

Classes of Applications for Social Robots: A User Study

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Abstract – The paper introduces an online user study on applications for social robots with 127 participants. The potential users proposed 570 application scenarios based on the appearance and functionality of four robots presented (AIBO, BARTHOC, BIRON, iCat). The items were grouped into 13 categories which are interpreted and discussed by means of four dimensions: public vs. private use, intensity of interaction, complexity of interaction model, and functional vs. human-like appearance. The interpretation lead to three classes of applications for social robots according to the degree of social interaction: (1) Specialized Applications where the robot has to perform clearly defined tasks which are delegated by a user, (2) Public Applications which are directed to the communication with many users, and (3) Individual Applications with the need of a highly elaborated social model to maintain a variety of situations with few people.

I. INTRODUCTION

The general objective of social robots research is to design robots that engage in social scenarios which are compelling and familiar to humans. Thus, robots have to provide a social communicative functionality that is natural and intuitive. Today, simple social robots are sold as toys and more complicated systems are used for research – but these are far from being commercial products even though researchers developed many different social robots performing various aspects of social functionality.

Research on applications offers attractive scientific challenges: 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 for naive users robots need to be self-explaining. This can be supported if appearance and functionality fit the robot's tasks. Altogether, there is a lack of application scenarios and classifications. Researchers do not know what potential users wish to have although knowing consumers' opinions is important for designing useful applications. Users are rarely included into the process of finding and developing new scenarios.

In our work we address this lack of systematic research for robot applications. This paper introduces an online study with potential users which were asked to suggest relevant applications. Our work focuses on applications for the four robots *AIBO* (Sony), *iCat* (Philips), *BIRON* (Bielefeld Uni-

versity) and *BARTHOC* (Bielefeld University).

Section II gives an overview of research on applications and appearance of robots. Section III describes technical details of the four robots used in the survey. Section IV explains the method of the user study and Section V presents results and discussion. Finally, Section VI gives a conclusion of the paper.

II. RELATED WORK

Social robots are physical entities embodied in a complex, dynamic, and social environment sufficiently empowered to behave in a manner conducive to their own goals and those of their community [1]. They form a subclass in the field of robotics and began to evolve due to a need for systems which are able to communicate naturally also with naive users. So far many social robots have been built mainly to demonstrate technical skills within very specific scenarios [e.g. 2,3]. Even though such robots enabled huge advances in research, they are far from being off-the-shelf consumer products. In contrast to current development social robots should become everyday life applications in order to take advantage of their ability to communicate with almost everybody.

In a first survey of social robotics Fong et al. [4] mentioned 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. Ljungblad [5] reported on a workshop held with the goal to create potential applications. As a result three interesting scenarios were selected: self-organizing robot plants, robots as travel companions, and amusement park guide robots.

Kaplan chose a different approach [6]. By asking what would actually make social robots valuable as everyday objects, he came to the conclusion that the value of the objects has to meet the needs of the users. Thus, the robot has to find its place in human life by adding value to it in terms of short- or long-term usage.

The place that a social robot acquires in everyday surroundings depends mainly on its application, functionality and appearance. Appearance has a major influence on the assumptions people have about applications and functions [7, 8]. Current research states that the appearance has to support

the correct estimation of the robot's real competencies by the user. The better his estimation the less the user will be disappointed during interaction [6]. All the more, it is surprising that research has hardly focused on appearance so far [9].

Among very few approaches Fong et al. [4] define four broad categories of social robots: antropomorphic, zoomorphic, caricatured, and functional. Anthropomorphism is described as tendency to attribute human characteristics to objects and animals in order to interpret their actions correctly [10]. According to Duffy a robot has to have a certain degree of anthropomorphic qualities for meaningful social interaction. In this context, DiSalvo proposes three categories which should be taken into account when designing robot heads [9]: a certain amount of robot-ness to stress the robots machine capabilities and avoid false expectations of its emotional capabilities; an amount of human-ness to make the user feel comfortable; and a certain amount of product-ness that the robot is seen as an appliance. The design of the head is very important in HRI because it has been shown that most non-verbal cues are mediated through the face [11]. A robot's physiognomy changes the perception of its human-likeness, knowledge, and sociability. People avoid negative robots and prefer to interact with a positive robot [12]. Furthermore, an expressive face indicating attention [13] and imitating the face of a user [14] makes a robot more compelling to interact with.

Zoomorphic robots are inspired by animals (often household animals) or have a creature-like appearance. Humanoid and animal robots convey anthropomorphic cues that get the user to make several attributions concerning the robot's abilities. 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[15]. If a robot looks like an animal it will express the traits this specific animal has.

Caricatured robots exaggerate distinctive features and functional design is based on the tasks the robot has to perform [4].

These categories are of interest for us, as we will include two zoomorphic, a humanoid and a functional robot in our research. The platforms are introduced in the following section.

III. TECHNICAL DESCRIPTIONS

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

A. AIBO (Sony)

The AIBO Robot ERS-7 is presented in Figure 1 (A). The design of AIBO is quite dog-like. The robot has a set of sensors on the head, the back, the chin, and the paws which allow AIBO to examine itself and its environment. It can perceive sound using a pair of stereomicrophones. Therefore, it can react to voice. Because of the color camera and distance sensors AIBO can recognize colors, faces, and obstacles. It is able to communicate its mood via sounds, a face display, and speech.

AIBO is using its four feet to act in its environment.

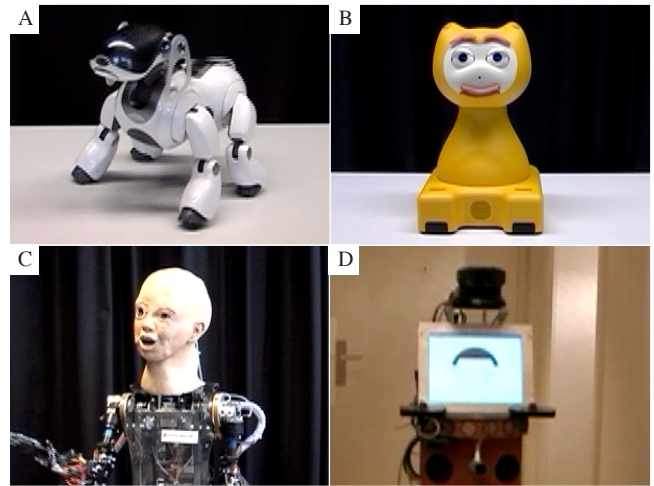


Fig.1 (A) AIBO, (B) iCat, (C) BARTHOC, and (D) BIRON

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. More information about the AIBO platform can be found in [16].

B. iCat (Philips)

The iCat research platform shown in Figure 1 (B) is a plug & play desktop user-interface robot developed by Philips Research (Eindhoven, the Netherlands). The iCat is a user-interface robot without an on-board processor. It can be controlled by a PC via USB.

The iCat can create facial expressions by moving its eyebrows, eyelids, eyes, lips, and the head. It can communicate its mode of operation (e.g. sleeping, awake, busy, or listening) via LEDs located in the feet and the ears. The USB webcam in the nose of iCat can be used for different computer vision tasks, such as object and face recognition. Stereo microphones, a loudspeaker and a soundcard placed in the feet of iCat are used for playing sounds and speech. Thus, it is possible to record speech and to use it for speech recognition and understanding tasks. More details can be looked up in [17].

C. BARTHOC (Bielefeld University)

Figure 1 (C) gives an impression of the humanoid robot BARTHOC (Bielefeld Antropomorphic RoboT for Human-Oriented Communication) [18]. This robot is designed by Bielefeld University in cooperation with Mabotic for research on human-like communication. It can mimic human behavior like speech, facial expressions, and gestures.

BARTHOC consists of a mechatronic head with human-like features 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. Actuators next to the upper lip and above the eyes simulate movements of lips and eyebrows which leads to basic human facial expressions. A camera is integrated in

each eyeball for stereo vision and microphones are currently placed on the shoulders.

D. BIRON (Bielefeld University)

The robot platform BIRON (Bielefeld ROBot companion) (see Figure 1 (D)) developed at Bielefeld University is based on an ActiveMedia™ Pioneer PeopleBot.

The mobile robot is equipped with a pan-tilt color camera at a height of 141 cm 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 106 cm. Therefore, BIRON has the capability to localize 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 follow a person and to move in a room. Additionally, it is able to track people and pay attention selectively to humans looking at it. Further technical information about the architecture of BIRON is given in [19].

IV. METHOD

The research presented in this paper is based on an internet survey. The method is described in depth in [8]. The questionnaire was published in German on the website of an online laboratory. Moreover subjects were invited via private and professional mailing lists. Participants needed an average of 11min 21sec (xmed=7min 40sec) to complete the questionnaire.

The first part of the study consisted of general questions about the participants. Altogether 127 people participated in the survey (61% male, 39% female). Their age ranged between 9 and 65 years (average=27,4). The educational background of the subjects was: 32,3% high school graduates; 55,9% university graduates; 9,5% doctoral degree; 2,3% other. However, the participants can be seen as 'naive' users in the sense that they are not working in the field of robotics. Table 1 gives an overview of the subjects' current professional status.

The second part of the questionnaire focused on the question which robots people know. The participants were allowed to enter multiple robots, but they should not put down more than five. In the third part of the questionnaire, participants were asked to suggest applications for the robots which were introduced to them in random order. All the participants in the survey got very basic information about the function of the four robots. For example, AIBO was described as a

robot with the ability of speaking and understanding speech, it can walk and recognize objects. Additionally, the participants watched a video which shows one movement of each system just to give an impression of the robot's form. Afterwards they had to name applications. Since the study was exploratory in its nature this question was an open question and the subjects were free to write down as many items as they could think of. Moreover, they had to rate for each robot whether they would use it. At the end of the questionnaire the participants were asked to decide:

- Which of the robots shown would you like to own?
- Which robot is most enjoyable to interact with?
- Which robot is most likeable?

For further analysis we developed a method to classify the applications. First, a content analysis was conducted [8]. Three researchers rated the applications mentioned by the participants of the study independently. Second, the applications were grouped into categories. The method includes an interpretation which is subjective, but it serves as a tool to infer further insights. Third, for a distinction between the applications four dimensions are proposed:

- (1) *public vs. private use*: This dimension describes to which degree the application is suited for public or private use. For instance, a business robot is valuable for public tasks whereas a personal assistant is used at home. The place of use, private and public, correlates with long-term and short-term interactions, respectively.
- (2) *intensity of interaction*: The term intensity represents the frequency of the interaction in a certain time frame. It does not express how often the robot is used in general. For example, delegating a transport task to a robot is less intense than using it as a toy.
- (3) *complexity of interaction model*: The complexity of the interaction model defines how elaborate the social model of the situation is. For instance, a personal assistant has to acquire a complex user model of the owner which a security robot does not need.
- (4) *functional vs. human-like appearance*: Form is eliciting expectations of how the robot behaves. Thus, the more human-like a robot looks the more it is expected to behave like a human. For example, a transport robot doesn't need a human-like design to manage its task whereas it might be advantageous for a robot in health care.

V. RESULTS AND DISCUSSION

This section presents the results of the study starting with general insights. Afterwards the relations between place of use and frequency of interaction and between complexity of interaction model and form are discussed. Finally, three classes of applications for social robots are proposed.

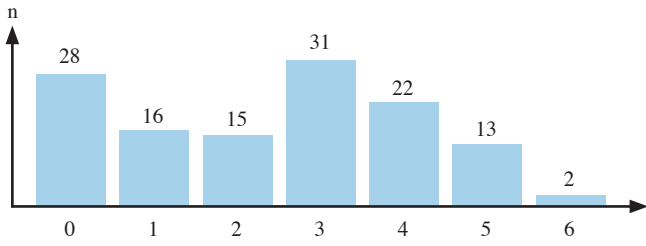
A. General Results

In the questionnaire the participants were asked to write down robots that came to their mind. Altogether 284 entries

Table 1. Professional status

	n	%
Student at School	2	1,6%
University Student	46	36,2%
Employed	70	55,1%
Unemployed	1	0,8%
Other	8	6,3%
Total	127	100%

Table 2. Number of robots mentioned



were made. Table 2 shows how many robots were named by the participants (average=2,39, SD=1,73). Table 3 lists the robots mentioned. The different robots known from movies and TV are grouped, because for this paper it is not important to distinguish them. It is obvious that most people think of industrial systems and robots from movies, TV and other media. Thus, it is even more surprising that 23 people mentioned AIBO and 18 wrote soccer robots, which in our opinion are closely associated with Sony’s robotic dog. None of the other robots used for research in this study was listed. Therefore, it seems especially interesting to evaluate whether knowing a particular robot will influence peoples’ attitude towards it. This question will be answered later in this section.

After writing down the robots they knew, the participants were asked to propose applications for AIBO, BIRON, BARTHOC, and iCat. Altogether 570 items were mentioned (see Table 4). There is a strong correlation between applications proposed for AIBO and iCat ($r=.77$; $p<0,01$ (two-tailed)). This might be due to their zoomorphic appearance. There was no correlation between the other robots. Gender and age do not have a statistically significant influence on subjects’ answers.

Altogether, there seems to be a widespread rejection to using robots (Table 5). As Kaplan [20] argues this is typical for Western in contrast to Japanese culture. Another reason might be that we still lack applications which add some value to peoples’ lives [6]. Although the participants rejected using the robots in general they preferred AIBO when asked which robot they would like to own, they found most enjoyable to interact with, and they regard as most likeable (Table 6). Answers to all three questions are correlated as can be seen in the table as well. Our results indicate that the preference for

Table 3. Robots named by the participants

Industrial Robots	49
TV and Media	71
AIBO (Sony)	23
Asimo (Honda)	14
Mindstorms (Lego)	9
Robots from Soccer	18
Service Robots	21
Mars Explorer	10
Toy Robots	6
Medical Robots	5
Other	58
Total	284

Table 4. Suggested application categories

Applications	AIBO	BARTHOC	BIRON	iCat	Total
Security	23	5	32	17	77
Research	11	4	2	1	18
Health Care	16	7	7	16	46
Personal Assistant / Interface	7	3	30	14	54
Toy	55	5	1	44	105
Business	3	32	12	12	59
Pet	20	0	0	6	26
Entertainment	10	2	0	8	20
Teacher	4	5	3	16	28
Transport	14	2	5	0	21
Companionship	8	2	2	3	15
Caregiver	3	1	1	6	11
Public Assistant	6	27	44	13	90
Total	180	95	139	156	570

AIBO is due to the fact that many people knew it before the study. We further found that many participants refused BARTHOC. Some participants even wrote that they find it scary.

B. Place of Use and Frequency of Interaction

Figure 2 (A) shows the evaluation of the 12 selected application classes depending on the place of use and the frequency of interaction. In this, as well as in the following figures, the size of the dots is determined by the number of entries for each application. For example, toys are usually tools for a home environment used in private life. Playing with a toy is characterized by a very intense interaction. In contrast, a security robot in public and private should work autonomously and not interact too often with its owners. The ratings indicated that a public assistant is not as interactive as a personal assistant. A personal assistant serves more as a

Table 5. Willingness to use the robot

	BARTHOC	iCat	AIBO	BIRON	average
n	122	124	121	118	
yes	9,0%	9,7%	15,7%	21,2%	13,9%
maybe	26,2%	25,8%	23,9%	27,1%	25,8%
no	64,8%	64,5%	60,3%	51,7%	60,3%

Table 6. Rating of the questions: (a) Which robot would you like to own? (b) Which robot is most enjoyable? (c) Which robot is most likeable?; Correlation between the answers: ** $p<0.01$.

	n	Barthoc	iCat	AIBO	BIRON	(a)	(b)
(a)	111	5,4%	17,1%	44,1%	33,3%		
(b)	114	9,7%	16,7%	57,0%	16,7%	.47**	
(c)	110	2,7%	39,1%	49,1%	9,1%	.41**	.33**

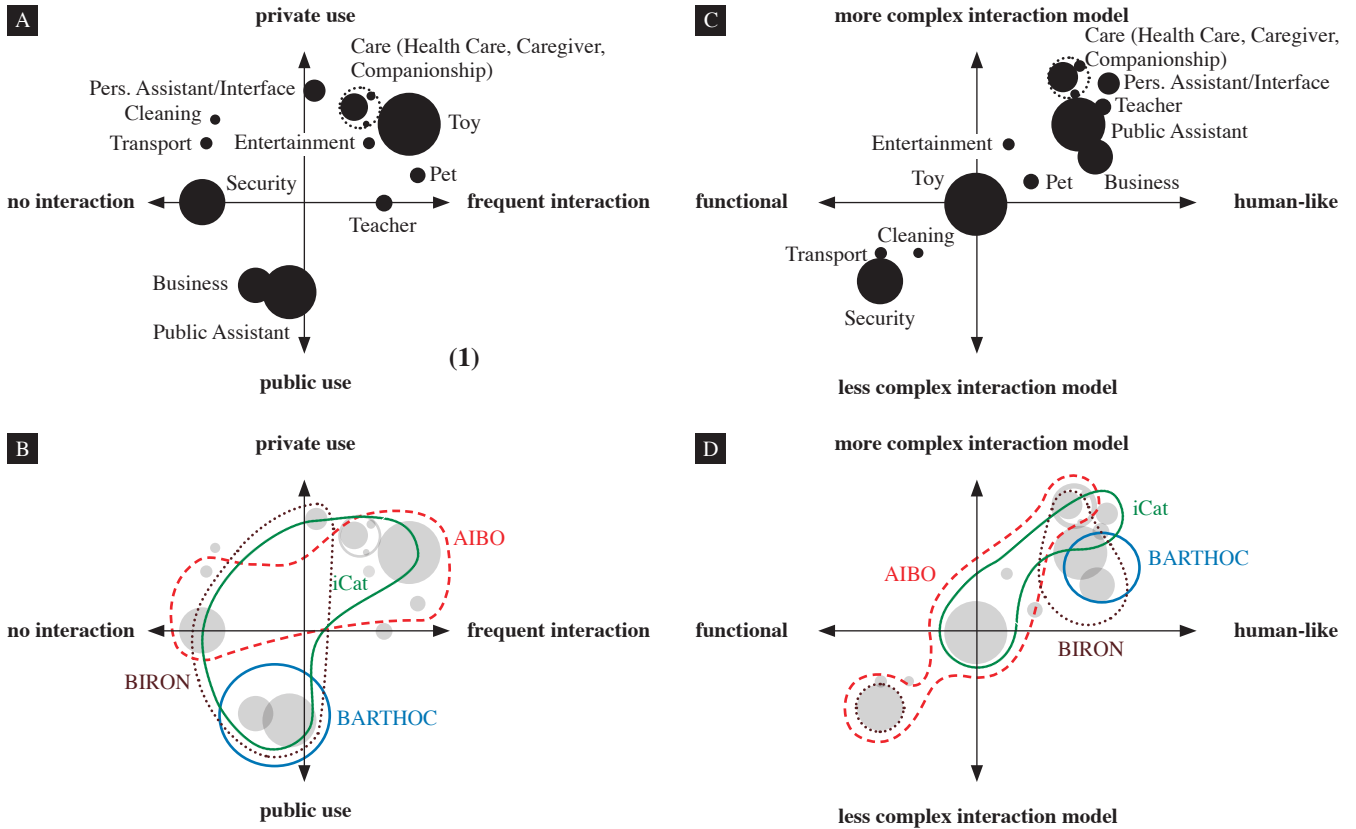


Fig.2 private and public uses and intensity of interaction of (A) applications and (B) robots, complexity of interaction and appearance of a robot of (C) applications and (D) robots

companion in private life while a public assistant gives some general information which usually is less frequent.

Altogether, we found a correlation between the frequency of interaction and the place of use. The more an application is used in a private context, the higher is the intensity of interaction.

In Figure 2 (B) each robot is mapped according to the applications mentioned. The map is derived from Figure 2 (A). For BIRON and BARTHOC the participants suggested mainly public applications which are characterized by less intense interaction. In contrast, many private scenarios for iCat and especially AIBO are proposed. Their intensity is much higher.

C. Complexity of Interaction and Form of a Robot

In Figure 2 (C) the relation between the complexity of interaction and the robots' form is presented. A strong correlation can be assumed. The more a robot looks like a human the more it is expected to behave like a human [21]. Complexity of interaction is a question of intelligent behavior – a human attribute. Applications like security, cleaning, and transport do not need a complex interaction behavior while personal assistants, teachers, and public assistants require some kind of human communication.

With only basic information about form and function the participants suggested applications within a social context which requires social robots. Only four industrial scenarios were mentioned.

From the raters point of view, most of the suggested applications, e.g. health care robots, imply the need for a more or less complex social behavior. On the other hand, the rating indicates that a robot that has to transport something does not need such a complex interaction structure. In this case the robot is rather a tool than a communication agent.

The mappings of the four robots in Figure 2 (D) represent this idea. BARTHOC and iCat have lots of human-like features. The applications subscribed to them are more complex which proves the hypothesis. AIBO covers the whole spectrum of tasks according to this categorization. It is mentioned as functional, because it should carry things which we interpreted as transport. BIRON is clustered in the field of human-like robots. This is probably due to its human-like features like speaking and understanding speech. Because of these features the participants suggested applications that are evaluated as complex and social.

Altogether, it becomes obvious that systematic differences can be found between the four robots and the applications mentioned for them. Due to these differences three classes of applications for social robots are determined which will be presented in the following section.

D. Three Classes of Applications for Social Robots

Based on Figure 2 (A-D) our results indicate three main classes of applications according to how social a robot has to be:

- (1) *Specialized Applications for Social Robots*
Specialized applications consist of clearly defined tasks which are characterized by less communication to a user. The robots rarely depend on elaborate social interaction. These applications take place as well in private as in public places.
- (2) *Public Applications for Social Robots*
Public applications are directed to lots of users and need a general communication model which is equal for all users. Adaptation is not required because interaction with public systems is usually short-term interaction. These robots need advanced models of social interaction.
- (3) *Individual Applications for Social Robots*
Individual applications are designed for complex everyday tasks in private life. These long-term applications require high communication skills and the ability to interact with a selected group of users. Thus, robots completing such tasks depend on highly developed social interaction skills. Especially, for the robots within this group a human-like appearance is profitable.

VI. CONCLUSION

This paper presents the analysis of an internet study. Participants were invited to suggest applications for the social robots AIBO, BIRON, BARTHOC, and iCat. 127 subjects proposed 570 items. These were grouped and analyzed with the help of the following criteria: public vs. private use, intensity of interaction, complexity of interaction model, and function vs. human-like appearance.

The results indicate that the majority of the participants could not envisage to use a robot even though they suggested relevant applications. Nevertheless, the robots were preferred if they were known by the subjects.

On the basis of the study we inferred three classes of applications for social robots: (1) Specialized Applications, (2) Public Applications, and (3) Individual Applications. These differ in the degree how social a robot has to be.

These classes are a first step towards an understanding of the relation between form and function of a robot – including its applications. They can be used as a tool to design form and functions of robots that fit the expectations people have about the tasks the robots perform.

VII. ACKNOWLEDGEMENTS

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