Exploratory Study of Future Remote Control Design

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Abstract: Completely integration of technology and life will be the future of human's lifestyle. "Remote Control" is a common operation behavior in human's daily life, and remote control technology is widely used in industrial production, military, family, entertainment and special using the given requirements. Popularization of human-machine interaction technology procures the remote control technology to produce sweeping changes. The design mode of single-handed remote control is not only a total solution to meet the needs of future life, but also is a process based on insight into the user's demand for interactive services.

This study develops a three-stage structured design approach for future remote control. First, the interdisciplinary team of experts organized expert meetings to explore forward-looking remote control mechanism, and propose a design vision and future trends. Next, the research team constructs prototype based on experts' recommendations. Finally, this study proposes an integrated structured approach to verify the prototype. The Interpretive Structural Model (ISM) technique is adopted to construct a hierarchical structure, and the Impact Matrix Cross-Reference Multiplication Applied to a Classification (MICMAC) approach is employed to analyze the effect and dependence among the design factors, and to consider the relationship network graph of distribution of factors in the prototype.

This study establishes a prospective study mode for creating a model of future remote control with multiple design factors is by building a hierarchical structure and analyzing the factors distribution.

Key words: Remote Control, Hierarchical structure, Interpretive Structural Model, Impact Matrix Cross-Reference Multiplication Applied to a Classification

1. Introduction

Since entering the digital era, users still will not consider the remote control as necessary living aids in home life. Even users consider the remote control is just only an appendage of home appliances, or a technological popular commodity. Information and Communication Technology (ICT) has become a design technology for home appliances at the end of the 20th century. "Control" such a prescriptive function, also show a considerable degree of evolution. Innovative remote control technology has generated significant impact on patterns of behavior that people interact with the environment.

Completely integration of technology and life will be the future of human's lifestyle. "Remote Control" is a common operation behavior in human's daily life, and remote control technology is widely used in industrial production, military, family, entertainment and special using the given requirements. Popularization of human-machine interaction technology procures the remote control technology to produce sweeping changes. The design mode of single-handed remote control is not only a total solution to meet the needs of future life, but also is a process based on insight into the user's demand for interactive services.

Since 1898, Nikola Tesla invented the first remote control has been 115 years. When people use smart phones and tablet PCs, remote control technology has been given a broader definition. The handheld device's App included remote control functionality, the seamless connection between hardware and software is an inevitable trend. Innovative control technology is often influenced by diverse factors. These factors, in addition to technology, but also include aesthetics, psychology, sociology and design ecology. The combination of various factors can produce the property of mutual influence, and reflect the property of the whole hierarchical structure [10]. The directional dependence relationships in a structured architecture with the hierarchical properties are often observed among each hierarchy.

This study develops a three-stage structured design approach for future remote control. First, the interdisciplinary team of experts organized expert meetings to explore forward-looking remote control mechanism, and propose a design vision and future trends. Next, the research team constructs prototype based on experts' recommendations. Finally, this study proposes an integrated structured approach to verify the prototype. The Interpretive Structural Model (ISM) technique is adopted to construct a hierarchical structure, and the Impact Matrix Cross-Reference Multiplication Applied to a Classification (MICMAC) approach is employed to analyze the effect and dependence among the design factors, and to consider the relationship network graph of distribution of factors in the prototype.

2. The Structural method of remote control design

2.1 Remote control technology

Nikola Tesla developed the first remote control in 1898. His patent, US Patent 613,809, named "Method of an Apparatus for Controlling Mechanism of Moving Vehicle or Vehicles" [5]. The first wireless remote control was developed in 1955 by Eugene Polley. Robert Adler developed a wireless remote which used ultrasound to change the channel and volume in 1956. It is the first modern wireless remote control device.

The current remote control technology means an electronic or mechanical device which could control only single specific object. Due to technological innovation, the remote control mechanism will provide users the following services: communication, experiences, entertainment, speed, identity characterization and popular culture, etc. In addition to the optical transmission and radio wave transmission technology, the remote control technology of the future will use placed on the application of biotechnology to the remote control mechanism, such as brain wave, hand gesture, eye-tracking and somatosensory control.

Remote control technology in the future is closely associated with human behavior patterns. To discuss the future development of remote control technology, must be analyzed for a variety of perspectives and factors.

2.2 Building Hierarchical Structure

The construction of the structure of hierarchical factors is useful for illustrating clearly the interactive relationship among all factors within the architecture. The ISM (Interpretive Structural Model) can assist designers to construct a hierarchical structure of the overall impact factors. ISM is system structure modeling approach presented by Warfield [6-9] to analyze and build the element connection model within the complicated system.

The theoretical foundation of ISM is based on discrete mathematics, graph theory, social science and collective planning. The relational sequence of each element within the complex system can be analyzed by ISM, and the graph of the relational structural hierarchy with the property of hierarchy can be built using quantitative methods. The calculation model of ISM is as follows.

(1) Analyze the binary relationship among constituent elements within the system. If the system is a set, S, consisting of n elements, then $S= \{S_1, S_2,\ldots, S_n\}$. And (S_i,S_j) is the ordered pair of element S_i and S_j. Elements in set S must have a binary relationship.

(2) Adjacency matrix Construction. The relevant factors are found from the system, and are defined as F_i, where $i= \{1, 2, 3,\ldots, n\}$. Factors are placed in the matrix to form a pair-to-pair comparison. If two factors have a direct relationship, then the corresponding element is given a value of 1. Otherwise, the element is given a value of 0. If factors F_i on row i are directly related to factors F_j in column j then $A= [a_{ij}]$ exists, and is defined as the adjacency matrix.

(3) Reachability matrix development. The adjacency matrix A and identity matrix I are added to become an element connection matrix, B. Restated: $B=A+I$.

The reachability matrix is defined a binary matrix in the hierarchical digraph. The matrix of B is calculated from the Boolean algebra, matrix product and get the matrix to the power n, where n is confirmed such that

$(A+I)^{n-1} < (A+I)^n = (A+I)^{n+1}$

The reachability matrix is R.

(4) Hierarchy graph establishment**.** The digraph is calculated from the reachability matrix, M. In the digraph:

(i) R denotes the adjacency reachability set.

$$R = \{s_i \mid s_i \in S, R(s_i, s_j)=1 \}$$

(ii) A denotes the adjacency antecedent set.

$$A = \{s_j \mid s_j \in S, R(s_j, s_i)=1 \}$$

(iii) If set S has the required n elements, then

$$R(s_i) \cap A(s_i) = R(s_i), \forall s_i \in S$$

If this requirement is satisfied, then s_i can be selected from in the same hierarchy. Elements in the same hierarchy are selected out, and the hierarchy graph is finished sequentially in Figure 1.

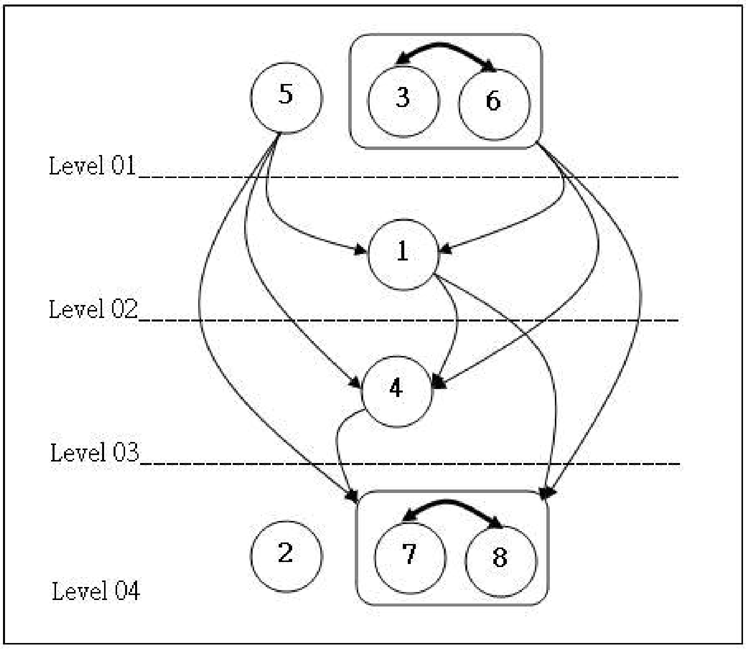

Figure.1 The hierarchy graph

2.3 Analyzing the Interaction of Factors

The Impact Matrix Cross-Reference Multiplication Applied to a Classification (MICMAC) approach can make an active or passive relationship analysis on each factor. The MICMAC is a structural analysis model presented by Godet [1-4]. MICMAC and ISM both apply the model of structural analysis matrix, analyzing the mutual relationship among factors. Hence, these two approaches have quite similar calculating processes. However, the ISM approach only addresses the direct binary relationship (0 or 1) between variables, and thus cannot analyze the conditions of delicate interactions between factors. However, a complex system comprising multiple factors has both direct and indirect relationships among factors. Mutual influence among factors may amplify the indirect relationships, thereby adjusting the overall system. The ISM approach first places factors in the complex systems into different hierarchies. Then the MICMAC approach is then used to analyze the interaction status of each factor, and to consider the influence of each factor on the current and future systems.

MICMAC defines relevant variables within a system to verify the relationship between variables, and to discover the key variables. The dependence relationships among all variables are drawn as the Influence - dependence Chart.

The explanation of MICMAC is as follows.

(1) Draw the influence - dependence chart

Assume that $\mathbf{t}_{ij}$ $(i,j=1,2,...,n)$ is the elements in the key variable matrix T. The definition is as follows.

A. Influence (D) Values on each row of the matrix are added.

$$D_i = \sum_{j=1}^{n} t_{ij} \quad (i = 1, 2, \ldots, n)$$

D_i denotes the sum of the influences of element i on other elements with element i as the cause. They include direct and indirect influences.

B. Dependence (R) Values of each column of the matrix are added.

$$R_j = \sum_{i=1}^{n} t_{ij} \quad (j = 1, 2, \ldots, n)$$

R_j is the summation of influences from other elements with element j as the result.

Figure 2 illustrates the influence -dependence chart. The horizontal axis (x) indicates the dependence, while the vertical axis (y) represents the influence.

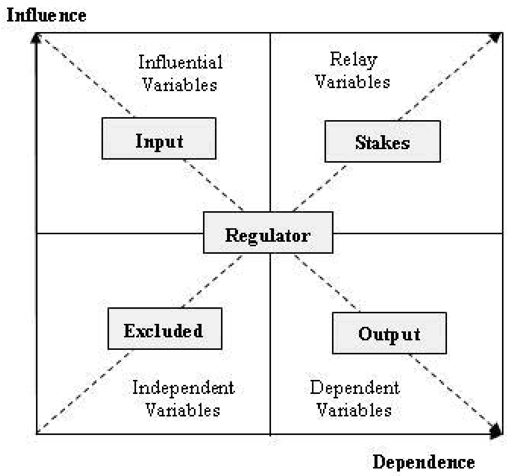

Figure. 2 Influence - dependence chart

(2) Factor Analysis

A factor analysis of the influence - dependence chart (Figure 2) is performed . Variables are classified, according to their clustered locations on the graph, as follows.

(i) Influential variables

These variables are located in the top left of the graph, representing a high influence and low dependence. These variables of this kind play leading roles in constructing the entire system. Most variables in the system are in this group. These variables affect the development direction of the system, and therefore are adopted as the input parameters when developing systems.

(ii) Relay variables

These variables are located in the top right of the graph, denoting representing high influence and high dependence. They not only influence other variables, but are also likely to be influenced by other variables, and thereby cause external factors to adjust the system. Because these variables are unstable, they are known as stake factors.

(iii) Dependent variables

These variables are located in the bottom right of the graph, denoting) low influence and high dependence. They are highly sensitive to changes in influential and relay variables, and are the output factors of the entire system. Since these variables can reflect the effect of influential factors, they can be regarded as the indicator factors to evaluate the effectiveness of the whole system.

(iv) Independent variables

These variables are located in the bottom left of the graph, and represent low influence and low dependence. Because the values of these variables are distributed very close to the origin, they are also called "disconnected variables", signifying that they have no influence on the overall dynamic changes to the system. However, if the values of a variable are distributed close to the area of high influence, then emphasizing this variable would raise the effectiveness of the system.

(v) Regulating variables

These variables are located in the center of the influence-dependence chart, and have the property of regulation.

3. Proposed Methodology

This study develops a three-stage structured design approach for future remote control. First, the interdisciplinary team of experts organized expert meetings to explore forward-looking remote control mechanism, and propose a design vision and future trends. Next, the research team constructs prototype based on experts' recommendations. Finally, this study proposes an integrated structured approach to verify the prototype. The Interpretive Structural Model (ISM) technique is adopted to construct a hierarchical structure, and the Impact Matrix Cross-Reference Multiplication Applied to a Classification (MICMAC) approach is employed to analyze the effect and dependence among the design factors, and to consider the relationship network graph of distribution of factors in the prototype.

Four experts, namely tow professors, an IT expert and a designer, examined the impact factors of the remote control design. The four experts obtained 20 critical factors of the remote control design (in Table 1). These 20 factors were analyzed in this investigation.

Table 1. The factors of remote control design

Factor	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**
Item	Popular Colors	Consumer Trends	Science and Technology	Lifestyle	Fashion	Universal Design
Factor	**F7**	**F8**	**F9**	**F10**	**F11**	**F12**
Item	Design Education	Design Policy	User Experience	Service Design	Design Market Analysis	Interface Design
Factor	**F13**	**F14**	**F15**	**F16**	**F17**	**F18**
Item	Kansei Engineering	International Exhibitions Observation	Green Design	Futurology	Cultural and Creative	Intellectual Property
Factor	**F19**	**F20**				
Item	Regional aesthetics	Design Tthinking				

3.3. The Construction of Hierarchical Structure

The 20 factors were arranged as a 20×20 analysis matrix. An incidence matrix was made according to regulation of interactive design defined by the experts for each factor. Experts assigned a value of 1 to each cell where the factor in the row had an effect on that in the column, based on their own design experience. The hierarchical structure was then constructed using ISM after the key factors and properties were defined. The original incident matrix was converted to adjacency matrix and reachability matrices (in Table 2). The relational factors were arranged in the rearranged matrix (Table 3). Figure 3 shows the resulting hierarchical structure graph.

Table 2. The reachability matrix of factors

	NO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	*D-Value*
Popular Colors	**1**	1	1	1	1	1		1		1	1	1	1		1		1	1		1	1	1	1	1	15
Consumer Trends	**2**	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	19
Science and Technology	**3**		1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	18
Lifestyle	**4**	1	1	1	1	1	1	1	1	1	1	1	1		1		1	1		1	1	1	1	1	17
Fashion	**5**	1	1	1	1	1						1	1		1		1	1		1		1	1	1	11
Universal Design	**6**		1	1	1		1	1	1	1	1	1	1					1			1		1	1	12
Design Education	**7**		1	1	1	1	1	1	1	1	1	1	1				1	1		1	1		1	1	15
Design Policy	**8**		1	1				1	1			1						1			1		1	1	7
User Experience	**9**		1	1	1					1	1	1	1								1		1	1	8
Service Design	**10**		1	1	1					1	1	1									1		1	1	7
Design Market Analysis	**11**	1	1	1	1	1				1	1	1			1		1	1		1	1	1	1	1	13
Interface Design	**12**		1	1	1					1			1				1				1		1	1	7
Kansei Engineering	**13**		1	1	1			1		1			1	1			1						1	1	8
International Exhibitions Observation	**14**	1	1	1	1	1					1	1			1		1	1		1		1	1	1	11
Green Design	**15**		1	1	1							1				1	1	1			1		1	1	8
Futurology	**16**		1	1	1		1	1	1	1	1	1	1		1		1				1		1	1	13
Cultural and Creative	**17**		1		1				1			1						1		1			1		6
Intellectual Property	**18**			1					1										1					1	3
Regional Aesthetics	**19**											1						1		1					3
Design Tthinking	**20**		1	1	1		1	1	1	1	1	1	1				1				1		1	1	12
R-Value		6	18	18	17	8	6	10	10	13	12	17	12	3	8	3	13	13	2	10	14	6	18	18	

Table 3.The rearranged matrix of factors

NO	1	13	7	5	15	16	6	4	18	2	3	8	14	9	10	11	12	17	19	20
1	1		1	1		1		1		1	1		1	1	1	1	1	1	1	1
13		1	1			1		1		1	1			1			1			
7			1	1		1	1	1		1	1	1		1	1	1	1	1	1	1
5	1			1		1		1		1	1		1			1	1	1	1	
15					1	1		1		1	1					1		1		1
16			1			1	1	1		1	1	1	1	1	1	1	1			1
6			1				1	1		1	1	1		1	1	1	1	1		1
4	1		1	1		1	1	1		1	1	1	1	1	1	1	1	1	1	1
18									1		1	1								
2	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1
3		1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1
8			1							1	1	1				1		1		1
14	1			1		1		1		1	1		1		1	1		1	1	
9								1		1	1			1	1	1	1			1
10								1		1	1			1	1	1				1
11	1			1		1		1		1	1		1	1	1	1		1	1	1
12						1		1		1	1			1			1			1
17								1		1		1				1		1	1	
19																1		1	1	
20			1			1	1	1		1	1	1		1	1	1	1			1

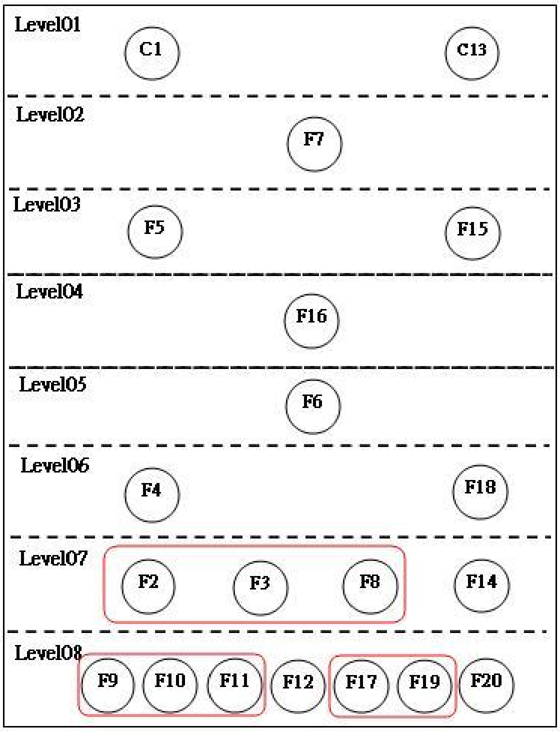

Figure 3. Hierarchical structure graph

3.4. Analysis of Influence – Dependence of Factors

After using ISM approach to construct the hierarchical structure, MICMAC was adopted to analyze the detailed interaction status among factors, and to investigate the stability and evolution of the overall architecture. The rightmost column of the incidence matrix presents the sums of the values of cells in each row based on the relational extent of interaction among factors, termed *D*. The bottom row of the incidence matrix shows the sums of values of cells in each column, termed the factor dependence or *R*.

Figure 4 illustrates the driver power-dependence diagram based on the values of *D* and *R*. In the diagram, the *y*-axis indicates the driver power of the factor, and the *x*-axis indicates its dependence. High-level and low-level factors are differentiated according to the means of *D* and *R*. The driver power-dependence diagram thus has four quadrants. According to MICMAC approach, factors in the first quadrant indicates have the property of relay; those in the second quadrant have influence; those in the third quadrant indicates have independence, and those in the fourth quadrant have high dependence.

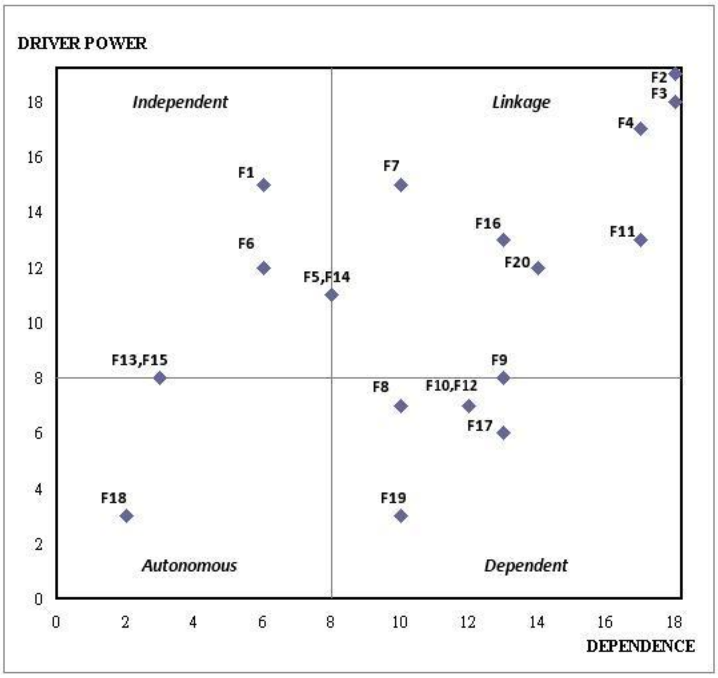

Figure 4. Driver power - dependence diagram

4. Discussion

The hierarchical structure graph is constructed to exhibit the vertical hierarchical relationships among each factor by analyzing the binary interaction among design factors by ISM. The direct and indirect relationships among elements in the hierarchical structure are then analyzed and defined using MICMAC. Combining the ISM and MICMAC approaches to construct factor's hierarchical structure graph and driver power-dependence diagram creates a design pattern strategy that enables rapid and flexible adjustment in the future.

The following discussions can be drawn from the observation of the hierarchical structure graph and the driver power-dependence diagram:

(1) Factors with high driver power and low dependence are mainly distributed in the high levels of the hierarchical structure graph levels 1–3. These factors F1, F5, F13 and F15 have active influences, and are the leading factors in all architecture.

(2) Factors with low driver power and high dependence, namely F8, F10, F12, F17 and F19, are often influenced by other factors, and are mostly placed in the bottom level (level 7 and level 8). These factors are frequently treated as the leading variable factors in all architecture evaluation.

(3) Factors such as F18, which have low driver power and low dependence. These factors are independent, and are not likely to cause overall changes to architecture.

(4) Factors with properties of high driver power and high dependence, such as F2, F3, F4, F7, F9, F11, F14, F16 and F20, merit special attention. These factors easily influence other factors, and are easily affected by other factors. They are usually located at the center of the hierarchical structure graph. They are unstable, and fluctuate considerably, meaning that they are stake factors deserving attention, especially since they may cause the designs of architecture to evolve or collapse.

(5) Some Factors have mutual influences in the same hierarchy, forming a module, such as F2, F3, F8, F9, F10, F11, F17 and F19.

5. Conclusions

This study establishes a prospective study mode for creating a model of future remote control with multiple design factors is by building a hierarchical structure and analyzing the factors distribution. The ISM method is then used to construct a clear model of hierarchical structure. And MICMAC approach is employed to analyze the influence and dependence among the overall impact factors, and consider the relationship network graph the relative locations of factors in the architecture.

The proposed approach enables designers to effectively grasp the different and rapidly changing demands of users or other impact factors, and reflect them in the combination of design strategy.

6. Examples Citations

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