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Design Research on Robotic Products for School Environments

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Abstract

Advancements in robotic research have led to the design of a number of robotic products that can interact with people. In this research, a school environment was selected for a practical test of robotic products. For this, the robot "Tiro" was built, with the aim of supporting the learning activities of children. The possibility of applying robotic products was then tested through example lessons using Tiro. To do this, the robot design process and user-centred HRI evaluation framework were studied, and observations of robotic products were made via a field study on the basis of these understandings. Three different field studies were conducted, and interactions between children and robotic products were investigated. As a result, it was possible to understand how emotional interaction and verbal interaction affect the development of social relationships. Early results regarding this and coding schemes for video protocol analysis were gained. In this preliminary study, the findings are summarized and several design implications from insight grouping are suggested. These will help robot designers grasp how various factors of robotic products may be adopted in the everyday lives of people.

Keywords

Robotic Products Design, HRI Evaluation, User-Centered HRI.

With the rapid progress of technology resulting from interdisciplinary research, robotic products are starting to be regarded as common objects, similar to vacuum cleaner robots and pet robots. Robotic products, in which robot technologies are applied partially or entirely, can perceive environmental information and react automatically with AI (Bartneck and Forlizzi, 2004).

In contrast with existing products, robotic products allow people to interact with the environment in new ways and create social relationships with it (Forlizzi, 2007), like as automobiles, portable video camera, and other new technology products. Therefore, it is interesting to understand the social impact of new robotic products.

Among the various applications, robotic products that can be employed in education and for psychical curing purposes have received considerable attention. These include "Robota" and "Met" of the AuRoRA project in Europe, and "ROBOVIE" by ATR in Japan.

Robotic products induce users to treat them socially; they change the lifestyle of users, in contrast to general products that are used for convenience and then fall into disuse. However, the design process should be managed carefully for such applications having psychological and cognitive effects on humans. In addition, if the design process can meet the extensive requirements of educational environments, the design process of robotic products in other areas can be facilitated.

For this study, designs of the appearance and scenarios for the robot "Tiro" were made. This robot was designed to assist the learning activities of children. An example lesson was tested using Tiro in an elementary school. Interactions with the robotic product from the viewpoint of a designer were analyzed through observations. Consequently, greater understand of how robotic products can be adopted in a school environment was sought.

Method

Robotic product design process is different from other design area. Several concurrent engineering design experiences were accessed and then applied to the design of the learning-assistant robot. This is introduced in 'Robot design' part. Next, the framework that helps designers easily plan HRI experiments is presented, and user requirements focusing on the most important part of the robot design process, or user-robot interaction design, are discussed.

At the end of this section, observation research of the field study is presented, consisting of a questionnaire, interviews, and video-ethnography.

Robot Design

For a product designer, the entire robot design process is divided into three basic steps: character design, appearance design, and human-robot interaction design (Oh, Kim, J. and Kim, M., 2005): This is based on the properties of social robots that include form, modality, social norms, autonomy, and interactivity considerations (Bartenck and Forlizzi, 2004). According to these design processes, the robot "Tiro" was designed to organize example lessons.

The specifications of the hardware and software of Tiro are shown in figure1. Additionally, a facial expression design using LEDs (light-emitting diodes) was designed to help children perceive the emotion and character of the robot, as shown in figure 2.

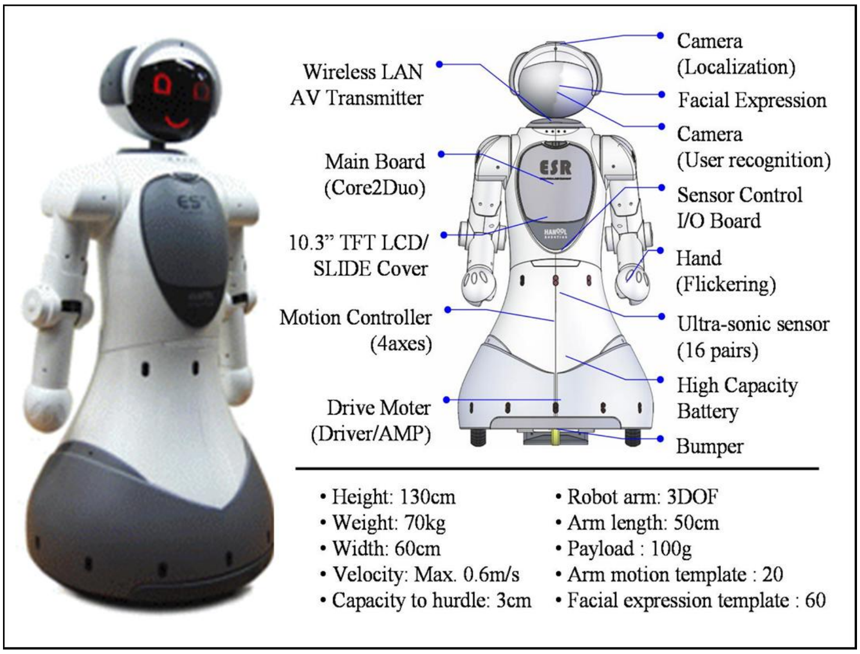

Fig.1. The specification of hardware and software of Tiro

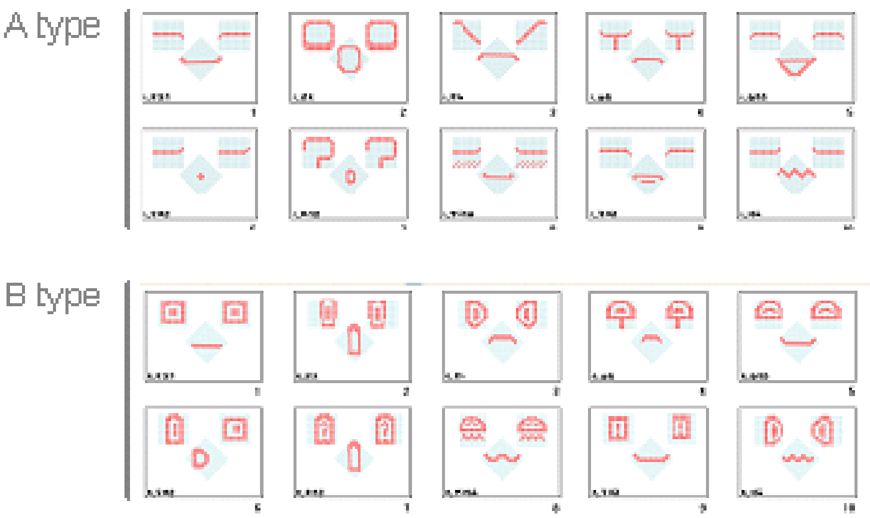

Fig.2. Set of facial expression design

A robot with character causes users to consider the robot as a social object rather than as a complex tool. In addition, it has the advantage of long-term interaction (Kanda, Sato, Saiwaki, and Ishiguro, 2007). The emotion shown by Tiro from its facial expressions consisted of a neutral mode as well as fear, anger, sorrow, delight, indifference, curiosity, shyness, self-reliance, and a temper-related emotion. Each emotion has a subset of optional expressions so that natural emotional interactions are possible. These robots give people a strong feeling of presence with their physical body and human-like ways of interaction. For this reason, they can play a physical, informative, and mental role as no current media can.

HRI Experiment Framework for Designers

Designers conduct HRI experiments for purposes different from those of engineers, they should take a different approach from the very definition of problems. That is, the outline and framework of experiments for designers should be developed in advance.

Robot designers carry out HRI experiments to determine three elements. The first is related to the exterior of robots; it pertains to emotions felt from the robots' exterior shapes or actions. Studies on the shapes and proportions that users feel are adequate for the character and role of the robots have been carried out, as well as research on what kind of materials will are suitable for given purposes of using robots.

The second is research on the usability of robots. These studies address whether the implementation of robots' physical functions is safe to users and how input/output devices should be set to ensure effective interactions.

The third is research on social contextuability that users gain from their interactions with robots, such as intimacy, bond, trust, and emotions. These studies investigate changes in humans' role setting, life patterns, and values resulting from the inclusion of robots in their daily lives.

The three experiment elements described above are in line with what Norman(2004) referred to as the three levels of design (behavioral, visceral, and reflective) and with what Forlizzi(2007) referred to as the three way people collect and use products (functionally, aesthetically, and symbolically).

By clarifying such ultimately sought-after elements and setting manipulatable independent variables for designer-led HRI evaluation experiments, it is possible to conduct effective HRI experiments only with low-fidelity prototypes. The framework for HRI experiments suggested here is shown in the figure 3.

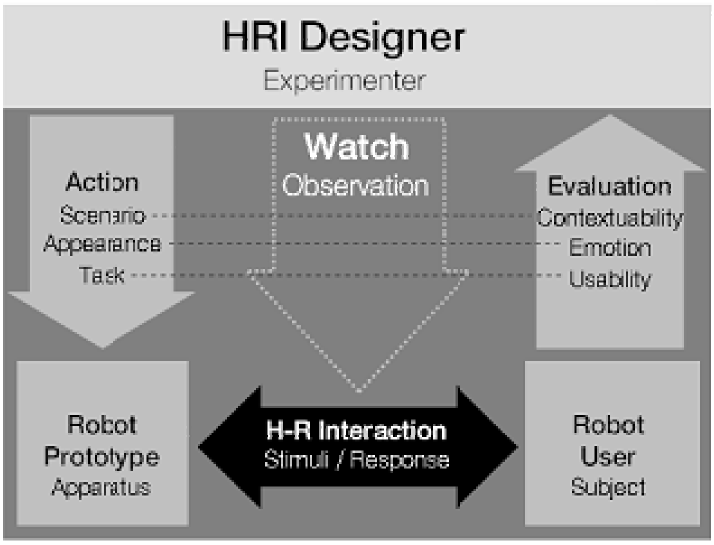

Fig3. HRI experiment framework.

Emotions based on robot's exterior shapes, robot usability, and social contextuability seen in the left of the figure are output information that designers ultimately seek to understand. For this purpose, the designers can put such operational elements (or independent variables) as appearance, task performance, and scenario into the HRI experiment system as input information. To apply each of the independent variables to the system, prototypes tailored to each element are developed and utilized in experiments: "look and feel" prototype, "function" prototype, "role" prototype (Yang, 2004).

The framework for HRI experiments using the aforementioned three prototypes is easy to produce and analyze in areas observable for designers, because the experiments' independent variables and the resulting dependent variables are design-based elements.

This framework was found to help designers overcome lacking of technical knowledge and easily determine and solve design-centred HRI problems (Oh and Kim, 2007). In this research, this framework was applied to define what kind of data should be collected in our example lessons and to set conditions of Tiro and class environment.

Example Lesson with Tiro

Field study of the interactions between children and robots in an elementary school were carried out by Kanda starting in 2004. Compared to his research, which focused on the evaluation of social relationships among children, the present study differs as it conducts actual lessons with an actual teaching and studying model in the pedagogy.

Condition of Field Study

The example lessons were conducted two times at the Daejeon Eo-eun Elementary School and once at the Cheongju Byun-il Elementary School in Korea. Using the English content of Tiro, the teacher created a lesson for students in a fourth-grade English class with nearly 30 students per lesson. All example lessons and observations were performed during the fourth class of the day and during the lunch period.

Though Tiro can recognize human speech and make verbal replies due to its programming, in this study it communicated with children using what is known as WOz (Wizard of Oz) techniques as well as TTS (tele-type-setting), which was controlled by the keyboard input of an operator.

The example lessons had the advantages of a real field experiment however, it was difficult to control diverse variables, and some observation data were biased as it was not a laboratory experiment. Nonetheless, for well-knit scenarios and content, some variables were restricted to low levels.

Fig.4. Example lesson with Tiro

Observation Methods

HRI experiments require thoroughly considered experimental environments, as they observe human perception and actions in their responses to robots. It should be noted that due to novelty effects, users interacting with robots for the first time tend to show excessively positive results in all items.

An important thing in the experiment is making participants recognize robot in a correct way through appropriate explanation and warm-up session prior to main experiment. Experimenter need to make them naturally understand its restricted functions. That can help participants to be efficiently immersed in the HRI.

Through observations and subsequent data analyses, attempts were made to understand how robotic products interact with children and how they naturally affect their learning activities. The observations were carried out using questionnaires, conversational interviews and video ethnography. The questionnaire was composed of items regarding the independent variables of the HRI experiment framework described above. The in-depth interviews were helpful to illustrate the patterns of thinking by the children as they pursued the reasons behind each interaction situation. Observation by video record had the advantage of capturing the unconscious behaviour and other responses of the users.

1) Questionnaires and interviews

On the basis of the HRI experiment framework, the questionnaires and interviews included contents concerned with the social aspects of the interaction, such as descriptions of an own robotic product, the process of developing a relationship between the robot and the children, differences from other learning-assistant products, the manners of perception and cognition, and perceived changes before and after the lesson with the robot.

2) Video-ethnography

Video recording was carried out in two ways. The first involved recording of the entire lesson by one or two fixed video cameras, and the second was in-depth recording of the areas in which communication and interaction responses occurred.

Insight was extracted from peculiar matters by video data observation. Video protocol analysis was made by arranging the atmosphere and the responses of children to the robotic products dia-chronically. In this paper, the protocol analysis was preceded until a coding scheme that involves a frame for encoding the video data was made.

As an essential design element to build interactions, a coding scheme determines a usable type of analysis and limits data conversion as well as the results. The independent variables of the HRI experiment framework are the fundamental elements designers should take from an evaluation process, and the coding scheme from the video record analysis represents subordinate details changeable according to each experiment.

Due to the difficulties of the field study, it was challenging to gather concurrent verbalization protocols through “think-aloud” activities. Thus, this study took post-event protocols through interviews after the example lessons. On the other hand, non-verbal interactions such as natural behavior or the facial expressions of children were valuable data that are not easily gained in controlled experiments in laboratories.

3) Product ecology

The concept of product ecology was very useful during the observation data analysis. Product ecology is a means to understand how people develop social relationships with new technology products and interaction systems and to understand how technology becomes a catalyst for change (Forlizzi, 2007). If these aspects of robotic products are understood, it is possible to classify the necessary elements of robots that easily induce affirmative effects on the mentality of the children.

Early Result

A product has both pragmatic attributes for behavioral goal and hedonic attributes for user's psychological well-being (Hassenzahl, 2002). Contrary to other robot researches which focused on pragmatic value of robots, this research is interested in robots' hedonic attributes at the view point of designers. As a hedonic function of product, it communicates identity of user. Generally the identity of user is related to purchase or possession, however for robotic products, the identity is more related to interactivity with robot or strength of relationship between robot and users. This is because strong relationship and interactivity presents that the user is special and very important for the robot.

In this research, verbal communications and behavioural interactions were easily found as a process of making relationship between children and Tiro.

Questionnaires were conducted with 33 children, and interviews were recorded with 20 children. Video data were recorded for approximately six hours. All of the participants were elementary school students who were eleven years old at the time of the study. This paper introduces the early results of simple analysis research regarding the correlation among questions in the questionnaire and video protocol analyses were conducted afterward.

Insights of the Questionnaire

1) Conceptual sense of distance to the high-technology robot:

General responses to the tone of voice of the robot were "easy to comprehend" (45%), and "sweet to listen to" (36%). According to the respondents, it was difficult to make the conceptual sense of the distance between humans and robots short as the robot was clearly perceived as a difficult artefact derived from high technology. On the other hand, it was generally understood that the use of the actual functions of robots such as a touch-screen or a voice-recognition function of robots is simple.

2) Desire to interact physically:

The question, "Which subjects do you want to study with robots?" was posed to the students. Their selections included "physical exercise" (45%), "mathematics" (30%), and "art" (9%). In addition, they also reported a desire to participate in physical activities such as "playing ball", and "hide-and-seek" with robots.

3) Desire for emotional interaction:

The children wanted to communicate (58%) and take pictures (18%) with the robot during their rest time. They were also eager to interact emotionally, an exercise that is not possible with a TV or PC To the question, "What type of robot do you want to have?", most children answered "a robot that can communicate like a friend", "a robot that can have a heart-to-heart talk with me", or "a robot that has a warm heart".

Insights of Interview

1) Ability to communicate:

Compared with other products, the children expressed that the most important difference of Tiro is the ability to communicate. Although they understood that Tiro was only a mechanical structure such as a PC, they communicated with it as they would communicate with their friends.

2) Content for a robotic product:

Responses such as, "Initially, it looked like a computer but after the lesson it felt like a friend or a warm-hearted teacher", suggest the importance of the content of the robot itself. On the other hand, the inclusion of the touch panel interface on the chest area of the robot caused children to perceive it as a machine.

Insights of Video Ethnography

1) Novelty effect:

Children marvelled at the simple movement of the robot, such as the nodding and shaking of its head. They regarded the robot as something with free will despite the fact that the operators of the robot were clearly apparent in the same room. Movements and the flickering of lights on the hand of the robot were highly effective to concentrate the attention of the children. In contrast to physical interactions, the novelty effect of the verbal responses as if the robot had intelligence continued to the end of the observation.

2) Self-expressions of children:

When the robot answered questions correctly, children became very excited and began to ask many more questions due to their desire to make their presence felt. Several projected behaviours to attract the attention of the robot were frequently observed.

3) The mimic:

Repeat studies with Tiro in a role-playing or a singing activity were very popular, and mimicking the speech or behaviour was very exciting for children. It was observed that these activities increased the level of participation by children in the lesson.

4) Development of a social relationship:

It was interesting that there were differences between the responses to human functions such as facial expressions or conversations and the responses to machine functions such as the flickering of lights or the touch screen interactions.

Some of the students appeared to be ashamed of one-to-one communication with Tiro, but were pleased when their names were called by the robot. This shows that social relationships had been created. These types of social attributions changed the content of the study as well as the attitude of the children in terms of participating in the lesson.

Coding scheme for the video protocol analysis

From the written records of particular matter while the example lessons were carried out and from ten-minute video records that were randomly extracted from the entire set of video records, the reactions and dialogues of the children were classified using a KJ method. On the basis of this classification and grouping, the coding scheme listed below was devised.

1) Malfunctions and limits: reaction to the limitations of the faculty of the robot.

2) Misunderstanding and confusion: misunderstanding of the action of the robot due to content imperfections.

3) Self-expression: all of the behaviours intended to establish the presence of the students and to attract the attention of the robot.

4) Physical interaction: responses to the gestures and movements of the robot.

5) Imitating: mimicking the facial expressions or behaviours of the robot.

6) Recognition as a product: dialogues and behaviours resulting from the consideration of the robot as a machine.

7) Verbal interaction: all of the responses from conversational interactions.

8) Positive or negative as a result of personification: liking or disliking of the human-like speech and behaviour of the robot.

The findings in this chapter help to illustrate how variable factors of robotic products can be adopted in a school environment.

Design Implication

A product designer fabricates its character by choosing and combining specific product features, i.e., content, presentational style, interaction style. However, there is no guarantee that users will actually perceive and appreciate the product the way designers wanted it to be perceived and appreciated. So from the initial stage of product development designers should think about how their intended character will be fetched out. Base on this, some broad guidelines for the design of robotic products are listed below.

Although the early result were only primary results and were not completely accounted for in the analysis, they reveal interesting insights regarding the use of robotic products and systems in interaction situations with children.

1) Use of an anthropomorphic form: Anthropomorphic forms of a product can cause users to build a social relationship with it, effectively increasing favourable impressions. Emotional interactions facilitate and trigger personification. Though it was driven by a very simple structure such as a LED panel, the emotional expression of products appears to have more advantages for human-robot interactions than designers may expect.

2) Satisfy self-expressive needs: In contrast to other products, Tiro was described not in functional terms but from a symbolic point of view. Children were very proud to communicate with Tiro. They tried continually to interact and make eye contact with the robot. This observation will be helpful to enhance loyalty to other robotic products.

3) Considering the aspects of emotion: In the example lessons, most of the children regarded the robot as a friend. The anthropomorphic form of the robot was designed not for efficient operation of the robot but to help it interact emotionally. As shown in early results, children mostly wanted to communicate and share their emotions with the robot.

4) Realization of physical interaction: Children were highly interested in the physical functions of Tiro. The teaching content coupled with physical interactions efficiently induced active responses from them, causing them to become fully immersed in the lesson.

Conclusion

Robotic products are recognized by users in different ways depending on the interaction systems applied even when the same technologies are utilized, because it moves autonomously by recognizing its using environment. This is the reason for robot designer should consider not only typical product design element but also HRI research with social context and using situation (e.g. user experience or user-centred issues).

This paper presents a field study involving a robotic product in a school environment. it evaluated how a robotic product would be adopted to the school life of children.

Thus far, most robot-centred studies have focused on robot perceptions and their cognitive awareness of humans and human-related actions. However, user-centred interaction research is focused more on how humans perceive robots. It concerns human interactions with robots more than it concerns how robots view humans. This is research on interactions from the perspective of robot designers rather than from robot engineers.

Therefore, the most important considerations here are how children think about and perceive a robotic product in their everyday life. To determine this, example lessons were carried out and the verbal and behavioural responses of the children were observed as they interacted with a learning-assistant robot.

The most interesting finding was that the robotic product was often personified not for its human-like appearance but for its communication ability and emotional interactions.

Particularly the relationship between children and robot was exciting, because children were very proud of warm relationship with robot and they expressed their self to other friends through it.

It was also interesting to note how the robotic product affected other teaching-assistant products that were used during the lesson and how it changed the context of teaching and learning.

Compared to other school products, robotic products are maybe not good for teaching and learning. But they stimulate children's interaction which can help them communicate their sincere idea and worry to others. They can be a good friend for children that feel empathy emotionally.

As a result of this research, insights and interesting design implications were revealed that can help designers develop proper content and build quality HRI systems. These results are good feedback regarding the current appearance and interaction design of the learning assistant robot "Tiro", and will contribute to the revitalization of HRI design research.

On the other hand, this was a small study and controlled experiments were not done, as is common practice in psychology and HCI. Hence, concerns exist regarding data bias in elements such as the novelty effects and regarding the generalizability of the findings. However, the in-depth interviews and the video-ethnography of subjects allowed for a consistent result from this relatively short-term research.

These research results are considered as an important touchstone to test the possibility of robotic products for educational areas. They are an opportunity for designers to conduct aggressive research involving new design areas or robotic products. Future work will include video protocol analysis and in-depth analyses of the correlations among items in the questionnaire. In addition, long-term research on the social functions of robotic products will be conducted.

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