Master's Thesis

Analysis of Drivers' Gaze Behavior on Winding Roads

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Analysis of Drivers' Gaze Behavior on Winding Roads*

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Abstract

Modeling of drivers' gaze is important to understand driving behaviors since we can predict the steering behaviors. Although there are many studies in simulated/natural situations, most of them focus on analyzing the gaze behavior in a single curve. In this thesis, we extend these studies to a natural situation, where roads are winding, and aim to investigate how gaze moves during driving on winding roads. Based on a conventional model called the tangent point (TP) model, drivers gaze near TP on winding roads and may move their gaze points jump from the front TP to the back one. To test the behavior, we collected real gaze data during driving on winding roads and analyzed their properties. Since there are multiple TPs in winding roads, we also take eye movements between TPs into account. As a result, the vertical position of the gaze did not correlate to the time while the horizontal position did, and drivers' eye movements were not saccades but like smooth pursuits. It implies that drivers' gaze does not jump from one TP to the next one. These results provide a new insight that we cannot express the gaze model on winding roads using the merely connecting two TP models, and also have to consider the gaze transition between two TPs.

Keywords:

driving behavior, driver monitoring, gaze, visual attention, wearable eye tracker

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蛇行区間における運転者の視線行動解析*

久田 将史

内容梗概

運転者の視線行動のモデル化は，操舵の予測ができることから運転行動の理解に重要である．現在までシミュレータや実車で視線行動に関する多くの研究が行われてきたが，多くの研究は単一カーブを対象としており，カーブが連続する蛇行区間では行われていない．そこで，本研究ではより自然な状況である蛇行区間において運転者の視線がどのように遷移するかを計測した．従来の TP(タンジェントポイント) モデルから，運転者は蛇行区間においても TP 付近を注視し，TP 間は飛ぶように視線移動させると考えられる．この視線行動を検証するため，実車による走行実験を行い，蛇行区間での運転者の視線を解析した．蛇行区間には複数の TP があることから，TP 間の視線遷移における眼球運動についても考慮した．その結果，視野内垂直方向にはあまり相関が見られなかったのに対して，視野内水平方向には相関が見られた．また，運転者はサッケードを使わずに滑らかに視線を動かして TP 間の視線移動を行なっていることが明らかになった．この結果から，蛇行区間の視線行動は単に TP モデルを 2 つ繋げるだけでは表現できず，TP 間の視線移動についても考慮しなければならないことが示唆された．

キーワード

運転行動，ドライバーモニタリング，視線，視覚的注意，視線計測装置

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Contents

List of Figures

List of Tables

1 Introduction

1.1 Background

Advanced driver assistance systems (ADAS) [1] or autonomous cars coexisting with general vehicles are under development [2]. Under such conditions, their systems need to predict other vehicles' behaviors in order to achieve appropriate driving without collisions or accidents [3]. Since a driver mainly obtains surrounding information and 80% of driving information using the vision [4] [5], a mathematical model of driving behaviors should be a function of visual information. In fact, the intention of a driver such as directions in which he/she wants to go appears in the gaze [6] [7], and the gaze affects a driver's steering behaviors [8]. Additionally, a model based on optical flow can predict steering behaviors [9].

Thus, if we make a model of a driver's gaze as a function of the visual information, we can predict the driver's steering behaviors. In other words, if we can understand the driver's gaze behavior, we can prevent accidents from the gaze of drivers.

1.2 TP model

One of the most popular models for a driver's gaze is the tangent point (TP) model (Fig. 1). TP is defined as the point on the lane edge on the inside of the curve where the line of sight is tangential to the lane edge. Existing works have shown that drivers mainly gaze at the TP in a curve [6] [10]. Drivers can drive smoothly by looking at the TP in a curve [11]. Also, looking at the direction of TP is very suitable for the driver to predict the curvature of the road ahead [12]. Therefore, TP is visually important for the driver during steering. Moreover, we can simply represent the TP model by using only one tangent point. Although

Figure 1: Gaze direction and tangent point (TP). The arrow shows the direction of the driver's gaze. Red circle shows TP.

this is still controversial since a driver changes the behavior when instructed to gaze at the tangent point (TP) [8], the difference between the real gaze points and TPs has been confirmed to be small [13]. Therefore, we discuss the gaze behavior based on the TP model in this paper.

However, the conventional studies considered the steering behaviors at a corner with a constant curvature. This study extends the scenario of these studies to a natural situation, where roads are winding, and the curvatures change not only its value but also its signature.

1.3 Gaze transition between TPs

There are multiple TPs in the view of the driver on winding roads. Therefore, if we consider the drivers' gaze behavior on winding roads, we also have to consider how the gaze points changed according to TP moving, including the case where multiple TPs appeared in the view. Here we consider the eye movement of the driver when moving the gaze from the front TP to the back one.

1.3.1 Types of eye movements

Eye movements are categorized into six types: fixations, saccades, smooth pursuits, optokinetic reflex (OKRs), vestibulo-ocular reflex (VORs), and vergence [14]. Since drivers mainly use saccades and smooth pursuits, we focus on them in this chapter. Saccades are the rapid movement of eyes like moving to jump. There is no visual information during saccades. Smooth pursuits allow the eyes to follow a moving object. Drivers strategically use saccades and smooth pursuits [15]. Also, expert drivers more often use smooth pursuits than beginner drivers since they can select visual strategies according to the complexity of the roadway [15] [16].

1.3.2 Gaze transition between TPs

There are multiple TPs on the winding roads. Based on the TP model, drivers' gaze points may jump from one TP to the next one in winding regions. If the driver always looks at the TP and moves the gaze from TP to TP promptly, it is considered that saccade is regarded to be appropriate. As mentioned above, however, drivers cannot get the visual information during saccades. Although transition time is longer than saccades, if a driver intends to obtain visual information firmly, the driver uses smooth pursuits.

1.4 Research question

In this study, we analyze the drivers' gaze on winding roads. Also, we take eye movement into account in order to analyze how to move the gaze point between TPs. We investigate whether drivers use saccades or not to move the gaze in the winding roads.

2 Materials and methods

2.1 Driving experiment

To measure the gaze points and eye movements during driving, experiments were carried out where drivers with an eye tracker maneuvered a car in winding roads. The experiments were approved by the ethical committee of Nara Institute of Science and Technology (2016-I-12).

Six participants (SK, YI, YY, JO, AY, SA) were recruited for the experiments who gave their informed consent in advance. They drove a car (i-MiEV, Mitsubishi Motors Corp., Fig. 2) along a winding road of seven kilometers length in Mount Ikoma, Nara/Kyoto Prefectures, Japan (Fig. 3), where no explicit intersections nor traffic signals existed. The drivers were instructed to drive as naturally as possible. They drove two laps along the road (12 laps in total). Table 1 shows the driver status.

Figure 2: Experiment car

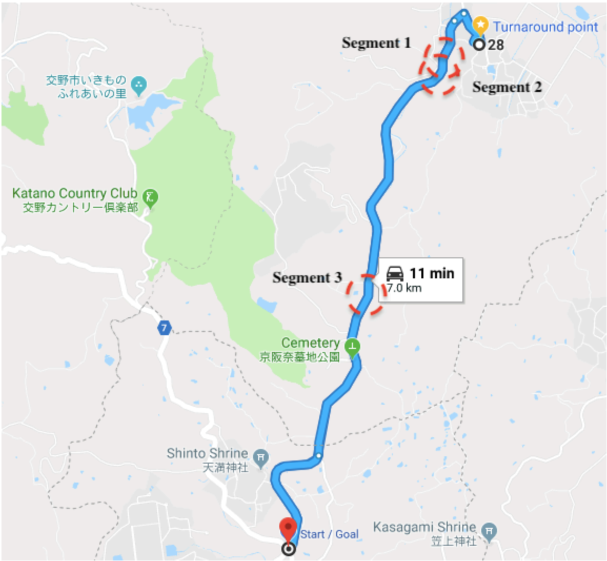

Figure 3: Driving course

Table 1: Driver status

Name	Frequency of driving cars	The getting date of a driver's license
SK	3 days per week	4 years ago
YI	3.5 days per week	4 years ago
YY	6.5 days per week	4 months ago
JO	7 days per week	5 years ago
AY	2 days per week	1 month ago
JO	5 days per week	4 years ago

2.2 Gaze measurement

During each session, the driver's gaze points were measured every twenty milliseconds using a glass-type eye tracker (Tobii Pro Glasses 2 [17], Fig. 4). The tracker equips a full-HD wide-angle scene camera that captures the front view of the driver and the software associated with the tracker shows the gaze point in the front view. The experimenter (the author) confirmed whether it could correctly measure in the back seat of the car using the Live Viewer which allows us to view real-time eye tracking data overlaid on the scene camera video while we make a recording.

2.3 Preprocessing

To consider how the gaze points change in the cases where roads are winding and the curvatures change not only its value but also its signature, three winding regions were extracted from the roads, named Segment 1, 2, and 3. The starting point of each segment (a red circle in Fig. 3) was the place where a driver recognized two curves, and the segment continued for eight seconds in Segment 1, seven seconds in Segment 2, and six seconds in Segment 3, since the location information was not included in the measurement. Fig. 5, Fig. 6, and Fig. 7 show enlarged views of each segment on the left side and front images of the eye tracker corresponding to the starting point on the right side.

Figure 4: Glass-type eye tracker

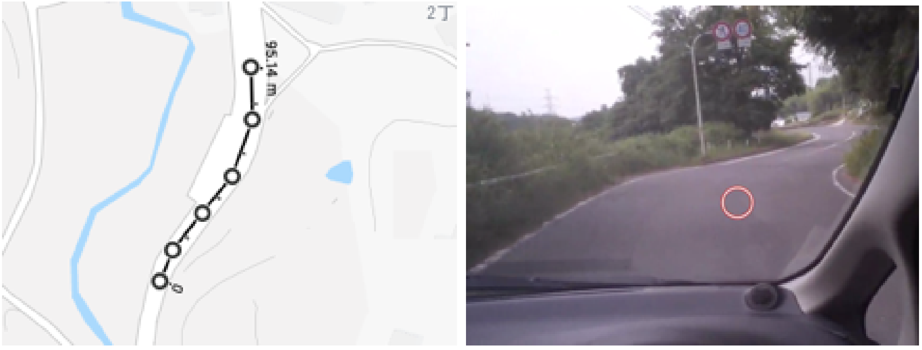

Figure 5: Course of Segment 1 and scene of its starting point

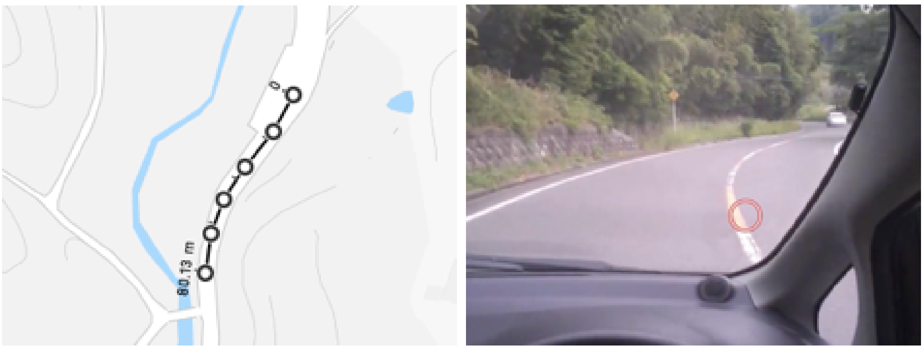

Figure 6: Course of Segment 2 and scene of its starting point

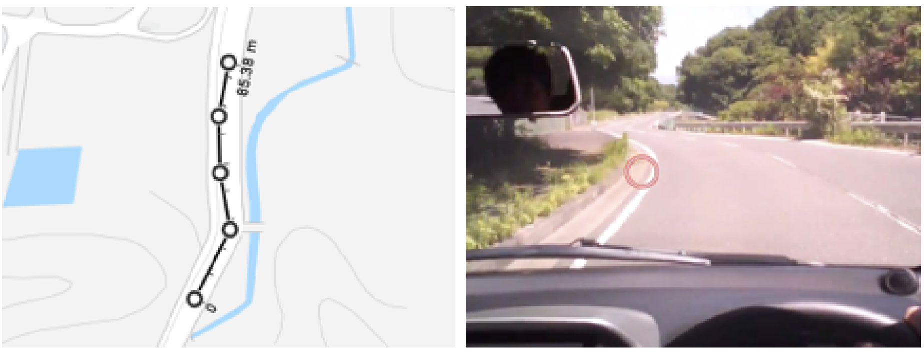

Figure 7: Course of Segment 3 and scene of its starting point

3 Gaze position on winding roads

3.1 Visualization results

Since these driving experiments conducted on the real road, sometimes the experiment car passed an oncoming car that may attract the driver's gaze [18]. Nevertheless, it is considered that a driver basically gazes at TP except for the gaze transition section between TPs in each curve by watching the videos of the front view of the driver. On the other hand, it takes too long for saccade during the gaze transition section between TPs.

3.2 Results of correlation coefficients

Due to the limitation of the analysis, we do not confirm the TP model so far. Instead, we calculated the correlation between the elapsed time and the horizontal position (hereinafter called "X direction") or the vertical position (hereinafter called "Y direction") to confirm the TP model indirectly. As a result, 81% of the data have a correlation with X direction. (Table 2, 3, and 4) On the other hand, only 31% of the data have a correlation with Y direction. (Table 5, 6, and 7) This result indicates that the drivers move gaze point linearly in the X direction in winding roads.

Table 2: Correlation coefficients in X direction in Segment 1

Data name	Correlation coefficient	P-value
SK1	-0.791	3.15×10^{-87}
SK2	-0.910	1.94×10^{-154}
YY1	-0.168	7.12×10^{-4}
YY2	-0.249	4.56×10^{-7}
JO1	-0.622	2.99×10^{-44}
JO2	-0.466	5.36×10^{-23}
AY1	-0.705	1.50×10^{-61}
AY2	-0.661	8.80×10^{-52}
YI1	-0.734	6.55×10^{-69}
YI2	-0.716	2.86×10^{-64}
SA1	-0.574	1.73×10^{-36}
SA2	-0.340	2.71×10^{-12}
Average	-0.908	5.45×10^{-153}

Table 3: Correlation coefficients in X direction in Segment 2

Data name	Correlation coefficient	P-value
SK1	-0.922	1.51×10^{-145}
SK2	-0.790	3.94×10^{-76}
YY1	-0.661	1.65×10^{-45}
YY2	-0.211	6.96×10^{-5}
JO1	-0.692	2.12×10^{-51}
JO2	-0.310	3.26×10^{-9}
AY1	-0.800	2.47×10^{-79}
AY2	-0.470	1.14×10^{-20}
YI1	-0.740	4.28×10^{-62}
YI2	-0.898	2.18×10^{-126}
SA1	-0.736	5.46×10^{-61}
SA2	-0.843	4.54×10^{-96}
Average	-0.951	2.30×10^{-179}

Table 4: Correlation coefficients in X direction in Segment 3

Data name	Correlation coefficient	P-value
SK1	0.905	3.04×10^{-113}
SK2	0.815	1.08×10^{-72}
YY1	0.435	2.69×10^{-15}
YY2	0.377	1.27×10^{-11}
JO1	0.439	1.24×10^{-15}
JO2	0.354	2.68×10^{-10}
AY1	0.823	2.64×10^{-75}
AY2	0.455	8.32×10^{-17}
YI1	0.495	5.36×10^{-20}
YI2	0.661	4.24×10^{-39}
SA1	0.707	7.92×10^{-47}
SA2	0.831	5.20×10^{-78}
Average	0.895	6.87×10^{-107}

Table 5: Correlation coefficients in Y direction in Segment 1

Data name	Correlation coefficient	P-value
SK1	-0.193	1.02×10^{-4}
SK2	0.643	3.67×10^{-48}
YY1	-0.710	6.77×10^{-63}
YY2	-0.566	2.37×10^{-35}
JO1	-0.602	7.64×10^{-41}
JO2	-0.275	2.22×10^{-8}
AY1	-0.652	6.03×10^{-50}
AY2	-0.187	1.65×10^{-4}
YI1	-0.485	5.16×10^{-25}
YI2	-0.128	1.05×10^{-2}
SA1	-0.356	2.18×10^{-13}
SA2	-0.335	5.93×10^{-12}
Average	-0.759	1.69×10^{-76}

Table 6: Correlation coefficients in Y direction in Segment 2

Data name	Correlation coefficient	P-value
SK1	0.773	5.95×10^{-71}
SK2	0.464	3.81×10^{-20}
YY1	-0.113	3.50×10^{-2}
YY2	0.325	4.35×10^{-10}
JO1	0.187	4.32×10^{-4}
JO2	0.380	1.56×10^{-13}
AY1	-0.626	1.45×10^{-39}
AY2	-0.397	1.12×10^{-14}
YI1	0.191	3.14×10^{-4}
YI2	0.175	9.65×10^{-4}
SA1	0.132	1.30×10^{-2}
SA2	0.760	2.60×10^{-67}
Average	0.625	1.87×10^{-39}

Table 7: Correlation coefficients in Y direction in Segment 3

Data name	Correlation coefficient	P-value
SK1	0.164	4.23×10^{-3}
SK2	0.198	5.35×10^{-4}
YY1	0.228	6.79×10^{-5}
YY2	-0.219	1.28×10^{-4}
JO1	-0.134	1.98×10^{-2}
JO2	0.065	2.59×10^{-1}
AY1	0.460	3.56×10^{-17}
AY2	0.119	3.95×10^{-2}
YI1	0.203	4.02×10^{-4}
YI2	0.057	3.24×10^{-1}
SA1	0.047	4.12×10^{-1}
SA2	-0.131	2.27×10^{-2}
Average	0.315	2.25×10^{-8}

3.3 Discussion

As well as in single curve, drivers gaze near TP in winding roads. Additionally, the TP model with jumping was not supported in our experiments since they moved their gaze smoothly between TPs. As a result of correlation coefficients, it is considered that drivers basically move their gaze in the X direction in winding roads. Fig. 8, Fig. 9, and Fig. 10 show the relationship between the gaze point in the X direction or Y direction and elapsed time in each segment. As can be seen in these figures, drivers gaze linearly moved in the X direction.

Here we consider the reason for the data with a low correlation coefficient. The gaze point of some data moved to the left and right like vibration many times. However, such data also move to the same X direction (from right to left in Segment 1 and 2, from left to right in Segment 3). As mentioned above, sometimes the experiment car passed an oncoming car. Also, there are traffic signs or signboards in Segment 1 and 2. These things may attract the driver's gaze.

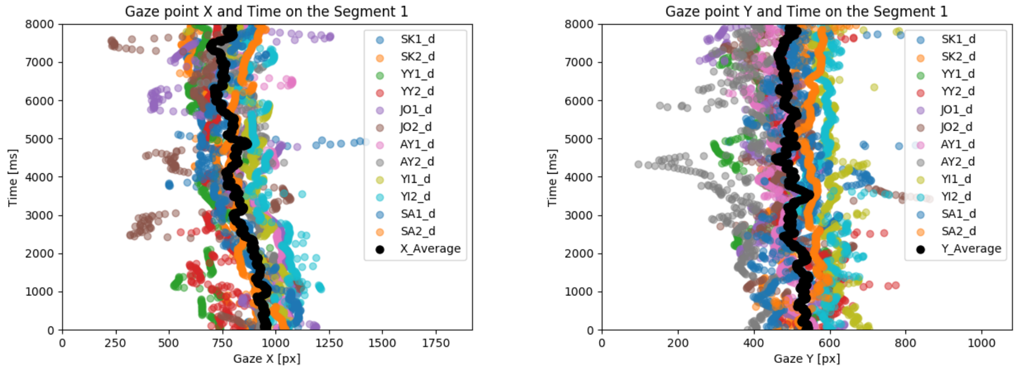

Figure 8: Gaze X and Y transition in Segment 1

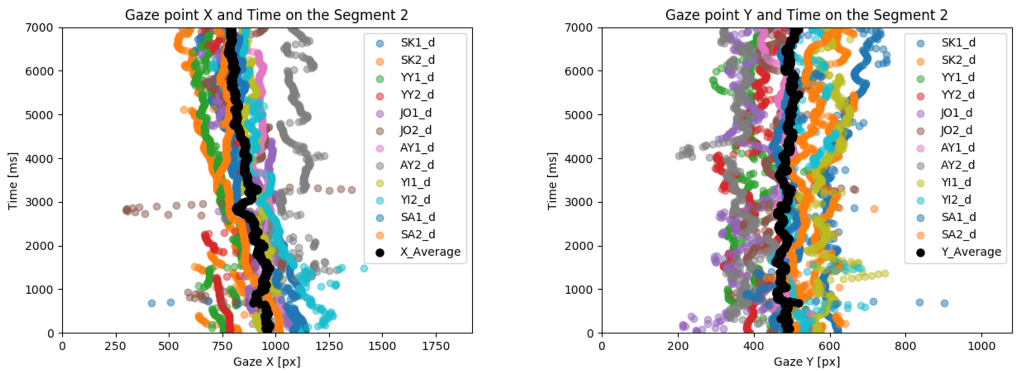

Figure 9: Gaze X and Y transition in Segment 2

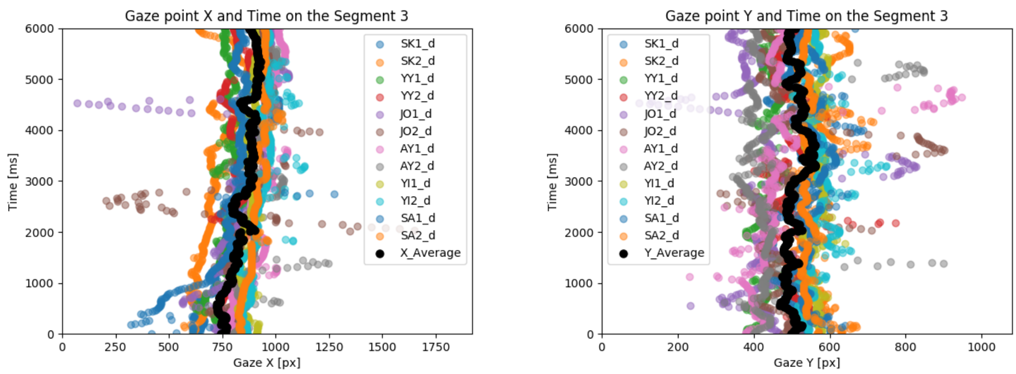

Figure 10: Gaze X and Y transition in Segment 3

4 Classification of eye movements

4.1 Classification method

As mentioned above, there are six types of eye movements : fixations, saccades, smooth pursuits, optokinetic reflex (OKRs), vestibulo-ocular reflex (VORs), and vergence. We found that fixations, VORs, and vergence little appear in the moving car since their magnitudes are small compared to the others. Additionally, smooth pursuits and OKRs are difficult to distinguish due to the resolution of the sensors. Thus, we regard both smooth pursuits and OKRs as non-saccades and classify the eye movements to saccades or non-saccades.

Saccades are eye movements where the gaze direction suddenly changes, say, faster than 30 deg/sec in angular velocity. In contrast, smooth pursuits are eye movements where the gaze direction tracks a moving object. We regard any eye movement other than saccades as non-saccades in the following analysis. Based on the TP model, drivers' gaze points may jump from one TP to the next one in winding regions where TPs appear one after another. To test this behavior more directly, we counted the time-points in each segment when the eye movement belonged to either saccade or non-saccade. If the eye movement was difficult to classify, we gave the label, unknown, to the time-point.

4.2 Results of classification

Table 8, 9, and 10 show the proportion of eye movements on each segment. As a result, the proportion of saccades is very small. More than 92%/96%/95% of eye movements are non-saccade in Segment 1/2/3.

Table 8: Types of eye movements of each participant in Segment 1

Data name	Saccade	Non-saccade	Unknown	Saccade rate
SK1	6	383	12	0.015
SK2	19	374	8	0.048
YY1	25	288	88	0.080
YY2	37	353	11	0.095
JO1	30	323	48	0.085
JO2	46	316	39	0.127
AY1	18	383	0	0.044
AY2	44	289	68	0.132
YI1	15	376	10	0.038
YI2	25	363	13	0.064
SA1	52	313	36	0.142
SA2	9	384	8	0.023
Sum	326	4145	341	0.073

Table 9: Types of eye movements of each participant in Segment 2

Data name	Saccade	Non-saccade	Unknown	Saccade rate
SK1	15	330	6	0.043
SK2	11	337	3	0.032
YY1	19	328	4	0.055
YY2	12	339	0	0.034
JO1	23	318	10	0.067
JO2	22	321	8	0.064
AY1	1	350	0	0.003
AY2	21	306	24	0.064
YI1	7	339	5	0.020
YI2	25	324	2	0.072
SA1	3	334	4	0.009
SA2	3	342	6	0.009
Sum	162	3978	72	0.039

Table 10: Types of eye movements of each participant in Segment 3

Data name	Saccade	Non-saccade	Unknown	Saccade rate
SK1	5	294	2	0.017
SK2	5	295	1	0.017
YY1	8	291	2	0.027
YY2	7	275	19	0.025
JO1	24	262	15	0.084
JO2	31	246	24	0.111
AY1	18	280	3	0.060
AY2	24	264	13	0.083
YI1	3	298	0	0.010
YI2	21	264	16	0.074
SA1	12	284	5	0.041
SA2	8	287	6	0.027
Sum	166	3340	106	0.047

4.3 Discussion

This is quantitatively confirmed by comparing to the proportion in the whole road (Table 11). As a result of analyzing eye movements, more than 90% are non-saccade in winding roads. Although there are some saccades, there was no one thought to have transitioned between TPs by watching the video. Additionally, Table 11 shows the ratio of saccade of each participant in the winding regions and the whole driving course. The rate of the saccades of the five experimental participants was smaller in the winding roads than in the whole driving course. The saccades observed in the winding roads may be not due to transition between TPs. It is considered that eye movement in the winding roads is not saccades.

If drivers use saccades during moving between TPs, we can express the gaze model on winding roads using merely connecting two TP models. However, we cannot express the model since we also consider the gaze transition between two TPs.

Why do drivers not use saccades? During saccades, a driver cannot have any visual information. Drivers may keep obtaining visual information by using smooth pursuit even when they need to change the gaze point from one TP to the next TP. As mentioned above, experienced drivers are known to use smooth pursuits more than beginners. Since we recruited participants who are used to driving, it may affect the result.

Table 11: Comparison of saccade rate between the winding regions and the whole road

Data name	Winding roads	Whole driving course
SK	0.029	0.049
YY	0.055	0.056
YI	0.047	0.057
JO	0.090	0.081
AY	0.063	0.071
SA	0.042	0.050

5 Conclusion

In this study, we measured drivers' gaze points during natural driving in a real road in order to understand the drivers' gaze behavior. Based on the TP model, drivers' gaze points may jump from one TP to the next one in winding regions where TPs appear one after another. To test this behavior indirectly, we calculated the correlation between the elapsed time and the horizontal/vertical eye movements, which did not support the TP model with jumping. To confirm this more directly, we evaluated the saccade rate to the whole eye movements and found that a driver rarely uses saccades when driving in winding regions, indicating that a driver changes their gaze smoothly from one TP to the next one.

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References

[1] Brookhuis, A. Karel, W.D. Dick, J.H. Wiel : Behavioural impacts of advanced driver assistance systems - an overview, European Journal of Transport and Infrastructure Research, Vol.1, No.3, p.245-253, 2001.

[2] U. Franke, D. Gavrila, S. Gorzig, F. Lindner, F. Puetzold, C. Wohler : Autonomous driving goes downtown, IEEE Intelligent Systems and Their Applications, Vol.13, No.6, p.40-48, 1998.

[3] J. Levinson, J. Askeland, J. Becker, J. Dolson, D. Held, S. Kammel, M. Sokolsky, G. Stanek, D. Stavens, A. Teichman, M. Werling, S. Thrun : Towards fully autonomous driving: Systems and algorithms, IEEE Intelligent Vehicles Symposium (IV), p.163-168, 2011.

[4] Sivak, Michael : The information that drivers use: is it indeed 90% visual?, Perception, Vol.25, No.9, p.1081-1089, 1996.

[5] E. Kowler : Eye movements: the past 25years, Vision Research, Vol. 51, No.13, p.1457-1483, 2011.

[6] M.F. Land, D.N. Lee : Where we look when we steer, Nature, Vol.369, p.742-744, 2004.

[7] Fletcher, Luke, Z. Alexander : Driver inattention detection based on eye gaze - Road event correlation, The international journal of robotics research, Vol.28, No.6, p.774-801, 2009.

[8] T. Itkonen, J. Pekkanen, O. Lappi : Driver gaze behavior is different in normal curve driving and when looking at the tangent point, PloS one, Vol.10, No.8, p.e0135505, 2015.

[9] Y. Okafuji, T. Fukao, H. Inou : Development of automatic steering system by modeling human behavior based on optical flow, Journal of Robotics and Mechatronics, Vol.22, p.136-145, 2015.

[10] M.F. Land, B.W. Tatler : Steering with the head: The visual strategy of a racing driver, Current Biology, Vol.11, No.15, p.1215-1220, 2001.

[11] F.I. Kandil, A. Rotter, M. Lappe : Driving is smoother and more stable when using the tangent point. Journal of vision, Vol.9, No.1, p.11, 2009.

[12] Raviv, Daniel, H. Martin : A new approach to vision and control for road following, Proc. of the IEEE workshop on visual motion. p.217-225, 1991.

[13] T. Suzaki, T. Kubo, T. Hiraoka, Y. Nakagawa, T. Terada, T. Yoshioka, K. Ikeda: Steering behavior model of drivers on driving simulator through visual information, Proc. APSIPA-ASC, 2016.

[14] O.V. Komogortsev, A. Karpov: Automated classification and scoring of smooth pursuit eye movements in the presence of fixations and saccades, Behavior Research Methods, Vol.45, p.203-215, 2013.

[15] H. Inou, T. Fukao : Modeling of driver steering operation based on optical flow, Proc. of the Society of Automotive Engineers of Japan, p.1-6, 2013. (in Japanese)

[16] Crundall, E. David, G. Underwood : Effects of experience and processing demands on visual information acquisition in drivers, Ergonomics Vol.41, No.4, p.448-458, 1998.

[17] Eye tracking technology for research - Tobii Pro. (n.d.). Tobii Pro Glasses 2, Retrieved January 21, 2019, from https://www.tobiipro.com/product-listing/tobii-pro-glasses-2/

[18] O. Lappi, P. Rinkkala, J. Pekkanen : Systematic Observation of an Expert Driver's Gaze Strategy - An On-Road Case Study, Frontiers in psychology, Vol.8, No.620, 2017