humaine

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1 The place of this report within HUMAINE

The final workpackage reports in HUMAINE have been designed as brief statements that complement other sources. On one hand, substantive content – particularly technical content – has been reported in deliverables throughout the project. On the other hand, several potentially overlapping sources are part of the final reporting process. In particular, the activity report for the final period sets out the goals achieved during the final period; and the final report for the project as a whole includes a relatively non-technical account of what the workpackage has achieved.

The core of this report is shared with the section on WP7 in the final report for the project as a whole. That consists of a short, non-technical summary of what the workpackage has achieved. However, there are details that do not belong in a report intended for the general reader (such as information about the participating institutions, meetings organised, etc). They are covered here.

Workpackage members invested a substantial amount of effort in the deliverables, and they form a continuing resource available to the community on the HUMAINE portal. They are listed for completeness. In some senses it would make sense to do the same for publications, but they are too difficult to allocate to individual workpackages. A full list is given in the final report for the project as a whole.

2 Workpackage remit, membership and structure

The objective of WP7 was identified in the TA to be a principled effort to achieve a better multidisciplinary understanding of basic issues and open research topics regarding the involvement of emotions in cognition and action, with a view to grounding and promoting sound research into artificial emotional systems for artifacts that must interact with humans. It was further specified in subsequent deliverables (D7b, c & d) the investigation of (computational) 'internal' mechanisms (emotion architectures) that allow to synthesize or generate emotions and to model their involvement in various aspects of cognition and action in emotion-oriented systems.

The exemplar of this WP, titled "Comparative Approaches to Emotion-Oriented Architectures: Assumptions, Integration Challenges and Guidelines for Future Research", was set to be a comprehensive framework (rather than a single-sided or exclusive approach) towards a critical understanding of the scope, uses, limitations, complementarities and needs of the diverse models and architectures of emotion that exist nowadays. Conceptual and technical work in the form of proofs of concept was carried around the four complementary themes or elements detailed below.

Our interactions and work over these four years have been a big success. Besides conceptual and technical achievements, probably our main and longer-lasting accomplishment has been the realization by researchers from multiple areas of the benefits and need of critical multidisciplinary collaboration to progress in our efforts. This was realized not only through regular joint work, but also through interchanges and visits, resulting in the formation of various working groups and projects that will outlast Humaine. This collaboration opened up new ways of looking at problems and posing research issues that would not have been considered otherwise. This spirit was adopted and promoted not only by senior scientists but also by the numerous junior scientists involved. Another manifestation of this was the increasing links with other areas in the study of emotions (and Humaine workpackages) related with expression, perception and communication, as a step towards "complete" interactive affective artifacts.

3 Achievements

The numerous publications and dissemination activities during these four years can be found in previous deliverables and periodic activity reports, and will not be repeated here. We could perhaps highlight the special issues of the *International Journal of Humanoid Robotics* and of *UMUAI*, the special sessions at ISRE 2005 and at the IST Event 2006, the series of ACE symposia, and ACII 2007.

3.1 Element 1: Emotion in Embodied Cognition and Action

The goal of this element of the exemplar was to investigate selected key aspects of emotions related to their embodiment, and in particular interactions between emotions and cognition-action as occurring through the body. Autonomous robots and ECAs were the platforms used as a basis for the conceptual and technical work developed here. The focus of this approach is on the dynamics of interactions between agents and their environment and on emotion (and intelligence) seen in terms of processes. Emotions are thus conceptualized as dynamical processes strongly rooted in the embodiment of agents and highly dependent on the dynamics of the interactions with the physical and social environment.

The main topics researched were the following:

1. Emotional modulation of perception-action in embodied agents: Taking an embodied AI perspective to regard cognition-action as tightly coupled perception-action loops mediated by a dynamically fluctuating internal environment, we modeled emotions in those perception-action loops in an incremental way, in terms of (patterns of) "neuro-/hormonal modulation" ("emotional modulation" for short) acting on the same underlying "neural substrate" – the nervous system in the case of humans, robotic architectures in our models – rather than modeling them in terms of basic categories or of points in a dimensional space. This approach to emotion modeling permits a more seamless integration of emotion and cognition-action since emotions correspond to different "functioning modes" of the same underlying "neural substrate" and associated cognitive and behavioral "functions" such as perception, attention, prioritization of motivations, behavior selection, and behavior execution.
2. Analysis of embodied emotion-oriented architectures and behavior: In addition to the assessment of the effects of "emotional modulation" from a functional point of view (i.e. on the agent's performance and adaptation), proper understanding of those emotion-oriented architectures and their behavior requires systematic (formal) analysis from the perspective of their emergent and dynamical properties.
3. Novelty detection and emotion-attention interactions: towards the study of the interplay between emotion and more complex forms of cognition-action, namely novelty detection and attention in the context of perception and production of facial emotional expressions. ECAs were used as main platform for this work.

At the beginning of the project, work focused more on a critical analysis to identify key issues, models and challenges, and on conceptual clarifications, on a second phase we concentrated on implementing proof-of-concept systems, to conclude with a more mature reflection based on work done and multi-disciplinary discussions and analysis of this work.

Key achievements could be summarized as:

a) Conceptual:

- Elaboration of a framework to implement emotions in terms of neuro-/hormonal modulation
- Systematic analysis of the relations between functions of selected emotions and their behavioural manifestations in the context of decision making (action selection), mechanisms underlying those functions, and elements of the enviroment for which they are adaptive.
- Study of simple emotional systems from 4 perspectives: the causes of the emotion, its adaptive value, its development, and its evolution.
- Reflection on how to move towards achieving "higher-level" forms of emotion/cognition-action interactions from the "bottom-up".
- Analysis of emotion-oriented robots in terms of dynamical systems
- Algebra to formalize "emotional" interactive systems as dynamical systems
- Integration of theories from neuroscience in architectures for ECAs as well as robots

b) Technological:

- Robotic architectures and scenarios for the study of emotions pertinent to decision making (action selection) in "competitive" interactions
- Robotic architectures and scenarios for the study of emotions pertinent to the formation of affective bonds and positive emotions in "cooperative" (infant-caretaker) interactions
- Artificial life environments to study the evolution of affect-oriented systems and behavior
- Simulation of a hormonally-modulated neural network applied to an action selection problem
- Design and implementation in an ECA of a novelty-based attention system that works towards the simulation of early stimulus evaluation checks (those pertaining to relevance detection) from the component process model of emotion

The main lessons learned, besides the benefits of interdisciplinary research, regard the need to overcome the radical separation between "lower-level" and "higher-level" elements of emotion and cognition-action nowadays present in embodied models, to advance towards a better understanding of the complex dynamics of our emotions as they occur in the brain and body.

3.2 Element 2: Emotion in reflective cognition and action

The various aspects of affective states that were considered in HUMAINE are tightly intertwined. Those of them which are classified as having a 'slow rapidity of change' (interpersonal stances, preferences/attitudes and affect dispositions) influence activation and intensity of 'fastly changing' ones (the emotions). Some slowly changing types are related to values and norms, to personality traits or to social relations. Repeated (in time) emotion mixtures influence moods. The goal of this element was to investigate and represent, in 'high-level cognition models', this relationship among affect types, in terms of relationship between beliefs, desires, goals, intentions and emotion activation. We aimed at studying how emotion activation is influenced by interpersonal stances, attitudes and affect dispositions and by the social context in which the triggering event occurs and is perceived; we wanted to study, as well, how these influencing factors could be modeled in their turn.

The models we developed can be situated across some of the categories which are mentioned in this WP: they are 'appraisal models' in that they assume that emotions are elicited by a cognitive evaluation of events; they may be seen as 'motivational models' as the intensity of activated emotions is a function of motivation and action tendencies; finally, they are, in a way, 'lexical models' because the emotions triggered are closely related to the categories of goals involved in the event occurred.

Cognitive models of emotions require going over the old distinction between 'rational' and 'emotional' thinking, to extend the Belief/Desire/Intention theory and models with emotional factors. This extension increases the need to include uncertainty in the representation of the relationships among the various components.

Work progressed, on the one hand, with the development of some prototypes and on the other hand, with a critical reflection on the limits of present approaches to individual and social emotion models. We could summarize our key achievements as:

a) Conceptual:

- We formalized cognitive emotion models with dynamic belief networks by applying them to a subset of the individual emotions in the OCC classification.
- We studied how to validate these models in terms of their sensitivity and predictive value.
- We represented dynamically how 'interpersonal stance' varies in natural language dialogues, from a combination of linguistic and acoustic features and context variables, again with dynamic belief networks.
- We studied a particular aspect of interpersonal stance (the 'negotiation attitude') and how this can be recognized and modeled (cooperation between the Universities of Bari and Southern California).
- We reflected on the meaning of 'cognitive-emotional inconsistency' (cooperation between the Universities of Bari and Manchester), and whether and how this can be represented in cognitive emotion models.

b) Technological:

- A tool (Emotional-Mind) which enables simulating how emotion activation and effects vary when several factors regulating the activating conditions are manipulated: characteristics of the event, social context, attitudes, dispositions and so on.
- Integration of this tool with an Embodied Character Player (built with Haptek), to test how emotions can be translated into facial expressions.

– A tool (Social-Mind) that enables representing a model of the social attitude of a user in human-computer dialogues and how this evolves during interaction.

The main lesson learned during these years of collaboration has been the importance of interdisciplinary cooperation in this domain, and the difficulty to represent appropriately the richness of cognitive psychological theories into computational models.

3.3 Element 3: Emotion in bridging the gap between embodied and reflective cognition and action

This element was concerned with the investigation of potential ways of bridging the gap, with a view to integrating, embodied/"lower-level" and reflective/"higher-level" aspects of cognition and action and the role that emotions may play in it. The main task of this element was to explore the roles of emotions in connecting the grounded, sensory, synchronous functioning of lower-level cognition and action to the detached, representation-based, asynchronous aspects of higher levels, relating insights and constructs from human emotion research to findings and developments in computational modelling (and deployments in complete systems). Activities comprised theoretical conceptual clarifications, critical analyses of current operationalizations of theory, as well as development of new designs. Interdisciplinary collaboration took place between OFAI, USC, USAL/HW, INESC-ID and IST from the engineering side, and GERG, UOXF, and KCL from the theory and human research side, including invited visits of representatives of the former group at GERG and sustained interactions and discussions, in 2004: at the first HUMAINE plenary meeting and the WP3 workshop[1] (where OFAI organised and chaired a session aimed at relating the needs of system developers to the offerings of theory, a synopsis of findings was published in the online workshop proceedings); in 2005: at the second plenary, the WP7 workshop, interchange visits of multiple weeks by USC's Jon Gratch at OFAI and INESC-ID's João Dias at USC, and the topical symposium at ISRE in 2005; in 2006: at the interdisciplinary ACE symposium on modeling the cognitive antecedents and consequences of emotion[2], the AISB symposium on Architecture of Brain and Mind[3], the HUMAINE cross-currents meeting, and the WP10 workshop; in 2007: around the IVA and ACII conferences, the tutorials on computational models of emotion contributed by USC at ACII and by OFAI at MICAI, a topical workshop organised by USC, and an interchange visit of HW's Sandy Louchart to OFAI. The computational models against which the possibilities and limitations/impossibilities of modelling of affective phenomena and processes without resorting to direct reifications were assessed and elaborated include: ActAffAct[4], BehBehBeh[5], Double-Appraisal[6], EMA[7], FaTiMa[8] and Tabasco[9]; the range of emotion-

[1] The proceedings of HUMAINE workshops are available online at the HUMAINE portal, http://emotion-research.net

[2] See http://www.ofai.at/~paolo.petta/conf/ace2006; a related special issue of the Journal of Cognitive Systems Research is to appear in 2008.

[3] Aylett, R.S. (2006) Emotion as an integrative process between non-symbolic and symbolic systems in intelligent agents. AISB workshop GC5: Architecture of Brain and Mind: Integrating high level cognitive processes with brain mechanisms and functions in a working robot. AISB.

[4] Rank S. (2005) Toward Reusable Roleplayers Using an Appraisal-based Architecture. In Payr S. (ed.): Educational Agents and (e-)Learning, *Applied Artificial Intelligence* 19(3-4):313-340.

[5] Rank S., Petta P. (2007) Basing artificial emotion on process and resource management, in Paiva A. et al. (eds.), Affective Computing and Intelligent Interaction, LNCS 4738, Springer, 350-361.

[6] Louchart S., Aylett R., Dias J. (2007): Double Appraisal for Synthetic Characters, in Pelachaud C. et al. (eds.), Intelligent Virtual Agents, Springer, Berlin/Heidelberg/New York, 393-394.

theoretical notions and related integration challenges researched include bottom-up modulatory and situated resource-management approaches to emotions, the conceptual elements of cognitive appraisal theories, and social constructs from interaction theory. Alongside, the development and exercising of a scenario-based method for the analysis of emotional architectures[10] proved a valuable tool well beyond the immediate scope of WP7: It was discussed in particular in occasion of the ACE 2006 symposium, and also informed work in WP3 (theory) in their comparison of theoretical models of emotion (cf. the contribution at the 3rd HUMAINE Summer School), as well as in WP9 (evaluation) by providing a conceptual basis for the evaluation of the fitness of emotion models for specific design scenarios and WP10 (ethics) by similarly helping to explicate the actual "emotion potential" of cases researched (cf. e.g. the related session at the WP10 workshop). In addition to the already mentioned publications (cf. also the footnotes) and contributions to the HUMAINE Handbook and the WP7 special journal issue, this WG also contributed to the forthcoming Oxford Companion to the Affective Sciences.

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[7] Marsella S., Gratch J. (2006): EMA: A Computational Model of Appraisal Dynamics, in Trappl R. (ed.), Cybernetics and Systems 2006, Austrian Society for Cybernetic Studies, Vienna, 601-606.

[8] Dias J., et al. (2007): I Know What I Did Last Summer: Autobiographic Memory in Synthetic Characters, in Paiva A. et al. (eds.), Affective Computing and Intelligent Interaction, LNCS 4738, Springer, 606-617.

[9] Petta P. (2005) Appraising the role of emotions in the design of situated social cognisers, in Scherer K.R., et al.: Computational modelling of emotion architecture, ISRE General Meeting, July 11-15, 2005, University of Bari, Bari, Italy, EU, 69.

[10] Rank S., Petta P. (2006) Comparability is Key to Assess Affective Architectures, in Trappl R. (ed.), Cybernetics and Systems 2006, Austrian Society for Cybernetic Studies, Vienna, pp.643-648.

3.4 Element 4: Emotion in social cognition and interaction

The goal of this element was to investigate the roles of emotions in social cognition and interaction. Contrary to the previous elements, emotions, cognition and action are not modeled from the perspective of the individual agent but from the point of view of the interaction itself. Therefore, the unit of analysis was not the individual (its embodiment or its mental states) but the relations in groups of two or more agents. These relations might appear as a result of a wide range of "internal" and "external" factors, and can be investigated from a micro- or a macro-level perspective. This element thus covered a very wide range of topics, in an effort to contribute towards an understanding of key representative problems in the thematic area, especially of the interrelations with other elements and workpackages.

Element 4 focused on two main key topics:

1. Towards socially meaningful emotional agents: Closing the emotion recognition-generation-expression loop. To be emotionally competent in the context of social interaction in a way that is meaningful to humans, an agent must integrate the capabilities to express and recognize/respond to emotions with an emotion-oriented architecture that grounds and coordinates such capabilities in a socially meaningful way. This theme seeked to make a contribution towards establishing principled and well-founded links between the production of socially meaningful expressive behavior, emotion-oriented architectures that can ground the generation of this behavior, and analysis/recognition of such expressive behavior in social settings. To ensure the feasibility of this task, we focused particularly on a type of (non-verbal) interactions involving the "sharing" of affective state by two or more agents as mediated though the body (including the face), to make that (shared) affective state recognizable from its behavioral manifestations.

2. Socially situated nature of emotions: Socially situated affective dialogue. With this theme, our goal was to further the understanding of the role of emotion in social interaction with a focus on conversational artifacts (including ECAs). Our work was based, among others, on the insight that recognition, interpretation and generation of emotions is a keystone to sustainable social relationships between humans and humans, and hence, between humans and "social machines". The focus of affective human-ECA interaction had been, so far, mostly on individual emotions (e.g., fear, anger, joy) rather than on social emotions (e.g., irritation, attraction). There is more to such a relationship than mastering emotional (verbal and non-verbal) expression during the interaction. Humans and interactive artifacts are cast in roles that are socially (globally) constructed outside the situation and locally "managed" by interactants, but not freely neglected or cast aside. We called this fact the "social situatedness of interaction", factored, among others, by power and trust relations among agents. The key topics researched were human-human and human-computer verbal and nonverbal interaction as situated, affective dialog; and qualitative methods of discourse analysis wrt. to the study of emotion in conversation.

Work evolved between 2004 and 2007. The first challenge in both topics was to establish common ground among people contributing to each working group. This turned out to be no

trivial task given the broad interdisciplinary approach taken (e.g. the second working group gathered work in sociology of emotion, social psychology, emotion research, interaction analysis, diverse schools of discourse analysis, conversation analysis and ethnomethodology, and systemic functional linguistics – Linguistic Appraisal Theory). Work developed from broad review and discussion of theories and methods to empirical work: around integrating algorithms for emotion recognition, generation and expression in social ECAs and robots in the first working group; around corpus-based analytical work (mainly DARPA Communicator corpus, OSU Quake Corpus, USC Rapport Experiment Data) in the second working group.

Key achievements include:

a) In the first topic:

- Integration and test on a common synthesis virtual environment (the ECA Greta) of feature-based appraisal checks for facial expressions, based on MPEG-4-related concepts, and dimensional models for facial expressions and hand gestures, building on experience from earlier projects.
- Development of tools to link high-level personality emotion parameters to face and body expressions in virtual humans
- Investigation of selected roles of rhythm, synchronization, movement and posture / gestures as components of emotional processes and conveyors of emotional content across various types of interactive scenarios and platforms, involving different combinations of human, robotic, and virtual social partners.
- Design of an empathic agent that recognises emotions of users from their movement and generates expressive reactions.
- Computational framework for emotion recognition based on the dynamics of movement expressivity. The framework was used to analyse and classify emotional piano performances.

b) In the second topic:

- The common understanding of theoretical background and methodology was substantially advanced not only inside the working group, but also across groups and workpackages, as reflected by (ongoing) collaboration in analysis and design of human-human and human-machine interaction.
- The core methodology is Conversation Analysis, or CA, an ethnomethodological technique that allows the researcher to expose the "what is done" with language in use.
- CA, combined with Linguistic Appraisal Theory and Interaction Analysis, will provide the tools that hopefully allow us to unify work on politeness, emotion and the social nature of talk in interaction.

The main lessons learned concern:

a) The “gap” between (in the broadest sense) cognitive-psychological on the one hand and sociological approaches on the other remains to be closed. This gap is mainly due to the lack of coherent emotion-related theories in the fields we draw on, and therefore not to be bridged by sheer force of will.

b) It has been recognised by researchers across HUMAINE that language has been under-represented in the network's agenda. This is, we argue, not a coincidence, but has its roots in the traditional view that language serves rational argument on the one hand and the expression of emotions on the other, with no connection between the two. Plans to overcome this deficiency in the framework of the HUMAINE Association exist.

4 WP7 DELIVERABLES

D7a	Workshop proceedings: Cognition & Action
D7b	Preliminary Plans for Exemplars - Cognition & Action
D7c	potential exemplars: cognition & action
D7d	Proposal for exemplar and work towards it: Cognition & Action
D7e	Outline of WP7 book contents
D7f	Pre-completion report on WP7 exemplar (Confidential)