A Logical Design Method for Good Interaction and Ergonomics

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Abstract: In this paper a logical design method is described. The method is required for designing complicated HMI (Human Machine Interface) devices, which consists of five aspects, the physical aspect, the information aspect, the temporal aspect, the environmental aspect and the organizational aspect. The logical design method was examined from three viewpoints of these aspects, especially the physical model, the functional model and the structural model of mental model. The physical model is used to design the external form of a product whereas the mental model used in information design is used to create GUI systems. An algorithm of constructing product designs and information designs is proposed based on the above approach.

Key words: mental model, physical model, functional model, structural model .

1. Introduction

Most designers do not design products or GUI (Graphical User Interface) logically. They tend to rely on their experience or design intuition. IDEO, the famous design firm in the USA, depends on the designer's ability and creative discussions. However, products with complicated operational procedures or GUI, such as ATMs, digital cameras, etc, require logical design methods based on models. As these methods are based on algorithms, designers may complete designs more efficiently by following standard procedures. First, the product or GUI is analyzed by using the Human Machine Interface (HMI) five aspect viewpoint, direct observation and 3P task analysis. The product or GUI is then designed using two models, the physical model for product design and the mental model for GUI design. The latter further consists of a functional model and a structural model. Finally, the final size of a product or the parts of a GUI is decided using the method of permissible range measurements.

2. Five aspects of the human machine interface (HMI)[1]

The five aspects of HMI consist of the physical aspect, the information aspect, the temporal aspect, the environmental aspect and the organizational aspect. All of aspects are needed in order to satisfy the conditions for good HMI. The five aspects are described in further detail in following sections.

2.1 physical aspect

The physical aspect represents a comfortable operation for the user, which may mean a reduction in the physical load. These may be represented by the viewpoints of 1) posture, 2) fit, and 3) torque, which are the physical aspects of interaction between human and machine. Most HMI design problems in the physical aspect are caused by poor posture, bad fit and unsuitable torque.

Example: the low height of the operation panel caused by a large physical load.

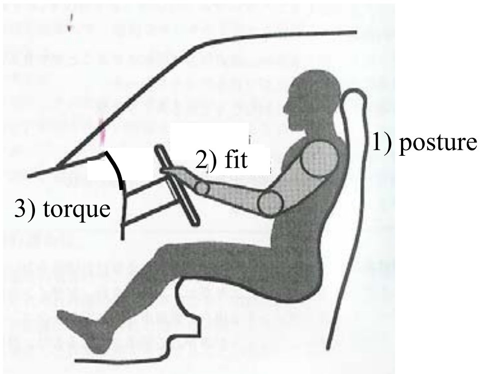

Figure 1. The physical aspect

2.2 information aspect

The information aspect between human and machine consists of the viewpoints of 1) the mental model, 2) simplicity in understanding, and 3) visibility. in information aspect between human and machine. As users innately rely on the mental model for interaction in everyday situations, they also operate a HMI system using the mental model.

Example: constructing a mental model using examples and metaphors to allow the user to grasp the major ideas of a system more easily

Figure 2. The mental Model

The information aspect is also related to the following 29 user interface design items[2].

(1)Construction of a user-oriented UI system

1)Flexibility 2) Customization for different user levels 3) User protection

4) Universal design 5) Application to different cultures

(2)Encouragement of the user's motivation

6) Provisions of user enjoyment 7) Provisions of a sense of accomplishment

8) The user's leadership 9) Reliability

(3)Construction for effective interaction

3-1 Effective acquirement of information

10) Clues 11) Simplicity 12) Ease of information retrieval

13) At a glance interface 14) Mapping 15) Identification

3-2 Ease of understanding and judgment

16) Consistency 17) Mental model 18) Presentation of information

19) Term/Message 20) Minimization of the users' memory load

3-3 Comfortable operation

21) Minimization of the physical load 22) Sense of operation 23) Efficiency of operation

(4) Common keywords

24) Emphasis 25) Affordance 26) Metaphor 27) System Structure

28) Feedback 29) Help

The user interface items are very useful for constructing a GUI system.

2.3 temporal aspect

The temporal aspect may be discussed using the viewpoints of 1) working time, 2) recess, and 3) response time between human and machine.

.2.4 environmental aspect

The environmental aspect consists of the 1) temperature, humidity, air current, 2) lighting, and 3) noise, oscillation etc. between human and machine.

2.5 organizational aspect

The organizational aspect may be discussed using the viewpoints of 1) deciding on organization's policy, 2) sharing the information, and 3) motivation of members between human and machine.

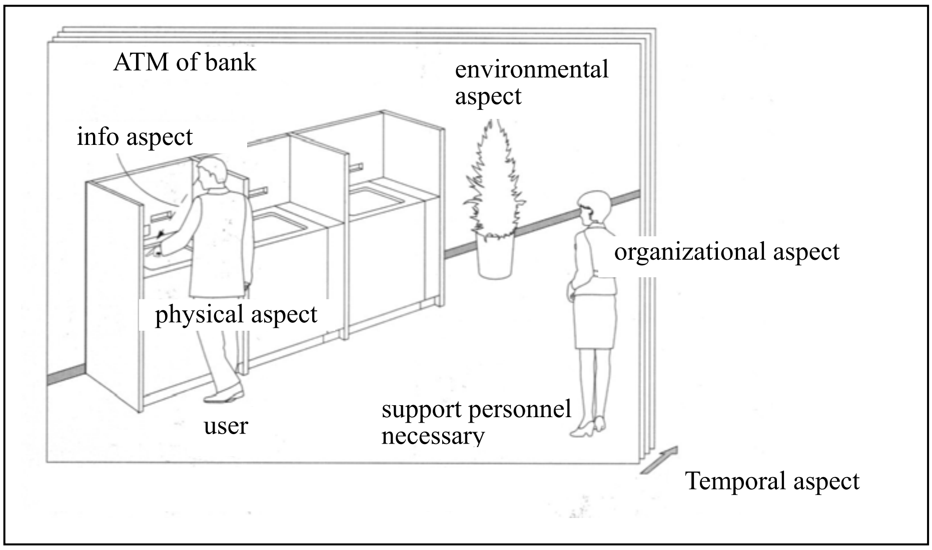

Figure 3. The five aspects of HMI

3. Pre-design user requirement research

3.1 Direct observation method [3]

The direct observation method extracts the problems and needs of the user by directly observing how they relate to systems and products. The following three approaches may be applied in the observation process.

(1) Observation focused on the five aspects of human-machine interface (HMI)

1) The physical aspect, 2) The information aspect, 3) The temporal aspect, 4) The environmental aspect

5) The organizational aspect

(2) Observation focused on the user

1) User actions (characteristics, flow) during operations

Observing the characteristics and flow of the users' actions as they operate machines and systems or as they conduct similar operation procedure..

2) User trace actions

Interactions between the users and the machines and systems are evident in the form of 'traces.' HMI-related problems can be identified through directly observing these.

(3) Products and systems

1) 'Cues' for operations and actions

As users initiate operations and actions based on cues, HMI-related problems can be identified by focusing on these user cues.

2) The flow of operations

Observations may be made by following the flow of operations, such as on an operational panel etc.

Tracing these flows of operations via link analysis may be used to identify problems with the product layout.

3) Identification

This is related to the observation of 'cues,' however problems may also be studied in terms of their identification.

4) System restrictions on user operations and actions

Check whether the system's design places any restrictions on the user operations or actions

Ex: To operate a vending machine, the user must insert a coin into a narrow opening.

3.2 3P (point) Task analysis method [4]

Consider a typical scenario where the product being surveyed will be used. Note the tasks that will be performed in each scenario in the order that they come up.

If a task comprises of subtasks, these are entered into the task column as well. The actual and anticipated user problems in the human information processing sequence is noted, which consists of effective acquirement of information --> ease of understanding and judgment -->comfortable operation. The cues of interest which are problem areas include 1) emphasis, 2) simplicity and 3) consistency for effective acquisation of information. Challenges faced in the ease of understanding and judgment include 1) term, 2) cues, 3) mapping, 4) consistency, 5) feedback and 6) system structure (whether the operating principle of the device is understood). In addition, the physical aspects of 1) posture, 2) fit, 3) torque for comfortable operation is considered. Finally, proposals for resolving the actual and anticipated problems were extracted and considered.

4. Designs based on the Physical model

Usual methods, such as deciding an external form of a product, are not considered systematic methods as most designers and engineers do not collect the necessary data for an algorithm based product design.

The physical model, however, often lead to superior design solution as the algorithms typically result in a much more suitable final product. The algorithm, which is based on the physical model, is constructed as follows.

(1) Construct a suitable physical model for product design.

(2) Decide the height of the eye for the physical model. (5 percentile, 50 percentile, 95 percentile)

Scenario: using a digital camera at a party					
task (+subtask)	pick up problems in "information acquisition →understanding / judgment →operation"			solution (requirement)	
	information acquirement -take account of 1) poor layout 2) difficulty in seeing 3) no emphasis 4) lack of information 5) mapping	Understanding & judgment -take account of 1)indecipherable 2) no affordance 3) confusing, easy to make mistake 4) no feedback 5) procedural problems 6) inconsistency 7) problems in mental model	operation -take account of 1)incongruity with humans' physical characteristics (posture, fitness and torque (force necessary for operation)) 2) cumbersomeness	at the present	in the near future
Use strobe 1.search button 2.push button	No cue to search	-Unclear meaning of term -Don't understand the procedure to operate	-It's difficult to push for a small button.	ABC ⇩ XYZ	
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Figure 4 3P task analysis

(3) The Eye range is examined based on working analysis if needed.

(4) A suitable line of sight is 15degrees below the horizontal line.

(5) Decide the viewing distance which is dependent on the tasks.

(6) Decide the size of the display based on the viewing distance and the suitable angle for informational detection. The angle is 35 degrees long, 20 degrees wide.

(7) The height of letters is decided based on the viewing distance.

(8) The location of middle finger (dactylion) is determined based on the physical model.

(9) The location of the input device like keyboard, etc is decided from the location of middle finger.

(10) The angle between the crus and the vertical line must be over 30 degrees for leg space.

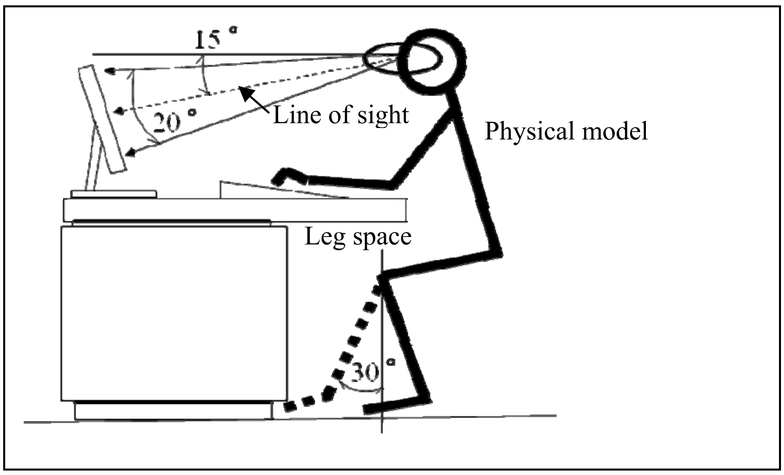

Figure 5. Design method based on physical model

The physical model is constructed as follows.

(1) Users are asked to have a natural posture for operating a product which is planned into the design.

(2) The angle between the parts of the body is calculated for a physical model.

(3) The 5,50 and 95 percentile distances between parts of the body is decided based on the anthropometric data.

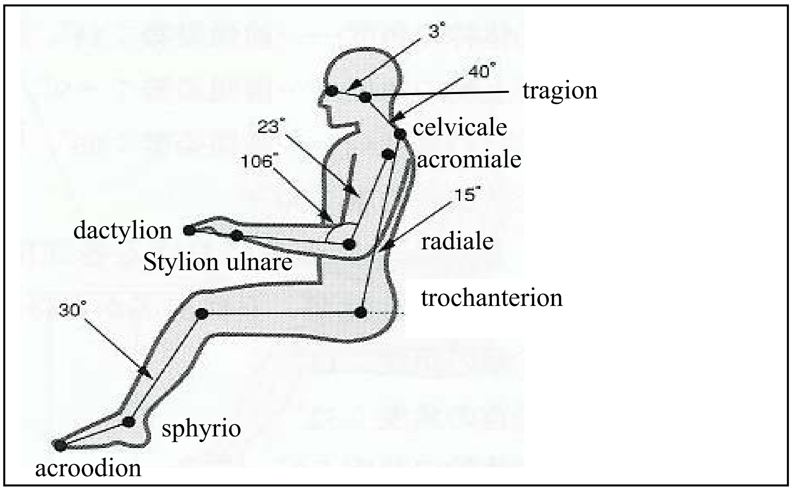

Figure 6. Physical model for VDT

Following the method, even inexperienced designers and engineers may construct the external form of a product. The design details of the external form are examined next.

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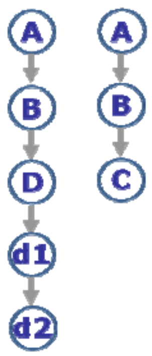
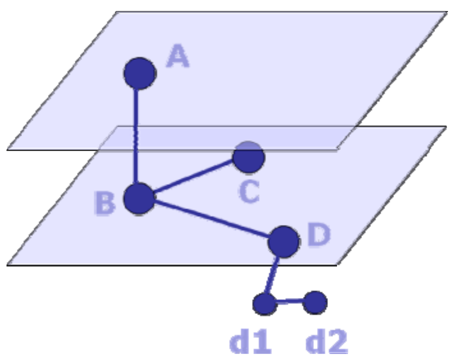
5. Designs based on the Mental Model

5.1 Functional models and structural models

The definition of a mental model is "A mental model is a representation of a system in which the essential features of the system and their interrelationship are stored in memory [5]." The mental model has a functional model and a structural model[6]. The structural model represents the "How to use?" aspect of the product structure. The functional model demonstrates the "How does it work?" facet of the product procedurals, which relies on procedural knowledge.





Functional model

Structural model

Figure 7 Functional model and structural model

If we were to know only the functional model or the structural aspect of the product, but not both, the mental model cannot be considered perfect. The role of functional and structural model in constructing a GUI is discussed as follows.

(1) The functional model

Clues and mappings are important design items for users, as they guide users towards the next subtask or operation in a screen.

(2) The structural model

The ease of information retrieval, at a glance interface, mapping and consistency are important design items, as they show users the structure of operation for constructing the mental model.

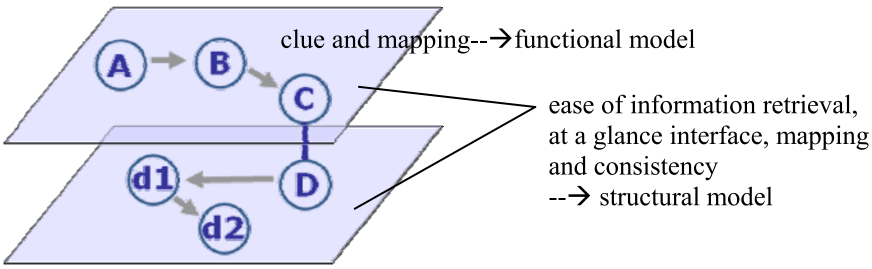


Figure 8 the design items for functional and structural model

5.2 The process to operate based on mental model

When we wash our hands at washstand in a washroom, at first, we find a faucet. We then identify the operation of the faucet from the spout and handle based on the mental model of an original faucet. We are able to identify the operation of faucet as we extract the script and schema of the original faucet. If no water results by operating the faucet using this method, we will make another attempt using a different mental model for the system.

According to above operation, the human information processing process is based on mental model as follows.

(1) Grasp context ------ex. We understand how to wash hands in a washroom from the context of washroom.

(2) Find an object (product) ------ex. we find a faucet.

(3) Extract script and schema------ex. we understand the script and schema of washing hands.

(4) Find related knowledge from schema------ex. We may find related knowledge from schema.

(5) Operate the object (product) using knowledge------ex. We operate the faucet using our knowledge

(6) Confirm the operation from feedback.

Basic design of faucet

Figure 9. users can speculate how to operate a new faucet based on the basic design of faucet

If a user doesn't have the mental model about the product's operation, an information guide on how to use the operational panel or screen is needed.

From procedure above, we may also create a functional model and the user interface should be designed as follows.

(1) Show the structure of the GUI on a screen based on the structural model.

(2) Show the context of use and situation if visualized.

(3) Show a simplified layout of objects for users to find objects (parts such as switches and buttons etc.) easily on a screen or a product.

(4) Show the relationship among parts using mapping.

(5) Show the flow of operation on a screen or an operational panel of the product.

(6) Provide feedback with users whenever users complete operations.

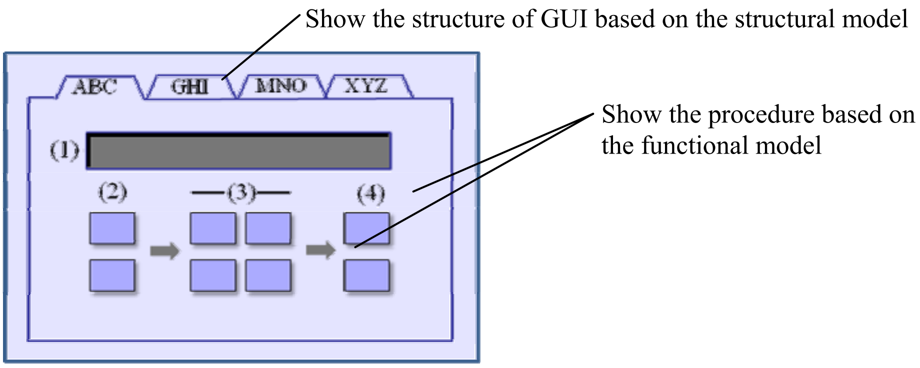


Figure 10. A GUI sample using functional and structural model

Designers and engineers can construct GUI designs based on the mental model procedures above, which is a very efficient and effective approach.

5. Decide the final size of a product or parts of a GUI

After the basic size and form factor of a product or parts of a GUI are decided upon approaches based on the models, the final size can be set using the method of permissible range measurements. The method is defined as one by which users from the 5th percentile female to the 95th percentile male may operate the system easily and satisfactorily within the permissible range of objects. The procedures of the method in deciding the size of object is detailed as follows.

(1) Participants of a test corresponding to the 5th percentile female and the 95th percentile male in height are selected.

(2) They are asked to point out an upper and a lower limit on the size of object.

(3) The measured value upon which the measurement is based is calculated.

The procedures of the method in deciding the size of letters for the GUI system is detailed as follows.

(1) Participants of a test corresponding to the 5th percentile (poor eyesight) and the 95th percentile (normal eyesight) are selected.

(2) They are asked to point out an upper and a lower limit on the size of part or letter.

(3) The measured value upon which the measurement is based is calculated.

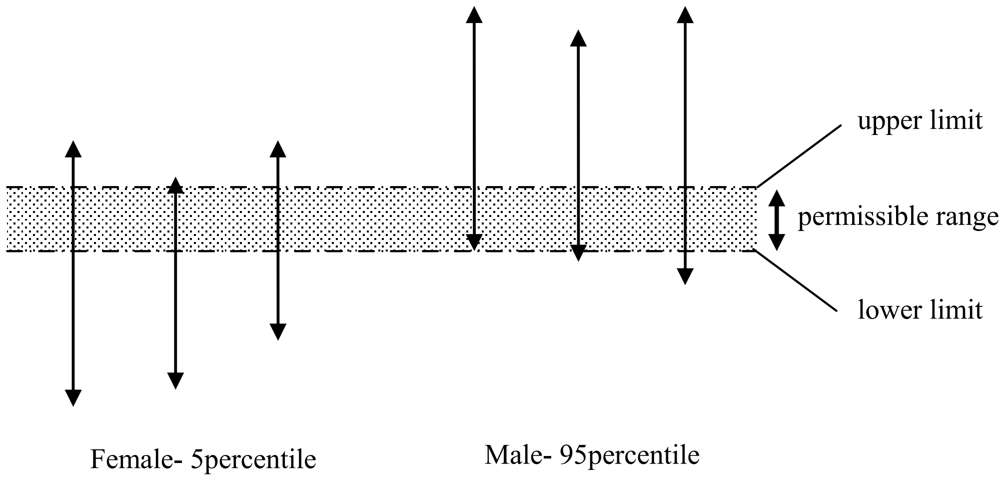


Figure 11. A method of permissible range measurement

6. Summary

A product or GUI is first analyzed based on the five aspects of HMI, by direct observation and with the method of 3P task analysis. The five aspects consists of the physical aspect, the information aspect, the temporal aspect, the environmental aspect and the organizational aspect. The physical model is used in the physical aspect of HMI. An external form of a product, such as a VDT, is designed based on this model. The mental model is used in the information aspect of HMI. Information designs, such as GUI systems, are based upon the mental model. Also in addition, the 29 user interface items are useful for constructing the GUI system. Finally, the final size of a product or parts of a GUI are decided using a method of permissible range measurements.

An algorithm of constructing product designs and information designs is proposed for good interaction and ergonomics. It is very useful tool for inexperienced designers and engineers to complete product design and information design efficiently and fruitfully.

7. References

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