Simulation of Empathy in Machines Incorporating the Subjective Nature of Human Emotions

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Abstract— In this paper, we present an interactive human-robot system with elements of reflecting emotions, inspired by the findings from the neurosciences about special cells called mirror neurons, believed to be the foundation of human empathy. Moreover, recent research in robotics has shown that the ability of machines express empathic emotions enhances human-machine interaction. We cope with the subjectivity of the stimuli used to elicit emotions for each of the users proposing a personalization of the robotic character based on subjective preferences of users during a human-machine dialog, where the most common used words during the conversation are assigned with a subjective emotional affect, performed by body-based expressions of the robot. The robotic expressions of empathic emotions enhance users’ satisfaction, engagement, perception of robots, and performance in task achievement. We believe that the system allows to communicate with human beings in natural way and thus to participate in human social activities.

Keywords—affective computing, human-robot interaction, subjective computing.

I. INTRODUCTION

“Machines are becoming devastatingly capable of things like killing. Those machines have no place for empathy. There’s billions of dollars being spent on that. Character robotics could plant the seed for robots that actually have empathy,” – these are the words of David Hanson in his famous TED talk [1].

Machines cannot feel and express empathy. However, it is possible to build robots that appear to show empathy, which is commonly understood [37] as the capacity to “put your-self in someone else’s shoes to understand his/her emotions.” There is a convergence between cognitive models of imitation, constructs derived from social psychology studies on mimicry and empathy, and recent empirical findings from the neurosciences, e.g. [3][4][5][6][7][8][9][10]. According to [6], empathy research indicates that it is made possible by a special group of nerve cells called mirror neurons, at various locations inside the brain. Mirror neuron activity helps people understand actions and intentions of others and is also involved in understanding emotions. Empathy may be facilitated through a process of automatic mapping between self and other. Perception of the actions and emotions of others activates areas in our own brain that typically respond when we experience those same actions and emotions.

The global challenge of our research is to design socially engaging robots and interactive technologies that provide people with long-term social and emotional support – in general to help people live healthier lives, connect with others, and learn better. In this paper, we present a system which reacts to the stimuli subjectively, depending on the user’s preferences. For the implementation of the emotional conversation we use the SDK kit created by Microsoft [30], concretely its program for speech recognition. We enrich the conversation between the human and the machine, a humanoid robot, with the expressions of personalized emotions.

Fig. 1. In study by [7], test subjects were asked to imitate facial expressions of others. fMRI scans revealed less brain activity in regions associated with mirror neurons in individuals with autism spectrum disorder (b) than in the control group (a).

Fig. 2. Hanson’s android reflecting his emotions as a mirror system that can be perceived a tip-off on artificial empathy. The artificial head reacts to the facial and verbal expressions of the human by...
This paper is organized as follows:

Section II presents the state of the art of related research focused on the field of social robotics. Next section III analyzes the term of emotion together with the research on subjective computing, considered as a new stage of computer science. Section IV introduces our approach to build a system that reflects the human emotional affect during the communication and in this way; the system seems more believable and natural for the human partner.

II. EMPATHY IN HUMAN-ROBOT INTERACTION

The current research beyond the hypothesis that giving machines the capability of expressing empathic emotions towards users demonstrates its great potential on improving the overall interaction, e.g. in [36][35][34][33][31][32].

Breaale [29] investigates emerging robotics applications for domestic or entertainment purposes which are slowly introducing autonomous robots into society at large. She claims that a critical capability of such robots is their ability to interact with humans, and in particular, untrained users. She explores the phenomenon that people will intuitively interact with robots in a natural social manner provided the robot can perceive, interpret, and appropriately respond with familiar human social cues.

In the area of social robotics, Kanda et al. [27] has achieved to improve route guidance interactions with a robot by incorporating cooperative body movements (e.g. synchronization of arm movements), enhancing both reliability and sympathy.

Rick et al. [28] studied the effect of automatic head gesture mimicking with a chimpanzee robot. The robot would listen to participants while either mimicking all head gesture, only nodding or no mimicking, resulting in different levels of interaction satisfaction. This work extends the state of the art by explicitly evaluating facial expression mirroring in contrast to head, arm or body gestures.

Coming back to the roots of artificial intelligence, Turing by himself was fascinated by the notion of affective responses, such as joy, interest, and surprise, in human interaction with computers [2]. Turing’s initial questions have led to more complex investigations into the ability of the computer to model human emotions, and to evoke emotional responses in its human user.

A wide spectrum of existing projects and applications (e.g. [11][12][13][15][16][17][18][19][20]) are trying to better understand human emotional behavior and develop a model according to their needs and expectations, implementing this model in machines that interact with people. Such projects assume that during the process of system migration to human society they will be considered beneficial and intuitive partners. How we believe future cooperation between robots and ourselves will look can be summed up in these words: machines fully adapting to man – that man no longer has to adapt his behavior to machines.

III. ON THE SUBJECTIVITY OF EMOTIONS

We believe that equipping machines with the ability to simulate empathy can drift towards intuitive mutual man-machine cooperation. Inspired by the psychological models of emotions, researchers in artificial intelligence and cognitive robotics have begun to recognize the utility of computational models of emotions for improving complex, interactive programs. Software agents may use emotions to facilitate the social interactions and communications between groups of agents and this way they can help in coordination of tasks, such as among cooperating robots. Moreover, synthetic characters can use a model of emotion to simulate and express emotional responses, which can effectively enhance their believability. Furthermore, emotions can be used to simulate personality traits in believable agents. Recently, however, cognitive neuroscience and related fields have demonstrated the inseparability of emotion from rational thought and normal human function [39] – as Minsky believes, “the issue is not whether intelligent machines can have emotions, but whether machines can ever be intelligent without them [14].”

Emotions comprise subjective experience and expressive behaviour, are motivators for actions, and will change according to the range of actions that the subject is able to take in a given situation [21]. On the other side, computer science and robotics use techniques which have been developed through objectivism. The domain of human-robot interaction is different-machines are not only evaluated by objective measures, but also subjectively. This phenomena as a specific research phase represents a new stage of computing based on the subjectivity in the human perceptual process.

Suzuki [22] from University of Tsukuba, introduced an approach of Subjective Computing (SC) in 1995, tightly related to cognitive science and including an integrated physical robot system for investigating varieties of mechanisms relevant to embodied. A modelling taking insight from the human subjectivity and individual preference is the main issue of this research. SC includes the terms of individual emotional resonance, comfort and satisfaction. It differs from a conventional evaluation based on objectivity and logic used in physics or mathematics. The subjectivity and individual preference should be treated as psycho-physiological interrelationship.

Harrel [23] at MIT Imagination, Computation, and Expression Laboratory, uses the term of Subjective computing systems for artificial intelligence and cognitive science-based computing systems for creative expression, cultural analysis, and social change.

We try to cope with the subjective experiences that influence the emotional affect of the meanings of the words during the verbal communication with the robot, described in section IV.

IV. IMPLEMENTATION

The goal of the research is to create user friendly interface, where a humanoid robot expresses emotions according to the word said by the user. It is difficult to define emotional affects for each person specifically, because every person has different express of emotion on different situations and circumstances. Thus it is very difficult to create system which is specified for wide spectrum of users. We developed a personalized system—a user can assign the type of the emotion to given word on the web interface, and then the chosen emotion will be implemented into the robot, based on the individual preferences of the user. The system can identify a speech command from user, which is followed by expressed emotion of the robot (for example, if the human assigns the emotional affect of “Joy” to the word “mother”, the robot performs the expression of joy every time when he recognizes
the word “mother” during the communication with the human).

To identify the types of emotions a user may feel during human-machine interaction, we explore the work of Plutchik [25]. Plutchik’s psychoevolutionary theory of emotions is one of the most influential classification approaches for general emotional responses. He considered there to be 8 primary emotions - anger, fear, sadness, disgust, surprise, anticipation, trust, joy. Plutchik’s proposed that these basic emotions are biological primitive and have evolved in order to increase reproductive ability of animals.

The program is written in a system environment of Microsoft Visual Studio 2010 Professional using the .NET platform because robot NAO and Kinect sensor supports this programming language and theirs API are well documented. Kinect [30] is a motion sensing input device by Microsoft for the Xbox 360 video game console and windows PCs. One of key feature of Kinect for Windows is speech recognition. Kinect contains 4 microphones linearly arranged. The sensor improves the sound quality through noise suppression and acoustic echo cancellation. Nao is humanoid robot created by Aldebaran Robotics, French company. His height is 57cm and the advantage is his simple manipulation. The API supports programming in various languages, e.g. C#, Python, C++, among others. We use the program API provided by the company Microsoft, concretely Microsoft for Kinect SDK beta, Microsoft speech platform, which is used for recognition of speech commands and API Naoqi created by Aldebaran Robotics for programming robot Nao.

The basic logic of the system consists in the following steps:

- A web interface for the creation of a personalized dictionary of words was designed. Here the user assigns the emotional affect based on his preferences.
- The personalized database of the emotional affects for the most common words used in the conversation with the humanoid robot is used during the proximate interaction.
- The Kinect sensor captures the word, compares it to the words saved in the database and if the human uses a word that is situated in the dictionary, the robot expresses assigned emotion. The speech commands are written in the form of dictionary.
- This process runs in cycle from start until end of program. If application does not find connected Kinect to PC, a message, informing user that Kinect was not find appears and the application is executed.

According to the Plutchik’s theory of emotions, eight types of basic emotions are created. As the humanoid platform Nao does not have face to create facial expressions, we implemented body-based expressions of emotions, by setting angles of the joints of the robot. Expressed emotions are based on technical capabilities of Nao and common human emotion expression.

![Fig. 3. Human interacting with the humanoid robot.](image1)

![Fig. 4. Robot expresses Fear.](image2)

**V. DISCUSSION**

Emotions and their expressions belong to the nature of every human, but are not so common in robots and computing systems. Systems capable of expressing emotions may have big impact not only on field of computing technology but psychology as well.

This paper introduces our approach of the interactive human – robot system with elements of emotions. The results of the work can be viewed also from a certain psychological point of view. The goal is not to create an application that serves only for entertainment, but also to receive some sort of feedback in the form of information and experiences from users. There are countless possibilities where a robot which can express empathy could help. Some people can open themselves and express emotions, tell their thoughts to machines rather than to humans. This implies that these systems can help many people. On the other hand, the system can be used for entertainment of people, for example in art, where robot could perform any theater play.

Now we need to conduct various experiments to prove whether mirroring emotional affects has a positive influence on the human-robot interaction. Giving emotional meaning to a word in conversation is one part of our greater project on human-robot empathy. The other parts include for example gesture recognition using neural networks, a learning framework for body-based expressions from human to robot and the emotional model, where the basic emotions are combined into complex emotional spectrum. Moreover, we develop a visual system for monitoring the interest of people in the interaction with the robot.

Future work will explore the contribution of the simulation of empathy in real environments, measuring and comparing the interest of human subjects in the interaction with and without the elements of the artificial empathy.

This work is part of a wider tendency to rethink the way that interfaces operate: “a shift toward a human-centered interaction architecture, away from a machine-centered architecture[38].” This shift recognizes the importance of human emotion and response in the design of interfaces and points up some changes in the human-machine relationship. For example, machines have begun to adapt to their users, rather than the other way round; the interface is becoming a responsive entity, rather than a passive portal.
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