Effect of Driver and Passengers’ Emotion on Driving Style in Autonomous Driving

Mohammad Hassan Uz Zaman
Behtarin Ferdousi
Research question:

How can a (semi) autonomous vehicle adjust its driving style in order to maintain comfort using awareness of its occupants' emotions?
Why?

- Acceptance of autonomous vehicles is increasing but there is still a long way to go
- Perceived safety is a major factor
- Personalization of driving style is very important
- Improvement of on-road experience
- This is currently a hot topic of research
Research question:

How can a (semi) autonomous vehicle adjust its driving style in order to maintain comfort using awareness of its occupants' emotions?
Two Dimension Emotion System by W. Wundt

Active

Valence +

Valence -

Passive

😊

😃

😠

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😢
Circumplex model
## Feedback by emotion

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<td>Respiration</td>
<td>Wire strains/PPG/foam-based pressure sensors</td>
<td>73.06% for valence 80.78% for arousal [7]</td>
<td>Only limited set of emotion</td>
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What does ‘driving style’ really mean?

- In order to modify the driving style, we must first understand what it means.
- A driving style can be represented as a set of features and the range of their values.
- Some example features are:
  - Distance maintained from other vehicles
  - Speed
  - Turn speed
  - Frequency of lane changing
  - Acceleration
  - Braking frequency
  - Jerks
- The selection of features varies because it depends on the scope of the system.
- We focus on metrics that affect comfort
Pre-defined driving modes example (Ford)

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<td>At or within 5 mph above speed limit</td>
<td>At or within 5 mph below posted speed limit</td>
<td>At least 5 mph below posted speed limit</td>
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<td>Following Distance</td>
<td>Maintain minimum distance</td>
<td>Maintain moderate distance</td>
<td>Maintain very cautious distance</td>
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<tr>
<td>Turn Clearance</td>
<td>Maintain minimum distance from other vehicles while turning</td>
<td>Maintain moderate distance from other vehicles while turning</td>
<td>Maintain maximum distance from other vehicles while turning</td>
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Driving style metrics - Examples

- Time to collision: The time left before two vehicles collide.
  \[ TTCC(t) = \frac{S_{n-1,n}(t)}{\Delta V_{n-1,n}(t)} \]

- Jerk: The change of rate of acceleration
  \[ F_{jett} = \frac{jerk^2}{3600} \]

- Time headway: The passed time between the arrival of a leading vehicle and a following vehicle at a specific point
Research question:

How can a (semi) autonomous vehicle adjust its driving style in order to maintain comfort using awareness of its occupants' emotions?
Comfort

- Comfort is a broad and subjective term
- Comfort can be physical:
  - Jerks, sharp turn, turning speed, etc.
- Or it can be psychological:
  - Traffic, frequency of turns, perceived safety, etc.
- A study in 2017 found that:
  - People prefer autonomous vehicles with a significantly more defensive driving style than them.
  - Preferences change significantly based on the scenario
Comfort

- The meaning of comfort can be different at different times.
- Driving style metrics, which focus on the vehicle’s motion, are often used to quantify comfort as well.
- Recently, there have been attempts to understand comfort by focusing on the motion of the passengers instead.
- A recent study showed that:
  - Inattentive passengers usually move more.
  - The motion of attentive passengers is usually more uniform.
- The same driving style can be judged more or less comfortable depending on the passengers’ own movements.
Modifying driving style to maintain comfort: Methods and Techniques
Solutions for different types of comfort issues
Common Approaches

- Many methods to improve driving style in terms of security, efficiency and comfort have been proposed or patented in recent years.

- Some common recent approaches are:
  - Incorporating comfort metrics in the development and training of the driving model
  - Learning a driver’s driving style from demonstration
  - Using comfort metrics and training a model on real-world traffic data
  - Using a RL-based system which makes changes to driving style based on feedback from passengers

- Very few research has been done on directly using passengers’ emotional data to improve driving style.

- Reinforcement learning is the most commonly used machine learning technique so far.
Reinforcement Learning
Learning personalized driving styles

- Driving styles can be learned from publicly available large traffic datasets
- But personalization is essential for comfort
- Driving style can be learned from demonstration by the driver
- Inverse reinforcement learning (IRL) has been shown to be an effective for this task
- So far, there has been no research that combines this approach with emotional recognition
- This would allow further personalization based on passengers’ mood
Velocity control system example

- Car following is one of the most common scenarios in traffic
- In one study, using deep reinforcement learning, a model for automated car following was trained
- A real-world traffic dataset from the Next Generation Simulation (NGSIM) project was used for training
- Car following situations were identified in the dataset and comfort metrics for each one were calculated for each one
- Deep Deterministic Policy Gradient was the reinforcement learning technique used
- The autonomous vehicle performed even better than human drivers based on metrics that they used for security, efficiency and comfort.
Velocity control system example

- The comfort metrics used were:
  - Safety: Time to collision
  - Efficiency: time headway
  - Comfort: jerk

- If this system is combined with the emotion recognition, the characteristics of this model can be personalized by finding a unique balance between the three metrics for each user.
“Adaptive Comfort Enhancement” (Google)

- Developed and patented by Google in 2018
- Does not require any training data
  - Very effective for first-time passengers
- Takes route information and road segment curvature into account
Reward function

Diagram:
- Audio data (201) flows into the Speech Recognition Module (205).
- Biological data (202) flows into the Facial Recognition Module (207).
- Both modules output to the Analog-to-Digital Conversion Module (209).
- The Reward Matrix Maintenance Module (211) receives the output and outputs an updated reward R (215).
Goal function

GPS

POSITIONING

ROUTE INFORMATION

DESTINATION

TRAJECTORY CALCULATION: OBTAIN ROAD SPEED LIMIT AND ROAD CURVATURE

GOAL FUNCTION G MAINTENANCE ALGORITHM

USER FEEDBACK -COMFORT RATING -SPEED RATING

VEHICLE SPEED CONTROL POLICY

UPDATE G FOR CURRENT ROUTE
Conclusion
Future research

- Collection of traffic data in combination with emotional data of passengers can be really useful in training models.
- Developing specialized emotional models for autonomous driving:
  - A subset of all emotions is far more important than the rest.
  - Most emotional feedback can be very subtle in cars.
- Identification of physical discomfort like headache, nausea and taking corrective actions.
- Most current approaches for improving the driving style with respect to comfort can be enhanced by incorporating emotion recognition:
  - Emotional feedback from passengers can be used instead of or in addition to calculated driving style metrics.
- Awareness of emotions of pedestrians can be very useful in increasing both comfort and safety.
Summary

- Driving style can be described using many different metrics which can be calculated on public traffic datasets and used for training.
- Comfort can be quantified in many different ways, using either driving metrics.
- Research has recently begun to focus on improving driving style based on comfort level.
- So far, in most studies, comfort metrics have been used to judge the comfort level provided by a driving style, instead of direct emotional feedback from passengers.
References

1. AUTONOMOUS VEHICLE MODES – Ford Global Technologies, LLC, Dearborn, MI (US)