What can I do for you? Appearance and Application of Robots

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Abstract. In recent years industrial robots have been successfully established because they fulfil meaningful tasks in production. In contrast the question of applications for social robots is still open. For quite some time they have only been used in research or at best as simple toys by real users in everyday life situations. However, we suggest that there are still unknown application fields that are suitable for existing robots. Therefore, our approach is to show short movies and descriptions of real robots to participants and ask whether there are any specific tasks these robots could perform in the naive users' everyday life. The systems' appearance and abilities strongly influence the user's expectations, that's why we suppose that we will find strong differences between zoomorphic robots like AIBO and iCat and other robots like BIRON (functional design) and BARTHOC (humanoid). We have conducted an online study with more than 100 participants to test this hypothesis.

1 Introduction

Developing useful applications for social robots seems to be a challenging task. At least today's scenarios are almost restricted to research and toys. Developers try to anticipate new applications but potential users are rarely included into this process. We argue that knowing consumers' opinions is important in order to design useful applications. This paper will introduce a first study with potential users. It focuses on robotic animals and compares them to a functional and a humanoid robot, respectively.

Beside market aspects, we argue that applications also offer attractive scientific aspects. First, many functional as well as socially relevant aspects are only observed when realistic applications are faced. Secondly, a thorough evaluation of the robot performance that includes social aspects of human-robot interaction gains significance from well defined application scenarios. Especially naive users need self-explaining robotic systems in order to get valid results in user studies. This can be supported by well motivated application scenarios.

In Section 2 we will introduce related work which gives a first impression of today's applications and the role of appearance in robotics. Section 3 describes the robot platforms AIBO, iCat, BIRON and BARTHOC which were shown to the participants during the trials. In Section 4 the method of the online study is explained in detail. Afterwards the results are presented in Section 5. The paper closes with a conclusion in Section 6.

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2 Related Work

In this section we will introduce related work beginning in Section 2.1 with a description of applications from a research perspective. Section 2.2 will go deeper into everday applications and Section 2.3 presents the relationship between the appearance of a robot and its applications.

2.1 Applications from a Research Perspective

Social robots have been a focus of research for several years. Most of them have been developed for a dedicated scenario that is defined in order to demonstrate skills and features of the robot rather than in terms of applications. For example, the MIT robot Leonardo is learning the names of buttons from human demonstration [4], the robots Ripley and its successor Trisk learn to integrate different modalities [24]. The robots SIG [21] and Robita [27] focus on multiple speaker tracking and conversation participation. Others demonstrate fetch and carry tasks (e.g. Hermes [2]), object manipulations on a table [5, 20], or human guided spatial exploration [26]. In the same line, the AAAI conference 2002 defined robotic challenges that included social abilities. The robot had to start at the entrance to the conference centre, needed to find the registration desk, register for the conference, perform volunteer duties as required, then report at a prescribed time in a conference hall to give a talk [25].

As impressive as the demonstrated robotic skills are, these scenarios are still far from market relevant applications and miss certain evaluation aspects.

2.2 Everyday Applications

Robots are not part of everyday life yet. We have to think about what their place in our public and private life could be. Therefore, the first important step is to ask what would actually make social robots valuable as everyday objects. One possibility is to find out which qualities objects have in our everyday life as short-term or long-term applications [17]. Furthermore, the value of the objects has to meet the needs of the users.

Fong et al. [10] propose several application fields: social robots as test subjects for research on communication and human development theory, as short-term and long-term service assistants in public and private life, as toys and entertainment devices, for therapy, for research on anthropomorphism, and last but not least in the field of education.

In a workshop on designing robot applications for everyday environments, organizers and participants brainstormed on new application scenarios [18]. After refining their ideas they selected three application concepts: self-organizing robot plants, robots as travel companions, and amusement park guide robots. This was a first official workshop which tried to find new applications in social robotics. As can be seen, there are few approaches to find applications for social robots, but neither one considers the needs and opinions of potential users.

2.3 Appearance and Expression of Robots

The appearance of a robot influences what the interacting users expect and how they will judge a certain application. The appearance of a robot becomes especially important when assessing its performance and appropriateness for an application. Humanoid and animal robots convey anthropomorphic cues that get the user to make several attributions concerning the robot's abilities. Thus, because of the appearance, a user has expectations whether an application for a specific robot is appropriate or not [13]. The more human attributes a robot has, the more it will be perceived as a human [9] and the more the appearance is expressing human traits and values [8]. If a robot looks like an animal it will express the traits this specific animal has.

Most nonverbal cues are mediated through the face. A robot's physiognomy changes the perception of humanlikeness, knowledge, and sociability. People avoid negative robots and feel more common ground interacting with a positive expressive robot [12]. Furthermore, an expressive face indicating attention [6] and imitating the face of a user [16] makes a robot more compelling to interact with. Also, faces with large eyes and small chins in proportion to the rest of the face are so called baby faces. Men with baby faces are perceived more honest, kind, naive, and warm. The same happens with robots if they have a baby faced design [22].

We want to resume, that users rate applications of a robot more or less appropriate because of its appearance and expression. Therefore, the design of a robot is an indicator for its application.

3 Technical Description

This section gives a short technical overview of the robot platforms presented to the users during the survey. Each of the four robots shown is used for research.

3.1 iCat

The Philips iCat research platform shown in Figure 1 is a plug & play desktop user-interface robot which is capable of mechanically rendering facial expressions. It is developed by Philips Research (Eindhoven, the Netherlands).

The robot platform contains 13 RC servos controlling the eyebrows, the eyelids, the eyes, and the lips and two DC motors for moving the head and the body which enable the iCat to create facial expressions. Four multi-colour RGB-LEDs and capacitive touch sensors are located in the feet and the ears. The iCat can communicate its mode of operation (e.g. sleeping, awake, busy, or listening) with these LEDs. A USB webcam with a resolution of 640×480 pixels and 60 fps is placed in the nose. Therefore, the iCat can be used for different computer vision tasks, such as object and face recognition. Stereo microphones, a loudspeaker and a soundcard can be found in the feet of iCat and are used for playing sounds and speech. Thus, it is possible to record speech and to use it for speech recognition and understanding tasks. Finally, the robot is equipped with an IR proximity sensor.

Figure 1. The Philips iCat research platform.

The iCat is a user-interface robot without an on-board processor. It can be controlled by a PC via USB. Researchers can use the Open Platform for Personal Robots (OPPR) software which provides a development environment for creating applications for user-interface robots. More details can be looked up in [23]. This website provides the infrastructure for supporting an online research community.

3.2 AIBO

The Sony AIBO Robot ERS-7 is presented in Figure 2. Its design is quite dog-like. AIBO has sensors on the head, the back, the chin, and the paws which allow the robot to examine itself and its environment.

Figure 2. The Sony AIBO ERS–7.

Moreover, it can perceive sound using a pair of stereomicrophones. Therefore, it can react to voice. Because of the colour camera and distance sensors AIBO can recognise colours, faces, and obstacles. It is able to communicate its mood via sounds and a face display and via words with humans.

AIBO is using its four feet to act in its environment. With the acceleration sensors on-board it is able to balance its body. AIBO has – considering its feet, head, ears, and tail – altogether 20 joints (degrees of freedom) which give the robot the capability to perform dog-like moves. Consequently, one application for AIBO – Sony had in mind – is the so-called watchdog scenario. The robot can guard its home by taking photos of unusual things and informing its owner via email. More information about the AIBO platform can be found in [7].

3.3 BARTHOC

Figure 3 gives an impression of the humanoid robot BARTHOC (Bielefeld Antropomorphic RoboT for Human-Oriented Communication) [15]. This robot is designed by Bielefeld University in cooperation with Mabotic for research in human-like communication. The main focus of the design is to realise the expression and behaviour of the robot to be as human-like as possible. It can mimic human behaviour like speech, facial expressions, and gestures with his soft- and hardware.

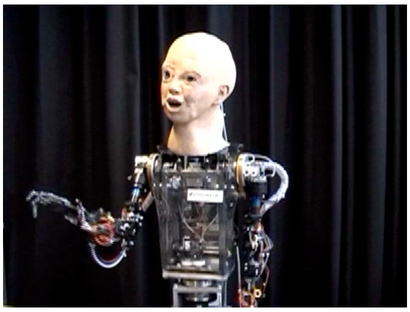

Figure 3. The humanoid robot platform BARTHOC (Bielefeld Antropomorphic RoboT for Human-Oriented Communication).

The anatomy of BARTHOC consists of a mechatronic head and two arms including hands. These components are mounted on a steel-frame backbone.

Each arm has three joints similar to the human ones. The given degrees of freedom (DOF's) allow BARTHOC to perform human-like gestures. The joints of hip, shoulders, upper and lower arms are driven by planetary geared DC motors with position feedback via precision potentionmeters. The hand is constructed as an external actuator type. Each finger is built with three spring pre-stressed joints driven by a flexible, high strain resistant nylon cable.

A complete mechatronic head has been developed with a more human-like appearance and human-like features. A camera is integrated in each eyeball for stereo vision and microphones are currently placed on the shoulders. Additionally, a removable latex mask is constructed to give the possibility to exchange characters. Actuators next to the upper lip and above the eyes simulate movements of lips and eyebrows. The movements drive the mask to express basic human facial expressions.

3.4 BIRON

The Bielefeld University developed a mobile robot platform called BIRON (BIelefeld RObot companioN) (see Figure 4). BIRON is based on an ActiveMedia Pioneer PeopleBot TM.

A Sony EVI D–31 pan-tilt colour camera is mounted on top of the robot at a height of 141cm for acquiring images of the upper body part of humans interacting with the robot. A pair of AKG far-field microphones is located right below the touch screen display at a height of approximately 106cm. Therefore, BIRON has the capability to localise speakers and process speech. Finally, a SICK laser range finder mounted at a height of 30 cm facing front measures distances within a scene. Since BIRON has wheels, it is able to move and to follow a person.

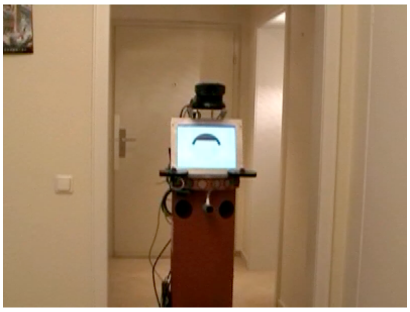

Figure 4. BIRON the BIelefeld RObot companioN.

The robot is equipped with two on-board computers. The first one is controlling the motors, on-board sensors, and performing the sound processing. The second one is used for image processing, especially skin-colour segmentation, face recognition, and face identification.

As BIRON can track humans and pay attention selectively to humans looking at it, a first application for the robot is the so-called home-tour scenario. In this scenario a human introduces all objects and places in a private home to the robot which may become relevant for later interaction. Additional information about the architecture of BIRON is given in [14].

4 Method

In our study we were mainly interested in the following questions:

- Which applications are proposed?
- Are there any differences between proposed applications for the robots according to their appearance?
- Which applications do people propose especially for zoomorphic robots? and
- What is people's attitude towards using zoomorphic robots?

We decided to conduct an internet survey for several reasons. First of all, interaction studies are very time-consuming. In contrast, online studies are very fast and provide a manifold sample. Therefore, they represent an alternative to traditional methods, especially when conducting highly exploratory studies [1]. Moreover, the internet survey – in which only short videos of each robot were shown to the participants – supports the general idea of the study. Subjects should only have a first impression of the robots. Thus, their assumptions are mainly based on the appearance of the robots and the information given about their functions. Their ideas were not restricted by technical problems which might have occurred in real settings.

We published the questionnaire on the website of an online laboratory and invited people via private and professional mailing lists to participate. Therefore, one part of participants was random users who visited the website of the laboratory and took part in the survey. Subjects who received an email are part of a deliberate sample because the mailing lists were chosen by the researchers. The sample is not representative because it only includes subjects that are using the internet frequently or have interest in psychology, surveys in general or robotics. Therefore, the results can not be generalised [3], which in any case is not the claim of the study.

The survey was conducted during one week in January 2007 with 113 participants (39,3% female, 60,7% male). Their age ranged between 9 and 65, with an average of 30,2 years. The majority is educated above average (highest degree: 34,5% high school graduates; 55,8% university graduates; 8,0% doctoral degree, 1,7% other). Nevertheless, we are of the opinion that the diversity of our sample is higher than in student samples which are often used in robotics research (Table 1). Subjects are naive in the sense that they are not working in the field of robotics. Most of them have German nationality (Table 2) which is due to the fact, that the questionnaire was published in German. Related to this, one more advantage of online-surveys is, that we will have the possibility to amplify the study by publishing the questionnaire on the web in different languages.

	n	percent
student	2	1,8%
university student	45	39,8%
employed	58	51,3%
unemployed	1	0,9%
others	7	6,2%
total	113	100%

Table 1. Participants' professional status.

	n	percent
Germany	102	91,1%
Switzerland	1	0,9%
Austria	3	2,7%
others	6	5,4%
total	112	100%

Table 2. Participants' nationality.

The study reported here is highly exploratory. Thus, the questionnaire contains several open questions. It is divided into introduction, sociodemographic questions and application questions for each of the four robots (e.g. Would you use this robot?; Which meaningful applications can you imagine for this robot?). For all of them a short video was shown, which illustrated their appearance. Figure **??** shows a screenshot of the questionnaire.

Especially the open questions concerning the applications are of interest for this paper. Participants were free to write down as many items as they could think of. Altogether, a fairly high number of 495 applications were mentioned (AIBO 148, BARTHOC 90, BIRON 120, iCat 137). Therefore, a content analysis in order to group the data was essential [11, 19]. The entries were analysed by three researchers. First, they were structured into more restrictive categories for each robot and then grouped into wider classes. The number of entries in each class was rechecked with the data. If people mentioned the same application twice for the same robot, only one entry was coded. Some people wrote remarks like "just as first robot". These answers were not coded because the order in which the robots were shown to the participants changed randomly. Subjects needed an average of 11min 32sec ($x_{\mathrm{med}} = $ 7min 40sec) to complete the questionnaire.

5 Results

In this section we want to introduce the results of the study and outline some interesting discoveries concerning the distinct perception of AIBO and iCat. As described above we defined categories of applications which are listed in Table 3. Within the table, groups, which assimilate different categories, are specified. An example is given for each category.

Obviously, the categories have different levels of abstraction which is due to the varying complexity of the applications. Moreover, it is important to mention that these categories can only provide an insight into the applications for the four robots tested. Nevertheless, they give a first idea how naive people view robotics. We are aware of the possibility to further reduce and structure the categories introducing broader dimensions. However, this is not the goal of this paper because we want to give an overview of the diversity of applications mentioned by the participants. We decided not to include the two following categories in Table 3. Seven participants stated that BARTHOC could be used for a horror film or haunted house, because they thought that his appearance was very frightening. We think these comments are rather ironical than useful applications. Nevertheless, they are a hint that we have to keep working on the appearance of BARTHOC. Furthermore, three industrial applications were mentioned which are not subject of social robotics.

Moreover, Table 3 sums up the applications subjects mentioned for all the robots which were shown to them. The question which applications users ascribe to AIBO and iCat has still to be answered. We noticed that many tasks proposed for AIBO are typical for a dog (guard dog, guide dog, fetch and carry tasks). Even more people stated that they could imagine the robot as toy and pet, which is also proposed by the developers (Section 3.2). iCat was also seen as a toy but surprisingly only few people thought of the robot as a pet. A reason for this phenomenon might be seen in the appearance of the robot which is only a torso and not a complete cat. It also doesn't have the functionality of a real cat. This might as well explain why no cat-like tasks such as "chasing mice" are attributed to iCat. Altogether, it is less similar to a cat than AIBO to a dog. Besides being used as a toy people uttered that iCat might be employed as a teacher (especially for languages) or for surveillance. One application which was brought up by six subjects exclusively for iCat was using the robot as an interface to control other technical devices. Since this is a scenario described by the developers (Section 3.1) one could think that the participants knew iCat. Surprisingly, they didn't say so in the questionnaire.

There's a huge gap between applications mentioned for AIBO or iCat and tasks people ascribe to the other robots. The most commonly mentioned applications for BIRON were Surveillance, Information

Category	Specification	Example	(a)	(b)	(c)	(d)	total
Security	Surveillance Military tasks Dangerous tasks Exploration Security	"the robot should watch my house"	4	14	19	27	64
Research	Research Robocup	"research in heuristics of movement"	4	1	8	2	15
Healthcare	Therapy Help for the sick and old	"help for people with disabilities"	5	14	13	5	37
Personal assistant, Interface	Personal assistant Butler Organizer Interface Household / Cleaning	"for programming VCR, TV, . . . " "electronic butler"	3	13	4	27	47
Business	Sales Reception Representation	"the new generation of ticket machine" "the robot could welcome people"	28	10	1	10	49
Public assistant	Guide (e.g. museum) Informationterminal Translator	"Infoterminal where it is needed"	25	11	5	36	77
Toy		"to play soccer"	3	38	46	1	88
Pet		"replacement pet"	0	5	18	0	23
Entertainment		"to entertain and to kill time"	2	8	9	0	19
Teacher (e.g. language)		"conduct tutorials", "language trainer"	4	16	3	3	26
Transport (fetch & carry)		"maybe it could fetch the newspaper"	2	0	11	5	18
Companionship for lonely people		"to keep company"	1	1	8	2	12
Caregiver for old/sick people or children		"to look after old people and children"	1	6	3	0	10

Table 3. Categories of applications, specification and examples; applications mentioned for the robots (a) BARTHOC, (b) iCat, (c) AIBO, (d) BIRON.

Terminal and Guide. BARTHOC was seen as Information Terminal, Sales Robot (e.g. ticket machine) and Receptionist. All these applications are rather "serious" in nature. These two robots were not associated with toys at all.

In the following we want to point out some more interesting results connected to the applications mentioned by the subjects. One important insight is that the majority of participants refuse to use a robot no matter what it looks like (Table 4). There are only slight differences for the robots researched in this paper. One tendency to be found is that the highest number of subjects would use BIRON, the rather functional robot.

	n	yes	maybe	no
BARTHOC	108	11 (10,2%)	27 (25,0%)	70 (64,8%)
iCat	110	12 (10,9%)	28 (25,5%)	70 (63,6%)
AIBO	107	16 (15,0%)	24 (22,4%)	67 (62,6%)
BIRON	104	23 (22,1%)	26 (25,0%)	55 (52,9%)
Average		14,5%	24,5%	61,1%

Table 4. Willingness to use robots.

We also asked (a) which robot participants would like to own, (b) which they think is most enjoyable to interact with, and (c) which robot is most likeable (see Table 5).

	n	BARTHOC	iCat	AIBO	BIRON
a)	97	6 (6,2%)	18 (18,6%)	41 (42,3%)	32 (33,0%)
b)	100	9 (9,0%)	17 (17,0%)	57 (57,0%)	17 (17,0%)
c)	96	3 (3,1%)	38 (39,6%)	46 (47,4%)	9 (9,4%)

Table 5. Rating of the questions (a) Which robot would you like to own? (b) Which robot is most enjoyable to interact with? (c) Which robot is most likeable?

At first sight there seems to be a contradiction between subjects stating they wanted to use BIRON most and the preference for owning AIBO. Looking at the applications mentioned for BIRON it becomes obvious that participants ascribe tasks in the public like "guide" to it which explains the difference. The majority of participants (57,0%) thinks that interaction with AIBO would be most enjoyable and rate AIBO (47,4%) and iCat (39,6%) as most likeable (Table 5). This might be due to appearance, social cues or familiarity. This question should be addressed by further research. Nevertheless, no matter why people prefer the robotic animals when asked for likeability, the results indicate, that zoomorphic design might be recommendable for future systems.

6 Conclusion

In this paper we tried to show in a first exploratory study that users should be included in the process of finding new applications for social robots. We propose that this is essential especially for the increasing number of off-the-shelf robotic platforms. A carefully designed application needs to consider a frequent tendency of users to reject all kinds of social robots. Furthermore, we found that the appearance of a robot strongly influences the user's perception. Thus, it should - as well as the functionality - be in the focus of design decisions. In contrast to the humanoid robot BARTHOC and the functionally designed robot BIRON, AIBO and iCat are above all seen as toys. Future development will show whether their appearance is also suited for other applications like robotic interfaces, business, or security.

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