

MuLSA: Multi-Layered Scenario Analysis for an Advanced Driver Assistance System

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Abstract: Safe driving is mandatory for an advanced driver assistance system (ADAS). We consider that the adequacy and safety of the driver assistance services can be monitored by observing drivers' positive and negative emotions, since, if they find a hazardous situation, he/she has a negative emotion, "surprised" or "dangerous." If they feel to be assisted by the system, they will have a positive emotion. In order to analyze requirements for the ADAS, we propose a multi-layered scenario analysis (MuLSA). MuLSA is developed by integrating a customer journey map and a service blueprint with the context of a scenario. A customer journey map consists of a scenario; as the customer's experiences, as well as a customer's emotions toward the services. The service blueprint represents a customer's journey, as well as a mechanism of the services. Thus, MuLSA consists of a driver's journey, his/her emotions, the mechanism of services, as well as the context of the service. In order to prioritize requirements for the safety of a future ADAS, we have observed driver emotions with regard to hazardous scenarios with MuLSA. This paper shows the results of the observation, and we discuss the effectiveness of MuLSA.

1 INTRODUCTION

We develop services and improve them to compete in the market. According to the SQuARE (Software product Quality Requirements and Evaluation) (ISO/IEC 25000:2005, 2005), customer satisfaction is evaluated as the satisfaction in the usability of services. We need a method to analyze the satisfaction of customers of the current system in order to prioritize requirements of the future system. In this paper, we introduce a method to elicit requirements of an Advanced Driver Assistance System (ADAS) base on the analysis of the current Adaptive Cruise Control system (ACC).

The Cruise Control system (CC) of a car is one of the driver assistance systems (DAS). It regulates the speed of a car. In general, the structure of such services consists of two layers: one is a service provider, while the other is a service receiver. CC is a service provider. It provides services, i.e. start, termination, and acceleration, to the driver who is the service receiver. The service of CC is provided by a request from the driver. If we can observe the ups and downs of emotions of a driver when utilizing the CC, we can

evaluate the customer's satisfaction of the CC. However, the structure of the latest driving assist system is not so simple. The ACC regulates the speed of the car, while also regulating the distance from the precedent car. The structure of the service of ACC consists of the precedent car, as well as the driver and the ACC. The lane departure warning system is another example of DAS. It helps the car navigate the traffic lane. In this case, the structure of the service analysis has to take into account the traffic lane. Some of these systems stop their services in heavy rain, since they cannot monitor the precedent car or the traffic lane under such a bad weather conditions. Thus, the weather must also to be a consideration within the service structure. ADAS provides more complex services than DAS and the lane departure warning system. It is able to monitor peripheral cars, load conditions, traffic lights, traffic signs, etc. and, make decisions in order to ensure the safety of the driver's journey. The purpose of this paper is to develop a scenario analysis method for the DAS in order to prioritize requirements of the ADAS. The method will help us evaluate the effects of driver emotion with regard to current services, and the quality of these services. We

refer to the method as multi-layered scenario analysis (MuLSA). This paper is constructed as follows. In the next section, we introduce the related work. In Section 3, we describe the basic concept of MuLSA and overview MuLSA with its analysis structure and process. MuLSA is evaluated by applying it to a case. We describe the case and the results of the application in Section 4. In the rest of the paper, we discuss the effectiveness of the method and conclude this paper.

2 RELATED WORK

2.1 Emotion Analysis

Plutchik (Plutchik, 1980) introduces three-dimensional circumplex model. In the model, every emotion is composed of the combination of eight basic ones: vigilance, rage, loathing, grief, amazement, terror, admiration, and ecstasy. We selected and categorized these emotions into positive and negative emotions. For example, ecstasy and admiration can be categorized into positive emotions. Thus, vigilance, rage, loathing, grief, amazement, as well as terror are categorized into negative emotions. If we map these emotions according to customer satisfaction, the positive/negative emotions are reflections of/and refer to the high/low quality of the service for the customer. For example, if the ADAS can provide safe driving, the driver is satisfied with the service of the ADAS, and will accept the system. "Acceptance" is a kind of admiration according to the Plutchik's three-dimensional circumplex model. On the other hand, if the driver is fearful of the system, we can regard the quality of the service as low, and needs to be improved.

There are several means to measure emotions (Lorr, 1989). We developed a tool to observe the drivers emotions by means of simulation, from which, we can get quantitative measurements by means of keys that are assigned to the positive and negative emotions. Some researchers use questionnaires to assess emotions (Wallbott and Scherer, 1989). We on the other hand, do not use questionnaire, but employ a tool and interviews.

2.2 Scenario Analysis

J. M. Carroll (Carroll, 1999) describes the strengths scenarios. Scenarios can explicitly envision and document typical and significant user activities. It also provides us reasoning with regard to the situation of use before we develop the system. Use case (Jacobson et al., 1992) and user story (Benyon and Macaulay,

2004) are categorized into scenario analysis methods. Persona analysis is sometimes used to analyze a specific user's activities (Aoyama, 2005). Even though a scenario reports a user's activities well, we need to analyze more than these reported activities. The problem with a simple scenario, such as use case, is that it is constructed in a single-layered structure. In order to evaluate the quality of ADAS, we need a more complex analysis space.

In the service analysis, there are methods to analyzing the quality of services by the customer satisfaction. The concept of those methods is that, "the customer is satisfied with good service." For example, if the customer is unsatisfied with the service, it should be improved.

A customer journey map (CJM) (Stickdorn and Schneider, 2012) is used to evaluate the customers' emotion while mapping them to their services. It is a kind of scenario analysis method. A scenario described in the CJM has a time line and a concrete story. The service receiver accesses the service at a *touch-point*. The emotions are presented according to the time line of a scenario in the CJM. The negative emotion of a customer implies some problems within the services provided. Though there is no standard notation for CJMs, most CJMs have a two-layered structure. In the first layer, services are shown as a user story with *touch-points*. The story can be regarded as a customer's journey or experiences in the forest of the services. In the second layer, the emotions or impressions of the customer are described according to the customer's journey. Richardson (Richardson, 2010) shows an example of a journey into shopping. The scenario commences from a customer's awareness to out-of-box-experience. During the customer's activities, a CJM is used to evaluate motivations, questions and barriers.

Risdon (Risdon, 2011) proposes a CJM to the analysis of the service of the Rail Europe. We can see a lot of examples of CJM on the Internet. CJM helps service marketing or business marketing improve their services or products. Our purpose is to analyze the quality and/or problems of the services provided by the DAS and prioritize requirements of the future ADAS. Its analysis space contains user's activities, user's emotions, environment of the usage, as well as services. Thus, our method has a multi-layered structure. We refer to this method as MuLSA, which is an abbreviation of "Multi-Layered Scenario Analysis."

A service blueprint (SB) is also a two-layered scenario analysis method (Shostack, 1984). This service is provided to a customer via a *front stage* of the service that is constructed in a *back stage*. In the front

stage, direct communication between a customer and services is shown. In the back stage, there is indirect interaction between the customer and the underground mechanism that supports the services. There are several relationships between these two layers. They represent how the services are implemented and serve to the customer. However, it does not analyze the emotions of a customer, but simply designs the services. We integrate a CJM and an SB in order to analyze priorities of requirements to improve the quality of services through the application of MuLSA.

Blueprint+(Polaine et al., 2009) is a method that integrates a CJM and an SB. It is also a two-layered scenario analysis method. The first layer is a customer's layer with three diagrams, i.e. fail line, emotion, and cost. The second layer is a system layer with a set of actors and a *touch-point* for each service. We can interpret the system layer as an actor that implements the service through the *touch-point*. The strength of MuLSA is that it has a context layer to represent the environment of the usage, which affects the services. Blueprint+ does not have such a layer. The context layer of MuLSA reflects the environmental factors of the services. It helps analyst understand the context of the service. The context of the service of the DAS is important, since the service of ADAS has to be modified according to the environment of the car in service.

3 MuLSA: MULTI-LAYERED SCENARIO ANALYSIS

In this section, we describe the basic concept of MuLSA and give an overview of MuLSA as a method of analyzing customer satisfaction and the quality of the services of the current system.

3.1 Basic Concept

It becomes possible to drive a car automatically. For example, a driverless Audi TTS climbed up the top of Pikes Peak in 2010 (Kuchinskas, 2010). Google also developed a google driverless car (Markoff, 2010). Our focus is not an automatic driving system. We consider that although a car can be driven safely by a computer, the autonomous system will not satisfy its human driver and passengers.

A car is on a road under various environments and other cars may not behave expected way. We have to analyze the environmental and mechanical circumstances under which the services perform. Events and/or objects that are monitored by the ADAS are referred to as the environmental factors. Some of the

environmental factors are called "hazards." When we elicit and analyze requirements of ADAS, we have to consider the possible hazard and keep the car and driver out of danger.

Drivers, however, are the experts who detect hazards when they drive their car. When they detect a hazard, they become strained. If they feel they are free from the hazard, they must be relaxed. When they realize that they are not being cared for by the ADAS, they become scared and/or irritated. We can refer to these emotions, i.e. strained, surprised, scared, irritated, etc., as negative emotions. Further, negative emotions may lead a driver to the dissatisfaction of the system. Thus, we can detect hazards by monitoring the emotions of drivers and define requirements for the future ADAS. We expect to elicit highly prioritized requirements by analyzing real driver's, and their emotions with regard to, and caused by the service reception from the ADAS.

On the other hand, emotions, such as showing enjoyment, being relaxed, etc., are referred to as positive emotions. The mission of the ADAS is not only to keep a driver and fellow passengers safe, but also to give positive feelings to the driver. In order to increase the satisfaction of a driver, we analyze the services that dissatisfy drivers, and clarify the reasons drivers feel negative emotions with regard to the services.

Companies that provide DAS sometimes research driver satisfaction through questionnaires. Some companies also survey driver satisfaction for each country the systems operate in. However, the questionnaire survey is not adequate for detecting problematic services. In order to detect problematic services, we need to analyze the process of the service provision and the usage of the service. MuLSA has been developed to analyze the process and usage of the service of DAS.

3.2 Overview of MuLSA

MuLSA integrates a CJM and an SB through the addition of extending with environmental factors as the context of the services. The analysis structure of MuLSA is shown in Figure 1. It has three layers.

- Customer's layer
In this layer, two kinds of information are presented. One is the customer's journey, and the other is the emotional changes of the customer. In Figure 1, this layer is shown at the top of the figure. The time line of the scenario is passed from left to right.
- Context layer
The context is shown in this layer. In the context

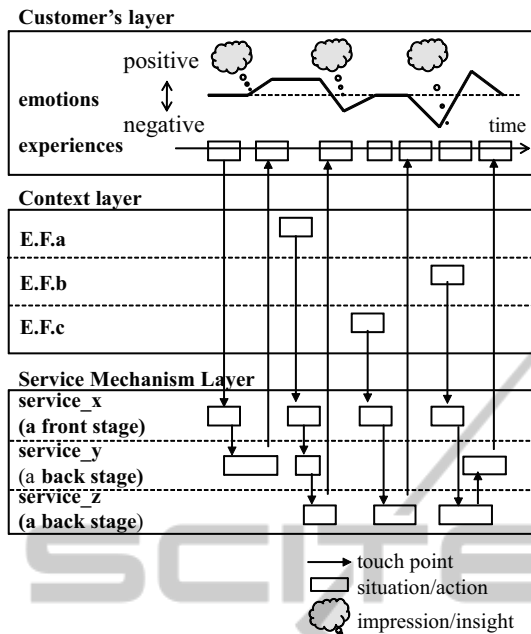


Figure 1: The structure of MuLSA.

of the services, environmental factors that affect the service contents are identified.

- Service Mechanism layer
This layer is constructed with two sublayers that are a *front stage* and a *back stage*. The *front stage* is a communication facade between customers and the system. The *back stage* represents major components of the system. This layer is shown at the bottom part of Figure 1.

3.3 Measurement of Emotions

Psychologists have proposed methods to measure emotions (Russell, 1989). For example, in the case of self-report questionnaires, it is the test subject who reports intuitively and/or subjectively their emotions expressed through the use of various words, e.g. happiness, surprise, fear, anger, disgust, or sadness. Another way of measuring emotions with regard to vocabulary usage is by the application of a response scale, on which a test subject is observed so that their facial expressions can be recorded. Our purpose in measuring emotions is to clarify any problematic behaviors with testing systems according to the subjective emotions of test subjects. Thus, we consider that, intuitive reporting is not only important, but if possible, we also expect a test subject to report their emotions consciously, because following the simulation or test, we may ask them what they feel and what they require of the future ADAS.

A tool to record their emotions is simple. A test

subject only inputs keys according to their emotions. The positive and negative emotions are ranked into four levels. The highest emotions are assigned to a key “a.” Further rankings on our declining scale are, higher, high and rather positive, which are assigned to the keys “s”, “d”, “f”, respectively. Similarly, worst, worse, bad, rather negative are assigned to keys “l”, “k”, “j”, “h”, respectively. Hence, the test subject can set their hands on a keyboard and type the characters according to their emotions. The tool is simple enough and needs little training. Moreover, the tool records the timing of the key ins and the key itself, and interprets input keys to the emotional scale described above, from -4 to +4. As a result, we can establish an emotional evaluation of the test subject as shown in Figure 2. In our next version of the tool, a joystick may be applied as an input device.



Figure 2: The emotions monitored via key ins.

3.4 The Requirements Analysis Process

With this three-layered scenario, we can gather the points of the emotional changes and analyze the state of the DAS and the environment. In order to develop the ADAS, we have to analyze problems within the DAS, which has already seen application in the market. The ADAS has to be able to analyze the circumstances and environment of the car through the use of numerous sensors. The requirements analysis process of MuLSA is shown below.

1. Identify subsystems and set them in the *back stage*.
These subsystems represent the limitations of the current system. The sensors and controllers of the DAS can be detected. Define the functionalities and efficiency of those components according to the real components in the current system. In order to elicit requirements for the future system, we need to visualize the limitations of the current system.
2. Identify components in the *front stage*.
A display is the most typical component in the *front stage*. Further, alarms, beeps, or announcements can be components as well.
3. Identify hazards as the environmental factors.
In order to assess the quality of the services of the

current system, listing hazards with regard to environmental factors as much as possible is done. Hazards will be the context of the scenario defined in the next step. Weather, road condition, peripheral vehicles, pedestrians and/or animals can be the hazards.

4. Construct a scenario as a customer journey. The scenario is defined to analyze how much a given hazard affects a driver's emotions. If we can know how much the environmental factors affect the drivers' satisfaction, we can prioritize sensors that can detect and monitor the environmental factors. The best length of the scenario is still under consideration. The scenario of our first case is less than 30 seconds.
5. Develop simulation. The scenario is transformed into animation that is developed with PreScan (Advanced Simulation Technologies Ltd., 0132). PreScan is a development environment for ADAS or intelligent vehicle systems. Two kinds of animation must be constructed as scenes seen through the windshield and a rearview mirror. Figure 3 represents the image of a tool with the movie being developed by PreScan.
6. Simulate the scenario with a test subject and get emotional data in the scenario. After the simulation, we map the emotional data in accordance with the simulation.
7. Analyze the emotional data and elicit requirements for the ADAS.

ACC is one of the current DASs. ACC safely controls the speed of the car, while establishing a safe distance from the precedent car. Sensors send signals to the ACC, which in turn sends other signals to the speed control unit and display. The future ADAS will have more sensors and be able to establish the driving context with regard to the environmental factors.



Figure 3: The tool image of MuLSA.

4 CASE STUDY

4.1 Overview

This section describes a case study by which we detect problems in the current ACC as an example of the DAS, which we then analyze in order to evaluate the effectiveness of MuLSA. There are various services on ACCs. The ACC used in this case study provides the following services.

- The ACC starts when the driver turns on the ACC.
- The ACC is terminated when the driver turns off the ACC.
- The driver can set the speed for the ACC.
- The driver can increase or decrease the speed of the cruise within the permissible range.
- If there are no precedent vehicles or, there is enough distance from the precedent vehicle, the ACC maintains the set speed of the cruising car.
- If there is a precedent vehicle, the ACC keeps the adequate distance from the precedent vehicle by adjusting the cruising speed. The precedent vehicle is detected by a radar sensor on-board.
- If the windshield wipers are used in strong mode, the ACC is automatically terminated, so that the radar or laser cannot detect the precedent vehicle.
- If the precedent car goes out of its lane, the ACC gradually turns the speed back to the set speed.
- If the speed of the cruising car becomes slower than a certain speed, the ACC is automatically terminated.

The display in which the state of the ACC is shown is identified in the *front stage*, with the sensors, speed controller and ACC being defined in the *“back stage”*. In order to evaluate MuLSA, we made a simulation with PreScan(Advanced Simulation Technologies Ltd., 0132). We took various environmental factors into account within the simulation. They were weather condition, a precedent vehicle, as well as another car that cuts in front of the cruising car. A test subject who is a driver accesses the simulation via a keyboard and display interface through a personal computer. The insights of the test subject were monitored by their utterances during the simulation. In our future tool, the emotions of the test subject will be automatically recorded from the keyboard.

4.2 The Scenario

The test scenario is as follows.

1. The driver increases the speed up to the desired speed and turns on the ACC.
2. The ACC comes into service state and starts to provide its services with the car cruising at the desired speed.
3. The driver releases the accelerator pedal.
4. A vehicle cuts in front of the car. Then, the sensor detects the vehicle and alarms the distance to the ACC.
5. The ACC decreases the speed of the car in order to keep an adequate distance from the precedent vehicle.
6. The driver feels the sudden gravity of reducing speed.
Since the test subject only watched the simulation movie, the change in gravity was communicated to the test subject from the staff. The event of the "reduced speed" was caused by the precedent vehicle, which is one of the environmental factors, and which is dispatched via sensor and the ACC.
7. It starts to snow heavily.
8. The driver turns on the windshield wipers to the strong mode to keep visibility.
9. The ACC catches the event.
10. The ACC terminates its services to avoid sensor errors and notifies the driver of the termination via the display.
11. The speed of the car is reduced: the result of which sees the following vehicle increasing its approach.
The simulation is made on the assumption that the driver can notice the termination of the ACC from the display. If the test subject does not notice the situation, the staff informs the tested of the situation. The simulation is a movie, so the test subject is not actually operating the car.
12. The driver notices the termination of the ACC.
13. The driver puts their foot on the accelerator pedal and restarts the manual driving.

The results of MuLSA is shown in Figure 4. The emotions of the test subject and their journey are shown in the customer's layer. Their insights, recorded from their utterance, are shown in balloons. There were two environmental factors: other vehicles and weather. These factors are shown in the context layer.

In the next section, we analyze the results.

4.3 Requirements Analysis for the ADAS

MuLSA consists of three layers. We can see the test

subject's *touch-points* through the ACC, as well as when and how strong the test subject (driver) had positive or negative emotions toward the system (ACC) within MuLSA's layered structure. We consider that, the negative/positive emotions of the test subject may imply problematic and/or ideal behaviors of the current ACC. In order to analyze in detail the emotion in and of each *touch-point*, we refer to the recorded utterances of the test subject. They are shown as balloons in Figure 4. For example, the first balloon (A) represents the feeling when the test subject displayed the positive emotion. This is the effect of the service (2).

The purpose of our research is to analyze requirements of the future ADAS. Hence, we focus on the negative emotions in Figure 4 and refer to the causes of the test subject's negative emotions. The causes must be shown in the context of the scenario. If the context of the car is correctly detected by the ACC, the problem is in the ACC software. If the context of the car is not correctly detected by the sensors of the ACC, we have to consider the addition of new sensors to the future ADAS. The priority of each sensor can be set in accordance to the level of the negative emotions.

The second balloon (B) represents the feeling felt when the test subject detected the sudden gravity change. Though they must have been surprised at the change in gravity, they thanked the ACC for avoiding danger, in this case, a car crash. We regard such a surprise may decrease the customer satisfaction. This is a problem with the software of the ACC itself. The future ADAS may require smoother speed control, so that the driver does not feel fear or surprise.

The problems that we have to solve lay within the balloon (C). The test subject did not understand the speed decline. This means that the ACC must communicate its state securely to the driver. However, the ACC had been terminated due to the snow, thus, the test subject noticed the state change securely. If the test subject knows that the ACC may be stopped in the inevitability of low visibility, they could prepare for the termination and would not have the negative emotion. We need to redesign the behavior of the *front stage*.

So far, we have been able to elicit two new requirements for the future ADAS. One is the smooth speed control, in which case, the ADAS does not allow a driver to feel a sudden gravitational change. In order to satisfy the requirement, we need to analyze the risks with regard to the safety of driving as relates to gravitational changes. The other is that of the communication between the driver and the ADAS. Some kinds of announcements may annoy drivers. How-

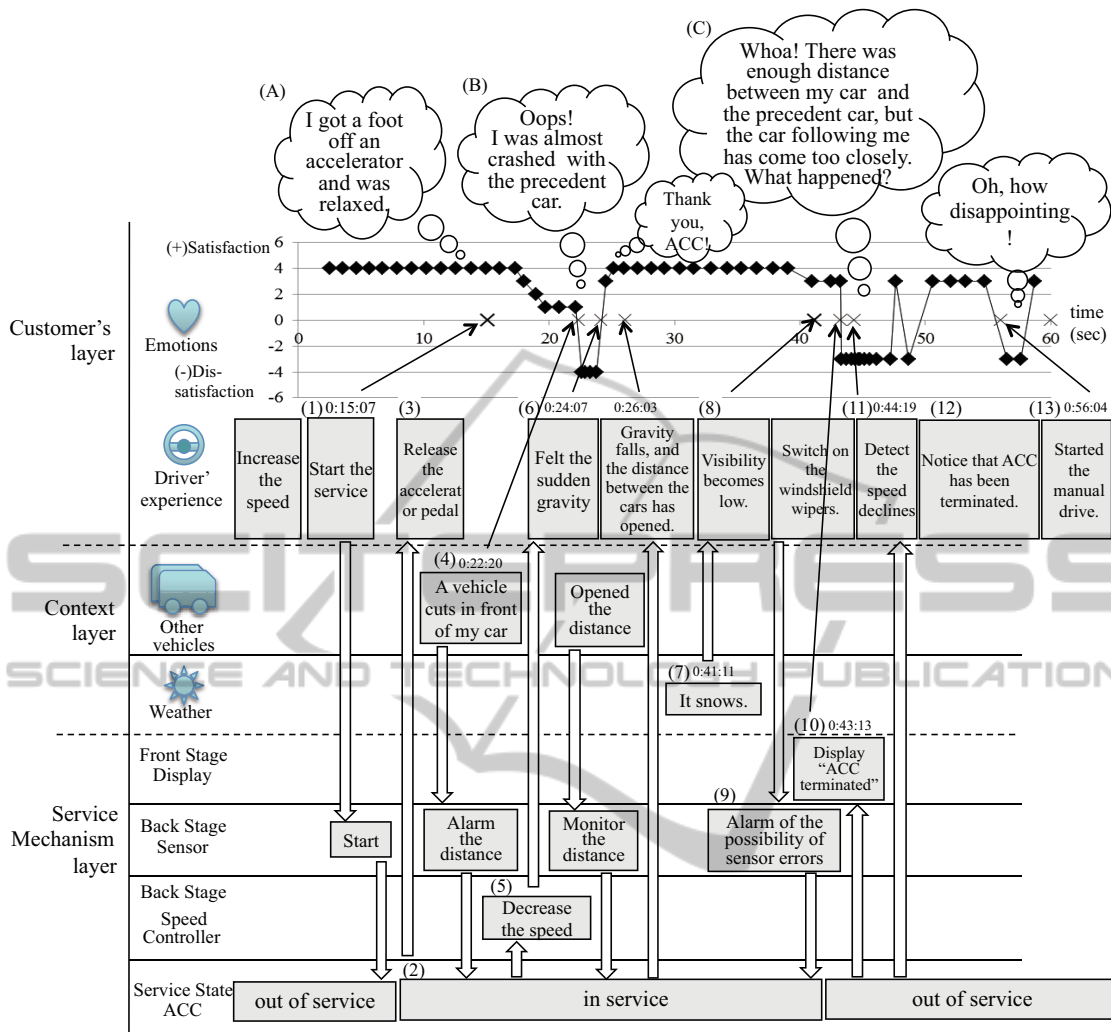


Figure 4: The analysis with MuLSA.

ever, important messages, e.g. start, termination, etc., have to be securely communicated to the driver. For example, if the driver does not notice the termination of the ADAS, a following car may run into their car. The balloon (C) tells us that the driver realized the possibility to be of such a situation. The priority of this improvement of the notifier within the display is high.

This case study shows us the effectiveness of MuLSA, because we were able to elicit new requirements and their priorities.

5 DISCUSSION AND CONCLUSIONS

MuLSA is a satisfaction basis method. In this paper, we elicited new requirements of the future ADAS by

applying MuLSA to the current ACC.

We are now developing other scenarios with more vehicles and various road conditions. In these future scenarios, we will put the ACC into the various hazardous situations, to be solved by the ADAS.

We were able to evaluate the effectiveness of MuLSA by the case study. However, MuLSA is not a method only for the ACC or ADAS.

As Kimbell (Kimbell, 2011) described, one of the strengths of the user stories is that they proposes ideas for new services components and also entirely new services. MuLSA is also applicable to most software, when an analyst needs to elicit new requirements based on the current software. The strength of MuLSA is that it analyzes requirements through the utilization of its multiple-layered structure in which there are users, context of the usage, as well as the mechanism of services. Researchers have proposed

a lot of methods for requirements elicitation, such as goal oriented analysis methods (Dardenne et al., 1993; Yu, 1997) or use case analysis (Jacobson et al., 1992) focuses on initial requirements elicitation for new software. In contrast, MuLSA focuses on software that is developed as an innovation on the current software.

The weakness of MuLSA is that its analysis process is not so systematic. It depends heavily on the emotions and/or insights of users, rather than the goals or purposes. MuLSA is a kind of scenario analysis method. The scenario provides a real story within time. As Carroll mentioned (Carroll, 1999), scenario is understandable for every user and gives a real experience to them. New requirements for innovations on current software are hard to elicit through interviews. We believe that most important requirements must be elicited from the users' real voice or emotions as a result of their experiences, rather than requirements analysis work based on a table.

An analyst with MuLSA does not expect the users to propose problems or new requirements, rather, their emotions and insights in their use of the current system is key. The effectiveness of MuLSA is to analyze the causes of the users' emotions. As a result, we can prioritize new requirements for the software of the next generation. This means that the scenario has to contain situations in which the user realizes the problems of the current system. For example, it can be used for the claim analysis (Carroll, 2000) which needs to analyze various users and usages.

In this paper, we proposed a method named MuLSA to elicit requirements and prioritize them according to a scenario analysis. The method is being developed for the improvement of future software as the next generation of current software or systems. The scenario has multiple-layers, with the customer's layer, context layer, as well as the service mechanism layer. The customer's layer can be used in claim analysis for various users. We are able to define negative actors in the context layer. It is efficient to analyze misuse cases and/or analyze requirements under various situations (Alexander, 2003). The multi-layered structure with time, makes it possible to analyze misuse cases more effectively than through a use case diagram.

In our case, we decompose the mechanism layer into several sublayers. If we apply MuLSA to a general software analysis, the mechanism layer may need two sublayers, i.e. a *front stage* and a *back stage*.

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