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Usability Factors and Guidelines for Climate Control Interfaces Using Big Data from Vehicles

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ABSTRACT

In this study, we used actual user driving data to quantitatively derive interaction patterns, especially in climate control systems. With annual data from 69,895 vehicles and 6.4 million driving cycles, we analyzed CAN signal to identify usage patterns across various scenarios, considering factors like season, temperature, and driving conditions. Utilizing vehicle data enabled us to uncover usage patterns not captured by traditional methods, aiding in tailored interface design. Our findings highlight the significance of big data analytics in enhancing user experience and interface design in the automotive sector.

Keywords: Usability index, Frequency of use, Ux strategy, Big data

INTRODUCTION

In recent vehicle development stages, reducing and integrating buttons has been a key issue to optimize the layout for better design elements and the utilization of the front-row space. Various usability factors have been reviewed to determine whether such reductions and integrations are feasible. These factors include the urgency of the function, frequency of use, the potential for alternative controls. Among these, the frequency of use is an important usability factor, revealing how often and how dependent users are on each function. Our usability principles focus on balancing urgency and frequency of use during driving, emphasizing that controls and information should be easily visible and accessible based on their importance. In this study, we specifically focused on climate control systems, using VCRM vehicle data collected in real-time from the field to quantify actual user control frequencies. VCRM vehicle signal data is collected in the car cloud from certain CAN signals and diagnostic communication data applied in Hyundai Bluelink and Kia Connect vehicles, providing information about the user's driving behavior. Through user data, this study aims to quantitatively identify users' needs for essential control functions. It also seeks to develop guidelines for optimizing climate control systems by analyzing operational patterns based on driving characteristics. Additionally, the study provides directions for enhancing control logic to minimize manual operation and suggests grouping functions for better usability.

VEHICLE BIG DATA ANALYSIS PROCESS

Analysis Method

Data provided by VCRM are time series status signals, and most climate control system are also collected as operating status signals. By detecting changes in status signals from the collected database as shown below, the user's control can be inferred.

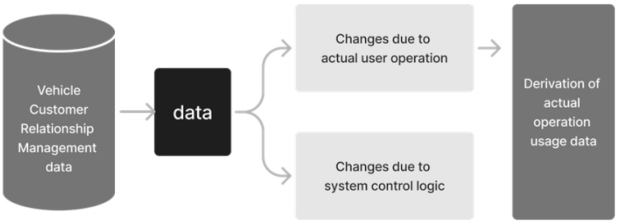


Figure 1: Schematic diagram of deriving real usability using VCRM data.

In order to increase the consistency of inferring the user's control behavior, accurate classification is necessary, and the following method was used for this.

- Using CANoe equipment, the signal values collected by VCRM were checked in real time when the actual climate control system was operated by connecting to the vehicle, and the signal behavior that can determine the operation was derived.

Figure 2: Climate control system signal confirmation using CANoe equipment.

- Climate control system specification analysis, signal behaviors that operate by control logic were classified and excluded. 1), 2) were used to extract the behavior of signals that can derive actual control behavior and several criteria necessary for analysis were established. Examples include the definition of misoperation, the control time criteria considering the characteristics of the control system by function, and the definition of valid driving. A common analysis guideline was established. Afterwards, data analysis was conducted and visualized.

Analysis Subjects and Conditions

Considering the climate control system layout and data collection conditions that can be operated 0-depth control among vehicles, the GV80 model was selected and analyzed. The detailed analysis control system and outline are as follows.

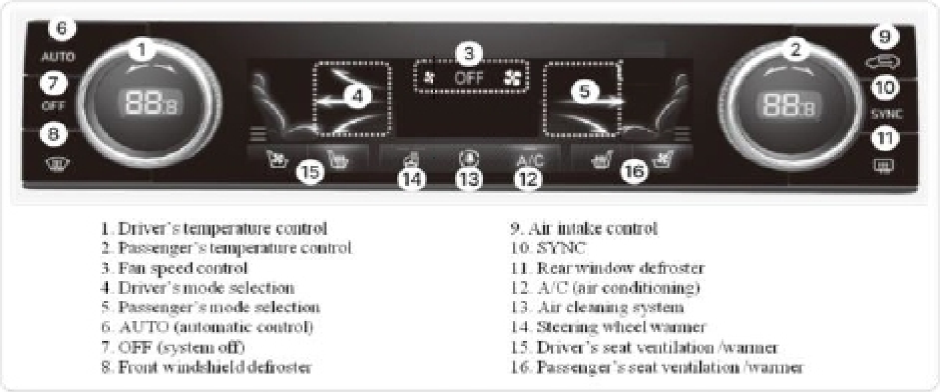


Figure 3: GV80 climate control system layout.

Among the above functions, (11) rear window defroster, (13) air cleaning system were excluded from the analysis due to the difficulty in collecting signals. When analyzing the results, The operation data from the driver and passenger control were combined for analysis. The detailed analysis outline is as follows.

Table 1. Data analysis outline.

Contents	Data
Target date	32 days
Total number of vehicles in operation	69,895 vehicles
Total number of trips	6,408,660 driving cycle

Since the data collected by VCRM is data from all trips with the engine turned on and off, preprocessing was performed on the entire trip under the conditions of ①Driving time lasting for more than 300 seconds and ② maximum speed exceeding 10 kph to reflect the conditions where user's climate control operation can occur. In addition, in order to distinguish data that had the intention of control, control operation was defined only when the signal remained the same for more than 3 seconds after control, and for functions that require multi-step continuous control such as temperature and wind speed, control within 5 seconds was considered as one control frequency regardless of increase or decrease. (For example, if the temperature was manipulated from 18 degrees → 25 degrees → 23 degrees within 5 seconds using a knob, it was considered as one control).

Analysis Results

Overall Control Frequency

The order of the main functions of climate control system is as follows: Fan speed, temperature, mode, AUTO, internal/external intake air, and DEF.

Table 2. Relative operation frequency of climate control functions.

Climate Control Functions	Relative Operation Frequency
Fan speed control	50.7%
Temperature control	28.3%
Mode	5.4%
SYNC	5.3%
Steering wheel warmer	4.4%
seat ventilation /warmer	2.1%
AUTO	1.6%
Intake	1.4%
A/C	0.5%
DEF	0.3%

Control Frequency by Weather

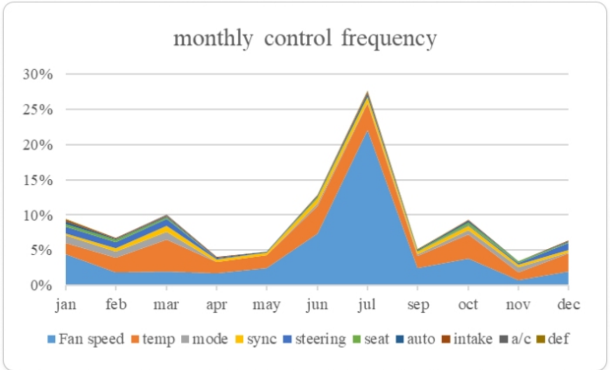


Figure 4: Monthly control frequency (*august was excluded).

In the case of seasons, the analysis date was distributed equally by season, and the average temperature/cold day/hot day/rainy weather of each season was considered for selection and analysis as representative annual data. The monthly control frequency is as follows, and the overall number of operations was in the order of summer > winter > spring = fall.

Considering the difference in absolute control frequency, if we look at the function usage pattern based on 100% for each season as shown in Fig. 5 below, the use of fan speed is particularly prominent in summer, and the use of steering wheel heating is particularly prominent in winter, and spring and fall show similar function usage patterns.

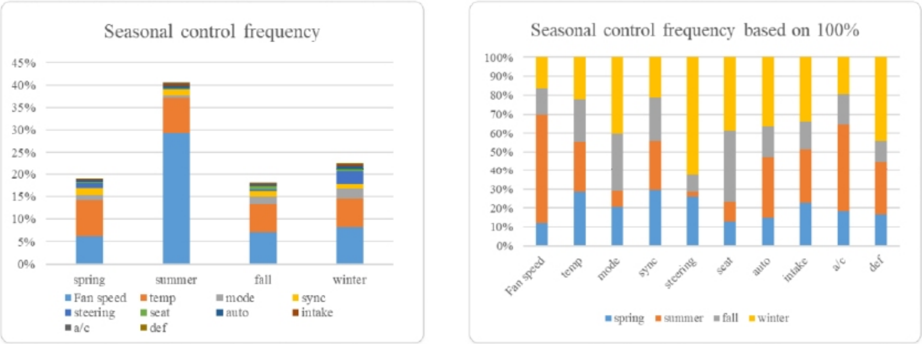
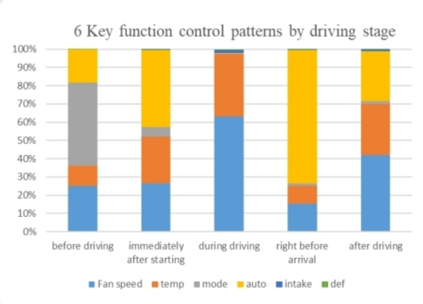


Figure 5: Seasonal control frequency and Seasonal control frequency based on 100%.

Considering the differences in absolute control frequency by function, if we normalize seasonal operation frequency to 100%, the functions least affected by season are temperature and SYNC, while those most affected by season are Fan speed, steering wheel heating, A/C, and DEF.

Control Frequency by Driving Characteristics

Given that a significant portion of the actual driving data corresponds to "During driving," the standard operating frequency (normalized to 100%) is classified by driving stage as follows.



Driving stage	criteria
before driving	From Engine Start to First 10 kph
immediately after starting	From First 10 kph to First 30 kph
during driving	Excluding stages 1), 2), 4), and 5)
right before arrival	From Last 30 kph to Last 10 kph
after driving	Below 10 kph to Engine Off

Figure 6: Function operating pattern by driving stage.

The most noticeable aspect of the control pattern during the driving stage is that various functions are utilized before driving and immediately after starting the vehicle. However, at speeds of 30 kph or higher, the primary functions used are temperature and Fan speed, which account for 97% of usage. There is no significant difference in the patterns based on driving distance or driving time. Therefore, it can be concluded that the driving characteristic with the greatest influence on the user is the transition to a driving stage at a speed of 30 kph or higher, during which user control becomes significantly simpler

USER SCENARIO AND USABILITY GUIDE

Based on the above results, the following guides were derived and user scenarios were derived.

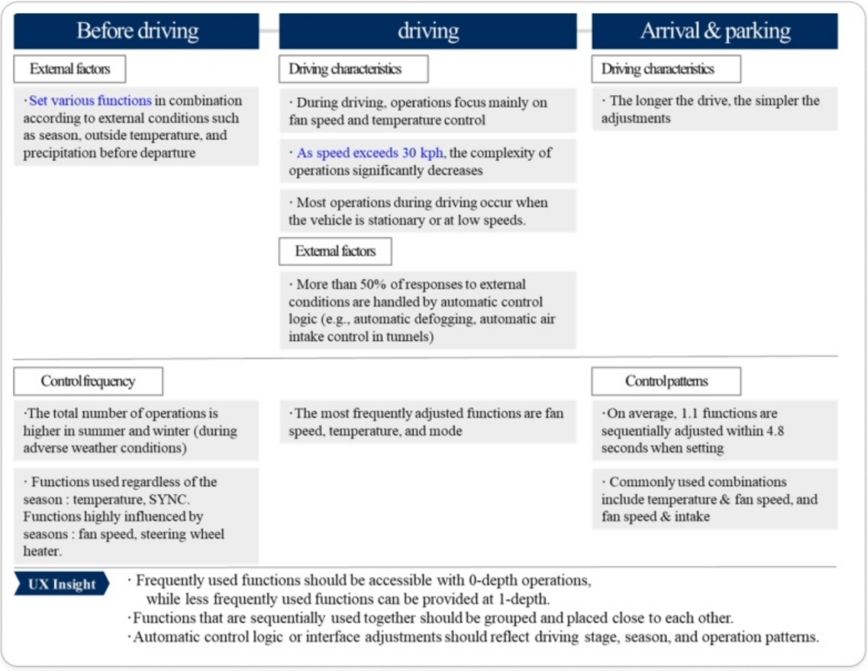


Figure 7: Data driven user scenario for climate control system.

1) Functions with a high usage frequency in the climate control system are positioned at the forefront for easy access. These frequently used functions are positioned on the left side, which is closer to the driver.

2) Functions with low operation frequency that can benefit significantly from automatic control should be developed to enhance the control logic, allowing for a lower arrangement priority. These functions can be positioned on the right side, which requires a relatively longer operation distance.

3) Considering that the control pattern varies depending on the driving stage or situation, when providing a customizable operation system in the future, detailed customization by driving stage and situation should also be included and referenced in the development of the control logic.

CONCLUSION

Usability Analysis of Climate Control Systems Using Real Driving Data

In the past, methods such as surveys, observational studies, and evaluation experiments were employed to analyze the frequency and patterns of climate control system usage. However, these methods had limitations in accurately reflecting the characteristics of the climate control system. This study addresses the shortcomings of previous methods by using real driving data, overcoming the constraints of limited driving scenarios and time. Representative analysis dates were selected to minimize seasonal impacts, which are crucial for climate control systems. Additionally, by considering various driving context factors, the study identified correlations among multiple elements affecting control frequency.

The Importance of Data-Driven UX Index from the SDV Perspective

A good climate control system should provide automatic control that minimizes user intervention while offering easy-to-operate controls when users wish to engage. This study identified the actual needs of users across various conditions, confirming their usage patterns. From an SDV (Software Defined Vehicle) perspective, this data is essential for understanding the interaction between software (functions) and hardware (controls). This data-driven UX index is expected to serve as critical evidence in future decisions regarding digital cockpit layouts and vehicle interface designs. The real-time, data-driven approach will be instrumental in developing intuitive and user-centered systems for future vehicle interfaces.

ACKNOWLEDGMENT

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