Proceedings of the 1st workshop on

Emotion and Computing –
Current Research and Future Impact

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Emotion and Computing - current research and future impact

Workshop

The workshop focuses on the role of affect and emotion in computer systems including the three dimensions: emotion recognition, emotion generation and emotion modeling. Both shallow and deep models of emotion are in the focus of interest.

The goal is to provide a forum for the presentation of research as well as of existing and future applications and for lively discussions among researchers and industry.
In recent years computer science research has shown increasing efforts in the field of software agents which incorporate emotion. Several approaches have been made concerning emotion recognition, emotion modeling, generation of emotional user interfaces and dialogue systems as well as anthropomorphic communication agents.

Motivations for emotional computing are manifold. From a scientific point of view, emotions play an essential role in decision making, as well as in perception and learning. Furthermore, emotions influence rational thinking and therefore should be part of rational agents as proposed by artificial intelligence research. Another focus is on human-computer interfaces which include *believable* animations of interface agents.

Which commercially interesting *applications* would incorporate emotional aspects? One of the first interesting applications are dialogue systems which intend to generate natural language that sounds human-like on the one hand and which also and especially intend to react on emotional aspects of the utterances of the human partner adequately. On the other hand an increase of acceptance and quality is the intended result of the effort.

Another field of application – which is well known to AI – is the field of computer games. After putting the graphical quality at first priority for years, the increasing interest in believable and intelligent NPCs (non player characters) can be recognized. A market volume of more than a billion Euros in Germany makes this application type even more interesting.

A third application type often mentioned as an outstanding example is a tutoring system. The success of eLearning depends on the quality of learner and teacher interaction. Adapting the way of teaching to the learner – and potentially to its emotional state – is required to achieve good learning results. Since more and more teaching will be at least supported by electronic tutoring systems and eLearning components this field will show increasing demand in techniques discussed in this workshop.

Considering emotion measurement and classification, product prototype evaluation could benefit from emotion based technology.
In general many applications which integrate a user model often leave emotion and mood out of the adaptation loop. If we manage to cover this aspect, the quality of user adaptive systems can be increased significantly.

This workshop intends to discuss the scientific methods considering their benefit for current and future applications. Especially when regarding the subject of emotion recognition, this also includes ethical aspects.

The presented papers discuss theories, architectures and applications which are based upon emotional aspects of computing. We especially encouraged prototype demonstrations in order to give a good basis for further discussion. The success of the workshop depends on the discussion and information exchange between application focused experts and researchers. Contributions are solicited from the following fields:

- Multi-agent System Technology
- Affective Computing
- Psychology and Cognitive Science
- Cognitive Robotics
- Speech Synthesis and Speech Recognition
- Dialogue Systems
- Computer Game Development
- eLearning
- Artificial Intelligence Research
- User Modeling

Organization and Scientific Committee

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Workshop Program

The workshop integrates an invited talk covering different aspects of emotion and computing. In addition further presentations of work will complete the variety of research approaches and applications to set a basis for a subsequent moderated discussion. The presentations are documented by reviewed short research papers.
As another component of the workshop, applications as well as demonstrator prototypes are shown and discussed in a poster and demonstration session as well as in the breaks. The third component is a moderated discussion on selected topics of emotion and computing.

Session 1:	Issues in emotion-oriented computing – towards a shared understanding (Invited Talk)
	Toward Building Adaptive User's Psycho-Physiological Maps of Emotions using Bio-Sensors
	A Computational Model of Capability-Based Emotion Elicitation for Rational Agent
	Evaluating Affective Embodied Agents Over Extended Interactions
	Modeling Primary and Secondary Emotions for a Believable Communication Agent
Session 2:	Will Artificial Emotional Agents Show Altruistic Punishment In The Public Goods Game?
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Issues in emotion-oriented computing – towards a shared understanding

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Abstract. Emotion-oriented computing is a broad research area involving many disciplines. The network of excellence HUMAINE is currently making a co-ordinated effort to come to a shared understanding of the issues involved, and to propose exemplary research methods in the various areas. This overview paper presents a proposed "map" of the research area, distinguishing core technologies from application-oriented and psychologically oriented work. Current research issues in the various areas are briefly outlined, and references for further reading are given.

1 A map of research in emotion-oriented computing

Creating competent emotion-oriented systems is a large scale challenge. The European Network of Excellence HUMAINE (HUman-MAchine Interaction Network on Emotions) was established to prepare the scientific and technological ground for this task, with funding from the EU IST programme from 2004 to 2007. A first challenge was to agree on a suitable dissection into thematic areas and to determine their links [1]. Figure 1 summarizes our current understanding.

The central column represents the areas where purely technological challenges loom largest. Detection and synthesis are distinguished because the background technologies used are very different. 'Planning action' involves modelling action patterns that might be expected in a particular emotional state, either for driving an artificial agent or for anticipating a human's action tendencies in a given state.

The left hand column deals with issues where application is most obviously of concern. Emotion-related usability issues are more difficult to address than task-oriented ones, because emotional responses are subtle and easily disrupted by interventions that are meant to measure them. Iterative user-centered design methods are used for tuning a system to non-rational preferences and dispositions in the user. Work on emotion in complex media is treated separately because the perspective towards applications in the relatively near future requires a different approach than the core technologies in the central column.

The right hand column contains the sub-areas with the strongest roots in psychology. We distinguish theory and empirical data, because existing theory is informed by different kinds of data than what seems relevant for emotion-oriented computing. As a result, there are creative tensions between that kind of

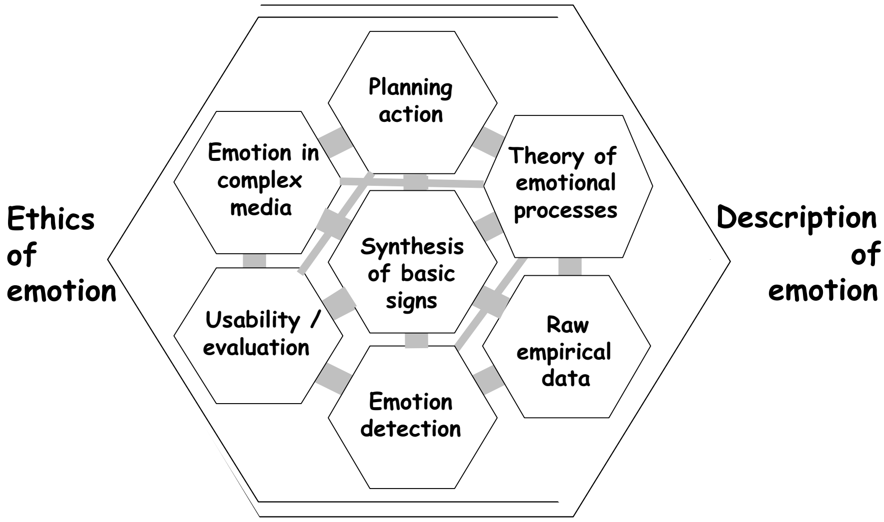

Fig. 1. Proposed map of the sub-areas involved in emotion-oriented computing

data collection and existing psychological theory. Similarly, psychological theory can use technology to test its accuracy and completeness, because the actions of artificial agents can be controlled with a precision that is impossible with humans.

The task of synthesising agents that can interact emotionally is at the center because it summarises the state of the art – it cannot be done well without satisfactory progress in all the others.

At either edge of the diagram are issues with a strong philosophical element which affect the whole enterprise – finding appropriate ways to describe emotions and emotion-related states, and the ethics of emotion-oriented systems.

2 Research issues and the state of progress

This section briefly touches upon the state of affairs in the various sub-areas as we address it. See the referenced work for more detailed presentations.

Description of emotion. Emotion-oriented computing needs tractable ways of describing the states that matter to it. Familiar schemes pull people to think in terms of pure fullblown emotion rather than pervasive emotion-related phenomena like friendliness, trust, distress, sincerity and mixed or time-varying emotions. Research in this area is clarifying the states most likely to matter to emotion-oriented computing, and adapting ideas from psychology such as soft coding, dimensional representation, and appraisal theory to provide representations that are more tractable than list of irreducible categories.

Theory of emotional processes. A joint understanding requires clear working definitions of jointly used terms. The term "emotion" has notoriously been used with very different meanings. Psychological theory has proposed working definitions of a range of affective states, including (fullblown) emotion, mood, attitude etc. These definitions are currently being refined in HUMAINE.

Different emotion models propose various analyses of emotional processes. Comparing such theoretical models with computational models provides new insights of what is actually required for an affectively competent agent.

Human behaviour is a natural reference for artificial systems, and as such it needs to be properly understood. It can provide a benchmark, but it is also important to understand individual and situational differences. One highly relevant aspect of this is research in the types of emotional and emotion-related states that are typically experienced by people in their daily lives [2].

Raw empirical data. Progress in most areas depends on good primary records, with appropriate annotation, of people interacting emotionally with each other and machines. There is a need for both generic material (to drive fundamental research) and application-specific (to achieve tuning to particular settings). Records also need to reflect differences between people related to their gender, culture, and individual characteristics, and the context in which they are set. Techniques for both collection and annotation have been developing, and are currently being exemplified in the collection of a pilot database [3].

Detecting emotion. Research has explored many of the channels that people use to form impressions of each other's emotions – facial expression, paralinguistic, gesture, choice of words and actions. Physiological correlates of affect also exert a special fascination. High recognition rates can be obtained with acted or carefully elicited data, but the field has moved on to deal with naturalistic material. There it is difficult to exceed 80% success in a binary distinction. Multimodal integration seems the likeliest key to real improvement [4].

Expressive behaviour. As in perception, the existence of multiple channels is critical. Early 'Embodied Conversational Agents' (ECAs) tried to convey emotion using analyses of static faces showing fullblown emotions. The results are recognisable, but disconcerting. Research has moved on to study the rich range of signals that transmit emotion-related information in interactions, and the ways they are co-ordinated and dependent on the other party's actions. That raises topics such as eye movements, backchannelling, gesture, and 'idle movements'. Co-ordinating such behaviour is a precondition for believable interactions [5].

Emotional cognition. An agent cannot engage emotionally unless it has a kind of empathy, i.e. it can understand at some level what a person's emotional state might dispose him or her to do, and how that disposition might be affected by different actions that the agent might take. Hence interfaces need to include models of central states and processes in the user that incorporate emotion. At present, several very different types of model are available – AI (using propositional representations); neurally inspired; and artificial life. Each has strengths, but it is difficult to combine them, and finding ways to do that stands out as the immediate priority [6].

Emotion in complex media. Emotion can be expressed and influenced not only through basic channels established by evolution, but also through music, colour, typography, and above all language. Within language there are many ways to express and influence emotion, including choice of argument, lexical selection, politeness, and humour. Work is in progress integrating all of these into the theory and practice of emotional communication [7].

Guiding system development. Translating theory into product poses special problems in the area, not least because emotional aspects of response are singularly difficult to measure without changing the experience. Innovative usability tests and user-centered design methods are needed to gauge the kinds of innovation people may want and the way they respond to prototypes, to deliver appropriate information to designers, investors, and users, and so on. Viable products depend on combining these streams with traditional research [8].

Ethics. Influencing people's emotions raises ethical questions, but over-reaction to the issue could stifle thoroughly desrirable developments. The field urgently needs an ethical framework that distinguishes between benign and suspect kinds of development, allied to appropriate monitoring systems. In HUMAINE, a framework based on Principlism has been proposed. It is important to consolidate that kind of framework and ensure that it is generally accepted [9].

Acknowledgements

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Emotion and Computing

- Scientific Publications -

A Computational Model of Capability-Based Emotion Elicitation for Rational Agent

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1 Introduction

A growing interest in designing animated characters expressing emotions has been observed in recent years. This is motivated by an attempt to enhance human-machine interaction. Indeed, virtual agents often embody some roles typically performed by humans (as for example an actor (André *et al.*, 2001)). Expression of emotions is necessary to create an *illusion of life* (Bates, 1994; Breazeal, 2003). Emotions enable to create believable agents and then to increase user's engagements (Breazeal, 2003).

For coherency expressing emotions, a virtual agent has not only to be able to display expressions of emotions but above all to know the circumstances under which emotions are triggered. According to cognitive appraisal theories (Scherer, 2000), they are elicited by a subjective evaluation of an occurred event. Most of existing computational models are based on these theories and more particularly on the well-known OCC model (Ortony *et al.*, 1988). In such a model, two major groups of emotions have been denoted: emotions triggered by an event that affects a person's goal (called *goal-based emotions*) and those elicited by an event that affects a person's standard (called *standard-based emotions*). Researchers in computer science (El-Nasr *et al.*, 2000; André *et al.*, 2001; Rosis *et al.*, 2003; Ochs *et al.*, 2005) have particularly focused on goal-based emotions (like joy or distress) whereas few attentions have been paid to standard-based emotions (such as shame or pride). Moreover, computational models that include standard-based emotions (Elliot, 1992; Reilly, 1996) are domain-dependent. Indeed, relations between possible occurred events and agent's standards (such as standard violation) have to be hard-coded. However, Gratch *et al.* (Gratch *et al.*, 2006) have proposed a domain-independent computational model of social attributions of blame and credit that enables an agent to elicit standard-based emotions towards other agents (such as reproach or admiration emotions).

In this article, we focus on a particular type of standard: the *personal* standard of performance (Ortony *et al.*, 1988). It is based on one's one model of performance, which is what one thinks to be able to do. In rational agent theories, it corresponds to the agent's beliefs on her capabilities. In the next section, we describe in more details the model of rational agent and capability we use. We then introduce a representation and formalization of capability-based emotion elicitation based on mental states of a rational agent. In addition, we present a formalization of pride and shame emotions.

2 A Computational Model of Rational Agent

Rational agents with an explicit representation of the notion of mental state (as for example BDI agents) allow to identify directly the elicited-emotions through their mental states without adding module enabling to compute what triggers the emotions. We use a model of rational agent based on a formal theory of interaction (called *Rational Interaction Theory*) (Sadek, 1991). This model uses a BDI-like approach. The implementation of this theory has given rise to a rational dialog agent technology (named *Artimis*) that provides a generic framework to instantiate intelligent agents able to engage in a rich interaction with both human interlocutors and artificial agents (Sadek *et al.*, 1997).

The mental state of a rational agent is composed of two primitive mental attitudes: *belief* and *choice*, formalized with the modal operators B and C as follows (*p* being a closed formula denoted a proposition): $\mathbf{B_i(p)}$ means "agent *i* thinks that *p* is true". $\mathbf{C_i(p)}$ means "agent *i* chooses/desires that *p* be currently true". Based on her mental state, a rational agent acts to achieve her goals through an intentional process. Several others operators have been introduced to formalize the occurring action, the agent who has achieved it, and temporal relations. For instance, the formula $\mathbf{Done_i(e, p)}$ means that the event *e*, done by the agent *i*, has just taken place and *p* was true before that event *e* occurred. For more details see (Sadek, 1991; Sadek *et al.*, 1997)).

Furthermore, we consider a notion of capability which specifies explicitly what an agent can or cannot do. A lot of important related works can be found on theoretical model (VanDerHoek *et al.*, 1994) and on implementation concerns of agent system (Busetta *et al.*, 1999). Here, we choose a predicate $\mathbf{Can_i(e,p)}$ which means that an agent *i* has the capability to perform the event (or action) *e* and, consequently, *p* which is an effect of this event. Incapability of an agent is stated with $\mathbf{\neg Can_i(e,p))}$ in case of either incapability to perform *e* or *p* not being an (rational) effect of *e*. Such an approach is based on Moore's (Moore, 1984) or more recently on Lesperance *et al.*'s (Lesperance *et al.*, 2000) works. That enables us to describe mental states of self-aware agents about their skills. In the next section, we show that capability can have a significant impact on emotion elicitations in the case of pride and shame.

3 A Computational Model of Capability-based Emotion Elicitation

According to appraisal theory of emotions (Ortony *et al.*, 1988), capability-based emotions are triggered by events that are evaluated as disturbing beliefs on one own capabilities. Two cases can happen: an occurred event is evaluated as *praiseworthiness* if one of agent's capabilities has been surpassed and *blameworthiness* in the contrary case. A praiseworthy event triggers *pride* emotions whereas a blameworthy event elicits *shame*. For instance, let's imagine a student that thinks to have a sufficient grade to pass a mathematic exam. If his grade is finally superior, he will feel pride; if it is inferior, he will feel shame.

A mental state of a rational agent corresponds to her cognitive representation of the world at a given instant. It includes a representation of the event perceived in the

environment and her capabilities. Accordingly, an occurred capability-based emotion eliciting-event is also represented through mental attitudes.
Consequently, we represent pride and shame eliciting-event by specific configuration of mental attitudes of belief, choice and capability as follow:

- **Pride elicitation**: The agent *i* triggers pride emotion after the event *e* if she has achieved *p* by *e* whereas she thought it was not possible to do so:

  $$\mathbf{B_i(p) \wedge Done_i\ (e, B_i(\neg Can_i(e,p)) \wedge C_i(p)) \Rightarrow Pride_i(e, p)}$$

  The left part of the formulae means that before the occurred event *e* the agent *i* has the choice *p* ($C_i(p)$) and believes that it is not able to achieve *p* by *e* ($\neg Can_i(e,p)$). After the event *e* has been realized by *i* ($Done_i\ (e)$), *i* thinks *p* is achieved ($B_i(p)$).
- **Shame elicitation**: The agent *i* triggers shame emotion after the event *e* if she has not achieved *p* by *e* whereas she thought it was possible to do so:

  $$\mathbf{B_i(\neg p) \wedge Done_i\ (e, B_i(Can_i(e,p)) \wedge C_i(p)) \Rightarrow Shame_i(e, p)}$$

  The left part of the formulae means that before the occurred event *e* the agent *i* has the choice *p* ($C_i(p)$) and believes that it is able to achieve *p* by *e* ($Can_i(e,p)$). After the event *e* realized by *i* ($Done_i\ (e)$), *i* thinks *p* is not achieved ($B_i(\neg p)$).

The examples of axioms of pride and shame elicitation given above enable a rational agent to determine if her mental state triggers shame or pride emotion by observing past and current situations[1].

4 Conclusion

In this paper, we have introduced a representation and formalization – based on the mental attitudes of belief, choice, and capability – of some conditions under which pride and shame emotions are elicited.

In the near future, we aim at integrating the axioms presented in a rational agent. We then project to evaluate the coherency of the
shame and pride conditions of elicitation of the agent during her interaction with a user.

[1] A situation that triggered shame or pride emotion can also elicit other emotions. In this paper, we focus on emotions related to the agent's capabilities. We use the conditions of elicitation described in the OCC model. In addition, the formalisation is specifically designed to enable the agent to elicit simultaneously several different emotions.

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Emotions And Digital Photo Sharing In A Smart Home

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Abstract. Emotion is a very private part of our personal life and how one displays it reflects one's lifestyle. Our photographs form an important part of this emotional experience in our life. In recent years increasing efforts have been put into preserving emotions in photos particularly with the advent of digital cameras. Now photographs have become an important part of our lives and have significant social role as they provide an affective communication link between friends and families. The project will look at digital photos and how can we capture emotions associated with pictures to store them in a way that is representative of their feelings towards the picture.

Keywords: Photo sharing, emotions, social interaction, digital photography.

1 Introduction

Photographs are a very affective and efficient ways of connecting people to each other. The increasing popularity of digital photography, combined with global networking, is likely to emphasize this link as sharing photographs will become cheaper, faster and easier. What might be required is technology that will create an environment of interaction within our homes to cater for emotional needs of individuals in relation to their pictures. We will be looking at finding a way of preserving the emotions associated with pictures and making photo sharing a fun and more enjoyable experience for the user. Vronay et al [2] has previously done work on preserving feelings and emotions in lists of contacts. However, the end user may not find representation of contacts with emotions as persuasive as emotions associated with digital photographs. As our survey revealed that photos serve as memory triggers, which allow emotions and memories to be conjured up by the picture, hence we are trying to design a photo sharing software, which will allow users to preserve the emotions in digital photos. Photography can be an expressive communication medium and the crafting of emotions in your images makes a much more effective, more communicative image than one that is merely ambivalent [2]. Photo sharing is more persuasive if it's done in a face-to-face environment and we will be trying to reproduce the environment with our prototype. We will be looking at how we could use emotions associated with a particular picture to annotate it for storage. We will also look at how this annotation could be used for search and retrieval of the picture. Emotions are physical expressions, often involuntary, related to feelings, perceptions or beliefs about elements, objects or relations between them, in reality or in the imagination [1].

2 Survey

We carried out a survey to measure the attitude of people towards digital photos and photo sharing. The survey was distributed around the university via e-mail. We had 16 responses ranging from people with families, people living alone, and students living in student accommodation. The first thing we looked at is the preference of respondents in storing their photographs. We found that a majority of respondents (80% yes, 20% No) preferred to store their photographs in digital format. In coming years, if we move to a completely digital format, these paper-based photos will need to be converted. At the moment there is no easy solution to this problem apart from scanning each photo and saving them digitally. Previous research [4] has brought this problem to light with the term “Funnel Effect”. It means that people take many pictures, keep some of them, shared a selected group of those, and printed an even smaller subset. It might predict the trend for the future where people might just not bother with paper format. Wilhelm et al [4] proposed that digital imaging is a key factor for many in the large volume of “throwaway” pictures, since the cost of throwing away digital photo is zero.

Most respondents feel that sharing photos on a display medium is a much-preferred option as it makes photo sharing and viewing more fun and enjoyable because it allows more people to view the pictures rather than coming together in a confined viewing space. This is even more evident with the invention of digital frames, which allow the storage of many pictures and allow the display of a slide show. Once the frames are connected to the central server the user can select which photos they want to be displayed on the frames depending on the mood they are in. Photos have a natural way of showing the evolution through which people go through from being born to when they are no more and leave memories behind for friends and families to enjoy. The response for the emotional attachment with pictures was interesting as respondents thought that viewing pictures brings out emotions in them and they would like pictures to represent these personal emotions in form of text, audio, video, or even facial expressions (Figure 1). Van House et al [3] has suggested that the major use of photos is as a record of individual and collective experiences, and to share experiences with others, such as using a family photos to give children a sense of family history.

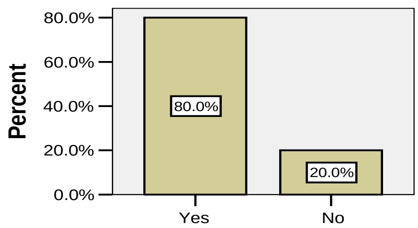

Fig. 1. Respondents who would like digital photos to represent personal emotions.

Emotions are generated when there is a dialogue with the natural, cultural, and social environment. These can be very random for example a smile can reflect different emotions in functionally different situations where the person wants to communicate something without actually speaking a word. If these expressions were captured using, for example, a camera, it will allow us to associate a particular mood or emotion with the picture we are seeing. Expressions reflect different emotions depending upon the context and are related to the environment one is in. Most photographs are intimate to us and this relationship was even more important to our respondents who agreed that they found a strong relationship between photographs and intimacy and how pictures represent one's social lifestyle (Figure 2).

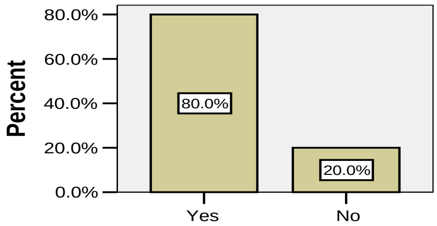

Fig. 2. Are pictures a representation of ones social lifestyle?

We found that adding audio to photos will help in elaborating memories associated with photographs (Figure 3). Another option people liked was the idea of adding text to a particular picture in the form of hand written text which gives it a more personal feel or using a keyboard to type a message regarding a particular memory that a picture invokes. One respondent explained that if a picture contains a group of people then the user could click on any part of the picture or the individual in that picture, which would open a dialogue box where the user can write a short description about that person or add a short audio description. It was revealed that users want to feel more involved with the pictures when sharing them with friends and families as well as ease of use being the most important factor when using any software for photo sharing. Those who liked the idea of adding audio to digital photos commented: "Sound could provide for strong memories so I might not want to attach a single sound" and "Overall, having a variety of sounds associated with the time would be most appropriate".

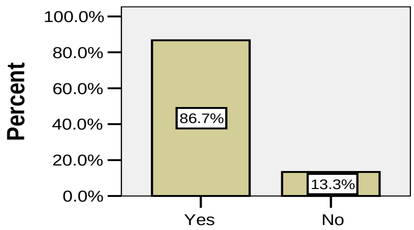

Fig. 3. Addition of audio will help elaborate memories associated with pictures.

The intimacy, representation of one's social lifestyle and the personal emotions associated with the picture are hidden from the viewer at the other end of the network when sharing across the Internet. A set of social uses of personal photography has been identified in [3]. They are constructing and maintaining social relationships; constructing personal and group memory; self-presentation; and self-expression. Regarding the emotional aspects of pictures, respondents have suggested that allowing a brief description of the folders about how, when or on what specific occasion the pictures were taken, would help in reviving emotions associated with that particular photo or event. Respondents have suggested support for audio as well as embedded sounds in reviving emotions. The ability of adding comments within the photo rather than just naming them with a ".jpeg" extension is also one way images could be stored, which could allow the users to search a picture in reference to the comment they remember form the occasion. Convergence was also a major focus point as all the respondents agreed that they would like a central device to handle the reception, storage and distribution of photos as well as connection to a central media server which can connect to various distribution mediums within the smart home.

3 Proposed Design

What we will be looking at initially is how digital photos can be imported into the home, stored by the user, and then distributed across different viewable platforms in the home. The research will also look at exploring ways in which we can represent the emotional factors related with pictures and how we can share it with our friends and family. We will be looking at using voice input and voice-to-text technology to represent emotions and also get user feedback as to how emotions change over a period of time. We will look at how we could get users to bring out their emotions associated with a particular picture and store it. We hope that in the future, digital cameras will be equipped with some form of wireless connection, which will allow us to send the picture directly form the camera to the central server or view them on the handheld device without actually having the camera with us in the home. It will also allow photos to be displayed on display mediums directly from the camera as long as they are connected by a network connection. We propose that the facial expressions of the viewer might be captured to represent the emotions of the viewer without their intervention and map it to an image like avatars are created in computer games.

4 Conclusion

We carried out this survey to measure the attitude of people towards digital photography, photo sharing and how we could design a prototype, which would help them in making this experience more fun and enjoyable. We wanted to know about what people want from photo sharing, what they enjoy, how specific design attributes will make them feel, what will delight them and how through this design process their experience might be enhanced. We want to design a system, which would provide a relaxed atmosphere to view the photos in and take the passivity out of photo sharing. We will look at how we could allow people to attach emotions to a picture and use this aspect in search and retrieval of pictures from databases as a better way of annotation.

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Emotions as Heuristics in Multi-Agent Systems

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Abstract. In this position paper we argue that a model inspired by human emotions will provide reasonable and useful heuristics for 1) reducing and controlling nondeterminism involved in an agent's decision making process, 2) flexible cooperation and coordination between agents, and 3) building efficacious human-agent interfaces to facilitate the interaction between human users and artificial agents in hybrid multi-agent systems.

1 Introduction

Many branches of computer science in general and multi-agent systems in particular involve problems that need heuristics to manage their complexities. In this position paper, we discuss three problems in multi-agent systems for which we propose heuristics inspired by human emotions. These problems are related to the autonomy of individual agents, the cooperation and coordination between agents, and the believability and efficacious interaction with agents.

In multi-agent systems, individual agents are assumed to be *autonomous*. This implies that they should have the capability to decide which actions or plans to perform in order to reach their objectives. For many practical applications, standard decision-theoretic concepts (e.g., probability and utility) and rules (e.g., maximizing expected utility) will leave an agent with multiple actions or plans with equal or near-equal preference. This gives rise to nondeterminism in an agent's decision making, which is a problem if the agent has to choose only one of the options. Moreover, individual agents need to *cooperate* and *coordinate* their actions in order to achieve their global (social) objectives, often called the objectives of a multi-agent system. Interaction protocols and mechanisms are the common means to specify the cooperation and coordination of individual agents to guarantee the achievement of their global objectives. However, the use of interaction protocols imposes restrictive constraints on the behavior of individual agents and thereby limits their autonomy. On the other hand, the absence of interaction protocols brings the problem of nondeterminism back to individual agents since there may be many options for interaction with other agents. It should be noted that an interaction protocol can in fact be considered as a way to solve the problem of nondeterminism. We believe that for many (non-critical) applications of multi-agent systems the restrictive interaction protocols can be replaced by more flexible and more general policies or heuristics. Finally, in hybrid multi-agent systems, where human users are also considered as constituting agents, efficacious *interfaces* are needed to enhance and optimize the complex interactions between humans and artificial agents. Also, as humans intuitively assign a personality, motives, and an affective state to any system displaying behavior, the challenge in human-agent interaction lies with living up to these expectations of the human user and thus creating *believable* agent behaviors.

In this position paper, we propose using heuristics inspired by human emotions to (partially) solve the aforementioned problems. In particular, we propose to formalize an (existing) model of human emotions and incorporate it in the existing models of multi-agent systems in order to reduce and control the involved nondeterminism and enhance the interaction between human and artificial agents. In section 2, we discuss the role and application of emotions to the three mentioned problems. In section 3, we discuss the current and future research activities as well as the results we expect to achieve.

2 Emotions in Multi-Agent Systems

We argue that as long as heuristics are needed for solving the three mentioned problems in multi-agent systems, a model of affect based on human-inspired emotions may provide reasonable and useful heuristics. Moreover, using a model of affect is especially beneficial because it is a single mechanism that functions as a heuristic for all three of these problems. Below we will discuss how we envisage the use of emotions in multi-agent systems.

Agent Autonomy For reducing nondeterminism in decision making, we propose using a heuristic based on secondary emotions [2, 11]. Secondary (also called deliberative) emotions are the biological heuristics for preventing excessive deliberation. As an example of how emotions might aid the deliberation and decision making process, suppose the affective mechanism of an agent is modeled after the cognitive model of Ortony, Clore & Collins ("OCC") [10], and that the agent generates a plan to achieve a goal. The agent now *hopes* to achieve the goal as long as it is committed to the plan. However, as soon as the execution of the plan fails (e.g., the execution of some action fails or the effect of some action is not perceived), the agent will also experience *fear* with respect to the plan and the goal. As soon as the intensity of the fear becomes greater than the intensity of the hope, the agent may drop the plan and start replanning to achieve the goal. Of course the agent will prefer new plans that have previously caused it to experience *satisfaction*, while avoiding those that have previously resulted in *disappointment*. In this way, the incorporated affect model indicates which plans need to be dropped or adopted and thereby helps to reduce the nondeterminism involved in an agent's decision making process.

Agent Cooperation and Coordination If agents, which have to cooperate with each other, know how they work internally, they can anticipate expected actions. Note that this assumption is realistic only for closed (not open) multi-agent systems where the design of agents is known. For example, if an agent predicts that a cooperating agent cannot perform its current plan which contributes to the achievement of a common goal and is about to drop it, then the agent may be able to take anticipatory actions in order to prevent the imminent failure of the other agent. We believe that, if all agents were using an affective mechanism as a heuristic for their decision making, this kind of cooperation can be achieved in much the same way as humans do in their interactions. Specifically, an agent could accomplish this by mapping the perceived state of another agent to its own affective mechanism and approximate the affective state of the other agent. It can then predict what actions the other agent is most likely to perform next by running its own affective decision making heuristic. This is what humans do in their interactions; building a model of another person's affective state and predicting how the other person might react. If agents were using the same affective mechanism, they could do the same type of (implicit) cooperation.

Human-Agent Interaction Humans are experts in social reasoning and behavior. If artificial agents were to use the same affective mechanism as humans, then humans would have an intuitive and efficacious way of interacting with them. A reason is that such agents would be able to live up to the affective expectations of the human to a far greater extent. An affective agent could also present information to its user according to its affective state, further facilitating an intuitive mode of interaction. Consequently, this could greatly increase the *believability* of agents. Conversely, if an agent had affective mechanisms like a human, then it could also map the perceived affective state of a human to its own affective mechanism and choose more suitable and anticipatory actions, just like in multi-agent systems as described above.

3 Future Research and Conclusion

We are currently working on the formalization and implementation of the 22 deliberative emotions from the OCC model as heuristics for controlling nondeterminism in goal-directed agents. The OCC model has previously been used for emotion synthesis (often partially adapted to the research domain), for example for modeling personalities in social relationships [5], facial expressions for poker playing agents [6], and believable animated characters [1, 9]. We use the OCC model because of its suitability for formalization, but we plan to broaden our research with alternative theories of emotion. Currently, we are formalizing the entire set of 22 emotions in a modest extension of the KARO framework [8, 7]. Specifically, we are formalizing the eliciting conditions of these emotions in terms of beliefs, goals, actions, and plans. We plan to extend the formal model with a quantitative model for these emotions, capable of handling emotion potentials, thresholds, and intensities. Because of space limitations, we cannot present the formal details, but the reader can find some of the formal results in our previous publications [3, 8]. To further prevent unnecessary deliberation, we plan to extend the resulting affective model with real-time reasoning capabilities; that is, reactive behavior induced by primary emotions [2, 11]. To solve the issue of cooperation and coordination in multi-agent systems, we plan to further extend the affective model with social reasoning capabilities. We expect to accomplish this by allowing agents to map the perceived affective states of other agents to their own affective model, which will allow agents to reason about the goals and plans of other agents as they reason about their own. It is our intention to use the final resulting affective model in the new incarnation of 3APL [4, 3], which provides a multi-agent platform for goal-directed agents that use beliefs, actions, and plans to achieve their goals. As an example scenario to show the usefulness of affective agents, we envisage such agents in a dynamic environment in which external influences can change such that the agents' tasks can be obstructed. This could be a spatial environment characterized by parameters such as weather (sunny or rainy), time (day or night), and area (inside or outside). Agents have to cooperate to replace and/or paint objects which can be obstructed because of the location of the objects in combination with the time, weather, and the actions of other agents (e.g., an object located in an outside area cannot be painted if it rains).

To conclude, we have identified three problems in multi-agent systems, namely nondeterminism in autonomous decision making, cooperation and coordination in multi-agent systems, and believability in human-agent interaction. We expect that the described affective model based on human-inspired emotions provides a reasonable and useful solution to these problems.

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Modeling Emotions in Multi-Agent Systems based on Petri-Net Modeling Technique

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Abstract. Starting from the hypothesis that emotions can be an important factor in the design of (multi-)agent systems we follow two directions within our research: First we focus on theoretical foundations of emotional phenomena; second, we aim to build a conceptual framework for modeling emotion in context of multi-agent systems. In this paper we discuss the use of Petri net formalisms for representing different aspects of emotions in a multi-agent system. Futhermore we propose the adoption of the Socionics modeling approach, initially specified in [2003b], for modeling theories of emotion.

1 Introduction

The increasing interest to investigation of emotional phenomena in the classical emotion research domains like psychology, neurology and cognitive science leads to new insights regarding the influence of emotional mechanisms on individual behaviour, on the social interaction, on the development of normative structures in the society etc. These new ideas are being adopted, investigated and applied in classical computer science research fields, like Human-Computer Interaction (HCI), Artificial Intelligence (AI) and Distributed Artificial Intelligence (DAI).

Today the research field of Affective Science ([2003a]) is divided into numerous theories, concepts and models and it still lacks an integrated computational theory of emotion in view of their large-scale causes and effects, both for the individual agent and the multi-agent society. Yet the special needs of emotion implementation in a multi-agent system require an appropriate theoretical underpinning for either psychological aspects of emotion, e.g. for the representative model of emotion appraisal, or sociological aspects, e.g. social determinants of emotions and their implications for the social structure ([2005b], [2005a]).

For an appropriate modeling of emotion in distributed artificial systems we need an integrated theorie of emotion which combines psychological, sociological, neurological and cognitive approaches to emotion. In this matter, a special aim of our research is the development of an appropriate technique for modeling emotional concepts and theories. By means of this general technique we seek to facilitate the integration of different theoretical perspectives on emotion in a unique model, describing different aspects of emotional phenomena and processes. Moreover, allowing representation of emotional theories with an original informatical modeling technique, we facilitate their integration into any computer applications and especially provide a possibility to combine different theoretical approaches and models of emotion in a single multi-agent system.

In this paper we propose the adoptation of the Socionics modeling approach to transform the theories of emotion into a formal informatical representations on the basis of reference nets modeling formalisms, which is an extension to a Petri-net modeling technique. The Socionics approach was initially specified and evaluated in [2003b] for sociological theories. The applied modeling formalisms suports direct integration of the resulting models into an executable multi-agent architecture Mulan, which is also implemented with reference nets, and thus enables simulation and evaluation of the modeled theories.

After short introduction to Petri nets/ reference nets modeling formalisms in the next section we discuss the use of application of Socionics modeling approach to model theories of emotion.

2 Modeling Emotional Agent Systems with Petri-nets

We seek to accomplish the integration of cognitive science and social science approaches to emotion using a general modeling technique that allows building a unique integrative model of emotion that (a) is usable in an MAS context and (b) provides general theoretical underpinnings for an implementation of emotion in (distributed) artificial systems. A practical evaluation of Petri net formalisms has revealed its important advantages for modeling different sociological theories ([2003b]). Basing upon these results, we propose application of Petri Net / Reference Net modelling technique for modeling emotion-based processes and concepts in multi-agent systems.

Unlike other automata formalisms Petri nets allow for direct modeling of concurrency (i.e. independent events and processes). High-level Petri nets permit the representation of recursive structures and emergent processes and are able to inherently express structural as well as process concepts at the same time. Due to its operational semantics and the broad range of available analytical methods, modeling with Petri nets allows an evaluation and formal checking of semantics of the models. Well established extensions of the basic formalism and sophisticated tool sets for most of these extensions exist. E.g., reference nets ([1998]) enable the execution of arbitrarily complex Java programmes through the use of synchronous channels ([1992]). Together with these extensions, Petri nets provide a powerful instrumentarium for modelling dynamic, hierarchical and recursive structures, as described by psychological, neurological and social theories of emotion. In addition, the formal representation of emotion models facilitates their integration into the computational domain. Further details on reference nets modeling are omitted here, but can be found in either [2003b] or [2004]). An efficient editing and simulating tool called Renew (Reference Net Workshop, [2005c]) provides a powerful support for designing and evaluating of petri net / reference net models.

3 Applying Socionics Modelling Approach for Modeling Theories of Emotion

To provide an appropriate theoretical underpinning for emotion modeling in (distributed) artificial systems, we aim at constructing a coherent conceptual framework for integrating psychological and social science perspectives on emotion. The formal model, on which the representation bases, is the recursive formalism of reference nets, as described in the previous subsection. With the help of this formalisms first of all a compact implementation of the multi-agent architecture MULAN is designed ([2004c]). Secondly it serves as a description language for the considered theories of emotion ([2003b]).

Proceeding in accordance with the general methodic and praxis of socionic modeling approach we aim to model psychological, sociological and neurological theories of emotion. Such modeling delivers an implementation of the central aspects of a theorie as a set of Petri nets, which can be integrated as a programming unit in an executable multi-agent system MULAN. Furthermore, this kind of modeling facilitates direct comparison of the theoretical statements, which take their origin in various theoretical approaches, through analysis of the corresponding Petri net models. A combination of several Petri net models delivers an integrated representation of certain aspects of emotionality, in which statements from different theories of emotion can be unified in a more general model.

In the first modeling step the textual representation of a theorie is translated into a set of net models, which specify the central elements of the theorie and their causal relationships. By means of detailed analysis of the resulting nets one would try to recognize the intrinsic model structure, which is constituted through the interaction of the model elements and which reflects the dynamics of their interaction.

The analysis of the Petri-net representations of processes and structures treated by a theorie of emotion often delivers (mutual) references or causalities between modeled elements, which cannot be directly derived from the original textual description. Thus we can obtain a more abstract representation of structural correlations (e.g. through falting the respective Petri net models) or can combine some seemingly discontiguous parts of the modeled theorie to a more general model (by means of combinig the corresponding nets). Besides these internal references within the scope of one theorie of emotion it is also possible to make up external references on some other theories of emotions, as the Petri net modeling facilitates the comparison of the fundamental intrinsic structures and processes specified in the theories and allows to identify structural analogies.

Since any informatical modeling technique demands precise specification of the modeled subject, it is easier to reveal the underspecified points or inconsistencies of a theoretical approach when converting it into a set of Petri net models. On the one hand these inconsistencies can be revealed by means of static analysis of model structures. On the other hand and particularly however it is done in the course of model simulation, which can even desclose some implicit propositions that were not expatiated in the original textual representation of the modeled theorie.

4 Discussion

In what follows, we will very briefly evaluate the modeling approach presented above and the perspectives it holds in view of modeling the functionality of natural emotional mechanisms in (multi-) agent systems. Nearly all computer science models of emotion share the fact that they are based either on psychological or on neurobiological theories of emotion, ignoring the fundamental social components of emotion and their significant influence of the social phenomena, which get especially relevant in distributed systems. However, a sociological consideration of emotions can open new and promising perspectives for computer science (cf. [2005a], [2005b]). In view of emotional agents being applied to distributed or multi-agent systems, we suppose that the foundational functional components of emotion in (artificial and/or hybrid) social aggregates have to be taken into account.Generally speaking, modeling the social functions of emotion is supposed to improve multi-agent systems, for example in view of alternative coordination solutions and robust structuration processes. However, strong evidence has yet to be presented that AI-models of emotion do indeed facilitate better solutions in this respect.

Using a reference net modeling technique we access the possibility to simultaneously represent interdisciplinary approaches and specifications of emotion within a hybrid reference-net based framework and to simulate the resulting Petri-net models. The openness and flexibility of this approach foster an analysis of different theories (of different disciplinary origin) and computational models of emotion using the same modeling technique within the proposed framework.

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Evaluating Affective Embodied Agents Over Extended Interactions

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Abstract. Research studies completed to date which have focused on our psychological responses to synthetic displays of emotion have started to suggest that emotional interface agents enhance our interaction with computers. Further research is required which concentrates on the impact of emotion simulation in human-computer interaction, especially over multiple and extended interactions. Research that we are currently conducting with affective embodied agents that attempt to motivate people to eat more healthily is detailed, along with an overview of other experiments we will be undertaking over the coming months.

1 Introduction

An important research area which has been neglected to date is that of how users respond to simulated expressions of emotion in interface agents. Do we prefer emotionally expressive agents over unemotional agents? How do we respond to synthetic displays of empathy, happiness, sadness, frustration and anger? Can we *catch* emotions from computers?

Research studies that have focused on this area have failed to clarify whether emotionally expressive interface agents enhance or hinder an interaction (e.g. [1]). Moreover, it is still unclear what psychological responses we have to synthetic displays of emotion and whether we respond to computer simulated emotion in a similar fashion to human emotion. With interface designers increasingly incorporating emotion into their interfaces through the use of textual content, speech, video and facial expressions (in embodied agents), it is essential that we understand in more detail what impact synthetic emotion has on users.

This paper will focus on emotion simulation in embodied interfaces and will start by discussing the psychological impact of incorporating emotion into such interfaces. The importance of conducting longitudinal studies in this area is then discussed and followed by an overview of an embodied interface that we have developed. Experiments that we are currently conducting are then detailed, along with general conclusions.

2 Psychological Impact of Simulating Emotion

A variety of studies have now illustrated that humans can recognise the emotional facial expressions of embodied agents with similar accuracy and reliability as that of recognising human emotional expressions (e.g. [2]). But what psychological effect do these synthetic emotional expressions have on people? Is a synthetic smile the same as a human smile? Do we prefer agents that are always happy or does this annoy us? How *strong* are our responses to simulated emotion?

Several recent studies have started to suggest that we may respond to synthetic emotion in a similar way to human emotional expressions. For example, Brave et al. [3] found that when an embodied agent was empathetic toward the user (through textual content and facial expressions) it was perceived to be more likeable and trustworthy than an agent which was not empathetic toward them. In human-human interaction, people that we like and trust often have more persuasive powers over us and we tend to act on their advice more than people we dislike and distrust [4]. Does the same apply in human-computer interaction? If we generally rate emotional agents as more likeable and trustworthy than unemotional agents, can they potentially influence peoples' attitudes and behaviour more effectively than unemotional agents?

3 Importance of Conducting Longitudinal Studies

Very few studies have focused on how we respond to emotionally expressive embodied agents over extended periods of interaction. As discussed above, some recent studies have suggested that we seem to perceive emotional agents as more likeable and trustworthy than unemotional agents. But does this effect remain consistent over five, six, seven or twenty separate interactions? The Microsoft Office Paperclip was an emotionally expressive agent that many people tended to find novel to interact with initially, but after further interactions it began to frustrate people and was ultimately rejected by users.

Bickmore and Picard [5] investigated whether an embodied agent could help motivate people to do more exercise over the period of a month, but studies such as these are a rarity. Most experiments that are conducted with embodied agents tend to be completed in a single session, typically lasting less than an hour. As we move more towards managing computer systems rather than directly manipulating them, we will work more closely with agents in everyday activities as they undertake tasks on our behalf. This means that people are likely to develop long-term relationships with agent entities in their interactions, who they will grow to know and trust. Therefore, it is essential that future studies concentrate on how we respond to emotionally expressive agents over both short and extended interactions to help us understand more fully how our perceptions of such agents change over time.

4 Current Research

In order to understand further how we respond to emotion simulation we have built an embodied agent which will simulate the role of a human health professional (Fig 1. contains a screenshot of the interface). The interaction will follow that of a standard (human) nutritional coach-client interaction (e.g. [6]), with the agent: (1) introducing itself and attempting to build rapport with the subject (2) clarifying both its own and the subject's role (3) enquiring about the subject's diet history and current eating habits (4) discussing the pros and cons of the subject's current diet and in changing their diet (5) discussing options that the subject has for changing their diet and offering tips (6) getting an initial commitment to change and terminating the interaction effectively.

Subjects will be able to respond to the coach's questions by selecting from a list of pre-scripted responses. They will also be informed that they can view educational pages about maintaining a healthy lifestyle for as long as they desire and that they can return anytime within the next month to look at the educational resources provided. Subjects will then be asked to complete an online questionnaire which will be based on the Working Alliance Inventory (WAI)[7], which is a measure used to rate the quality of a therapist-client relationship.

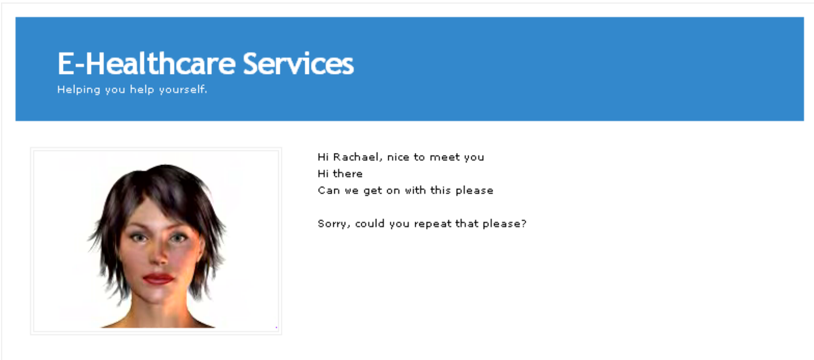

Fig. 1. Screenshot of the nutritional coach

4.1 Research Questions

We have developed both an emotional and unemotional version of the agent. The emotional agent's voice ranges widely in pitch, tempo and loudness while the unemotional agent's voice varies little in these. Furthermore, the emotional agent's facial expressions simulate happiness, warmth and concern (i.e. empathy) whilst the unemotional agent's facial expressions remain more neutral. The dialogue and type of (human) voice used for both agents is the same. We are currently investigating the following research questions: (1) are emotional synthetic health professionals perceived more positively than unemotional agents? (2) can emotional agents help motivate people to change unhealthy habitual habits more effectively than unemotional agents over extended periods of interaction? (3) how do our perceptions of embodied agents change over extended interactions?

We intend to run the initial experiment over a short interaction (i.e. less than an hour) to see if subjects prefer the emotional coach and whether they feel more motivated to make changes to their diet. Subjects' answers to the WAI questions will be used to analyse their perceptions of the agent. Motivation to change eating habits will primarily be measured through four behavioural measures: (1) the amount of time spent viewing the educational content provided (2) the number of educational pages viewed (3) the number of suggested healthy recipes viewed, printed or saved (4) the number of times subjects return to the website to view the resources provided. Subjects will also be debriefed and interviewed to obtain more qualitative information about their perceptions of the interaction and their motivation to improve their diet.

The initial experiment will also be used to analyse what people think of the interface and the system will be updated according to this feedback. The experiment will then be conducted over an extended period of time, the length of which has yet to be finalised. We then intend to run another longitudinal study with a different problematic behaviour (e.g. smoking) to test the consistency of any effects found.

5 Conclusion

It is imperative that more studies investigate how we respond to emotion simulation over both short and extended periods of interaction to examine how our perceptions of emotionally expressive agents change with time and what impact this has on our interaction with them. These types of studies will enable interface designers to understand what impact incorporating emotion simulation into their interfaces has on users and how the use of simulated emotion can potentially be used to help people for beneficial purposes.

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Will Artificial Emotional Agents Show Altruistic Punishment In The Public Goods Game?

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Abstract: In a public goods game with punishment option free riders will likely be forced by the others to follow the rules. The punishing action is not free of costs. In experiments with human players, punishment also takes place if the players are not scheduled to meet again in a game constellation. This makes the punishment action irrational and it is given the attribute 'altruistic'. Emotions are identified as reasons for the phenomenon of altruistic punishment which contradicts the theory of the "homo oeconomicus". The intention of the research work presented here is to model the behavior of players so that their emotion and personality are bases for decisions and can be recognized as such. In this paper a model of an emotional agent is derived from experiments. The emotion generation is based upon the model of Ortony, Clore and Collins and brings this approach together with a basic model of personality. A first implementation shows plausible behavior in a simulation environment.

Introduction

In this approach of modeling emotional behavior, the public goods game (PGG) serves as a scenario in which humans show emotion driven decisions. An agent model which eventually shows similar behavior can therefore claim to be emotional. The scenario is very limited and only a few decisions are required. Nevertheless, emotional behavior can be shown and nicely imitated by an artificial player agent.

In the public goods game the punishment option leads to higher average payments (see [1]). It has an educational effect, but it also costs the punisher a certain amount of money. The rationality of this action is based on the assumption that the game is iterated and the behavior of the free rider is changed by the punishment. Fehr and Gächter [1] describe a scenario in which they repeat the game with the condition that the group composition changes from period to period. This makes the punishment decision altruistic, since only others may benefit from it. The presence of altruistic punishers is therefore a reason even for selfish players to raise their contributions to the common project. Fehr and Gächter showed a significant correlation between the emotion *anger* and the willingness to punish. How could an artificial emotional agent look like which behaves humanlike in the described scenario? This paper describes an approach for modeling an emotional player which shows plausible reactions.

Outline of the agent architecture

First the typical behaviors of human players are identified. These behaviors have rational and emotional background and serve as role model and orientation for simulated agents. The architecture of the emotional agent includes the generation of emotions and the influence of emotions on decisions. An often quoted cognitive theory of emotion is given by Ortony, Clore and Collins (OCC) [2]. In this approach, the OCC model is adapted to the PGG. In addition, the resulting model is enhanced by a personality model and the representation of mood.

The simulation scenario

The simulation scenario is closely related to the one used by Fehr and Gächter [1]. The core configuration of the public goods game is chosen as follows: each player gets the amount of 20 Euros which he or she can invest in a public project. The public project is bearing 60 % interest. The invested amount plus interest is equally split. The invested amounts are disclosed and a player can invest up to 10 Euros to punish any of the other players. Each invested Euro results in a punishment of 3 Euros. The game is repeated for 12 rounds in the same constellation before groups are recombined.

Human player behavior

In a first step experiments and interviews with (non-experienced) human players are carried out. Abstraction leads to the following typical behavior patterns:

- Start with a contribution of 15-20, no punishing after the first round, later if only one single candidate tries a free ride (but only by low amounts)
- Start with a contribution of 0-5, do not punish, raise contribution in the next round if punished and less than average income is the consequence
- Start with a contribution of 10, raise contribution if punished, reduce the contribution if unpunished, do not punish

The experiment reveals that the expected punishment for a free rider averages 3.3 Euros. This makes the situation worse for the free rider compared to a complying agent. Even though the players claim to follow the mentioned strategies, some of the observed actions cannot be explained by the scheme:

- A player who usually does not punish or only punishes by low amounts, assigns a rather high punishment amount to another player because this player pays nothing after a few rounds of complete compliance.
- A player who usually always pays, skips one round.

It is assumed that these exceptions are result of an emotional disturbance of the subjectively rational strategy the agent chose. Our model of an emotional agent should be capable of generating similar behavior. As a first step in the simulation, the emotional agent performance is compared to the performance of agents following the above strategies.

Emotion generation

The architecture of the player agent integrates the emotion generation and the action decisions. A further requirement is the interface to an emotion expression module which is needed for future experiments in which the reaction of humans to emotional agents will be tested.

The OCC model has become the standard model for emotion synthesis. It specifies 22 emotion categories and groups them in three dimensions: *goal relevant events*, *actions of agents* and *aspects of objects*. In the presented model, first the intensities of the predefined eliciting events or actions are derived from the scenario. Each of them is associated to an emotion category. The personality model provides non-linear transfer functions which generate emotion intensity from the current mood and the elicitor intensity.

Two *events* take place in the game: the publication of the payments and of the punishments. Depending on the *goal* of a player (*maximize* own income or get *higher* income than others) the ‘well-being’-emotions *joy* and *distress* are generated. The elicitor’s intensity is given by a distance function comparing result and goal. The agent model records previous games and derives the *likelihood* of future game situations. Two decisions are made: the payment and the punishment. For each option, a likelihood of the future situations is computed as a (rational) basis for decision. Attached to the likelihood, the emotions *fear* and *hope* are generated. Two factors are considered by a generation-function for those emotions: likelihood and desirability, the latter again based upon the goals of the agent. These emotions are generated before the steps payment and punishment and are (kind of) transformed into the emotions satisfaction (goal achieved), fears-confirmed (“I knew they would punish me for this!”), disappointment (“They should have paid more!”), relief (“I really got through with my trick without getting punished!”). The current model disregards ‘fortunes-of-others’-emotions.

The *actions* of the agents are also elicitors for emotion categories computed by the same principle as events. The main factor for the elicitor intensity is the praiseworthiness of the action, which depends on the (moral) standards of the agent. Paying the full amount may be considered praiseworthy since it is beneficial for all. For example: paying nothing whereas all others pay 20 leads to joy but also to shame. Just the degree of shame depends on the personality and therefore the transfer function from the eliciting intensity to the emotion is provided by the personality model. An important point is raised in the example: compound emotions. Especially interesting for this game is the combination of reproach and distress which reveals anger and which in turn can cause a punishment. On the other hand shame (see above) and distress (high punishment) leads to remorse and as a consequence to higher compliance in the next round.

The *attraction* of another player plays a role in the decisions. Here, the elicitor is based upon the benefit/cost caused by the agent in earlier games. Again, the personality model provides a mapping from the elicitor intensity to the emotion intensity including the current mood.

The basics of a personality model

A *mood* can be regarded as a long term emotional state influencing the behavior. In our case it is modeled on the good-bad scale only. It gets better by positive (e.g. joy) and worse by negative (e.g. distress) emotional experience (without memorizing the concrete experience by now). How does personality affect the actions? It affects the intensity of the emotions – at least the intensity with which they are shown. Using aspects of Eysencks personality theory [3], the agent's personality model is described by the attributes *openness* and *energy*. Energy describes how *fast* the mood changes and how *high* the amplitudes of the emotion intensities are. Openness describes to what extent experiments (like skipped payments) are possible options.

Emotional and rational decisions

Once the emotion is generated, its influence on the player's decisions is needed. In the selected game context emotions are regarded as input to a (flat) rule based system. This system contains two kinds of rules: direct emotional reactions and reactions with 'deliberation'. If a rule of the first type fires, it cuts off the deliberation. As an example for the second type, the punishment of a player which the agent *hates* a lot has to be decided. In case this agent performs an action which is *disapproved* (does not comply again) it is increased depending on the intensity of the hatred.

Conclusion and future work

On the one hand the model described above allows a lot of adjustment by using parameters and functions for the personality. On the other hand its straight-forward realization does not make it a generally applicable model of emotional behavior. As a result of the experiments, watching the actions of the player agent may subjectively suggest the presence of emotions already but closer analysis is needed.

Further steps also include adding 'fortunes-of-others'- emotions and learning. This includes the model of the individual players and a general model of the group. Current work is done on the visualization of the generated emotion by an animated face. This includes a further aspect of the emotional model: the *time*. How fast are emotions generated and how long does it take them to fade? The overall intention is to verify the plausibility of the generated emotion by experiments with human players.

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Modeling Primary and Secondary Emotions for a Believable Communication Agent

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Abstract. The integration of emotion and cognition in cognitive architectures for embodied agents is a problem of increasing importance. In this paper, we describe how two separate modules for these tasks, as we employ them in our virtual human Max, can give rise to secondary emotions such as frustration and relief. The BDI-based cognitive module is responsible for appraisal as well as reappraisal of elicited emotions that our conversational agent Max becomes aware of. The emotion dynamics simulation system is driven by the valence information of every emotion and assures a general consistency of the simulated emotions over time by dynamically providing an awareness likelihood for every emotion.

1 Introduction and Motivation

When trying to build socially intelligent agents, the integration of simulated emotions into an agent's cognitive architecture seems to be unavoidable. In our work we follow the ideas of cognitive modeling with a cognitive architecture based on the BDI-theory and an emotion dynamics simulation system based on dimensional emotion theories. We further follow the ideas of [5] by distinguishing "primary" and "secondary" emotions. "Primary" emotions are elicited as an immediate response to a stimulus, whereas "secondary" emotions are the product of cognitive processing. Up to now our set of simulated emotions has been limited to undirected, "primary" emotions such as fear, sadness, anger and happiness. After we validated a desirable effect of these emotions empirically [4], we now want to let our agent control its own emotions to prepare him for social scenarios, where the application of coping strategies is necessary. In these situations the general limitation on "primary" emotions must also be overcome by further combining cognition and emotion to simulate "secondary" emotions such as frustration and relief as well.

In the next section, we will start with an overview of related work along the lines of two major emotion research trends in psychology. In Section 3, we introduce our virtual agent's modular architecture and describe our approach to simulate primary and secondary emotions as a combination of cognitive appraisal and an underlying emotion dynamics. We conclude this paper by discussing some advantages and possible drawbacks of our architecture.

2 Related Work

According to [1] at least two main viewpoints can be distinguished in modeling emotions: cognitive theories of emotions and dimensional theories of emotions.

The well-known OCC-approach [11] to emotion simulation relies on rational reasoning about the eliciting factors of emotions. Appraisal is the basis of every computational emotion theory, but in the OCC model it is indistinguishably intertwined with the cognitive processing of an agent. Despite its comprehensiveness and explanatory power, this model was frequently criticized, e.g., for not taking into account the mutual interaction of emotion categories. Ortony himself [10], however, has proposed later that it might be sufficient to simulate only ten emotion categories and that it may even be adequate to start with an agent that can only differentiate positive from negative, letting it evolve richer emotional experience by means of machine learning techniques.

Initially Wundt [12] has claimed that any emotion can be characterized as a continuous progression in a three-dimensional space of connotative meaning and several researchers (e.g. [7]) have provided statistical evidence for this assumption. These dimensions are commonly labeled *Pleasure/Valence (P)*, representing the overall valence information, *Arousal (A)*, accounting for the degree of activeness of an emotion, and *Dominance/Control (D)*, describing the experienced "control" over the situational context (PAD-space, in short).

We combine these approaches as they can complement each other in a reasonable and beneficial way.

3 Simulating Primary and Secondary Emotions

Our virtual human Max is a testbed for studying and modeling human-like communicative behavior in natural face-to-face interactions [6]. Max architecture consists of a cognition module and an emotion module (see Figure 1).

The cognitive module builds on the belief-desire-intention model (BDI, in short) of rational behavior. It can be divided further into a reasoning layer, in which the agent's conscious deliberation takes place, and a reactive layer, which is mainly responsible for the agent's unconscious generation of reflex behaviors.

Two major assumptions, as supported by psychology literature (e.g. see [9]), are underlying our realization of a concurrent emotion dynamics simulation module. First, emotions have a fortifying or alleviating effect on the mood of an individual and an emotion is a short-lived phenomenon. A mood, in contrast, is a longer lasting, valenced state. The predisposition to experience emotions changes together with the mood, e.g. humans in a positive mood are more susceptible to positive than negative emotions, and vice versa [8]. This "emotion dynamics" is realized in the first component of the emotion module labeled *dynamics/mood* in Figure 1. Second, every primary as well as secondary emotion can be positioned in the PAD emotion space introduced above with respect to its inherent degree of *Pleasure*, *Arousal* and *Dominance*. This assumption underlies the second component of the emotion module labeled *PAD-space* in Figure 1.

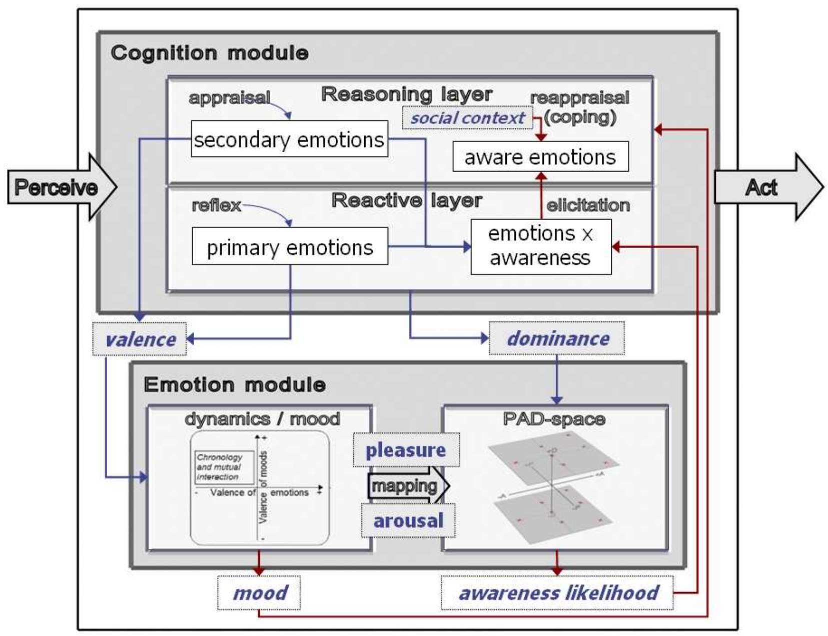

Fig. 1. The mutual interaction of cognition and emotion. A stimulus is appraised leading to the elicitation of primary and secondary emotions. Emotional valence and dominance values drive the emotion module to calculate an emotion awareness likelihood, which is used to filter the elicited emotions. Finally, the aware emotions are reappraised in the social context.

The emotion module [2] processes valenced impulses together with the actual degree of dominance as input signals. The valence information is driving the *dynamics/mood* part by changing the emotional valence on the *valence of emotions* axis. This leads to an increase or decrease of the agent's *valence of moods* indirectly, which is sent back to the cognition module as a general indicator of the agent's well being. Pleasure and arousal are derived from these values mathematically and combined with the actual value of dominance. As every emotion is represented by its corresponding PAD-triple in *PAD-space*, a distance metric is used to calculate an *awareness likelihood* for every emotion. For example, the secondary emotion "frustration" can be associated with negative pleasure and high dominance whereas "relief" can be characterized by positive pleasure and medium arousal. The primary emotions "sadness" and "anger", however, are co-located in the same region as frustration so that in case of negative pleasure and high dominance either anger, sadness or frustration might be elicited as encoded in the *awareness likelihood*. This *awareness likelihood* is sent back to the *elicitation* subcomponent of the cognition module and applied as a filter on the *primary* and *secondary* emotions that may have resulted from the initial appraisal processes. The actual set of emotions that the agent becomes aware of (the so-called *aware emotions*) are finally reappraised taking the *social context* into account. These *aware emotions* can influence the reasoning process on a sub-symbolic level as explained in [3].

4 Discussion and Conclusion

We presented a cognitive architecture for emotion simulation that combines cognitive and dimensional emotion theories. The BDI-based reasoning power of the cognitive module is used to generate secondary emotions by appraisal and reappraisal, while on a reactive layer primary emotions are concurrently realized. A possible drawback is that our architecture might suppress plausible mixtures of emotions such as fear and joy occuring at the same time, e.g., when taking a joy-ride in a roller coaster. The advantage of the proposed combination of separate modules for cognition and emotion lies in the fact that simultaneous elicitation of conflicting secondary emotions such as frustration and relief can be successfully avoided.

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Toward Building Adaptive User's Psycho-Physiological Maps of Emotions using Bio-Sensors

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Abstract. We present a method applied to the emotional subjective experience of the user for extracting emotional semantic information from Autonomic Nervous System (ANS) physiological signals (skin conductance and heart rate) sensed via bio-sensors. We present a physiologically-inspired data structure based on intra-individual rule extraction used to reach an interpretation of the physiological measure closely related to the user own emotional experience.

1 Introduction

Being able to include affect sensing in Human Computer Interaction (HCI), e.g. in teaching application, Human-Robot Interaction (HRI), e.g. for assisting tele-healthcare patients remaining autonomous, and Computer Mediated Communication (CMC), e.g. mailing or artistic collaborative systems depends upon the possibility of extracting emotion without interrupting the user during HCI, HRI, or CMC. Emotion is a mind-body phenomenon accessible at different levels of observation (social, psychological, cerebral and physiological). Among these observables, physiological activity is continuous and accessible by bio-sensors coupled with computers, which makes it an interesting modality for emotional computational sensing. The field of psychophysiology of emotion establishes links between the psychological level (the conscious and subjective emotional experience of individuals) and the physiological level (the measured signals associated with emotional activity). In this paper, we follow a psychophysiological approach, and aim at designing a computing system able to extract continuously (and without interrupting the user) the conscious affective state of the user by reaching a suitable interpretation of physiological activity. We thus present how to combine the 'subjective experience' and 'physiological processor' components of the Multimodal Affective User Interface (MAUI) computing framework ([1]) to estimate the user's emotional state by introducing the subjective experience as a central guideline for emotional interpretation during HCI.

2 Proposed approach for psychophysiological emotional sensing

Previous computing approaches on emotional sensing using psychophysiology. Several affective computing systems based on psychophysiology aimed at interpreting user's physiological activity as emotional categories or affective dimensions toward near to real time recognition of emotion. Main works are those of [2],[1], [3], [4], [5]in which an emotional situation is presented to the user and physiological recordings are performed, mainly for heart rate (HR) and skin conductance (SC). The emotion associated to the situation is then retrieved from recorded physiological activity offline (or near to real-time) using statistical analysis and/or machine learning. Some of these approaches ([1],[2]) do not extract from the raw signals the features specifically related to *emotional modulation* of the ANS (and process them together with irrelevant information in terms of emotional arousal). Furthermore, many of these systems ([1],[3]) are effective and robust to perform emotion recognition at the inter-individual level (they use a common training database for different subjects) and lead to user-independent interpretations which cannot be tailored to the emotional specificity of a user nor be used to build a precise *user-model*. However, existing litterature point to the existence of psychophysiological rules or a relation between physiological signal and its psychological emotional meaning (e.g. heart rate acceleration and fear are usually positively correlated accross subjects) (see [6] for a good survey). Other approaches to emotion recognition are single-subject based and are therefore not generalizable([2]).

In an attempt to address some of these issues, we hence propose to ground our computational approach on emotional physiological findings and: (1) extract and select only emotionally-relevant features from the ANS sensed signals; (2) combine both the derived average/synthesis of known pschophysiological mappings from existing litterature and subjective modulation; and (3) design a parametric emotional model adaptable specifically to each user.

Emotionally-specific choice of features from ANS signals. Peripherally measured activity of the Autonomic Nervous System (ANS) is an indirect measure of cerebral emotional processing. Furthermore, it has been shown that ANS can discriminate affective states, both in dimensional and discrete representations [7]. This emotional information is peripherally accessible through the HR and the SC whose activity is controlled by the ANS. However, *emotional modulation* of ANS (as opposed to other modulations of the ANS) is found in phasic patterns called Skin Conductance Responses (SCRs) [8], and in the Heart Rate Variablity (HRV) in spectral domain [9]. Thus we preprocess these features to extract emotion-specific information from ANS signals.

Psycho Physiological Emotional Map (PPEM). As shown in figure 1, we propose the PPEM as a descriptive mode of representation for the psychological links to physiological features (SCRs and HRV). We define the PPEM (see equation 1, and fig. 1.1) associated to a subject i (single subject form) as a group of specific patterns (S), represented as sets of features values derived from physiological signals, and a psychological part denoted by a coordinate or a dynamic (x, y) into the dimensional affective representation valence*arousal space (which coordinates are convertible into discrete emotion , see [10]) :

$$PPEM_i = \{(x_j, y_j), S(j)\} \quad \text{with} \quad j = 1, \dots, N \tag{1}$$

where N is the number of PPEM elements, and j the number of the element.

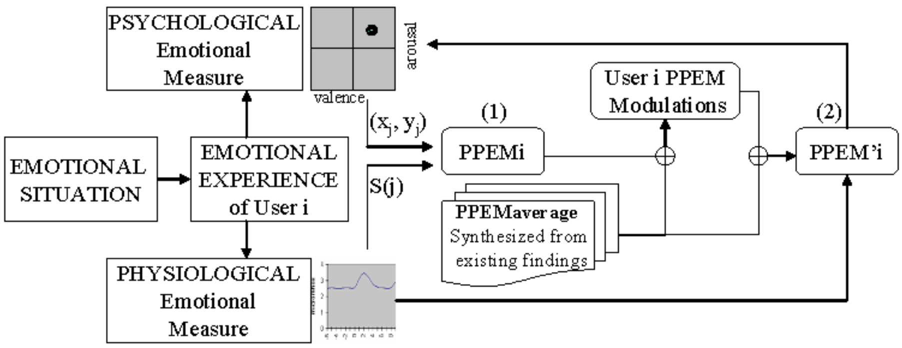

Fig. 1. Psycho Physiological Emotional Map (PPEM) construction and use.

Once created, a PPEM is used by a recognition system using the map made of elements. To be able to tailor interpretation without building a complete PPEM for each user, and taking benefits of previous approaches, we define the *parametric* form of PPEM, refered to as $PPEM'_i$ (see equation 2, and fig. 1.2). The psychological output is based on the modulation of a virtual subject PPEM, which represent the pshychophysiological links of the average population found in an experiment and/or in the literature ($PPEM_{\text{average}}$), and has similar behavior of single subject form. Inter-individual differences ($dx_{j,i}$ and $dy_{j,i}$, related to personality) are considered as subject i modulation of ($PPEM_{\text{average}}$) output, for the pairs $((x_j, y_j), S(j))$. Intra-individual differences ($dx_{j,i,c}$ and $dy_{j,i,c}$, related to mood and body state), as showed with "Day-dependance" phenomenon ([2]), are considered as subject i modulation due to specific conditions c.

$$PPEM'_i = \{((x_j + dx_{j,i} + dx_{j,i,c}, y_j + dy_{j,i} + dy_{j,i,c}), S(j))\} \tag{2}$$

Experimental set up. Our experimental set up is made of the following steps: we propose an emotional situation to the subject, and measure its emotional evaluation with both psychological method (e.g. explicit emotion expression) and physiological measures (HR and SCRs). The relations between these two types of data are analyzed to extract a semantic of physiological measure, which is used to design the $PPEM'_i$ using the $PPEM_{\text{average}}$. We continuously extract physiological parameters from the user, and try to extract in real-time his or her affective state, according to the semantic interpretation of the measures obtained with the previously assessed PPEM. We are in the process of applying this methodology to an experiment involving 40 subjects.

3 Conclusion

In this paper, we proposed a method and a system to infer psychological meaning from measured physiological cues, oriented toward near to real-time processing. We introduced the notion of Psycho Physiological Emotional Map (PPEM) as the data structure hosting the emotional mapping between psychological responses and the affective space. The PPEM approach might allow to establish a common model, taking into accounts and precisely describing both inter and intra-individual differences. Starting from an average population process, we aim at tuning the average model for each user by using the descriptive and explicit nature of the PPEM.

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Psychologically Grounded Avatars Expressions

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Abstract. Progress in computer graaphics over the last decade has rendered the creation of believable anthropomorphic graphical avatars possible. Issues in rendering these animated graphical avatars believable and engaging during Human-Computer Interaction still remain. In this article, we focus on the animation of avatar's facial expressions. We explain how we created our animation on Scherer's theory of emotion generation associated with facial expressions to create five facial expression animations (happiness, disgust, sadness, fear and anger) that are congruent with Scherer's theory. We discuss the specific steps and issues we followed as well as the evaluation results of a user study we conducted.

1 Introduction

Progress in computer graphics over the last decade has rendered the creation of believable anthropomorphic graphical avatars possible. Issues in rendering these animated graphical avatars believable and engaging during Human-Computer Interaction still remain.

In this article, we focus on the animation of avatar's facial expressions from a commercially a available generator software (Haptek, [1] which we evaluated as providing the best graphical rendering for believable anthropomorphic avatars. We created our animation on Scherer's theory of emotion generation associated with facial expressions [2–4] because we are concurrently developing an emotion-based architecture for intelligent social agents [5, 6] and we want to be able to link dynamically internal emotion-like states to external facial expressions in a manner that will be as close as possible to Scherer's theory of emotion generation.

We have currently created five facial expression animations (happiness, disgust, sadness, fear and anger) that are congruent with Scherer's theory using Haptek generator and we discuss the steps and issues involved in the process. We also show the results of an initial evaluation of the avatar's expression in terms of recognition and believability compared to that of a human.

2 Haptek avatars

Haptek avatars have been developed to represent believable human faces, and Haptek tools are commercially available software generators to enable the insertion of avatars in applications or web pages. Haptek animation is based on dedicated technology, similar to MPEG-4 FAP (Facial Action Parameters). There are different levels of control over Haptek avatars: from the control of global facial expressions, morph and position of the avatar to the control of basic facial movements. Basic control of the avatar is possible by Haptek hypertext technology. Through hypertext one can control text to speech, avatar position and launch Haptek switches. Switches are collections of states which represent the still expression of the avatar as well as its morphs in term of combinations of facial parameters defined by Haptek. Through switches one can, therefore, control the evolution of states over time as well as the softness of the transitions from one state to another, i.e. the evolution of the avatar expression.

3 Scherer psychological theory

We based our work on Scherer's multi-level process theory of emotions. According to Scherer [2–4], emotions are experienced depending upon the result of the individual's evaluation or appraisal of the events surrounding him in terms of their significance for one's desires and aversions. Scherer describes this process of appraisal as a process of sequential evaluation of parameters that he calls Sequential Evaluation Checks (SECs). The number and the nature of these checks have changed over time but they always refer to four categories: 1) *relevance*, or how relevant the event is for someone, 2) *implications*, or what the implications of this event are, 3) *coping potentials*, or how one can cope with these consequences and 4) *normative significance*, or what the significance of this event is with respect of one's self-concept and to social norms and values.

Sequential Evaluation Checks (SECs) are evaluated one after the other in temporal order from those representing *relevance* to the *significance* ones. For some of them Scherer also gives predictions about the corresponding facial expressions in terms of Ekman's [7] facial Action Units (AUs), the smallest independent facial muscle mouvement/action possible in the human face. Combining properly these predictions, it is possible to, on the one hand, recognize displayed emotions, and on the other hand display facial expressions (and the corresponding emotion), not in terms of a label (happiness, sadness etc.) as many computational animations do, but rather in terms of the underlying SECs structure of the emotion.

The use of SECs will also play a fundamental role in our cognitive-affective archicture.

4 Avatar Animation based on Scherer's SECs

It is not straightforward to automatically convert SECs to Haptek parameters, and we have identified four steps for the process: 1) convert each SEC to AUs; 2) convert AUs to Haptek parameters; 3) find appropriate intensities for the AUs; 4) exploit the temporal and intra-SEC correlation adapting AUs intensities.

For *Step 1 - Converting SECs to AUs*, we used tables directly extrapolated from Scherer's [2–4]. The other three points are fairly more complicated.

For *Step 2 - Converting AUs to Haptek parameters*, we created a conversion table and software designed to create switches representing single AUs at different intensities. A problem is that some movements are not really describable in term of Haptek parameters (we would need sub-parameters). To resolve this, we designed the AUs representing movements that are at least similar to the original ones. The average quality of the conversion has been evaluated as very good by an informal internal questionnaire.

For *Step 3 - Finding the right intensities for the AUs*, we based our decisions on the Scherer theory, [2–4] and converted SECs intensities to the Ekman scale from 'a' (min. intensity) to 'e' (max. intensity).

For *Step 4 - Exploiting temporal information*, the problem is that Scherer's theory does not exploit any intra-SEC or temporal correlation. It does not explain how the SEC sub-expressions are linked to each other over time, nor how long one single sub-expression should be displayed on the face before it vanishes. We referred to standard videos contained in a database of different actors expressing six universal expressions [7]. As it became evident that some AUs must be activated in time over different SECs and have their intensities reduced in a fluid way, we relaxed the constraints over AU intensities and adapted the intensity to reach fluid expressions. The transitions for *fear* are shown in Figure 1 and all of the five expressions will also be demoed at the KI Workshop Demonstration Session applied to an e-tutoring context [8].

Fig. 1. Possible evolution of the expression for Fear according to Scherer theory

5 Recognition and Believability Evaluation User Study

We conducted a user study to compare the resulting expressions against the ones of human actors and generic expressions developed by Haptek. The results of the study of five different expressions (happiness, disgust, sadness, fear and anger), experimented on a group of 16 people, are shown in figure 2. The subjects were first asked to recognize the shown emotion using a closed questionnaire and then to express their opinion, by chosing a mark between 1 and 5, about the expressions shown by one actor, an avatar tuned by standard Haptek expressions and another tuned with the designed parameters.

The scores are good in that the shown emotions were recognized in the 94% (see table in Fig. 3) of the cases and the believability of the developed expression

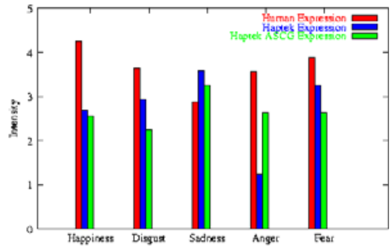

Fig. 2. Expressions believability

recogn. \ shown	Happin.	Disgust	Sadness	Fear	Anger
Happiness	**100%**	0%	0%	0%	0%
Disgust	0%	**63%**	0%	0%	38%
Sadness	0%	0%	**100%**	0%	0%
Fear	0%	6%	0%	**94%**	0%
Anger	0%	13%	0%	0%	**88%**

Fig. 3. Recognition scores

has been judged in a similar way to the one of human expression and of the Haptek default expressions (see [9] for further details).

6 Conclusions and future work

This study shows the feasibility of facial emotion expression based on Scherer's component process theory. Expresions created through this paradigm have shown to be believable and understandable. Nevertheless this study has been developed over only five expressions and will be expanded to other combinations of SECs, as well as linked with an affective-cognitive computational architecture.

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Generation of Facial Emotional Expressions Based on Psychological Theory

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Abstract. Facial expressions are an important aspect in affective social computing. They express internal states of robots during social interactions. In this paper we present the use of Scherer's psychological theory to express facial emotions. This theory has the advantage of linking cognitive and emotional processes. We have implemented a part of this theory on a robot: iCat. We present results by comparing several representations of the same emotions.

1 Introduction

We present in this paper the use of Scherer's psychological theory to express emotional facial expressions. This work forms a part of development of an affective-cognitive architecture to create socially intelligent robot. In the following, we focus on the way which robots express emotions. We explain Scherer's theory and emotional predictions. Then we introduce iCat (a robot created by Philips), how we use it to test emotional theory, and discuss the results of user studies.

2 Application of psychological theory on robot

2.1 Scherer's theory description

Scherer defines emotional behavior as a dynamic process rather than a steady state. This process, called "The Component Process Model of Emotion", is grounded on a multi-level and multi-component approach.

In [1], Leventhal and Scherer present a hierarchical processing system where emotional process is organized at three levels: the sensory-motor level where organism has its primary emotional responses with for example reflexes, the schematic level based on learning history of individual and abstract representation of stimulus responses, and the conceptual level where individuals reason about environment and emotional responses. These three levels are linked to appraisal objectives or components: relevance of the event for an individual and how it can be affect him (relevance), consequences of the event on individual's goals (implications), how an individual can cope with this event (coping potential) and if the event respects individual's social norms (normative significance) [2]. These components are used in emotional predictions in a chronological order: from relevance component to normative significance component. For each component, Scherer defines intensities of emotional responses that vary in function of the expressed emotions. Emotional responses depend on individuals and how they evaluate events that occur. In this paper we are interested in the facial expression emotional responses and how they are represented by Action Units (AUs), as defined by Ekman [3]. The final emotional response is the result of the sequence of intermediate emotional responses, corresponding to each of the four components.

2.2 iCat robot

Fig. 1. iCat robot

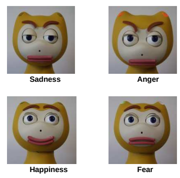


Fig. 2. iCat facial expressions

iCat is a robotic research platform developed by Philips. It is focused on human-robot interaction with speech and facial emotional feedback [4]. We will interest in iCat's social aspect and its abilities to express basic emotions such as sadness, anger, happiness or fear (figure 1 and 2). We implemented Scherer's psychological theory to express facial emotions in term of Action Units which represents a muscle or a set of muscles. AUs are used to describe facial activity with FACS (Facial Action Coding System). They have been defined for human and iCat has not a human appearance: we can express some Action Units on iCat but not others. It can move its neck, eyes, eyebrows, lids and lips but for the three last, iCat lacks some degrees of freedom. For example it is impossible for iCat to move bottom lids, to retract lips or to raise all eyebrows. For each AU necessary to emotional responses, we have to adapt them in terms of iCat possibilities: some AU remain unchanged (AU2: outer brow raise), others are extrapolated (AU4: brow lowered is expressed as AU2) or even ignored (AU17: chin raising), as shown in Table 1.

3 Believability, Exaggeration, and Recognition User Studies

In this study, we compare, on iCat robotic platform, different ways of expressing the following emotions: happiness, disgust, sadness, anger and fear.

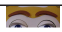
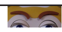
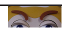
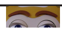
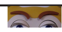
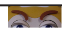
Action Units	FACS Name	Neutral Example	Medium Example	Very High Example
POSSIBLE ACTION UNITS				
AU2	Outer Brow raise			
AU12	Lip Corner Puller			
AU15	Lip Corner Depressor			
EXTRAPOLATED ACTION UNITS				
AU4	Brow Lowered			
AU26	Jaw Drop			
AU41	Lid Droop			

Table 1. Possible and Extrapolated Action Units

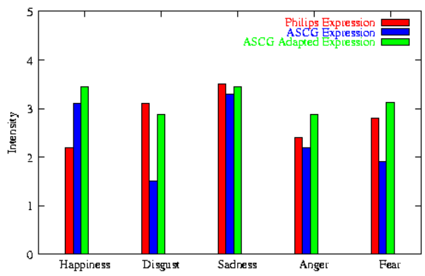


Fig. 3. Emotions believability

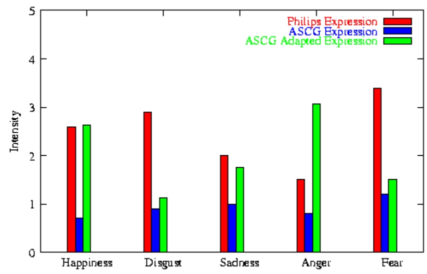


Fig. 4. Emotions exaggeration

The first experiment involved eleven persons, four women and seven men, between twenty and thirty years old. They had to compare emotional expressions created by Philips and by our research group with a questionnaire evaluating the believability and the exaggeration of each emotional expressions. Philips research has used principles of animation defined by Disney to animate characters [5]. Our group has implemented Scherer's emotional responses. We can observe that Philips' expressions are more believable in general (figure 3) but more exaggerated (figure 4) than our expressions (ASCG expression). The believability of emotional expressions created by Philips is due to their exaggeration. Indeed, emotional responses defined in Scherer's theory are for humans and not for robots. Because of these results, we adapted Scherer's theory on iCat in a second implementation using all possibilities provided by this platform: head and neck movements, lights in paws and ears. For this we have conducted a second user studies in which fifteen participants have to recognize the expressed emotions (table 2). In general, participants recognized happiness, anger, fear and indifference better than others expressions. Disgust expression is confused with contempt expression. Pride is recognized as pride with 38% and as fear with 31%. Some expressions such as contempt, pride indifference and shame are very difficult to represent because they use gaze expression and iCat is unable to do this.

The third experiment involved fifteen persons, three women and twelve men. They had to evaluate the believability and the exaggeration of ours new ex-

Showed \ Recognized	Happ.	Disg.	Cont.	Sadn.	Prid.	Fear	Ange.	Indi.	Sham.	None
Happiness	**75%**	13%	0%	0%	0%	0%	0%	0%	6%	6%
Disgust	0%	**25%**	56%	0%	6%	0%	0%	6%	0%	6%
Contempt	6%	0%	**19%**	0%	63%	6%	0%	0%	0%	6%
Sadness	0%	19%	0%	**56%**	0%	0%	0%	0%	25%	0%
Pride	13%	0%	0%	0%	**38%**	31%	0%	6%	0%	13%
Fear	0%	0%	0%	0%	0%	**69%**	0%	6%	13%	13%
Anger	0%	0%	6%	0%	0%	0%	**88%**	0%	0%	6%
Indifference	0%	0%	0%	6%	19%	0%	0%	**63%**	13%	0%
Shame	0%	0%	0%	31%	0%	0%	6%	19%	**31%**	13%

Table 2. Emotional recognition rate for iCat

pressions (ASCG Adapted Expression). We can observe that the results have increased with these new emotional facial modelisation.

4 Conclusion and future works

In this paper we propose to represent emotional facial expression with Scherer's emotional predictions. We use it because of the link between cognitive and emotional processes and this approach permits us to develop an emotional-cognitive architecture.

We implemented emotional expressions on iCat by combining Scherer's prediction and principles of animation defined by Disney. The results showed that our representation is believable.

For more believability, we will generate different but similar expressions for same emotions. Indeed, when a human smiles, the way of express his smile is always different with little variations. Furthermore we will develop an application of interaction between human and iCat.

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Toward Affective Dialogue Modeling using Partially Observable Markov Decision Processes

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Abstract. We propose a novel approach to developing a dialogue model which is able to take into account some aspects of the user's emotional state and acts appropriately. The dialogue model uses a Partially Observable Markov Decision Process approach with observations composed of the observed user's emotional state and action. A simple example of route navigation is explained to clarify our approach and preliminary results & future plans are briefly discussed.

1 Introduction

We aim to develop dialogue management models which are able to act appropriately by taking into account some aspects of the user's emotional state. These models are called *affective dialogue models*. Concretely, our affective dialogue manager processes two main inputs, namely the user's action (e.g., dialogue act) and the user's emotional state, and selects the most appropriate system's action based on these inputs and the context. In human-computer dialogue, this work is difficult because the recognition results of the user's action and emotional state are ambiguous and uncertain. Furthermore, the user's emotional state can change quickly. Therefore, an affective dialogue model should take into account both the basic dialogue principles (such as turn-taking and grounding) and the aspects of the user's emotional state. We found that Partially Observable Markov Decision Processes (POMDPs) are suitable for use in designing these affective dialogue models.

In this paper, we first introduce a short overview of POMDP and its application to the dialogue management problem. Second, a general affective dialogue model using POMDP is described. Then, we present a simple example to illustrate our ideas and discuss future work.

2 POMDP and dialogue management

A POMDP is defined by the tuple $\langle S, A, Z, T, O, R \rangle$, where S is the set of states (of the environment), A is the set of the agent's actions , Z is the set of observations the agent can experience of its environment, T is the transition model, O is the observation model, and R is the reward model (Fig. 1a).

In a dialogue management context, the agent is the system (i.e., the dialogue manager) and a part of the POMDP environment represents the user's state. The system uses a state estimator (SE) to compute its internal belief about the user's current state and a policy π to select actions. SE takes as its input the previous belief state, the most recent action and the most recent observation, and returns an updated belief state. The policy π selects actions based on the system's current belief state. Two of the main tasks of a POMDP are computing belief states and finding an optimal policy (i.e., optimal dialogue strategy). These two tasks are explained in [4].

The first work that applied POMDP for the dialogue management problem was the robot home-assistant application [5]. The work following this track is [7, 8]. All these approaches focus on spoken dialogue systems.

3 A POMDP approach to affective dialogue modeling

We select the factored POMDP [2] for representing our affective dialogue model. The state set and observation set are composed of six features. The state set is composed of the `user's goal` (G_u), the `user's emotional state` (E_u), the `user's action` (A_u), and the `user's dialogue state` (D_u) [7]. The observation set is composed of the `observed user's action` (OA_u) and the `observed user's emotional state` (OE_u). Depending on the complexity of the application's domain, these features can be represented by more specific features. For example, the user's emotional state can be encoded by continuous variables such as *valence* and *arousal*, and can be represented using a continuous-state POMDP [3]. The observed emotional state might be represented by a set of observable effects such as response speech, speech pitch, speech volume, posture, and gesture [1].

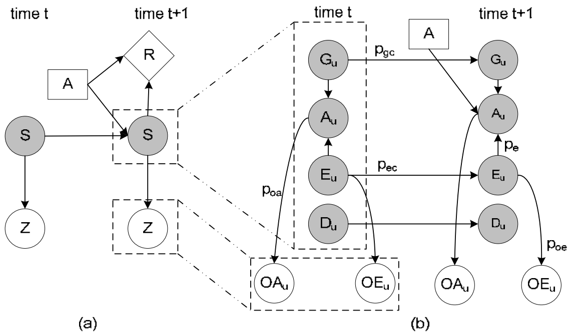

Fig. 1. (a) Standard POMDP, (b) Two time-slice of factored POMDP for the ADM

We are at this moment working with finite-state discrete-time POMDPs. Fig. 1b shows our affective dialogue model (ADM). The features of the state set, action set, observation set, and their correlations form a two time-slice Dynamic Bayesian Network (2TBN). The 2TBN in Fig. 1b is built for our route navigation example that will be presented in Section 4. We can easily modify this 2TBN for representing other correlations, for example the correlation between the user's goal and emotional state. Parameters $p_{gc}, p_{ec}, p_e, p_{oa}$, and p_{oe} are used to produce the transition and observation models in case no real data is available, where p_{gc} and p_{ec} are the probabilities that the user's goal and emotion change; p_e is the probability of the user's action error induced by emotion; p_{oa} and p_{oe} are the probabilities of the observed action and observed emotional state errors.

The reward model depends on each specific application. Therefore, it is not specified in our general affective dialogue model.

4 Example: Route navigation in an unsafe tunnel

We illustrate our affective dialogue model described in Section 3 by a simulated toy route navigation example. An accident happened in a tunnel. A rescue member (denoted by "the user") is sent to the unsafe part of the tunnel to evacuate some injured victims. Suppose the user is in one of three locations (a, b, c). The user interacts with the system. It is able to produce the route description when knowing the user's current location. Furthermore, the system can detect the user's stressful state ($stress$ or $nostress$) and uses this information to act appropriately. In this simple example, the system can `ask` the user about his current location, `confirm` a location provided by the user, show the `route description` of a given location, and stop the dialogue by choosing `fail` action.

The POMDP for this problem is represented by $S = \langle G_u \times A_u \times E_u \times D_u \rangle = \langle \{a, b, c\} \times \{a, b, c, yes, no\} \times \{stress, nostress\} \times \{firstturn, nofirstturn\} \rangle$, $A = \{ask, confirm\text{-}a, confirm\text{-}b, confirm\text{-}c, rd\text{-}a, rd\text{-}b, rd\text{-}c, fail\}$, and $O = \langle OA_u \times OE_u \rangle = \langle \{a, b, c, yes, no\} \times \{stress, nostress\} \rangle$. The full flat-POMDP model is composed of 61 states (including a special `end` state), eight actions, and ten observations.

The transition and observation models are generated from the 2TBN (Fig. 1b). We assume that the observed user's action only depends on the true user's action (i.e. $P(oa_u|a_u) = (1 - p_{oa})$ if $oa_u = a_u$, otherwise $P(oa_u|a_u) = 1/4 \times p_{oa}$). The observed user's emotional state is computed in a similar way. We use two criteria to specify the reward model, helping the user obtain the correct route description as soon as possible and maintaining the dialogue appropriateness [7]. Concretely, if the system `confirms` in the first turn, the reward is `-2`, the reward is `-5` for action `fail`, the reward is `10` for action `rd-x` where $g_u = \mathtt{x}$ ($\mathtt{x} \in a, b, c$), otherwise the reward is `-10`. The reward for any action taken in the absorbing `end` state is `0`. The reward for any other action is `-1`.

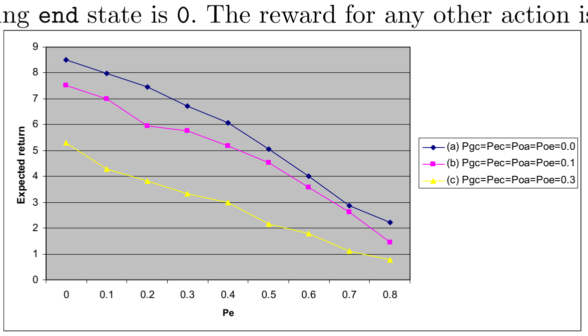

Fig. 2. *Expected return vs. the user's action error induced by stress* p_e

The expected return of the optimal policy (Fig. 2) is computed using the Perseus [6] which is an approximate POMDP algorithm that requires two inputs, a number of belief points and a maximum runtime value. We found 1000 belief points and a runtime of 60 seconds be a good choice for testing our problem. The probability of the user's action error being induced by stress p_e changes from `0` (stress has no influence to the user's action selection) to `0.8` (the user is highly stressed and acts almost randomly). Three lines in Fig. 2 are: no observation error ($p_{oa} = p_{oe} = 0$); low observation error ($p_{oa} = p_{oe} = 0.1$); and high observation error ($p_{oa} = p_{oe} = 0.3$). All these lines show that the expected return of the optimal policy depends on p_e.

5 Conclusions and future work

We have presented a POMDP approach to affective dialogue modeling and illustrated our affective dialogue model by a simple example. The 2TBN representation allows integrating the features of states, actions, and observations in a flexible way. We have also shown that even if the observation is perfect, the expected return of the optimal dialogue strategy depends on the correlation between the user's emotional state and the user's action.

Three important issues we plan to tackle are: (1) scaling up the model with larger state, action, and observation sets for real-world dialogue management problems; (2) extending the model representation, especially by adding more specific features related to the user's goal and emotion and specifying their correlations; and (3) collecting and generating both real and artificial data to build and train the model as well as to validate the model design.

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An Emotional Decision Making Model for Word Sense Disambiguation

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Abstract

A model of emotional decision making for Word Sense Disambiguation, called Sense Space Approach, has been suggested and implemented. In Sense Space Approach a reduction of the context of the part of the text that contains the word (to be disambiguated) is represented in the Sense Space by moving/reshaping a geometrical identity (normally by moving a dot) in a highly multi-dimensional space. The dimensions are selected specific to the problem and are usually senses of words. Normally, those of the senses that are a more basic or more general representative of the other senses are desired as dimension, such as senses of about the 2000 control words of LDOCE (Longman Dictionary Of Contemporary English) that define the other words of this dictionary. The WSD system implemented under this model uses the Similarity between senses to use the space. The system has been evaluated and compared to a rival, another similarity-based WSD system and prevails. A competitive hybrid WSD system should combine several of such methods to achieve high performance.

Keywords: *Word Sense Disambiguation, Emotional Decision Making, Natural Language Processing, Hard Problems*

1. Introduction

Emotions are capable of being not only explained, but also justified -- they are closely related to the reasons that give rise to them. If someone angers me, I can cite my antagonist's deprecatory tone; if someone makes me jealous, I can point to his poaching on my emotional property [10]. The variety and difference of the expression of emotions among people tells us that the reasons and justifications behind emotions and decisions made based on them are complicated and are processed by brain in a decision making process which we may call Emotional Decision Making (EDM). The process may be active after the expression of emotion as well, however not usually for a long time. When we fear and scream, the part of the brain that has decided the awakening of the “physiological fearing process” in the body, remains active until there is enough time and a “good” situation for the (more) rational functionality of the brain to reappear. There are also good evidences in neuroscience that shows emotions are very important for decisions human make [5]. There is no rough border in human between rational and emotional decision making. When talking about these two kinds of decision making in human, we need to talk about a grey scale, namely we should consider the degree of logic that is used in the process to find out how much rational/emotional the decision making has been. Neuroscientists Saver and Damasio [5] studied people who had brain injuries with one specific effect: to damage that part of the brain where emotions are generated in. They found that their ability to make decisions was considerably impaired. They could logically describe what they should be doing, but in practice they found it very difficult to make decisions about where to live, what to eat, etc. Decisions may have many pros and cons on both sides and such situations are resolved by emotional decision making in human. There’s the same case of decision making for choosing the right sense of the words when we want to read a text *fast* (we often do it faster than we can think deeply about each word).

A *very* emotional decision is typically very fast. It takes considerable time (at least 0.1 seconds) for the rational cortex to even activate, more than available in the reactive (and largely subconscious) decision-making for managing great fear or anger situations. According to Sloman [7], the need for speed leads to architectures and algorithms that are fallible in ways that explains why intelligent agents are susceptible to emotions and errors. Emotional decision making is the art of running and jumping to climb the hill of decision making instead of taking careful logical steps, which can result in more error. It is not normally good for precision-critical situations, because loosing precision and making more mistakes is natural in emotional decision making. Choosing this technique is forced by severe resource restrictions because considerable accuracy should be refused.

Emotional Decision Making: a kind of decision making in which much accuracy is refused for tackling a situation where considering all the problem-specific limitations of resources of decision making, a very hard problem should be solved.

Decision making resources*:* deciding time, energy, known decision making methods, process implementation time, etc.

In Artificial Intelligence, Emotional Decision Making is a much newer term than phenomenon. Usually, complex problems, including those in AI, such as WSD, can be solved better by combining several **Emotional Decision Makers** and **Decision Making Experts**. *Emotional Decision Makers* have an idea of how to widely deal with the general problem while *Decision Making Experts* specialize in accurately solving a limited sub-problem or sub-task. Emotional Decision Makers do big chunks of the problem with little accuracy and Decision Making Experts do little chunks with high accuracy. The border between these two is blurred and we can talk about them as fuzzy sets with members that have a grey scale of membership values. Marvin Minsky [3] seems to agree in his own way: “The main point of the book [his book: The Emotion Machine] is that it's trying to make theories of how thinking works. Our traditional idea is that there is something called ‘thinking’ and that it is contaminated, modulated or affected by emotions. What I am saying is that emotions aren't separate.”

Providing a model of human's Word Sense Disambiguation is not easy due to the complexity of the brain, lack of our knowledge, and even due to differences among languages and people. However, it seems that Word Sense Disambiguation (WSD) in human can be divided into two steps: a preliminary step (*Emotional Decision Making step*) and a complex step (use of *Decision Making Experts*). We often have an immediate opinion about what the meaning of the words we read/hear can be. Our general understanding of the context combined with the impact of the words just read/heard help us to decide the more likely sense(s) of the word being read in most cases. When this fast preliminary (*emotional*) process is not enough to determine the sense, a complex combinatory (and more *rational*) process is started in the brain to determine the chosen sense of the word by carefully using human's knowledge of the world, grammar knowledge and sense usage in example sentences. Sense Space Approach (SSA) is a model for WSD, *inspired* by our vague understanding of the preliminary level of human's way of doing WSD. It should be noted that SSA is not a simulation of that brain process.

Sense Space Approach can be a part of high-accuracy multi-method systems and it also can be implemented to perform WSD independently. The WSD system developed by Stevenson [9] is a good examples of combinatory multi-method systems, but present systems are still far from being very accurate (the most accurate system in the worldwide "Senseval-3 all words English test scheme" had achieved about 70% accuracy).

2. Sense Space Approach

Sense Space Approach (SSA) is an emotional decision making model for performing word sense disambiguation. It is also a sense relatedness-based approach in which relation of senses to each other is used for WSD (relations such as co-occurrence rate of senses in corpora or similarity of senses to each other). Sense similarity is a kind of sense relatedness and our present implementation of SSA package is based on sense similarity (similarity of two arbitrary senses to each other).

Before proceeding to the main part of describing SSA, we mention Lesk's way of measuring similarity of senses. Lesk [2] considered using word overlaps between sense definitions of the dictionaries as an indicator of similarity. His method was later revised to form Extended Lesk method [1] which considers the information in definitions of the senses of the words that appear in the definition of the two compared senses as well. This extension tries to give Lesk method more power to overcome inaccuracies arising from the information limit in short sense definitions.

2.1. A Framework for Sense Space Approach

A **Sense Space** is a highly multidimensional space in which dimensions are a set of chosen word senses and every other sense is represented by a geometric object, here in this paper *a dot* (or we can say *vector*) in the space, which shows the presently estimated relation of that sense to the dimension senses. There has been slightly similar ideas for sense discrimination [6] in which unsupervised learning has established a space and some kind of sense inventory, but we are considering a more accurate method for sense disambiguation (not discrimination) based on sense relatedness, in which dimensions are also practically much more: a large subset of the senses of the words of the language (here, English language). It may be said that most researches in multidimensional spaces try to reduce the number of dimensions, not increasing them. This is only a part of the fact about such kind of work. It is true that the time complexity of algorithms working in multidimensional spaces may exponentially grow when the number of dimensions grows, but it is not always the case. In some cases, simplifying an algorithm (regarding its complexity) can be much more time-slice saving than reducing the dimensions.

To give an example of estimating the location of a word in Sense Space, we assume our imaginary language contains only one (the most common) sense for each word listed in ordered string of words A and then we will define (determine the location of) the animal sense of the word "bat" by assigning weights in [0, 1] to every word in the language (showing their level of conceptual relation to the word "bat") in form of the ordered string v_B (representing bat's vector/dot in the space, when all the other senses are dimensions of the space):

A = (mammal, bird, foot, beak, teeth, big, small, food, is, human, plant, object, mouth, uncle)

v_B = (1.00, 1.00, 0.40, 0.20, 0.50, 0.10, 0.80, 0.20, 0.02, 0.20, 0.15, 0.05, 0.60, 0.10)

Generally, v_B can be calculated, revised by learning, extended and updated, automatically or manually. For example it can be calculated automatically by methods such as Lesk similarity measurement [2] or Extended Lesk [1]. There are also other ways for estimating v_B, including statistical methods based on co-occurrence frequency of the senses in corpora. Idea of an expert human about the level of conceptual relationship between the pairs of words can also be an accurate but time consuming starting point to estimate v_B (similar to the above estimation). Given a Fuzzy Sense Net (a Semantic Net with fuzzy labels), a mapping of the senses in it to the sense space can also be derived. For example the quadruple relation (bat, is, almost surely, bird) can result in the level of relationship between "bat" and "bird" to be set to 0.95, and (bat, has, surely, mouth) can result in the level of relationship between "bat" and "mouth" to be set to 0.60 . The difference of labels such as "is" and "has" is also considered here and can be defined in form of conceptual relationship weights.

2.1.1. SSA Algorithmic Framework's Assumptions

A. We assign consecutive natural numbers to each of the whole senses of the language being used (here, English). The number of the whole senses is shown by n.

B. There's an N×N matrix, called M, in which the cell M (x, y) indicates the present amount of estimated co-occurrence/ meaning/conceptual relationship of sense number x to sense number y. The matrix is not necessarily symmetric, namely there may be an x and a y such that M (x, y) ≠ M (y, x). The matrix M is created by an algorithm which will be determined later, and can for example be the co-occurrence of word x with word y, in LDOCE or other sources or corpora.

2.1.2. SSA Algorithmic Framework

The framework has the following general steps for disambiguating words in their context:

Step 1: Determine the start point: S (m_1, …, m_n) (which for example can be the topic of the text which can be a sense, or can be mapped to a sense). At the beginning, the start point is put into the Present State point variable, P (r_1 , …, r_n). The latter will continuously be revised and used in the next steps of the algorithm. Thus in this step:

P (r_1 , …, r_n) is set to S (m_1, …, m_n)

Step 2: A loop starts: If there's no word remaining in the text, skip this loop by going to 6, otherwise read the next word of the text (which will be the first word of the text at the beginning) and find its Base Form (root of the word, without prefixes, postfixes and transformations). Also save the difference of the word with its root as a number assigned to that group of words, for example, number 12 for plural nouns, that for example results in word "men" to be saved for example as (man, 12). If the text has n words, the array T(i,j) will contain the saved data such that: i∈N, 1 ≤ i ≤ n, j∈{1,2}and T (i, 1) contains the *most frequent sense* number corresponding to the root of i^{th} word of the text and T (i, 2) contains the Difference Number of the i^{th} word of the text with its root.

Step 3: Revise the present state point (vector) based on the newly read information, previous information including previously chosen senses for the text being disambiguated, and Present State point's current value, using the function f (P (r_1 , … , r_n) , T (i, 1), T (i, 2), PastDisambiguationRecord) which will be defined later. Therefore in this step:

P (r_1 , …, r_n) is set to f (P (r_1 , …, r_n) , T (i, 1), T (i, 2), PastDisambiguationRecord)

Step 4: The chosen sense(s) for the n^{th} previously read word (n= -1 is the easiest to do, however e.g. n = 4 can provide a more accurate result, because the information in words after the word to be disambiguated is also considered for the disambiguation) is (are) the one(s) which its (their) corresponding dot(s) (or vector(s)) in the sense space has (have) the highest score/nearest distance (for example Euclidean distance) according to the present state point (the score/distance can also be a measure to determine next preferences of the chosen sense, which are particularly important in hybrid approaches that try to combine the results of different methods). PastDisambiguationRecord should be updated here. A weighted set of chosen senses can be added to it, rather than just the chosen sense. The weight can be the score or 1 divided by distance.

Step 5: Continue the loop by going to Step 2.

Step 6: End.

How can the distance function be defined for example? Suppose the presentation of the sense T (i, 1) in the Sense Space is:

SenseSpace (T (i, 1)) = S (q_1, …, q_n)

If we assume n=1 in the fourth step of the algorithmic framework (which is not the best assumption), among the ways to consider for defining f (P (r_1 , …, r_n) , T (i, 1), T (i, 2)), it can be for example defined as follows:

$$f (P (r_1 , …, r_n) , T (i, 1), T (i, 2), PastDisambiguationRecord) = (\sqrt{\frac{(r_1^2 + q_1^2)}{2}} , …, \sqrt{\frac{(r_i^2 + q_i^2)}{2}})$$

Note 1: If all the coordinates of the Sense Space are in [0, 1], It can be proved that 0 ≤ f ≤ 1 which means the output of the function f, namely the present state point, is still in the initial [0, 1] as needed in some cases.

Note 2: In this definition of f, T (i, 2) has not been used. PastDisambiguationRecord is also not used directly here, but it has been used in forming the present state point.

3. The implemented variant of the SSA

An algorithm under the SSA framework has been suggested and implemented using C++ and Perl and the algorithm has been revised based on the experiments done by using our implemented SSA software package. The package contains the SSA and a few research tools/capabilities to study SSA.

SSA can be implemented in many ways depending on the score/distance function, present point movement function, initial point, etc. These are the characteristics of the implemented SSA:

A. Initial Point: For each of the dimension values (coordinates) of the point, sum of the squares of the Extended Lesk similarity value between:

every sense of every word of the context of the word being disambiguated

and

the sense corresponding to dimension value being set

For better results, it can be improved to a weighted sum in which weight of the word senses is their frequency number in WordNet normalized between 0 and 1 by the sum of frequencies of senses of the word.

B. Score/Distance Function: For every sense, every dimension value of the present point is multiplied to the square of the corresponding dimension value of the sense, to be added to the total score of that sense. The C code:

```
Score = 0;
for (Dimension=0; Dimension<NumberOfSenses; Dimension++)
    Score +=  (PresentPoint [Dimension] * SimilarityMatrix [SenseCounter][Dimension] * SimilarityMatrix [SenseCounter][Dimension]);
```

For better results, a weighted sum of all the senses can be used instead of the chosen sense. The weights can be the square of the score of each sense, which rewards higher scores.

C. Present Point Movement Function:

```
for (Dimension=0;Dimension<NumberOfSenses;Dimension++)
    PresentPoint [Dimension] =   pow ( 0.5 * pow (PresentPoint [Dimension], 1.5)  +
                                       0.5 * pow (SimilarityMatrix ChosenSense][Dimension],  1.5) ,  0.666);
```

This function is smoother compared to the one mentioned after the SSA framework. The distance importance is here formulated as $x^{1.5}$ instead of x^2 to avoid rigid domination of the senses near the word being disambiguated. The number 1.5 is a result of some experiments done using the SSA package.

D. Relatedness Matrix: It is a Similarity Matrix in this implementation (similarity is only one of the types of relatedness). We chose to use Extended Lesk similarity measurement method [1] because it can measure similarity between senses which are in different part of speech and because it has proved to result in a better performance in a study by Pedersen et. al. [4] in which they used their own similarity-based algorithm with each of several similarity measurement methods and then compared the results.

4. Results

SSA Package Test Results and Facts Compared to the Implementation of Pederson-Banerjee-Patwardhan Algorithm [4]:

Precision: We achieved a 30% *accuracy* (percentage of correct disambiguations according to an answer key) for some difficult tasks in Senseval-2 Lexical Sample Test data (a test scheme known and used worldwide). Pederson et. al. [4] have achieved 20% accuracy on these hard test cases (however their total accuracy for the test cases were above 40% and high performance *hybrid* systems in Senseval-2 had achieved about 70%). Test cases and their keys are available via Senseval site (http://www.senseval.org)

About Timing Statistics: It took about one minute for the program of Pederson et. al. [4] to disambiguate a word in a Senseval-2 Lexical Sample Test task, while our SSA program does WSD for whole the known words of ten of such tasks in about thirty seconds, *using the same computer*.

5. Conclusions

One contribution of the research is suggesting a new method of doing WSD for hybrid multi-method systems, which has been inspired by human's preliminary phase of emotional decision making for disambiguating words. The parts of a system that the nature has found useful are not to be missed. The research has also contributed to our understanding of the nature of emotional decision making and its relationship to hard AI problems, especially word sense disambiguation.

The implemented algorithm needs improvements to better show the strengths and drawbacks of the SSA framework. The way we set the initial point, design the score function, design present point movement function and utilize relatedness between senses and words are problems that their better solution can significantly enhance the algorithm. Studying the hard (unsolved/less-solved) cases of WSD according to the previous Senseval schemes can hopefully help us enhance the algorithm to be a highly contributing part of powerful hybrid systems. This research is in progress.

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Emotional User Interfaces in the Car

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Abstract

Due to the increase of electronic functions in modern cars, human machine interfaces (HMIs) in the cockpit have significantly gained complexity over the last years and are nowadays comparable to multi-functional computer systems. Today, automotive user interfaces suffer from the same restrictions as interfaces from various other fields of human machine interaction. The communication between the system and the user is restricted to the transmission of commands and factual information. In most cases users have to adapt to the rules of the technical system in order to achieve 'interaction'.

However, automotive human machine interaction is unique in the fact that a lot of information about the context of use can be obtained and utilised for streamlining the interaction process. In addition, the interaction in the car is characterised by multitasking activity for the driver and its crucial impact on the user's physical safety.

In this article we describe an abstract approach to enrich purely information based human machine communication in the car by employing means of expression that correspond to social and interpersonal interaction. This so called 'emotional indication' can be used to rate factual information in terms of sense, consequence or relevance in order to help the user understand the 'meaning' of a system output.

1. Introduction

The permanent increase of electronic functions in the car has caused manufacturers to develop human machine interfaces that are able to cover the new complexity. On the one hand, the current development of HMIs addresses automotive-specific issues as e.g. the integration of a growing number of functions into limited interface-space, the reduction of the operation complexity or the avoidance of visual distraction of the driver. On the other hand, automotive HMIs are subject to the same issues of ergonomics and usability as HMIs for e.g. personal computers, mobile phones or TV-devices [1].

Many user interfaces of commercial products suffer from the fact that untrained users need to adjust their behaviour to the implicit functional rules of a technical system in order to operate it. Modern interfaces like 'Windows' therefore try to 'hide' the technical system behind a metaphorical representation that is exposed to resemble more the process of human information processing. Nevertheless, human machine interaction still creates moments of bilateral incomprehension and frustration of the user. In particular, unexpected system output often leaves users unaware of its sense, relevance or meaning with regard to potential consequences.

In the context of the automotive HMI, these effects might lead not only to an unsatisfactory product experience, but also to increased interaction effort to achieve results and thus to safety risks while driving. Especially inaccurate output from driver assistance systems may result in a lack of trust and false or delayed decisions in (time-) critical situations.

One of the major issues of today's automotive user interfaces is their general restriction to the exchange of plain information and the neglect of other levels of communication that the user is used to from social interaction and interpersonal communication. Most users tend to send and receive non-informational signals also when interacting with technical systems – signals that are either not received by the technical system or, coming from the system, misinterpreted by the user.

2. Emotional Indication

Non-informational signals are however an important component of each communication process, comparable to interpersonal non-verbal communication. They affect the communication process by creating solidarity, signal understanding, acceptance, priority, urgency, identification, refusal or agreement [2].

Maglio et al. [5] call technical systems, which comprise non-informational (implicit) messages into human machine communication 'attentive user interfaces': "systems that pay attention to what users do so that they can attend to what users need. Such systems track user behaviour, model user interests, and anticipate user desires and actions."

For interfaces, which enrich purely information-based communication by employing additional means of expression that correspond to communication known from social and interpersonal communication, we suggest the term 'Emotional Human Machine Interface'.

The first goal for establishing an implicit level of communication is the utilization and adjustment of existing communicational components which already have an implicit meaning. Such a meaning can be either deliberately designed (e.g. colours, sounds or frequencies of warnings) or subliminally included (e.g. the shape and appearance of control elements). Moreover, selected additional implicit elements may explicitly be added to the factual communication: The machine sends specified emotional indications, which rate the factual information, imply meanings and express implicit decision recommendations (e.g. with regard to safety, seriousness, urgency, etc.). We suggest calling the application of implicit messages in order to rate information 'emotional indication'.

Furthermore, it is conceivable that the machine receives emotional signals from the user and decides on this basis on the representation form of the actual information, as well as on 'timing' or 'penetration'.

The issue of identifying and testing the effect of emotional indication and implicit messages is most critical. Cultural imprints as well as interpersonal differences must be taken into account

However, the technical system 'car' and its specific context of use provide, in contrast to other areas of application, excellent basic conditions for an 'emotional indication' that allows the driver to gain evaluated insight into the system status and creates understanding for system decisions.

Contrary to other systems, there exists only a comparably limited range of possible control actions in a vehicle. Therefore, the automotive human machine interface is characterized mainly by recurring interactions.

Beyond that, essential data for an implicit evaluation of factual information and data of the driver's emotional condition can be derived from already existent data, as future driver assistance systems in detail acquire the environmental context of the vehicle, the situation inside the car as well as the driver's condition.

3. A model for emotional human machine communication

A possible theoretical model for automotive emotional human machine communication contains elements of classical human machine communication as well as elements of interpersonal communication.

Today's models for automotive human machine communication are mostly task-oriented. Timpe [8] describes communication as an explicit non-interpretative act of sending and receiving information with little scope for interpretation.

Models of interpersonal communication strongly focus on semantic aspects and usually incorporate multiple layers of communication. Schulz von Thun [7] e.g. comprises four aspects of human communication: factual information, appeal, information about the relationship between the communicators and information about the speaker himself.

In the following, we outline an extended model for automotive human machine communication. We assume that there exist at least two layers in each act of human machine communication: an explicit and an implicit layer.

Figure 1 shows a typical model of today's automotive human machine communication. Output from the automotive system is coded for different channels: visual, acoustic and haptic. Regardless which channel is used, the complete message consists of an explicit layer and so called 'non-directional implicit messages', e.g. a red light flashing in the instrument cluster of a car linked with a beep sound transports implicit meaning in the way the light is flashing and by the volume of the sound.

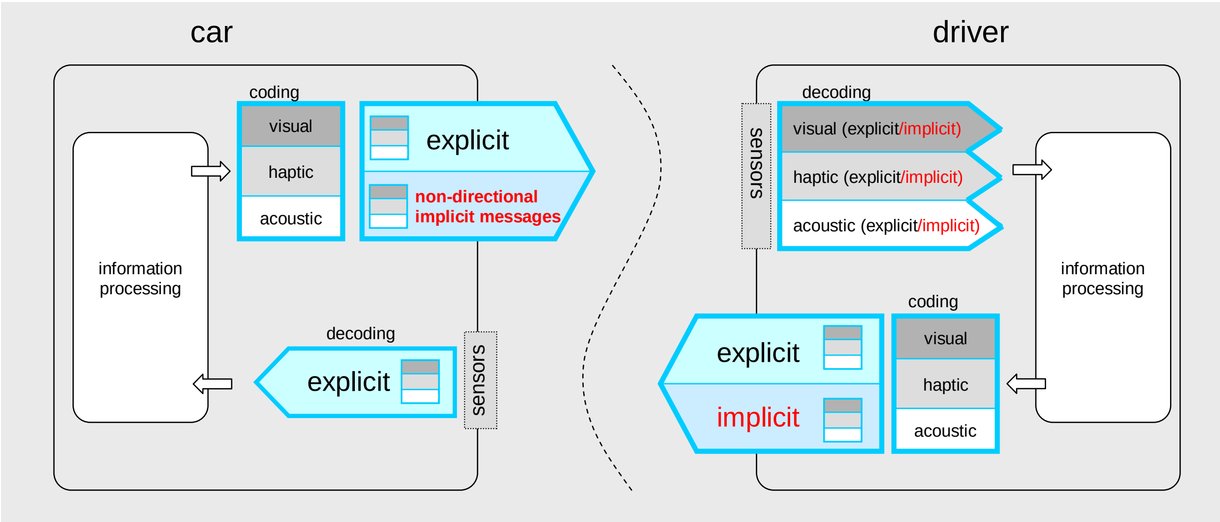

Figure 1: Automotive human machine communication today

We assume that the driver receives messages from the car in total (explicit and implicit layer) and decodes explicit and implicit meanings for each channel. Even though the driver can suppress some layers of interpersonal communication when interacting with the machine, he may interpret e.g. light and sound as aggressive, inadequate or even invasive.

Beyond that, the driver's messages sent to the automotive system contain both an explicit and an implicit layer. However, today's cars cannot decode implicit layers of communication.

Therefore, today's model for automotive human machine communication has to be extended as shown in figure 2.

In the future, automotive systems might be able to compose specific implicit messages for system output. Moreover the decoding and interpretation of the implicit meanings of the messages sent by the driver further enrich the communication process and support the selection of appropriate implicit aspects for system output. We assume the decoding process in tomorrow's cars will resemble the decoding process present in interpersonal communication.

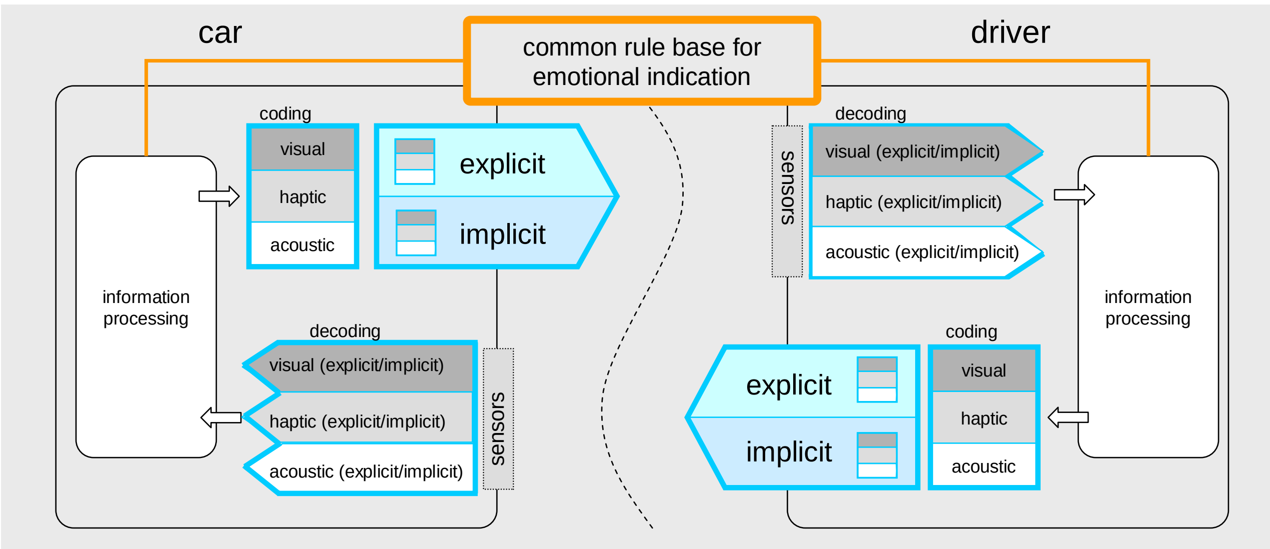

Figure 2: Automotive human machine communication tomorrow

4. Effects and Applications

The specific situation of use in the car suggests many areas of application for emotional indication. Our initial objectives are to create a more comprehensive understanding of system output, decision support in time-critical situations and enhancement of the interaction experience.

Comprehensive understanding of system output: Today, the overuse and the design of warnings and other unexpected system output often cause surprise and uncertainty among users. Future HMIs might be able to communicate the contextual ‘meaning’ of a warning in terms of urgency or need for immediate reaction by parallel implicit signalling. The implicit message can thereby be transferred either on the same modal channel as the primary information (e.g. shape, position of appearance, animation, intensity, transparency, colour) or on an additional channel (e.g. acoustic or haptic).

Decision support: Emotional indication can happen in extremely short time and parallel to the transmission of the factual information (see. Fig. 2). Thus, it might be used for decision support in time-critical situations. Drivers might receive implicit messages on how to react best (e.g. through haptic feedback on the throttle) e.g. when suddenly traffic lights turn yellow or when oncoming cars approach during an overtaking manoeuvre. The intentional effect would be an affective and expedient reaction of the driver.

Enhancement of the interaction experience: Beyond possible functional benefits for safety and comprehension, emotional human machine communication forms the basis for a specific generation of pleasurable interaction experiences [7], [4]. In contrast to HMIs of e.g. mobile phones or music players, automotive HMIs mostly ‘serve’ the underlying functions and are hardly created for the purpose of joy or pleasure. A human machine communication beyond the functional exchange of information allows developers to incorporate aspects of intrinsic motivation [6]. As a result, coming interfaces might be able to generate ‘emotional benefits’ resulting from e.g. empowering interaction impact or micro-challenges within the interaction process and thus develop self contained qualities beyond utility and usability.

In excess of emotional indication, the potential of emotional communication between the user and the automotive system still expands, especially when emotion recognition and functional reactions to detected emotions are taken into account. User’s emotions might control not only the interface but also the functions of automotive technical systems themselves, e.g. the automatic distance between cars on the basis of fear detection. In any event, coming generations of automotive user interfaces will have to take the challenge of compensating the (negative) emotional consequences of the limitation of the driver’s control when using active assistance systems [3] by applying communicational means that establish trust and reduce potential fear.

5. Conclusion

In the field of automotive, the special situation of human machine interaction is characterised by conditions that suggest the application of emotional communication between user and interface. Especially in the area of driver assistance, the application of emotional indication can lead to an improvement of driving safety, better usability and an enhancement of the overall product experience. In this article we have presented a theoretic approach to utilize the potential of emotional communication in order to improve tangibility of system decisions and system output in automotive HMIs.

In a next step, the feasibility and the actual effect of emotional indication on the user must be tested. This requires the formation of a repertoire of implicit messages that will be similarly interpreted by different users, the creation of a selection-mechanism for these signals dependant on the context of use and the definition of a representation form of these signals that is adequate for the automotive situation of use. An essential element therefore is a user model that describes the user’s emotional state as well as his basic values and mental attitudes. It is obvious that an interdisciplinary cooperation between system engineers, communication designers and psychologists will be necessary to develop an emotional automotive HMI.

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Emotion and Computing

- Demonstrations -

Sensor system for emotion-related physiological parameters

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1 Introduction

Emotions have been shown to have a significant influence on the decision-making process of human beings [1] and hence play an important role in intelligent behaviour. Researchers and engineers around the world work on ways to incorporate and exploit emotion in artificial systems, agents, and applications, computer scientists investigate the role emotions play in Human-Machine Interaction, and psychologists, sociologists and anthropologists examine potential effects of affective systems on people and their relations to each other, machines, and media (cf. [2, 3, 4, 5, 6]). They all rely heavily on reliable and robust equipment to detect signs of emotions in the human in focus.

At the department for Human-Centered Interaction Technologies of Fraunhofer IGD Rostock we focus on developing technology for human-computer interaction to be used in everyday settings.

The system

At Fraunhofer IGD we developed a wireless and easy to use sensor system for collecting the emotion-related physiological parameters skin resistance, skin temperature, and heart rate (figure 1). The system has been designed for emotion researchers who want to examine emotional aspects of life outside the lab, for software developers who want to make use of emotion information in their systems without bothering about physiology, measurement artefacts, or filter chains, and of course also for psychologists who want to perform their studies in a natural setting without the irritating and distracting effects of wires on a subject. The system has been designed for use by lay-persons in an everyday environment, mobile or stationary, and without putting restrictions on the user's behaviour. It gives the researcher and programmer the most possible freedom in handling the data, providing the measurements conveniently in engineering units. Developed with the researcher and application developer in mind, the device is fitted with robust and reliable error handling and diagnosis mechanisms, guaranteeing sensible data continuously being available along with reliability information. The system is small, light-weight, functions wirelessly, transmits data immediately and is also able to store data locally. It operates several days with one battery pack. It has an open architecture and sends out the data in an open format, allowing software developers to easily incorporate the device into their systems as emotion sensing input source.

Figure 1: The sensor system consists of a glove containing sensors for skin restistance, skin temperature, ambient air temperature, and a heart rate data receiver; and a base unit processing, storing, and transmitting the data to a host.

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Playing the Cards Game SkipBo against an Emotional Max

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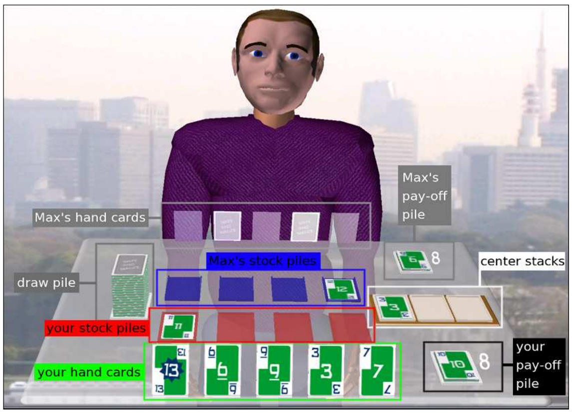

Fig. 1. *Skip-Bo* as an interaction scenario for an Empathic Max (from [1]).

1 Description of the Gaming Scenario

As an affective face-to-face gaming scenario, we present the classical cards game *Skip-Bo* (see Fig. 1), which was implemented for an empirical study [1]. The players have the conflictive goal of getting rid of the eight cards on their pay-off piles to the right side of the table by playing them to the shared white center stacks. As on these center stacks the order of cards from one to twelve is relevant, the hand and stock cards must be used strategically to achieve this overall goal of winning the game.

In the negative empathic condition presented here, Max appraises the users actions as negative with regard to his own goal of winning and his own actions as positive respectively. The elicited *primary emotions* drive the agent's facial expressions and a variety of nonverbal, vocal sounds. Moreover, they continuously modulate the simulated breathing and eye-blinking, giving the user the impression of interacting with a life-like anthropomorphic agent.

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Demo proposal: Agents for Learning Environment

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Fig. 1. Example of Interaction

Abstract. VALERIE (Virtual Agent for Learning Environment Reacting and Interacting Emotively) [1] is a CAI (Computer Assisted Instruction) designed to test basic French grammar. The agent, originally embodied by Haptek avatars, has the capability of showing certain predefined emotions. The showed emotions depend directly on the performance of the student (with regards to its average) and on the personality of the agent. Paleari and Lisetti argue systems like VALERIE, through their emotional feedback system, may improve student performances.

iCat is a robotic research platform designed by Philips to be able to express emotions and act in a companion-user environment. iCat look is friendly and it is specially suitable for children and young people. Thanks to the development of current speech synthesizer and recognizer interaction with such a kind of platforms will become more and more natural. For those reason we believe iCat may attract more attention than an avatar and therefore be preferable and more effective.

We have implemented VALERIE system on iCat adapting the logic for the new platform. In this demonstration we will show the basic VALERIE tuned with new facial expressions designed accordingly to Scherer psychological theories and the basic adaptation of VALERIE for the robotic platform iCat tuned with similarly designed facial expressions.

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Facial Emotional Expressions Designed on iCat Robot

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Abstract. Facial expressions are a mean to communicate internal states. They allow to improve interactions between individuals. In Human-Robot Interaction, they are also important to give more believability to robots. Intelligent robots must integrate cognitive and emotional processes. In order to develop such architectures, we base on a psychological theory developed by Scherer (Scherer, 1987). In his theory, Scherer links cognition and emotion. Furthermore, he considers emotions as rational which implies the possibility to implement them in a computational way. We use iCat to express emotions. iCat is a research robotic platform developed by Philips for social interaction with humans. We have adapted emotional responses defined by Scherer in his theory. Adaptation had been necessary because this theory is designed for humans and not for robot with a cat appearance (Grizard, 2006) .
In this demonstration, we will present the resulting implementation of nine emotions: happiness, disgust, contempt, sadness, fear, anger, indifference, shame and pride. The representations of these emotions have been evaluated with user studies confirming their believability. For more believability, we would like to generate them dynamically in order to obtain variations in expressions of the same emotions. Therefore, to express one emotion we take the parameters of this emotion representation and we add some randomness to these parameters in order to generate different but similar expressions. In this demonstration, we will focus on the expression of some emotions using this approach.

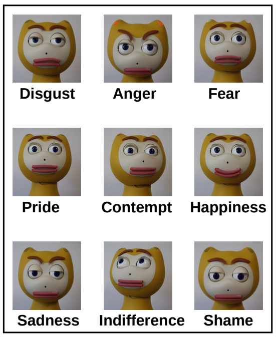

Fig. 1. Facial expressions examples