Development and Evaluation of a Near-Miss Map System utilizing Driver's Emotions

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Abstract – To realize a safe car society, it is necessary to support drivers not only in mechanical aspects but also human aspects. We propose a system for automatically generating a near-miss map utilizing driver's emotion. Existing near-miss map systems only use conditions of the car such as heavy braking to detect unsafe locations. However, the accuracy of the near-miss map is not so high because there are many false negative and false positive errors. To decrease the false positive errors and false negative errors for generating a high-accuracy near-miss map, we introduce human emotions into the detection of unsafe locations and realize a high-accuracy near-miss map system. In this paper, we report the design and implementation of our prototype system and evaluation results of the prototype system in terms of false negative and false positive errors.

Keywords: Emotion, Near-Miss Map

1 INTRODUCTION

There are 77 million cars in Japan [1] and 1.1 billion cars in the world [2]. The cars are useful and essential for people to live a daily life. On the other hand, there were 540 thousand traffic accidents in Japan. 4100 people died as the victim of the traffic accidents and 670 people were injured [3]. The cars also pose a significant danger to people and we must decrease the risk. As mechanical approaches, recent cars equip driving assistance technologies such as ESC (Electronic Stability Control) and ABS (Antilock Brake System). In addition, more advance technologies which include pre-crash safety are coming into practical use in recent years such as ADAS (Advanced Driving Assistant System) and DSSS (Driving Safety Support Systems). With assistance of these technologies, the traffic accidents decreased from 950 thousand in 2003, when there were the highest number of the accidents, to 540 thousand in 2015. The decrease ratio, however, draws a shallow slope in recent years and it needs other solutions than just the mechanical ones.

It is said that a reason caused majority of the traffic accidents is human error. To decrease the traffic accidents, we need to focus on human and support drivers introducing more human approaches. As the human approaches, it is recognized that the driver's emotion affect the driving performance. The typical example is "Road Rage" [4]. The road rage is a term used to denote aggressive behaviors by drivers when they are cut into their line, overtaken by the others and got angry by other reasons. It causes fatal and injury accidents. In this way, the human emotions are important for the driving safety. Many researchers study influence of the driver's emotion and apply the driver's emotion to the driving support system [11]-[16].

In this research, we develop a system which creates a high-accurate near-miss map utilizing the driver's emotions. The near-miss map is a map which shows unsafe locations gathering information. The information gathering of the unsafe location in the existed system is realized by 2 different ways. The first is a manually operated way which gathers from human (e.g. questionnaire survey) the second is an automatically operated way which gathers from sensors (e.g. heavy braking detection). The manually operated way requires a great deal of time and the automatically operated way has an accuracy problem of unsafe location detection. We introduce driver's emotion to the automatically operated way in order to improve the accuracy of unsafe location detection. In our proposed system, a smartphone is used to recognize driver's surprise and fear emotions by facial expression and detect an unsafe location using the driver's emotions in conjunction with sensed car conditions. The information of unsafe location is sent to the server via the Internet. The other drivers which come by near the location can receive warning to be aware of the risk of traffic accidents.

The paper is organized as follows. In the next section, we describe human emotion researched in psychology and applied studies of the human emotions in the automobile field. Section 3 shows existed near-miss map system and their problems as a preliminary study. We propose a near-miss map system utilizing driver's emotion in section 4 and implement a prototype system in section 5. Section 6 evaluates the prototype system and reports the experiment results. Section 7 gives some conclusions and our future work.

2 RELATED WORK

As related work, we explain human emotions at first. After that, we describe existed researches which utilize human emotions in automobile field and the effectiveness to apply human emotions to driving assistance systems.

2.1 Human Emotions

Human emotions have been researched in the field of psychology. Ekman defined six basic emotions by researching facial expressions of human [5]. The basic emotions are "happiness", "surprise", "fear", "sadness", "anger", and "disgust". Seven emotions added "neutral" to the six basic emotions are frequently used in the field of facial expression recognition with image processing technologies [6]-[8].

In some researches applied human emotions to information systems, the emotion model defined by Plutchik is used. Plutchik defines dimensions which include eight basic emotions “joy”, “trust”, “fear”, “surprise”, “sadness”, “disgust”, “anger”, and “anticipation” [9]. These emotions presents a circumplex model. In this model, similar emotions are placed on the neighborhood and opposite emotions are placed on the opposite side. Plutchik also defines eight combinations of two basic emotions “love”, “submission”, “awe”, “disapproval”, “remorse”, “contempt”, “aggressiveness”, and “optimism”.

Parrot classify human emotions and define them as hierarchical tree structure [10]. The primary emotions are “love”, “joy”, “surprise”, “anger”, “sadness”, and “fear”. Other a lot of emotions more than one hundred are also defined as secondary emotions and tertiary emotions.

In the above emotion models, there are several common basic emotions such as “surprise”, “anger”, “sadness”, and “fear”. From these common basic emotions, we focus on the “surprise” and “fear” emotions in our research because these emotions can be appeared on driver’s facial expression in near-miss situation.

2.2 Emotions in Automobile Field

There are a lot of researches to detect emotions of drivers using sensor devices and grasp conditions of the drivers. Jones researched a method to detect driver’s emotion using his/her speech and developed a system for emotion recognition in a car [11]. Riener proposed a method to detect driver’s emotions using his/her heart rate variability [12]. Haak tried to detect driver’s emotion by analyzing his/her brain signals [13]. Moreover, Anzengruber developed a system which can detect driver’s emotions using his/her face surface temperature and evaluated the system on a driving simulator [14]. In this manner, we can detect driver’s emotions utilizing information collected by various sensor devices.

There are also applied researches utilizing the detected driver’s emotions. Jeon studied effects of driver’s angry and fear emotion on his/her driving performance [15]. He found angry drivers made more mistakes than fear drivers and fear drivers had heavier workload than angry drivers. Cilfford described traffic accidents cloud be decreased if a navigation system changes emotional expression of voice guidance [16]. The energetic voice of the navigation system was effective when driver was happy and subdued voice was effective for upset drivers in the experiments. In this manner, these researches indicate the driver’s emotions affect his/her driving performance significantly. To grasp not only car conditions but also driver’s conditions using his/her emotions is necessary and utilization of the driver’s emotions will be effective to develop a system which creates a high-accurate near-miss map.

3 PRELIMINARY STUDY

In this section, we describe several existed near-miss maps and their map generating methods. Then, we clarify a problem of the generating methods.

3.1 Existed Near-Miss Maps

Many local governments and organizations create and offer near-miss maps for citizens and communities. To create and offer the near-miss maps, it is necessary to gather information of unsafe locations and warn the information to people. In this research, we focus on information gathering of unsafe locations.

There are two methods for the information gathering to create near-miss maps. The first method is manual information gathering. It gathers information manually by means of questionnaire surveys and interview researches (called "manual information gathering" hereafter). Most near-miss maps [17]-[20] are created by the manual information gathering. This method can gather high-accurate information. However, a great deal of time and effort is required and it is difficult to gather information in real time. The second method is automatic information gathering. It gathers information automatically by means of analyzing sensor data (called "automatic information gathering" hereafter). Typical example is the SAFETY MAP of Honda Internavi [21]. The automatic information gathering detects a heavy braking and bad road using acceleration sensors and so on. This method does not need time and effort. However, accuracy of the map is not so high because it uses only car conditions although it does not always show the driver feels a sense of danger at that time.

3.2 Manual vs. Automatic Information Gathering

To determine whether there is difference between manual information gathering and automatic information gathering, we compare the existed near-miss maps. In this preliminary study, we compared a near-miss map at the station of Muikamachi, Minamiuonuma city of Niigata in Japan [20] with a map of the SAFETY MAP [21] at the same location. The former map is created by manual information gathering (called "manual near-miss map" hereafter). The latter map is created by Honda Internavi which detects -0.2G acceleration and estimates a heavy breaking (called "automatic near-miss map" hereafter).

By comparing these two near-miss maps, we found the manual near-miss map said unsafe locations but not unsafe locations in automatic near-miss map. This problem is called “false negative error”. The term, false negative error is a result that indicates a given condition is not fulfilled but the actual condition is fulfilled. There are many false negative errors in the automatic near-miss map. Thus, these false negative errors mean the driver felt a sense of danger but did not brake hard. Especially, these errors were found around locations where city areas prohibited speeding.

On the other hands, we found the automatic near-miss map said unsafe locations but not unsafe location in manual near-miss map. This problem is called “false positive error”. The term, false positive error is a result that indicates a given condition is fulfilled but the actual condition is not fulfilled. There are many false positive errors in the automatic near-miss map. Thus, these false positive errors mean the driver did not feel a sense of danger but braked hard.

Table 1: False negative and false positive error

		Condition (Correct Answer)	
		Positive	Negative
Test Outcome	Positive	True Positive	**False Positive**
	Negative	**False Negative**	True Negative

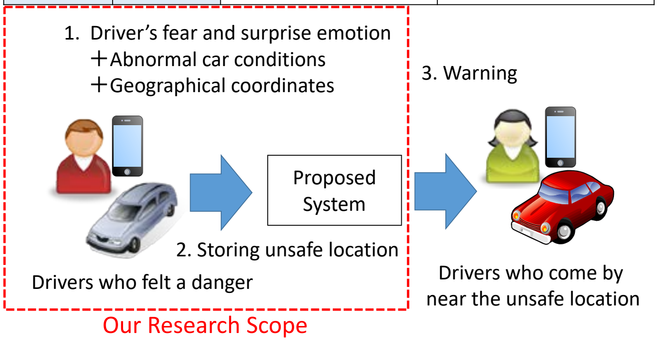

Figure 1: The model of our proposed system

Especially, these errors were found around locations where long straight road with a good view allowed speeding.

Table 1 shows supplementary explanation for the false negative and false positive errors. The false negative and false positive errors must be solved in order to increase accurate of the automatic near-miss map. As mentioned above, car conditions such as heavy brakes are not enough to detect actual unsafe locations where the driver feels a sense of danger. If we apply the driver's emotions to the automatic information gathering, more high-accurate near-miss map can be created without time and effort.

4 PROPOSED SYSTEM

We propose a system which creates a high-accurate near-miss map utilizing the driver's emotion.in order to realize a safe car society. Figure 1 shows the model of our proposed system. The proposed system utilize driver's fear and surprise emotions and abnormal car conditions to gather information of unsafe locations. By using not only car conditions but also driver's conditions, it improves accuracy of the automatic information gathering for unsafe locations. The proposed system uses the information of unsafe locations and warns of a danger to drivers who come by near the locations in order to encourage them to drive carefully. In this research, our research scope is the mechanism of information gathering for unsafe locations in a high accuracy.

The proposed system use general-purpose smartphones and does not need any dedicated devices so that more people can use the system. Therefore, we use only general sensors such as a camera and an acceleration sensor equipped in the general-purpose smartphones. Figure 2 shows the architecture of the proposed system. The procedure of proposed system is as follows.

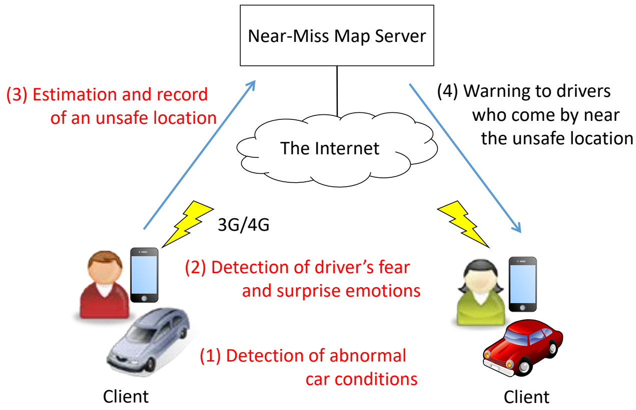

Figure 2: The architecture of the proposed system

(1) Detection of abnormal car conditions
(2) Detection of driver's fear and surprise emotions
(3) Estimation and record of an unsafe location
(4) Warning to drivers who come by near the unsafe location

In next section, we implement a prototype system using the above procedure.

5 IMPLEMENTATION

In this section, we describe implementation of functions (1) detection of abnormal car conditions, (2) detection of driver's fear and surprise emotions, (3) estimation and record of an unsafe location, and (4) warning to drivers who come by near the unsafe location. The function (4) is out of our research scope but we just implement it.

5.1 Detection of Abnormal Car Conditions

We detect heavy brakes to detect abnormal car conditions. An acceleration sensor equipped in a smartphone is used for the function of heavy brake detection. The function detects a certain measure of acceleration. In the prototype system, a smartphone is mounted on dashboard of a car and senses variation of the acceleration. When the variation value exceeded by -0.25G which is defined by reference to the other existed system for automatic near-miss map, the function recognizes it as a heavy brake.

5.2 Detection of Driver's Fear and Surprise Emotions

For the detection of driver's fear and surprise emotions, we use clmtrackr [22],[23] which is a library of facial expression recognition. This library presents each emotion as a probability value from 0.0 to 1.0 by the facial expression. It uses a camera of the mounted smartphone and gets driver's facial expression images in real time. From the image, the library calculate the probability value for each emotion as shown in Fig. 3.

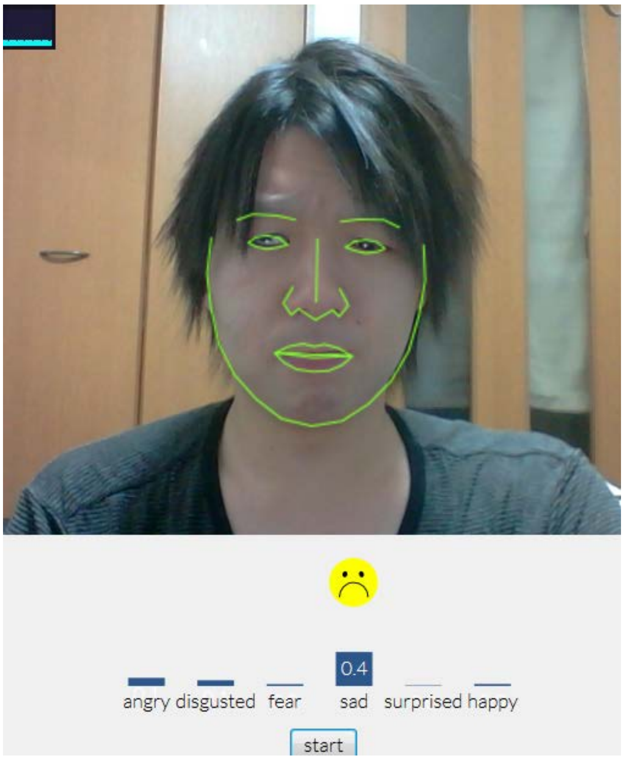

Figure 3: The detection of each emotion by facial expression image in real time

5.3 Estimation and Record of an Unsafe Location

We conducted a preliminary experiment to assess a reference probability value of fear or surprise emotion for estimation of unsafe locations and set it to 0.3 with heavy brakes. However, it could not detect unsafe locations when the heavy brake was not detected in a city areas prohibited speeding. In such a case, we use a high probability value of fear or surprise emotions with no heavy brake to estimate unsafe locations in low-speed areas. The high probability value for fear and surprise emotions is used for 0.6 which is twice as much as 0.3 with heavy brakes. After the detection, information of the unsafe location is sent to a server on the Internet via 3G/4G wireless network. The client communicates with the server using WebSocket and the information includes geographical coordinates of an unsafe location, probability values of the driver's emotions and acceleration data.

5.4 Warning to Drivers

Figure 4 shows a user interface of the prototype system on a smartphone in order to detect unsafe locations and give a warning to the driver. The user interface presents a driver's current location on the map by using GPS equipped in the smartphone. The current location is updated in real-time. Unsafe locations are also displayed on the map by getting unsafe location information from the server. The driver's facial expression image is taken from a camera equipped in

Figure 4: The user interface of the prototype system

the smartphone and driver's emotions are detected in real time. The acceleration value is displayed for heavy brakes. The client communicates with the server every 5 seconds. It sends current location information and receives unsafe location information. When the driver comes close to an unsafe location, the client give a warning to the driver with alarmed sound and text. After a fixed time, the alarm is stopped.

6 EVALUATION

We evaluate the prototype system in terms of false-negative and false-positive errors. At first, we explain the experimental methodology. Then, we show the results and discuss about accuracy of the near-miss map.

6.1 Experimental Methodology

In the experiment, we create a manual near-miss map created by a questionnaire and an automatic near-miss map created by the prototype system. After that, we compare them if the automatic near-miss map achieves low false-negative and false-positive errors.

Figure 5 shows the driving route in the experiment. The route includes residential sections around our university, straight road where the driver can put on speed, sloping, and various types of roads. It is 17 km long and takes time for approximately 30 minutes to go around the route.

At first, we created a manual near-miss map by a questionnaire. The subjects are 30 students, who have driver license, of our university. Before conducting the questionnaire, we developed a system for the questionnaire survey which presents a driving video on the route and current car location on a map as shown in Fig. 6. The subjects used the system and answered unsafe locations and their reasons. Figure 7 shows the format of the questionnaire. In this time, there were no dangerous scene in the video and we asked subjects to remember their experience when passed the locations. We defined the unsafe locations where the subjects of 10 percent

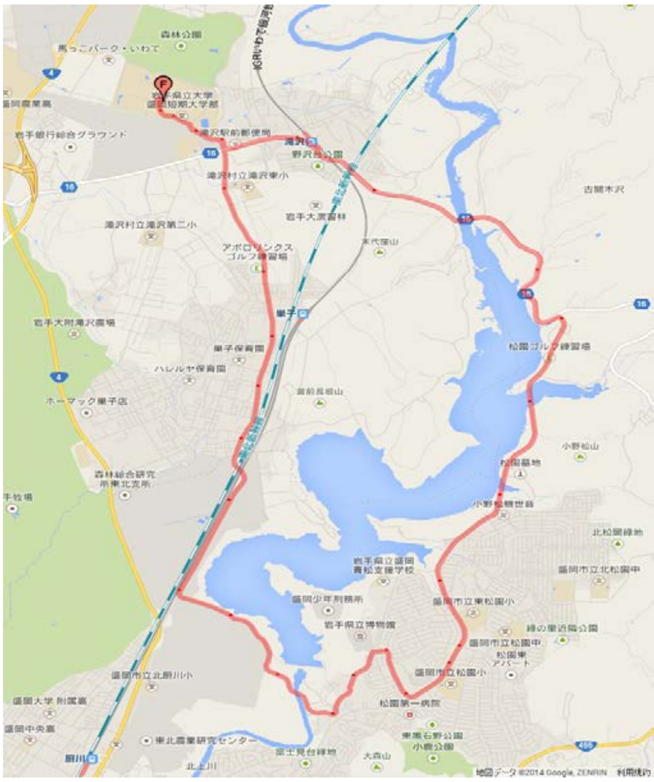

Figure 5: The driving route in the experiment

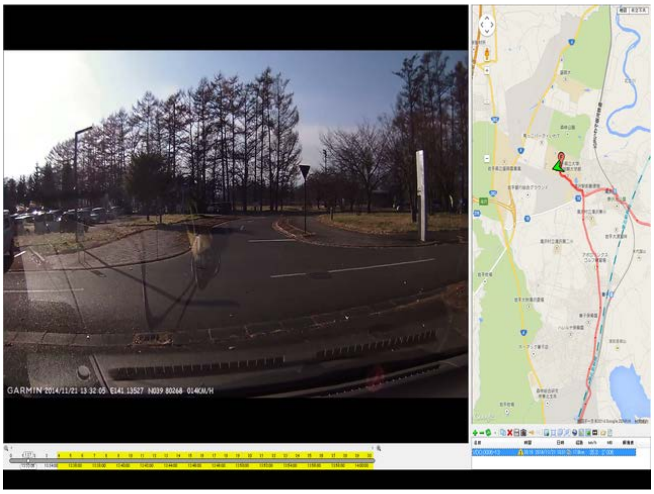

Figure 6: A system for the questionnaire

(3 subjects) answered it was unsafe in the questionnaire.

Secondly, we conducted an experiment on the road with a real car which mounted a smartphone on the dashboard for the prototype system. In this experiment, the subjects were 20 students, who have driver license, of our university. We suppose the proposed system is utilize driver's emotion. However, for the safety of the subjects, they rode in the front passenger seat of the car and the author drove the car. We also record the driving video for analytical use. Figure 8 shows the experimental environment in the car.

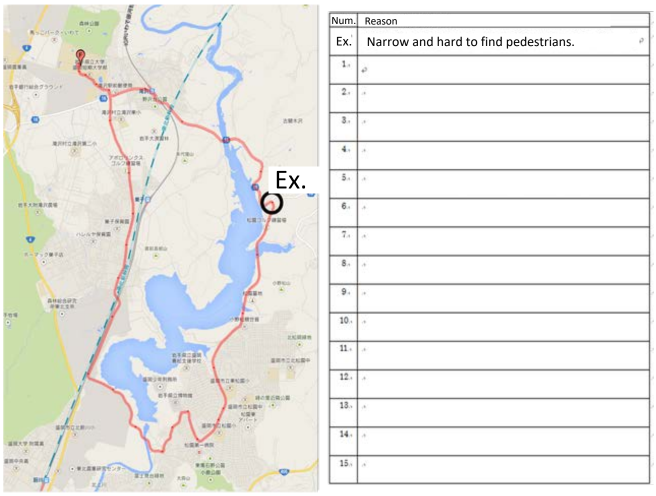

Figure 7: The format of the questionnaire

Figure 8: The experimental environment in the car

6.2 Results and Discussions

Figure 9 shows the result of the manual near-miss map created by the questionnaire. The pins show the unsafe locations defined by the questionnaire. In this evaluation, we use this map as a correct data which presents unsafe locations.

Figure 10 shows the locations where the heavy brake was detected on the road with a real car. We can see there are many false positive and false negative errors comparing with the manual near-miss map. It is difficult to create a near-miss map only using heavy brake detection.

Figure 11 shows the location where the heavy brake was detected with greater than 0.3 probability value of fear/surprise emotions. This result can be reduce false positive errors. However, there are false negative errors yet comparing with the manual near-miss map.

Figure 12 shows the automatic near-miss map created by the prototype system. This is a map which are added locations greater than 0.6 probability value of fear/surprise

Figure 9: The manual near-miss map created by the questionnaire

Figure 10: The locations of heavy brakes

Figure 11: Heavy brake with greater than 0.3 probability value of fear/surprise emotions

emotions to Fig. 11.

Figure 13 shows the comparison result of these two maps. The circles show the locations of false-positive errors and the triangles show the locations of false-negative errors. Table 2 shows the result of false-positive and false-negative error rate.

The locations of false-positive errors were three points. The one point was detected by heavy brakes and 0.3 probability value of fear/surprise emotions. The other two points were detected by 0.6 probability value of fear/surprise emotions. The rate of the false-positive errors was 14 % which was on 3 errors of 21 detected locations and the prototype system achieved low false-positive error rate.

The locations of false-negative errors were eight points. The rate of the false-negative errors was 36 % which was on 8 errors of 22 actual unsafe locations. The prototype system should be improved in terms of the unsafe locations. Possible reasons for the false-negative errors are low accuracy of the emotion detection. Since the emotion detection of facial expression is difficult and has a limit of accuracy, the prototype system could not detected the subject’s fear/surprise emotions. One of the solutions is to use together with other methods for emotion detection such as utilization of driver’s heart rate, body temperature and so on.

Figure 12: The automatic near-miss map created by the prototype system

Table 2: Percentage of false-positive and false-negative error in the evaluation

False-positive	14 %
False-negative	36 %

7 CONCLUSION

In this paper, we proposed a high-accurate near-miss map system utilizing driver's emotions and developed the prototype system. From the evaluation experiment, we found our proposed system could achieve false-positive error rate although it required to improve false-negative error rate. For the future work, we will introduce other methods for emotion detection to reduce false-negative error rate.

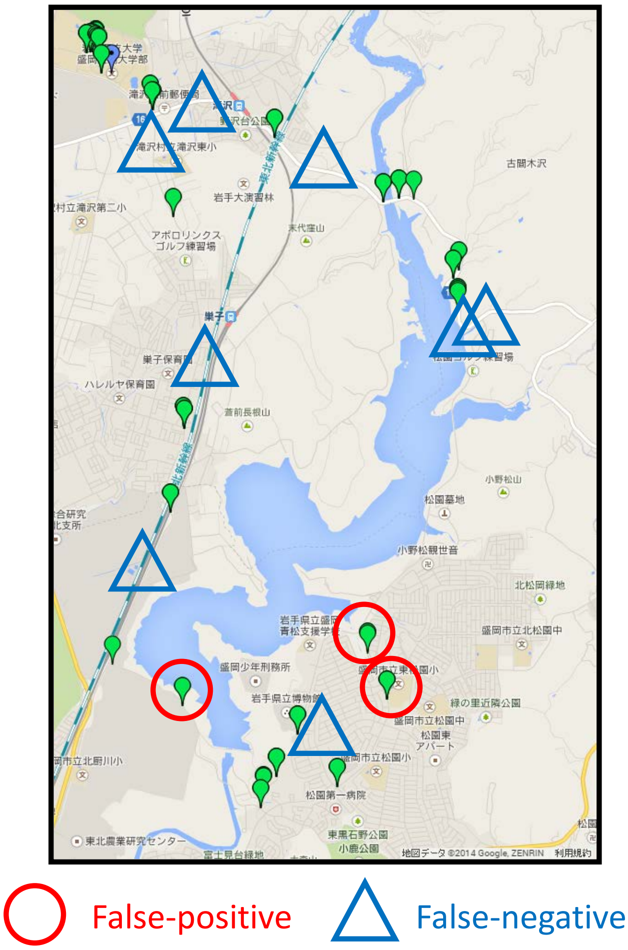

Figure 13: The result compared between the manual and automatic near-miss maps

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