Should My Vehicle Drive As I Do?

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Problem Description

situation today: drivers have varying preferences for implemented automation behavior

approach: adaptation of the automation to individual driving preferences

goal: increase of driving comfort and attractiveness of vehicle automation

<table>
<thead>
<tr>
<th>individual driving styles</th>
<th>driver A: defensive</th>
<th>driver B: assertive</th>
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</table>

But should my vehicle drive as I do?
Modelling of Driver Preferences

1. situation dependent learning of individual driver behavior
2. clustering of inter- and intraindividual differences

development of the tool CONFORM

(Conflict recognition by image processing methods)

method: multivariate time series clustering with pattern recognition
Use Case: overtaking on two lane highway
Use Case: overtaking on two lane highway
Simulator experiment: goals

phase 1: How do I drive?
• modelling of individual driving styles and clustering

phase 2: Should my vehicle drive as I do?
• drivers' preferences: same driving style, similar, different?
Simulator experiment: automation level

phase 1: How do I drive?
  • modelling of individual driving styles and clustering

phase 2: Should my vehicle drive as I do?
  • automated driving – SAE level 2
Simulator experiment: methods

phase 1: How do I drive?
- dynamic simulator: 41 subjects (34 male, 7 female)

phase 2: Should my vehicle drive as I do?
Simulatorexperiment: Versuchssetting

phase 1: How do I drive?
• dynamic simulator: 41 subjects (34 male, 7 female)

phase 2: Should my vehicle drive as I do?
• dynamic simulator: 35 of the 41 subjects from phase 1
Phase 1: How do I drive?
Procedure with subject John Doe

John gets invited to participate in the study at DLR.
Phase 1: How do I drive?
Procedure with subject John Doe

simulator training
5 min
Phase 1: How do I drive?
Procedure with subject John Doe

simulator training
situation A: 25 times
5 min 15 min

120 km/h
100 km/h

Situation A
Phase 1: How do I drive?
Procedure with subject John Doe

<table>
<thead>
<tr>
<th>Simulator Training</th>
<th>Situation A: 25 times</th>
<th>Situation B+C: 50 times</th>
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<tbody>
<tr>
<td>5 min</td>
<td>15 min</td>
<td>30 min</td>
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**Situation A**
- 120 km/h
- 100 km/h

**Situation B**
- 140 km/h
- 120 km/h
- 100 km/h

**Situation C**
- 160 km/h
- 120 km/h
- 100 km/h
Phase 1: How do I drive?
Procedure with subject John Doe

Manuelles Überholmanöver:
Situation B - Linke Spur PKW 140 km/h
Phase 1: How do I drive?
Procedure with subject John Doe

situation B – left lane car with 140 km/h:
trajectories of all 25 overtaking maneuvers of John Doe
Phase 1: How do I drive?
analysis and modelling

John Doe has completed the first phase and will be asked to return in 3 months.

… meanwhile, analysis of phase 1
Phase 1: How do I drive?  

**goals:**

1. determine a representative overtaking maneuver for each driver for each situation
2. assign drivers to driving style clusters

**approach:** modelling with CONFORM

determine the input variables:

- lateral deviation to the middle of the right lane
- own velocity
- lateral acceleration

all relativ to the distance between ego vehicle and leading vehicle
Phase 1: How do I drive?

analysis: driving data from the overtaking maneuvers

situation B – left lane car with 140 km/h:
trajectories of all 25 overtaking maneuvers of John Doe
Phase 1: Wie fahre ich?
Analyse: Herleitung des individuellen Fahrstils

situation B – left lane car with 140 km/h:
trajectories of all 25 overtaking maneuvers of John Doe
Phase 1: How do I drive?

analysis: determination of individual driving styles

situation B – left lane car with 140 km/h:
trajectories of all 25 overtaking maneuvers of John Doe

Max Mustermann fährt in...

30% der Fälle ähnlich dem roten Fahrstil
70% der Fälle ähnlich dem blauen Fahrstil
Phase 1: How do I drive?

**result 1: representative driving style for one situation**

situation B – left lane car with 140 km/h: trajectories of all 25 overtaking maneuvers of John Doe
Phase 1: How do I drive?

result 1: representative driving style for one situation

situation B – left lane car with 140 km/h:
trajectories of all 25 overtaking maneuvers of John Doe

same procedure for all 41 subjects
Phase 1: How do I drive?

result 2: classification of driving styles

situation B – left lane car with 140 km/h:
trajectories of all 25 overtaking maneuvers of John Doe
Phase 1: How do I drive?
result 2: classification of driving styles

situation B – left lane car with 140 km/h:
trajectories of all 25 overtaking maneuvers of John Doe

Cluster 1 | Cluster 2 | Cluster 3 | Cluster 4
Phase 1: How do I drive?

result 2: classification of driving styles

situations B – left lane car with 140 km/h:
trajectories of all 25 overtaking maneuvers of John Doe

| distribution of subjects | 10 | 11 | 6 | 14 |

alternative B1 | alternative B2 | alternative B3 | alternative B4
Phase 2: Should my vehicle drive like me?

procedure for John Doe

It is summer now and John Doe may return for phase 2.
Phase 2: Should my vehicle drive like me?
procedure for John Doe

input from phase 1: „pool“ of driving styles
- driving styles A1-A4, B1-B4, C1-C4
- individual driving style of John Doe for situation A-C

Best-Worst-scaling for preference measurement

alternative 1: driving data from B1 (~40 Sek.)
alternative 2: driving data from B2 (~40 Sek.)
alternative 3: driving data from John Doe in situation B

1. trial (~2.5 Min.)
Phase 2: Should my vehicle drive like me?

procedure for John Doe
Phase 2: Should my vehicle drive like me?
procedure for John Doe

evaluation after trial 1:

**experimenter:** "Which overtaking alternative was best / worst?"

**John Doe:** "Alternative 1 was best, alternative 2 worst."
Phase 2: Should my vehicle drive like me?

procedure for John Doe

input from phase 1: „pool“ of driving styles

- driving styles A1-A4, B1-B4, C1-C4
- individual driving style of John Doe for situation A-C

Best-Worst-scaling for preference measurement

alternative 1: driving data from B1 (~40 Sek.)

alternative 2: driving data from B2 (~40 Sek.)

alternative 3: driving data from John Doe in situation B

2. trial (~2.5 Min.)
Phase 2: Should my vehicle drive like me?

procedure for John Doe

input from phase 1: „pool“ of driving styles
- driving styles A1-A4, B1-B4, C1-C4
- individual driving style of John Doe for situation A-C

Best-Worst-scaling for preference measurement

alternative 1: driving data from B1 (~40 Sek.)
alternative 2: driving data from B2 (~40 Sek.)
alternative 3: driving data from John Doe in situation B

2. trial (~2.5 Min.)

30 trials altogether, 6 ratings per alternative
Phase 2: Should my vehicle drive like me?

individual results for John Doe

situation A: left lane free

situation B: left lane car 140 km/h

situation C: left lane car 160 km/h

best rating  worst rating
Phase 2: Should my vehicle drive like me?

Overall results

- situation A: left lane free
- situation B: left lane car 140 km/h
- situation C: left lane car 160 km/h

- maximum count = 35 (subjects) x 6 (alternative ratings) = 210
Phase 2: Should my vehicle drive like me?

**overall results**

- one alternative per condition which was rated significantly worse than others
  - alternatives with more lateral acceleration and less safety distance
Phase 2: Should my vehicle drive like me?

Overall results

- Subjects rate in all 3 conditions their own driving style as positive.
- Extent of preference varies with situation.

Diagram showing the comparison of different driving situations (A, B, C) and the counting of alternatives rated as the best or worst.
Phase 2: Should my vehicle drive like me?

**overall results**

- **intermediate result:** my car does not necessarily have to drive like I do

- **situation A:** left lane free
- **situation B:** left lane car 140 km/h
- **situation C:** left lane car 160 km/h

![Graphs showing comparisons between different situations and alternative selections with best and worst ratings highlighted.](image)
Phase 2: Should my vehicle drive like me?

Further questions and results

1. Should my automation drive similar to me?

2. Can we predict preferences from the manual driving data?

3. Which benefit has a driver adaptive alternative compared to a standard profile?
Phase 2: Should my vehicle drive like me?

further questions and results

1. Should my automated car drive similar to me?

• analysis based on driving style clusters

![Bar chart showing 76% same or similar and 24% different]
Phase 2: Should my vehicle drive like me?  
Further questions and results

2. Can we predict preferences according to manual driving data?

3. What benefit has the driver adaptive alternative compared to the baseline?

1. Use standardized measures of Best-Worst-scaling to gain a better understanding of driver preferences
2. Define baseline and driver adaptivity
Phase 2: Should my vehicle drive like me?

- definition of standardised measures = Best-Worst-Scores (BWS)

\[
\text{count rating as best alternative} - \text{count rating as worst alternative} \\
\text{count of ratings for this alternative}
\]

- example: John Doe rates alternative A2 twice as best alternative and once as worst alternative

\[
-> \text{BWS „Best-Worst“} = \frac{(2-1)}{6} = \frac{1}{6}
\]
Phase 2: Should my vehicle drive like me?

further questions and results

- **definition driver adaptive:**
  Adaptation of the driving styles based on a predictor function, which estimates the preferred automated driving style based on the manual driving style.

![Diagram](image-url)
Phase 2: Should my vehicle drive like me? 
**further questions and results**

- **definition driver adaptive:**
  Adaptation of the driving styles based on a predictor function, which estimates the preferred automated driving style based on the manual driving style.

- **definition baseline:**
  The driving style cluster rated best on average for each situation.
Phase 2: Should my vehicle drive like me?

further questions and results

2. Can we predict preferences based on manual driving data?

3. Which benefit has the driver adaptive alternative compared to the baseline?

<table>
<thead>
<tr>
<th></th>
<th>baseline: mean standard. „Best-Worst“</th>
<th>driver adaptive: mean standard. „Best-Worst“</th>
<th>increase</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>0.41</td>
<td>0.48</td>
<td>17%</td>
</tr>
<tr>
<td>B</td>
<td>0.23</td>
<td>0.40</td>
<td>74%</td>
</tr>
<tr>
<td>C</td>
<td>0.23</td>
<td>0.48</td>
<td>110%</td>
</tr>
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Summary and Discussion

Should my car drive like me or similar?

• majority prefers an automation driving style similar to their own style

• two limitations:
  - Some subjects prefer an automation style contrary to their own style -> interaction with the automation may be necessary
  - Subjects with high lateral accelerations and short safety distances when driving manually prefer large safety distances and lower lateral accelerations

• driver adaptive alternative received higher ratings compared to the unadapted baseline
Thank you for your attention

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