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A Guideline for Personal Service Robot Interface Design

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Abstract. Along with the advanced technology and network development, as well as the changes in the intelligence-based society, the robot development is in active progress. Especially, the research on the personal service robot, which can naturally interact with human in a daily life, are becoming more important. However, the personal service robot studies are generally focused on the development of basic technology or functions, the robot interface design studies are at am insufficient level. Thus, this research concentrated on providing guidelines for the personal service robot interface design. To do so, the personal service robot interface factors have been organized and a user survey and an expert survey were conducted. As a result, a total number of 16 interface factors have been gathered to include shape, structure, size, color, face appearance, tactile, mechanical parts, movements, gesture, voice, sound effect, light, facial emotion, GUI, VUI, and TUI. Also, their details have been organized to suggest the guidelines for the personal service robot interface design by factor. This research can be used to evaluate the personal service robot interface or to design the personal service robot; and after all, it would help seek the development direction of the personal service robot.

Keywords: Personal service robot, robot interface, robot design, robot interface design

1. Introduction

Robots and humans live together in various situations today. Although the robots had been existed around human beings by mainly being involved in the industrial and scientific fields for several years, but now their existence is being popularized to be drawn into human's homes and society(Brenna & Billard, 2010). Especially, personal service robots that can naturally interact with people in a daily life are being spotlighted. The personal service robots are one type of the intellectual

service robots; they usually deal with tasks from managing the user's schedules in a normal household to providing personalized services and information in order to allow the people to continually communicate with the society as well as taking a companion role to offer pleasures of culture and entertainment(Park & Ryoo, 2020). It is expected that the personal service robots will be more popularized due to the social change as we are entering an aging society along with the increased number of single households and the change in the users' needs since more and more people tend to invest in their own pleasure(Park & Ryoo, 2019).

However, the studies on the personal service robots that is rapidly rising are mostly stressing on the development and functions of the generic technology. They are focusing on the technical aspects such as voice recognition, facial expression analysis, and gesture recognition that give the robots the basic tools to understand the human's orders and actions(Lee et al., 2004). In other words, the studies on the robot designs that the users actually want from the personal service robots are insufficient. The personal service robot design is very important because this robot will interact with the user face-to-face on a daily basis.

Specifically, the interface design in the robot design is an essential subject. Because the users expect smooth and friendly communications with the personal service robots, the research on the robot's interface design that will boost up the communications between the robot and human to its utmost is absolutely necessary. Therefore, this study focused on suggesting the guidelines for the personal service robot's interface design.

So, this study started off by systematizing the interface factors of the personal service robot through considerations of the HRI and the robot interface. Then, a survey for both users and experts were conducted with the high-fidelity prototype of the personal service robot. The user survey was to examine the issues of the interface when the user makes use of the personal service robot, and the expert survey was to find out any concrete proposals for each interface factor for the personal service robot interface design. Finally, based on the outcomes of the investigation, the guidelines for each interface factor have been suggested.

2. Personal Service Robot Interface Factor

To organize the factors to use in the personal service robot interface design investigation, the preceding research on the Human-Robot Interaction, HRI, and the robot interface have been examined. In the perspective of HRI, the factors that can affect the trust issue in the interaction between human and robot are human-related, robot-related, and environmental with their detailed subcategories (Peter et al., 2011). Since this research is to take a look at the robot's interface factors, the subcategories of the robot-related section were studied. The robot-related factors can be divided into the performance-based and attribute-base factors. The performance-based factor is related to the robot's behavior and the level of

automation, while the attribute-based factor is related to the robot type and anthropomorphism (Peter et al., 2011). With this standard, the factors that appear in the robot interface literature have been classified.

In addition to these factors, the interface factors such as GUI(Graphic User Interface), VUI(Voice User Interface), and TUI(Touch User Interface) have been added in this paper out of the user interfaces, as shown in Table 1, which can have a significant impact on the user when developing the personal service robot. GUI is the environment where graphic can be used when the user exchanges information on a device and it is an importance interface factor of the devices with display such as laptops or smart phones. With VUI, As the user controls the device using a vocalized language and receive desired services with VUI, it is also an important interface in the personal service robot with voice assistance. Furthermore, since TUI is based on the sense of touch, it can advance the performance of the remote operator by touch input whereas GUI depends on the vision.

Table 1: Robot interface factor classification found in literature

Classification	**Factor**
Attribute	Tactile(Jessie et al., 2007), Color(Kanda et al., 2008), Shape(Kanda et al., 2008; Chung & Ryoo, 2018), Mechanical parts(Kanda et al., 2008), Screen(Chung & Ryoo, 2018), Face(Chung & Ryoo, 2018), Structure(Chung & Ryoo, 2018), Size(Chung & Ryoo, 2018)
Performance	Audio(Jessie et al., 2007), Haptic(Jessie et al., 2007), Voice(Jessie et al., 2007; Chung & Ryoo, 2018), Gesture(Jessie et al., 2007; Chung & Ryoo, 2018), Walking mechanism(Kanda et al., 2008), Sound effect(Chung & Ryoo, 2018), Movements(Chung & Ryoo, 2018), Light(Chung & Ryoo, 2018)
User interface	GUI, VUI, TUI

On the other hand, the sub-factors of the robot interface factors found in the preceding researches are comprehensive and they need to be sub-divided or integrated or eliminated due to similar meaning. Thus, this research focused on re-categorizing and integrating the robot interface factors from the preceding studies and organized the personal service robot interface factors.

First of all, 'face' includes the sub-division of facial components materialization degree, facial visual representation, face actualization type, facial emotion expression type, and facial emotion expression degree; they need to be reclassified as either attribute or performance(Chung & Ryoo, 2018). Facial components materialization degree, facial visual representation, and face actualization type are the attributes of the robot, but facial emotion expression type, and facial emotion

expression degree are the performance of the robot according to the interaction. Hence, in this research, 'face' factor is divided into face appearance and facial emotion and they are included in the attribute and performance respectively.

Table 2: Personal service robot interface factors and their definitions

Classification	Factor	Definition
Attribute	Shape	External appearance of the robot as in abstract, mechanical, animal, or human type
	Structure	Connection method of the robot's external factors such as number of joints or the ratio of the face and the remaining joints
	Size	Height of the whole robot
	Color	External color of the robot
	Face appearance	Robot's face such as characters or humanoid
	Tactile	Feel of the robot such as temperature or material
	Mechanical parts	Formative location of the mechanical parts such as camera or screen
Performance	Movements	Method of movement like distance or direction
	Gesture	Robot's movement expressed by using each joint in various situations
	Voice	Robot's voice and tone of female, male or child
	Sound effect	Non-verbal sound that the robot makes
	Light	Visual wavelengths emitted from the robot's externals such as location where the light is being emitted or color of the light
	Facial emotion	Robot's emotional facial expressions in various situations
User interface	GUI	Environment where graphics can be used when the user exchanges information with the robot
	VUI	Environment where the user controls by using a vocalized language
	TUI	Environment where the user can operate the robot by inputting orders by touch

Next, 'screen' includes the layout type or the information display type and they need to be re-categorized according to the parent standard. The layout type of the screen indicates the location of the screen whether it is a head-integrated screen or a

body-mounted screen(Chung & Ryoo, 2018). This concept falls under the mechanical parts which means the formative location of the mechanical parts such as camera or screen, so the layout type has been integrated into the mechanical parts(Kanda et al., 2008). Unlike this, the information display type of the screen has the same meaning of the factors of GUI such as text, icon or real image within the screen; it has been combined with the GUI.

Walking mechanism refers to the methods of the movement which goes together with the meaning of movements so they have been united under movements(Kanda et al., 2008; Chung & Ryoo, 2018). As 'haptic' is the concept of controlling the device by button or remote control(Jessie et al., 2007), it has been integrated into TUI. Lastly, 'audio' represents all of the robot's auditory factors(Jessie et al., 2007); it has been eliminated since there are voice and sound effect in the existing factors.

Through integration and elimination of the similar concepts and addition of GUI, VUI and TUI to the robot interface factors appeared in the literature, the re-organized interface factors of the personal service robot are as in the following Table 2.

3. Robot Interface Design Survey

A user survey and an expert survey have been conducted with a high-fidelity prototype of a personal service robot for an interface design investigation. The user survey was to check any issues that may rise while using the robot through users' various opinions, and the expert survey was to inquire the experts in each field of their opinions focusing on the interface type.

3.1. User Survey

The user survey was conducted with a total number of 11 participants of female and male in their 20s to 30s. It was an individual survey where a participant was observed to execute an assigned task with a personal service robot and was interviewed after.

During the performance of the task, the think aloud technique was utilized. The participants were asked to say out loud what they were thinking while interacting with the robot in order to know what the participants think and why. The survey results were organized according to the classification of the interface factors, which are attribute, performance, and user interface as in Table 2.

3.1.1. User Experience Analysis by Attribute Factor

There are seven factors under attribute, which are shape, structure, size, color, face appearance, tactile, and mechanical parts and the user experience analysis is summarized in Table 3.

3.1.2. User Experience Analysis by Performance Factor

There are six factors under performance, which are movements, gesture, voice, sound effect, light, and facial emotion and the user experience analysis are organized as in Table 4.

3.1.3. User Experience Analysis by User Interface Factor

There are three factors under user interface, GUI, VUI and TUI, and the user experience analysis are organized as in Table 5.

Table 3: User experience analysis by attribute interface factor

Factor	Experience Analysis
Shape	• Should be in a friendly shape - Due to the shape of a pet, it was friendly and had favorable impression • Needs an identity of a shape - If the identity is ambiguous, it gives unfavorable impression
Structure	• Natural and formatively stable joint structures are preferred - If it is divided into too many parts, it feels shoddy - If there is no division, it feels crude
Size	• Needs to be familiar and intimate size to the user - If too big, it feels like it cannot move efficiently or quickly and feels very slow - If it is the same size of a pet, it feels very friendly - It needs to be smaller size that does not take up too much space and also needs to be the size which does not damage the house
Color	• Should be in the color that considered the identity - Use of too many colors with no meaning seems unattractive
Face appearance	• Not revolutionary facial appearance is preferred - Extreme realistic pictures feel repulsed
Tactile	• Should be made with the material that can is easily manageable - Seems like it is going to get stained easily - Worried about contamination • Should be made with the material with high durability - Worried about being wrecked due to collision when moving around the house
Mechanical parts	• One or zero screen for communication is suitable - More than two screens seem unnecessary - Too many screens may disturb the friendliness of the robot

Table 4: User experience analysis by performance interface factor

Factor	Experience Analysis
Movements	• The level of freedom to move should be high - Would be better if it can move around in 360 degree range, not only front and back
Gesture	• When voice recognition is attempted, the robot turns its head toward the user and the user perceives as if it is trying to listen - When it turns its head toward the direction of the voice, it looks like as if it is trying to listen • A clear feedback on an action should be provided - When the robot turns its head, the screen was disturbed and looked like it's stopped - When there was no feedback on the delay before the robot moved, the user assumed it was malfunctioning • Too many gestures in one situation is confusing - The user will be surprised when too many joints are moving at a time
Voice	• A playful tone and young voice should be used in the robot with cute appearance - An adult female voice does not suit for the cute looking robot - A playful tone should fit better for the robot's appearance • A various range of pitch should be used - A monotone pitch gives a unnatural feeling
Sound effect	• If the expression displayed on the screen does not go well with the sound, it feels disharmonious - Mechanical sounds arise dislikes • Repeated sounds should be avoided - The repeated sounds when turning back to the home screen are only noisy and bothering

Table 5: User experience analysis by user interface factor

Factor	Experience Analysis
GUI	• The pronounced sentence should be displayed on the screen in order to clearly understand the voice recognition status - It was clear to know whether the robot understood well by displaying the pronounced sentence in real time • It should undoubtedly tell the user when to start the voice command using the sound wave screen or the voice command standby screen on the existing smart phones - The red dot which shows to start the voice command looks like a pause button, so it is hard to recognize whether it is a command standby screen or not - The two red dots that tell to standby look like two bloodshot eyes; they look rather scary • The interface that the user uses frequently should be provided so that the user can use it without a problem from experience - The existing applications and the icons on the smart phones are similar to the ones on the robot to be used easily - It is easy to see the applications as in the icon types that are categorized and aligned at a glance • Return and cancellation buttons should be clearly written - It was confusing how to go to the next page - It felt inconvenient without a return button • The menu and the icon image of the application should reflect the corresponding functions - When the name of the menu and the icons are similar to the existing ones on the smart phones, it is easy to use • The color of the icon within one menu should be consistent - The IoT icon in green color seems odd while all the other icons are in blue
VUI	• The length of the conversation should be long enough to make the user feel that they are exchanging emotions - When the conversation does not last long and are broken down, it does not feel like they are exchanging emotions • When the voice command is tempted one after another, it should be recognizable without calling its name before each command - It is hard to make a long command recognized - It would be nice to be able to talk for up to 2 minutes freely after calling 'Hey Robot' • It should be user friendly for a slow talker to recognize their command without cutting off - It is hard to make a long command recognized
TUI	• The touch interaction should be composed considering affordance - The robot did not recognize to return to the previous page by the touch on the chin • It should apply the previously well used methods to make the object move so that it is user friendly - Controlling a joystick is more familiar and easy to manage rather than a double touch • Operating methods should be consistent - It is confusing when the operating methods are different from the home viewer to the home guide

3.2. Expert Survey

The expert survey was conducted with two experts from the product design field, two experts from the robot field, and one expert from the interface field. The experts were requested to observe and actually use the personal service robots and suggest their opinions by the interface factor organized in Table 2. They brought their overall opinions about the interface factors, especially focusing on their own specialities. The survey results have been organized by the standard interface factor classifications of 'attribute', 'performance', and 'user interface' factors as in Table 2.

3.2.1. Expert Suggestions by the Attribute Factor

The expert suggestions regarding the seven attribute factors are summarized in the following Table 6.

Table 6: Expert suggestions by the interface factor under attribute

Factor	Suggestion
Shape	• A formative point that can conquer out from the ones in competition is recommended • The formative similarity issues with the competitors should be improved • Shapes with a friendlier image is required • Various try-outs of the boundary expressions of the characters and the screen layouts are necessary
Structure	• A shape that can aggressively reflect the visual 3-axis motion is preferred
Size	• It should be in a size which does not burden the user to live with
Color	• By using the identity color, it can improve the similarity issues from the competitors
Face appearance	• Although there are personal preference differences, a robot looking type is popularized in the market so far
Tactile	• Texture with various CMF applied is suggested
Mechanical parts	• The display should be able to stimulate the interests • The screen size should be proportional to the robot's external size • The shape and the screen of the character should be formatively harmonious

3.2.2. Expert Suggestions by the Performance Factor

The expert suggestions regarding the six performance factors are organized in Table 7 below.

Table 7: Expert suggestions by the interface factor under performance

Factor	Suggestion
Movements	• The movement should be smooth
Gesture	• If the gesture expresses an emotion, it needs to be similar to the one of human or an animal
Voice	• The voice should be friendly so that the user feels the robot as a family • The pronunciation recognition should be easy
Sound effect	• The sounds should be the ones that are already familiar to the users
Light	• The emotions should be delivered efficiently and visually by using symbolic colors • The display light should be transmitted in many different ways • The display light can be a good factor
Facial emotion	• An emotion should be delivered well visually • The expressions on the display should be represented in various ways • The expressions on the display is an effective factor to exchange emotions with the user

3.2.3. Expert Suggestions by the User Interface Factor

The expert suggestions regarding the three user interface factors are organized below in Table 8.

Table 8: Expert suggestions by the interface factor under user interface

Factor	Suggestion
GUI	• The animation can reduce the boredom of waiting when there is a delay • The current status indication is preferred to be displayed with LED, an icon within the screen, or texts • The screen layout with the mental model from the existing smart phones are required
VUI	• When a pronunciation error is made, a more convenient method without having to re-input the command is wanted • When a mistake or problem is occurred, it is preferred to guide through with a voice • Besides the method of inputting command again when a pronunciation mistake is made, a more active recovery is necessary • Active listening is desired
TUI	• Various tactile feedback is wanted

4. Personal Service Robot Interface Design Guideline

Based on the user survey and the expert survey results, the guidelines for the interface design of the personal service robot have been suggested in the following Table 9.

Table 9: Personal service robot interface design guideline

Classification	Factor	Guideline
Attribute	Shape	• A shape that has an identity that can be distinguished from the competitors' • A friendly image shape
	Structure	• A structure with visually noticeable joints • A formatively stable joint structure, not overdone
	Size	• Smaller size to live with • A size that does not take up much space
	Color	• Use the color that represent the identity
	Face appearance	• A friendly looking, less revolutionary • A face looking not too realistic
	Tactile	• Materials that are easy to manage • Materials with high durability • Use the materials that various CMF can be applied onto

	Mechanical parts	• A screen size that is formatively balanced to the whole robot size • A screen that is harmonious to the robot appearance • Enough number of screens to deliver the information
Performance	Movements	• High degree of freedom to move around • Smooth and natural, not so stiff, movement
	Gesture	• Gestures that recognize the user's location • Not complicated gestures • For an emotional gesture, it should be similar to the one of a human or an animal
	Voice	• Voice with a variety of pitch • Voice that is suitable for the appearance • A friendly voice that the user can feel like a family • Clear pronunciation for the user to understand
	Sound effect	• The sound that goes well with the robot's expression • Unnecessarily repeated sounds • Sounds that the user does not feel alien
	Light	• Consistent light color emission • Diverse colors of light • Emission of the light with different colors in different situations considering the color symbolism
	Facial emotion	• Emotional expression to created friendliness • Emotional expressions that match with other factors
User interface	GUI	• Harmonious feedback with VUI and TUI • Visual feedback of the current status due to delay or idling • GUI that has considered the user's mental model made in the existing smart phones • A sense of color unity • Visible icons
	VUI	• A long conversation for emotional exchange • Active listening using additional questions • Very smooth and human-like natural pronunciation • Relatively active recovery through voice rather than re-inputting the command when a pronunciation mistake is

		made • Voice guidance feedback when a pronunciation error is occurred
	TUI	• Touch interaction composition considering affordance • Tactile feedback that is less simple • Not complicated operation method

5. Conclusion

This research was conducted in order to suggest the interface design guidelines for the personal service robots. To do so, based on the literature related to the HRI and the robot interface, the interface factors for the personal service robots have been organized into 16 factors; such as, shape, structure, size, color, face appearance, tactile, mechanical parts, movements, gesture, voice, sound effect, light, facial emotion, GUI, VUI, and TUI. Moreover, with a high-fidelity prototype of the personal service robot, a user survey and an expert survey were conducted in regards to the personal service robot interface. After all, the guidelines for each interface factor have been suggested. The key implications of the guidelines are as follows.

First, the factors that are included in the robot's attributes should be able to represent the product's identity. The typical factor that should express the identity is the shape. However, if it is hard to have distinction from the existing personal service robots in the market due to the formative similarity issues, it can be solved by using an identity color to differentiate it from the competitor's products. Besides, the factors under attribute are formatively stable and all the factors under attribute should be harmonious with each other. The structure should be formatively stable; the less number of joints the robot has, the more stable it will be. Besides, the screen should match the robot's shape and size so that it does not look awkward. Additionally, the size and the tactile should consider the durability. For the shape and the face appearance, it would be better not to use revolutionary attributes which may decrease the marketability due to the unfamiliarity to the users.

Secondly, for the factors of the robot's performance, the interface that is harmonizing and less disparate from the robot's basic attributes. The typical factors are voice and sound effect. The users expect vocal expressions that go along with the robot's external shape or face. Also, the factors of the performance should be not too simple or random but should be able to implement the performance with the rules that the user can recognize. The corresponding factor is light. When the robot has only one color of light, the user will easily lose interests, but too many lights emitted at random will confuse the user. Lastly, a broad range of freedom of performance is required, which can be carried out through movements and voice.

Thirdly, for the robot's user interface, the interface needs to be easily recognizable from the user's mental model and the affordance should be considered. GUI and TUI are the classic examples. For GUI, the users required the icons within GUI, texts and layouts to be similar to the ones from their smart phones or computers. Moreover, for TUI, the user's touch input and the robot's corresponding performance are desired to be reasonably convincing. Furthermore, the users wanted less complicated interactions for TUI because overly complex touch operating methods will make the users use that function relatively less often. Also, for the user interface factors, a clear feedback is necessary when idling; these include GUI, VUI, and TUI and they can complement each other.

The above guidelines for the personal service robot interface designs can be utilized to evaluate the personal service robot's interface or to design them; it can also be employed not only for the personal service robots but for the robot's overall ideas or solutions.

Reference

Argall, B. D., & Billard, A. G. (2010). A survey of tactile human–robot interactions. *Robotics and Autonomous Systems*, 58(10): 1159-1176.

Chen, J. Y. C., Haas, E. C., & Barnes, M. J. (2007). Human performance issues and user interface design for teleoperated robots. *IEEE Transactions on Systems Man and Cybernetics Part C (Applications and Reviews)*, 37(6): 1231-1245.

Chung, S. E., & Ryoo, H. Y. (2018). Aural and behavioral factor research for robot design. *International Journal of Multimedia and Ubiquitous Engineering*, 13(2) : 1-6.

Chung, S. E., & Ryoo, H. Y. (2018). Level values of robot visual interface factors based on user's experience on screen, light, face. *International Journal of Control and Automation*, 11.5: 117-128

Chung, S. E., & Ryoo, H. Y. (2018). Study on the level value standard of the robot appearance interface factor for user experience design. *International Journal of Advanced Science and Technology*, 113.0: 153-164.

Hancock, P. A. , Billings, D. R. , Schaefer, K. E. , Chen, J. Y. C. , Visser, E. J. D. , & Parasuraman, R. (2011). A Meta-analysis of factors affecting trust in human-robot interaction. *Human Factors*, 53(5): 517-527.

Kanda, T., Miyashita, T., Osada, T., Haikawa, Y. , & Ishiguro, H. (2008). Analysis of humanoid appearances in human-robot interaction. *IEEE Transactions on Robotics*, 24: 725-735.

Lee, S. H., Choi, J. M., Baek, S. M. & Moradi, H. (2004). Cognitive Human-Robot Interaction for Service Robot. *Journal of The Korean Institute of Communication Sciences*, 21.10: 44-54.

Park, J. H. & Ryoo, H. Y. (2020). Derivation and Analysis of Home Robot Care Services. *International Journal of IT-based Public Health Management*, 7.1: 15-22.

Park, J. H. & Ryoo, H. Y. (2019). User-centered Service Concept for Home Robot Development. *Journal of Integrated Design Research*, 18.4: 47-62.