The application of Work Domain Analysis (WDA) for the development of vehicle control display

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Abstract: As the initial work to apply Ecological Interface Design (EID) technique to the development of car control display, this research developed Work Domain Model by performing and using Work Domain Analysis of the work domain related to the car operation. Further, Information Requirements were extracted to develop car control display on the basis of completed model. Analyzing the drawn Information Requirements, it was confirmed that the information appeared on the car control display currently in use is low-leveled (only the physical state of car) among the information necessary for car operation. Thus, the possibility of developing new car control display on the basis of newly extracted Information Requirements is confirmed. Based on the result of this research, this paper will provide basic frame of EID application in the specific development of car control display hereafter.

Key-Words: Ecological Interface Design (EID), Work Domain Analysis (WDA), Information requirement

1 Introduction

Since 3-wheeled steam car, the progenitor of modern car, powered by steam engine was developed in 1770, car has been developed to be indispensable necessities in modern life. However, the development of car technology and variation in car operation environment has considerably complicated acquisition and processing of information, decision making and task that should be done by driver to operate car.

The driver gets more than 80% of necessary information through the visual organ while driving and one of the main interfaces for this objective is car control display [1]. Since such visual information display traditionally focused on providing physical information on the state of low system or low component in the work domain, much Cognitive Workload was added when operator searches, integrates and infers information [2]. As shown in the accident of Three Mile Island, the improper design of display may cause fatal accident in the safety of system. On the contrary, effectively designed display may reduce error or workload of operator [3]. Since the form of basic car control display currently used in car is based on the form designed at the beginning of car development, we need to check whether it is proper to the continuously developed car technology and complicated car operation environment.

While researchers are constantly making effort to design effective visual information display, there is a result of research that the contents and structure of information to be provided by display is the important factor which determines the effect of display [4]. This means that providing operators with necessary information and designing display which reflects the structure between such information are important for system operation.

In this aspect, Ecological Interface Design (EID) methodology through Work Domain Analysis (WDA) provides useful tool to design effective display. The ecological approach method focuses on the interactivity between operator and work environment rather than between operator and system [4]. Therefore, interface designers can easily extract constraints which are essentially possessed in system and verify structures between necessary information which is essentially required for the operating system [5]. Namely, Ecological display can easily and promptly provide operator with critical information to solve problem based on these constraints and information structures. Further, ecological display provides pertinent knowledge to

improve the work performance of operator more than the existing design approach method so that the operator may effectively solve problem when encountering unexpected situation caused by altered work environment [6].

The objective of WDA is to make WDM that describes how system works. Constraints can be extracted from WDM. And WDM is the basis of EID. As such, it can provide clue for effective problem solution by enabling operator to make mental model for system operation [7].

Rasmussen suggested frame work named Abstraction Hierarchy (AH) to identify and understand constraints of work domain [8]. EID has adopted the abstraction hierarchy as a fundamental way to analyze the environment, the work domain. By gathering these relationships in the form of information requirements, designers can create interfaces that will aid problem solving and retain their robustness in unanticipated situations. As the constraints at each level of AH are connected in the relation of Means-End, the constraints in higher level is generally affected by constraints in lower level. Thus, the structure between them can be understood after checking the constraints in each level by using AH [9]. Based on AH, WDM is serially composed in the order of Functional Purpose which means "For what is Work Domain designed?", Abstract Function, Generalized Function, Physical Function and Physical Form.

Thus, this research performs WDA for the work domain of driving and made WDM on the basis of it to check whether the basic car control display is proper to the changed operation objective of car and car operation environment. Therefore this paper will to provide basic frame of specific development of car control display hereafter by extracted Information Requirements for design of ecological car control display from WDM.

2 Main subject

This research was conducted in the large division of Work Domain Analysis to make Work Domain Model for the work domain of car operation, stage to supplement model and stage to extract Information Requirements. The overall research procedure is as shown in Figure 1.

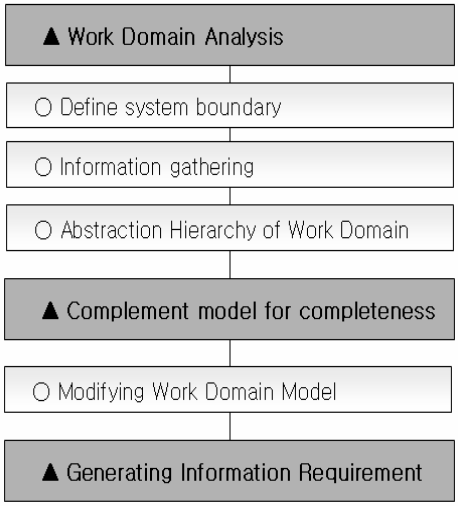

Fig. 1. The overall research procedure

2.1 Work Domain Analysis

2.1.1 Deciding system boundary

WDA is embodied not by analysis centering on the human, but by close analysis of work environment. Thus, it is required to decide the boundary of analysis, depending on the analysis objective of system, types of problem and the use of result [6]. Namely, deciding the boundary of system is the first important stage for analysis.

Table 1

Driving Tactics
1. Awareness of dangerous situation
2. Decision making to avoid dangerous situation.
3. Driving tactics enforcement by decision making
Driving Strategies
1.What kind of potential danger being there? And how do you recognize danger?
2. How do you decision making if the potential danger becom danger in actually?
3. Do you exactly doing critical decision?

This research was conducted to extract Information Requirements for drivers to safely and promptly move car in the car operation environment as well as to utilize it to develop ecological display. Thus, the analysis boundary of system was decided as physical process of car (based on medium sedan) and car operation environment which is composed of natural environment, road environment and driver. In addition, Driving Tactics and Driving Strategy were also considered.

The contents of Driving Tactics and Driving Strategy are Table 1 [1].

2.1.2 Information Gathering

As the purpose of this research is to develop display that supports drivers, the purpose of driving, difficulties and required function were surveyed for 11 drivers with varied career in driving (less than 1 year to 9 years). In addition, opinion on analysis of the work domain was reflected. The reference book was examined to analyze the physical process of car [10].

2.1.3 Abstraction Hierarchy of Work Domain

Based on Abstraction Hierarchy, Work Domain Model is composed of Functional Purpose, Abstract Function, Generalized Function, Physical Function and Physical Form. In this research, Physical Form was excluded for research objective. Though 2 models were constructed as WDA was respectively performed to physical process of car and car operation environment, this paper only introduces the model corresponding to physical process of car and extracted Information Requirements from 2 models.

To begin with, the following Key questions (Table 2) suggested by Burns were considered to decide Functional Purpose of physical process of car.

Table 2

Key questions
1. What was the work domain designed to do?
2. How do I know if it is working correctly?
3. What is good performance as opposed to bad performance? Do my purposes express these criteria?
4. Have I found at least two purposes?
5. Are my purposes generic? Do they hold across all possible tasks?

Considering the above Key questions (Table 2), this research sets Functional Purpose as 'Move from A to B quickly' and 'Move from A to B safely.'

Abstract Function is a description of casual relationships

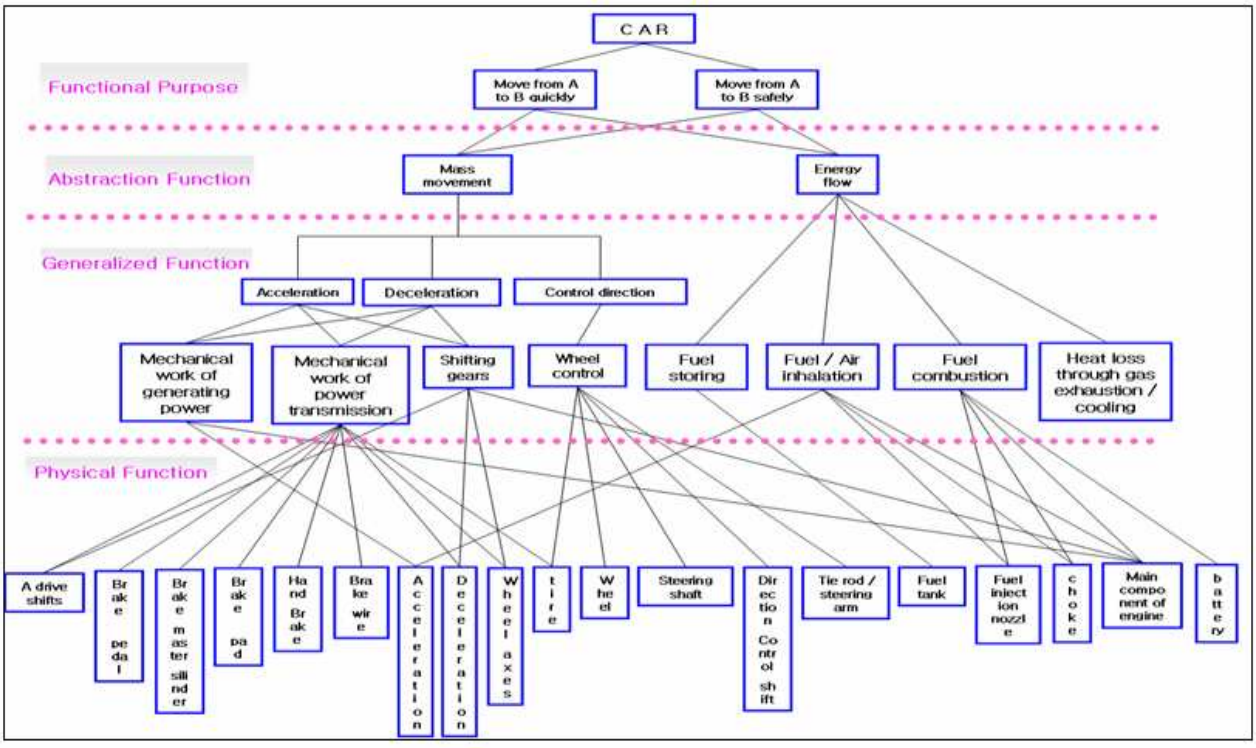

Fig. 2 Work Domain Model(Physical process of car)

the laws, the priorities and the fundamental nature of the work domain. So Abstract Function was decided to 'Mass movement' and 'Energy flow' which are necessary to accomplish Functional Purpose. Generalized Function explains how the casual laws of the Abstract Function level are achieved.

Deciding Physical Function as the specific car components necessary to perform the process, As a result of the above process, WDM was acquired as shown in Figure 2. As shown in Figure 2, the constraints in each level could be checked. As such constraints are appeared in the relation of Means-End; the relation between constraints can be identified.

2.2 Evaluation of Work Domain Model

To evaluate the completed WDM, this research used Scenario Mapping test method first suggested by Burns [11]. The scenario for test focused on basic acceleration, deceleration, steering and fuel control which are enforce for car operation. The scenario used to evaluate WDM was decided as shown in Table 3.

Table 3
The events for Scenario Mapping Test

No.	Events
1	Accelerate speed from 40Km/h to 60Km/h
2	Decelerate speed from 50Km/h to 30Km/h
3	Maneuvering to avoid forward obstacle during driving
4	Controlling the effective fuel combustion
5	Decision refueling time according to remained fuel

For test, the purpose was explained to 2 drivers much experienced in driving (career in 7 years and 3 years) and incumbent car mechanic with special knowledge in car mechanism (career in 13 years) and they were agreed with a written consent. In the test, completed WDM was shown and each event was presented to objects in the supposition of car operation. Then, they were given questions on the appropriateness of model and the parts which need to be improved. After test, the author confirmed that though completed WDM cannot perfectly explain the physical structure of car, it is proper to the purpose of developing car control display.

2.3 Drawing Information Requirements

Out of the 2 Work Domain Models (physical Process of car, operation environment of car) confirmed by test, Within-Domain Requirements and Between-Domain Requirements were extracted. First, the thing that should be considered to design a car control display among constraints in each level of each WDM was selected from 3 subjects participating in the evaluation test through questionnaire. Then, from the selected constraints, Information Requirements generating within and between the two models were acquired. The generalized Within-Domain Requirements and Between - Domain Requirements are shown in Table 4.

Table 4
Extracted Information Requirements
(An asterisk ("*") denote the essential information which is provided in current car control display)

a) Physical process of car

No.	Information Requirements
1*	Driving speed
2*	The state of RPM
3*	The state of transmission
4*	The state of brake
5*	The state of battery charging
6*	The state of oil pressure
7*	The state of engine
8*	The state of remained fuel
9	The ability of car control direction
10	The state of effective fuel combustion

b) Driving environment (nature, road, driver)

No.	Information Requirements
1	Humidity, visibility
2	Road condition(snowy, rainy, ice)

3	Limited driving speed by kind of road
4	The level of traffic
5	Aid information for navigation
6	Information related to traffic regulations
7	Social Requirements (comfortable, safety, enjoyment, convenience)

c) Between Physical process of car and Driving environment

No.	Information Requirements
1	imited driving speed by kind of road
2	The state of safety driving condition (driving speed + road condition + Visibility and so on)
3	The possible driving distance by remained fuel (remained fuel + driving speed + road condition and so on)
4	The guide for lane change (relative driving speed and distance with other cars)
5	The guide for parking
6	The essential summarized information for navigation

In Table 4 a), the Information Requirements from 1 to 8 is the standard contents commonly observable in the current car control display. The 8 Information Requirements can be checked in Physical Function, the lowest level in the completed WDM (Figure 2). This means that the current car control display mainly provides physical and single information on the low components of car. This in turn means that driver who is forced to constantly make decision in the time pressure while driving suffers workload as he checks single information and combines information by information processing and then performs action which is related decision.

Thus, it is judged that cognitive work load of driver may be reduced by providing higher level and combined information to driver through car control display. And through providing information driver's knowledge-based problem solution would be improved in the unexpected operation environment.

3 Conclusion

This research developed Work Domain Model by performing Work Domain Analysis for the work domain of car operation to make basic frame of EID application in the specific development of car control display. Then, it was confirmed that the information contents of currently used car control display are mostly composed of information in low level and such information of low level results in excessive workload as it is mutually combined and inferred through Information processing in the brain of drivers. So, additionally necessities for development of new car control display were confirmed. And the Information Requirements and information structures for further specific design of display were extracted from constraints in each level of completed model.

Based on the result acquired so far, this research confirmed that it is possible to improve the car control display by EID technique. On the basis of extracted information requirements in this research, the further study will discern the priority of information contents to be design as the car control display and develop one of them into specific Ecological Design.

References:

[1] Korea Appraisal Board of Traffic Accident, 2007, http://www.carsago119.co.kr.

[2] Goodstein, L. P., *Discriminative display support for process operators*, In J Rasmussen(Ed), Human detection and diagnosis of system failure, Plenum Press, New York, 1981.

[3] Woods, D. D., *The cognitive engineering of problem representations*, In G. Weir(Ed), Human-computer interaction and complex systems, Academic Press, New York, 1991.

[4] Vicente, K. J. and Rasmussen J., The ecology of human-machine systems II: mediating direct perception in complex work domains, *Ecological Psychology,* 2(3), 1990, pp. 207-491.

[5] Burns, C. M., et al., *Ecological Interface Design*, CRC Press, 2004.

[6] Vicente, K. J., Ecological Interface Design: Progress and Challenges, *Human Factors*, 44(1), 2002, pp. 62-78.

[7] Burns, C. M., Bryant, D. J., and Chalmers, B. A., Boundary, Purpose, and Values in Work Domain Models: Models of Naval Command and Control. *IEEE Transactions of system, Man, and*

Cybernetics-Part A: Systems and Humans, 35(5), 2005, pp. 603-616.

[8] Rasmussen, J. and Vicente, K.J., Coping with human errors through system design: Implications for ecological interface design, *International Journal of Man-Machine Studies*, 31, 1989, pp. 517-534.

[9] Ham, D. H., and Yoon, W. C., The Effect of Presenting Functionally Abstracted Information in Fault Diagnosis Task, *Reliability Engineering and System Safety*, 73, 2001, pp. 103-119.

[10] Han, Y. C., *Introduction to automotive engineering*, Munundang, 2004.

[11] Burns, C. M., Bryant, D.J., and Chalmers, B. A., Scenario mapping with work domain analysis, *Proceedings of the 45th Annual Meeting of the Human Factors and Ergonomics Society*, 2001, pp. 424-428.