Current Trends in Human–Robot Interaction: Towards Collaborative & Friendly Machines

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Abstract— The focus of robotic research continues to shift from industrial environments, where robots perform repetitive tasks, to service robots placed in a wide variety of environments, often in human-habited ones. Thus, the importance of the field of Human–Robot Interaction (HRI) has been denoting an increasing growth. This paper identifies current trends in the research of Human–Computer Interaction, focusing on new kinds of interfaces, as it has many overlapping challenges and applications with HRI. We also discuss the question whether robots are a distinctive case of study than other technologies studied in HCI. We believe that the quality of HRI will determine the effectiveness of the collaboration and in general, the acceptance of robots in the society. Our main research is focused on developing computational models for humanoid robots which try to predict what a person is thinking or wanting. We illustrate this idea on two case studies: the first one is an architecture based on the robot IROS, endowed with a system for prediction of human’s goals in a collaboration task and the second is an architecture based on the robot NAO, possessing an emotion technology, which is used for guessing user’s future behaviour based on his/her emotional expressions. We consider this approach useful to make the HRI more natural and efficient.

Keywords—human–computer interaction, human–robot interaction, social robotics, robot IROS, robot NAO.

I. INTRODUCTION

“Above all, the human animal is social. For an artificially intelligent system, how could it be otherwise?”[1]

As robots increasingly make their way into functional roles in human environments (e.g. homes, schools, and hospitals), they need to react appropriately to human expectations and behaviour. Moreover, a person working with a robot should not be required to learn a new form of interaction. Thus, we need to develop computational models of social intelligence for these robots that will allow them to have interactions that are natural and intuitive for a human partner.

According to the Human-Robot Interaction (HRI) Research Portal for the HRI Community [2] “HRI is a field of study dedicated to understanding, designing, and evaluating robotic systems for use by or with humans”, including topics of gesture and natural language communication, perceiving emotions and expressing their own artificial emotions, establishing social relationships, exhibition of different personalities and characters, recognition of interaction partner and others.

Interaction requires communication between robots and humans, which may be remote (teleoperation/telemanipulation), proximate (may include a physical interaction, e.g. robot assistant) and social (including social, emotive, and cognitive aspects).

The field of cooperative work sees robots and humans acting like team members rather than autonomous, independent devices. If an intelligent behaviour is required, devices should be endowed with metaknowledge and meta-communicative skills, e.g. consciousness and self-awareness. Current trend is to involve emotion technology in such systems-it can help to determine goals and communicate internal states of humans and robots. A number of cognitive scientists believe that intelligent behaviour cannot take place without emotion [11].

This paper has the following contributions: In Section II we try to draw attention to the new generation of Human–Computer interfaces that can be useful for developing more efficient HRI presenting a survey of them. Section III develops an idea of human-oriented robotics, where we consider the emotional technology as a new trend in such systems. Section IV presents experiments with cognitive robots in the human–robot collaboration tasks.

Researchers want to construct robots to behave more like people, so that people do not have to behave like robots when they interact with them. The global idea is that communication and interaction should be easy and enjoyable, both for unfamiliar users and trained professionals.
II. NEW TRENDS IN HUMAN-COMPUTER INTERACTION

As the field of HRI is growing, it benefits researchers in HCI (and vice versa) and it has been nurtured by HCI organizations. This field is still a young one - sometimes considered a specialized offshoot of the wider area of human-computer interaction (HCI), other times a new field - we point out some of many contributions it has from HCI.

Microsoft Research summarizes major transformations that affect how people will interact with computing technology in future. They argue that computing no longer has a single interface (as the conventional computer with a keyboard and a mouse), but many different ones - some are created by computers encroaching people’s personal space, even being embedded within them, others are produced by computers moving away and disappearing into the richness and complexity of the world around them.

A. Transformation of HCI interfaces

As a new trend can be considered Intelligent HCI designs - interfaces that incorporate at least some kind of intelligence in perception from and/or response to users, e.g. speech enabled interfaces that use natural language to interact with user or devices that visually track user’s movements or gaze and respond accordingly. (Adaptive HCI designs, on the other hand, may not use intelligence in the creation of interface but use it in the way they continue to interact with users.)

From GUIs to multi-touch, speech to gesturing, the ways we interact with computers are diversifying as never before [4].

Speech-recognition systems support a different kind of ‘natural’ interaction, allowing people to issue commands and dictate through voice. Multi-touch surfaces enable interaction with the hands and the fingertips on touch-sensitive surfaces, allowing people to manipulate objects digitally as if they were physical. Within tangible interfaces physical objects are embedded with computation, sensing and reacting to the ways they are picked up, manipulated, and moved in space. The ability to sense our interaction without direct physical engagement with computer systems or input devices is also a growing trend. The visual based HCI is probably the most widespread area in HCI research. Researchers tried to tackle different aspects of human responses which can be recognized as a visual signal, e. g. Facial Expression Analysis, Body Movement Tracking, Gesture Recognition or Gaze Detection (Eyes Movement Tracking). Eye movements have been used for many years as a way of supporting the disabled in interacting with computers, but now we are also seeing the advent of ‘brain computer interfaces’. These systems can be useful for disable people using brain waves to interact with their environment. Real-time brainwave activity is beginning to be used to control digital movies, turn on music, and switch the lights on and off. The most difficult and costly devices to build are haptic devices. These kinds of interfaces generate sensations to the skin and muscles through touch, weight and relative rigidity.

Ambient Intelligence (AmI) is defined by [5] as „the convergence of ubiquitous computing, ubiquitous communication, and interfaces adapting to the user, “, where ubiquity involves the idea that something exists or is everywhere at the same time on a constant level, for example, hundreds of sensors placed throughout a household. The objective of AmI is to broaden the interaction between humans and digital information technology through the use of ubiquitous computing devices.

Virtual Reality replaces the real world with a simulated one, instead the Augmented Reality (following Wikipedia) s a live, direct or indirect, view of a physical, real-world environment whose elements are augmented by computer-generated sensory input. These paradigms are used especially in robotics research for testing the robot’s performance.

B. HRI versus HCI

Authors in [7] identify several reasons why autonomous robots are a distinctive case of study than other technologies studied in HCI. They argue that people seem to perceive autonomous robots differently than they do most other computer technologies. People’s mental models of autonomous robots are often more anthropomorphic than are their models of other systems – we expect more from robots than from conventional computers. Secondly, robots are ever more likely to be fully mobile, existing in the physical proximity with other robots, people, and objects. Mobile robots have to negotiate their

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1 For example, the first International Conference on Human-Robot Interaction was sponsored by ACM’s Computer-Human Interaction Special Interest Group
interactions in a dynamic, sometimes physically challenging, environment, creating a complex feedback system. Furthermore, robots learn about themselves and their world, and they exert at least some control over the information they process and actions they emit. An autonomous robotic system adds more complexity because it must adjust its decisions sensibly and safely to the robot's abilities and to the options available to the robot in a given environment. The system also must detect and respond to changes in the environment and its users.

Their [7] main argument is that a conventional computer looks like a machine and acts like one and robots are designed to resemble humans and mimicking people's behaviour. We argue to this opinion up to some point, as conventional computers are changing to new kinds of interfaces described in Section II. All of interfaces mentioned have application potential in robotics. For example, robots can learn in augmented reality and use this knowledge in „real” reality. For example, such techniques are used to support remote interactions in NASA’s Robonaut. Brain computer interfaces can control robot arms, allowing paralysed individuals to manipulate objects. Haptic devices are designed for humanoid robots (in Europe especially Italian Institute of Technology for humanoid iCub). Some suggest that telepresence, the natural extension of human awareness of a remote space, is a goal of interface design in HRI. Also, game industry is a wide application area, sophisticated multi-player online games may become useful in understanding how natural language can be used to support HRI and how human-robot teams should interact.

Physical embodiment via a robot opens up a number of new research challenges to us. Unlike virtual agents, robotic agent co-habit with the human in a physical space in which social interactions take place.

III. ROBOTS THAT PREDICT WHAT A PERSON IS WANTING

New trend in HRI is to program robots that respond and adapt to people’s needs accordingly. In the past, most machine-learning applications operated ‚off’–line’, where a set of training data would be collected and used to fit a statistical model. The fields of artificial intelligence (AI) and cognitive science have a great deal of relevance to the field of HRI. Cognitive models are being used for modelling how a human might interact and as the basis for generating robot behaviour.

As mentioned before, robots are expected to interact with humans in social environments, like hospitals, schools or at home, a comfortable and intuitive way of communication has to be established. Case study with platform IROS in Section IV.A illustrates such a communication. This platform has a system for indentifying human intentions so it predicts his/her goals. In such manner it helps human in a collaborative task efficiently. When humans communicate with each other, they do not only use speech to convey the content of a message. At the same time, they employ a large variety of emotional and social signals to express consciously or unconsciously additional information, for example, about their attitude towards the conversational partner, their level of attention and their personality. In Section IV.B we present a case study built on platform the NAO where a robot possess an emotional model.

Researchers in different fields of developing technologies consider social and emotional levels of interaction as a critical role in a person’s acceptance of and overall experience with any technology. Emotions are an essential part of human intelligence, and play a crucial role in perception, rational decision making and learning. By providing a robot with a personality, it helps provide people with good models and good understanding of the behaviour.

Marvin Minsky in his The Society of Mind [8] reasons about artificial emotions: “the question is not whether intelligent machines can have emotions, but whether machines can be intelligent without any emotions.”

IV. CASE STUDIES WITH REAL ROBOTS

A. Case Study with IROS: Predicting Human’s Goals

Based on the research of [9], we performed experiments with the robot IROS (Figure 4.), which has verbal and non-verbal communication skills for natural and efficient HRI. It is endowed with an architecture which implements a flexible mapping from observed action of a user onto “to-be-executed” complementary behaviour. This output behaviour is a speech output and/or a goal-directed action.

The mapping takes into account the inferred goal of the user (team-partner), shared task knowledge and contextual cues to accomplish a task. First of all, the robot has to infer what object the human user intends to build. Subsequently, the team formed by the robot and one human partner, constructs the target object from its components following the assembly plan. An action monitoring system which detects a mismatch between predicted and perceived action outcomes is also presented. Its direct link to the robot’s motor representations of complementary behaviours guarantees the alignment of actions and decisions between the co-actors also in trials in which the human user performs unexpected behaviour.

His mental model for making decisions is based on the theory of dynamic neural fields, explained in [10]. The snapshots of video sequences, which can be found at http://youtu.be/86fn9RTii78, shall illustrate the processing mechanisms underlying the robot’s capacity to anticipate the user’s needs and to deal with unexpected events.
B. Case Study with NAO: Predicting User’s Behaviour by Emotional Analysis

In recent years huge progress was made in the effort to express emotions with humanoids, mainly with facial expressions. Our results with the implementation based on the Body Movement expressions suggest that a humanoid robot, such as Nao, should be able to display emotions using its body (via postures, body movement and proxemics) Postures, specific positioning that the body takes during a timeframe, postures are an effective medium to express emotion, also many emotions are differentiated by characteristic body movements, and that these are effective cues for judging the emotional state of other people even in the absence of facial and vocal cues. Body movements include the movements themselves as well as the manner in which they are performed. Proxemics is the distance between individual during a social interaction, which is also indicative of emotional state.

To develop our model, we propose to use a Membership-function ARTMAP neural network (NN), a clustering technique with supervision, in order to learn different expressions of emotions from various users. Moreover, this paper seeks to demonstrate the usefulness of our methodology by adapting a model from psychology developed by R. Plutchik. It consists of eight basic emotional states and all other emotions are mixed or derivative states; that is, they occur as combinations, mixtures, or compounds of the primary emotions. Firstly, a database of expressions which describe these primary emotions is constructed, serving as input data for our NN. The system is able to recognize emotional expressions of various users and is transferred to a humanoid robot. Afterwards, the robot is capable to recognize emotional expressions of different users interacting with the robot and also can express its internal state by adopting the emotional expressions. Thus he can predict user’s intentions based on the current emotional states. More about this research can be found in [11].

V. CONCLUSION

When the robot expresses his internal states via his non-verbal and verbal expressions during communication, humans should better understand him. The question is, if robot can express emotions understandable by human society, he should learn to recognize people's intentions to help him as a team partner in collaboration tasks.

Our future research will concentrate on the implementation of reactive social behaviours. NAO should be able to analyze social signals from the human during their collaboration and respond to it in real time. It is a complex task, including adaptation, learning, memory, motivation, focus of attention, internal model, communication and exchange of information, sensory integration, objectives management (creation of new goals, priorities) up to the emergent phenomena. Robotic sensing, cognitive, and actuating capabilities need to achieve a certain level of complexity such that people could treat them more as team-mates or companions to move them out of industry into everyday life.

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