

Wilson, F. A. W. and Rolls, E. T., 1993, The effects of stimulus novelty and familiarity on neuronal activity in the amygdala of monkeys performing recognition memory tasks. *Experimental Brain Research*, pages 367–382

Morèn, J. 2002. Emotion and Learning-A Computational Model of the Amygdala, *Phd Thesis*, Lund University Cognitive Studies,

Balkenius, C. and Morèn, J, 2000. Emotional learning: a computational model of the amygdale *Cybernetics and System*, 611-636

Bechara, A., Damasio, A. R., 2005. The somatic marker hypothesis: a neural theory of economic decision *Games and Economic Behavior* 52 336-372

Damasio, 1994. Descartes' Error:Emotion reason and the human brain,. *Grosset/Putman*, NewYork.

Taylor , J. G., Fragopanagos, N. F., 2005. The interaction of attention and emotion, *Neural Networks*, 18, p.353-369

Damiano, R., Lombardo, V., Pizzo, A., Nunnari, F. ,2006. Dramatization Meets Narrative Presentations, 17th *European Conference on Artificial Intelligence* (ECAI 2006), IOS Press, Riva del Garda,pp. 31-35.

Norman, D.A., 2001. How might humans interact with robots? Human Robot Interaction and the Laws Of Robotology, *Notes for a Keynote Address to the DARPA/NSF Workshop on Human–Robot Interaction*, San Luis Obispo, CA, September 2001.

Severinson-Eklund, K., Green, A., Hüttenrauch, H. , 2003. Social and collaborative aspects of interaction with a service robot, *Robotics and Autonomous Systems* 42 223–234, Elsevier

Fong, T., Nourbakhsh, I., Dautenhahn, K., 2003. A survey of socially interactive robots, *Robotics and Autonomous Systems,* Volume 42, pp. 143-166, Elsevier

Yoon, S. Y., Blumberg, B. , Schneider., G., 2000. Motivation driven learning for interactive synthetic characters, in: *Proceedings of the InternationalConference on Autonomous Agents,*

Breazeal, C. , 2000. Sociable machines: Expressive social exchange between humans and robots. Doctoral dissertation, Department of Electrical Engineering and Computer Science. MIT.

Mateas M. and Stern, A., 2005. Structuring content in the faade interactive drama architecture, in *Proceedings of Artificial Intelligence and Interactive Digital Entertainment,* AIIDE 200, Marina del Rey, CA

Relevance Feedback Icon
Mehto, K., Kantola, V., Tiitta, S.; Kankainen, T., 2006. Interacting with user data – Theory and examples of drama and dramaturgy as methods of exploration and evaluation in user-centered design *Interacting with Comput*ers Volume: 18, Issue: 5, September, 2006, pp. 977-995
Cañamero, L., Fredslund, J., 2001. I show you how I like you—can you read it in my face? IEEE *Transactions on Systems, Man and Cybernetics* 31 .
Ogata, T., Sugano, S., 2000. Emotional communication robot: WAMOEBA-2R emotion model and evaluation experiments, in: *Proceedings of the International Conference on Humanoid Robots*.
Kiesler, S., Goetz, J., 2002. Mental models and cooperation with robotic assistants, in: *Proceedings of CHI*.
Lisetti, C. L., Brown, S. M., Alvarez, K. and Marpaung, A. H. , 2004. A Social Informatics Approach to Human–Robot Interaction With a Service Social Robot. *IEEE Transactions On Systems, Man, And Cybernetics*—Part C: Applications And Reviews, Vol. 34, No. 2, May 2004
Jenkins, H., 2004. Game design as narrative architecture, MIT Press.
Plutchik, R., 1991. The emotions, University press of america, Lanham, MD
Ortony, A., Clore, G. & Collins, A., 1988. The Cognitive Structure of Emotion, Cambridge University Press, Cambridge, UK