博士学位論文審査要旨

2018年1月16日

論文題目：　Identifying Distracted and Inattentive Driving of Vehicles by Detecting Driver-induced Steering Oscillations
（ドライバ起因のステアリング振動の検出による不注意な車両運転の識別に関する研究）

学位申請者：　DIPAK GAIRE SHARMA

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要　　旨：

本論文は，ドライバに起因するステアリングの振動を検出することによって注意散漫や不注意な車両運転を特定する方法論を提案したものである．人間要因による交通事故の原因のひとつは運転に割かれるべき注意の量が不足している状態（ドライバを注意散漫や不注意にする認知的負荷が与えられた状態）にあり，その兆候は運転時の反応や操作の遅れとして現れる．

そこでドライバへの不適切な認知的負荷に起因するフィードバック遅延がステアリングの振動を生ずるとの仮説に基づき，人為的な遅延および人については運転時のメール操作によって生ずる遅延が直進・カーブへ入り・カーブからの出の一連の運転時のステアリング動作に振動を引き起こすことをエージェント・ベースのシミュレーションおよび被験者実験により実証している．

次にステアリングの振動と車の横方向の加速度との関係に着目し，横方向の加速度信号のパワースペクトラム分析により振動を識別できることを確認している．さらに遺伝的アルゴリズムを用いたスペクトラムの重み係数の最適化を行い，それを踏まえて横方向の加加速度に基づく適応的な閾値調整機構を開発し，ドライビングシミュレータを用いた被験者実験により不適切な認知的負荷に起因するステアリング振動の実時間検出に成功している．加えてスマートフォンのアプリとしても実装し，実車による実験でもその有用性を確認している．

本論文は，ドライバ起因のステアリング振動から注意散漫な運転車両を特定する方法論に関する先駆的かつ実用的な研究であり，これらの成果はこの分野の発展に多大なる貢献をなすものである．よって本論文は，博士（工学）（同志社大学）の学位論文として十分な価値を有するものと認められる．

総合試験結果の要旨

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要　　旨：

論文提出者は理工学研究科情報工学専攻博士後期課程に在籍している．本論文の主たる内容はIEEJ Trans. on Electronics, Information and Systems (in press), SICE J. of Control, Measurement, and System Integration, Vol.10, No.3等に掲載され，十分な評価を得ている．

2017年12月23日13時から1時間50分にわたって提出論文に関する学術講演会（博士論文公聴会）が開催され，種々の質疑討論が行われ，論文提出者の説明により十分な理解が得られた．

さらに講演会終了後，審査委員により論文に関連した諸問題につき口頭試問を実施した結果，十分な学力を有することが確認できた．

提出者は，英語による論文発表および口頭発表を行っており，十分な語学能力を有すると認められる．

よって総合試験の結果は合格であると認める．

博 士 学 位 論 文 要 旨

論 文 題 目 : Identifying Distracted and Inattentive Driving of Vehicles by Detecting Driver-induced Steering Oscillations
「ドライバ起因のステアリング振動の検出による不注意な車両運転の識別に関する研究」

氏　　名 : DIPAK GAIRE SHARMA

要　　旨 :

With the ongoing evolution of automobile technology, human errors have become one the most prominent factor of traffic accidents. The primary reason of these errors is inadequate cognitive load of drivers, in which the amount of the attention dedicated to driving is lower than the attention required by the current traffic situation. The most relevant symptom of inadequate cognitive load is the delay in response of a driver. In principle, we could infer the inadequate cognitive load by measuring directly the amount of delay of a driver's response to various environmental stimuli during driving, e.g., the delay of pressing the brake pedal in emergent situations. Such an approach, however, could not be used for early warning of the eventual inadequate cognitive load of drivers.

The objective of our research is to detect indirectly the delay of a driver's response as a symptom of inadequate cognitive load. In other words, the main objective of this study could be considered as identifying drivers' distraction and inattention in normal driving situation. Also, as an accident-preventive approach, the detection should be done in routine driving situations – such as (i) driving on a straight, (ii) entering- and (iii) exiting a turn.

In the proposed approach, we consider a driver as a controller of a system (car) with feedback. In addition to applying the feedback control theory, we imply that feedback delay would result in unstable, oscillating behaviour of the system. Focusing on steering of the car, we hypothesize that the feedback delay caused by inadequate cognitive load of drivers would result in steering oscillations. Detecting these oscillations would be crucial for early warning of inadequate cognitive load of drivers.

Moreover, we applied agent-based modelling in which an agent evolved via genetic programming, models the steering behaviour of a human driver in accordance with the servo-control model of the driver.

In our experiments, instead of relying on a real car, we use a car simulated in The Open-source Racing Car Simulator (TORCS). TORCS offers the advantages of being (as a

software system) a crash safe, realistic (by modelling faithfully the laws of vehicle dynamics), open-source, and free of charge.

To verify our hypothesis that inadequate cognitive load would result in detectable steering oscillations, we conducted three different experiments. They were conducted for a routine driving (with constant speed of 50km/h) on a straight, entering- and exiting a corner: first, we comparatively analysed the steering behaviour of an artificial driving agent with instant and with artificially delayed (100ms, 200ms and 400ms) steering. Then, we experimented with ten different human drivers with instant steering and with steering, that is artificially delayed by 400ms. Finally, we experimented with the same ten human drivers subjected to naturally occurring (by texting) cognitive delays.

Experimental results suggest that both the artificially introduced and naturally occurring delays yield subtle, yet detectable oscillations in steering behaviour of both the driving agent and human drivers. These oscillations are manifested in characteristic dynamics of steering angle, and the resulting trajectory and lateral acceleration of the car. The power spectrum of Fourier transformed lateral acceleration signals indicates a well-distinguishable (from normal driving) frequencies and amplitudes of the driver-induced oscillations.

Additionally, we investigated novel approach on detecting these oscillations. First, we applied single threshold (based on spectrum analysis) in each situation for detecting steering oscillation. We further optimised our method by evolving the weight coefficients of power spectrum, in a way that oscillated signals (due to cognitive load) would naturally yield higher power spectrum than non-oscillated signals, via genetic algorithms. We further extended our study by examining individually adaptive threshold mechanism (based on the absolute value of lateral jerk). Finally, this mechanism was further tuned with feature identification and was implemented for real-time detection in fully-fledged driving simulator and tested in real-time by developing a smart phone application.

As a conclusion, our investigation shows that - well-detectable steering oscillations are induced as an effect of cognitive delays in human drivers and these oscillated signals could be well detected by our proposed methods. Further, the detection of these signs using our approach could be used for early warning of the eventual inadequate cognitive load of drivers.

We view the obtained outcome as a significant step towards the development of a more robust system for early-warning of the inadequate cognitive load of drivers in routine driving conditions – well before any urgent reaction to an eventual dangerous traffic situation might be needed.