Display of Emotions with the Robotic Platform ALIAS

Darstellung von Emotionen mit der Roboterplattform ALIAS

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Abstract

Emotions are an important communication channel and therefore, human-machine interaction can be enriched by displaying emotions. Especially for a robotic system designed for technology-inexperienced users as in an AAL context, display of emotions is a good way to increase the familiarity with a technical system. In this contribution, we describe how the robotic head of the robotic platform ALIAS is used to display emotions. In the project ALIAS, the robot is equipped as a communication platform for elderly people. Emotions are used to enrich the human-machine interaction. ALIAS can thus better adapt to its users during a dialogue. The robotic head has several degrees of freedom to display different facial expressions. Five different facial expressions corresponding to five different emotions have been developed. In a user study it was tested, how humans perceive the displayed emotions. The results are promising, however, the absence of a mouth makes it difficult to design emotions which can be recognized by humans very robustly.

Kurzfassung

Emotionen sind ein wichtiger Kommunikationskanal und dadurch kann Mensch-Maschine-Interaktion durch die Darstellung von Emotionen angereichert werden. Gerade für ein Robotersystem, welches für technologie-unerfahrene Nutzer wie in einem AAL-Kontext entwickelt wird, ist die Darstellung von Emotionen eine gute Möglichkeit, um die Vertrautheit mit dem technischen System zu erhöhen. In diesem Beitrag beschreiben wir, wie der Roboter-Kopf der Roboter-Plattform ALIAS verwendet wird, um Emotionen darzustellen. Im Projekt ALIAS wird ein Roboter als Kommunikationsplattform für ältere Menschen ausgestattet. Emotionen werden verwendet, um die Mensch-Maschine-Interaktion zu bereichern. ALIAS kann sich somit während eines Dialoges besser an die Bedürfnisse seiner Benutzer anpassen. Der Roboter-Kopf verfügt über mehrere Freiheitsgrade zur Anzeige verschiedener Gesichtsausdrücke. Fünf verschiedene Gesichtsausdrücke entsprechend fünf verschiedenen Emotionen wurden entwickelt. In einer Nutzerstudier wurde getestet, wie Menschen die angezeigten Emotionen wahrnehmen. Die Ergebnisse sind vielversprechend, aber das Fehlen eines Mundes macht es schwer, Emotionen zu gestalten, die durch den Menschen robust erkannt werden können.

1 Introduction

Emotions are an important aspect of human-human communication. Based on the work of Freud, Zimbardo and Ruch describe communication in an ice berg model [1]. Thereby, only 20 % of communication consists of a visible part, which involves facts and figures. The larger part consists of non-visible aspects like personality, fears, conflicts and emotions. In communication, emotions have the functions of dialogue control, transmission of information, social bonding, competence and personalisation. This model concerns mainly human-human communication. But since it is desired to make human-robot interaction as natural as possible, it is necessary to include emotions in a human-robot dialogue. While industrial robots are not well-suited for the display of emotions, especially robotic platforms in the fields of AAL, health care, entertainment or service robotics can be enriched by emotions.

There are several tasks a companion robot can perform to support elderly people. Physical assistance is not addressed here in the context of social robotics but it is definitely a future key selling point. The ability to lift or carry things or act as a mobility aid are important features but need more stable technical solutions to be able to be employed without safety risks. In its function as a communication platform, a robot can serve several duties. It can interact with its elderly users, provide cognitive assistance and promote social inclusion. Communication plays a major role for a social robot for elderly people. In order to keep the human-robot dialogue lively and attractive, emo-

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tions can be applied as an additional communication channel. Emotions are not only used to give feedback about the current state of the robot, but also to equip the robot with a certain human-likeness. Thus, emotions help to enrich the human-robot dialogue and to reduce anxiety of communicating with a technical system.

1.1 Related Work

Several robots with abilities to display emotions have been developed. In Figure 1, four examples for robotic platforms that can display emotions are given.

EDDIE (Emotion Display with Dynamic Intuitive Expressions) [2], displayed in Figure 1a is a human-like robotic head. It has 23 degrees of freedom at its eyes, eye brows, ears, mouth and jaw. Additionally, two animal-like features are mounted in order to strengthen the ability to display emotions. EDDIE is also developed with child-like characteristics (e. g. the large eyes). The basic emotions joy, surprise, anger, disgust, sadness and fear can be displayed with EDDIE. In [6], a robotic platform based on EDDIE that enriches a multimodal human-robot dialogue with emotional feedback was described.

Similar to EDDIE, the robotic head Kismet [3] (Figure 1b) resembles a human head, but without any additional animal-like features. Kismet has 15 degrees of freedom at its eyes, eye brows and lids, neck, ears, lips and mouth. It can display the emotions happiness, sadness, surprise, anger, calm, displeasure, fear, interest and boredom.

Compared to the robotic heads described so far, Sparky [4] (Figure 1c) is relatively small with its dimensions of $60 \cdot 50 \cdot 35\ cm$ but it consists of a whole body and not only a head. With its cartoon-like character, the uncanney valley [7] can be dodged. In order to display emotions, Sparky has only ten degrees of freedom: Its eye brows and lids, top and bottom lip, neck, back plate and wheels are movable. The tiltable back plate can be interpreted as an animal-like feature. Sparky can display the emotions happiness, sadness, anger, surprise, fear, curiosity, nervousness and sleepiness.

The robot dog AIBO [5] (Artificial Intelligence roBOt, Figure 1d) is an already commercially available robotic platform. It has 20 actuators and can move its mouth, head, ears, tail and legs. AIBO displays not only separate emotions, but complete behaviours, which are exploring, demanding and giving attention, fear, playing, learning and seeking protection.

Further examples for social robots capable of displaying emotions are CERO [8], FEELIX [9], VIKIA [10], PARO or the Sony Dream Robot.

All of the presented robotic platforms have different features to display emotions, where especially the mouth, eyes and eye brows play an important role.

1.2 Overview

The robot ALIAS is designed as a communication platform for elderly persons [11]. Therefore it is well suited for the incorporation of the ability to display emotions, to enrich the human-robot dialogue. Since it has no mouth, it is especially difficult to display emotions with ALIAS. Five different emotional facial expressions have been developed and evaluated with the robotic platform ALIAS.

In the next section, we present the robot ALIAS and the hardware of the head of the robotic platform. The implemented emotional facial expressions are described in Section 3. Experimental results are presented in Section 4 before conclusions are given in the last section.

2 Robotic platform ALIAS

2.1 The ALIAS Project

In the project ALIAS (Adaptable Ambient Living Assistant[1]), the robotic platform ALIAS is equipped as a communication platform for elderly people. ALIAS is a mobile robot system that interacts with elderly users, monitors and provides cognitive assistance in daily life, and promotes social inclusion by creating connections to people and events in the wider world. The system is designed for people living alone at home or in care facilities such as nursing or elderly care homes. The function of ALIAS is to keep the users linked to the wide society and in this way to improve their quality of life by combating loneliness and increasing cognitively stimulating activities. In a first series of field-trial experiments, the robotic platform was already tested with elderly users [12].

To fullfill it's goals, ALIAS is equipped with several capabilities: An easy-to-use and fault tolerant human-machine interface is achieved by employing automatic speech recognition (ASR) together with a module for natural language understanding (NLU). Communication is enriched through the utilization of person identification methods using voice and face and laser-based leg-pair detection. In order to promote social inclusion, services for net-based linking are employed to link users with the wider world, enabling to maintain a wider horizon by exploiting new kinds of on-line and remote communication techniques. Autonomous, socially acceptable navigation capabilities enable the robot to find its way in its environment. In addition, the robot is equipped with a brain-computer interface (BCI), enabling users like stroke patients to remotely control the system.

Several use-case scenarios are developed to showcase the different functionalities of the robot. For example, in the ground lighting scenario, it is shown how ALIAS can guide persons at night in the dark, using its navigation capabilities and applying the touchscreen display as a light source. The gaming scenario has been designed to test the

[1] See AAL-JP project ALIAS `www.aal-alias.eu`

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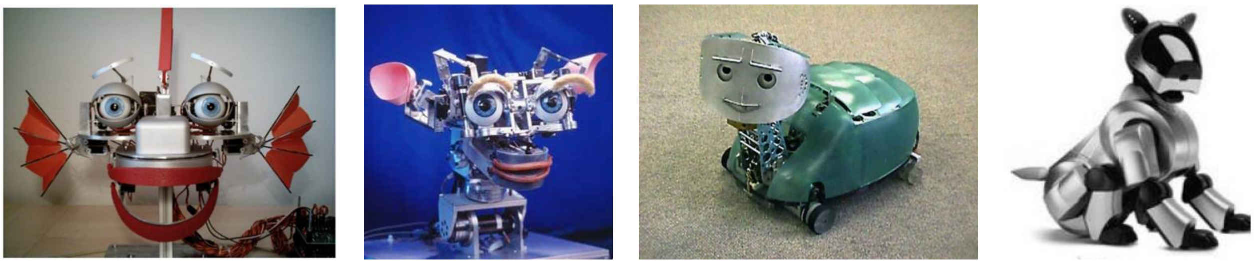


(a) EDDIE. From: [2] **(b)** Kismet. From: [3] **(c)** Sparky. From: [4] **(d)** AIBO. From: [5]

Figure 1: Different examples of robots capable of displaying emotions.

human-machine interface. An entertaining game is played through the touchscreen and can additionally be controlled by speech commands. At the same time, ALIAS is addressing its user by employing face detection to detect the user and hold eye-contact with him. This scenario is best suited for integration of the display of emotions.

2.2 Hardware Setup

The hardware configuration of the robot platform ALIAS (see Figure 2) is based on the SCITOS G5 robot family of the robot manufacturer MetraLabs[2].

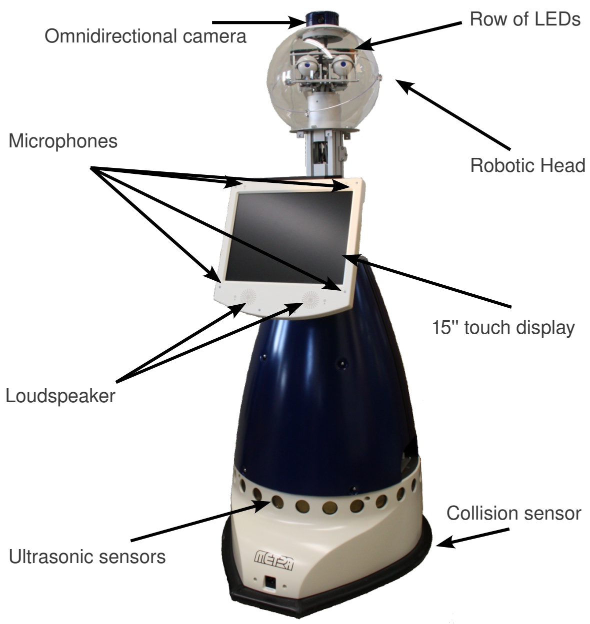


Figure 2: Overview of the hardware setup of the robotic platform ALIAS, divided into driving unit (lower part) and interaction unit (upper part) consisting of the touchscreen display and the robotic head).

ALIAS is an approximately 1.50 m tall robot platform and can be divided into a driving unit and an interaction unit. In order to approach a user, navigation is provided by the driving unit, which uses a differential drive system. In a known environment, the robot can localize itself, navigate autonomously and approach a user in a socially acceptable manner using a laser range finder and ultrasonar sensors. The interaction unit consists of a movable robotic head and a 15" touchscreen, which is used for user interaction with the robot and is best suited as an easy-to-use human-machine interface. In addition, it is equipped with four microphones and two loudspeakers which can be used for speech input and output.

[2] www.metralabs.com

2.3 Robotic Head

ALIAS is equipped with a head that is used to display emotions. On top of the head, an omnidirectional camera is mounted, which delivers a 360° image. Due to its mounting position, the main purpose of this camera is to localize and identify persons using face detection. The head has several degrees of freedom. In Figure 3, all of the degrees of freedom of the robotic head are displayed.

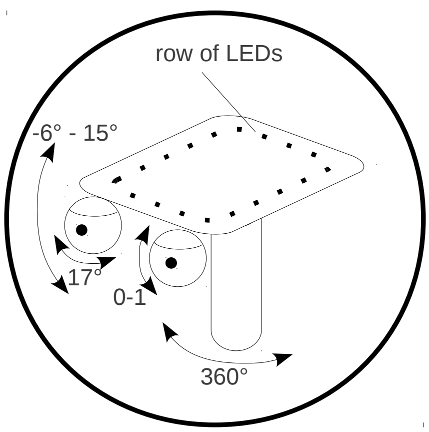


Figure 3: Features of the robotic head of ALIAS. The head can be turned horizontally and vertically and the eyes can be opened/closed and turned vertically. Additionally, above the eyes, there is a row of LEDs.

It can be turned 360° horizontally and vertically up (15°) and down (6°). The two synchronized movable eyes can be turned up to 8.5° in both horizontal directions and the eye lids can be opened or closed (independent of each other) on a continuous scale. Horizontal rotation of head and eyes is not used to distinguish between emotions, in order to ensure the possibility to perceive emotions independent of the viewing angle. Above the eyes, a row of blue LEDs is mounted, which can be turn on and off or set running or blinking with any frequency. Additionally, the brightness of the LEDs can be controlled. In total, this sums up to 6 degrees of freedom which are used to display different facial expressions. Compared to other robotic heads, this is a relatively small number of degrees of freedom. It should also be noted that ALIAS has no mouth or eye brows, which are important for displaying emotions. Therefore, it will be rather difficult to display emotions with ALIAS.
Two different computers are mounted on the robot. An industrial PC running Linux is used to control the hardware of the robot, e. g. the driving wheels, the collision and ultrasonic sensors and the robotic head. To control the touchscreen display, the robot is equipped with a Mac mini running Windows. The microphones and loudspeakers are also connected to the Windows PC. All modules on both computers can communicate with each other through various interfaces. More technical details about the robot platform ALIAS are provided in [11].

3 Emotional facial expressions

In addition to a neutral facial expression, five emotional facial expressions are implemented. In this section, the concept and the implementation of these facial expressions are described.

3.1 Concept

The basic emotions disgust, fear, joy, sadness and surprise have been chosen. These emotions are considered "basic emotions" because they are said to be represented and interpreted equally in the whole world [13]. It is important to limit the number of different emotions in order to allow the user to distinguish between the possible facial expressions. However, when the evaluation is performed on a continuous scale (e. g. with arousal and valence), it is feasible to include a larger set of emotions. Figure 4 shows how our chosen emotions are roughly distributed in the continuous space of arousal and valence. Mapping emotions onto the two-dimensional space of arousal and valence is a simple model to display emotions on a continuous scale.

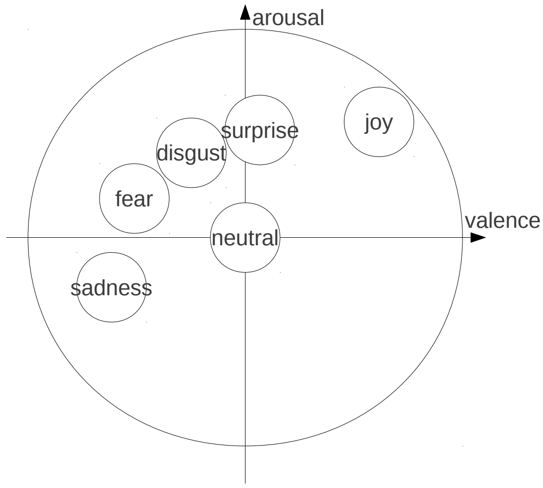
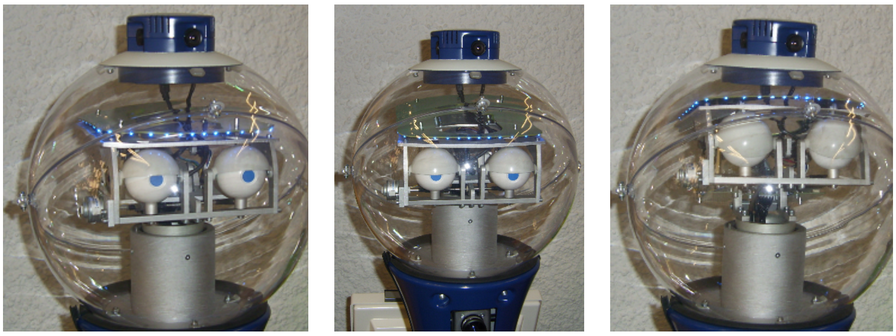


Figure 4: Distribution of the five implemented emotions in the two-dimensional space of arousal and valence.

From Figure 4, it can be seen that some of the chosen emotions are very near next to each other. Therefore, it was especially carefully tried to design facial expressions which help to distinguish between those emotions.

3.2 Implementation

The implemented facial expressions are based on human emotion display, using the head tilt angle and eye lids. Another important feature that is used here to distinguish between different facial expressions is the row of LEDs above the eyes. For this feature, the settings can not be based on human emotion display. The brightness of the LEDs is roughly correlated with arousal. Therefore higher brightness values are chosen for joy or surprise. The frequency of the LEDs (when set running or blinking) is another important feature. A small frequency (i. e. slow blinking) generally expresses slowness, fatigue or lethargy, while high frequency values indicate speed, hecticness, excitement or nervosity. Based on these assumptions, the LED frequency was set accordingly for the different emotions.
Three exemplary facial expressions are displayed in Figure 5. The neutral facial expression is displayed in Figure 5a and is characterized by slightly closed eyes and unmoved head while the LEDs are turned on with a medium brightness. In Figure 5b, the facial expression showing sadness is displayed. The head is turned down with slightly closed eyes and the LEDs are blinking with a slow frequency. The facial expression for the disgust emotion is displayed in Figure 5c. The robotic eyes are completely closed and the head looks upwards.
In order to display joy, the eyes are opened and the LEDs are set running with a medium speed and maximum brightness. The head is slightly turned upwards. For fear, the eyes are wide open and the LEDs are set blinking with a relatively high freqency. Surprise is displayed by LEDs blinking with a very high frequency at maximum brightness and opened eyes.



(a) Neutral facial expression **(b)** Sad facial expression **(c)** Disgust facial expression

Figure 5: Different facial expressions of the robotic head of the ALIAS platform.

In Table 1, all settings of the head for the implemented emotions are displayed.

Emotion	Head tilt	Eyelids	LEDs	LED freq.	LED brightn.
Neutral	0.0	0.85	on	-	0.5
Disgust	12.5	0.0	on	-	0.2
Fear	0.0	1.0	blinking	35	1
Joy	5.0	1.0	running	35	1
Sadness	-6.5	0.81	blinking	220	0.2
Surprise	0.0	1.0	blinking	10	1

Table 1: Settings for the actuators of the robotic head of ALIAS for the implemented emotions.

4 Experiments

A user study has been conducted to evaluate how good humans can identify the emotions displayed by ALIAS. 12 male adult subjects, aged between 23 and 30 participated in the study. The robot was presented to the users and the five different emotions have been shown five times each, in a random order. Always between two emotions, the neutral facial expression was displayed. The subjects had to identify the displayed emotion and could choose from a list of 10 different emotions (or "other"), which are: acceptance, anger, boredom, curiosity, disgust, fear, joy, sadness, seriousness and surprise. The 10 possible answers are the same Breazeal used to evaluate the robot Kismet [14]. In addition, subjects rated their guess on a scale from 1 (very unsure) to 10 (very sure). Table 2 shows the identification rates resulting from the user study.

Emotion	Identification rate (in %)
Disgust	33.3
Fear	6.6
Joy	23.3
Sadness	38.8
Surprise	33.3
Average	27.1

Table 2: Human identification rates for emotions displayed with the robotic head of ALIAS.

The identification rates are promising, although none of the emotions could be identified very clearly. Sadness achieves the highest accuracy with 38.8 % while fear was only identified 6.6% of the time. The average identification rate is 27.1 %. There was a strong variation between the different subjects. Some subjects achieved an identification rate of 50 % while others had almost none of the emotions guessed correctly. There are clear tendencies visible in the confusions of different emotions. The confusion matrix is displayed in Table 3.

Disgust and sadness have been reconised as boredom very often, joy as curiosity and surprise as anger or curiosity. This can mainly be attributed to the absence of a mouth, which is a very important feature for display of emotions. On the other hand, the LEDs are the main feature that is used to differentiate between emotions, supported by head tilt and eye lids. Most of the confusions appear between emotions which are close to each other in the arousal-valence space, which supports the value of our results.

5 Conclusions

We presented the robotic platform ALIAS and the implementation of different facial expressions according to different emotions. The robotic head was used to display five different emotional facial expressions. In a user stuy, it was evaluated how the different emotional facial expressions of ALIAS can be recognised by humans. While the identification rates for the emotions are not too high, it is already

Emotion	Acceptance	Anger	Boredom	Curiosity	Disgust	Fear	Joy	Sadness	Seriousness	Surprise	Other
Disgust	6.6	0	35	0	33.3	10	1.6	11.6	0	0	1.6
Fear	18.3	3.3	3.3	15	0	6.6	10	6.6	10	20	0
Joy	5	5	0	28.3	3.3	5	23.3	6.6	10	11.6	1.6
Sadness	0	10	31.6	0	11.6	0	0	38.8	8.3	0	0
Surprise	5	16.6	5	15	1.6	10	10	0	1.6	33.3	1.6

Table 3: Confusion matrix (in %) for emotions displayed with the robotic head of ALIAS. Five different emotions were displayed to the subjects and they could choose from 10 possible emotions or "other".

very promising that with such limited hardware it is possible at all to distinguish between different emotions. The addition of a mouth could be very promising to increase the identification rates of emotions, as well as the introduction of different colours for the LEDs. Reducing the set of different emotions could also lead to a better separation by the human observer. Furthermore, we want to test the influence of emotional facial expressions in a dialogue situation between a human and a robot.

6 Acknowledgements

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