The Robot ALIAS as a Gaming Platform for Elderly Persons

Der Roboter ALIAS als Spiele-Plattform für ältere Menschen

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Abstract

Entertainment is an important aspect of social robots in an AAL context. Especially for elderly people, a robot can be the right platform for entertaining games. This paper describes the robotic platform ALIAS as a gaming platform. In the project ALIAS, a robot is equipped as a communication platform for elderly people. One aspect of the project is to provide cognitively stimulating games using a natural human-machine interface. Therefore, a computer game with multiple interaction channels is integrated on the robot ALIAS. The robot has a touchscreen with a graphical user interface where the game Tic-tac-toe can be played. Additionally, the game can also be controlled by speech commands, whereby a speech dialogue system is employed. In order to enrich the human-machine dialogue, the robot uses face detection to control its gaze behaviour and look at its conversational partner. This demonstration scenario can be seen as a first approach to evaluate a multimodal user interface using haptics and speech in conjunction with a cognitive dialogue system.

Kurzfassung

Unterhaltung ist ein wichtiger Aspekt von sozialen Robotern in einer AAL-Umgebung. Insbesondere für ältere Menschen kann ein Roboter die richtige Plattform für unterhaltsame Spiele darstellen. Dieser Beitrag beschreibt die Roboter-Plattform ALIAS als Spiele-Plattform. Im Projekt ALIAS wird ein Roboter als Kommunikationsplattform für ältere Menschen ausgestattet. Ein Aspekt des Projekts ist es, kognitiv anregende Spiele mit einer natürlichen Mensch-Maschine-Schnittstelle auszustatten. Daher ist ein Computerspiel mit mehrere Interaktionskanälen auf dem Roboter ALIAS integriert. Der Roboter verfügt über einen Touchscreen mit einer grafischen Benutzeroberfläche auf der das Spiel Tic-Tac-Toe gespielt werden kann. Darüber hinaus kann das Spiel auch durch Sprachbefehle gesteuert werden, wobei ein Sprachdialogsystem zum Einsatz kommt. Um den Mensch-Maschine-Dialog zu bereichern, verwendet der Roboter Gesichtsdetektion um sein Blickverhalten zu steuern und Blickkontakt mit seinem Gesprächspartner zu halten. Dieses Anwendungsszenario kann als ein erster Ansatz gesehen werden, eine multimodale Benutzerschnittstelle mit Haptik und Sprache in Verbindung mit einem kognitiven Dialogsystem zu evaluieren.

1 Introduction

With growing progress in the field of robotics and human-machine interaction, more elaborate robotic applications can be developed. One possible field of applications for a home robot is entertainment robotics, where games play a major role. Especially for elderly people in the Ambient Assisted Living (AAL) context, a robot can be the right platform for entertaining games. Compared to a conventional electronic entertainment systems like a video game console or a tablet PC, a robot can provide several advantages. Due to its human-like and friendly appearance, a social robot is appealing to elderly persons who might otherwise be reluctant to use technical systems. In addition, a convincing human-machine interface employing innovative communication channels leads to a higher user acceptance. Therefore, with an easy-to-use human-machine interface (speech control) and its appealing appearance, a robot is the ideal platform to approach users who are not so technologically adept.

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. The other important field of application for robots in AAL is communication. In its function as a communication platform, a robot can serve several duties. It can interact with its elderly users, pro-

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vide cognitive assistance and promote social inclusion. In order to stimulate cognitive activities, entertainment games can be the right manner. Equipped with an easy-to-use human-machine interface and embedded in a robotic system with an appealing appearance, entertainment games are well suited to encourage elderly people to perform cognitive stimulating activities.

1.1 Related Work

One of the most famous entertainment robots is Aibo [1], which is designed as a pet dog. The robot Paro is a robot in the form of a baby harp seal and is used as a therapeutic agent in the care of people with dementia. It was also used to study the social interaction among elderly people [2]. Robotic assistants have also been used in therapy for children with autism [3].

There are several research projects which follow similar goals as ALIAS. In [4], the robot Maggie is presented which is used as a gaming platform. In the CompanionAble project [5], a mobile robot platform is combined with Ambient Intelligence technologies to provide a companion for elderly people. The project ExCITE [6] has the goal to develop a mobile robotic platform for telepresence applications. A service robot designed to help humans in the household is developed in the Care-O-bot 3 project [7].

In [8] it was examined how robotics could support the independent living of elderly people. Entertainment robotic systems are useful for preventing loneliness and for therapeutical applications, especially for elderly people.

1.2 Overview

In this work, we present the robotic platform ALIAS in its functionality as a gaming platform. Using the touchscreen of the robot, the game Tic-tac-toe can be played. Alternatively, the game can be controlled with speech commands. The robot will also answer with speech messages. To enrich the feedback with natural behaviour, the robot uses face detection to always looks at its conversational partner. All these software modules are controlled by the dialogue system. The choice for Tic-tac-toe as a simple strategy board game and the possibility to control the game via touchscreen or speech commands leads to an easy-to-use human-machine interface where no instructions for the user are necessary.

The rest of the paper is structured as follows: In the following section, the robotic platform ALIAS is presented. The employed dialogue system is described in Section 3. In Section 4, the implemented game is presented, before a conclusion is given in the last section.

2 The Robot 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 [9].

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 which is described in this work is used to test the 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. The hardware and software setup of the robot as used in the gaming scenario are described in this section.

2.2 Hardware

The hardware configuration of the robot platform ALIAS (see Figure 1) is based on the SCITOS G5 robot family of the robot manufacturer MetraLabs[2]. It 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

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

[2] `www.metralabs.com`

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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 [10]. 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. Additionally, it is equipped with four microphones and two loudspeakers which can be used for speech input and output.
The robotic head has five degrees of freedom (head pan and tilt and eye pan plus two eye lids) and additionally, a row of LEDs for additional user feedback is mounted on it. 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 and identification.
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. Thus, all dialogue control and speech processing modules are also running on 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].

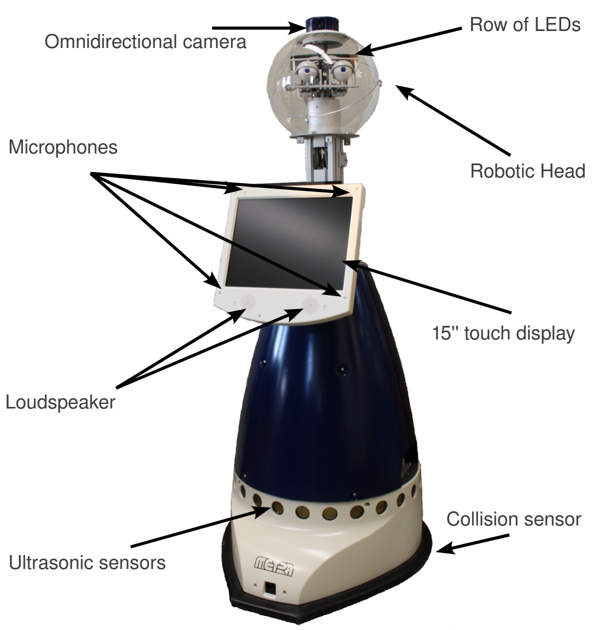

Figure 1: Overview of the hardware setup of the robotic platform ALIAS, divided into driving unit (lower part) and interaction unit (upper part) consisting of the touchscreen display and the robotic head).

2.3 Software Overview

To provide an optimal multimodal interface for a gaming platform, the mobile platform is equipped with several software modules. An overview over the involved software modules is shown in Fig. 2.

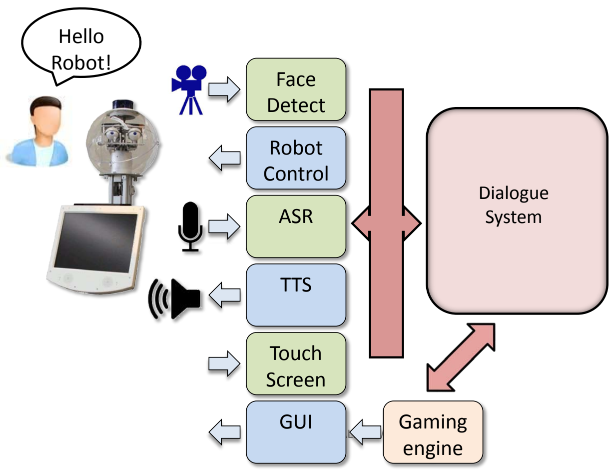

Figure 2: Software modules for the described gaming scenario. User input/perception modules are displayed in green, action/output modules in blue.

The central module is the dialogue system (running on the Windows PC). It communicates with all other modules. Automatic Speech Recognition (ASR) is used to give commands to the robot, and answers are created using the speech synthesis module (text-to-speech, TTS). The dialogue system is described in detail in Section 3. The touchscreen is used to display the graphical user interface (GUI) for the game, which is handled by the gaming engine. Additionally, the touchscreen serves as haptic control channel. The gaming engine controls the Tic-tac-toe game including the artificial intelligence for the computer player. A face detection module is running to localize users and to control the robotic head. As a result, the robot always looks at its conversation partner. This guarantees for natural behaviour of the robot. All the involved software modules are described in detail in the next sections.

3 Dialogue System

The dialogue system is the most important software component of the robot. It is the connection between all other modules. For example, it controls speech input via automatic speech recognition, speech output via speech synthesis, the gaming engine (leading through the different steps of the game) and the GUI.
In Figure 3, a complete flow chart of a speech dialogue situation is displayed.

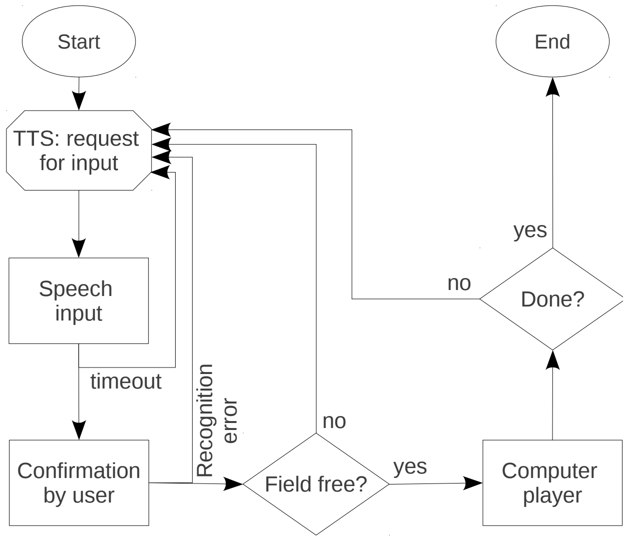

Figure 3: Complete dialogue flow chart for the Tic-tac-toe game, including TTS (speech synthesis), speech recognition and the computer player AI.

After starting the game, the dialogue system controls the proceeding. First, the user is asked to make his next turn. After the user chooses his field on the playing board, he is asked for a confirmation (yes/no) before his symbol is placed. This behaviour helps to compensate errors of the speech recogniser, which makes it possible to play the game without any unwanted moves in the game. Following the user's turn, the implemented computer AI is used to determine the next turn of the computer player. Depending on the current state of the game, appropriate speech synthesis commands are used, e. g. to start the game, to ask the user to take his turn in the game (which is repeated after a certain interval) or to notify the winner at the end of the game. Speech recognition is used to record the commands of the user. Alternatively, the user can also make his choice by directly clicking on the touchscreen. Speech recognition and synthesis are realized through the commercial software DialogOS (see `http://www.clt-st.de/produkte-losungen/dialogos/`) which uses the VoCon 3200 speech recognition engine.

3.1 Automatic Speech Recognition

In this scenario, automatic speech recognition (ASR) can be used to choose a space on the 3x3 playing board. Speech is recorded by the microphones built in around the touchscreen, so no additional handheld or headset microphone is necessary, providing a hands-free communication. However, since the display (where the microphones are attached) is close to the user position, the sound quality is very good. Figure 4 shows a flow chart of the ASR module. Whenever input from the user is expected, e. g. to make a turn in the game, the ASR module is activated. Voice activity detection (VAD) is used to detect an utterance, which is then forwarded to the recognition process. In the recognition process, a dynamic grammar and vocabulary (adapted to the current dialogue state) are used. This behaviour is controlled by the dialogue system. Therefore, in each dialogue step, only a specific set of commands can be recognized.

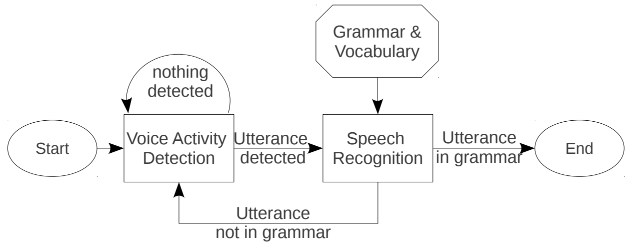

Figure 4: System overview of speech recognition including Voice activity detection (VAD).

The recognised sentence is then processed by the dialogue system. Several commands are possible to address the different fields on the playing board, e. g. "bottom left" or "left bottom". For answering of yes/no questions, also several utterances are possible.
User studies have been conducted to find out the different commands the users would use when not being instructed about possible ASR commands. These commands were then chosen to be implemented into the grammar of the ASR system. Therefore, the implemented grammar and vocabulary cover a broad range of possible user input and the ASR module is not limited to a fixed small vocabulary. To use the ASR system, no additional training phase (e. g. to perform speaker adaptation) is needed for the user. Thus, the ASR system is easily usable out-of-the-box without any instructions for the users.

3.2 Speech Synthesis

The robot uses a TTS module to communicate to the user. Any possible text can be converted into spoken language. Four different voices can be chosen: For English and German, each a male and female voice are possible. The voices are clear and easily understandable for humans. Speech synthesis is used at various points in the scenario, e. g. to welcome the user at the beginning of the game. Then, in each turn of the game, the user is asked for his decision. After the answer of the user, he is asked for a confirmation (yes/no). At the end of the game, the outcome (win/loss/draw) is also communicated by the TTS module. In order to design the dialogue rich in variety, for each possible TTS command, several variants are implemented. This brings more lifeliness into the dialogue, especially for dialogue steps which are repeated several times (e. g. asking for the input of the user).

3.3 Touchscreen

The touchscreen is used to display the GUI of the Tic-tac-toe game. Using the 15" touchscreen is a simple way to provide an easy-to-use human-machine interface. In addition to using speech commands, the game can also be controlled via the touchscreen. Thus, two natural interaction channels are provided to communicate with the robot.

3.4 Gaze Behaviour

In order to provide a human-like behaviour of the robotic head, a vision-based attention system (similar as in [12]) is employed to control the gaze behaviour of the robotic head. A face detection module is used to localize the face of the conversational partner and turn the head and eyes of the robot towards the user. When the user moves his head, the robot will follow this movement. Constant movement of the head and eyes makes the robot appear more lively and attractive.

Face Detection

Face detection is the task of determining if and where in an image faces are located. Sensor data (usually from a camera) are the input to the system, while coordinates of regions containing faces (usually bounding boxes) are the system output. Typically, scaling and rotation parameters of the detected faces are not provided. To detect faces, the approach of Viola and Jones [13] using adaptive boosting and a Haar cascade classifier is employed. This approach is effective and fast and achieves high detection rates. The fast processing speed is based on three facts: first, the applied Haar-like features computed on a so-called integral image, second, adaptive boosting (adaBoost), and third, the cascade structure of classifiers (with increasing complexity). The features used in the cascade classification structure are called Haar-like features, because the have resemblance with Haar-Wavelets. The results of the computation of the Haar-like features represent certain characteristics of the input image: edges, texture changes, borders between light and dark image regions. Using these features, adaBoost is applied to select and combine several weak classifiers in a cascade resulting in a strong classifier capable of detecting human faces.
In our system, the image from the omnidirectional camera on top of the robotic head is used as input to the face detection system. The camera consists of four individual cameras whose images are merged together to a 360-degree image. Images are recorded with a frame rate of 15 images per second. Therefore, persons standing at any angle around the robot can be detected. First, all recorded images are transformed to greyscale, since the employed face detection system uses greyscale images. Then, faces are detected using the approach of Viola and Jones. Only the hypothesis with the highest probability is returned, in the form of a rectangle as a bounding box of the face. This means that only one face is detected at a time, which is always the largest face in the view. This makes the assumption that in a multi-person scenario, the interaction partner is always the person with the smallest distance to the camera, which should be true most of the time. In order to speed up the detection process for subsequent images, the information about the current position of the face is utilized. For the following frame, not the whole image is searched for faces, but only a bounding box around the last position of the face.

Head Control

The position of the detected face is then used to control the robotic head. Adjusting the head's pan and tilt angle and the pan angle of the eyes, the robot tries to hold eye contact with the user, using a human-inspired motion model for the coordination between head and eye movement [14]. From the coordinates (in pixels) of the detected face within the camera image, the corresponding world coordinates are obtained using the known geometrics properties of the camera setup. These coordinates are then used to direct the robot's head and eyes towards the middle of the face.
The targeted head pan angle (horizontal angle) can simple be computed using the x-position (in pixels) of the detected face within the camera image. As long as the difference between the target viewing angle and the current viewing angle is below the maximum pan angle of the eyes ($8.5°$), only the eyes will be moved. For larger angular changes, head movements are utilized: the pan angle of the eyes is turned back to zero and the head pan angle is set to the target viewing angle.
To determine the head tilt angle is more complex, due to the fact that the camera is not positioned in the robot's eyes. The geometric setup for controlling the robotic head's tilt angle is shown in Figure 5.

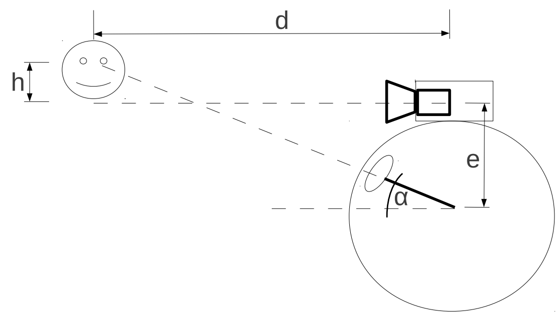

Figure 5: Geometry of the setup for controlling the head tilt angle according to the position of the detected face.

The distance d of the face to the camera is estimated based on the height (in pixels) of the detected face, assuming an average-sized face. The height offset h of the face is computed with known opening angle of the camera of $45°$. With known distance e of the eyes (in their initial position)

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to the camera, distance d of the face to the camera, and height offset h, the required tilt angle α can be determined exploiting the geometric properties of the recording setup:

$$\alpha = \mathrm{atan}(\frac{e+h}{d}) \tag{1}$$

The target tilt angle is smoothed over time in order to account for outliers resulting from erroneous estimation of d. Then, this angle is used as a target angle for the robotic head.

The chosen implementation of the face detection together with the properties of the hardware actuators of the robot is fast enough to provide fluid head and eye movements. Employing such a motion model results in natural-looking head movements.

4 Use case: Tic-tac-toe game

Tic-tac-toe (also known as noughts and crosses) is a simple two-person strategy game. On a 3x3 playing board, players alternatively mark the spaces with their symbol (circle or cross). The first player to mark a horizontal, vertical or diagonal row with three of his symbols wins the game. If neither player manages to mark a row of three symbols before the grid is full, the game ends in a draw.

This game was chosen for integration because of the simplicity of its rules, the short playing time and because it is widely known. For almost none of the users, an explicit explanation of the rules is necessary. It is not very tedious to play one round of the game (compared to, e. g. chess) and even after playing a couple of rounds, the user will not be bored too quickly. In addition, the game is well suited for speech control due to the possibly limited vocabulary. Beyond some commands for game settings and to start a new game, only nine different decisions (one for each field) are possible.

4.1 Graphical User Interface

The implemented graphical user interface (GUI) of the game is shown in Fig. 6.

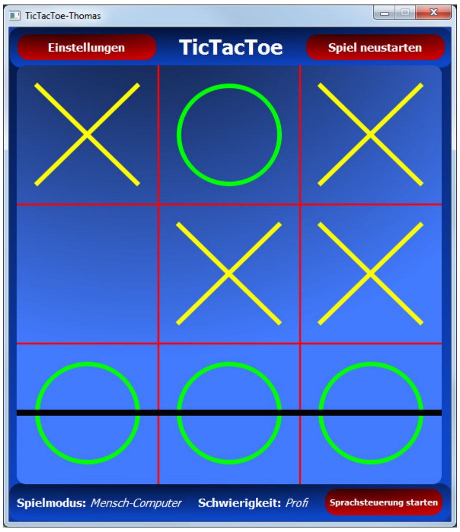

Figure 6: Graphical User Interface of the integrated Tic-tac-toe game.

To keep the GUI simple and neatly arranged, it consists of the 3x3 playing grid and buttons to start a new game and to adjust the game settings. The current game settings are always displayed on the main window. The game can be played either by two human players against each other or versus the computer player. When playing against the computer played, it can be chosen if the computer or human player should begin. In addition, there are two different game engines for the artificial intelligence available.

4.2 Game engine

Two different kinds of game engines have been developed to control the computer player of the Tic-tac-toe game. Using a set of rules, an optimal strategy can be applied, which always leads to a win or draw. A simplified version of this optimal strategy has been implemented. Therefore it is very challenging (but not impossible) to win against the computer. In addition, to give the human player a better chance to win the game, a simple computer strategy is integrated, where always a random field is chosen. Using the settings button from the main GUI, the user can choose between these two degrees of difficulty.

5 Experiments

Preliminary experiments have been conducted with users to test the design of the GUI and the dialogue system including speech control. The GUI was rated very good and especially the large buttons were commented positively. Using speech control was judged to be very convenient and fault-resistant. The integrated human-inspired head movement model was very well appreciated. This behaviour equipped the robot with a certain human-likeneess and brought it to life. In general, the system was highly appreciated and accepted by the users and due to the design

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of the dialogue system, it showed a high robustness against speech recognition errors. Further experiments will show the influence of the head control module on the likability of the robot.

6 Conclusions

We have described our robotic system ALIAS which, within the ALIAS project, is equipped as a communication platform for elderly people. One aspect of the robot is entertainment. Therefore, we integrated a simple strategy game with an easy-to-use interface. The game can either be played by directly using the touchscreen or via speech commands.

The robot can be used to play the game without any need for instructions: The rules of the game are known to almost everybody, the ASR needs no training phase and covers most of the keywords the users will naturally use, and in addition, the game can also by played by using the touchscreen. This leads to a high acceptance of the system and provides the possibility to study the user behaviour when facing a robot without any given instructions.

The presented robotic system is easily extendable and the involved components can be used to develop more entertainment applications. More complex demonstration scenarios using the components described in this paper are in development.

In the future, we will use the features of the robot (e. g. the row of LEDs) to display basic emotions, which leads to a higher immersion.

7 Acknowledgements

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