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Technical Model for Basic and Complex Emotions

W. Burgstaller, R. Lang *Member, IEEE*, P. Pörscht, R. Velik *Member, IEEE*

Abstract— **The present work addresses the demand of context- and situation-aware environments in computational areas. A concept is introduced, using emotional validation for the perception and decision making unit of a technical system. Giving a detailed definition of the used neuro-psychoanalytical concepts, a possible implementation within such a system is introduced. The advantage in fast reactions by basic emotional valuation and a possibility of social interaction by the use of complex emotions has been outlined.**

I. Introduction

Computer-aided automation is dealing with a huge amount of sensor data, constantly increasing. This leads to a massive stream of data that has to be processed. It was shown in [1], that common techniques are not able to handle such a data stream. To address this problem, the project ARS (Artificial Recognition System) [2] was founded three years ago, focusing on developmental research for broadband data mining as well as data processing. The basic idea is to use bionic concepts, deduced from research results of neuronal and psychological processes of the human brain.

In [3], an overview about the ARS project is given. It consists of two different bionic approaches–a neuroscientific concept and a psychoanalytical concept– that are combined to one unified model. Neuroscience provides concepts for data perception and symbolization, leading to higher-level data representation. It serves as a template for the architecture in the form of a bottom up design. Sensor data is condensed upwards and transformed into symbols of higher semantic meaning.

In psychology, there exist many different, partly conflictive models. They are describing the human behavior from different points of view. The psychoanalytical model of the human brain, which was first initiated by basic research of Sigmund Freud and essentially improved within the last 20 years, is the most complete functional model of the humans mind [6].

At the Institute of Computer Technology, a first approach of a bionically based concept has been developed with assistance of various technical centers of excellence and active cooperation with neurologists and psychoanalysts. One of the main goals was to find a consistent neuro-psychoanalytic model of the human brain and mind, which can be transformed to a consistent technical model emulating the functionality of the human brain.

This article describes a possible approach to apply emotions in a technical system for evaluation and processing of perceived data. Emotions are split up into basic emotions and complex emotions. In the next two chapters, these two concepts are explained in their basics, including psychoanalytical aspects. In chapter IV and V, a model is proposed how these concepts can be integrated into a technical system using autonomous agents as an implementation platform.

II. Basic Emotions

Basic emotions cannot only be found in the human brain but also in the mammalian brain. Modern medical imaging methods like fMRI (Functional Magnetic Resonance Imaging) give an evidence for the existence of basic emotional systems [5]. In the (neuro-psychoanalytic) scientific community, there is a broad agreement about the existence of basic emotions. Nevertheless, the scientists have not yet found a broadly accepted definition. A summary of different definitions of basic emotions can be found in [4].

In the ARS project, the model of Jaak Panksepp [5] is used. Mark Solms, who is one of the first who tried to find a neuro-psychoanalytic model of the human brain [6], refers to the model of Panksepp. Since the ARS project aims to implement a consistent (neuro-psychoanalytic) model of the brain [7], the model of the basic emotional systems according to Panksepp is used in this project.

According to the model of Panksepp, the basic emotional systems are hardwired, meaning that they are evident in all mammals soon after birth. These emotional systems have developed during evolution separately. They influence the psyche relatively independently from each other. The basic emotional systems allow the individual to valuate situations, especially those, which have biological significance (e.g. danger). They can cause very fast (reactive) (re)actions. However, these reactions can be

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W. Burgstaller is with the Institute of Computer Technology of the Vienna University of Technology: phone +43 1 58801 38433, fax +43 1 58801 38499; (e-mail: burgstaller@ict.tuwien.ac.at)

R. Lang is with the Institute of Computer Technology of the Vienna University of Technology: phone +43 1 58801 38458, fax +43 1 58801 38499; (e-mail: langr@ict.tuwien.ac.at)

P. Pörscht is with the Institute of Professionalizing Research of the University of Vienna and counselor of the ARS-PA research team at the Institute of Computer Technology of the Vienna University of Technology.

R. Velik is with the Institute of Computer Technology of the Vienna University of Technology: phone +43 1 58801 38463, fax +43 1 58801 38499; (e-mail: velik@ict.tuwien.ac.at)

inhibited by higher cortical functions of the human mind [6].

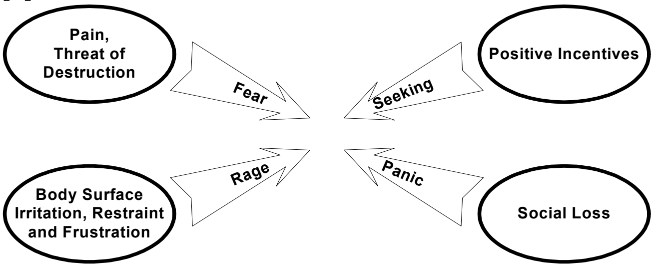


Figure 1: Four basic emotional systems [5]

In Figure 1 the four basic emotional systems

- the seeking system,
- the rage system,
- the fear system, and
- the panic system

are illustrated according to [5]. These four emotional systems are influencing the individual and its actions.

Bodily need states are the representation of the actual state of the human body according to the homeostasis (the inner world) [6]. In [8], Freud describes a hypothesis, which is also known as the structure theory, consisting of the three elements Id (Es), Ego (Ich), and Super-Ego (Über-Ich). Id encloses the psychic representatives of drives, which can be compared to these bodily need states. These need states are mainly influencing the seeking system.

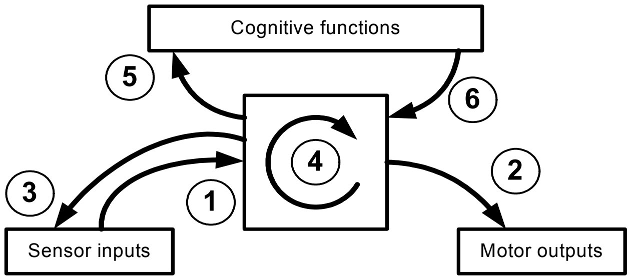
The *seeking system* acts as a mild optimism system that pushes mammals to search for a satisfaction of their needs.

The *rage system* is mainly activated in case of frustration and restraint or body surface irritation. It causes aggressive behavior. It allows the individual to survive violent encounters, especially the first encounters, where the individual has no change to learn a proper behavior.

The *fear system* ensures that the individual can escape rapidly from dangerous situations–respectively avoids dangerous situations. It is activated in case of pain and threat of destruction. The rage system and the fear system are the two negative emotion command systems.

The *panic system* is associated with panic as well as with the feelings sorrow and loss, e.g., the loss of the mother. If the panic system is stimulated, the seeking behavior and the vocalization are activated. Such a behavior increases the possibility to find e.g. the mother or being found by her. After some time, the behavior changes and the being retreats into isolation in order to decrease the change to be found by a predator. This behavior can be compared to the effects of early experience in terms of psychodynamic structures defined by Freud or Bowlby's attachment theory [12], where the function of the attachment behaviour system is to ensure the protection of the child.

In contrast to the seeking system, the rage system, fear system and panic system are mainly influenced by sensors from the outer world.



1... sensory stimuli
2... instinctual motor outputs
3... modulate sensory inputs
4... positive feedback
5... cognitive inputs
6... modify cognitive activities

Figure 2: Interaction of the basic emotional systems with other functions of the brain. [5]

Although the emotional systems are based on different neurobiological principles, the basic concept of all systems is the same. This concept is illustrated in Figure 2 has been inspired by [5]. Sensor data from the outer world trigger the emotional systems (1). This trigger can directly result in a motor output (2). Such an output is also known as an instinctual action. The influence of the sensor inputs can be increased (excitation) or decreased (inhibition) by basic emotions (3).

A positive feedback within the basic emotional system ensures that the basic emotion does not decline immediately after the trigger from the sensors passed (4). The basic emotional systems do not only interact with the periphery but also with the higher functions of the brain. They can be modified by cognitive inputs (5) and are incorporated in the activities of the higher functions of the brain (6). Beside the basic emotional systems, the higher functions of the human brain are influenced by the complex emotions, which are described in the following chapter.

III. Complex Emotions

The basic emotional evaluation system is the root of the human emotional evaluation. With increasing complexity of situations the individual is involved in, the emotional evaluation is getting an emotional spectrum with a broader bandwidth including learned experiences that are stored in the human emotionally afflicted episodic memory.

All emotionally based systems that are ***not*** evident in all mammals soon after birth as described in chapter II are defined as complex emotions in our model. They are also a cognitive evaluation system but highly influenced by social rules forcing the individual to suppress several drives to cope with the current situation. As defined in [8], these social rules are stored in the Super-Ego that encloses the moral and ideal rules.

One concept underlining the difference between basic and complex emotions would be the concept of mental models introduced by [12]. This attachment theory points out Freud's notion that infant-mother and adult-adult relationships are similar in kind. This leads to the theory of inner working models. The attachment theory concerns the developmental conditions leading to appropriate individual feeling, thinking, and proceeding to keep in touch with reality and living together with others.

Typically human complex emotions would be hope, joy, disappointment, gratitude, reproach, pride, shame, etc., which does not necessarily mean that they are completely detached from basic emotions. They are all directly influenced by basic emotions or the bodily need state. For instance, as described in [13], shame and disgust are important for a healthy affective live because they are a barrier against unbridled drives.

Some complex emotions are generated by desire. Desire pushes an individual to reproduce an already experienced situation that lead to the satisfaction of a need and therefore to an increase of sensed pleasure defined in [11]. It consists of the need that will be satisfied, an object of desire, and internalized experience. Internalized experiences comprise emotional and cognitive aspects and associated action patterns.

We distinguish between prospective and retrospective complex emotions [14]. The term prospective indicates that the object of desire is located in the future; according actions to meet this object can be planned. Retrospective indicates an object that lies in the past; the individual remembers the related situations and episodes. In both cases, the complex emotion is generated in the presence. The intensity of a complex emotion is not only influenced by the perceived situation the individual is placed in but also by the estimated probability of success to satisfy a need or meet the object of desire.

According to the origin of the situation that leads to a complex emotion, whether the individual itself or another individual initiated it, the intensity of the complex emotion can also be influenced [15]. In this context, gratitude could e.g. lead to acceptance in a social group of individuals.

IV. Technical Model of Basic Emotions

The main goal of the ARS project is to implement a system that emulates the functionality of the human brain. Therefore, the emotional systems, which play a major role in the human brain, have to be incorporated. The basic emotional system as described in chapter II has to be integrated in all parts of the ARS system because both the perception and the higher brain functions are influenced by the basic emotional systems as well as they influence the basic emotional systems.

The complex emotions only influence the higher cognitive functions of the brain. The technical model of the complex emotions is described in chapter V. An overview of the technical model of the basic emotional systems applied in the ARS project is shown in Figure 3.

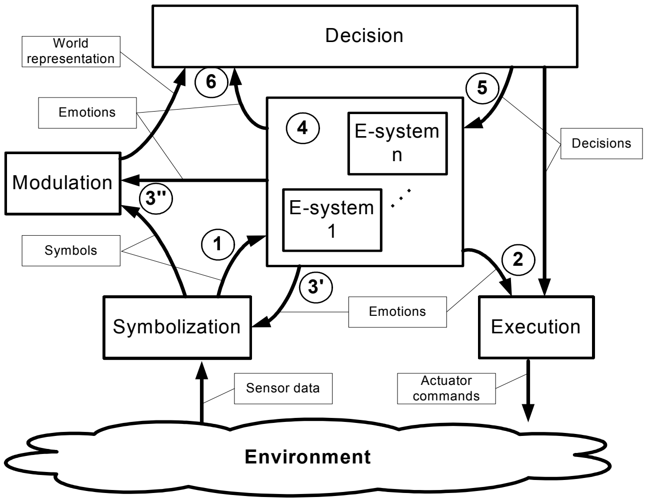


Figure 3 Model of the basic emotional systems applied in the ARS project

The technical model for the basic emotional system is designed to emulate the concepts described in chapter II. The designations of the arrows correspond with the designations of the arrows in Figure 2. In the middle of Figure 3, the module containing the e-systems is shown. The number of e-systems[1] is not fixed in the model and can therefore be adapted to the needs of the application of an implementation. As with the basic emotional systems of the mammal, the systems are independent from each other. Within an e-system module the positive feedback-loop is modeled (4), which is responsible for sustaining the e-status[1] when the trigger for has passed.

The functionality of the other modules and the interactions between them is explained based on the data flow through the module, starting with the sensor values received from the environment[2]. The module symbolization receives these data and creates a symbolic representation of the humans, objects, and scenarios recognized by the system. It is designed according to the model of A. R. Luria and has a three-layer hierarchical architecture of symbolization levels. A detailed description of this symbolization can be found in [9] and [10]. The symbolization is influenced by the e-status (3'). This influence can inhibit or amplify the perception of sensory input.

The output of the module symbolization is an input of

[1] e-system stands for the technical implementation of the functionality of a basic emotional system. e-status stands for the technical representation of the basic emotional status. This notation should help to distinguish between the neuro-psychoanalytic model and the technical model.

[2] Since the decision module is intended to check the implications of the decisions of the environment (outer world) and the inner world, the data flow has to be seen as a cycle.

the e-systems as well as an input of the module modulation. The input into the e-systems from the symbolization (1) can cause a change of the e-status by acting as sensory stimuli of the basic emotional systems. The task of the module modulation is to valuate the recognized scenarios depending on the e-status (3''). The input (3') into the module symbolization and the input (3'') emulate the functionality of the sensory inputs (3) of the basic emotional system is emulated as shown in Figure 2. The output of the module modulation is the world representation of the outer world perception including a valuation depending on the e-status of the system.

The module decision emulates the higher cognitive functions of the human brain. It uses the world representation and the e-states (6) in order to make decisions. Internally it uses complex emotions additionally to the basic emotions to influence the decisions of the system. The taken decisions influence the e-systems (5) like the cognitive input influences the basic emotional systems. Additionally the decisions are executed by the module execution.

Beside the input from the module decision, the module execution has an input from the e-systems (2). This input is used to model the instinctual motor outputs, which can be triggered by the basic emotional systems of the mammalian brain. The execution module controls the actuators, which influence the environment of the system. The sensors then measure the changes in the environment and the loop of the dataflow is closed.

As mentioned above the module decision uses beside the basic emotions the complex emotions to evaluate situations in order to make decisions. In the following chapter, the technical model of the complex emotions of the ARS project is described in more detail.

V. Technical Model of Complex Emotions

The psychoanalytical model of complex emotions, described in chapter III is used as an archetype for the decision unit. In contrast to the basic emotions, which can cause very fast reactions through the reactive path, complex emotions are not meant to arise by short stimuli but by long-term decision-making. They are long term emotions, interacting with experienced memories, social rules that are stored within the Super-Ego, and especially occurring desires, defined in that are a central part of human planning. Figure 4 shows the main blocks of the developed model, inspired by neuro-psychoanalytical concepts. The current state of the internal (body) and external world is perceived by corresponding sensors. They are pre-evaluated within the per-decision unit where bodily need states (the drives) are considered, and basic emotions are influenced. First actions can be taken either by using the reactive path–according to the human's reflex actions–or by using the routine path, representing once triggered, automatically executed action patterns. The pre-evaluated perceived information is used as an input of the decision unit where complex emotions are influenced by scenario recognition or created desires, the complex analog of drives. Strategies are calculated and according actions are taken. The decision unit can inhibit low-level actions originating from bodily need states.

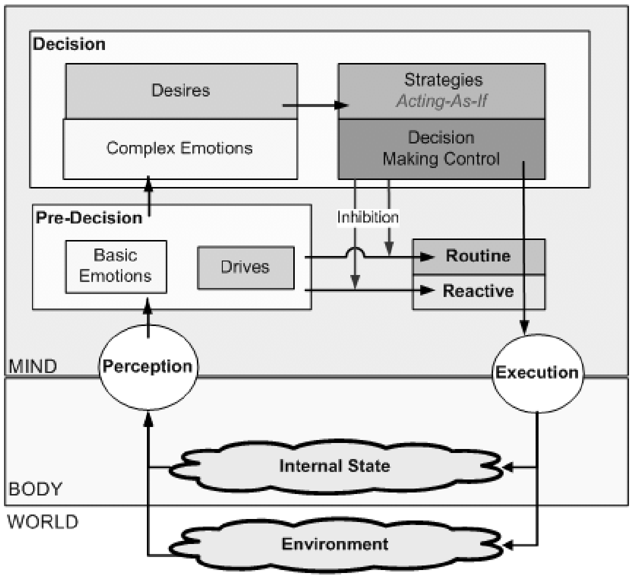


Figure 4: Main blocks of the decision unit

Within the developed system, complex emotions can be defined arbitrarily. There is no limitation in the number of complex emotions. However, they have to be predefined and cannot be automatically learned during the lifetime of an agent in this phase of the project. Using XML as a definition language, the complex emotion of an agent can be defined in an initialization file. A node of a complex emotion consists of the following sub-nodes, representing the following information:

InitialValue – Using a value range from -1 to +1, the starting value of a new instance has to be configured.

ValueType – The behavior of summation can be defined, whether it is a linear or nonlinear system.

SelfDependent – Indicating the origin of the complex emotion. This can be the agent itself or another agent that causes the specified complex emotion.

TargetBasicEmotion – A list of basic emotions that are influenced by a variation.

TargetDrive – A list of drives that can be influenced by variation.

Complex emotions can be initiated within the scenario recognition engine when a fully recognized scenario occurs, representing an object of interest. Complex emotions can also be associated to any state of an active desire. The action plan of a desire is realized within the developed system as a finite state diagram. To define the impact of such scenarios or desire states, complex emotion values have been defined. A new instance of a complex emotion value is created when a corresponding scenario is recognized or a desire reaches an active state.

The complex emotion values (CEV) are holding the following information:

Complex Emotion – Defines the affiliation to the corresponding complex emotion.

Value – This value is added into the list of complex emotion values when the CEV is created.

Decay Time – Defines the decay, the value decreases gradually.

Occurring CEVs are registered by the registration list of the complex emotions. This assures that a complex emotion can be influenced by more than one occurring circumstance at the same time. The resulting level of the complex emotion can be calculated by the sum of each value or another nonlinear operation. During the time of an active CEV, the level will be decreased by time according to the decay function defined within each CEV. This behavior automatically guarantees that values with the same decay function but recently added are of higher impact than older values.

When discarding a scenario or desire, or when the active state of a desire changes, the CEV is unregistered from the complex emotions' registration list. It is possible that the registered value was not zero by decay. Therefore, the summation value of the corresponding complex emotion is decreased erratic in this moment. Figure 5 shows a possible sequence for the lifetime of CEV.

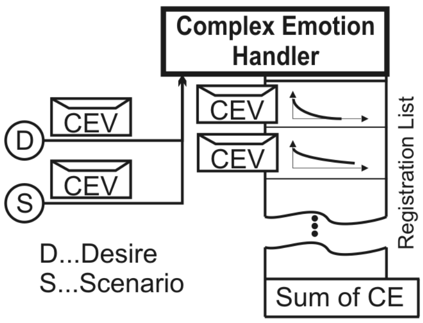


Figure 5: Complex Emotion Handler

Each complex emotion is unique within an agent. A singleton pattern has been used. By using different definition files for each agent, it is possible to create different characters of agents, which leads to different behavior.

The first version of our system has only implemented basic emotion, which made interaction with other agents impossible. The advantage of implementing complex emotions in our system is given by the possibility to support ‘social’ interaction between agents. Therefore it is possible to support scenarios that need team work, which is a first step towards the estimation of another agent’s behavior, e.g. when an agent requests help as described in the simulation results in [17]. This estimation of another individual’s behavior is essential in developing robots that may interact with or support humans in real world scenarios. In the described decision unit, the Ego is composed of functions that cope with the relation of individual with his environment, including other agents or humans. Here, all bodily need states, basic and complex emotions and social aspects are deliberated to support the execution unit with corresponding actions.

VI. Conclusion

This article has shown a concept using emotions within the perception and decision unit of an autonomous agent. By using the term emotion, it was set a high value on a correct psychoanalytical definition. Therefore, a consistent neuro-psychoanalytical concept of basic emotions and complex emotions has been defined and described in detail. These definitions allow an implementation in a technical system. The system’s perception is essentially influenced by basic emotions that are occurring within the pre-decision unit containing the perception and the evaluation system.

A higher decision layer influences the developed e-systems which influence the decision behavior itself. Within a decision unit, complex emotions have been introduced as a value system concerning social aspects of decision-making.

It has been shown that a system using basic emotions is only able to perceive and recognize current situations and act impulsively, but it is not capable of interacting with other agents or in a next step with a human opponent.

In order to deal with a high number of sensors, future computer-aided automation systems can use emotional validation for perception, scenario recognition, and decision-making. This will be an essential advantage especially in the area of integration of technical systems into a ubiquitous environment for interaction between systems and humans.

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Wolfgang Burgstaller studied Electrical Engineering at the Vienna University of Technology. His diploma thesis was dedicated to building automation systems. Since 2002, he is working on his doctoral thesis at the Institute of Computer Technology of the Vienna University of Technology. His major research interests are e-integration of neuron-psychoanalytical models into technical systems, building automation, and payment solutions.
burgstaller@ict.tuwien.ac.at

Roland Lang was born 1978 in Vienna/Austria. He finished his studies of electronics, especially control engineering and tele- communications in June 2001 at the University of Applied Sciences Technikum Wien (Fachhochschule). He is currently employed at the Institute of Computer Technology and has gained experience on cognitive automation (within the project ARS – Artificial Recognition System). He is IEEE Member, Organizing Committee member of the INDIN2007 and Secretary of the IEEE Student Branch, Section Austria.
langr@ict.tuwien.ac.at

Patricia Pörscht, Mag.rer.nat., studied Psychology at University of Vienna until 1998. She finished her post-graduate studies in 2000 as a Clinical Psychologist and Health-Psychologist and is Psychotherapist in Group-Psychoanalysis. She is in the employ of a public hospital with focus on neurological work and is working on free practice. She is teaching the subjects psychology of development and educational coaching on teachers' college at the University of Vienna, Institute of Professionalizing Research. She has been counselling on the study-group of Artificial Recognition System - Psychoanalysis (ARS-PA) at the Technical University Vienna, Institute of Computer Technology (ICT) since 2004. The focus of her interests in research work lies on psychology of emotions, on hysteria and also on psychosomatic disorders.

Rosemarie Velik was born in Sept. 1981 in Klagenfurt. After graduating at the HTL for Computer and Internet Engineering in Klagenfurt she began studying Electrical and Automation Engineering at the TU Vienna in Oct. 2001 and completed her degree in April 2006. Since July 2006 she is a member of the department staff and works in the Project ARS (Artificial Recognition System). Her research interests are devoted to the topic of building automation, bionics, neural networks, cognitive intelligence, and artificial perception. She is an IEEE Member.