Timeaxis Design of Health Monitoring Seat System
Using M Method and SysML

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Abstract

This paper describes the design of Health Monitoring Seat System, a safety device that prevents health related traffic accidents. The current system can only prevent drowsy driving, and cannot consider individual differences. Therefore, the purpose of this study is to design a new system that optimizes to an individual, and provides functions that work towards the driver's health condition. To realize this system, the Timeaxis Design, a concept incorporating the viewpoint of time into the theory and methodology of design, is introduced. The perspective of Timeaxis Design, enables the design of a system undergoing several development stages necessary for realizing this system. The system undergoes three development stages: STAGE I (existing technologies), STAGE II (developing technologies), and STAGE III (conceptual technologies). In order to design the system, the driver's physical and psychological health conditions must be put into concern. Therefore, the M Method and SysML is used in the designing process. The M Method is a design method that can describe the relationship of the physical and psychological element of a human. The SysML is a graphical modeling language that visualizes the development process of a system. As a result, three subsystems: "Data analysis system", "Monitoring system", and "Seat system" that construct this system are proposed. Furthermore, by considering the Timeaxis Design, the road map for the technological development of this system is derived.

Keywords: M Method; SysML; Timeaxis Design
1. Introduction

Recently, the number of traffic accidents caused by the driver's health problem have increased in Japan [1]. It is expected that, by providing health care to the driver can avoid such accident and reduce the overall traffic accidents. Therefore, a new safety device, the Health Monitoring Seat System has been developed as a solution.

This Health Monitoring Seat System is a car seat developed to reduce the number of car accidents caused from health problems by monitoring and estimating the driver's health conditions. The behavior of this system is as follows. First, the sensor mounted inside the car seat monitors the driver’s biological signal. Next, the system’s computer analyzes the monitored biological signals and estimates the driver’s health condition. Lastly, the system displays the driver’s condition and provides necessary functions, such as alarm noise if drowsiness is detected. However, the current Health Monitoring Seat System has problems in preventing health related traffic accidents for diverse drivers, due to the lack of accuracy for individual differences. Moreover, the current system can only provide alarm functions, and lacks function that work towards the driver’s health conditions. In order to prevent health related traffic accidents, a system providing functions that works on the driver’s health condition is needed.

Against this background, this study is aiming to design the basic architecture of the Health Monitoring Seat System considering individual differences and providing functions working towards the driver’s health condition. In designing the system, the technologies for developing this system is taken into account. Therefore, the Timeaxis Design is introduced as a design concept in this study. The Timeaxis Design incorporates the perspective of time into the theory and methodology of design, enabling to adapt to diverse circumstances such as technological development and changes over time. To design the system, the health condition including the human’s physical and psychological conditions are considered in this study. Moreover, the proposing system is assumed to be complex. In order to realize the system, the human’s elements and staged development process of a complex system are taken into account. Therefore, the M Method (Multispace Design Method) and the SysML (Systems Modeling Language) are used to design the new system. The M Method is a design method that can correspond to the human’s physical and psychological elements. The SysML is a graphical modeling language that supports the specification and architect of a complex system.

2. Timeaxis Design

In this study, the Timeaxis Design is introduced as the design concept. Timeaxis Design is a concept that supports product development that can adapt to the changes of the environment and perspective by applying the viewpoint of time to the design [2]. By applying the perspective of Timeaxis Design to the system, enables the design of a system that can adapt to diverse circumstances and viewpoints that changes through time.

For example, a fountain pen is considered as a product that is based on the Timeaxis Design. Overtime, the pen molds to the user’s hand. In addition, by repairing and maintaining the pen, it is possible to extend its life and increase its fitness, leading to an increased value. However, most of the existing product that expresses the Timeaxis Design are unintentionally made. It is expected that by further applying the Timeaxis Design to the development process of the product, realizes a product expressing the Timeaxis Design. Therefore, this study discusses the application of Timeaxis Design to the development process of the Heath Monitoring Seat System.

Herein the system proposed, performs individual optimization of the system by receiving feedback from the driver's monitored biological signals and provides functions that work towards the driver's health conditions. However, with the current technologies, the realization of the proposed system is expected to be difficult due to its complex functions. Therefore, to realize this system, several development stages are necessary. By undergoing the stages, enables to consider the changes in technological development and problems through time. This allows to organize and derive technologies necessary in developing the proposed Health Monitoring Seat System. Moreover, by applying the viewpoints of the Timeaxis Design to the system design, visualizes the road map for the development of the proposed Health Monitoring Seat System.

The system proposed in this study composes three development stages: STAGE I, STAGE II, and STAGE III. STAGE I is a system consisting of functions based on the existing technologies. STAGE II is a system consisting of functions based on developing technologies. STAGE III is a system consisting of functions based on conceptual technologies. By designing a staged developed system based on the Timeaxis Design, allows the system to adapt to
the changes of diverse circumstances and viewpoints. For example, as the stages proceed, more accurate monitoring and various functions to the driver are provided. Thus, the stages are necessary to enable the visualization of the system design with gradual developments. The analysis and clarification of the difference and common parts of each stage allows the extraction and organization of technological development important to realize each stage. Therefore, the Timeaxis Design is applied as the design concept in this study, to realize a system with individual optimization and various functions.

3. The System Design Method

3.1. M Method Overview

The driver’s health condition this study concerns include both the physical and psychological conditions. Therefore, the M Method is effective when considering the physical and psychological elements, to the design.

M Method is based on the M Model (Multispace Design Model), one of the design theory frameworks [3] [4]. As shown in Fig.1, M Model is composed of, knowledge space describing the knowledge used in designing, and thinking space describing the designing. In this model, the space is referred as a collection of design element or design knowledge used in designing. This model allows express the relationships that exist between these spaces.

The knowledge space is comprised of objective knowledge and subjective knowledge. Objective knowledge consists of generalities such as theories and methodologies, including physical laws in natural sciences, social sciences, and humanities. Subjective knowledge includes specialties that depend on individual contexts.

The thinking space is comprised of psychological space consisting of psychological elements such as the user’s feelings towards the design objective, and the physical space consisting of physical elements that realize the psychological elements. These spaces are further divided: the psychological space into value space and meaning space, the physical space into state space and attribute space. The 4 spaces are referred as the multispace, and is used to organize design elements.

- Value space: consists of diverse values, including social value, cultural value, and individual value.
- Meaning space: consists of functionality and image required to express the meaning.
- State space: consists of the system’s characteristics that are dependent on its circumstances.
- Attribute space: consists of characteristics independent of circumstances.
- Circumstances: refers to the usage environment, including the user and the ways in which the artifacts are used.

With the elements relationship diagram that consists of the multispace, the relationship between the design elements for the Health Monitoring Seat System is generated and organized.

![Fig. 1. M Model](image-url)
3.2. SysML Overview

The Health Monitoring Seat System proposed in this study is to be a complex system, including various domains such as seat body, data, driver, car equipment, and environments. Therefore, the SysML, a graphical modelling language that supports the analysis, specification, design, verification, and validation of a large and complex system with various domains, is used [4].

The SysML is a tool that supports the model based systems engineering process to specify and design a system. The language describes the systems, their components and environments, and supports modeling of the whole system by using nine diagrams: requirement diagram, activity diagram, sequence diagram, state machine diagram, use case diagram, block definition diagram, internal block diagram, parametric diagram, and package diagram. These diagrams are classified into four groups: requirements, behavior, parametric and structure diagram. SysML enables the development of solutions that organizes the large and complex systems.

3.3. System Design using the M Method and SysML

The M Method allows us to generate and organize design elements that construct the Health Monitoring Seat System. Then, to implement the generated ideas into the system, the constraints that compromise the system are taken into account. This can be expressed by using SysML. The SysML supports the specification, design, verification, and validation of a mass and complex system. Therefore, by combining the M Method and SysML, it is expected to structure a system with newly generated ideas. Fig. 2 shows the combined system design method. In this procedure there are four phases that are repeated optionally.

Phase 1. Modeling element relationship diagram by using the M Method.
   Extract and organize the design elements and their relationships.
Phase 2. Translating the elements relationship diagram to SysML.
   Translate the design elements to SysML and is express the elements using SysML diagrams.
Phase 3. Detailing the System in SysML.
   Detail system in SysML, through systems engineering process.
Phase 4. Arranging the system architecture.
   Translate extracted elements from SysML to elements relationship diagram, and arrange system architecture.

By repeating these steps, the system's architecture is modelled. In the process of realization, verification, and validation, the system is developed based on models obtained in the process of design.

Fig. 2. Process of System Design Using M Method and SysML
4. The System Design of Health Monitoring Seat System

4.1. The Proposal of Health Monitoring Seat System

With the M Method, the design elements that compose the Health Monitoring Seat System is generated and organized. Fig.3 shows the elements relationship diagrams of our system. As the value element, "Health related traffic accidents prevention under diverse conditions", "Fatigue relief and recovery under diverse conditions", and "Beauty enhancement under diverse conditions" are derived. To realize the value of the system, six types of functions are derived as the meaning element: "Drowsiness prevention function", "Drunken driving prevention function", "Stress relief function", "Fatigue relief function", "Driver condition management function", and "Beauty enhancement function". For the state element, drivers state such as "Body pressure distribution", and the seat state such as "Vibration" were derived. Then, for the attribute elements, "Aroma diffuser" and "Piezoelectric sensor" were derived. For the circumstance, elements such as "Diverse drivers" and "Hospital" are derived. The next section explains the design of the Health Monitoring Seat System comprised of these design elements.

4.2. The Behavior of Health Monitoring Seat System

The Health Monitoring Seat System this study proposes, performs individual optimization of the system. To design the system behavior, the SysML is used. By modeling the system to the sequence diagram Fig. 4 (a), a diagram that describes the behavior of the system, the system behavior is obtained. First, the system monitors the biological signal of the driver, then analyze it, and estimate the driver's condition. Next, the data of the driver's condition is transmitted to a server, and is stored. Then with the stored data, the threshold data of the driver used to estimate the driver's condition is kept updated. The updated threshold data, provides a more accurate estimation for the driver, enabling the individual optimization of the system.

The proposed system provides six types of functions: "Drowsiness prevention function", "Drunken driving prevention function", "Stress relief function", "Fatigue relief function", "Driver condition management function", and "Beauty enhancement function" to realize a system that works towards the driver's health condition. The "Drowsiness prevention function", is a function for awakening the driver by using alarm noise and seat vibrations.

Fig. 3. Elements Relationship Diagram of Health Monitoring Seat System
The second function, "Drunken driving prevention function" is performed by alerting the driver using alarm noise and forcefully stopping the engine. The third function, "Stress relief function" provides aromatherapy, massage, rhythmic breathing guide, and relaxing music to the driver. The fourth function, "Fatigue relief function" provides aromatherapy, massage, and sitting posture guide to the driver. The fifth function, "Driver condition management function" is performed by transmitting driver's data to their hospitals and companies. The final function, "Beauty enhancement function" is performed by relieving the swell of the leg by using the seat heater.

The interactions between the system and the driver for these six functions are modeled in the sequence diagrams. As an example, Fig. 4 (b) shows the sequence diagram of rhythmic breathing guide for the "Stress relief function". After the system receives signals that the "Stress relief function" is necessary, the system calls out the data for the rhythmic breathing guide. Then, the system orders the interface inside the vehicle to display and play the rhythmic breathing guide to the driver. By providing the rhythmic breathing guide, relieves the driver's stress. The other function's interaction between the system and the driver is described using the sequence diagram as well.

4.3. Health Monitoring Seat System Including Perspective of Timeaxis Design

In this study, the consideration of technological development is necessary for designing the Health Monitoring Seat System. First, the value that realizes this system is expressed as the requirement diagram, a diagram that expresses the relationship between the requirements and the design elements to support requirements traceability. Then, the relationship between the requirements of the three development stages: STAGE \( \Pi \) (existing technology), STAGE \( \Pi \) (developing technology), STAGE \( \Pi \) (conceptual technology) is derived and organized, shown in Fig. 5.

In STAGE I, the system monitors and provides functions when the driver gets on the vehicle. Therefore, "Health related traffic accident prevention when the driver gets on the vehicle" is derived as a requirement of the value for STAGE I. This requirement consists of: "Traffic accident prevention by performing health management", and "Traffic accident prevention by preventing risky driving " when the driver gets on the vehicle. In STAGE II, the system monitors and provides functions during the vehicle stoppage. Therefore, "Health related traffic accident prevention when the vehicle is under a stop" is derived as the requirement of the value for STAGE II. This requirement contains: "Traffic accident prevention by performing health management" and "Traffic accident prevention by preventing risky driving " when the vehicle is under a stop. In addition, new requirements: "Driver's health promotion", "Driver's fatigue relief ", and "Driver's beauty enhancement" when the vehicle is under a stop are derived. In STAGE III, the system is individually optimized, enabling to provide functions during diverse conditions, including when the vehicle is moving. Therefore, "Health related traffic accident prevention under diverse conditions" is derived as a requirement that corresponds to the value for STAGE III. This requirement also consists of two requirements: "Traffic accident prevention by performing health management", and "Traffic accident prevention by preventing risky driving " when the vehicle is moving under diverse conditions.
prevention by preventing risky driving" under diverse conditions. Moreover, the other requirements such as, "Driver's health promotion under diverse conditions", "Driver's fatigue relief under diverse conditions", and "Driver's beauty enhancement under diverse conditions" are derived.

The validation of the value that each stage realizes are acquired by organizing and clarifying the relationship between the requirements and system behaviours. In STAGE I, the system will monitor and provide "Drowsiness prevention function", "Drunken driving prevention function" when the driver gets on the vehicle. In STAGE II, the system monitors and provides the two functions from STAGE I, "Stress relief function", "Fatigue relief function", "Driver condition management function", and "Beauty enhancement function" when the vehicle is under a stop. In STAGE III, the system is individually optimized and will be constantly monitoring and providing the six functions under diverse conditions. By detailing the systems for each development stages, enables the description of the relationship between the system requirements and behaviours. In addition, this supports the verification of the system due to the ensuring traceability of the system requirement and behaviour changes for each stages.

4.4. The Basic Architecture of Health Monitoring Seat System

The basic architecture is designed by deriving the subsystems that constructs the Health Monitoring Seat System. In order to derive the subsystems, the system behavior is described and detailed to the sequence diagrams for each development stages. As a result, three subsystems: "Data management system", "Monitoring system", and "Seat system" are derived. These subsystems comprises the basic architecture of the system, and their relationship is detailed and clarified using the internal block diagram, a diagram that describes the interconnection between structural elements. Fig. 6 shows the internal block diagram of the system in STAGE III. The "Data management system" composes of "Database", "Data transmission device", and "Data management computer". This subsystem behavior is to manage the driver's data, transmit data to external server or system, send command signals to other subsystems, estimate the driver's condition, and feedback data used for individual optimization. The "Monitoring system" composes of "sensor system" and "Data analysis computer". This subsystem monitors and analyzes the driver's biological signal. The "Seat system" composes of "Massage device", "Aroma diffuser", "Seat body", and "Seat adjusting device". This subsystem performs functions such as, aromatherapy and massage.
By detailing and organizing the system, the basic architecture composing this system is achieved. For example, in order to realize a system that can optimize to an individual, data storage and feedback system must be established. It was originally assumed that the system will use the database built inside the vehicle. However, by undergoing system design, it was confirmed that the original database lacked data capacity and the function to receive and transmit data. Therefore, to store and manage mass data, the external server was derived. This external server enables the system to store the data gathered from each development stages necessary to improve the monitoring algorithm and update the driver's threshold data for the optimization of the system. As a result, the basic architecture, such as the system behaviour and structure, of this system were derived and technological problems were clarified. With the designed model of the Health Monitoring Seat System, the roadmap for the development of this system is visualized. In the future study, it is necessary to develop and verify the system by using the proposed model.

5. Conclusion

In this study, the system realizing the growth in value through several development stages is designed, by applying the view point of Timeaxis Design to the development process. In addition the design of the basic architecture realizing the Health Monitoring Seat System that can take individual differences into account and provide functions that work towards the driver’s health condition is developed by using the M Method and SysML. As a result, a system that can optimize to the driver by interacting and exchanging data of the driver is proposed. The proposed system provides six interactive functions: "Drowsiness prevention function", "Drunken driving prevention function", "Stress relief function", "Fatigue relief function", "Driver condition management function", and "Beauty enhancement function". Next, by including the perspective of Timeaxis Design, a system that undergoes three development stages are proposed, and the relationships of requirements and design elements that composes each stages are detailed and organized. Furthermore, in the process of detailing the system, "Data management system", "Monitoring system", and "Seat system" were derived as a subsystem. Lastly, by detailing and organizing the system, technological problems and the roadmap for the development of the system were organized and derived. In further study, to verify and validate the Health Monitoring Seat System, it is necessary to further detail and develop the system by using the proposed model.

References

[1] Ministry of Land, Infrastructure, Transportation, and Tourism Road Transport Bureau, Annual Automobile Accident Statistics Report for Car Transport Business (Year 2012), Japan, 2014.
[2] Y. Matsuoka, in: Oukan, Concept of Timeaxis Design, Vol.6, No.1, Japan, 2012, pp.9-16.
[3] Y. Matsuoka, Y. Ujiie, T. Asanuma, Y. Takano, Y. Izu, K. Sato, T. Kato, M method - Design Thinking on Multispace. Kindai-Kagaku-Sha, Japan, 2013.
[4] Y. Matsuoka, DESIGN SCIENCE ~“SIX VIEWPOINTS” FOR THE CREATION OF FUTURE~, Maruzen Co., Ltd., Japan, 2010.
[5] S. Friedenthal, A. Moore, R. Steiner, A Practical Guide to SysML, The Morgan Kauff-man OMG Press, Massachusetts, 2008.