Realization of Safe Driving Environment

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In the field of transportation and traffic, big data are beginning to be used for improving transport efficiency and assisting in safe driving. Fujitsu has commercialized FUJITSU Intelligent Society Solution SPATIOWL, a cloud service that uses location data, to build a system that accumulates in the cloud various types of information associated with location data of mobile objects including vehicles. We have also developed sensing technologies for use in vehicles or on road infrastructure that promote road traffic safety. Data acquired by sensing technologies related to road traffic systems have so far only been used in limited applications such as individual vehicle systems and safety systems for specific road sections. But systems are now in place that make it easier to connect with data in the cloud, and this facilitates data aggregation and accumulation. Adequate analysis of the massive amounts of accumulated data makes it possible to identify information about points requiring attention in driving, and to do this requires analysis technology that can accurately identify significant pieces of information that suit the purpose of analysis, out of massive amounts of data. This paper presents a technique of efficiently analyzing massive amounts of data from drive recorders and detecting truly necessary information. Then we introduce a system that utilizes SPATIOWL to implement that technique as a functional component for assisting in safe driving.

1. Introduction

The advancement of transport systems has brought great benefits to humanity, but it has also given rise to many problems, including traffic accidents, traffic congestion and environmental pollution, which are sometimes referred to as negative legacies of transport systems. Of these problems, this paper focuses on the mitigation of traffic accidents, and describes our efforts in developing an environment that enhances the safety in driving.

In Japan, the number of fatal traffic accidents continued to decrease for 13 consecutive years up to 2013, and it has been kept under 5000 casualties in recent years.[1] However, the year-on-year rate of decline in traffic accident fatalities has been minimal. Possibly an efficient way to address this is to tackle some of the most frequent fatal accidents to further reduce traffic accidents. Most fatal accidents occur when the driver is not concentrating, is distracted or makes an improper driving maneuver. These accidents caused by human errors have not decreased so much.[1],[2] In the case of the drivers not concentrated or being distracted, it is highly likely that accidents may be avoided by warning them of the dangerous situations. Similarly, the improper driving maneuver is attributed to the drivers' losing calm and panicking,[3] which may also be alleviated if they are informed of the potential danger well in advance, thus leading to a reduction of accidents. Providing drivers with the "right information" in advance will help reduce the number of traffic accidents.

In 2011, Fujitsu commercialized FUJITSU Intelligent Society Solution SPATIOWL,[4] a cloud service that uses location data to build a system. This system aggregates, accumulates and analyzes various types of information taken from many mobile objects. It then gives drivers the right information at the right time, aiming to reduce traffic accidents and promote safe driving.

We assume the following two types of right information. One is geographical point information. This includes information about certain points where the incidence of traffic accidents is high when certain external factors are present, or where many drivers recognized the danger or narrowly avoided an accident by making an emergency maneuver (hereafter referred to as "cautious driving points"), together with information on risk factors involved in these points. The cautious driving points are generated as information accumulated on SPATIOWL and organized into a database. The second type of information for drivers is information about each driver's operational conditions. The data regarding the driver's maneuvers are aggregated and accumulated on SPATIOWL, and used to analyze their driving patterns. When a certain abnormality is detected in the driver's maneuver, the system sends an alarm notifying the driver of the unusual driving pattern.

In preparing for the development of the database for cautious driving points, we succeeded in creating a technology to analyze the driving data stored on the drive record and extract the necessary information efficiently.

2. Outline of SPATIOWL

The target users of the system behave on the basis of gathering and analyzing a diverse range of information in order to achieve certain goals. A good service for a transport system would give appropriate information to people depending on the purposes, time, locations and local conditions of their movements, and guide them accordingly. The SPATIOWL service is available on the cloud, and is applicable to many fields that use location data. The concept of SPATIOWL's data use is shown in **Figure 1**. Being analogous to human action cycles, the system is equipped with the functions necessary for each area of data collection, data analysis, and provision of information/service, and it expands as more data are accumulated.

This section presents the method of generating the right information for drivers, and efforts to make the system commercially viable, with a focus on technological aspects.

1) Collection of driving data

We collect data from drive recorders as the source data of driving conditions. A drive recorder is a device capable of recording images and vehicle data, and these can be useful in case of a car accident. Virtues of the drive recorder are recognized as expediting the post-accident procedures, serving evidence to avoid disproportionate fault percentages being allocated, and raising drivers' awareness of safe driving, with more and more cars installing the device. Drive recorders would make significant contributions to collecting the data on roads and vehicle movements because they

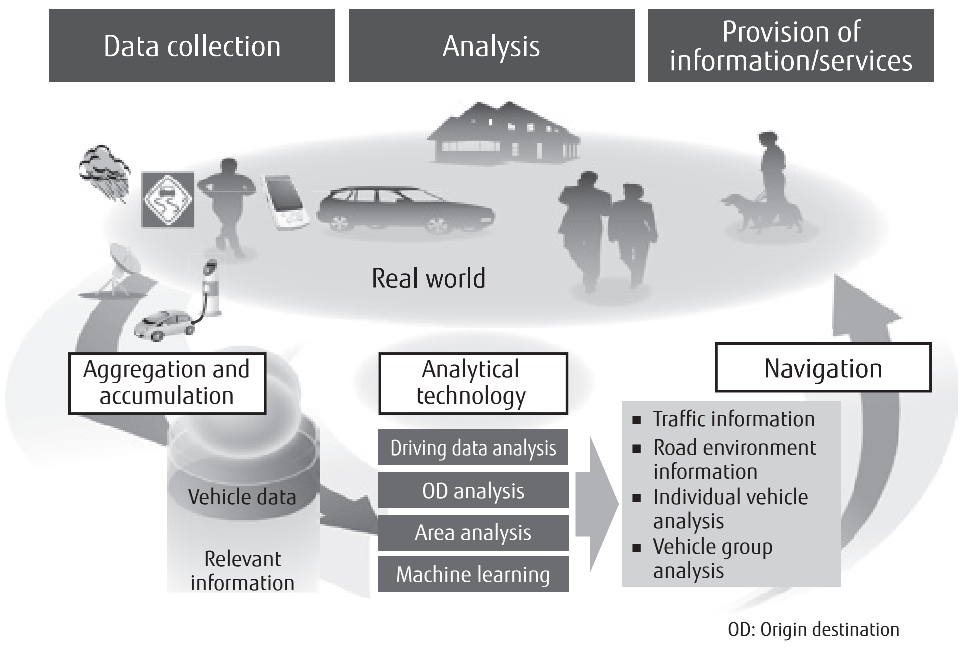


Figure 1
Concept of SPATIOWL data use.

retain accurate data that can be used to reconstruct the situations in which the driver was found, including the locations, time, speed and acceleration as well as image data. Leveraging these data would make excellent media for resolving issues regarding transport systems. Moreover, the data could also be more useful if they were accumulated on the cloud extensively and in a large volume.

2) Drive recorder data analysis

Several performance tests have already been conducted to verify the driving data use for the purpose of preventing car accidents.[5] One such test was on near-miss spot mapping. There have been reports of activities based on the outcomes of these tests, raising awareness among drivers and prompting road maintenance/repairs by the national or municipal agencies. Meanwhile, these data from drive recorders are also leveraged in providing training on safe driving. However, the bottleneck is the human cost because the large amounts of data are handled manually for analysis. For this reason, an urgent task is to automate the analytical processes. Against this backdrop, Fujitsu has obtained drive recorder data through its unique route and analyzed them for possibilities of developing a new business to provide information on cautious driving points.

We conducted an experiment in which 837 records from drive recorders were submitted to a visual analysis, and we confirmed that places where there was a high incidence of sudden acceleration or deceleration did not coincide with points of near-miss incidents (cautious driving points). **Figure 2** shows the results. It shows the relationship between the speed (on the horizontal axis) and acceleration (vertical axis) after drive recorder data were visually processed into categories. We divided the data into three categories: no problem (shown as ◇), dangerous (□) and high potential of danger (△).

There is no apparent correlation between speed and acceleration (◇, □ and △) from the visual assessment of dangerousness. When defining the acceleration of 0.6 G and above as uniformly a dangerous situation, the accuracy of visual assessment (to discern a dangerous situation from non-dangerous ones correctly) was 47%, while the rate of oversight, the cases in which a visual verdict of dangerous situations was not being registered as such, accounted for 60%. In order to mechanically analyze the collected data, and statistically aggregate them to identify cautious driving points, the accuracy rate must be more than 50% while the rate of oversight has to be kept less than 50%.

We have thus developed a multiple-analysis

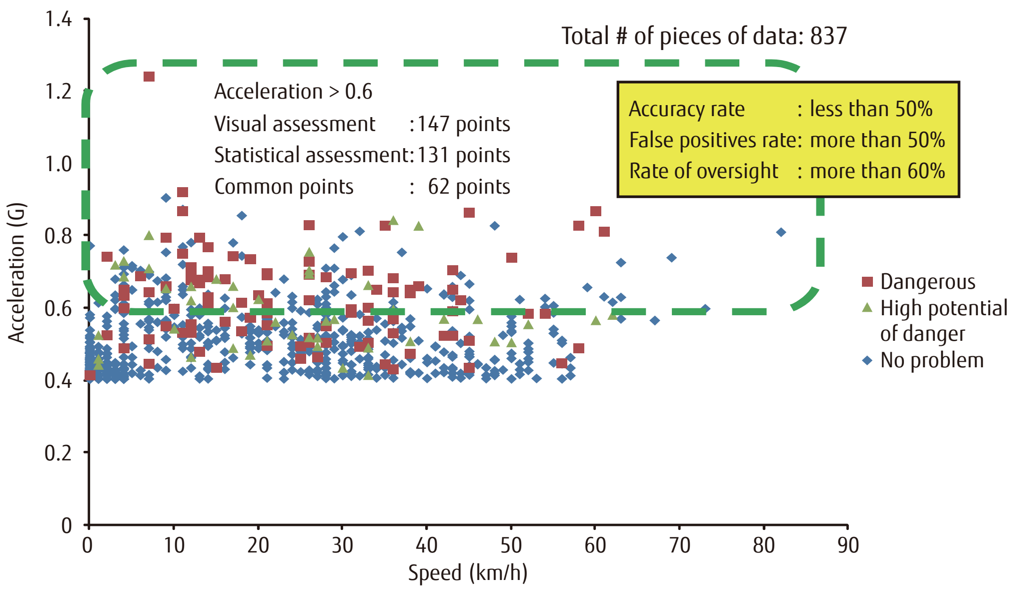


Figure 2
Results of visual analysis of drive recorder data.

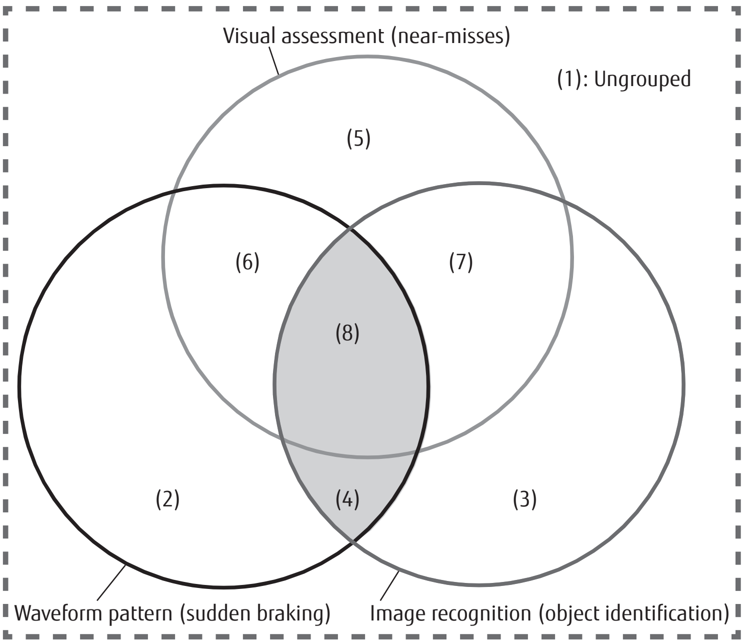
function, combining numerical analysis and image-recognition/analysis, aiming to achieve those thresholds. We also succeeded in automating the process. In terms of the numerical analysis, we focused on the changes in acceleration and analyzed the principle components of the acceleration waveforms. The results were classified using the Support Vector Machine (SVM), one of the pattern recognition techniques that employ a supervised learning method.[6] As for the image-recognition/analysis, we employed the Generic Object Recognition to identify objects for potential collisions such as vehicles and people, and calculated the level of danger by measuring the distance to the detected objects. As a result, we attained an accuracy rate of 73% and a rate of oversight of 27%, as shown in **Figure 3**.

The function we have developed for this experiment comes with two advantages. One is the selection of data groups to be investigated out of the total data set (reducing the volume of data submitted to the analysis). The other is the identification of assessment points in the selected data groups (simplifying the assessment processes). The time required for visually assessing one set of data is said to be three minutes[7] for a skilled assessor. Based on this figure, it would require about 40 hours to visually process all the data provided for the experiment. We estimated that the new function would reduce it to approximately four hours.

An additional benefit of the image-recognition/analysis function is that it shows what drivers should be cautious about, as opposed to merely pointing out the locations where caution is needed while driving.

3) Evaluation

Our experiment has shown that the function will contribute to transport systems, particularly in reducing the incidence of traffic accidents, providing information to meet drivers' requirements, and navigating the traffic. Regarding the automation processes and techniques employed, we used the supervised learning method for a waveform analysis. In addition, combining the image-recognition/analysis and the numerical analysis has proved to have a synergistic effect. As the image recognition has a reference point in human perception and learning, this function has been improved in accuracy by correlating numerical values/components with drivers' near-miss experiences. The waveform analysis, however, tends to overburden itself in learning processes, which is an issue that must be addressed in the future.



	Concept	Number
(1)	Irrelevant	194
(2)	Simple braking	54
(3)	Object	233
(4)	Misjudgment	147
(5)	Unexpected	5
(6)	Missed	24
(7)	Lack of braking	11
(8)	Correct	108
Total		776
Filtering rate (%)		32.9
Identification rate (%) Σ (1)(2)(3)(8) / Total		75.9
Accurate identification (%) (8) / Σ (5)(6)(7)(8)		73.0

Figure 3
Results of automated multiple-analysis of drive recorder numerical/image data.

Regarding the analytic techniques, we employed a multiple-analysis function to process two types of data that were very different in nature: structured, numerical data and non-structured image data. We used the SVM to analyze the former, and this is also gaining more recognition in the area of image pattern recognition techniques in tandem with the application of artificial intelligence (AI) technology.[8] We hope to explore ways to leverage SVM more in the future. We also found that it was possible to improve the effectiveness of the function by mutually applying the judgement criteria through visual association between values and images, even in tasks that involve a degree of ambivalence in judgement, such as the near-miss incident recognition employed in this experiment.

3. Perception of driver's operational conditions

In the previous section, we described a method to efficiently develop a database regarding the cautious driving points, which constitute the "right information" for drivers, as one of the approaches to reduce traffic accidents. In this section, we will describe another approach, a system which is more preventive in that it monitors the driver's operational conditions and alerts the driver at the "right time" to guide them out of potentially dangerous situations. To achieve this, the system must correctly understand the driver's operational conditions. We assumed that the operational conditions could be inferred from the vehicle maneuvers and resulting vehicle movements. Thus, we developed a system that involves various sensors to collect in-driving data. To ensure ease of use, we incorporated smartphones for data collection. As smartphones are equipped with many sensors, the data they produce from within an automobile will reveal the vehicle movements. Such embedded sensors include GPS for locational and temporal data, 3-axis accelerometer sensors, 3-axis gyroscopes and geomagnetic sensors. We also prepared software libraries for collecting data from these sensors and sending them to SPATIOWL, which will facilitate an easy cloud-based storage of the data regarding the vehicle conditions.

We are also discussing the utilization of smartphone cameras to make the system incorporate data concerning driving environments. The idea is that the camera captures the front view, and those images are processed through the image recognition system to identify the road marker lines and the vehicle in front, as shown in **Figure 4**. The distances to the road marker lines on both sides are constantly monitored and the data thus indicating the vehicle's sideways movements are stored on SPATIOWL. The distance to the vehicle in front is similarly computed and stored. These data also reveal the driver's driving patterns and characteristic of driving.

With the recent advancement in wearable sensors, they may also be useful for obtaining biometric data to better understand the driver's conditions. As for the biometric data to be collected, there has been research conducted on the pulse data to determine the wakefulness level of a driver.[9] We hope to develop a system that includes information like this as one of the indicators in the future.

Each driver's longitudinal data thus gathered from those sensors and accumulated will help to create a better understanding of their individual driving patterns. For example, the data on acceleration will depict the driver's habits in acceleration and deceleration, while the image data will serve to reveal the distance the driver usually keeps from the vehicle driving ahead, as well as their steering wheel controlling patterns, which are interpreted from the distance with road marker lines. The analysis results will highlight the driver's normal driving tendencies, and the system recognizes any abnormality in current driving by identifying a significant difference between the standard and

Figure 4
Smartphone camera image for detecting road marker lines and vehicle in front.

current data, whereby the system issues an alert to the driver.

To summarize, we have developed an environment where SPATIOWL is deployed to accumulate data regarding two different factors: cautious driving points and drivers' operational conditions. As for the former, drivers' acquired rules were applied to determine the safety of driving conditions based mainly on visual data, taking into consideration certain external environmental factors. The data from the drivers' judgements on cautious driving points are categorized by external environmental conditions and accumulated. Similarly, the data on drivers' operational conditions such as not concentrating or being distracted also go into categories according to the types, conditions and other factors of the information/service users. The system thus provides drivers with the right information regarding the external environmental conditions and drivers' operational conditions, at the right time, thereby helping to promote safe driving and reduce road accidents.

4. Conclusion

To develop a safe driving environment, we need to reduce the number of road accidents. We consider it important to have comprehensibility and acceptability as the requirements, and for this the requirement is to give drivers the right information at the right time. Fujitsu strives to make this a reality through a system based on SPATIOWL. The big data serve as the basis of various types of information regarding driving patterns, driving conditions, and transport systems. The mainstream in analytical techniques is now said to be "the amalgamation of machine learning and large-scale parallel computing."[10),11)] Thus, we employ this very technique, and aspire to finding further ways to use it in a broader scope of applications. We will continue our efforts to enhance comprehensibility and acceptability for drivers, making our contribution to safe and secure driving.

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