Validation of the Driving by Visual Angle car following model

David Käthner & Diana Kuhl
Institute of Transportation Systems
DLR Braunschweig

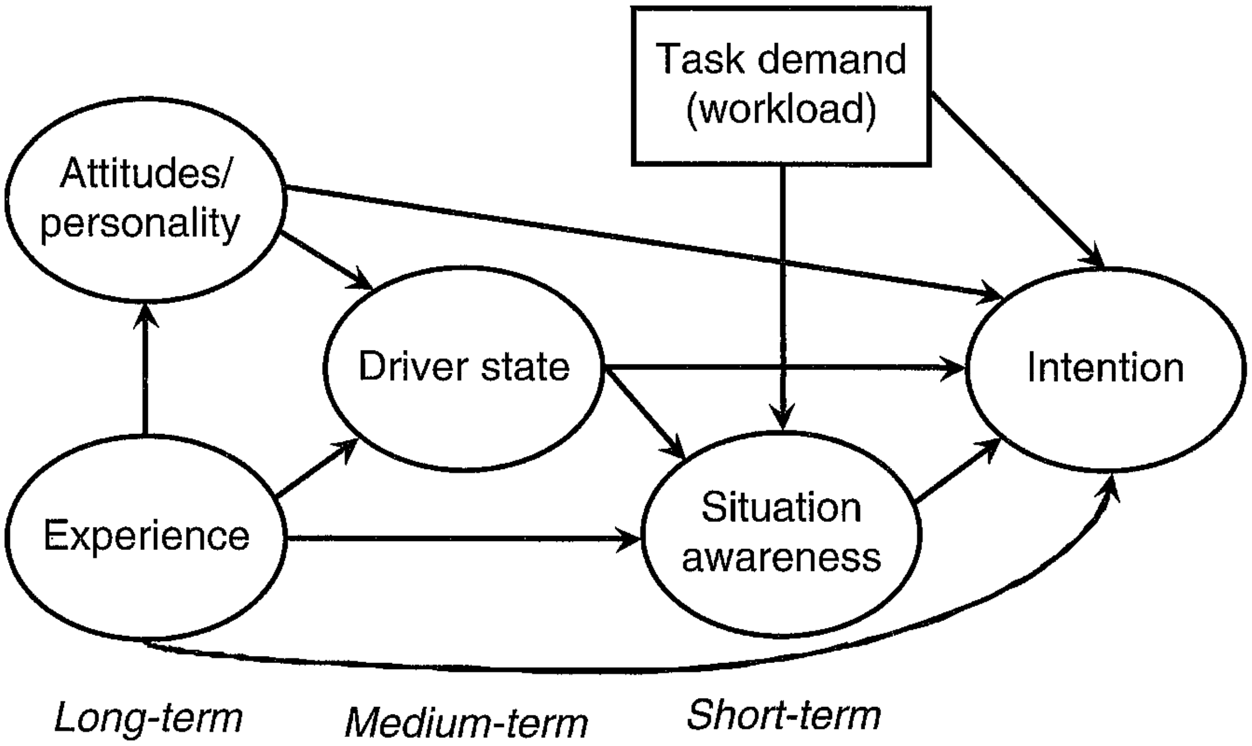
DLR

Why modelling car following?

ACE

Examples of models

Box-and-Arrow



Carsten (2007)

Examples of models

Cognitive architecture, production rules

```
(p decide-lc-lane1
  =goal>
    isa drive
    stage decide-lc
    task lk
    lane lane1
    v =v
    fkind car
    fthw =thw
  !eval! (< =thw *thw-pass*)
==>
  =subgoal>
    isa check-lc
    lane lane1
    v =v
    result =result
  !push! =subgoal
  =goal>
    stage =result)
```

(Salvucci, e.g. 2005)

Examples of models

Psychophysical controller for car following behavior

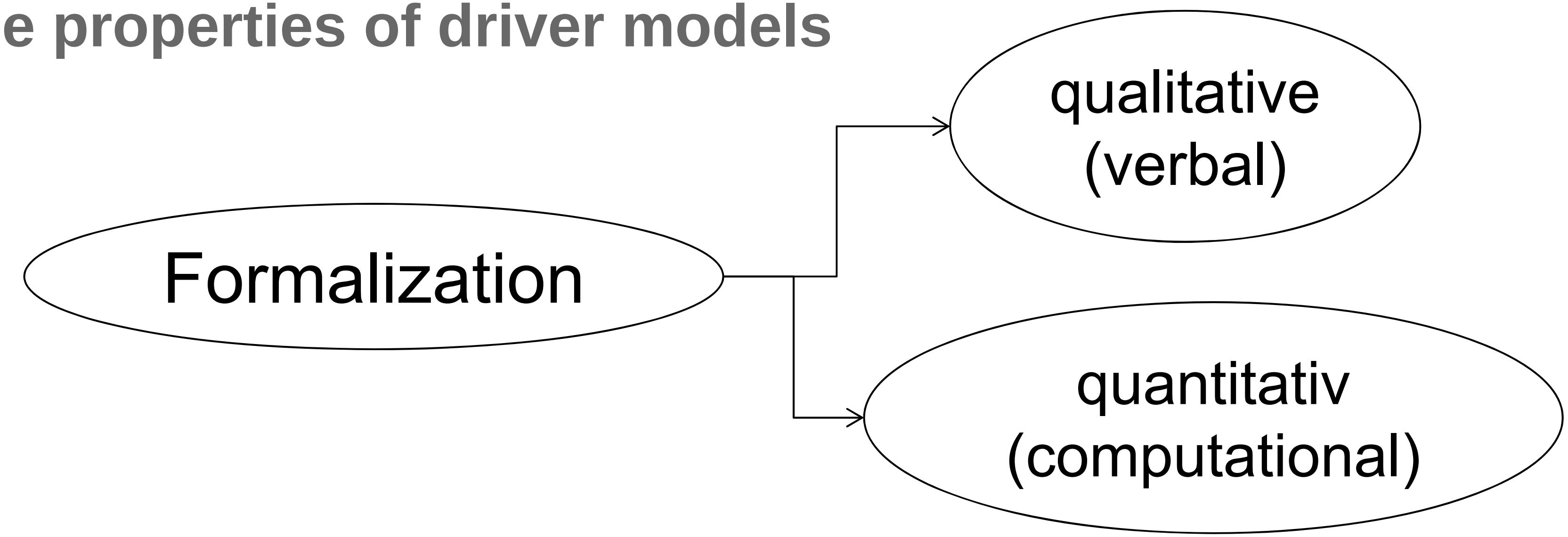
$$a_{t+1} = j\left(\frac{1}{\alpha_t} - \frac{1}{\alpha'}\right) + k\frac{d}{dt}\alpha_t$$

Anderson and Sauer (2007)

Some properties of driver models

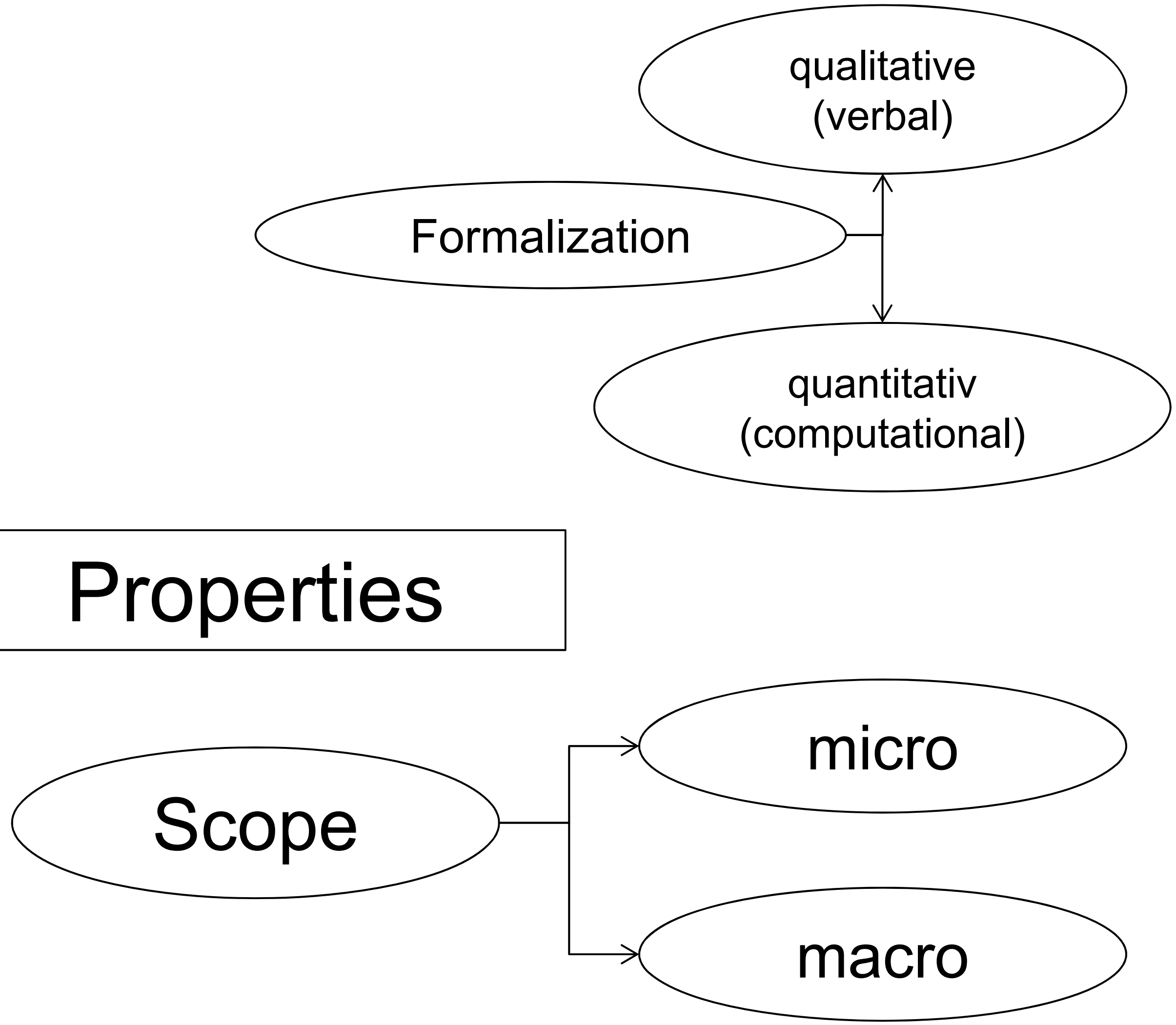
Properties

Some properties of driver models

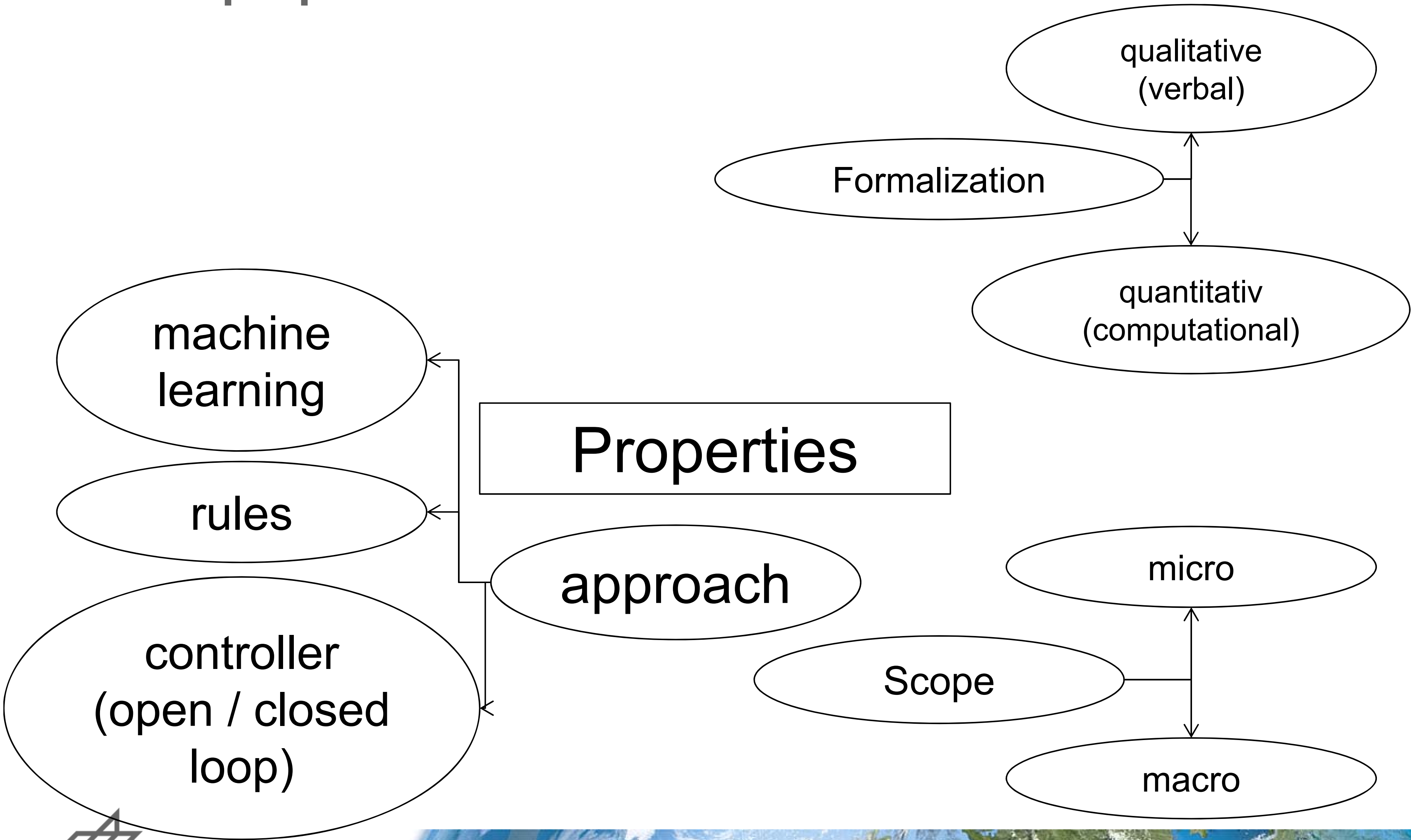


Properties

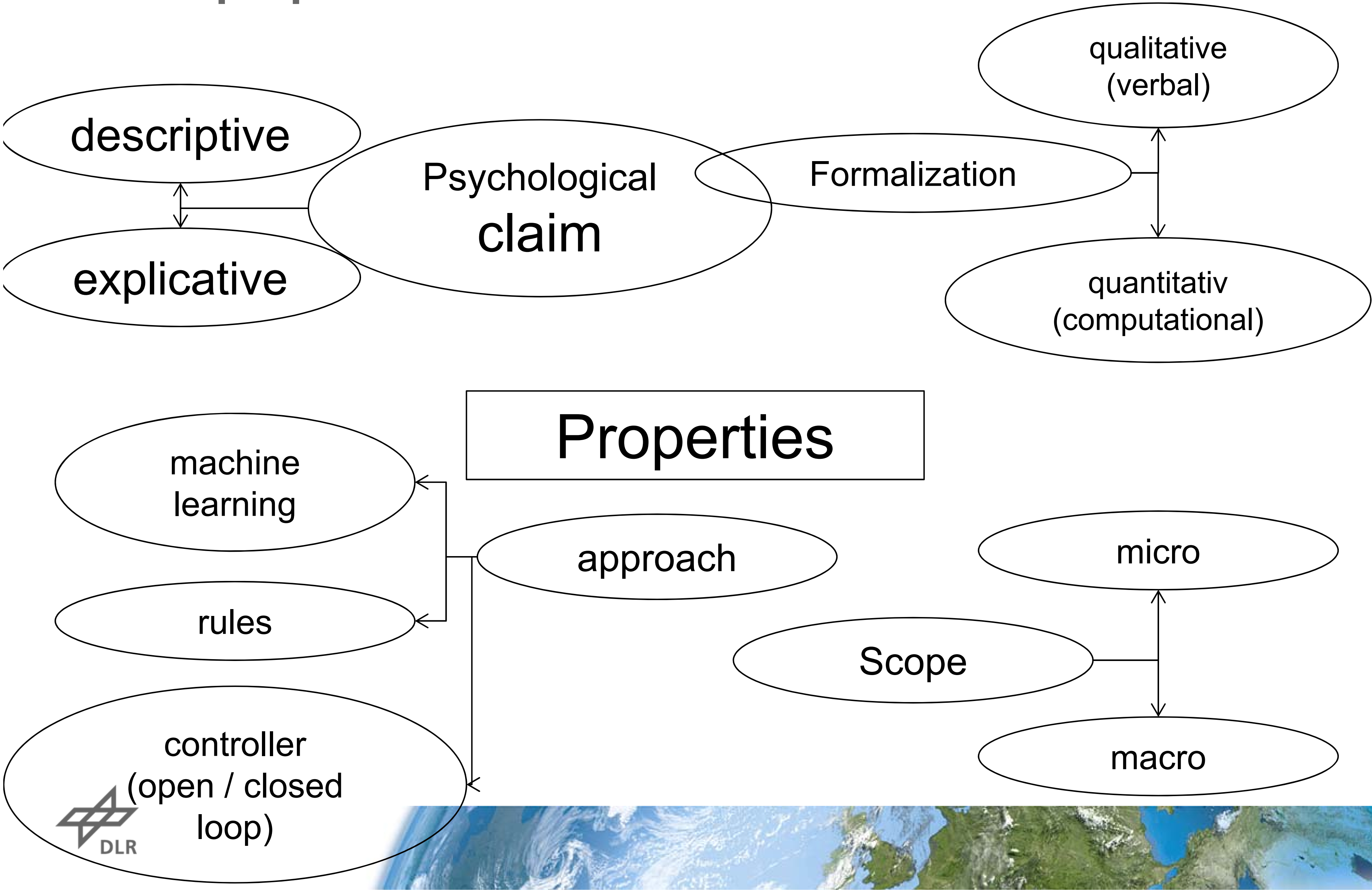
Some properties of driver models



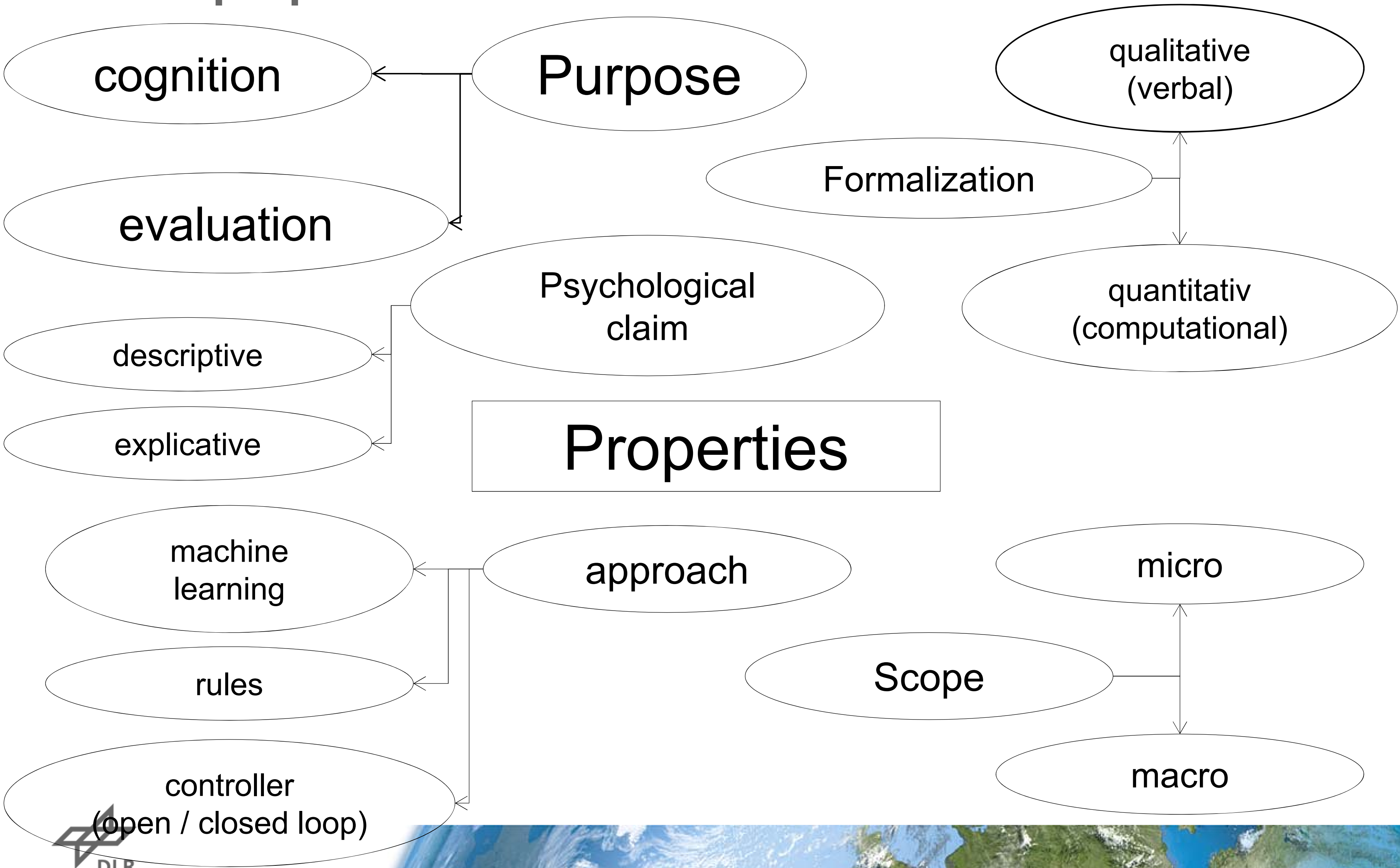
Some properties of driver models



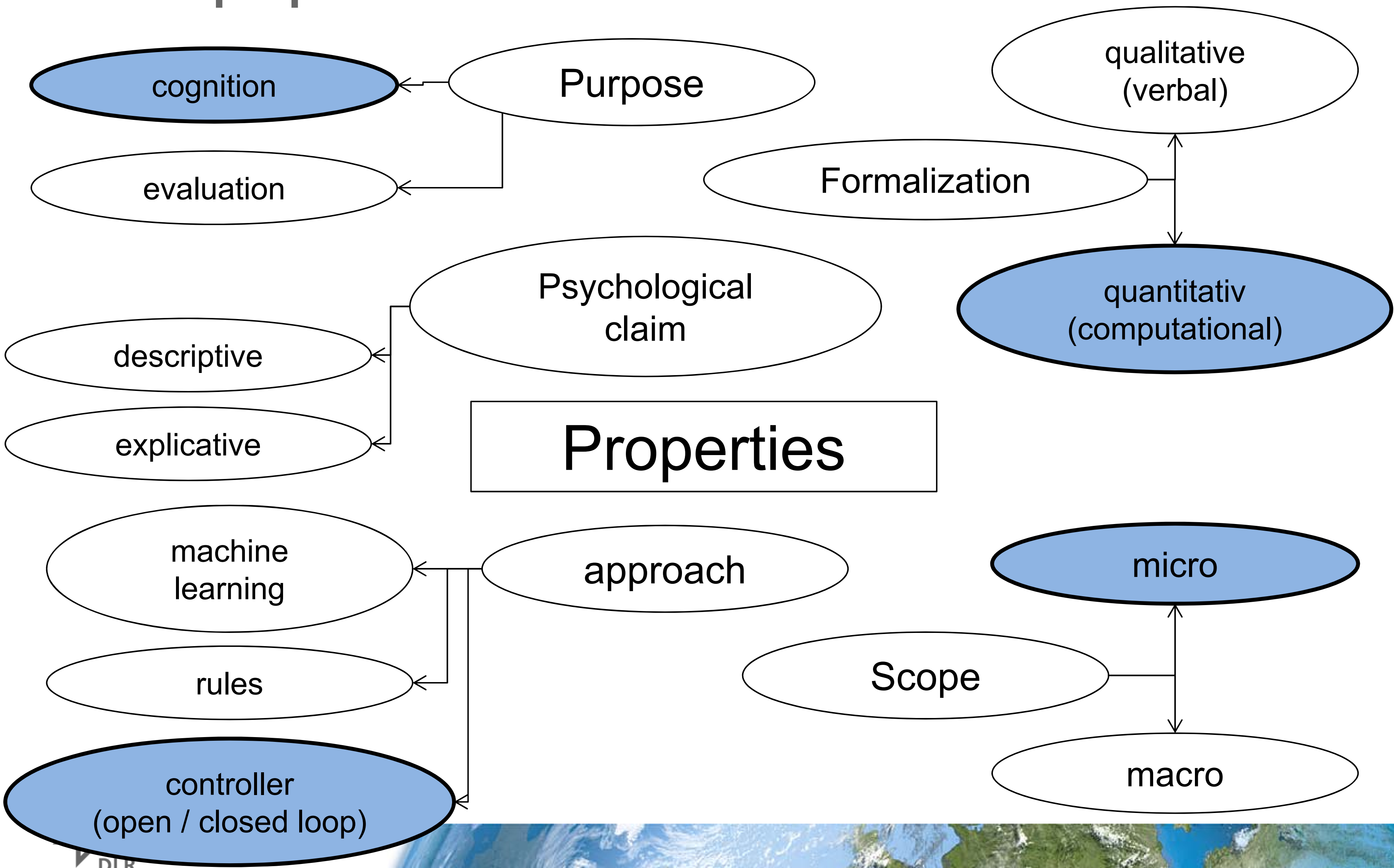
Some properties of driver models



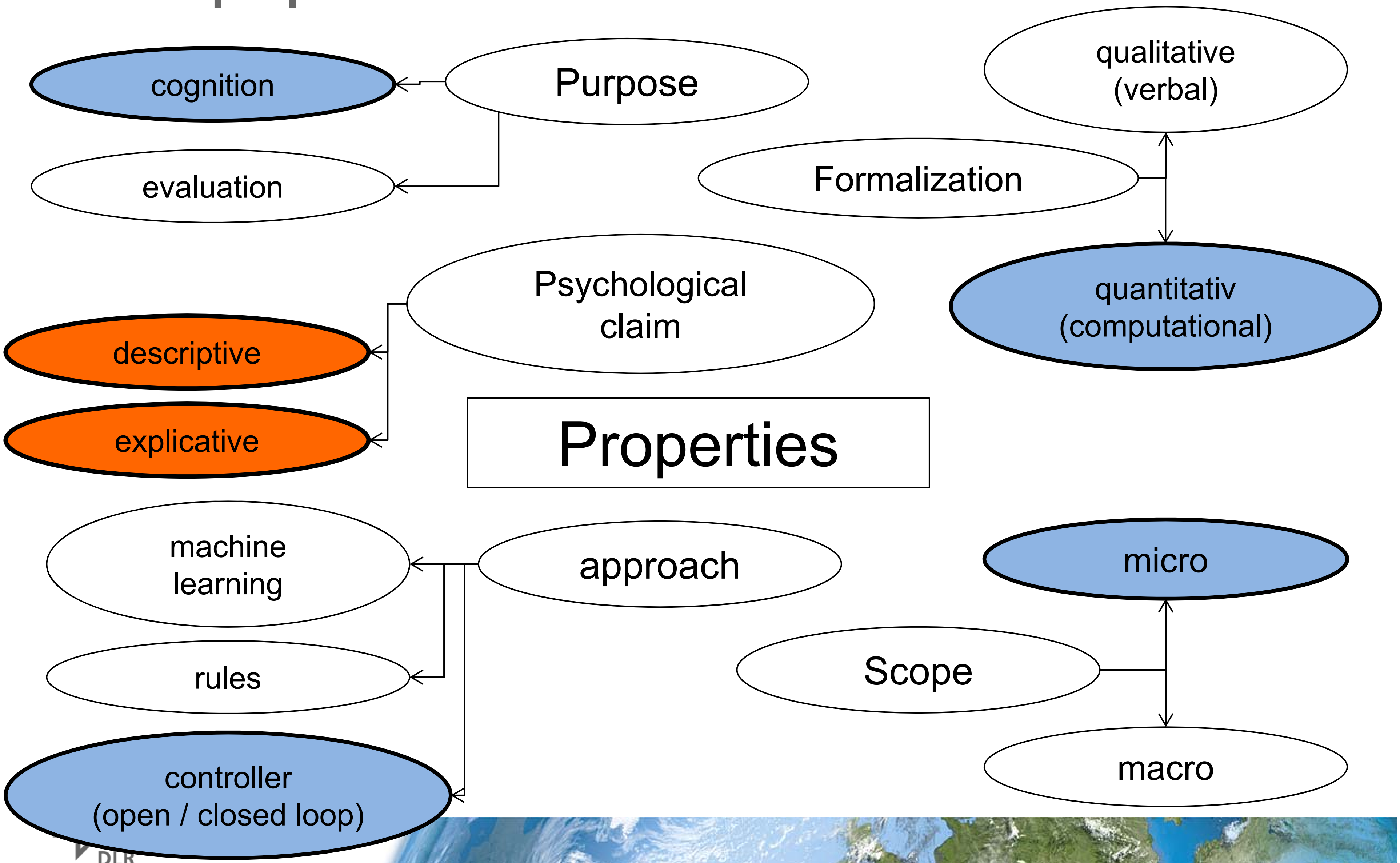
Some properties of driver models



Some properties of driver models



Some properties of driver models



Why modelling car following?

basic driving task

- essential for higher cognition driver models
- comparatively easy modelling of a driving task

extremely useful for design of assistance systems

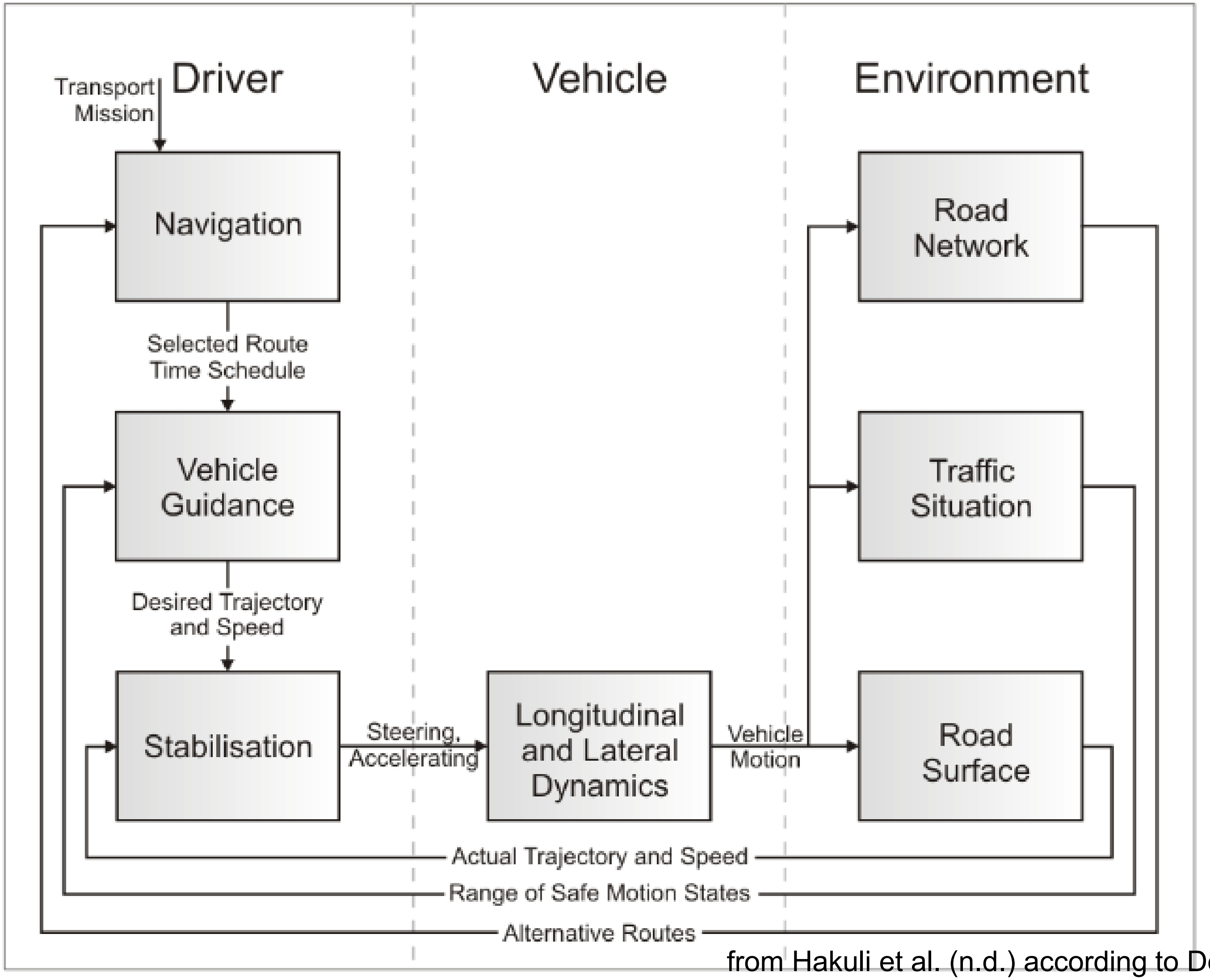
lacking so far

- good data on individual car-following behavior
- systematic evaluation of models on this data

we contribute to close that gap

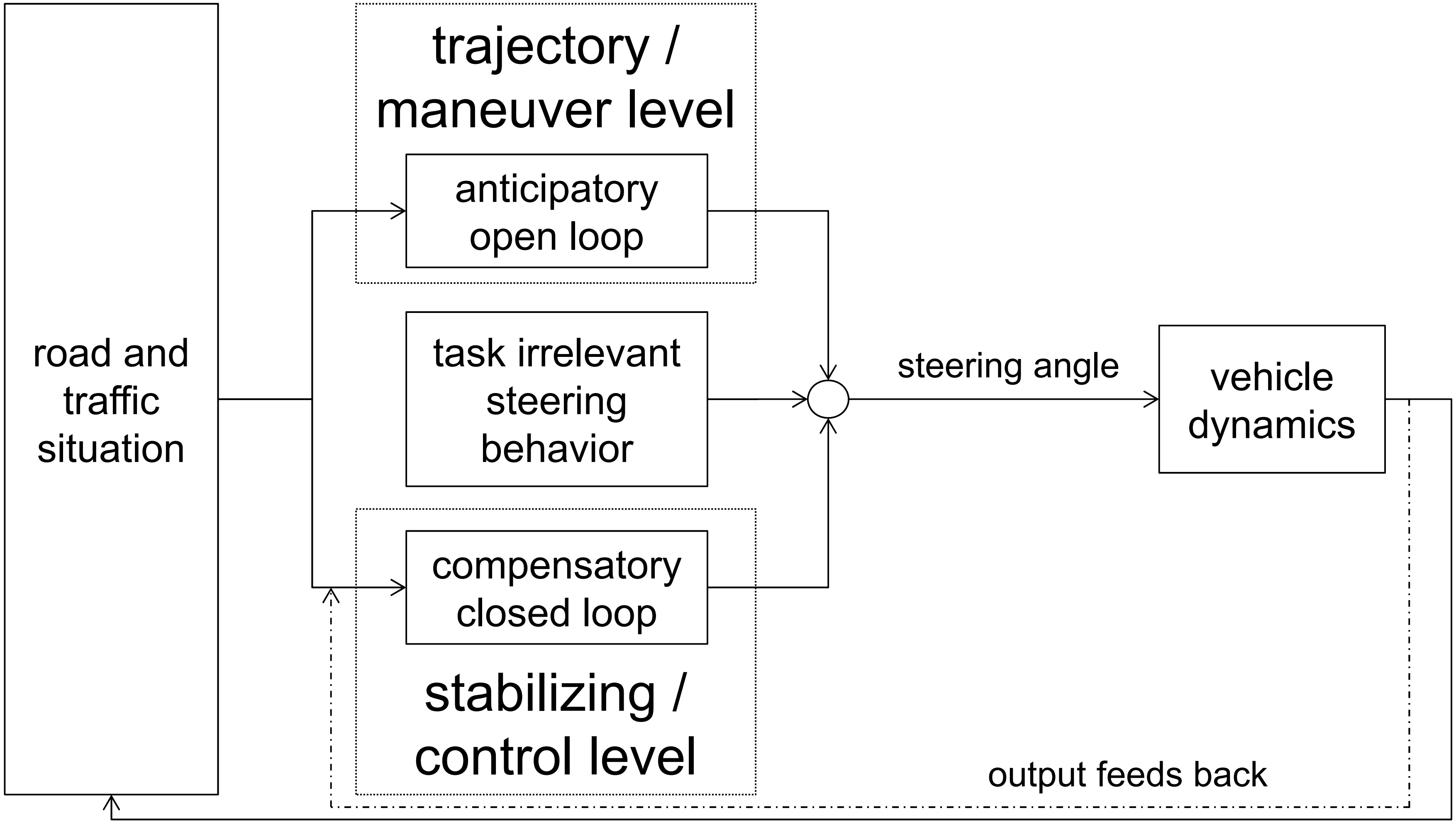
- data for individual drivers
- from real traffic with instrumented vehicle
- systematic variation of road type (city, highway, country)

Basic driving tasks



from Hakuli et al. (n.d.) according to Donges (1982)

Control level of driving



adapted from Donges (1978)

A very simple car following model

$$a_t = s\left(v_{VF_{t-T}} - v_{FF_{t-T}}\right)$$

with

$a(t) =$ acceleration at time t,

$v_{VF_{t-T}} =$ velocity lead vehicle one timestep ago,

$v_{FF_{t-T}} =$ velocity following vehicle one timestep ago,

$s =$ free parameter

Pipes (1953)

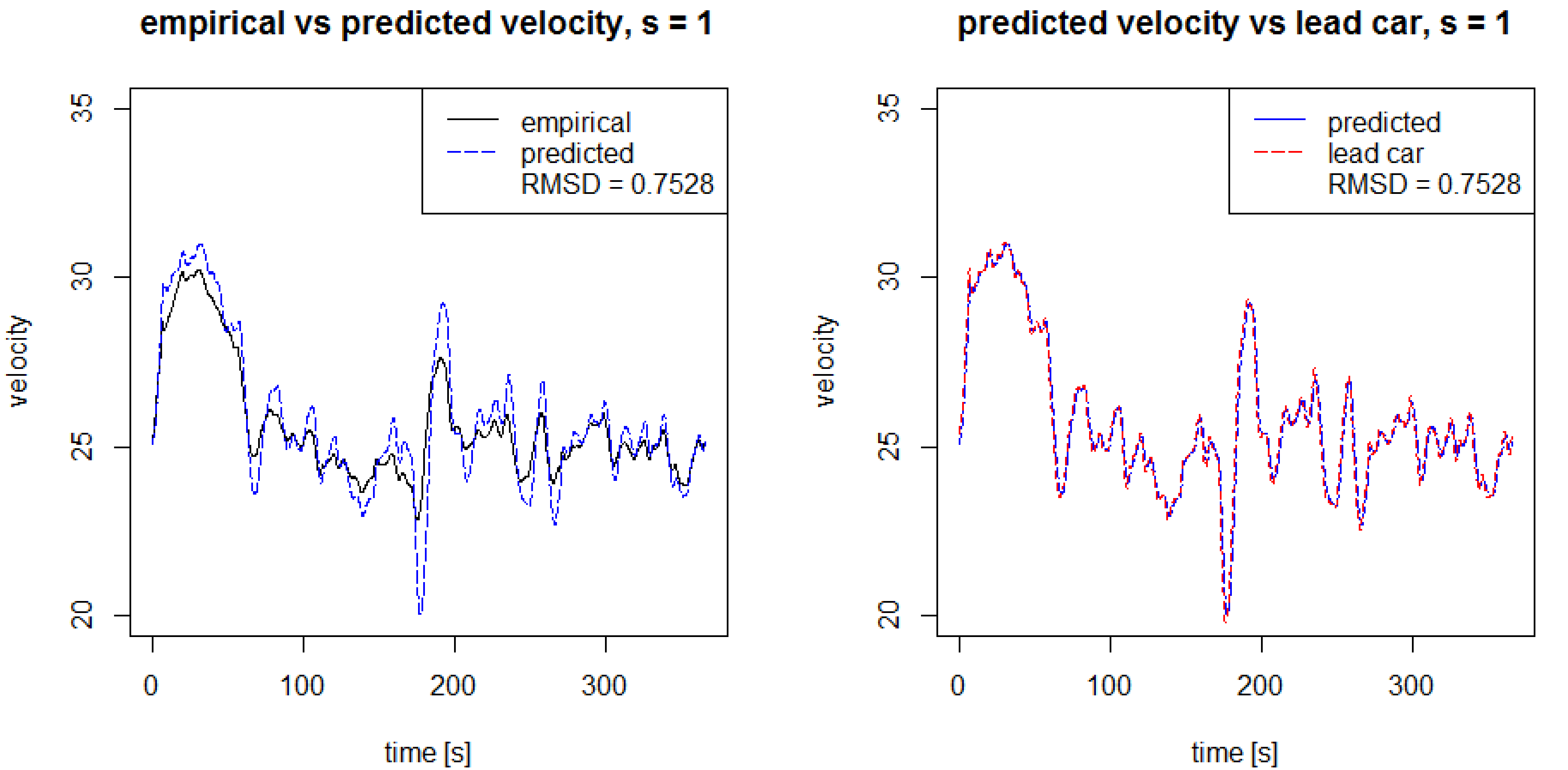
A very simple car following model

$$a_t = s\left(v_{VF_{t-T}} - v_{FF_{t-T}}\right)$$

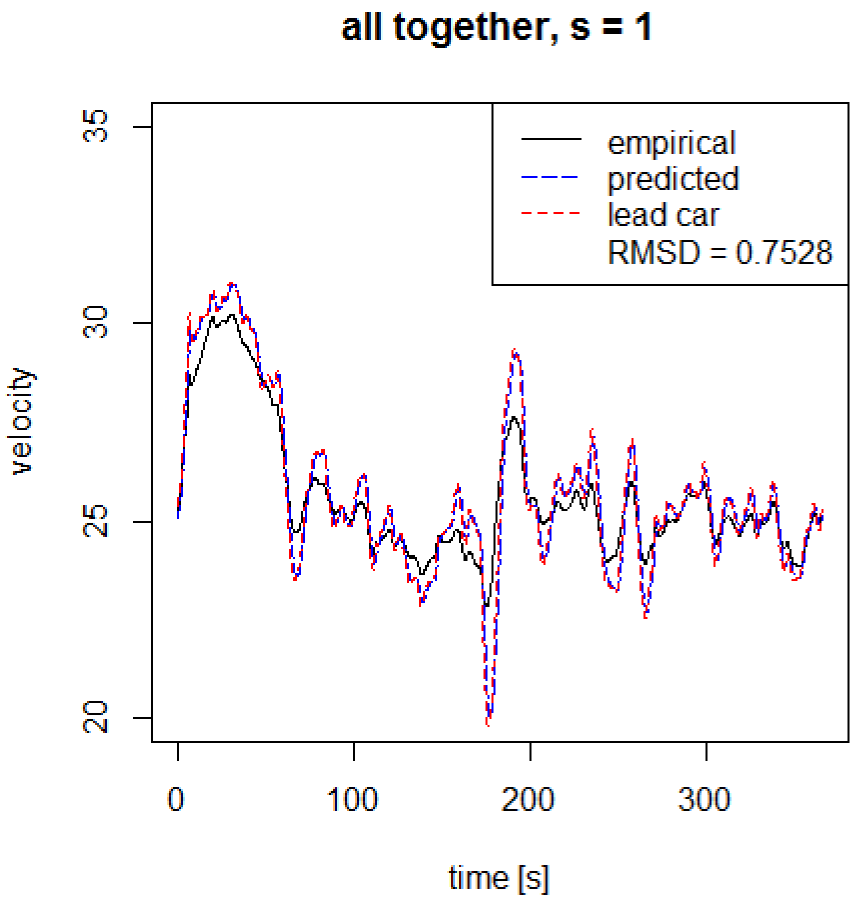
basic algorithm

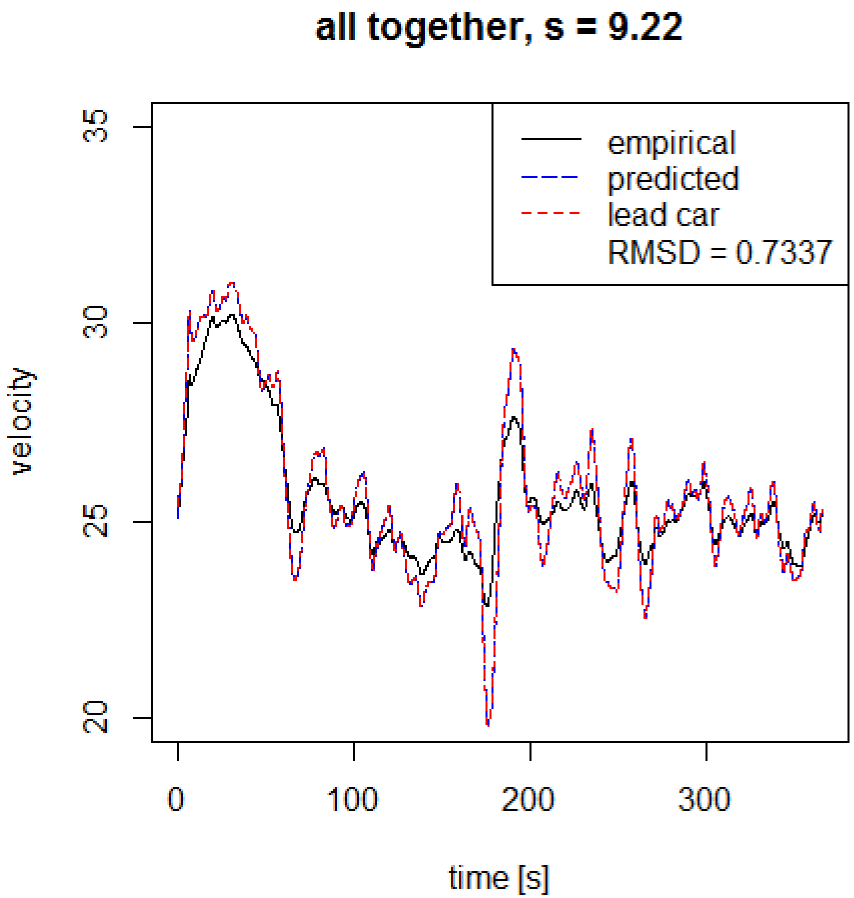
1. choose a start parameter for *s*
2. take values for leading vehicle from data
3. take first value for following vehicle from data
4. compute prediction for the next time step by using the predicted *a*
5. do so until the end of the vector
6. compute error metric
7. test next parameter, until the error metric is at a minimum

A very simple car following model



A very simple car following model





The Gipps model

$$v_{t+\tau} = b^{max} + \sqrt{(b^{max})^2 \cdot \tau^2 - b^{max} \cdot \left(2 \cdot [d_t + d^{min}] - v_{FF_t} \cdot \tau - \frac{v_{VF_t}^2}{b^{est}}\right)}$$

Gipps (1981)

with

b^{max} = most severe braking of the driver,

b^{est} = estimated braking of the leading vehicle,

d^{min} = safety distance,

d_t = velocity of leading vehicle at time t,

τ = apparent reaction time, a constant for all vehicles,

$v_{VF_{t-\tau}}$ = velocity lead vehicle one timestep ago,

$v_{FF_{t-\tau}}$ = velocity following vehicle one timestep ago

The Helly model

$$a_t = j \cdot (d_{t-T} - d'_t) + \ k \cdot (v_{VF_{t-T}} - v_{FF_{t-T}})$$

with

$d'_t = \ s + r \ \cdot v_{FF_t},$

$s =$ safety distance,

$v_{VF_{t-T}} =$ velocity lead vehicle one timestep ago,

$v_{FF_{t-T}} =$ velocity following vehicle one timestep ago,

$r =$ weight factor,

$T =$ time step

Helly (1959)

DLR

The Driving-by-Visual-Angle model

$$a_{t+1} = j \cdot \left(\frac{1}{\alpha_t} - \frac{1}{\alpha'} \right) + k \cdot \frac{d}{dt} a$$

with

$$\alpha' = 2 \cdot atan\left(\frac{w}{THW \cdot v_{FF_t}} \right)$$

and

α_t = visual angle,

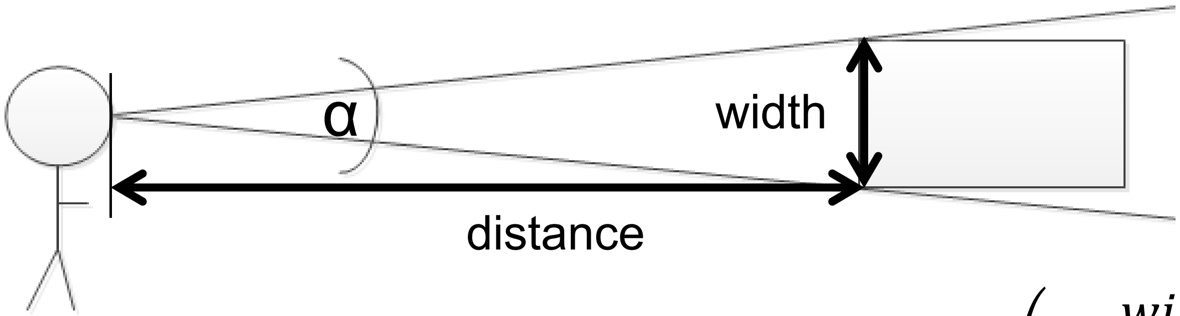
α' = desired visual angle,

w = width of lead car,

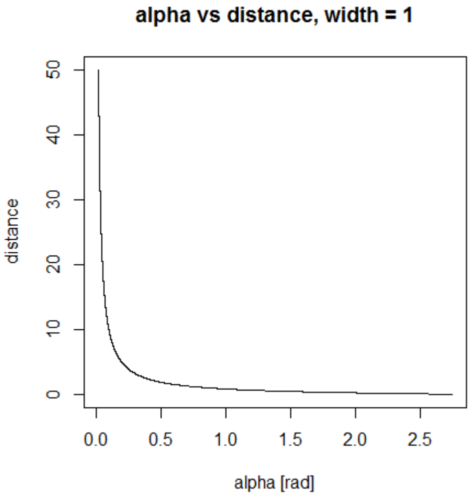
THW = timegap,

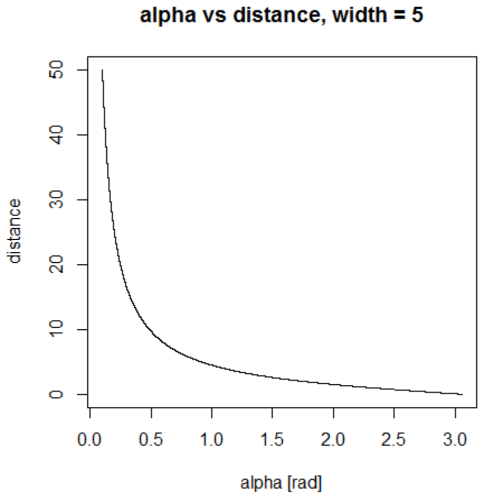
v_{FF_t} = velocity lead car

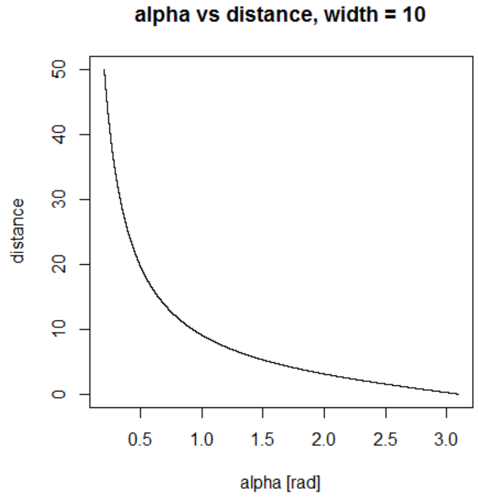
The Driving-by-Visual-Angle model



$$\alpha = 2 * \operatorname{atan}\left(\frac{width}{2 * distance}\right) \approx \frac{width}{distance}$$







Helly's model vs. DVA

Helly

$$a_{t+1} = j(d_t - d'_t) + k(v_{LV_t} - v_{FV_t})$$

DVA

$$a_{t+1} = j\left(\frac{1}{\alpha_t} - \frac{1}{\alpha'_t}\right) + k\,\frac{d}{dt}\alpha$$

$$= j\,\frac{1}{w}(d_t - d'_t) + (-k)\left(w\left(\frac{d_{t-1} - d_t}{d_t^2}\right)\right)$$

Validation methods

driving simulator: often sinusoidal speed profiles

- disadvantage: might be too artificial

real driving data: cameras, induction loops etc.

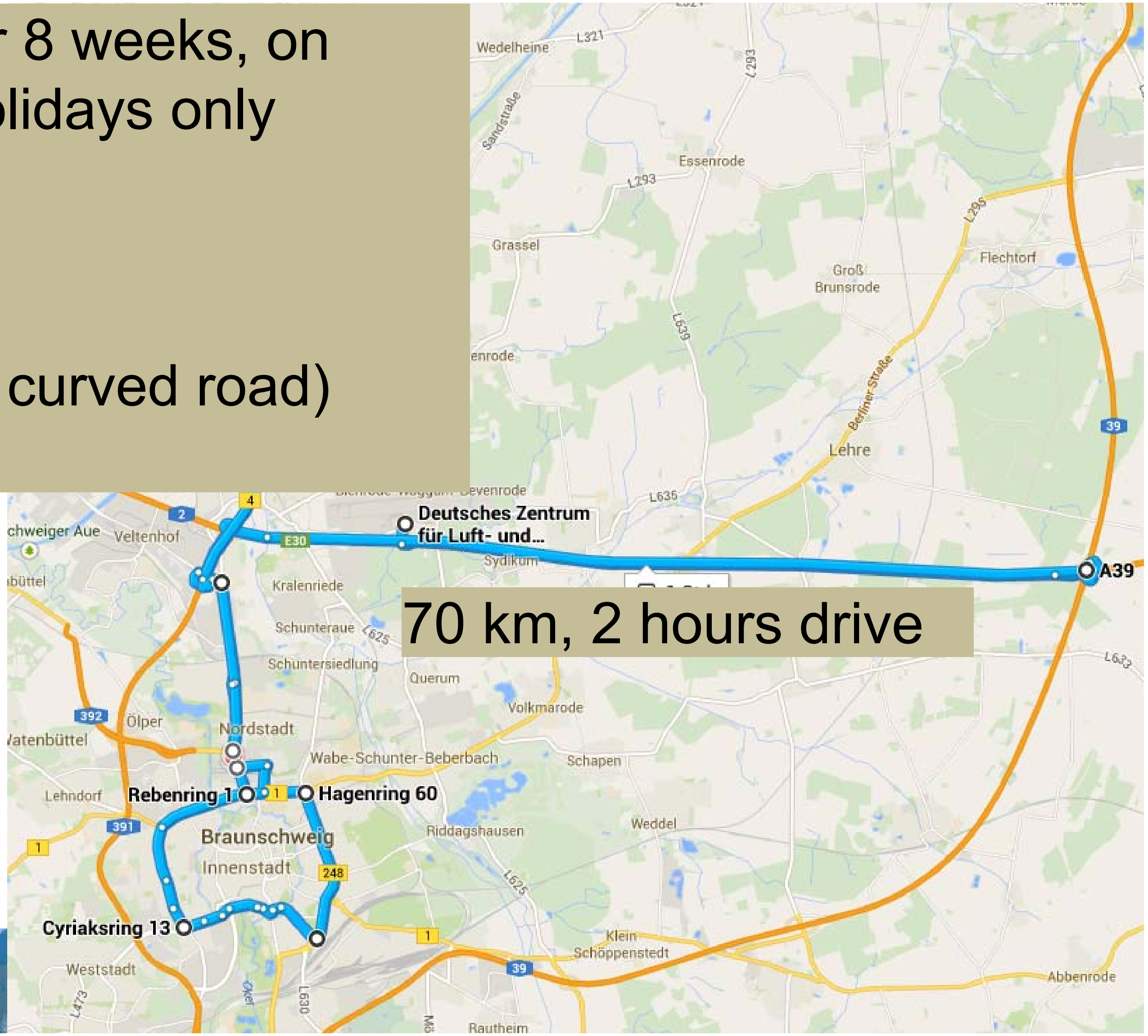
- disadvantage: dirty data, absolutely no control over situation

Methods

12 participants over 8 weeks, on Sundays / public holidays only

road types:

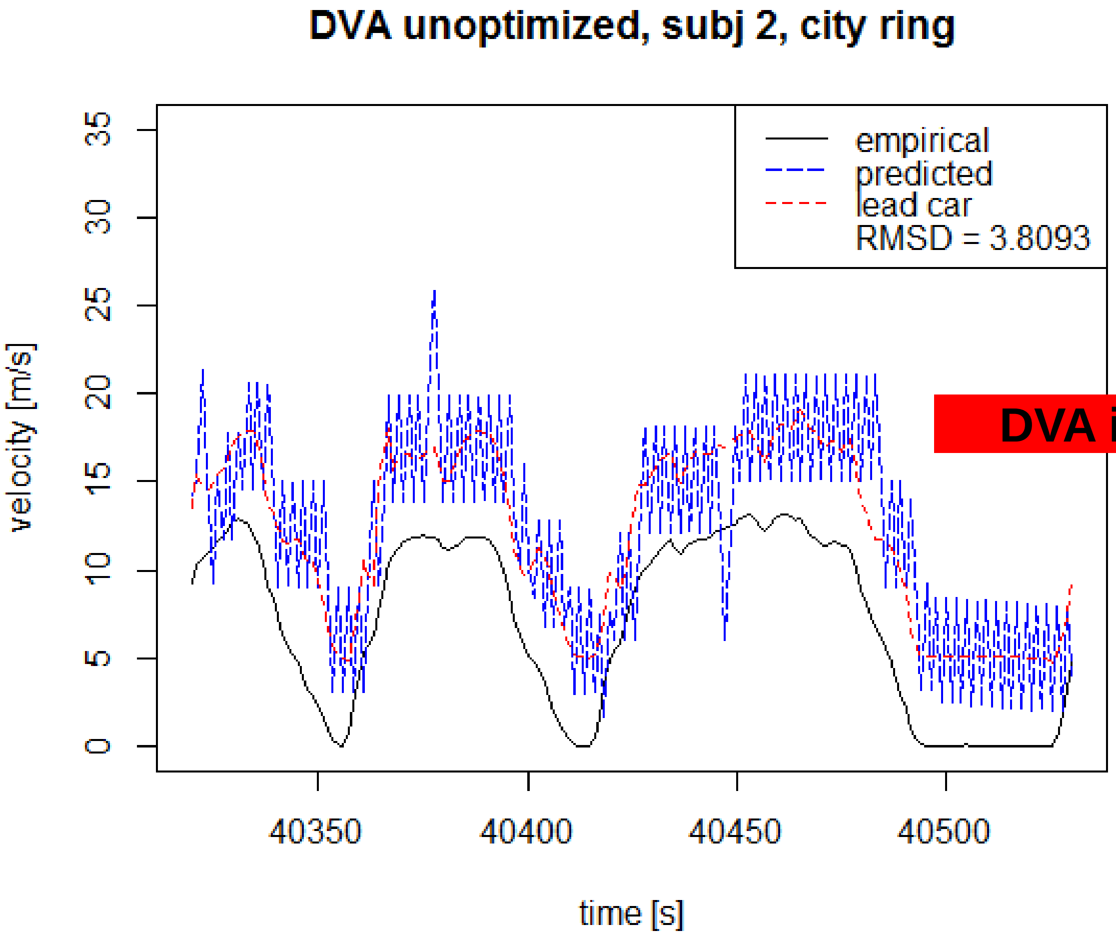
- highway
- city (straight and curved road)
- country



70 km, 2 hours drive

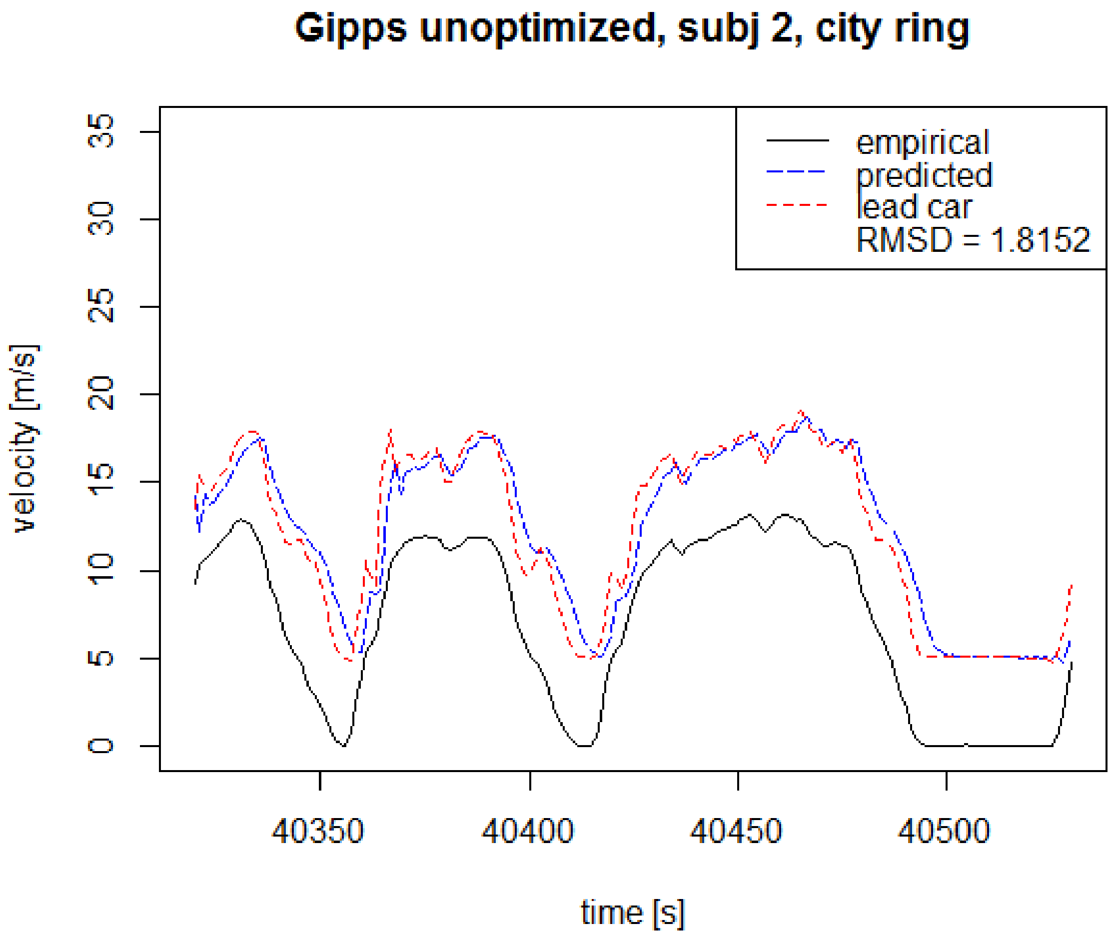
Methods

Predictions unoptimized

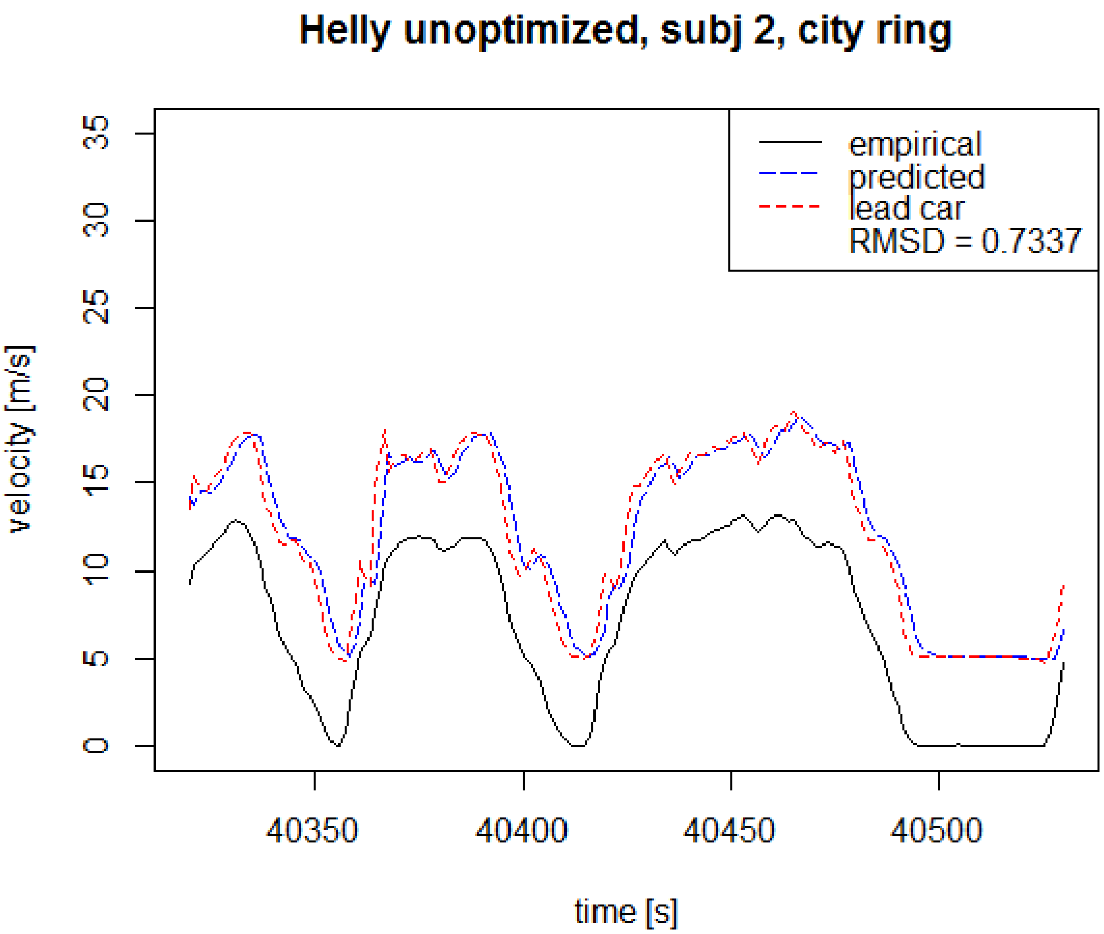


DVA is unstable!

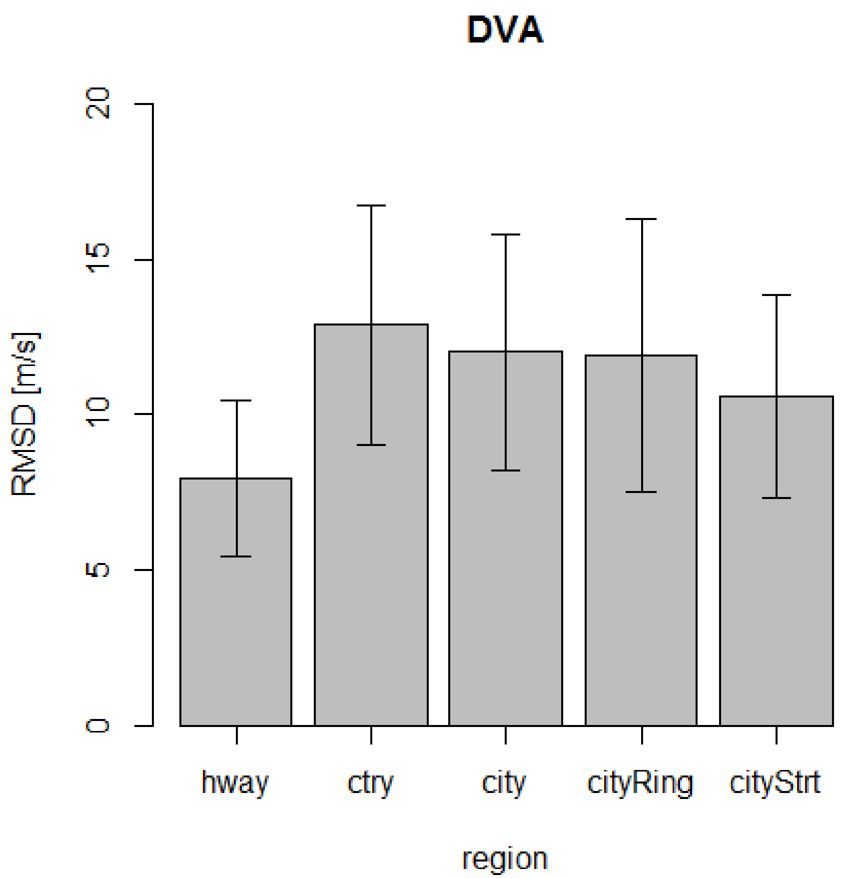
Predictions unoptimized

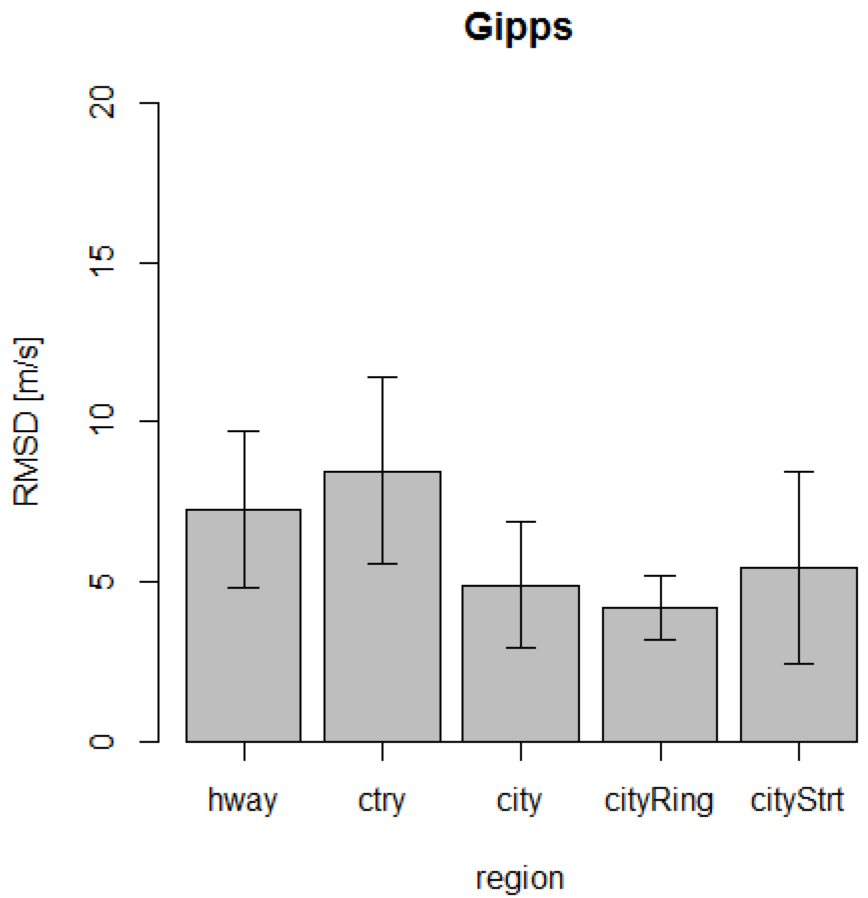


Predictions unoptimized

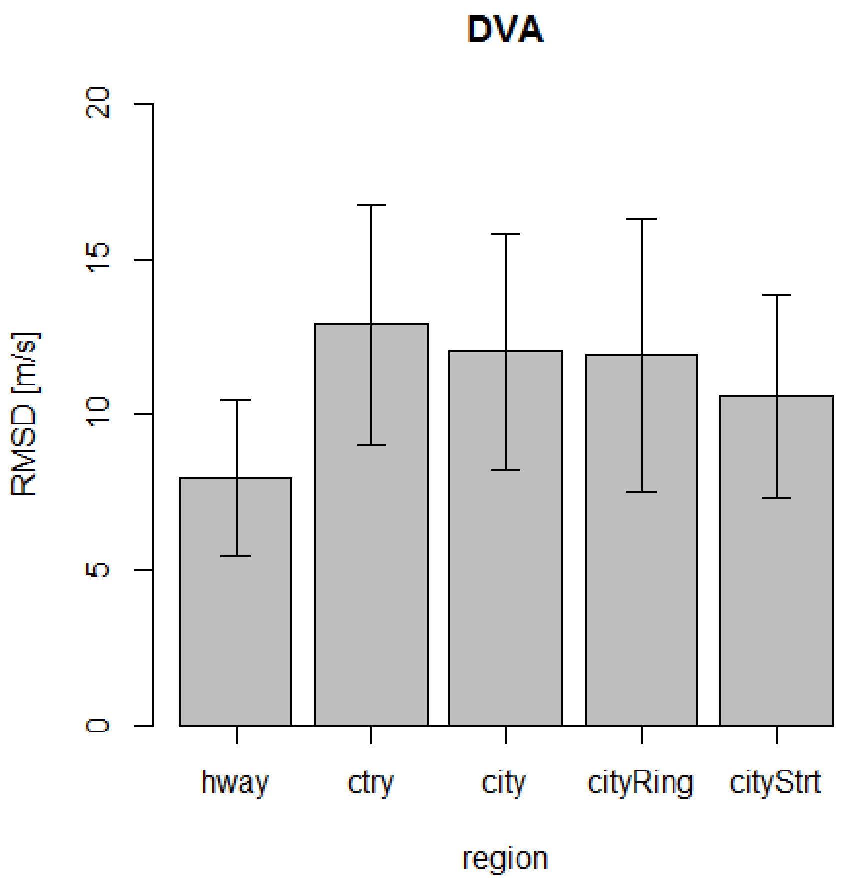


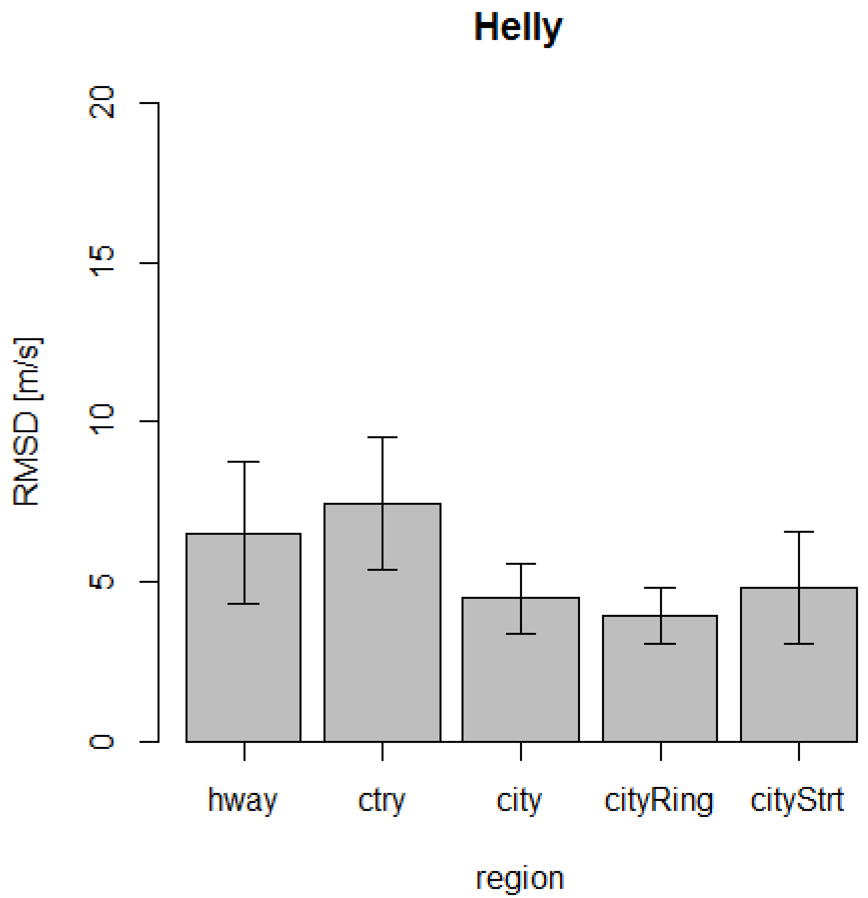
Results constrained, distance





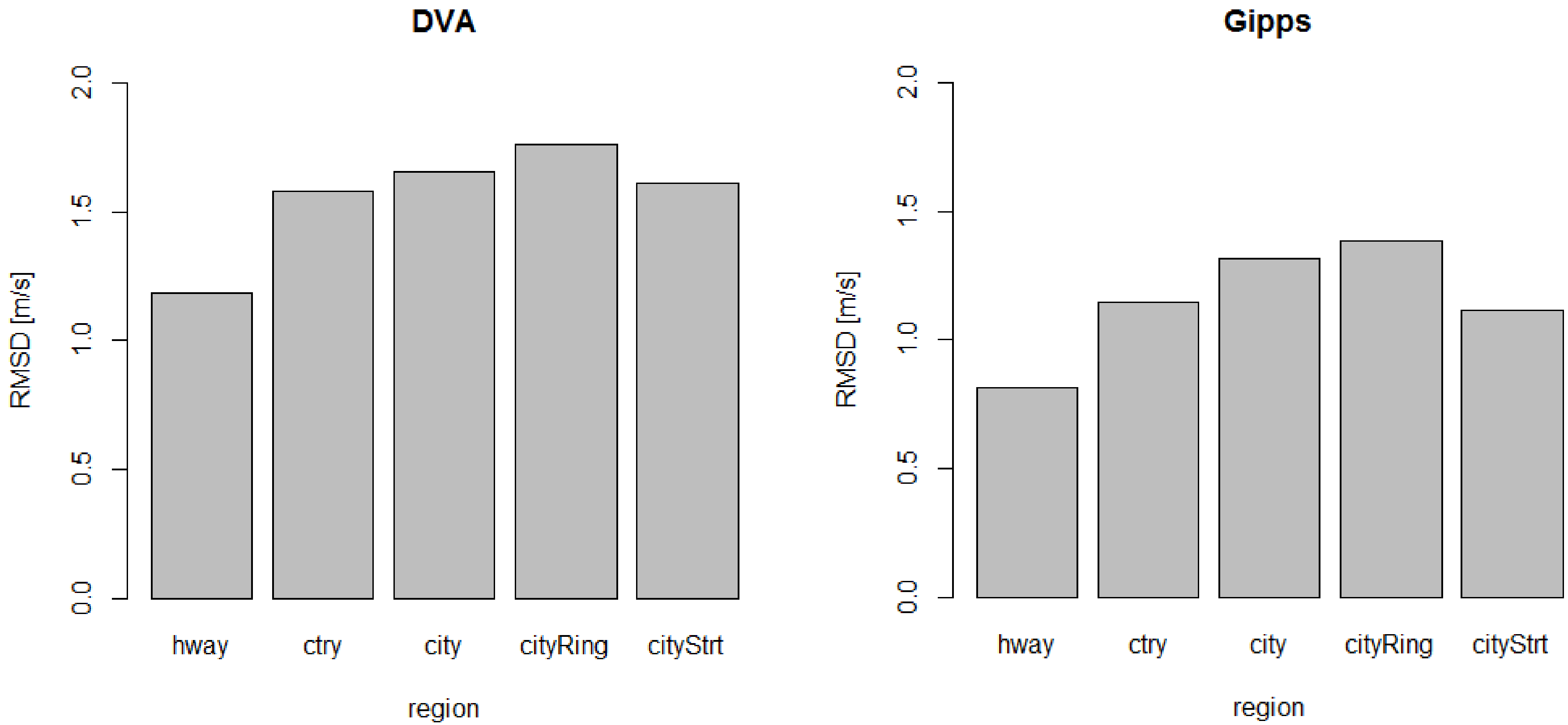
Results constrained, distance



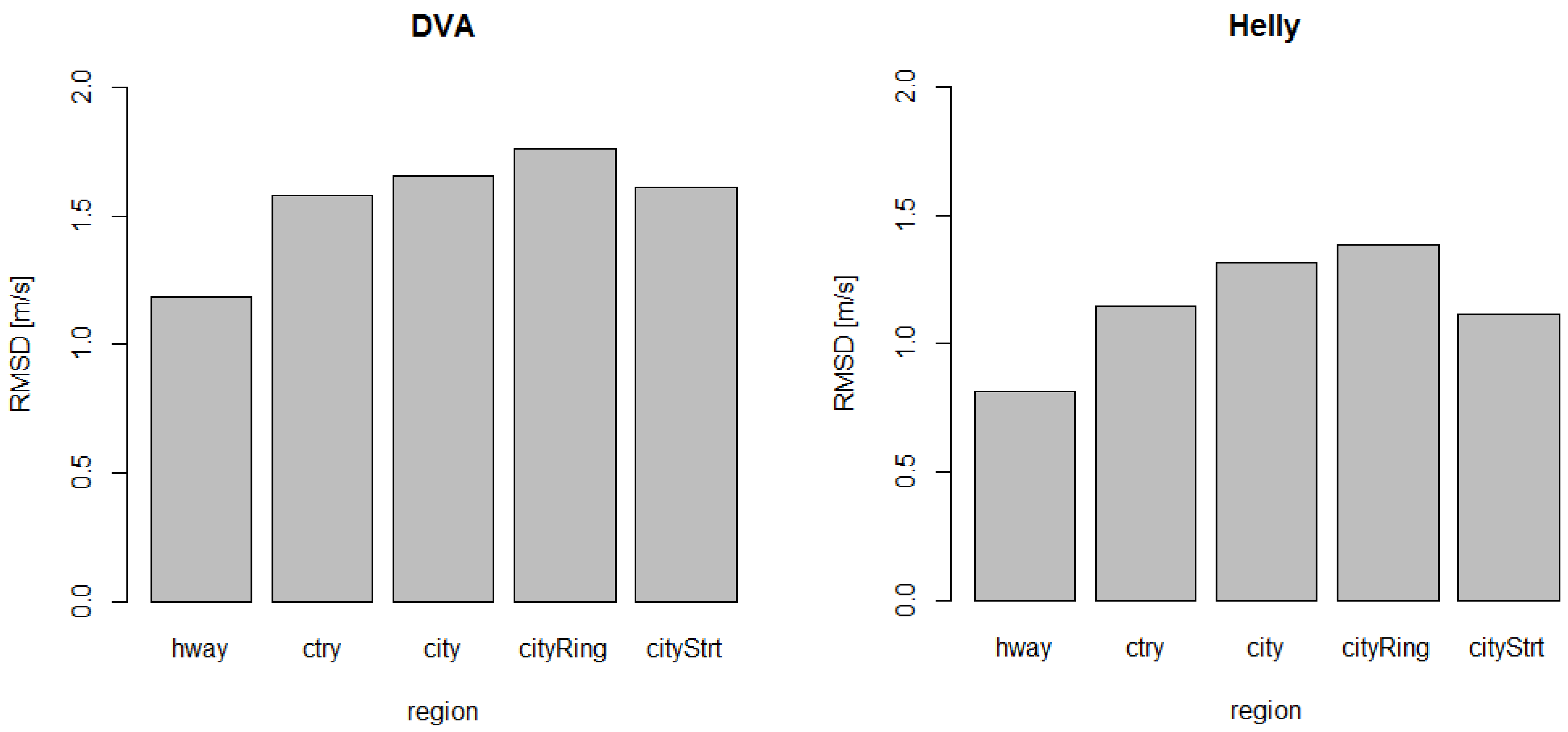


DLR

Results unconstrained, speed



Results unconstrained, speed



Discussion

DVA does not hold its promises

- a few psychophysical additions doesn’t make it psychologically plausible!
- unstable controller?

degree of psychology in car following controllers

- non-trivial question
- depends a lot on handling of parameters

interaction of parameters and optimization algorithm

- some algorithms are more sensitive to starting parameters than others

Outlook and Lessons Learned

systematic evaluation

- more models
- different driving simulators
- possibly new data collection in the field with better sensors

parameter

- other optimization algorithms
- windowing
- maximum likelihood methods
- bootstrapping
- grid search

more computational power / less precision

- more efficient code
- cluster
- less optimized parameters

Literature

Andersen, George J.; Sauer, C. W. (2007): Optical Information for Car Following: The Driving by Visual Angle (DVA) Model. In: *Human Factors* 49 (5), S. 878–896. DOI: 10.1518/001872007X230235.

Carsten, Oliver (2007): From Driver Models To Modelling The Driver: What Do We Really Need To Know About The Driver. In: Pietro Carlo Cacciabue (Hg.): Modelling Driver Behavior In Automotive Environments. Critical Issues in Driver Interactions with Intelligen Transport Systems. London: Springer, S. 105–120.

Donges, Edmund (1978): Ein regelungstechnisches Zwei-Ebenen-Modell des menschlichen Lenkverhaltens im Kraftfahrzeug. In: *Zeitschrift für Verkehrssicherheit* 24 (3), S. 98–112.

Gipps, P.G (1981): A behavioural car-following model for computer simulation. In: *Transportation Research Part B: Methodological* 15 (2), S. 105–111. DOI: 10.1016/0191-2615(81)90037-0.

Hakuli, Stephan; Schreiber, Michael; Winner, Hermann (2009): Entwicklung eines Methodenkatalogs für manöverbasiertes Fahren nach dem Conduct-by-Wire-Prinzip. Ein Fahrerassistenzkonzept auf Bahnführungsebene. Automobiltechnisches Kolloquium, 2009.

Helly, W. (1959). Simulation of Bottlenecks in Single Lane Tracffic Flow. In Proceedings of the Symposium on Theory of Tracffic Flow., Research Laboratories, General Motors (pp. 207±238). New York: Elsevier .

Salvucci, Dario D. (2005): Modeling Driver Behavior in a Cognitive Architecture. In: *Human Factors*.

Soria, Irene; Elefteriadou, Lily; Kondyli, Alexandra (2014): Assessment of car-following models by driver type and under different traffic, weather conditions using data from an instrumented vehicle. In: *Simulation Modelling Practice and Theory* 40, S. 208–220. DOI: 10.1016/j.simpat.2013.10.002.