特集 Prediction of Driver's Turning Intention for Car Navigation System*

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We propose new navigation system interacts with driver. By predicting driver's intention, the system can make adequate guidance in consideration of the intention. In this paper, we show the model for predicting driver's turning intention at next intersection and verify that the model predicts the intention on driving simulator. Our model enables the navigation system to understand driver's intention and to improve communication and performance.

Key words : Prediction, Car navigation system, HMI

1. INTRODUCTION

In order to make vehicle more comfortable and safer, advanced electronic systems such as car navigation, lane keep assistance and automatic brake have been evolved.[1] With the advanced electronic systems, a vehicle is changing from the machine operated by driver to the intelligent system interacts with driver. For interacting with driver, it will be important that vehicle understands driver's intention and operates according to the intention.[2]

In this paper, we propose the interactive navigation system, which makes adequate guidance according to driver's intention, and show the model of prediction driver's intention for the system.

2. INTERACTIVE NAVIGATION SYSTEM

In present, a navigation system guides a route by road and own vehicle information such as map, position and speed. However, to make a intelligible and friendly guidance, the system should be designed to include human factors.[3) 4)] For example, in approaching to the intersection where a navigation system guided to turn, if the driver has no understanding of the guidance or misses the turning intersection, the system makes an additional guidance once again. For operating in consideration of driver's situation, the system requires the ability of predicting driver's intention. In order to realize the system, we have developed the model of predicting driver's turning intention from driving behavior, own vehicle information and surrounding situation.

3. MODEL OF PREDICTING INTENTION

In real world, driver recognizes surrounding situation and operates pedals, steering wheel, etc. to change the surrounding situation according to own intention. Therefore, we have to recognize both driving behavior and surrounding situation to predict the intention.[5] Through this concept, we have developed the model consists of 2 phases, first phase is recognition of driving behavior, second phase is inference from surrounding situation. The model is shown in **Fig. 1** and we will explain each phase below.

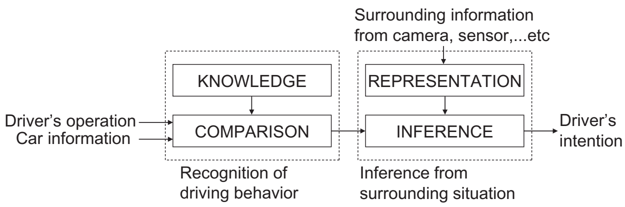

Fig. 1 Model for predicting driver's intention

3.1 Recognition of driving behaivior

In this phase, we recognize the driver's preparing behavior arranged for intention such as turning, stopping and changing the lane from driver's operation and vehicle information. The preparing behavior has tacit features such as amount of brake pedal, actuating time and releasing time. To recognize in consideration of the features, we represent the preparing behavior as some

＊Reprinted from "Proceedings of the 11th World Congress on ITS in Nagoya (2004)" patterns kept the information of amount and timing and compare these patterns and actual driving behavior. In **Fig. 1**, "KNOWLEDGE" consists of some preparing behavior patterns and "COMPARISON" is to detect preparing behavior with the pattern.

3.2 Inference from surrounding situation

In this phase, we verify the result of first phase from the surrounding situation. If driver's preparing behavior detected in first phase is not suitable to now surrounding situation, the detection is rejected as being impractical. In **Fig. 1**, "REPRESENTATION" extracts the information of surrounding situation such as "own vehicle is near the intersection", "other vehicle is overtaking" and "signal is red" from electronic systems including laser radar, navigation and image processing through the camera. "INFERENCE" judges whether preparing behavior is suitable to the information. For example, if "COMPARE" detects turning preparing behavior and "REPERESENTATION" extracts "near the intersection", "INFERENCE" is sure that driver's intention is turning.

4. CONSTRUCTION OF THE MODEL

With the experiment on the driving simulator (**Fig. 2**), we have constructed the model of predicting driver's turning intention at next intersection for the interactive navigation system. We now explain each phase of the model.

4.1 Recognition of driving behavior

In this phase, we must prepare some patterns to recognize individual driver's behavior that has different features. Therefore, we recorded 10 people's driving data that consists of an accelerator pedal operation, a brake pedal operation and own vehicle speed. After that, we extracted 80 samples of approaching to intersections during 10 seconds and classified them into some groups with similar features by k-means clustering. Consequently, we acquired 5 groups and generated the patterns representing each group by averaging the samples in the group. "KOWLEDGE" is constituted of the 5 patterns shown in **Fig. 3**. The vertical axis represents a normalized

Fig. 2 The experiment on the driving simulator

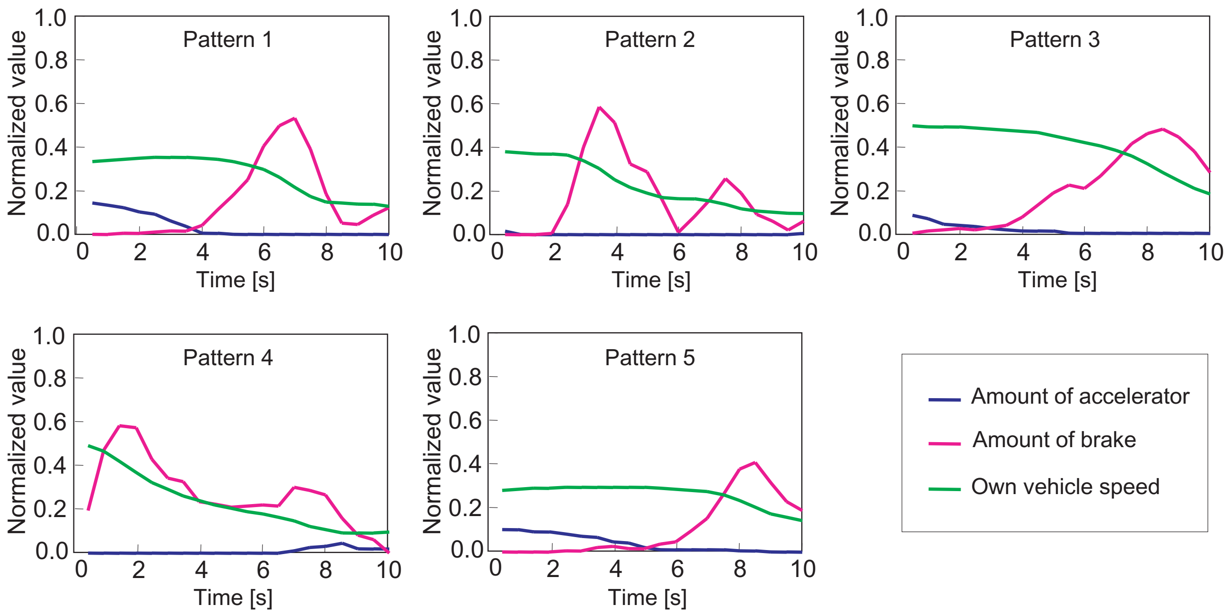

Fig. 3 Patterns of driver's preparing behavior for turning

value from 0.0 to 1.0. The horizontal axis represents time to intersections during 10 seconds and sampling is in every 0.5 seconds. For example, the **pattern 1** is the typical case appeared on many intersections and the **pattern 2** is other case that drivers step brake on twice.

In order to detect preparing behavior, we compute the similarity between each pattern and actual driving behavior. The similarity is computed by:

$$S_t^{m,r}=\sum_{i=0}^{n}\sqrt{(v_{t-\Delta t*i}-V^m_{r-\Delta t*i})^2+(b_{t-\Delta t*i}-B^m_{r-\Delta t*i})^2+(a_{t-\Delta t*i}-A^m_{r-\Delta t*i})^2} \quad (1)$$

where $S_t^{m,r}$ denotes the distance between the subset of pattern m, from time r- $\Delta t*n$ until time r, and actual driving behavior at time t. v_t , b_t and a_t denote the normalized values of driving behavior at time t, own vehicle speed, amount of brake pedal and amount of accelerator pedal. V_r^m, B_r^m and A_r^m denote the value of pattern m at time r. In this work, setting Δt= 0.5 seconds and n = 10, similarity is during 5 seconds. After that, the minimum of all $S_t^{m,r}$ is computed by:

$$S_t^{'}=\min(S_t^{M,R}) \quad m\in M,\ r\in R \quad (2)$$

where smaller $S_t^{'}$ means higher similarity. The goal is therefore to compute:

$$S_t=(\max(S_T^{'})-S_t^{'})/\max(S_T^{'}) \quad t\in T \quad (3)$$

where S_t denotes the similarity at time t, outputted from "COMPARE" in **Fig. 1** and $\max(S_T^{'})$ denotes the maximum of S_t in past.

4.2　Inference from surrounding situation

For predicting the driver's turning intention, it must be important to extract "near the intersection" from surrounding situation. However, such information is an abstract concept and not be able to been represented with a clear definition. Therefore with Fuzzy function, we try to change the distance to the intersection, acquired by a navigation system, into the concept of "near the intersection". **Figure 4** illustrates to the fuzzy function that represents a relationship between the reliability of "near the intersection" and the distance to the intersection. We designed that the reliability increased from 150 to 100 meters. Since, in the experiment, drivers often gazed at the intersection at such a distance, we considered that drivers perceived the situation of "near the intersection" at the distance. However, this function may be dependent on surrounding situation. If we use another scenario on driving simulator, we expect this distance changes.

Finally, we compute the reliability of turning by:

$$P_t = S_t\ f(t) \quad (4)$$

where P_t denotes the reliability of turning at time t, S_t the similarity of preparing behavior at time t and f(t) the reliability of "near the intersection" at time t.

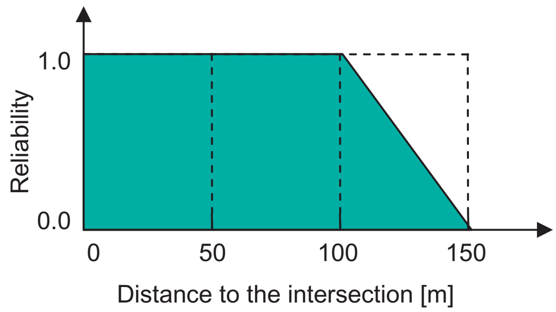

Fig. 4 Reliability of "near the intersection"

5. VERIFICATION OF THE MODEL

We simulated the model on the driving simulator and verified that the model could predict driver's intention.[6] The result is illustrated in **Fig. 5**. The vertical axis represents the reliability of turning, and the horizontal axis represents simulation time. The filled rectangles represent the range of the intersection where a driver turned, and the empty rectangle represents the range of the intersection where a driver went straight. The solid line represents the result of "INFERENCE" with consideration of surrounding situation, and the dotted line represents the result of "COMPARISON" with recognition the driving behavior. The solid line shows the reliability increases greatly only in front of filled rectangles. In contrast, the dotted line shows it increases even except for the filled rectangles. This result shows our model have succeeded in predicting driver's turning intention with inference from surrounding situation.

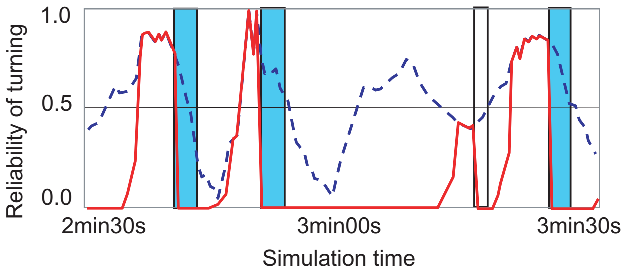

Fig. 5 The result of predicting intention

The recognition ratio is shown in **Table 1**. This result is in the case that the reliability over 0.5 is judged to be “turn at next intersection”. In **Table 1**, “learned drivers” mean that their samples, without verification data, are used to construct “KNOWLEDGE” and “un-learned drivers” mean not used. The recognition ratio is 82.4% even for un-learned drivers. **Figure 6** shows the timing that the model predicts correctly for un-learned drivers. The vertical axis represents the own vehicle speed at the time, and the horizontal axis represents the distance to the intersection then. As the speed is faster, the model tends to predict far away from the intersection. The approximate line shows that we can recognize driver’s intention at 80.9 meters in approaching at 60 kilometers an hour. The distance is far than 30 meters, which is the suitable timing of turning winker in Japanese driving school.

Table 1 The recognition ratio of predicting intention

	Recognition ratio
Learned drivers	82.4(%)
Un-learned drivers	94.1(%)

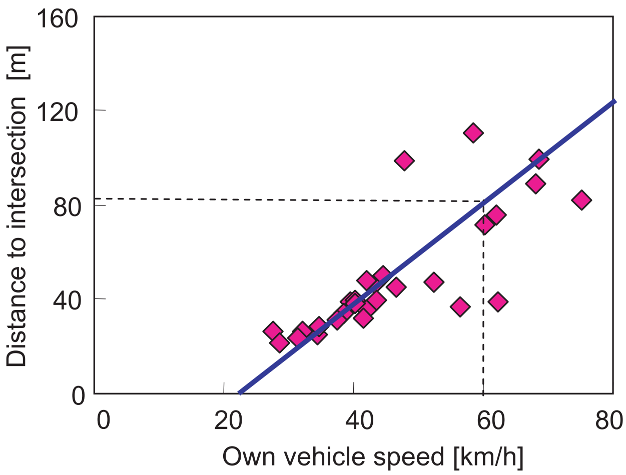

Fig. 6 Timing of predicting intention

6. EVALUATION OF THE MODEL FOR NAVIGATION SYSTEM

In this chapter, we evaluate whether our model is available for the interactive navigation system. With the experiment on driving simulator, we examined the required timing to guide a route based on our prediction.[7] [8] In the experiment, we showed drivers the marker indicates the direction of turning at different timing and observed driver’s reactions to each maker. We made drivers evaluate each marker into 3 levels, “safety”, “late” and “danger”. The “safety” means driver turned with the margin, the “late” means driver turned but busily and the “danger” means driver turned with abrupt steering or could not turn. **Figure 7** shows the result and the approximate line of **Fig. 6**. The field above the line means earlier timing that our model can not predict. Since “danger” doesn’t exist in this field, our prediction model must be available for guidance. However, one of “late” exists above the line and “danger” exists in the neighborhood of the line. Therefore we have to improve on the prediction timing.

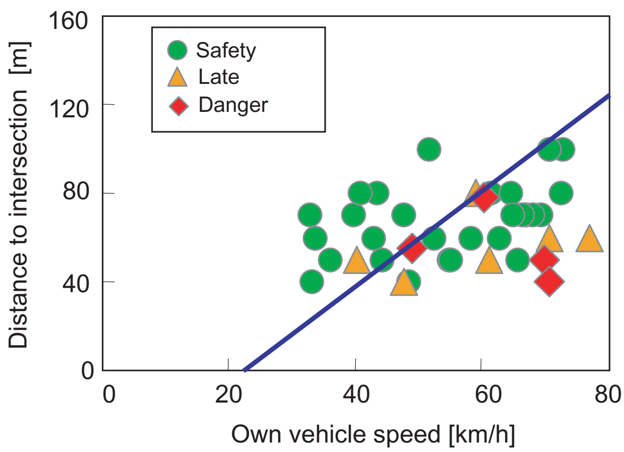

Fig. 7 Evaluation for predicting timing

7. CONCLUSION

We proposed the concept of the interactive navigation system and explained our predicting model for the system. Moreover, we verified the model was able to predict intention on the driving simulator and examined the effect to the navigation system. In the results, the recognition rate for learned drivers is 94.1 %, which is higher than the rate for un-learned drivers 10% or more. Therefore, we will develop the model to learn individual driving behavior automatically and also improve prediction timing with consideration of the individual features. Furthermore, to predict more complex intention, we will include human factors such as gaze, face direction and expression in "KNOWLEDGE", and research advanced image processing to understanding surrounding situation well. Finally we will install the model on vehicle and verify in the real world. In parallel, we will find the effective usage of our prediction model for various systems.

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