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# Selection of Suitable GUI for Various Controllers Using Analytic Hierarchy Process

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***Abstract*— This paper proposes a method of selecting design strategies for user interfaces for various controllers based on an analytic hierarchy process. The goal of this model is to modify the graphical user interface of a remote controller to one that is the most suitable for each user. This paper proposes a new model with six evaluation criteria — Physiological, Knowledge, Psychology, Complicated System, Complicated Peripherals, and Habit. As alternatives, *we* decided our design strategy for the user interface — Vision assistance, Cognition assistance, Operation assistance, Memorizing. This proposed method was realized and evaluated by incorporating a processor assumed to be for AV remote controller use as practical applications. This paper verifies its effectiveness.**

***Keywords*— component, Analytic hierarchy process,design strategy, optimized user interface**

## I. INTRODUCTION

This paper proposes a method of selecting design strategies for user interfaces for various controllers based on an analytic hierarchy process. As practical applications, this paper discusses about an audio-visual (AV) remote controller.

An AV remote controller and its user interface have the problem of who is using the AV remote controller. There are many kinds of user in homes such as children and the elderly, as well as those with vision impaired and different levels of ability with AV equipment. When different people use the same AV remote controller, it cannot satisfy all their requirements.

When considering the many needs of users, system complexity, functions and additional equipment, the controller requires various interfaces, which are not practical to produce.

The authors have proposed some design strategy models on user interface of AV remotes [1, 2]. However, these targeted general users interface (UI) and have not discussed special alternatives for Graphical User Interface (GUI).This study proposes solving this problem by changing the GUI of a multi-wireless remote controller.

This paper describes a new model of AV remote controller GUI using an Analytic Hierarchy Process (AHP) [3]. It proposes a method in which the GUI evolves with each user. The method of selecting the GUI design strategy in accordance with a user's requirements is also described. Finally, a prototype AV remote controller was built for verification.

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## II. CONCEPTUAL MODEL OF UI DESIGN USING AHP

### A. Problems of GUI of AV remote controls

The UIs of AV remote controls have conventionally been designed on the basis of the functions of the entire AV device or the AV system. This design method is based on technological ideas, and it has been a technology-pushed design policy.

However, the following problems occur when the remote controller is used by many kinds of user.

(1) Users have different physiologies such as failing eyesight due to aging.

(2) Users have different knowledge, capabilities and experiences with AV systems.

(3) The same user may have a different state of mind depending on the details of the operation, the working environment and other factors.

(4) Each user has an AV system with different equipment.

(5) Each AV device has various numbers of functions.

(6) The device used and performed operations frequently of the AV machinery differ according to the user.

Consequently, what users require of the GUI of their AV remote controls is that the interface should be optimized according to the situation and the condition of the users themselves in relation to the problems above.

### B. Conventional model for GUI design strategy based on AHP and its problems

In this section, this paper proposes a new model for GUI designs based on AHP to solve the problem of the before discussing the content of this paper.

Figure 1 show the conceptual model proposed by the authors for the GUI design strategy, with the model composed of three steps: goal, evaluation criteria, and alternatives proposal.



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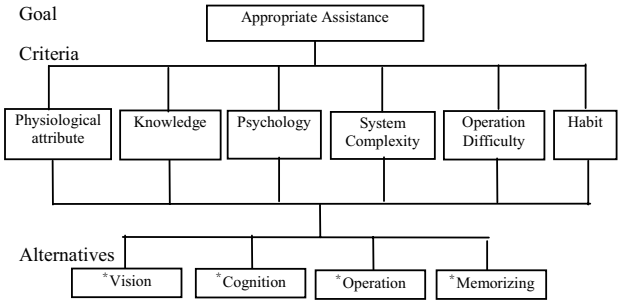


Figure 1. Proposed GUI design strategy model based on AHP

The goal of this model is to modify the GUI of a wireless remote controller to one that is the most suitable for each user. Next, the six basic evaluation criteria given below are introduced. Physiological attribute criterion (Phy) shows the user's age, sex, and eye-sight. Knowledge criterion (Kn) means the ability to understand an AV system. Psychographic criterion (Psy) shows the user's feeling based on their situation and operation status. System complexity criterion (Sys) shows the complexity of the AV system. Operation difficulty criterion (Ope) shows the complexity of operating the AV system. Habit criteria (Ha) show the user's habits.

Finally the authors evaluated the demand of each user based on these evaluation criteria and chose most suitable GUI from the following four interfaces as alternatives.

Figure 1 shows the proposed model for the GUI design strategy based on an AHP. In this figure, the alternative interfaces are abbreviated as follows. *Vision means a vision assistance interface which is for the display method. Cognition means a cognition assistance interface which is for the expression method, Operation means an operation assistance interface which is to select the speed of the reaction, and Memorizing means a memorizing interface where the AV remote controller learns the functions that the user controls frequently.

TABLE I. POSITIONING OF SIX CRITERIA

| | Static | Dynamic |
|---|---|---|
| **User** | Physiological Attribute | Psychology |
| | Capability | |
| **AV system** | Complicated System | Habitual |
| | Complicated Peripherals | |

Table I shows the relationship between the six evaluation criteria. The relationship ranking is based on the distinction of whether the cause lies with the user or the AV system, or whether the information stays constant as an attribute or changes with the situation.

## III. SAMPLE CALCULATIONS OF SUGGESTED MODEL AND PROTOTYPE

This section gives a specific sample calculation using an AHP, assuming the users described below and the environment around the users, to as samples.

This paper gives two examples below a value to show the six evaluation criteria in Table II.

The assumed user is the elderly or children. These users have contrasting criteria for Vision. The elderly person has a vision problem, the child doesn't. The others are common to the two examples, with limited understanding. The AV device and neighboring equipment are not complicated. Also they are using the AV remote controller for the first time. In addition, there is no particular stress is using the GUI.

### *A. Case of the elderly*

Based on the information given above, a paired comparison was performed between every two of the six criteria in order to compare their importance. Then the importance was evaluated by a scale with four grades: equal importance, weak importance, strong importance and very strong importance. In this study, 1, 3, 5 or 7 marks were given to each evaluation.

TABLE II. EVALUATION VALUES FOR THE SIX CRITERIA

| Criteria | Phy | Kn | Psy | Sys | Ope | Ha | Weight |
|---|---|---|---|---|---|---|---|
| **Phy** | 1 | 1 | 3 | 5 | 3 | 7 | 0.320 |
| **Kn** | 1 | 1 | 3 | 5 | 3 | 7 | 0.320 |
| **Psy** | 1/3 | 1/3 | 1 | 3 | 1 | 5 | 0.134 |
| **Sys** | 1/5 | 1/5 | 1/3 | 1 | 1/3 | 3 | 0.061 |
| **Ope** | 1/3 | 1/3 | 1 | 3 | 1 | 5 | 0.134 |
| **Ha** | 1/7 | 1/7 | 1/5 | 1/3 | 1/5 | 1 | 0.032 |

C.I.=0.031.

Table II shows the values of the six criteria. The consistency index (C.I.) value is 0.031, which is lower than 0.1, indicating that it is effective.

This table shows average values of evaluation results by the following four people: a man and a woman in twenties, a woman in thirties and a man in fifties.

Next, the values are set for four alternative design strategies by criteria, as shown in Table III to VIII.

The subject who is a man with 1.0 of corrected eyesight in fifties evaluated the alternatives by method of paired comparisons.

From Table III, the calculation of the weight of each alternative strategy in relation to the procedures criteria will obtain the values of 0.657 for vision, 0.191 for cognition, and 0.076 for operation and memorizing. The values given in these tables result from a comparison of importance after paired comparisons between the four design strategies of the user interface, which are alternatives as in the case of criteria. A mark of 1 is given to equal importance, 3 to weak importance, 5 to strong importance, and 7 to very strong importance.

TABLE III. SETTING OF ALTERNATIVE DESIGN STRATEGIES IN RELATION TO PHYSIOLOGICAL ATTRIBUTE

| | Vis | Cog | Ope | Mem | Weight |
|---|---|---|---|---|---|
| **Vis** | 1 | 5 | 7 | 7 | 0.657 |
| **Cog** | 1/5 | 1 | 3 | 3 | 0.191 |
| **Ope** | 1/7 | 1/3 | 1 | 1 | 0.076 |
| **Mem** | 1/7 | 1/3 | 1 | 1 | 0.076 |

C.I.=0.025.

TABLE IV. SETTING OF ALTERNATIVE DESIGN STRATEGIES IN RELATION TO CAPABILITY

| | Vis | Cog | Ope | Mem | Weight |
|---|---|---|---|---|---|
| **Vis** | 1 | 1 | 3 | 3 | 0.368 |
| **Cog** | 1 | 1 | 3 | 3 | 0.368 |
| **Ope** | 1/3 | 1/3 | 1 | 1/3 | 0.096 |
| **Mem** | 1/3 | 1/3 | 3 | 1 | 0.169 |

C.I.=0.052.

TABLE V. SETTING OF ALTERNATIVE DESIGN STRATEGIES IN RELATION TO PSYCHOLOGY

| | Vis | Cog | Ope | Mem | Weight |
|---|---|---|---|---|---|
| **Vis** | 1 | 1/5 | 1 | 1/5 | 0.078 |
| **Cog** | 5 | 1 | 5 | 3 | 0.538 |
| **Ope** | 1/3 | 1/3 | 1 | 1/3 | 0.096 |
| **Mem** | 1/3 | 1/3 | 3 | 1 | 0.169 |

C.I.=0.052.

TABLE VI. SETTING OF ALTERNATIVE DESIGN STRATEGIES IN RELATION TO COMPLICATED SYSTEM

| | Vis | Cog | Ope | Mem | Weight |
|---|---|---|---|---|---|
| **Vis** | 1 | 1/3 | 1 | 1/5 | 0.095 |
| **Cog** | 3 | 1 | 3 | 1/3 | 0.249 |
| **Ope** | 1 | 1/3 | 1 | 1/5 | 0.095 |
| **Mem** | 5 | 1/3 | 5 | 1 | 0.560 |

C.I.=0.015.

TABLE VII. SETTING OF ALTERNATIVE DESIGN STRATEGIES IN RELATION TO COMPLICATED PERIPHERALS

| | Vis | Cog | Ope | Mem | Weight |
|---|---|---|---|---|---|
| **Vis** | 1 | 1/5 | 1 | 1/3 | 0.099 |
| **Cog** | 5 | 1 | 3 | 3 | 0.523 |
| **Ope** | 1 | 1/3 | 1 | 1/3 | 0.116 |
| **Mem** | 3 | 1/3 | 3 | 1 | 0.263 |

C.I.=0.039.

TABLE VIII. SETTING OF ALTERNATIVE DESIGN STRATEGIES IN RELATION TO HABIT

| | Vis | Cog | Ope | Mem | Weight |
|---|---|---|---|---|---|
| **Vis** | 1 | 1/3 | 1 | 1/5 | 0.095 |
| **Cog** | 3 | 1 | 3 | 1/3 | 0.249 |
| **Ope** | 1 | 1/3 | 1 | 1/5 | 0.095 |
| **Mem** | 5 | 3 | 5 | 1 | 0.560 |

C.I.=0.015.

Tables IV to VIII show the other five criteria computed in the same way.

The above sample calculations resulted in C.I. values of 0.025, 0.052, 0.052, 0.015, 0.039, and 0.015 all being less than 0.1, and it can be said that the results of these calculations are effective.

Based on the Eigen value of criteria obtained from Table II and the Eigen value of each design strategy obtained from Tables III to VIII, comprehensive evaluation results are determined using the following equation;

$$\begin{bmatrix} \textit{Vision} \\ \textit{Cognition} \\ \textit{Operation} \\ \textit{Memorizing} \end{bmatrix} = \begin{bmatrix} 0.657 & 0.368 & 0.078 & 0.095 & 0.099 & 0.095 \\ 0.191 & 0.368 & 0.538 & 0.249 & 0.523 & 0.249 \\ 0.076 & 0.096 & 0.076 & 0.095 & 0.116 & 0.095 \\ 0.076 & 0.169 & 0.305 & 0.560 & 0.263 & 0.560 \end{bmatrix} \cdot \begin{bmatrix} 0.320 \\ 0.320 \\ 0.134 \\ 0.061 \\ 0.014 \\ 0.032 \end{bmatrix}$$

$$= \begin{bmatrix} 0.555 \\ 0.344 \\ 0.090 \\ 0.215 \end{bmatrix} \quad (1)$$

This example concludes that Vision is the most important alternative for GUIs, followed by Cognition and then by Memorizing, and Operation is not important.

## *B. Case of children*

This paper calculated the case of child in the same way.

The values are set for the four alternative design strategies by criteria, as shown in Tables IX to XIV. The values given in these tables have the same use as the case of the elderly person.

TABLE IX. SETTING OF ALTERNATIVE DESIGN STRATEGIES IN RELATION TO PHYSIOLOGICAL ATTRIBUTE

| | Vis | Cog | Ope | Mem | Weight |
|---|---|---|---|---|---|
| **Vis** | 1 | 1/5 | 1 | 1/3 | 0.095 |
| **Cog** | 5 | 1 | 5 | 3 | 0.560 |
| **Ope** | 7 | 1/5 | 1 | 1/3 | 0.095 |
| **Mem** | 3 | 1/3 | 3 | 1 | 0.249 |

C.I.=0.014.

TABLE X. SETTING OF ALTERNATIVE DESIGN STRATEGIES IN RELATION TO CAPABILITY

| | Vis | Cog | Ope | Mem | Weight |
|---|---|---|---|---|---|
| **Vis** | 1 | 1/5 | 1/3 | 1/5 | 0.068 |
| **Cog** | 5 | 1 | 3 | 1 | 0.390 |
| **Ope** | 3 | 1/3 | 1 | 1/3 | 0.152 |
| **Mem** | 5 | 1 | 3 | 1 | 0.390 |

C.I.=0.015.

TABLE XI. SETTING OF ALTERNATIVE DESIGN STRATEGIES IN RELATION TO PSYCHOLOGY

| | Vis | Cog | Ope | Mem | Weight |
|---|---|---|---|---|---|
| **Vis** | 1 | 1/5 | 1 | 1/5 | 0.078 |
| **Cog** | 5 | 1 | 5 | 3 | 0.538 |
| **Ope** | 1 | 1/5 | 1 | 1/5 | 0.076 |
| **Mem** | 5 | 1/3 | 5 | 1 | 0.305 |

C.I.=0.052.

TABLE XII. SETTING OF ALTERNATIVE DESIGN STRATEGIES IN RELATION TO COMPLICATED SYSTEM

| | Vis | Cog | Ope | Mem | Weight |
|---|---|---|---|---|---|
| **Vis** | 1 | 1/3 | 1 | 1/5 | 0.095 |
| **Cog** | 3 | 1 | 3 | 1/3 | 0.249 |
| **Ope** | 1 | 1/3 | 1 | 1/5 | 0.095 |
| **Mem** | 5 | 3 | 5 | 1 | 0.560 |

C.I.=0.015.

TABLE XIII. SETTING OF ALTERNATIVE DESIGN STRATEGIES IN RELATION TO COMPLICATED PERIPHERALS

| | Vis | Cog | Ope | Mem | Weight |
|---|---|---|---|---|---|
| **Vis** | 1 | 1/5 | 1 | 1/3 | 0.099 |
| **Cog** | 5 | 1 | 5 | 3 | 0.560 |
| **Ope** | 1 | 1/5 | 1 | 1/5 | 0.095 |
| **Mem** | 3 | 1/3 | 3 | 1 | 0.249 |

C.I.=0.014.

TABLE XIV. SETTING OF ALTERNATIVE DESIGN STRATEGIES IN RELATION TO HABIT

| | Vis | Cog | Ope | Mem | Weight |
|---|---|---|---|---|---|
| **Vis** | 1 | 1/3 | 1 | 1/5 | 0.095 |
| **Cog** | 3 | 1 | 3 | 1/3 | 0.249 |
| **Ope** | 1 | 1/3 | 1 | 1/5 | 0.095 |
| **Mem** | 5 | 3 | 5 | 1 | 0.560 |

C.I.=0.015.

The above sample calculations resulted in C.I. values of 0.014, 0.015, 0.052, 0.015, 0.014, and 0.015, all being less than 0.1 and it can be said that the results of these calculations are effective.

Based on the Eigen value of criteria obtained from Table II and the Eigen value of each design strategy obtained from Tables IX to XIV, comprehensive evaluation results are determined using the following equation;

$$\begin{bmatrix} Vision \\ Cognition \\ Operation \\ Memorizing \end{bmatrix} = \begin{bmatrix} 0.095 & 0.068 & 0.078 & 0.950 & 0.950 & 0.905 \\ 0.560 & 0.390 & 0.538 & 0.249 & 0.560 & 0.249 \\ 0.095 & 0.152 & 0.076 & 0.095 & 0.095 & 0.095 \\ 0.049 & 0.390 & 0.305 & 0.560 & 0.249 & 0.560 \end{bmatrix} \cdot \begin{bmatrix} 0.320 \\ 0.320 \\ 0.134 \\ 0.061 \\ 0.014 \\ 0.032 \end{bmatrix}$$

$$= \begin{bmatrix} 0.084 \\ 0.407 \\ 0.111 \\ 0.331 \end{bmatrix} \quad (2)$$

This example concludes that Cognition is the most important for the GUI, followed by Memorizing and then by Operation, and Vision is not important.

Therefore, vision was the most important alternative for the elderly, but not for children.

Using evaluation values provided by the attributes of each user in this way, a strategic design policy for GUIs suitable for each individual was achieved.

### *C. Example of prototype of the proposed model*

The weight calculation above can be simply determined by setting the criteria values using the method mentioned above.

Figure 2 shows the system structure of the prototype system.

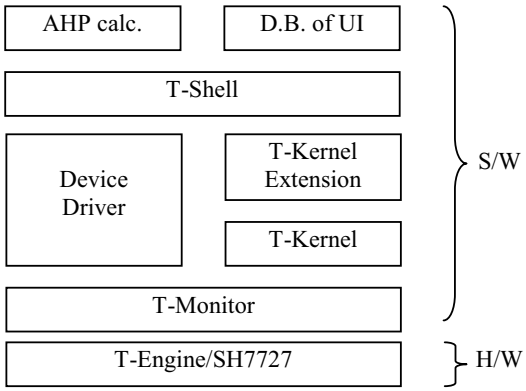


Figure 2. System structure of the prototype system

TABLE XV. SPECIFICATIONS OF PROTOTYPE SYSTEM OF REMOTE CONTROL

| Item | Model and Specifications |
|---|---|
| **MPU** | 32-bit RISC<br>Internal clock frequency: 96 MHz<br>External clock frequency: 48 MHz |
| **Memory** | SDRAM: 8 MB<br>Flash: 32 MB |
| **External size** | 120×75×50 mm3 |
| **Software size** | Total: 1.8 MB<br>RTOS: 1.2 MB(T-Kernel)<br>AHP applicayion:0.6 MB |

This calculation algorithm was used in the evaluation system of the AV remote control. Figure 4 is a prototype of an AV remote controller employing our suggestion model.

It was assumed that the prototype is a wireless remote controller for household appliances with small CPU resources and a real-time OS. The evaluation system confirms its operability. Table XV lists its specifications.

This implementation was performed according to flow chart in Figure 3 below.

The flow chart is as follows. First it, asks the user some questions to find the user's capabilities. Next, it gets information about complicated system and complicated peripherals. Then it, calculates based on this information. Finally, based on the results it, revises the GUI and displays it.

This evaluation system confirms its operability.

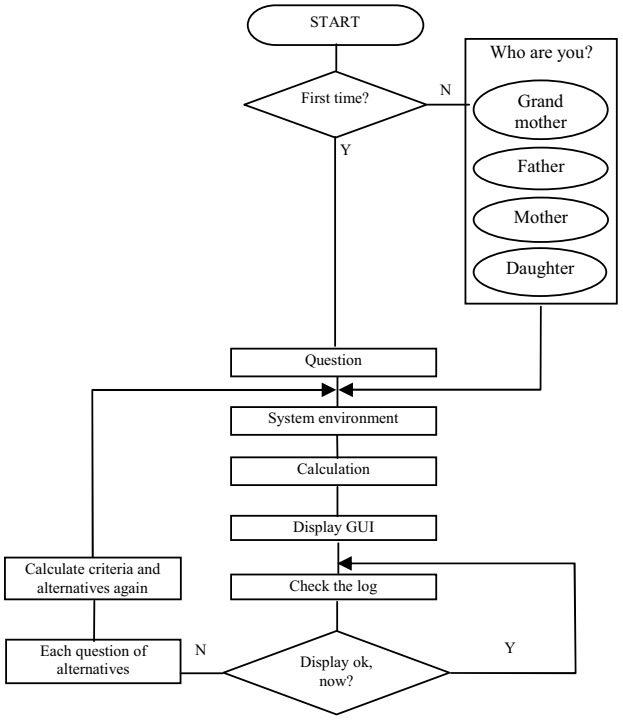


Figure 3. Flow chart of this system

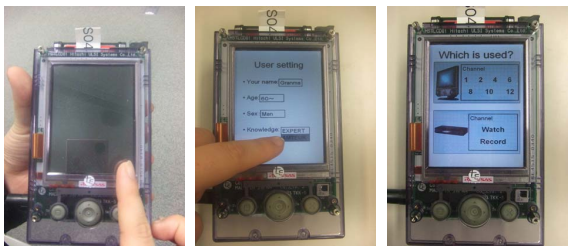


Figure 4. Example of prototype of the suggested model

## IV. CONCLUSION

This paper has proposed a method of selecting design strategies for user interfaces for AV remote controllers based on an analytic hierarchy process.

In this method, the design policy for the optimum UI is selected on the basis of the functions and scale of the AV system and the user's knowledge. The goal of this model is to revise the GUI of a wireless remote controller to one that is the most suitable for all users. This paper proposes a new model with six evaluation criteria; Physiological Attributes, Knowledge, Psychology, Complicated System, Complicated Peripherals, and Habit. As alternatives, we decided our design strategy for user interfaces as Vision assistance, Cognition assistance, Operation assistance, Memorizing.

This paper has described this evolution by incorporating a processor assumed to be for an AV remote controller, and has verified its effectiveness. This paper calculated the cases of the elderly and children. The elderly person has a vision problem, on the other hand the child doesn't. As a result, vision was the most important alternative for the elderly person, but not for the child. Using evaluation values provided by the attributes of each user in this way, a strategic design policy for GUIs suitable for each individual was achieved. Next, this calculation algorithm was used in the evaluation system of an AV remote control, actually selecting the GUI and confirming its operability.

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