# User interface for remote control robot

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**Abstract**: The recent growth of the robot technology has made robots be popular and provides people with many opportunities to apply various robots. But most robots are controlled by its unique program, users feel hard and unfamiliar with robot. Therefore we need to find ways to make user feel comfortable and familiar with the usage of robot. First we will analyze how the user interacts with the robot. Next we will discuss a standard human-robot interface provide more usability with that analysis. In this paper, 10 degree of the Level Of Autonomy(LOA) are proposed. It is evaluated that what interface components and designs are proper to each LOA. Finally we suggest a way to design the standard human-robot interface for remote controlleds robot through handheld devices like the Personal Digital Assistant(PDA) and smart phone.

**Keywords:** robot, remote control, user interface, autonomy

## 1. INTRODUCTION

The user interface(UI) is like a passage from a robot to a user. It defines how the robot and the use interact and determines how the user controls the robot[1][2].

Nowadays the UIs are dedicated to implement functions of robot and do not consider the user's comfortableness[3]. It is difficult for the user who does not know robot system in detail and has no experience using the robot, because most robots have unique interface[4]. We need a standardized UI to resolve this problem[5]. Controlling a car or application programs of Windows OS have the standard UI, and thus even though the user use new car or program, the user can be familiar with those systems[6]. The human feels comfortable when they use similar interfaces which are already used. Therefore the standard UI can make the user be familiar with the robot.

It should be analyzed that how the user interacts with the robot to develop the standard UI. Also it should be evaluated what the criterion determines the interaction.

In this paper, a certain way is proposed to design the standard human interface through the autonomy of the robot.

The autonomy of the robot does not merely supplant but changes human activity and can impose new coordination demands on the human operator. The autonomy refers to the full or partial replacement of a function previously carried out by the human operator[7]. In other words, the autonomy of the robot determines the human-robot interaction because the user's control can differ in the level of the autonomy[7].

In this paper, the autonomy will be classify into 4 types and 10 levels which are provided by Parasuraman[8]. And also it is proposed that how to design the standard UI for each level. Since the UI can be determined with the level of autonomy and human-robot interaction, if these are standardized, the standard UI can be designed.

Since handheld devices are already popular and most people can connect to the network at anywhere, the robot can be controlled through network at remote area[9][10]. In the near future, everybody will be enable to control the robot at anytime and anyplace. Therefore in this paper, remote control robots which are connected via handheld devices like PDA are mainly treated.

## 2. THE AUTONOMY OF ROBOT

The level of autonomy(LOA) refers how much replacements of functions previously carried out by the human operator. The LOA decide the source and amount of information. Therefore the design of the UI is determined according to the LOA.

The designs of the UI are standardized as a consequence of the LOA standardizing. If the design of the UI is defined, user can select the robot by the LOA which means that the robots of same LOA have similar UI. The user who has used a robot of a certain LOA can use other robots easily which are with the same LOA. Finally the user has advantages of selecting and using the robot.

The research of system automation began with Sheridan's 'Telerobotics, Automation, and Human Supervisory Control'[8]. Many of the recent autonomy articles use this as a reference for an initial understanding of how humans and computers interact. Many of Sheridan's examples focus on Telerobotics where the human is physically separated from the system but still issuing commands[11].

Following figure helps in considering the future of supervisory control relative to various degrees of automation, and to the complexity or unpredictability of task situations to be dealt with.

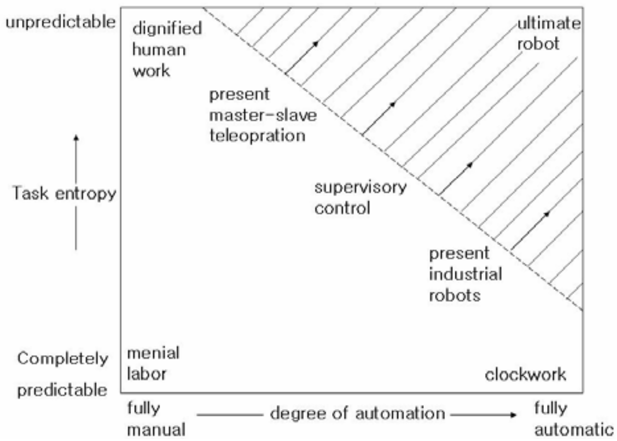


Fig. 1 Supervisory control relative to degree of automation and task predictability

The meanings of the four vertex of this rectangle should be considered. The lower left is labeled "menial labor" because to employ a human being to perform completely predictable tasks is demeaning (though the truth is that many of us operate voluntarily pretty close to this in doing many small task each day). The upper right, "use of machine for totally unpredictable tasks," is usually not attainable, and might be considered an ideal for technology. However, in special and narrowly defined cases, such as the use of computers to generate random numbers or to experiment with "chaos" for art or mathematics, we might have to admit that machines are already working. The upper left is where most of us feel humans belong: working on problems undefined and unpredictable. Indeed, this seems to be where creativity and dignity, at least of the intellectual sort, are to be found. The lower right, in contrast, seems an entirely appropriate locus for full automation; however, none but the simplest fully automatic machines already exist. Few real situations occur at these extremes. Supervisory control may be considered to be a frontier (diagonal line in figure) advancing gradually toward the upper right corner with improved technology[8].

Sheridan[8] proposes a 10 level scale of degrees of automation of decision and action selection as seen in the table below.

Table 1 The Level of Autonomy of Decision and Action Selection of Computer System

| | | |
|---|---|---|
| HIGH | 10 | The computer decides everything and acts autonomously, ignoring the human. |
| | 9 | Inform the human only if, the computer, decides to |
| | 8 | Inform the human in if asked, or |
| | 7 | Executes automatically, then necessarily informs the human, and |
| | 6 | Allows the human a restricted time to veto before automatic execution, or |
| | 5 | Executes that suggestion if the human approves, or |
| | 4 | Suggests one alternative |
| | 3 | Narrow the selection down to a few, or |
| | 2 | The computer offers a complete set of decision/action alternative, or |
| LOW | 1 | The computer offers no assistance: human must take all decisions and actions. |

This scale could be relabeled as Sheridan's Levels of Autonomous Decision-Making and Execution. Clearly, Levels 2 through 4 are centered on who makes the decisions, the human or the computer. Level 5-9 are centered on how to execute that decision. Level 1 and 10 are appropriate bounds for either issue[11].

We are going to make the standard design of UI for each of the LOA. If the user buys a new robot which has the same LOA, the user can control the robot through a familiar UI which is similar to the UI previous used robot had and the user feels comfortable and adjust easily.

The most important issue for the user to feel comfortable and adjust easily is make familiar and standard UI[5][6].

## 3. TYPES AND LEVELS OF AUTONOMY

At the beginning, the LOA of the robot are estimated with Sheridan's 10 level scale to design the interface. The user-robot interaction for each level is analyzed at previous section.

In 2000, Sheridan, et al. provided a revised model for the levels of automation with 'A Model for Types and Levels of Human Interaction with Automation'[3]. This model split the tasks that any human or system would ever have to perform into four categories: Information acquisition, information analysis, decision and action selection, and action implementation. Information acquisition is the task of sensing, monitoring, and bringing information to a human's attention. Information analysis is performing all of the processing, predictions, and general analysis tasks. Decision and action selection result in making choices. For example, "Based on the available analysis, what should the system do?" Action implementation is acting on decisions or commanding new actions. Levels in this category include the computer asking for authority to proceed and allowing human overrides.

Information analysis and action implementation are not related to the UI. Information analysis correlates with brain of the robot and action implementation correlates with the behavior of the robot. But information acquisition, decision and action selection affect the UI because the user collaborates with the robot to send or receive information and select and decide the next action.

### 3.1 Information Acquisition

The autonomy of information acquisition can divided into 10 levels as shown in table 2 below.

Table 2 The Level of Autonomy of Information Acquisition

| | | |
|---|---|---|
| HIGH | 10 | The robot gains all information by itself without considering the user. |
| | 9 | The robot gains all information by itself and informs user when it is necessary. |
| | 8 | Send some information which the user requested. |
| | 7 | Robot sends all information to the user. |
| | 6 | The robot finds information, then ask for approval. |
| | 5 | Robot estimates the information previously inputted by user and decides whether information is useful or not. If the robot needs more information, ask user information |
| | 4 | User sends new information which robot does not know. User command robot to gather information. Robot provides user with easy interface to help in gathering information. |
| | 3 | UI provide user with intuitional menus which help user to select a source and amount of information. The UI makes the user to know what actions is needed to gather information by intuition |

| | | |
|---|---|---|
| | 2 | UI simply provide with menus of every action of the robot. User decides and selects actions. |
| LOW | 1 | Robot does not offer any assistance to user on information acquisition. |

At levels 2 through 4, user commands robot to gather wanted information or to input information which the robot needs to do tasks. At the higher level, UI provides more abstract menus thus user can control more easily. At level 5, robot can estimate its information and determine whether it needs more information or not. If information is needed, robot asks user for more information by printing message or showing input-menu to the UI. At levels 6 through 9, the robot can gather all information by itself and inform user. Level 1 robot has no interface and level 10 is completely automated robot. Level 10 does not need collaboration with human. So UI is useless at levels 1 and 10.

### 3.2 Decision and Action Selection

In previous section, table 1:'Sheridan's 10 level scale of degrees of automation of decision and action selection' is discussed. The computer system in the table is changed into the robot as below table 3.

Table 3 The Level of Autonomy of Decision and Action Selection of the Robot

| | | |
|---|---|---|
| HIGH | 10 | The robot decides everything and acts autonomously, ignoring the user. |
| | 9 | Inform the user only if, the robot, decides to do so |
| | 8 | Inform the user when only asked, or |
| | 7 | Executes automatically, then necessarily informs the user, and |
| | 6 | Allows the human a restricted time to veto before automatic execution, or |
| | 5 | Executes that suggestion if the human approves, or |
| | 4 | Suggests one alternative |
| | 3 | Narrow the selection down to a few, or |
| | 2 | The robot offers a complete set of decision/action alternative, or |
| LOW | 1 | The robot offers no assistance: user must take all decisions and actions. |

Decision and action selection mean that robot support user to decide and select next action. The UI must make the user and robot collaborate to each other so that user can decide and select next action easily.

At levels 2 though 4, robot only support user to select next action. At level 5 and 6, robot can decide action by itself with the user's approval. At levels 7 through 10, robot works by itself even without the user's command.

### 3.3 The level of autonomy for remote control

Now the level of autonomy of the remote control robot will be discussed. The level of 'information acquisition' and 'decision and action selection' should be combined to analyze practical user-robot interaction for remote control at each level[7][11].

Next figure show how the user and robot interact at each level and how the user controls the robot from remote area.

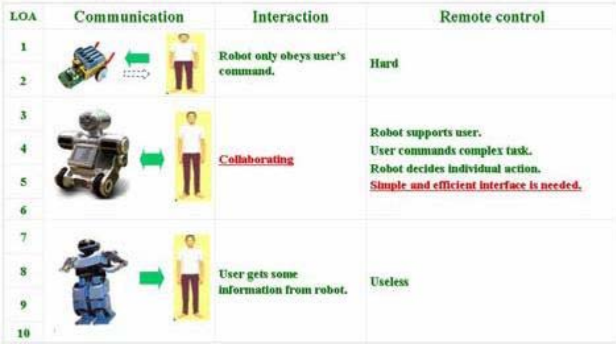


Fig. 1 Interaction of Each Level of Autonomy

At levels 1 and 2, the robot just receives user's command for executing. All the user sends is information and commands and the user receives simple numeric data like sensor value from the robot. The user has to give a full detail of action and information to the robot and thus if the user is far from the robot, it is very hard for the user to control it. Therefore the UI becomes very complex and difficult.

At levels 3 through 6, the user and robot will collaborate to gather information and decide actions. The robot can be adjusted to its environment by itself and inform the user and support to decide actions[3]. Also the robot can send information about its environment and suggest action[4]. Therefore the user can control at remote area with handheld devices.

At levels higher than 7, the robot works by itself and only inform the user. Therefore communication and the user's control is needless. The UI will be not needed or useless.

## 4. STANDARD USER INTERFACE FOR REMOTE CONTROL ROBOT

When the robot is controlled with handheld devices, we should consider the restricted environment[9]. Display screen is very small and input-output devices are limited. Therefore we cannot implement every function of the robot on the UI. So we need to increase the level of autonomy and make a simple and efficient interface, so that even if the user sends simple command selecting just one or two menus, the robot can understand user's command and extract complex actions from that[3]. For example, the user may just command the robot to clean room. But the robot needs many kinds of information to clean the room like room size or obstacle positions. The UI on PDA is very restricted and user cannot send all of the information the robot needs. Therefore even if the user is unable to send enough information, the robot has to gather information by itself to clean the room and begin cleaning. For remote control robots, it is needed to standardize the level of autonomy and UI to each level. And also it is essential to find common elements.

We propose the standard UI library. First, we will analyze each interface of every level and extract atomic elements. Next, we will make an interface library with those elements. If the UIs are made from the library, user can always use familiar interfaces even if the user uses any of the robots which have any the level of autonomy. And UI developer does not implement every interface individually.

### 4.1 Critical elements of user interfaces

There are many detailed actions in individual robot action. Also there are many atomic interface elements in the detailed action. For example, object detecting, distance checking and path planning are used to avoid obstacles. Also, several interfaces for coordination, approval and display window are used to plan the path. Those interfaces are called atomic elements and if certain atomic interfaces are used frequently, they are called critical elements.

To extract atomic elements, we use logic tree tool shown in the figure below.

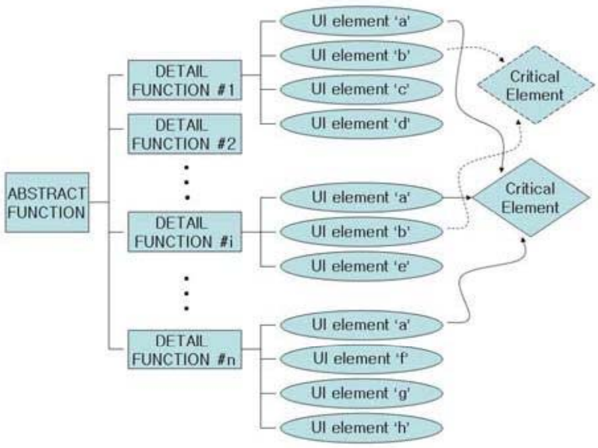


Fig. 2 The Logic Tree to Extract Interface elements

We need several steps to draw the logic tree. First we make a scenario based on the behavioral model, how the user uses remote control robot. Second, we extract all actions of the robot behaviors. Then we divide an action into detailed functions. Finally we can extract interface elements from the detailed function and collect the critical elements.

### 4.2 Library pool

We can make a library pool through an analysis of a variety of robots. We can make interfaces for each level of robot as seen in the figure below.

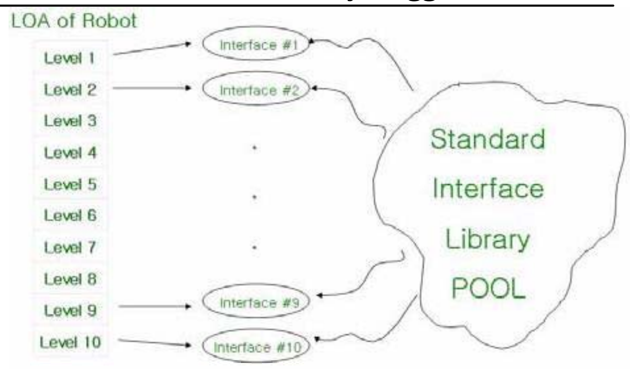


Fig. 3 The Library Pool for Standard Interface

After building the library pool, if the developers want to make a UI program, all they have to do is select and assemble some libraries. Since it is made from the pool, elements might overlap. Therefore anyone who has an experience of using any level of the interface program will be familiar with the other ones.

Most home robots have certain common functions. If an analysis is made of the functions that are essential for remote control, not only the interface design but the design of the robot can be acquired. First of all, the interface elements for the general functions of robots which are vision, sensor, navigation, network, map, security and user interaction should be made. The library pool can be made with these functions and then the design of a robot can be made with the library pool. Nowadays most robots are specific to certain purposes. But robots will be general and used for home in the near future. The robots will be the full or partial replacement of functions previously carried out by the household electric appliances. Such a general robots should be designed concurrently with designing of UI.

## 5. CONCLUSION

The UI is essential for user-robot interaction. If the user uses familiar UI even though the robot is different, the user can control the robot easily and feel comfortable. The autonomy of the robot should be graded and the robot and UI should be produced for the each grade. In previous sections, the user-robot interaction is graded with LOA in table 2, 3. Follow the LOA table, the remote control should have over than 3 degree of LOA. Then the interface elements of UI can be extracted through the Logic Tree in figure 2. Finally the standard library pool is proposed and the UI for each LOA can be made.

When the user controls the robot at remote area with handheld devices, the UI should be efficient and simple. Moreover it is essential for the remote control that the robot should have high level autonomy, because the robot should extract complex actions from the user's abstract command and also collaborate with the user on communication and execution. The robot should request information and support to decide and select actions dynamically.

The design of UI and robot should be synchronized. Robot designers should decide the robot to be able to remote control and its LOA. The remote control robot should have be autonomous and specific UI for remote control. If the robot is controlled by handheld devices, the designers should consider its restricted resource.

If the robot can be controlled at anywhere and anytime and its UI is comfortable, the robot make our dream life come true.

## REFERENCES


[1] Julie A. Adams, "Critical Considerations for Human-Robot Interface Development," *AAAI Fall Symposium: Human Robot Interaction Technical Report FS-02-03.* Nov. 2002, pp.1-8

[2] R. Parasuraman and M. Mouloua, "Automation and Human Performance: Theory and Applications. Mahwah," *NJ: Erlbaum*, 1996.

[3] Fong. T. W., Grange. S, Conti. F. and Baur. C. "Advanced Interfaces for Vehicle Teleoperation: Collaborative Control, Sensor Fusion Displays, and Remote Driving Tools", *Autonomous Robots 11*, Vol. 1. July 2001. pp 77-85.

[4] T. Fong, C. Thorpe, and C. Baur, "Multi-Robot Remote Driving With Collaborative Control," *IEEE Transactions on Industrial Electronics,* Vol. 50, No. 4, pp. 699-704, Aug. 2003.

[5] Scott W. Ambler, "User Interface Design:Tips and Techniques," *Cambridge Univ.* Oct, 2002

[6] Macquire M. C. "A review of user-interface design guidelines for public information kiosk systems," International Journal of Human-Computer Studies, 50, 262-286

[7] Parasuraman, R., Sheridan, T. B. and Wickens, C. D. "A Model for Types and Levels of Human Interaction with Automation," *Proceedings of IEEE Transactions on Systems, Man, and Cybernetics – Part A: Systems and Humans, Vol. 30, No.3*, 2000.

[8] Sheridan, T. B. "Telerobotics, Automation, and Human Supervisory Control," *The MIT Press*. 1992

[9] Brad A. Myers, Jeffrey Nochols and Jacob O. Wobbrock, "Taking Handheld Devices to the Next Level," *IEEE Computer Society,* Dec, 2004

[10] Chanitnan, "Internet-based control," *University of Texas of Arlington,* May 2002.

[11] Proud, R.W., Hart, J.J and Mrozinski, R.B. "Methods for determining the level of autonomy to design into a human spaceflight vehicle: a function specific approach," *Proceedings of the 2003 Conference on Performance Metric for Intelligent Systems*, 2003.

[12] S. Musse, M. Kallmann and D. Thalmann, "Level of autonomy for virtual human agents," *Proceedings of ECAL 1999*