Reviewer 1 of CCTA 2023 submission 211

Comments to the author

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The authors proposed a method to analyze the friction utilization of a road network was proposed. The following points may help to improve the quality of your work:

1) The 3 DOF model doesn't consider the changes in the normal tire forces, which could be caused by the vehicle's pitch and roll dynamics and can significantly affect the longitudinal and lateral tyre forces. This will affect the friction utilization, especially in safety critical scenarios.

Yes, the reviewer is quite correct. Indeed, the work by one of the authors (Gao) does include such weight-shift effects and is cited in this work.

However, the goal of the paper is to study situations where nominal driving behavior (non-emergency) would be predicted in traffic simulations to result in safety-critical behavior. Namely, when does normal driving result in abnormal situations that WOULD require more advanced models. This is indeed a key concern for us, as the microsimulations are not capable of simulating safety-critical behaviors (ABS, TCS, ESC, weight-shift, hydroplaning) across the road network with 5000 interacting vehicles. However, the paper reveals that they are still useful to geo-locate the hazardous areas where detailed study, data collection, and control work should be done within the network based on the obvious violations of microsimulation predicted behavior to safety-critical assumptions.

2) As a nominal road condition with a maximum friction of 1.0 was assumed, the application of the developed map is not clear when the weather changes the road surface to wet/snow/icy. The friction utlization map may significantly differ in such situations, which are in fact important situations for vehicle safety. These cases aren't considered.

This omission was intentional, as the work by Gao included these variations. We’ve since published that work in journal form with key focus on wet/snow/icy road conditions.

3) Maintaining friction margins require the knowledge of the maximum tire-road friction coefficient, but the work assumed it to be 1.0. Therefore, it isn't clear how it can be used to plan vehicle maneuvres such that friction margins are maintained.

Again, this was the work of Gao published separately.

The work presented clearly involved significant engineering work. However, scientific contribution is questionable. Considering the above points (and possibly others) may help on this front.

Many thanks to the reviewer for the comments! It is difficult when presenting a body of work to partition years-long efforts across roughly a dozen researchers into self-contained papers. The reviewer here (and ones that follow) correctly note many shortcomings in the paper, and while many are addressed in other papers, the comments emphasized areas where in the revised work we could connect the results better to those works and better explain the results herein.

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Reviewer 4 of CCTA 2023 submission 211

Comments to the author

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The paper proposes a method to map typical tire friction utilization in a road network. The proposed method uses a traffic simulator to generate common vehicle kinematic trajectories. Friction information is obtained by using the kinematic trajectories as references for a position controlled dynamic vehicle model.

While the method is potentially interesting to analyze the safety of road networks, the presentation does not do justice to the work. More worryingly, results seem to match common sense qualitatively, but not quantitatively. Furthermore, the proposed tool usefulness is not highlighted in the presented results.

We thank the reviewer for their close reading and very insightful comments. Unfortunately, the original version of the paper – more than 10 pages – required much of the content to be removed, and this was content that directly addressed many of the comments noted by the reviewer. The authors in the revised version attempted to be more concise to re-include the requested content.

The reviewer comment about quantitative agreement seems incorrect, especially as there are, from our research on the topic the past 3 years, no published works with quantitative friction utilization across an entire traffic network prior to this work.

In the following, I report comments for each section.

I) Introduction

The usefulness of the generated likely friction utilization is not clearly outlined.

For example: how would it be useful in warning human drivers? Would it be used by the regulatory agencies to impose stricter speed limits? If so, it would help regulatory agencies, not drivers. Would this analysis be performed during the design phase of roads? If not, when? I understand the exploitation of the map is not the focus of the paper but a more punctual contextualization is necessary.

The introduction was largely rewritten to address these concerns. It now includes an example of how human drivers could be warned if a “hazard” map of dangerous areas is known. And it also emphasizes that such a map may not be completely known during design stages, or even static in the operation of a road network.

“Specifically, it is an assumption of this work and of federal roadway design guides [19] that, to avoid skidding or spinning out, the friction margin:” is this an assumption? Isn't this the physical behavior of

vehicles/models of vehicles?

This is an assumption, and the introduction now includes examples in normal driving – severe cross-winds, vehicle-to-vehicle collisions, tire blow-outs – where this assumption would be violated.

The literature analysis is not clearly connected to the presented work. A relevant amount of time is spent discussing major causes of accidents, without highlighting why this is relevant to the presented work. Similarly, a specific ADAS system (ISA) is presented in detail, but it’s not clear how this is affected by the presented work. These are examples that show how friction estimates can be used, but do not present the innovative contributions of the paper, nor highlight topics not addressed by the literature.

The rewrite of the introduction sought to correct these shortcomings as noted by the reviewer.

The conclusion argues that there is a lack of literature that discusses what to do if friction estimates are wrong, however this is not proven by the presented literature. No mention is given to robust vehicle dynamics control approaches.

The reviewer is very correct in this statement. Unfortunately, there is insufficient material available in a 6-page conference paper to discuss impacts of errors in detail, and reference is given in the conclusion of the introduction to the report by the authors that specifically study these errors.

The case of loss of connection with a friction database is presented as an issue solved by this work, but the proposed method cannot run online on the vehicle and thus needs a connection to download such map, which is effectively a database.

The reviewer is assuming that a vehicle could not self-identify hazardous road conditions and save these geolocations onboard itself for use later. In most of the sponsored work by the authors, this is the modality requested by the customers, to save data on-vehicle rather than use a database!

Deeply revising this section is fundamental for the comprehension of the article and its contribution.

The introduction was deeply revised, and these comments were very helpful in guiding these revisions.

II) Methods

From the introduction it is not clear why a traffic simulation is needed. Why can’t a simulation with a single vehicle be used to evaluate maximum friction utilization? I am guessing that this allows to statistically predict where accelerations and decelerations occur (if this is the case, this is not clearly presented).

Yes, exactly. Wording was added to emphasize this.

Does the simulator give more insight into these conditions with respect to common sense predictions? (i.e. a traffic simulator is not necessary to predict that braking actions will frequently be taken in the vicinity of traffic lights while accelerations on highway ramps).

The reviewer emphasizes a good point: that the original manuscript did not emphasize why the tools are used. The following sentence is added to the discussion:

“Common sense indicates that vehicles will slow down in the vicinity of a traffic light, but only the traffic simulator will easily indicate – based on queue length, road grade, rules of road, and surrounding intersections – where exactly that slow-down is most abrupt.”

The OSM acronym is never defined.

This is now defined at first usage – Open Street Map.

If possible, cite the work related to the development of the traffic simulator and its calibration instead of just mentioning the authors.

The publication of that work is still in review, so was not included. However, these results can be found in the upcoming thesis and reports by the author, all of which are soon publicly available.

"This was an involved process that is the topic of a concurrent paper." I suggest some level of explanation is given on this process, as this would help to make the paper more self contained and to easily understand it.

This part is now published and a citation is given in the revised version

When presenting the models employed it is stated that the 3DOF model directly controls the wheel slip, which however is not present in the presented equations. Rather, equation (5) shows torque inputs.

I am guessing the model with torque inputs is the 7 DOF one. No detail is given on which model is used to represent the slip-force relationship, which is fundamenteal, given the nature of this work.

This is detailed in Mitrovich’s thesis, now cited.

“only reference vehicle trajectories that had no lane changes were analyzed” why was this choice made?

This is detailed in Mitrovich’s thesis, now cited.

What is a section ID ?

This was reworded to “road segment”. A section ID is the PenDOT designation (and designation used my nearly all DOTs) of a portion of a road, a designation that is also used in microsimulation toolsets. Rather than confuse the reader, a more general wording is now used.

III) Results

Results only show examples of results that match common sense. It would however be interesting to see results providing more insight. Is this tool capable of highlighting unexpected dangers?

Many of the results were not known prior to the simulation! For example, the section of the highway with large friction utilization appears obviously hazardous after examining the simulation results. Yet several people have died at this segment and no prior analysis was done.

For example: was the road section in Figure 7 predictably dangerous?

No, other than looking at crashes and fatalities – e.g. a post-hoc analysis, and thus a very poor method of safety analysis or enforcement.

The analysis of Figure 3, as presented, seems to suggest that the method is not capable of representing realistic dynamics in some contexts, like stop signs and traffic lights. More details should be given on the reasons and the effects of this shortcomings.

These effects were given in the longer version of the paper prior to cutting it to 6 pages, and will be explained in the presentation of the material. As well, these results are found in the thesis by Mitrovich cited in the work.

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Reviewer 13 of CCTA 2023 submission 211

Comments to the author

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The double simulation procedure is well explained and reproducible, and the work methodology is coherent throughout the paper.

There only one part less clear: in section 2A, a 7-DOF vehicle model is introduced, however, it is unclear which are the states of this model,

This is a good comment, and the states were unfortunately not clear in the original text, and is clarified in the revisions by more clearly introducing the 3DOF and 7DOF models separately, rather than introducing the 7DOF model as simply differences in the 3DOF model.

and how the single-wheel rotational speed is controlled by the wheel slip controller if those dynamics are neglected in the simulation.

This area was also rewritten to emphasize the focus on typical driving.

Also, it comes to the mind of the reader to ask why did you use a brush tire model, especially concerning the computational problems you encountered, while the Pacejka model is much simpler, computationally wise.

The brush tire used was the Pacejka model, and this is noted in the revision.

Minor comment: 5 lines after defining equation (5), you refer to it as equation (4)

Response: Thank you! This has been fixed