Group 1-3 – Discussion

Friction Potential Estimation

1. Cornelia Lex: Road Condition Estimation for Automated Driving Considering Driver's Acceptance
2. Pavel Sarkisov: Experimental Analysis of a Contact Patch Form of a Rolling Tire: Influence of Speed, Wheel Load, Camber and Slip Angle
3. Thorsten Lajewski: Using car2x Data for Friction Potential Estimation
4. Gerd Müller: Methods and Results of Project Friction Estimation at TUB

1. Describe in a few sentences what you just heard:
- Motivation
- Approach/Method
- Outcome/Results

Paper 1

- Human acceptance of estimation in warning and assistance systems
- Goal: minimize false positives

Paper 2

- Go into detail of one of the most important contributors for friction
- Get insight in the relative friction potential use (but not in the complete friction potential)

Paper 3

- Get an idea what friction estimation has to fulfill for applications in automated driving
- Broad analysis of many data sources with mostly consistent results

Paper 4

- Development of a friction database representing real world situations: by test braking pulses
- Development of a friction estimator: by logistic regression application to influencing parameters

Further Comments

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Paper 1

- SAE 3 and above: false negatives are no longer acceptable; sensitivity of outcomes to mu; TTC based; driver perception of surface conditions; need for higher resolution in mu values for low mu conditions.

Paper 2

- Tyre as a sensor. How does the contact patch shape and form depend on slip angle etc., how to model this, how to use it as a sensor, including mu estimation. Including focus on higher frequency vibrations. Strong focus on physics and modeling. Results are convincing at least under the conditions tested.

Paper 3

- from human driving data, extrapolating to autonomous vehicles what requirements are there for friction potential estimation; review of data sources and factors that influence friction potential; 0.6 is the magic number in Europe!

Paper 4

- established a 'cheap and cheerful' database based or real driving conditions. Large range of mu, not always directly connected to road surface type (due to effect of interlayer); using a fixed vehicle and making short braking events; logistic regression gave high probability of success, but with a wide friction range.

Further Comments

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Paper 1

- For automation level 3+ environment monitoring is done by the automated driving function. Adapting the driving function to road condition dependent on intervention strategy driving context. There seem to be an understanding of normal drivers of what cues are important for determining the road surface friction.

Paper 2

- The motivation is to model and analyzing sticking and sliding of the tire contact patch. Combining the brush tire model with inner tire liner acceleration measurements. Simulation of tire contact patch shape and the two regions.

Paper 3

- Giving an overview of influencing factors for road friction and the required speed adaptation. Evaluating naturalistic data and literature review. An overview.

Paper 4

- Predicting a range for friction based on environment conditions. Regression models for each influence. Validation test using braking showed the results.

Further Comments

- Still work to be done. No reliable friction value obtained for unknown roads.

2. What are the main scientific contributions?
- What does it tell us what we didn't know before?

Paper 1

- Results from questionnaire: most based on vehicle response, not so much on weather etc.

Paper 2

- Understanding how the contact patch changes
- Lateral slip can be used too, reduction to one tire sensor is possible

Paper 3

- Comprehensive overview of different studies coming to a distinct conclusion

Paper 4

- Surprisingly low grip in distinct locations, even under dry conditions
- High variance under same conditions
- Using logistic regression is quite successful, even though it's a very simple approach

Further Comments

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Paper 1

- subjective categories of road conditions, low weighting for weather conditions

Paper 2

- A new tyre model; detailed data relating to contact patch form and size.

Paper 3

- Mostly a review, the main contribution was to compile and evaluate the relevant/available research

Paper 4

- establish a database; estimation of interlayer; combining vehicle and external sources

Further Comments

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Paper 1

- Connecting the drivers perception of road condition to the adaptation of the intervention characteristics.

Paper 2

- Capturing the tire contact patch dynamics with a low complexity model and one acc sensor.

Paper 3

- Literature review of naturalistic driving data to determine used acceleration.

Paper 4

- Determination of the interlayer based on environment parameters from 4000 measurements.

Further Comments

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3. How realistic is a practical application of the shown method?

Paper 1

- "Current technologies" are more long term research technologies
- Paper mentions vehicle dynamics based estimation – can this currently be used?

Paper 2

- It is far away from application due to technological complexity, but the experimental method and results are very valuable for further work.

Paper 3

- application of the statistical insights seems to be realistic

Paper 4

- measurement approach is very realistic, prediction method is very much dependent on application context

Further Comments

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Paper 1

- not applicable, the paper does not formulate a method

Paper 2

- positive opportunities, but a practical implementation would need to be applicable for different tyres, this is not yet known. Commercial feasibility depends on many factors (reliability in service, sensor fault probability, cost, etc. etc.)

Paper 3

- we think there will be something of this CAr2X kind available in the future (5-10 years?)

Paper 4

- highly realistic except … see (5)

Further Comments

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Paper 1

- No, not yet.

Paper 2

- For estimation of friction potential: NO, for wheel slip control (ABS): OK

Paper 3

- No, not yet.

Paper 4

- Yes but remains to be done.

Further Comments

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4. What other approaches are we aware of in this field?

Paper 1
- every single approach may contribute to a fusion solution

Paper 2
- finite element methods to analyze tire behavior
- Alternative methods for friction estimation: wheel speed frequency analysis

Paper 3
- all kind of data analysis, e.g scanning grip level on a road network (like SKM of BASt)

Paper 4
- deep learning

Further Comments
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Paper 1
- EU FRICTION project using a range of sensors and vehicle dynamics

Paper 2
- Similar approaches from TNO for example.

Paper 3
- In Japan collection of data from taxis, also weather conditions (data collection and analysis only at present); SHRP2 database;

Paper 4
- data fusion via fuzzy systems, classical regression, ANNs, special sensors

Further Comments
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Paper 1
- Check out EU Project, ADAS and Me.

Paper 2
- Use FEM modeling.

Paper 3
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Paper 4
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Further Comments
- Acceleration neutral wheel torque excitation to determine friction.
- Use information from smart phones in driving communities.

5. What are the gaps and other questions regarding the overall topic and the particular papers?

Paper 1
- "Current technologies" are more long term research technologies
- Sensor fusion makes the solution complex and costly

Paper 2
- Technological implementation complexity
- Extension on real road situations (today: only test bench based results)

Paper 3
- Only fusion based approaches seem to be promising for reaching sufficient reliability

Paper 4
- its statistics, no guarantee

Further Comments
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Paper 1
- coordination of AEB etc. function with self driving function (e.g. test brake pulse) may offer some advantages; ACC function can adapt headway to friction estimates (don't make the same mistakes humans make!!)
- No field data available for autonomous driving

Paper 2
- Effects of vertical vibration and road surface roughness etc., how to bring down the costs of such systems, how reliable will this be in the field, how well will it work in low mu conditions,

Paper 3
- How will autonomous cars drive (e.g. high brake events after late detection of object); accuracy of information sources (how important is it to have accurate weather information etc.)

Paper 4
- vehicle factors not considered, large range of friction bands currently, no consideration of lateral forces/combined slip/bank angle, no consideration of micro texture etc.,

Further Comments
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Paper 1
- Implementation of adaptation strategy. Verify that this increases acceptance.

Paper 2
- How to determine the absolute potential.

Paper 3
- How to use in applications?

Paper 4
- Decrease the range using fuzzy logic?

Further Comments
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