

Care-O-bot 3 — Rationale for human-robot interaction design

Christopher Parlitz*, Martin Hägele*, Peter Klein†, Jan Seifert† and Kerstin Dautenhahn‡

*Fraunhofer IPA

Nobelstr. 12, D-70569 Stuttgart, Germany

Email: {parlitz, haegele}@ipa.fraunhofer.de

†User Interface Design GmbH, Teinacher Str. 38, D-71634 Ludwigsburg, Germany

Email: {pklein, jseifert}@uidesign.de

‡ Adaptive Systems Research Group, School of Computer Science, University of Hertfordshire, Hatfield, Hertfordshire AL10 9AB, UK

Email: K.Dautenhahn@herts.ac.uk

Abstract—This paper presents the design rationale for a new service robot, Care-O-bot 3 that is meant to operate as a companion robot in people’s homes. Note, the emphasis in the paper is on the design of a companion robot as a product, not as a research prototype. The design is motivated from a multi-disciplinary viewpoint and compared to other approaches in the field which often focus on a humanoid appearance. In this paper we put forward an abstract design with iconic features. We argue that such a more ‘technomorphic’ design may be appealing to a potentially large user group. Potential target user groups of the robot are identified. The realization of such a design, including details on the robots mobile base and torso, manipulator, sensors, and remote interfaces are presented in the paper.

I. INTRODUCTION

It makes a great difference whether you may pursue a vision or whether you want to claim a market niche. Both aims are equally admirable. Still, not surprisingly they do require totally different strategies. We refrain from the notion of a humanoid robot in the short run and claim: the humanoid robot as a product is a matter of the less near future. Based on this, we would like to give an account of our strategy on how to design a household robot of the nearer future using established remote user interfaces and creating a unique external design for intuitive human-robot interaction.

II. PHYSICAL LOOK & FEEL: ANTHROPOMORPHISM OR TECHNOMORPHISM

Humans talk! They talk to other humans whom they suppose to be listening. But they do also talk to perfectly unsuited ‘fellows’. They talk with a *cranky* car, with a *headstrong* computer, with their *pushy* alarm clock, even with a *stubborn* ketchup bottle. [2] reports: 47% identify their vehicle by gender and nearly 26% had given it a name. [13] reports similar results about computers. The phenomenon

This work was partly funded as part of the research project DESIRE by the German Federal Ministry of Education and Research (BMBF) under grant no. 01IME01A and partially conducted within the Integrated Project COGNIRON (‘The Cognitive Robot Companion’ - www.cogniron.org) and funded by the European Commission Division FP6-IST Future and Emerging Technologies under Contract FP6-002020.

that humans attribute human-like characteristics, motives, or behaviour to inanimate objects is called anthropomorphism.

Anthropomorphism is a constant pattern in human cognition [4], [8], [19], [29]. The interaction of a human with a robot (or any kind of machine) can not completely elude it. However, we may want to keep such attributions to an absolute minimum. The engineer needs to decide whether to promote an anthropomorphic perceived robot or to minimise it.

According to [16] the uncanny valley would suggest to either stay in the domain of very non-human, toy-like robots, or to create a robot that appears to be almost perfectly human-like, because a robot in between may elicit rather fearful responses. Unfortunately, at present the uncanny valley is not a good starting point for robot engineering and lacks a solid empirical foundation [14].

Furthermore, there is disagreement. The matching hypothesis [9] predicts the most successful human-robot interaction if the robot’s appearance matches its role in the interaction. In highly interactive social or playful tasks participants in a study preferred the human-like robot. In serious, less emotional tasks however they did prefer the machine-like robot [9]. Similar findings done in our own studies are described below. We must be aware of the fact that the appearance of the robot communicates its strengths and competences to the user.

Further arguments against a human-like robot can be derived from basic usability principles. Firstly, we need to establish a stable channel of communication. The interaction with a machine shall minimise tendencies of ‘misunderstandings’. The more complex interaction techniques based on gesture or language are still in an early stadium of development. Albeit the achievements of these technologies they are still error-prone and cannot provide a stable basis of human-machine communication in real-world applications.

Secondly, successful interaction is not merely a question of establishing a reliable channel. Since we do not want to create an individual personality but a tool to support us in our lives, the interaction with a machine shall satisfy the users’ expectancies [1]. This requires that the machine interprets its

input correctly.

Human-like appearance is likely to trigger expectations that go beyond the actions of a machine. But being humanoid in appearance does hardly suffice to meet the expectancy of human-like reactions. To achieve this, the robot needs to interpret situations correctly to adapt its behavior. This requires elaborate models of cognition and emotion. Even though research makes progress in these matters, e.g. within the Cogniron Project, this is not suitable every-day technology yet. Instead findings suggest, that if a machine triggers high expectations concerning its capabilities, the user adapts accordingly and tends to overchallenge the machine [23] while getting frustrated himself.

Furthermore, the relation between human and robot gets even more complicated if we expand the focus from the capabilities of the robot to the characteristics of the interaction. Research about human-machine interaction is well established in science. The interaction between a human-like robot and a human, however, goes far beyond a traditional human-machine relation. In this context patterns of social behavior become more important [18], [22]. Thus, robot designer also needs to be familiar with issues regarding social interaction aspects. At present, however, findings are still too preliminary to serve as design guidelines for a socially acceptable humanoid service robot.

Based on these arguments, we decided against a humanlike robot and investigated measures to avoid anthropomorphic attributions, and instead support *technomorphic* perceptions. Nass et al. repeatedly noted measures that are supporting anthropomorphic attributions: use of natural language, display of a face, demonstration of emotion, interactivity, and role acquisition [17], [18].

As summarised and supported by [21] anthropomorphic attributions may be enhanced if the robot permits a clear attribution to a gender. A genderless appearance should improve technomorphic perceptions. From this follows that the engineer needs to carefully reflect about the robots shape and especially the display of a face. Furthermore, language output needs to be carefully designed to avoid gender attributions (provided that this is possible).

Since a face enhances the impression of a human-like interaction ‘partner’ [17], [27], which we try to avoid, the use of faces is not recommended in our particular approach. Altogether we deduce the claim of a non-humanoid appearance.

We may now take a closer look at behavioral variables. In the long run, language and gesture communication will inevitably replace buttons, keyboards, or touch pads. But, as noted above, such techniques may amplify interaction problems. While including some of these techniques on the robot, we are aiming for an interface guaranteeing an unambiguous communication channel between human and robot.

Many interaction problems may be seen as a consequence of anthropomorphic attributions, because it favors the perception of autonomous actions [4], [13]. In any situation the robot shall communicate to the user what it is doing and

that its actions are deduced from the commands of the user. The users’ perception of control should gain more attention than usual. Usability literature provides a bunch of measures, especially a task-oriented interaction design, supplemented by a feedback strategy using informative messages and continuous status display.

In our approach we avoid emotion-like robot behavior or any display of a distinct, explicit personality. For example, the robot should not describe itself as being ‘hungry’ when the battery is empty. Status indication shall avoid explicit metaphors taken from living beings. The robot shall not refer to himself by name as ‘I’, because this implies the notion of a self and the robot’s awareness of its individuality [19]. The same is valid for the use of voices [19], [20]. Note, as we will discuss in more detail below, anthropomorphic projections and interpretations of a robot cannot be avoided completely, due to the inherent tendency of human beings to perceive the world in terms of intentional and motivated entities, however, from a design stance there is a choice: either to exploit and build on such tendencies, or to try to avoid any *explicit* reference to anthropo- or zoomorphic designs. Our choice is the latter alternative.

Despite of all the constraints described above, we still want to build a pleasurable device. The robot itself may not be the cause of amusement. But it is to find amusement with friends. It is a modern lifestyle product. A tool that may make life easier and more comfortable. The design shall be appealing, not too mechanical. We aim for an organic shape and a smooth touch. These considerations provide the basis for appearance and functionality, as well as interaction and interface design.

III. VIEWS OF POTENTIAL USERS OF INTELLIGENT SERVICE ROBOTS

What are people’s views on the role of an intelligent service robot in the home? Different studies have investigated people’s attitudes towards domestic robots. Khan [28] carried out a survey in order to examine adults’ attitudes towards an intelligent service robot. Participants were 21-60 years old, and the majority belonged to the age group 21-30. Results show that most participants were positive towards the idea of an intelligent service robot and view it as a domestic machine or a smart intelligent equipment that can be ‘controlled’, but is intelligent enough to perform typical household tasks. Participants also prefer a robot to be neutral towards gender and age. Scopelliti et al. [26] investigated people’s representation of domestic robots across three different generations and found that while young people tend to have positive feelings towards domestic robots, elderly people were more frightened of the prospect of a robot in the home. Studies within the European project Cogniron assessed people’s attitudes towards robots via questionnaires following live human-robot interaction trials [7]. Responses from 28 adults (the majority in the age range 26-45) indicated that a large proportion of participants were in favour of a robot companion, but would prefer it to have a role of an assistant (79%), machine/appliance (71%) or servant

(46%). Few wanted a robot companion to be a ‘friend’. The majority of the participants wanted the robot to be able to do household tasks. Also, participants preferred a robot that is predictable, controllable, considerate and polite. Human-like communication was desired for a robot companion, however, human-like behaviour and appearance were less important. These three studies, conducted in different European countries, agreed with respect to the desired role of a service robot in the home: an assistant able to carry out useful tasks, and not necessarily a ‘friend’ with human-like appearance. Such findings are consistent with the definition of a robot companion which must be a) able to perform a range of useful tasks or functions, and b) must carry out these tasks or functions in a manner that is socially acceptable and comfortable for people it shares the environment with and/or it interacts with [28]. This approach, that we put forward in this paper, complements other approaches that view a robot as a ‘pet’ or even a ‘child substitute’, relying on people, as ‘caregivers’ to bond with and ‘care’ about the robot, see a discussion of different paradigms in [5].

IV. ROBOT DESIGN

A. Approach

Considering the above, the goal was to create an unique and iconic design for a service robot depicting an innovative product perception away from a humanoid approach. The design intends to convey a future product vision that is very different from existing humanoid robots, and that will create fascination and acceptance for service robots.

To extract necessary functionality, first of all the roles (Butler, Info-Terminal, Attraction, ...) and typical tasks (Lay a table, Serve drinks, Fetch and Carry tasks) of the robot were defined. Simultaneously, available state-of-the-art robot technology was evaluated. Constraints concerning size and weight set by a typical house-hold environment had to be considered. Finally, the experiences made with former robot developments [10], [11] delivered valuable input. The basic concept developed was to define *two sides* of the robot. One side is called the ‘working side’ and is located at the back of the robot away from the user. This is where all technical devices like manipulators and sensors which can not be hidden and need direct access to the environment are mounted. The other side is called the ‘serving side’ and is intended to reduce possible users’ fears of mechanical parts by having smooth surfaces and a likable appearance. This is the side where all physical human-robot interaction will take place. One of the first design sketches can be seen in fig. 1. After several steps of design-technology convergence a simplified rendering can be seen in fig 2. Based on these images the underlying technology was integrated into this shape.

The robot can be divided into the following components: Robot mobility and base, torso, manipulator, tray and sensor carrier with sensors.

The robot is driven by four wheels. Each wheel’s orientation and rotational speed can be set individually. This gives

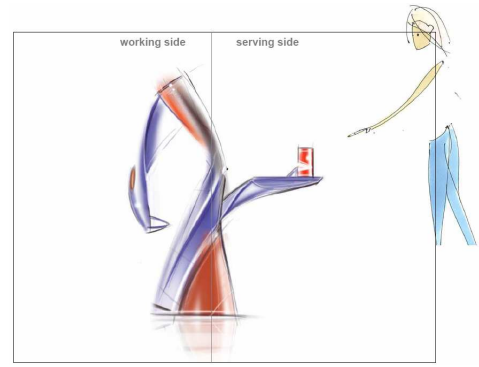


Fig. 1. First design sketch

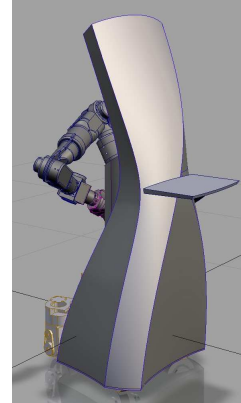


Fig. 2. First technical rendering

the robot an omnidirectional drive enabling advanced movements and simplifying complete kinematic chain (platform-manipulator-gripper) control. The wheeled drive was chosen over leg drive because of safety (no risk of falling) and stability during manipulation. The base also includes the Li-Io battery pack (50 V, 60 Ah) for the robot, laser scanners and one PC for navigation tasks. The size of the base is mainly defined by the required battery space. Nevertheless the maximal footprint of the robot is approx. 600 mm and the height of the base is approx. 340 mm.

The torso sits on the base and supports the sensor carrier, manipulator and tray. It contains most of the electronics and PCs necessary for robot control. The base and torso together have a height of 770 mm.

The manipulator used is based on the Schunk LWA3, a 7-DOF light-weight arm. It has been extended by 120 mm to increase the work area so that the gripper can reach the floor but also a kitchen cupboard. It has a 6-DOF torque-force-sensor and a slim quick-change system between the manipulator and the 7-DOF Schunk Dexterous-Hand. The force-torque sensor is used for force controlled movements like opening draws and doors but also for teaching the robot new tasks by physical interaction with the human. The quick-change system allows the use of other grippers and robotic hands like Schunk Anthropomorphic-Hand. The robot hand has tactile sensors in its finger making advanced gripping possible. Special attention was paid to the mounting of the

arm on the robot torso. The result is based on simulations for finding the ideal work space covering the robot's tray, the floor and area directly behind the robot following the 'two sides' concept developed. Since the manipulator has a hollow shaft no external cables are needed.

The tray is the main human-robot interface attached to the robot. Experiences with former robots showed that the passing of objects directly from human to robot via a robot's gripper was not satisfying. The very close interaction necessary for such a task is not simple. The crucial timing of when the object can be released can not be easily detected by the robot. Similarly the user is not used to explicitly engage into a 'passing mode' if an object is handed to an other person, which is necessary for a robot. Between humans it is something which is done very unconsciously and automatically. We have therefore developed the tray concept as an interface between robot and human for the passing of objects but also by integrating a touchscreen for traditional human-computer interaction. If the tray is not used it can be retracted so that the robot is as compact as possible in stand-by. If the robot needs to handy anything to a human it is placed onto the tray and then offered to the human, who can take it when it is suitable for him. Similarly a human can place an object onto the robot's tray at any time, not needing to wait for the robot to extend and open its gripper.

The robot has a sensor carrier carrying high-resolution Firewire stereo-vision cameras and 3D-TOF-cameras, enabling the robot to identify, to locate and to track objects and people in 3D. These sensors are mounted on a 4-DOF positioning unit allowing the robot to direct his sensors in any area of interest. It is very important in our concept not to create a face with these sensors and is very difficult to avoid.

The convergence of the original design idea and the underlying technology can be seen in 3 showing the robots final appearance.



Fig. 3. Final Design

V. WHY THE ROBOT LOOKS AS IT DOES

Interestingly, while the careful consideration of appearances of service robots has only relatively recently attracted attention in the robotics community, comic designer Scott McCloud presents an interesting framework for the design of

cartoon faces, namely a triangular design space along the dimensions of realistic/objective, iconic/subjective and abstract [15]. Applied to robots, Androids clearly fall in the *realistic*, objective, corner of the triangle, where researchers attempt to faithfully imitate human appearance (and behaviour). The iCat (Philips) or Papero (NEC) robots are situated in the *iconic* corner which is more oriented towards inviting playful, entertaining, and more socially-oriented interactions. Numerous examples of robot faces (and bodies) along the realistic-iconic spectrum exist, however, the *abstract* dimension is far less populated. Here, we may find robots that are neither iconic, nor do they try to mimic closely human or animal shapes (anthropo- or zoomorphic), they are 'something else', compared in art e.g. to the work of Picasso and others. For abstract designs the focus of attention moves from the *meaning* of the representation to the *representation itself*. Applied to a robot it means that abstract robotic designs are more likely to be considered as a 'piece of art', or a luxury item, which is the concept we are pursuing. Note, anything that moves and operates in the physical world, due to its embodiment, will invite to some extent comparisons with living beings, as it has already been shown by Heider and Simmel more than 60 years ago: even abstract geometrical shapes moving on a computer screen invite anthropomorphic interpretations [12], [6]. However, there is a clear difference between robot designs that explicitly *invite* such anthropomorphic projections, and our approach, which does not make any such direct attempts (unless the anthropomorphic features are part of the robots functionality, i.e. possessing an arm, which is a functional necessity). As discussed in [3], [6], designs that are very realistic will invite people to consider the robots as 'individuals', e.g. an Android robot will be considered to be of a particular gender, age, personality, background etc, based on its appearance. An iconic design on the other hand is far more open to subjective interpretation. For example, a person who prefers a male robot, might recognize it in the design, a person who prefers a female robot might perceive it as well in the same design. Thus, iconic designs may appeal to much larger user groups than realistic designs, they may evoke very different subjective interpretations and psychological projections by their users. In our view, this work is supporting a synthesis of abstract design as well as some iconic features. Correspondingly, Care-O-bot 3 possess few iconic human-like features (e.g. an arm), which is important so that people can relate to it and are able to interpret the robot's behaviour, but it possesses an overall very abstract design that focuses on the representation which is very suitable for an expensive high-tech domestic robot.

Based on this design rationale, the next section identifies the target user groups and presents remote interfaces for the robot.

VI. TARGET USERS AND DESIGN OF A REMOTE INTERFACE

With this project we target the area of household helper robots. There exists a smorgasbord of different stakeholders

for this scenario (e.g. ‘Soccer moms’, ‘Techies’ etc.). We define the minimum common ground for all users by:

- being open to new technologies
- experienced with electronic devices (like PIM, digital camera or MP3 players)

We used the scenario based design method [25] to produce our first interface concept. Each scenario is based on a single persona [24].

Central to most scenario based designs is a textual description or narrative of a use episode. This description is called a scenario. The scenario is described from the user’s (persona) point of view and may include social background, resources, constraints and background information. The scenario may describe a currently occurring use, or a potential use that is being designed.

Based on these premises we explored different scenarios for a touch-pad based interaction concept. The persona used in this phase ranged from millionaires with the need for an electronic butler, retired engineers with the wish to have technical companion to diabetic programmers with the need to have a dependable nurse.

Because of the diversity of the persona used we came up with different hardware solutions, ranging from small form PDAs to full size Tablet PCs. As diverse as the hardware were the results for the actual user interfaces. The UI represents the traditional gateway to the Care-O-bot 3 hardware. Its abilities can be accessed through all designed UI variants. As an example we will show two versions in less detail and a third variant in more detail. The first version is based on a persona called ‘Hartmut von Geiss’. He is a young manager of an IT business. He uses the robot at his home to support his daily housework. Casually his robot helps him in multitasking situations: Video phone call from his boss, during his dinner while a parcel service is ringing. Figure 4 shows the first design of an UI for this scenario.

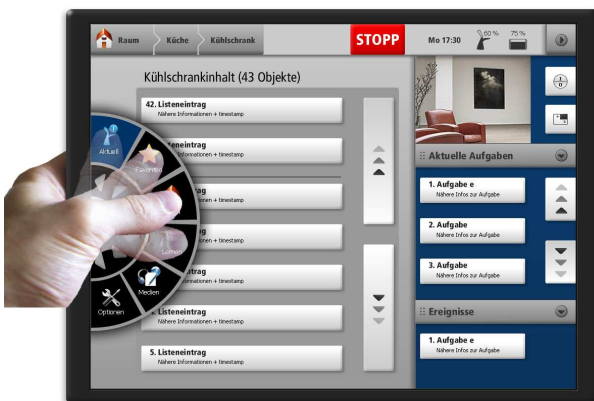


Fig. 4. UI for scenario 1

This is a very straight forward design using a small tablet PC with a decent segmentation of the available screen. All designs that are based on a touch screen (design 1 and 3) take the usual touch screen norms (e.g. VDI/VDE 3850) into account. Design 2 is based on a PDA and uses the guidelines

that are appropriate for stylus passed input devices. The story behind the design contains a persona called ‘Fabian Krasse’. He is a diabetic programmer who wants a reliable nurse that fits his technophile life-style. The interface (see figure 5) of this scenario is based on a PDA that fits Fabians way of life and working.

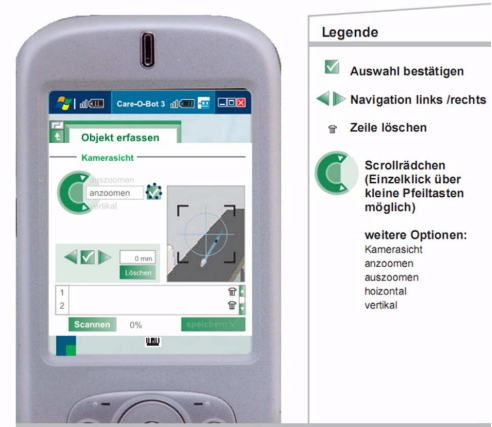


Fig. 5. UI for scenario 2

The last concept presented is based on a persona called ‘Patricia van der Dellen’ and represents the group of so called ‘soccer moms’ - meaning they have the technical equipment but not necessarily the knowledge of the underlying technology. This is a more challenging group of users and leads to an interesting UI concept. The hardware consists of a tablet PC with finger touch capabilities. The interaction concept is based on various ‘genies’ that represent the different characteristics and services that the Care-O-bot 3 can offer (see figure 6).



Fig. 6. UI for scenario 3

The different genies cover the following areas: Household, entertainment, medical, education, cooking and personal secretary. These different clusters are also colour coded in the UI. To support this user group in an optimal way we decided to use a more system guided interaction model. All functions are more or less deployed in a user guided way. First impressions of the genie-metaphor seems promising. Next

step is to evaluate these different concepts with a usability test as soon as the Care-O-bot prototype is available.

VII. CONCLUSIONS

In these days, many laboratories in the world contribute to gain knowledge in robotics. Most of them focus on isolated aspects of a robot's capabilities, such as manipulation, navigation etc.

But creating an appealing product is not solely a question of bringing individual functions to perfection and to assemble them afterwards. So far, few teams do ever come to the point, when they can even start to reflect about a fully-fledged product.

When constructing a holistic product for a service robot application an engineering team faces totally different challenges. Beyond technological expertise it requires a common vision and an interdisciplinary team with each member feeling obliged to it. Hardware engineers, designers, information technologists, psychologists, mathematicians, sociologists need to develop a common understanding about the humans living in this world, about their ideas and tasks. Also, the design team needs to have a clear idea on who the potential users might be, people who might be interested to change their lives by acquiring a robot. Knowing the target user group also requires to study and understand the desires, motives and attitudes of the user group. Such a challenging endeavour requires an open-minded viewpoint and an interdisciplinary design team.

This paper highlighted a few challenging issues in the design of a service robot product, i.e. a robot meant to fulfill a role as a useful and socially acceptable companion in peoples homes. Placing the robot in domestic environments, and testing it with real users will be a future challenge.

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