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Emotions and Robot Artists: State-of-the-Art and Research Challenges

Ana Lucia Păiş, Sunita Andreea Moga, Cătălin Buiu

Laboratory of Natural Computing and Robotics, Politehnica University of Bucharest, Spl. Independenței 313, 060042 Bucharest, Romania
e-mail: {lpais, amoga, cbuiu}@ics.pub.ro

Abstract

Emotions play a vital role in communication and mutual understanding between humans. This should also be true for human-robot interaction, but complex emotional robots are just beginning to be developed. This paper presents a personal point of view on emotions and art-making robots, a class of robots which is under-represented in the today's robot world. State-of-the-art in emotional robotics is critically described, including existing models and theories of emotions. Representative emotional robots are grouped in three categories: robots expressing emotions through body language, robots expressing emotions through art and virtual robots. The paper briefly presents an original cognitive architecture of a system that is able to analyze literary texts, extract the dominant emotion that is expressed in the text and transpose that emotion in a graphical form using a drawing robot. The paper ends presenting examples of emotional synthetic agents in virtual reality environments and future research directions in the presented robotics field.

Keywords: *human-robot interaction, emotion, robot artists, cognitive architecture, emotion detection, drawing robot*

Introduction

Human-robot interaction is an interdisciplinary research field with contributions from human computer interaction, robotics and artificial intelligence, to name but a few areas. Emotions play an important and increasing role in improving communication between humans and robots. This paper aims firstly at giving an overview of several known theories of emotions, presenting definitions and examples about what emotions are, why their implementation on robots is desired, how they can be implemented and some practical applications where they have been developed so far.

The main purpose of this survey paper is to provide a general discussion on emotions from the psychological point of view, to discuss possible ways of developing emotional robots and to give examples of actual robots capable of displaying emotions. A special category comprises robot artists that may not necessarily mimic emotions themselves but by being performing artists, they aim at inducing emotion in the audience. The paper also presents a project that falls into this category of robot artists currently being developed at the Laboratory of Natural Computing and Robotics at Politehnica University of Bucharest. This project aims at developing models and cognitive architectures for dramatic arts robotic performers (or robot artists, also called artbots). The main theoretical foundation of this project is presented in [4] where are defined fundamental aesthetic emotions that a robot artist should be able to evoke in a human audience. Based on that result and related developments of the authors, this paper presents a cognitive architecture for a system that is able to identify basic emotions from a literary text, and to instruct a drawing robot to draw a picture expressing this dominant emotion.

The paper is organized as follows. The first section gives an overview of fundamental theories of emotions, discussing the relevance and number of basic or fundamental emotions according to various researchers. Next section presents some robots that are able to express emotions through body language. Then artbots or robot artists are presented, including an original cognitive architecture for a robotic system able to express emotions through drawing. Virtual robots or synthetic agents capable of expressing emotions in virtual reality environments are briefly described in the next section. The final section contains conclusions and directions for further research in the described robotics field.

Fundamental Issues Concerning Emotions

What Are Emotions?

Emotions are considered to be a fundamental part of the human being, motivating actions and enriching experiences. Traditionally, human-computer interaction has been viewed as the exception, because emotion seamed to be marginally relevant in this case [6]. Recent research in psychology and advances in technology suggest and allow a very different view of the relationship between humans, computers, and emotions. It is now understood that a wide range of emotions plays a critical role in every computer-related, goal-directed activity, from developing a 3-D CAD model and running calculations on a spreadsheet, to searching the Web.

Many psychologists now argue that it is impossible for a person to have a thought or perform an action without engaging, at least unconsciously, his or her emotional systems [6]. It is known that any interface that ignores a user’s emotional state or fails to manifest the appropriate emotion can dramatically impede performance and risks being perceived as cold, socially inept and untrustworthy [6]. Therefore the need for robots and other intelligent agents to perceive and understand emotional states of the users and also to express their own emotions is pressing.

In order to address this fundamental but controversial question – what are emotions – several definitions and theories are presented and discussed. In 1984, Fehr and Russell claimed that “everyone knows what an emotion is until asked for a definition” [15, 9] while Damasio, in 1994, stated that “emotions are a series of body state changes that are connected to mental images that have activated a given brain subsystem” [25]. Emotions can also be defined as an intense mental state arousing the nervous system and invoking physiological responses [25].

Currently, there are over 90 theories known about emotions, and the large number of emotions identified in humans have been narrowed down to a group of so called “fundamental”, “basic” or “primary” emotions. These emotions are considered fundamental because they represent survival-related patterns of responses [12]. The number and definition of these generally accepted basic emotions differ from scientist to scientist, as shown in Table 1.

Many psychologists agreed upon six main types of basic emotions: happiness, anger, fear, sadness, disgust, and surprise. All other emotions are varieties of basic emotions. Each emotion is characterized by physiological and behavioral qualities, including movement, posture, voice, facial expression, and pulse rate fluctuation. Although there are many different types of emotions, they all have some common characteristics. First, emotions are largely non-purposeful and instinctive. The basic emotions that human's express are shared with most mammals. Second, on the physiological level, emotional behaviors are closely tied to the autonomic nervous system responsible for the control of non-purposeful behaviors such as heart rate and respiration. A third basic characteristic of emotions is that, to a large degree, they appear to be innate. For example, sociologists have found that facial expressions associated with the basic emotions such as fear, anger, and happiness are the same across cultures [20].

Table 1. Basic Emotions according to different theorists [42]

Theorist	**Number and nature of basic emotions**
Plutchik	8: Acceptance, anger, anticipation, disgust, joy, fear, sadness, surprise
Arnold	11: Anger, aversion, courage, dejection, desire, despair, fear, hate, hope, love, sadness
Ekman, Friesen, and Ellsworth	6: Anger, disgust, fear, joy, sadness, surprise
Frijda	6: Desire, happiness, interest, surprise, wonder, sorrow
Gray	4: Rage and terror, anxiety, joy
Izard	10: Anger, contempt, disgust, distress, fear, guilt, interest, joy, shame, surprise
James	4: Fear, grief, love, rage
McDougall	7: Anger, disgust, elation, fear, subjection, tender-emotion, wonder
Mowrer	2: Pain, pleasure
Oatley and Johnson-Laird	5: Anger, disgust, anxiety, happiness, sadness
Panksepp	4: Expectancy, fear, rage, panic
Tomkins	9: Anger, interest, contempt, disgust, distress, fear, joy, shame, surprise
Watson	3: Fear, love, rage
Weiner and Graham	2: Happiness, sadness

One of the most widely known theories of emotions is that of the American psychologist Plutchik, who proposed one of the most influential classifications of general emotional responses. He proposed a set of eight basic emotions, which are divided into four pairs of opposite states: joy – sadness; acceptance – disgust; fear – anger; surprise – anticipation. All these emotions are considered to be innate**.** Plutchik also created a wheel of emotions used to describe how emotions are related (Figure 1).

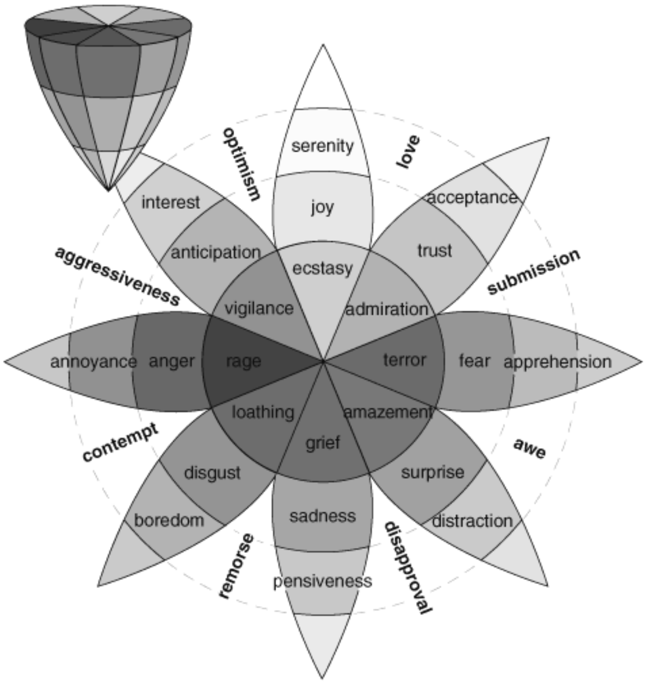

Fig. 1. Plutchik’s wheel of emotions [44]

His circumplex model makes connections between the idea of an emotion circle and a colour wheel. Like colours, primary emotions can be expressed at different intensities and can mix with one another to form different emotions. The circumplex model is actually seen as a cross-section of a three-dimensional cone shaped model of emotions [43]. According to Plutchik people cannot have opposite emotions at the same time [35]. Emotions found at the base of the cone are considered the most intense and as the intensity decreases they are harder to be distinguished.

Unlike Plutchik, Arbib and Fellous analyze emotions in a different way and propose the following classification [35]:

1. “Emotional expression for communication and social coordination”. They consider this level as an “external aspect of emotions”.
2. “Emotions for organization of behaviour (action selection, attention and learning)”. They consider this level as an “internal aspect of emotion”.

If emotions are seen as ways for organizing attention, learning and action selection, then the advantage is that they can be easily simulated. Aube considers that “the more complex an animal’s life appears to be, the more likely it is to evidence emotional behaviour” [1].

Why Emotional Robots?

As robots become more prevalent in social spaces, such as healthcare institutions, schools, and museums, people need to be able to interact with them in a smooth, natural way. One way to improve these interactions is to have robots display changing moods and emotions, just as humans do [16]. A well-studied effect of human–computer interaction is that people tend to treat talking computers in the same way that they treat other people, forming social relationships with them [38]. This is even more evident when interacting with robots. People will answer the robot's emotions and expect the emotional response of the robot to be adequate [16].

Many of the existing robots have incorporated at least some rudimentary emotional behaviours, but such behaviours are usually ad-hoc and cannot be generalized to other robots. Robots with infant-like abilities of interaction, such as Kismet [45], have been used to demonstrate the ability of people to interpret and react appropriately to a robot’s display of emotions. Another reason to implement emotional systems for robots is that social intelligence is based on emotions; people have emotions, recognize them and express them [13]. A lot of information is discovered through facial expressions and voice. According to [13] artificial emotions are used in social robotics because they provide feedback to the user and this sort of feedback can be understood even by untrained users like a child for instance and therefore a robot with emotions would become a natural interaction partner. Artificial emotions can act as a control mechanism, driving behaviour and reflecting how the robot is affected by, and adapts to, different factors over time [24].

In the current development stage, robots are able of displaying (mimicking) emotions with a certain degree of intensity based on external stimuli, but a natural question arises: can robots be capable of experiencing true emotions and feelings, the way humans envision them? Reference [18] presents the idea that “the kind of emotions one feels depends, at least to some extent, on the kind of body one has”, therefore, radical embodimentalists argue that “no emotions are really available for autonomous agents” [18] because of the different kind of embodiment involved. If robots should only react to situations in an emotional manner than the problem is similar to that of believable agents, presented in [2], that only provide the illusion of life. The believable agents technique has been used since the early years of animation for creating realistic animated characters. In this perspective, the simple fact of displaying emotions means to achieve believability, thus robots capable of mimicking believable emotions would have the possibility of replacing classical types of entertainment (cartoons, theatre, movies) and to improve the performance by mixing it with interactivity and learning.

How to Design Emotional Robots

There are two possible approaches in order to make human-robot interaction (HRI) "human-like" or at least "creature-like": biologically inspired robots or functionally designed robots [24]. With the biologically inspired approach, designers try to create robots that internally simulate the native or learned social behaviour and intelligence of living creatures, as nature is the best model for life-like activity and is also adequate because it can be observed and tested [24]. But what it doesn't take into account is that nature also evolves and robots can mimic certain behaviours and intelligence but to some extent. On the other hand, the objective of the functionally designed category of robots is to create a robot that outwardly appears to be socially intelligent. This approach helps to create the impression of an artificial social agent and it assumes that superficial attitude is sufficient for short term interactions [24]. This sort of approach can provide compelling interaction in games and toys. According to [24] common design problems for socially interactive robots include: human-oriented perception (the way the robot interprets human behaviour), natural HRI (this includes social expectations, conventions and norms), readable social cues (e.g., appropriate feedback, like emotion) and real time performance (step with human interaction rate).

One of the existing frameworks for modelling affective robotic behaviour is TAME. It is one of the most developed emotional models for robots at this time [30], and considers the four affective categories of personality: traits, attitudes, moods, and emotions. The input into this architectural module consists of relevant perceptual information (stimuli and their strengths) [30]. An emotion, or "emotional response," is an immediate affective response to the evaluation of some event (or stimuli) as being of major significance. In the robots case, however, emotions are meaningless unless they result in some outward change in the robot, including facial, vocal, or behavioural modifications. The events that cause emotional responses, and the intensity of those responses, vary according to a person's personality traits, and also traits may influence emotion processing [16].

Moods are more "diffuse" affective states [39]. They are typically of lower intensity than emotions and have fairly low variance over the course of a single day. Moods may be caused by changes in physiological state or life events. Several studies have indicated that positive moods tend to reduce negative emotions (in frequency and intensity), and vice versa [16]. An attitude is an amalgamation of emotions experienced with a particular person (or thing), reflecting one's relationship with that person over time. Attitudes may change due to emotional events, and the frequency and duration of the relationship. Attitudes are a key part of long term relationships [16]. Emotions, moods, and attitudes all interact. In particular, both emotions and attitudes help to shape the overall mood, and at the same time, the mood affects how strongly emotional reactions occur [16]. The TAME affective architecture has been initially tested on the entertainment robot Aibo [31] and its use for humanoid robots has some advantages like making the communication between human and robots more natural, commonplace and prolonged [31].

Another view on the cognitive structure of emotions and the OCC model (Ortony, Clore, Collins) are described in [33]. An interesting model of emotion-specific influences on judgment and choice is described in [27]. Another emotion modeling approach is the MAMID cognitive architecture discussed in [21]. A cognitive-motivational-emotive system architecture is presented in [19]. There are also various fuzzy implementations, like FLAME (Fuzzy logic adaptive model of emotions) [14].

Categories of Emotional Robots

Until now, emotional robots have been designed for both real and virtual environments. The real world robots can be divided into two large categories: robots expressing emotions through body language and robots expressing emotions through art, in any of its forms. Virtual environments on the other hand are places where people can interact with virtual representations of other people, modelled as avatars, or objects. Robots can also be designed and studied in these environments. In the following section, several types of robots will be presented, according to the categories mentioned above.

Robots Expressing Emotions through Body Language

Kismet is a robotic head developed at the MIT Artificial Intelligence Lab and completed in 2001 (Figure 2). Kismet can communicate with people in a natural, almost human way. It has auditory, visual and expressive systems [45]. Kismet is the first robot designed to explore emotions at the face-to-face level and was designed for "exploring the origins of social interaction and communication in people" [7]. Twenty-one degrees of freedom direct the robot's facial expressions who are created through movements of the ears, eyebrows, eyelids, lips, jaw, and head [8]. Kismet is capable of expressive speech, voice expression, emotional responses, facial expressions, face-to-face interaction, and reaction at objects [8]. What makes Kismet special is its ability to interact socially. It recognizes human body language (mimics, gesture, posture) through 4 colour CCD cameras, voice inflections and responds accordingly. As shown in [8], Kismet acts like an infant and it will develop more complex skills in the future.

Fig. 2. Kismet

Besides humanoid robots, animal-like or zoomorphic robots were developed. Such an example is iCat (Figure 3) developed by Philips for the study of behaviour and human-robot interaction [46]. iCat is able to smile, be sad, or remain indifferent. iCat is 38 cm high and has 13 electric motors that control different parts of the face such as eyes, mouth, eyebrows and head position to produce the right emotion. It can express a range of emotions like excitement, happiness, arrogant, thinking, shocked, apologise, anger or scared [11]. iCat can also have different states like sleep, awake, busy or listening and the difference between these states is marked by the colour of the LED's in the ears [46]. As shown in [34], iCat can play a game of chess with an human player. The article highlights the idea that a robot (as iCat) can arouse more enjoyment in humans, than using a simple computer as counterpart. The features of this robot make it suitable to be used in interactions with children or even in therapy for autism (a disorder characterized by impaired social interactions) because infants can learn to mimic the robot's gestures or can better understand the moods expressed.

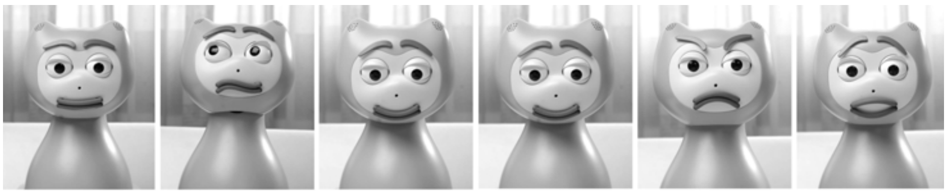

Fig. 3. iCat displaying the basic set of emotions

Another example of a zoomorphic robot is Aibo (Figure 4), a robotic pet, designed in the late 1999 through 2004, but which is currently no longer manufactured [34]. It was capable of facial expressions by patterns of LEDs [47], while a more recent model of Aibo featured voice interaction. With a vocabulary of 1000 words, Aibo was able to understand commands [41] and to display three emotions: happiness, sadness and anger through LED display, body language or melodies [41].

Using LED patterns in iCat and Aibo to mark moods or to display facial expressions is a simple way to convey a message. It may not appear to be efficient but people can easily adapt to this type of communication as it has been used in many other electronic devices to display state changes.

Fig. 4. Entertainment robot Aibo

An example of an emotional robot that combines utility with entertainment functions is Paro, a therapeutic seal robot that became a real help in hospitals [48]. Paro was equipped with five types of sensors to perceive the environment and communicate with people: tactile (and responds by moving its tail and eyes), light sensors, auditory sensors (to distinguish voice, words like names and greetings), temperature sensors and posture sensor (allowing it to feel if it is held in someone's arms) [48]. Paro weights 2.8 kilograms and was designed to interact with people on a physical level [29]. It was used for animal-assisted therapy. As shown in [29], Paro can express three different behaviors: proactive, reactive and physiological. Paro was tested at nursing homes, and helped with social interaction among the elders [23].

Leonardo is a robot developed at the MIT Media Lab. Leonardo is able to interact with people, to memorize their faces and then to recognize them. It sees through a camera mounted in its right eye. It is able to recognize people also after voice. This robot is capable to track people in real environment and interpret their activities [49]. Leonardo has 69 degrees of freedom (32 are in the face) and is therefore capable of facial expression very similar to humans. It is considered to be the most expressive robot at this time [49]. Leonardo also has a sense of touch to express the pleasure of hugs or pain when tightened too much. In brief and as mentioned in [49], Leonardo is a "sociable robot" capable of emotional expression, vision and "socially guided learning".

Robots Expressing Emotions through Art

A special category of emotional robots are those capable of expressing emotions through art. In the last decade there has been a constant increase of such robot artists including robots able to sing vocally or instrumentally, fashion models, actroids, and drawbots.

The HRP-4C is a humanoid robot created by the AIST in Japan [50] and was publicly presented in March 2009. It is 158 cm tall and weighs 43 kg including battery. Although current motion patterns (including walking) of HRP-4C are limited, they are quite similar to humans, because of the three degrees of freedom posted in the hip, three in the neck and eight in the face. The robot is able to interact with humans through speech recognition, and to display facial expressions and arm movements in order to express basic emotions like anger and surprise [50].

The Toyota Partner Robots are a series of humanoid robots developed by Toyota to enrich and assist the lives of Japan's aging population [22]. They debuted playing music on drums and trumpets. The goal of the project was to create technologies that can be applied in assistive, elderly care. Toyota says it wants the partner robots to have humanoid characteristics, "to develop partner robots designed to function as personal assistants for humans" [22]. There are a total of 5 robots, most of which having different movement system (either bipedal, the robot being able to walk similar to a human person, Segway-like wheels, or a unique wire system developed by Toyota that uses power source actuators located on the robot's torso and wires to move the arms and legs). They are 100, 120 or 180 cm tall and weighs 35 or 75 kg [51].

Actroid is an interesting robot developed by Osaka University and unveiled in 2003 at the International Robot Exposition in Japan. The term "actroid" is defined as a "humanoid robot which has made it possible to look just like a human being with an overwhelming realism and ultimate functions of expression abilities"[52]. The Actroid can imitate human-like behaviour with slight shifts in position, head, neck, arms, body, eyes, eyelids and mouth movements using its 33 motors. It can also create the appearance of breathing in its chest. Additionally, the robot can be "taught" to imitate human movements by facing a person who is wearing reflective dots at key points on their body. By tracking the dots with its visual system and computing limb and joint movements to match what it sees, this motion can then be "learned" by the robot and repeated [28].

EveR-2 is a female robot developed in KITECH (Korea Institute of Industrial Technology). The project of the robot EveR-2 is to implement and test emotional expressions (facial emotions) and human-robot interaction. It is 165 cm tall, weighs 60 kg and it has the appearance of a Korean female. The body has a total of 59 degree of freedom which are distributed as: 22 in the face (eyeball: 4), 3 in the neck, 12 in the arms, 8 in the hands, 2 in the torso, 6 in the hips, 2 in the knees, 4 in the ankles and also has 2 small CCD cameras in the eyes. EveR-2 can be used in guidance service, oral narration and singing- it can synchronize lip with voice; and conversation using a dialog database, it has 100 gesture data. It can express 6 facial emotions like happiness, sadness, fear, surprise, anger and disgust [26].

WF-4RIV is an anthropomorphic flutist robot built at Waseda University, shown in Figure 5. The research began in the '90s and focused mainly on reproducing human organs that are required for playing the flute (lips, lungs, neck, arms, fingers, tongue). The main goal of the research was to clarify the flute playing mechanism from the engineering viewpoint and to enable the communication with humans at the emotional level [53].

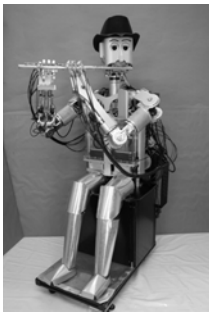

Fig. 5. WF-4RIV anthropomorphic flutist robot

J2 Jumping Joe is an artistic robot designed by the Kyushu Institute of Technology and exhibited at the Aichi Expo in 2005. According to [32], the main objective of the robot is to realize acrobatic motions such as fast wake up, jumping, rolling and somersault in order to extend the field of robot activity. Jumping Joe is an artistic, agile robot that walks on two legs and performs artistic movements, while developing new behaviours like jumping, rolling and their combinations. In order to realize special motion, robot joints need high specifications. Special robot joints that employ parallel mechanisms have been developed as a solution to these problems. The purpose was to make joints light and high speed and also to achieve high power and high rigidity [40].

Addressing another category of art are the drawbots, robots designed specifically for drawing, featuring simple style and creativity. Starting from simple to complex there have been a number of implementations in this area of robotics. A project started in 2005 by an international, multi-disciplinary, group of researchers attempted to use evolutionary and adaptive systems methodologies (genetic algorithms, neural networks) to make an embodied robot that can exhibit creative behaviour by making marks or drawings (in the most general sense). The motivations behind the project include the production of machine art and the exploration of whether it is possible to develop (minimally) creative artificial agents [10].

Another example of an artistic, drawing robot is being developed as a Laboratory of Natural Computing and Robotics (natuRO) project [54] and is part of an integrated framework for emotion recognition and expression using e-Puck robots. The project focuses on finding a way for transposing emotions from literary texts to robot drawings. Advantages of the presented approach include the possibility to use this technique to aid accelerated learning by stimulating visual memory or for text interpretation. It will be presented in the following only the expression stage of the transposing system. The recognition of emotions in text part is completed separately by the text analysis module.

The application involves a robot artist, capable of evoking an aesthetic experience in the human audience, not a robot with emotional states. The human robot interaction issue has been taken into account and therefore the physical representation of emotions consists of face drawings because facial expressions can be best used to suggest an emotion and can be easily recognized and understood by the human viewer. In addition, the interaction between a person and a robot is more natural than using other type of devices. Similarly, humanoid robots like the ones presented above help people even better understand their behaviour and react easily to the intended message due to their type of embodiment.

An e-Puck robot [55] has been used as a drawing agent, having a soft pen attached that marks its trajectory (Figure 6). As a result it can only draw single-coloured continuous line images.

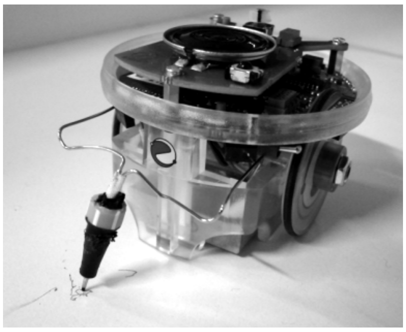

Fig. 6. e-Puck robot with a soft pen attached

A schematic representation of the emotion to drawing module can be seen in Figure 7. More details about the whole architecture and related results can be found in [5]. The input is comprised of user parameters and an emotion graph resulted from a text to emotion module which identifies the dominant emotion from a literary text [5]. The emotion graph presents the dominant emotion of the analyzed text that will be expressed in the drawing and several related emotions used to model the intensity and dynamics of the dominant emotion [3]. The program parameters that can be set by the user are the following: drawing type (the robot can either automatically generate a face from the given parameters or draw a face extracted from an image file), a scaling factor that determines the output size of the drawing, the drawing rate (or speed), that can be either predetermined (slow, medium or fast) or can be modified dynamically during the drawing process.

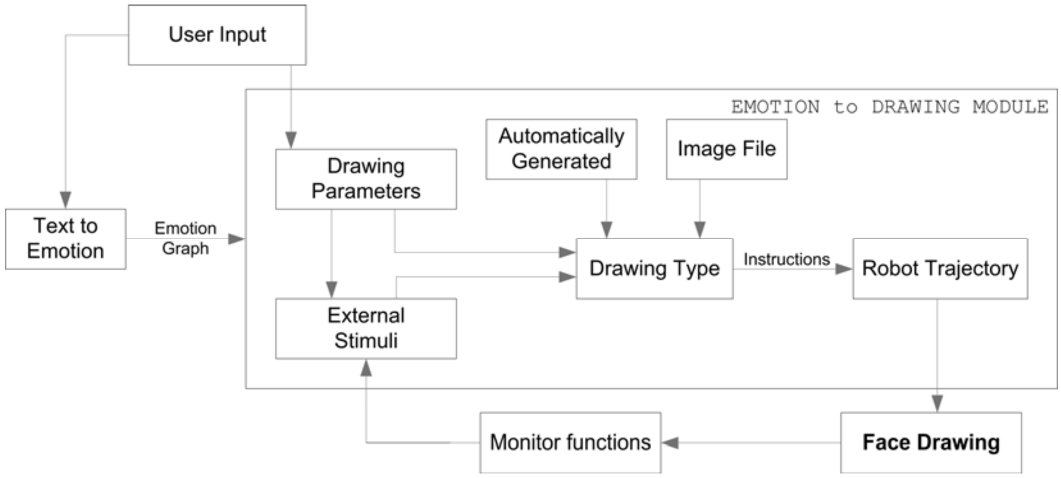

Fig 7. Schematic representation of the emotion to drawing module

The program will determine a colour range corresponding to that emotion (according to Plutchik [43]) to be used in the representation and will require that the right coloured pen will be mounted on the robot. The robot can also mark the end of the drawing through a sound pattern specific for each emotion. The robot is capable of drawing the six basic emotions, according to Ekman: happiness, sadness, anger, fear, disgust and surprise. An overview with all the corresponding face types can be seen in Figure 8.

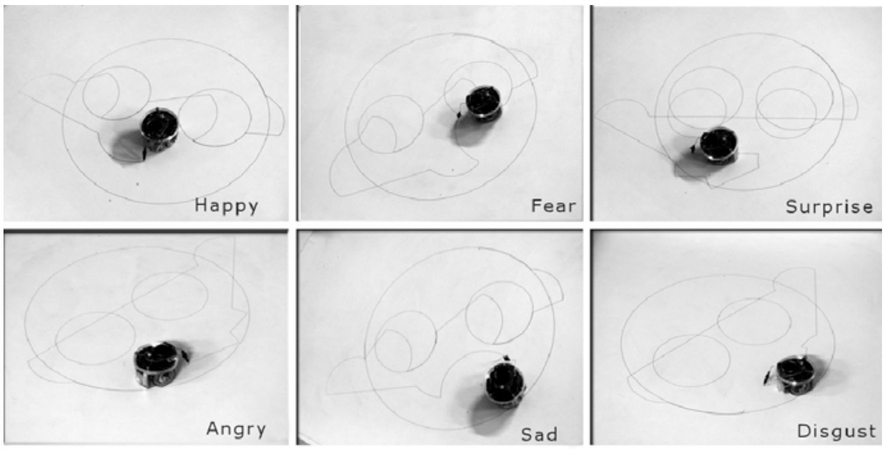

Fig. 8. Examples of facial expressions drawn by the robot

Monitor functions are also included as described in [5], to provide information on the system and the overall progress of the drawing. The first function concentrates on the output provided by the robot and the second one gives feedback on the drawing by highlighting the covered portion of the image and showing the instantaneous values of dynamically modified parameters. The efficiency of the drawing method is given by the optimization of robot's trajectory for single, continuous line drawings, resulting simplified, yet realistic representations of the face and the basic facial expressions.

It is important to notice that the robots presented above do not experience and understand emotions in the way humans perceive emotions and related mental states. The robots are actually only capable of displaying certain behaviours that are generally known to be associated with certain emotions, to interact socially with humans and respond in an emotional manner by mimicking the emotional aspect, therefore the feeling part that is strongly related to personality and consciousness is not yet conveyed. In the case of artistic robots the present purpose is to improve the robots' performance skills so that their work of art will evoke emotional responses in the human audience.

Virtual Implementation of Emotional Agents

The roboceptionist Valerie (Figure 9) is the product of collaboration between the Robotics Institute and the School of Drama at Carnegie Mellon University (CMU) that has the goal of investigating human-robot social interactions. Valerie's office is near the main CMU entrance so anyone who walks through the building can interact with her [17]. The face is used for expression of emotions and for head gesture. Valerie handles some of the task that a real receptionist would do, such as providing directions and looking up office numbers [17]. She interacts with people talking about her boss, her love life, her therapy business, her singing career and about her receptionist job.

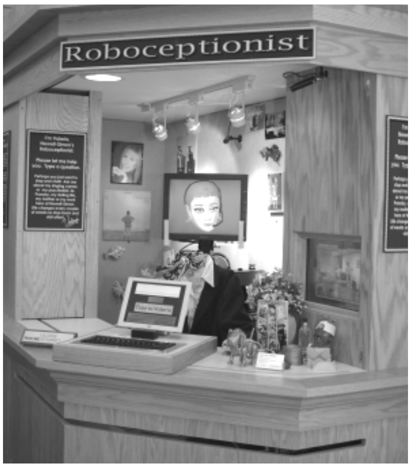

Fig. 9. Roboceptionist Valerie

Second Life (SL) is a 3D environment, developed by Linden Lab. It allows registered users (residents) to perform multiple activities and social interactions (events, games, e-commerce, collaboration, education). It allows experimentation with new means of inter-personal interaction and media communication. In [36] it is presented a "project of the University of Siena whose aim is that of developing and investigating the role and potentials of robotics platforms in SL". The article brings in discussion the issue of cooperation between people and robots in the same environment.

Some of IEEE-Robotics and Automation Society activities are being hosted in a building on the IEEE Island in SL. The building has five floors and each of them is focused on a particular theme like: helpdesk for welcoming users, virtual auditoria for organizing events and even a library of information for designing, building and controlling a robot in Second Life [37]. A sample robot designed by the students at naturRO and residing in SL is shown in Figure 10 (a). An example of conveying emotions in virtual environments is through animating avatars representing humans, shown in Figure 10 (b) or through building various objects that convey emotions, as shown in Figure 10 (c).

Fig. 10. (a) Example of a custom robot built in Second Life; (b) humanoid avatar displaying boredom; (c) happy face built out of primitive objects.

Conclusions and Further Work

This paper presented an overview on emotional robots and robot artists. The importance of emotion modelling in robots' behaviour has been underlined. Several theories concerning emotions and also emotional models, related architectures and physical implementations of various emotional robots were presented and discussed.

In the context of the survey of existing models and applications of emotional robotics, an innovative category of robots and their application in the art field has been presented. An original, practical approach for transposing emotions from text to drawings has been briefly described, the main idea being to use a drawing robot to express or represent emotions through drawn faces. The faces drawn by the robot represent the dominant emotion in a literary text that is automatically analyzed. In order to achieve this, several problems have been addressed, taking into consideration the constructive limitations of the robot used. Several usage scenarios for the application have been presented. The paper ends with presenting virtual implementations of emotional agents.

The importance of developing emotional robots is increasing in an era of intensive interactions between humans and various devices, specially robots with growing autonomy and intelligence, allowing them to be included in more and more complex tasks, and enhancing their involvement in human life. They will be able to offer support with elder care by understanding their needs or to get involved in education, assisting children in the learning process from young ages by developing efficient communication methods. Besides increasing the quality of life for people with special needs robots will be able to entertain a human audience through aesthetically pleasing performances.

Acknowledgement

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Emoții si roboți artişti: starea actuală şi provocări în cercetare

Rezumat

Emoțiile joacă un rol fundamental în comunicația şi înțelegerea mutuală între oameni. Acest lucru este adevărat şi pentru interacțiunea om – robot. Această lucrare prezintă un punct de vedere personal asupra emoțiilor şi a roboților capabili de a crea artă. Este descrisă critic starea actuală în robotica emoțională, incluzând modele existente şi teorii despre emoții. Roboții emoționali reprezentativi sunt grupați în trei categorii: roboți care exprimă emoții prin limbajul corpului, care exprimă emoții prin artă şi roboți virtuali. Lucrarea prezintă pe scurt şi o arhitectură cognitivă originală a unui sistem capabil să analizeze texte literare, să extragă emoția dominantă exprimată in text şi să transpună acea emoție în formă grafică folosind un robot care desenează. Lucrarea se incheie cu exemple de agenți sintetici în medii de realitate virtuală şi cu prezentarea unor direcții de dezvoltare în domeniul roboților emoționali.