Complex Socio-Technical Systems

ESRC Complexity Research Seminar 6
LSE

July 8, 2010
London, England

Alois Ferscha
(with Andreas Riener, Kashi Zia and Alexei Sharpanskykh)

(supported by the EC under grant SOCIONICAL and OPPORTUNITY)

Univ. Prof. Dr. Alois Ferscha
Universität Linz, Institut für Pervasive Computing
Altenberger Straße 69, A-4040 Linz
ferscha@soft.uni-linz.ac.at

Motivation: Complex Systems

[source unknown]

What is a complex systems?

*"... a **dynamic network** of **many** agents (which may represent cells, species, individuals, rms, nations) **acting in parallel**, constantly **acting and reacting** to what the other agents are doing where the control tends to be **highly dispersed** and **decentralized**, and if there is to be any coherent behavior in the system, it has to arise from **competition** and **cooperation** among the agents, so that the overall behavior of the system is the result of a **huge number** of **decisions made every moment** by **many individual** agents.".*

[Castellani, B., Haerty, F.W.: Sociology and Complexity Science. Springer Verlag, 2009]

Motivation: Complex Systems

Complex adaptive systems:

[source unknown]

(i) the ***number of elements*** (or part) and the relations among them are ***non-trivial*** (or non-linear), and/or

(ii) the system has ***memory*** or ***feedback***, and/or

(iii) the ***relations*** between the system and its environment are ***non-trivial*** (or non-linear), and/or

(iv) the system can be ***influenced*** by, or can ***adapt*** itself to a situation or the environment, and/or

(v) the system is highly sensitive to initial conditions.

Alois Ferscha

Challenge: AmI Technology influenced Complex Systems

[Continental, 2010]

Observations from Automotive Domain:

“Man-made”- driving has changed

(i) from ***pure mechanical*** (steering, accelerating, breaking, shifting, etc.) to ***“computer controlled”*** (ESP, DC, DSG, DBW, etc.)

(ii) from ***pure driving*** to ***safety, comfort, navigation, traffic management, road pricing, entertainment, experiencing***, …

(iii) from ***primary tasks*** (vehicle steering) to ***secondary, tertiary tasks*** (dashboard functions, entertainment, communication, Internet, …),

(iv) from ***explicit*** to ***implicit*** interaction …

Example for a Complex Socio-Technical System (CS-TS):

Ubiquitous GPS-based Navigation

“Make a U-Turn if Possible…”

Accident in Strenger Tunnel, February 7th, 2010

- tourists travel on S16 motorway in the Tyrol (Austria) towards the “Arlberg” on Feb. 7, 2010
- missed the exit ramp “Pians/Paznauntal” and entered on their way the 7km long “Strenger tunnel”
- car navigation system recommends:

  “make a U-turn if possible ..”
  - driver trusts and turns car in the tunnel !!!
  - soon after, driver recognizes his mistake and turns car once again !!!

    (surveillance cameras tape the accident)
- fortunately, nobody injured

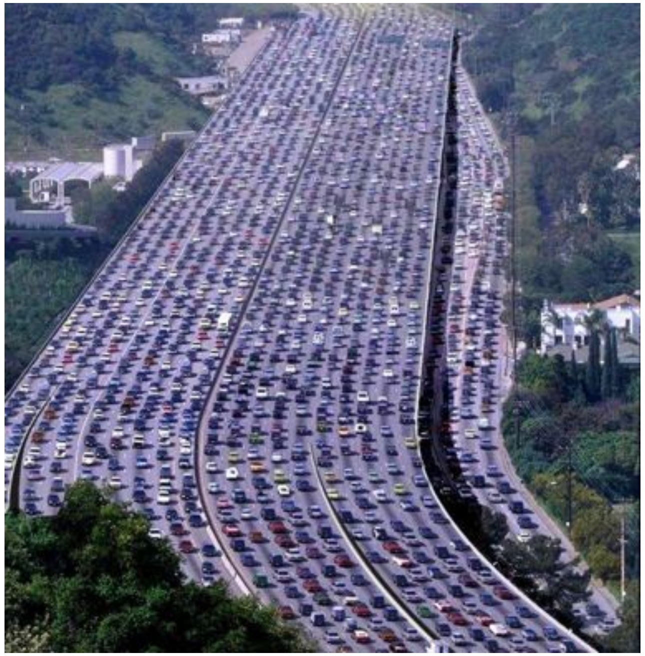
- police later reported that such accidents have happened already several times on this road segment (!)

> AmI Technology changes behaviour at the microlevel of a CS-TS

Example for a Complex Socio-Technical System:

Ubiquitous GPS-based Navigation

"Traffic Jam shifting due to deterministic re-routing…"



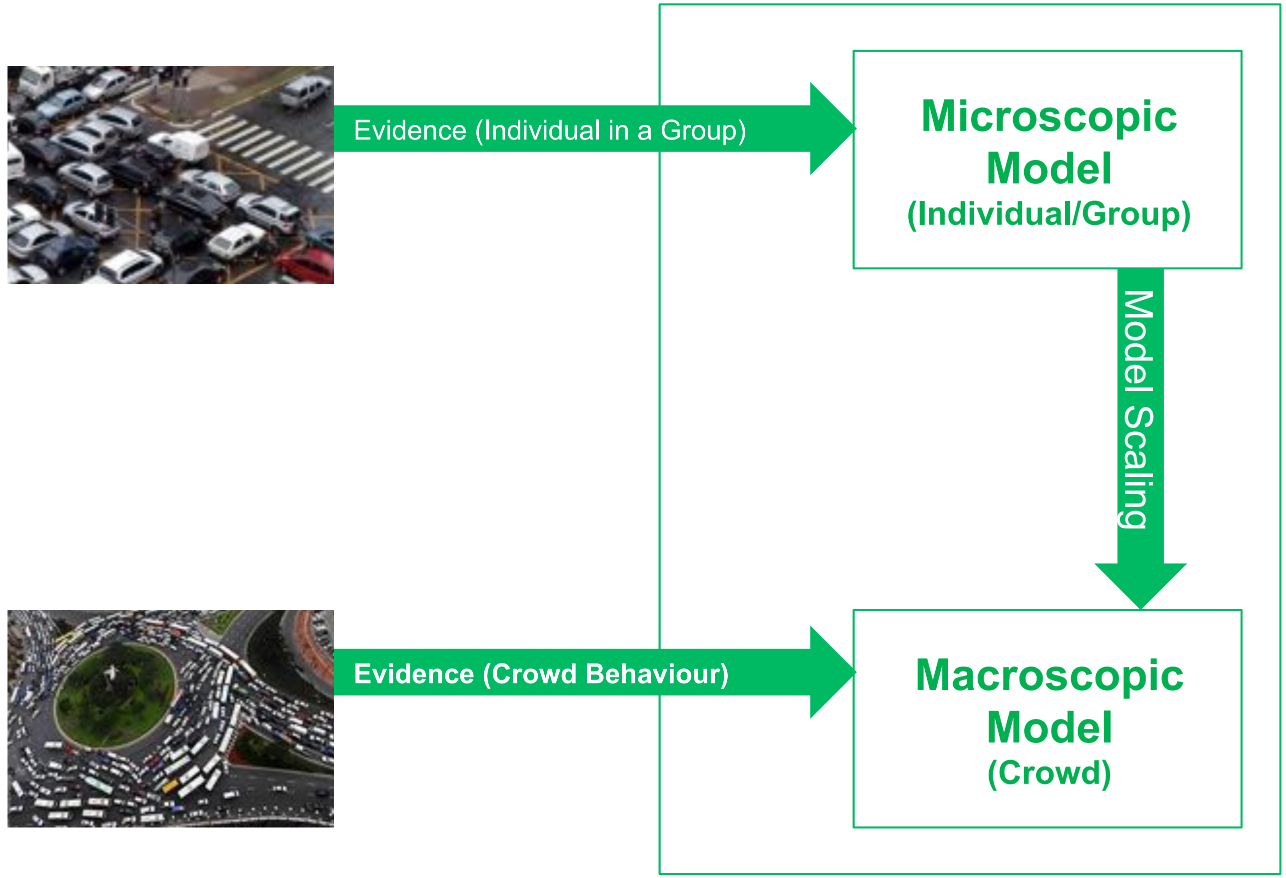
> AmI Technology causing effect at the macroscopic level of a CS-TS

SOCIONICAL: Scenario-Based Multiscale/Multiaspect Modelling

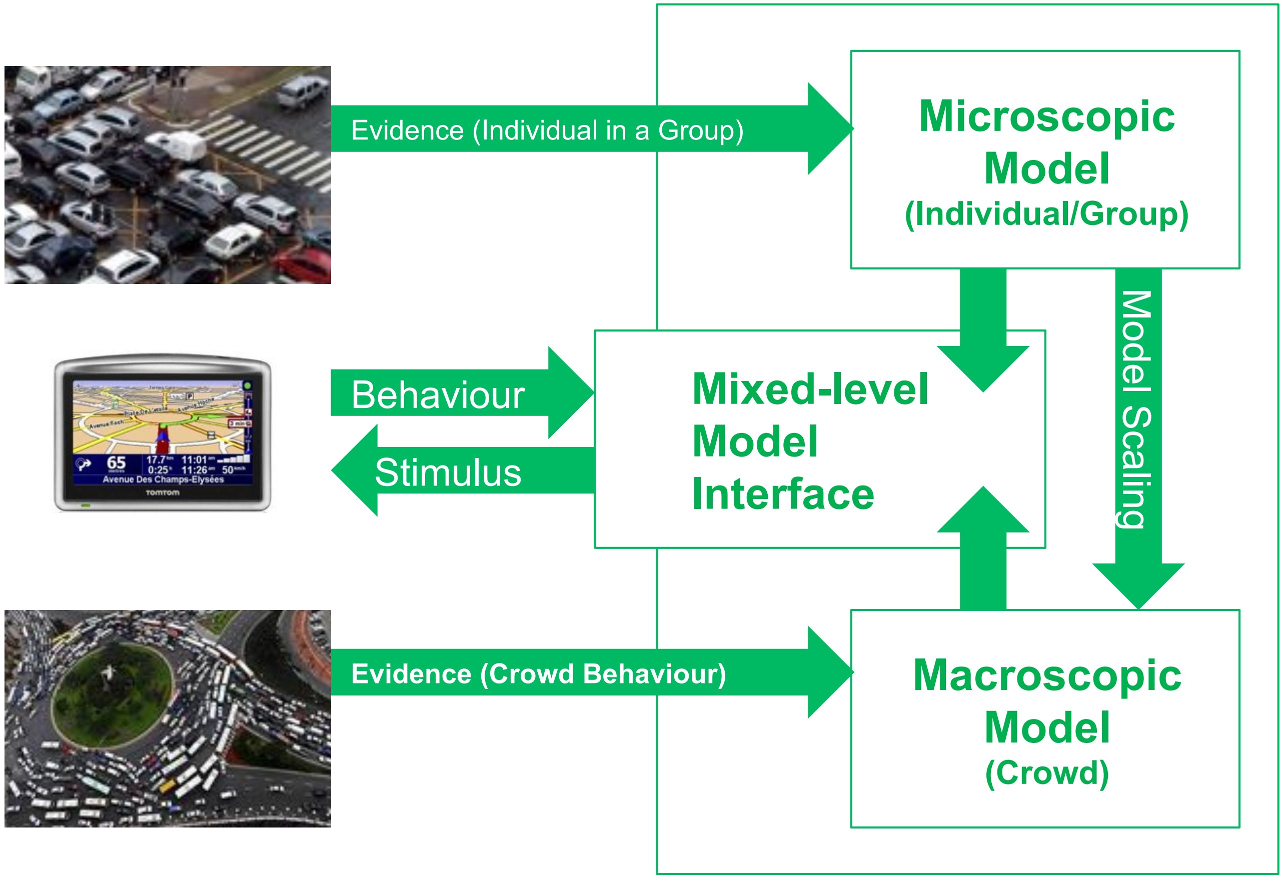
Evidence (Individual in a Group)

Microscopic Model
(Individual/Group)

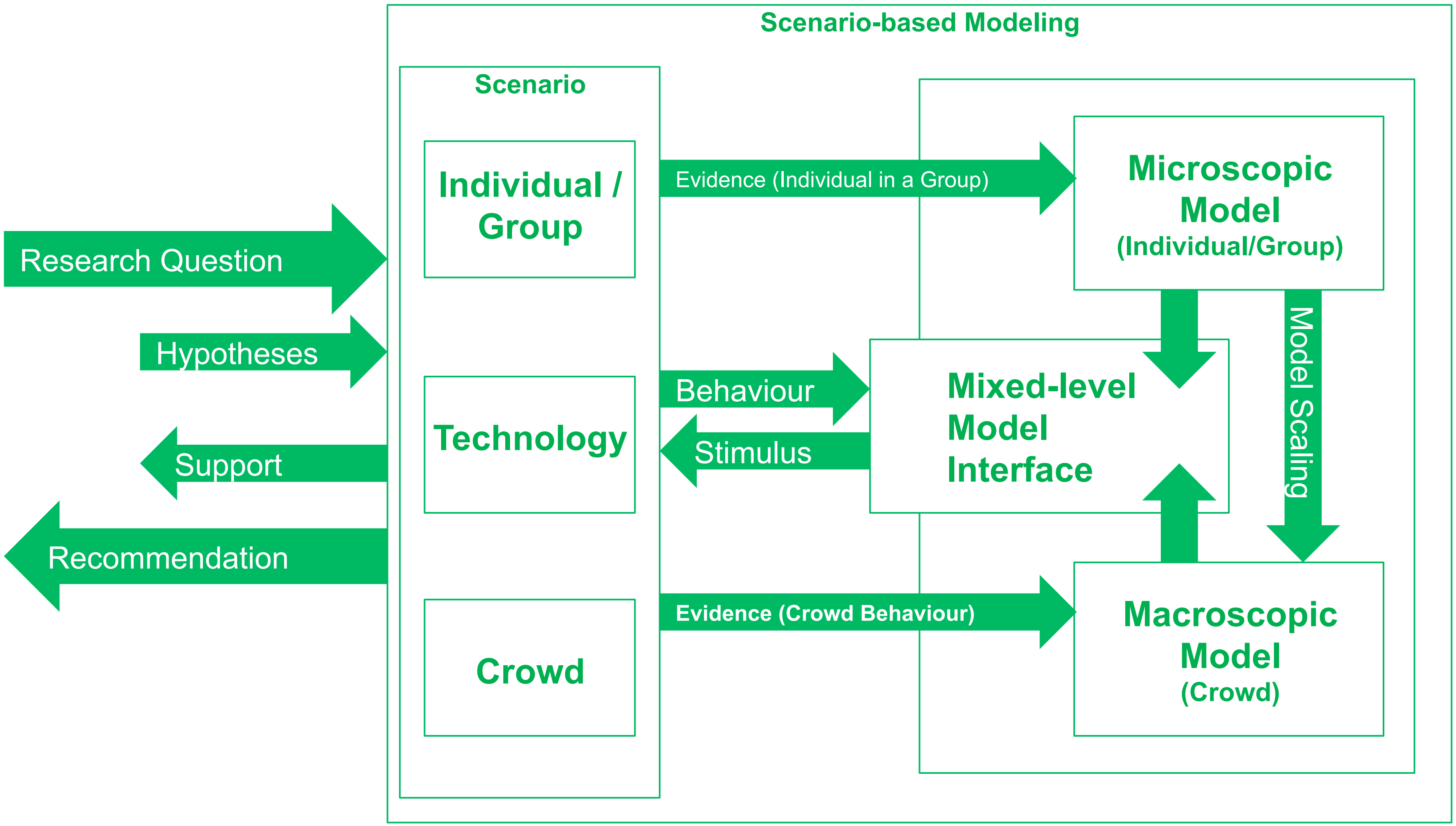
SOCIONICAL: Scenario-Based Multiscale/Multiaspect Modelling



SOCIONICAL: Scenario-Based Multiscale/Multiaspect Modelling



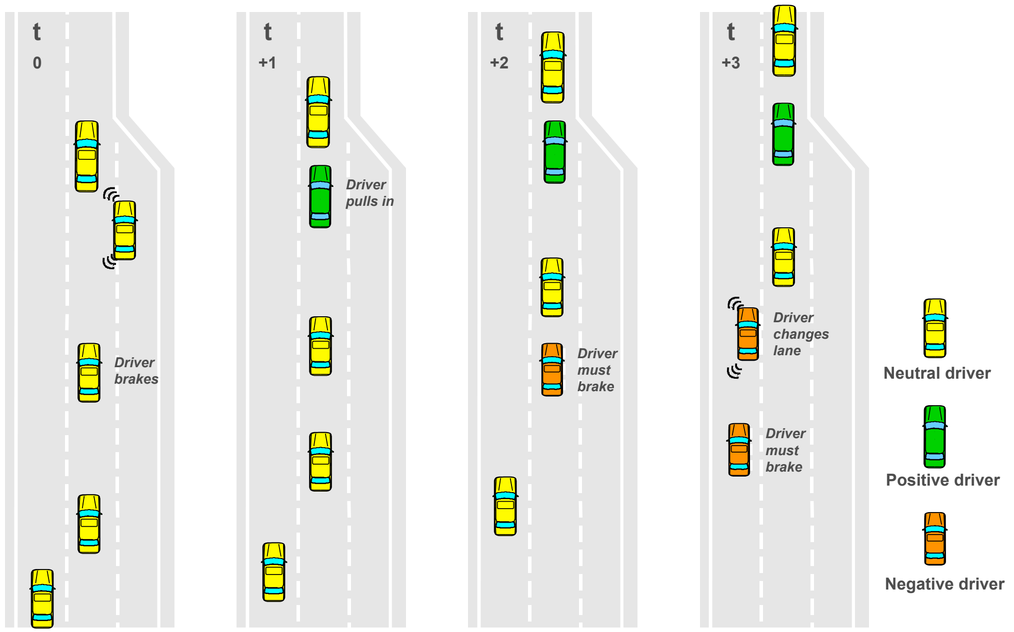
SOCIONICAL: Scenario-Based Multiscale/Multiaspect Modelling



Example: Research Question / Hypothesis

“Perceiving the driving style of other drivers, influences the emotional state and hence driving style of the observer …

Case: Merging Lanes



[SOCIONICAL IZVW 2010]

SOCIONICAL Approach: Modelling Feedback Loops

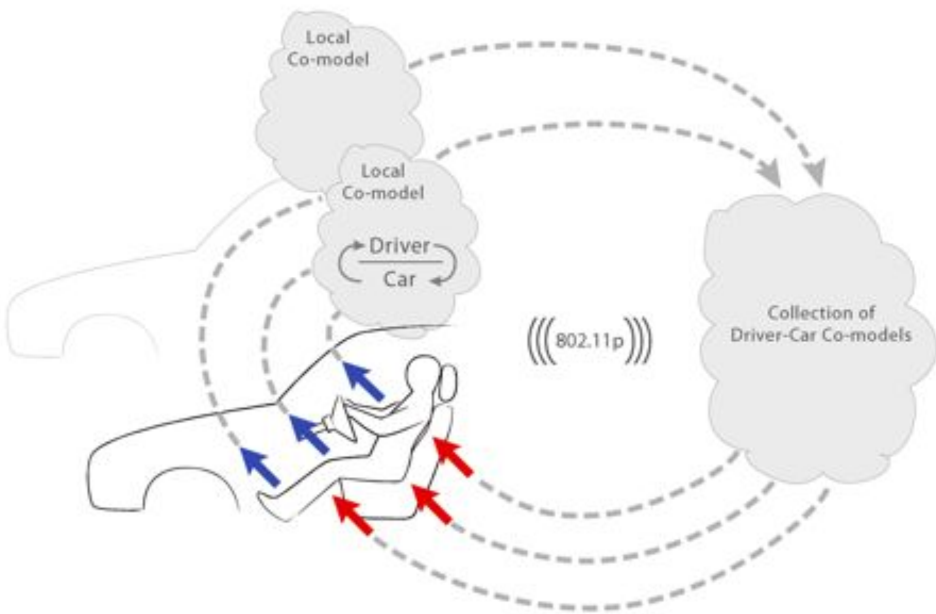
Modelling Feedback Loops: "Collective Driver-Vehicle Co-models (CDVC)"

- Local „Emotional“ (Vital) State Recognition
- Sharing „Emotions“ among drivers (while driving)
- Observe/Assess global behavior (Collective Driver-Vehicle Co-Model)

Pervasive adaptation is adaptation that happens seamlessly and further affects the humans and their surroundings, forming a "closed driver-car loop control".

- **Context-aware, context-sensitive interaction**
- **Natural interfaces**
- **Implicit interaction/interfaces**
- **"Experience tracking„**

[Nikola B. Serbedzija, 2008]

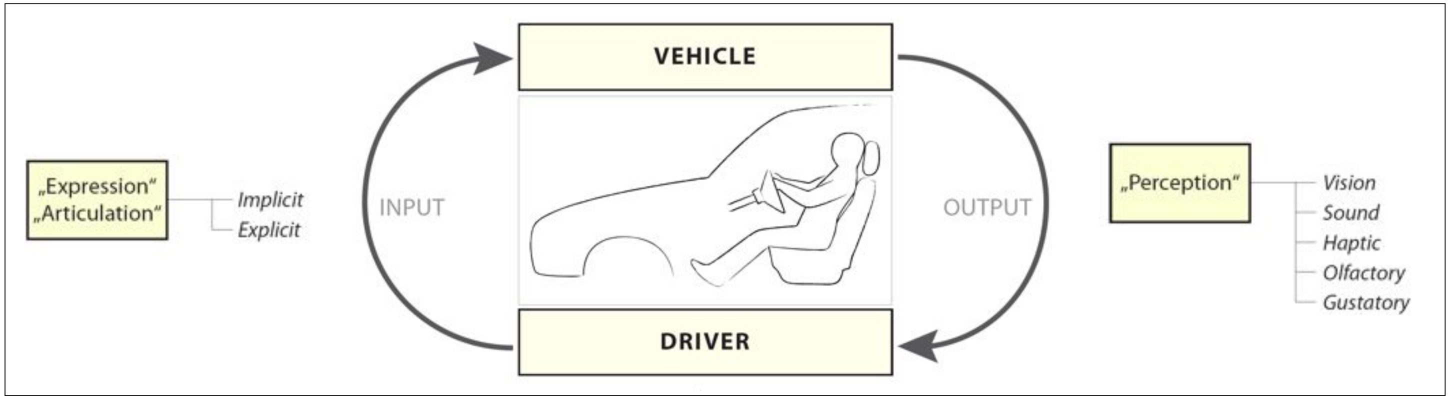


A collective Driver-Vehicle Co-model is built from local DVC-models

Driver-Vehicle Co-Model

Significant advances in in-car interaction technologies

Driver-Vehicle Interaction



Output: Uni- or Multimodal feedback from the system to the user.

Input: User reacts on stimuli or interacts with a device or application (submit control actions toward the system).

Vital / Emotional State Recognition

From physical sensing to vital / emotional context

Motion
- Acceleration
- Rotation
- Speed

Strain

Pressure

Electricity

Distance

Humidity

Magnetism

Sound
- Frequency
- Volume

Radiation

Vibration

Temperature

→

Respiration
- Frequency
- Volume

Eyes
- Direction
- Blinking Rate

Skin
- Temperature
- Conductivity

Body
- Motion
- EMG
- Posture
- Temperature

Cardiovascular System
- Blood Pressure
- Heart Rate
- ECG
- Heart Rate Variability

→

Concentration

Health

Tiredness

Stress

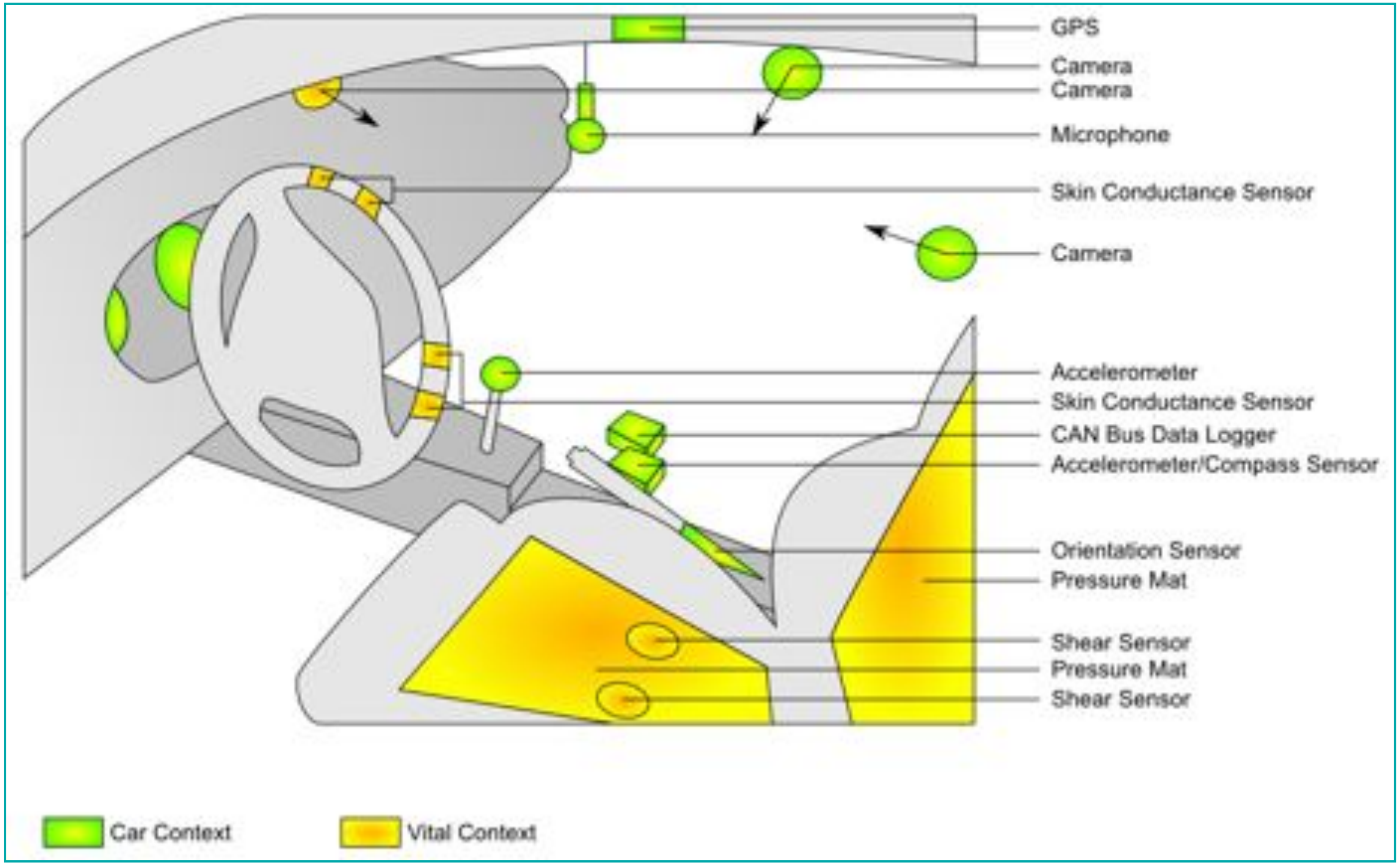
Relaxation

Happyness

Sadness

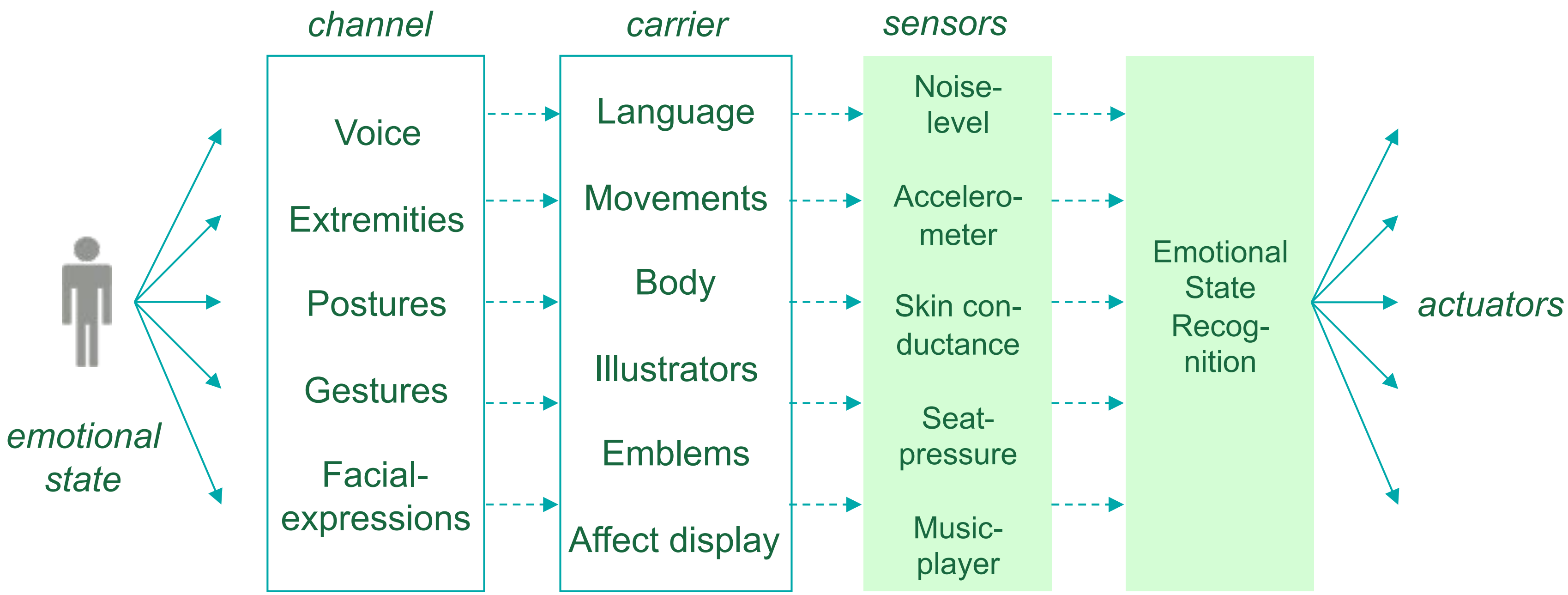
Vital / Emotional State Recognition

From physical sensing to vital / emotional context



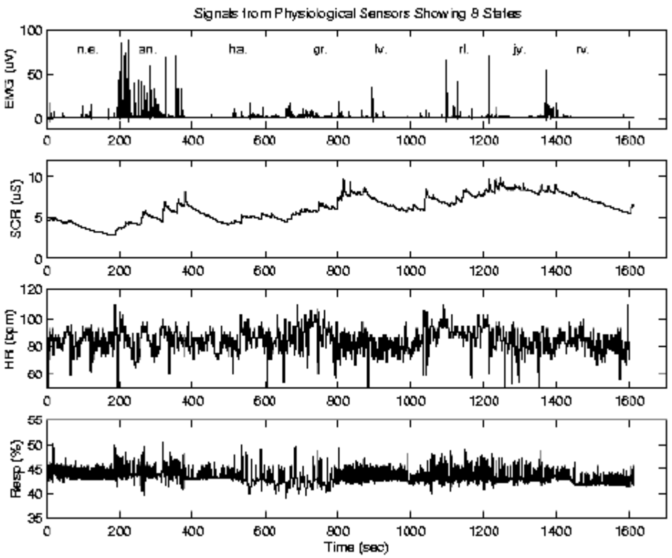
Vital / Emotional State Recognition

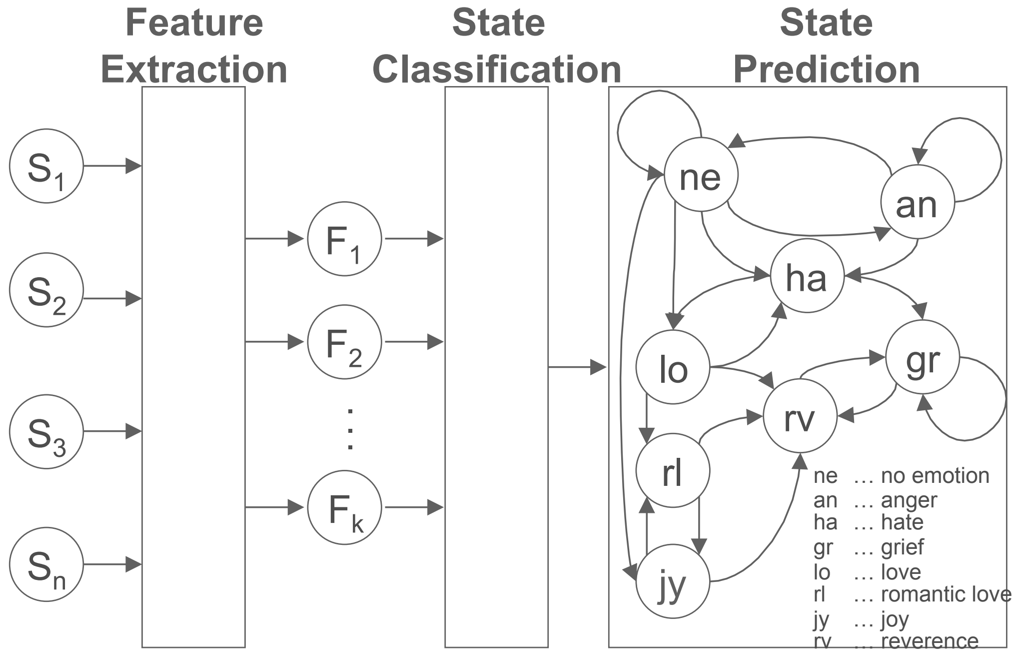
Exploiting In-Car Sensors for Emotional State Recognition



Vital / Emotional State Recognition

Apply pattern classification chain / time series analysis





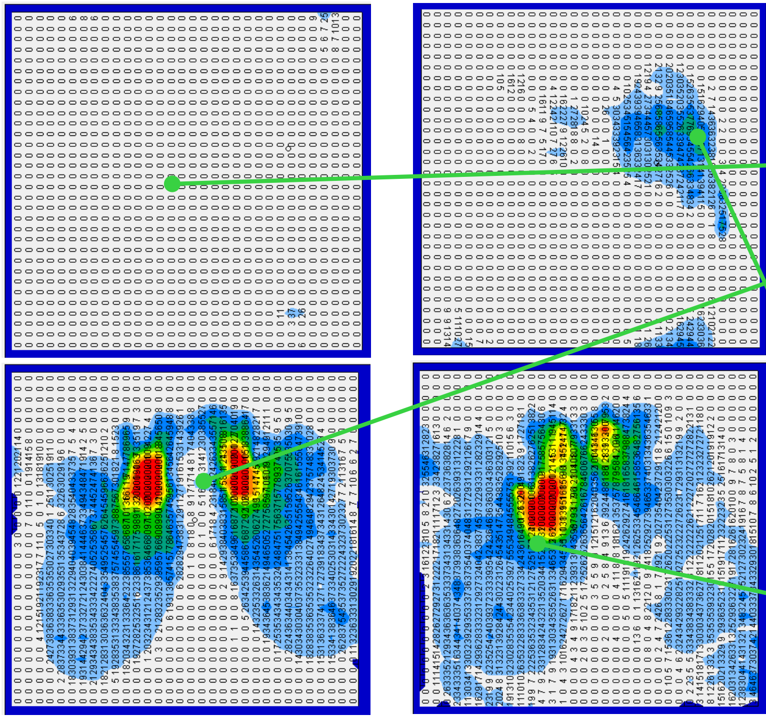
Sensors
- EMG on the masseter muscle in microvolts
- Skin conductance waveform (in micro-Siemens)
- Heart rate (in beats per minute)
- Respiration waveform (in % expansion)

Pattern recognition
etc.

Clustering
- Partitioning
- Hierarchical
- Density-based
- Grid-based
- Model-based
- etc.

- Averaging
- Smoothing
- ANN, SOMs
- Bayesian FC
- HMM, SVM
- ARMA / ARIMA
- etc.

Behaviour: Driver-Vehicle Co-Model :: Implicit Input



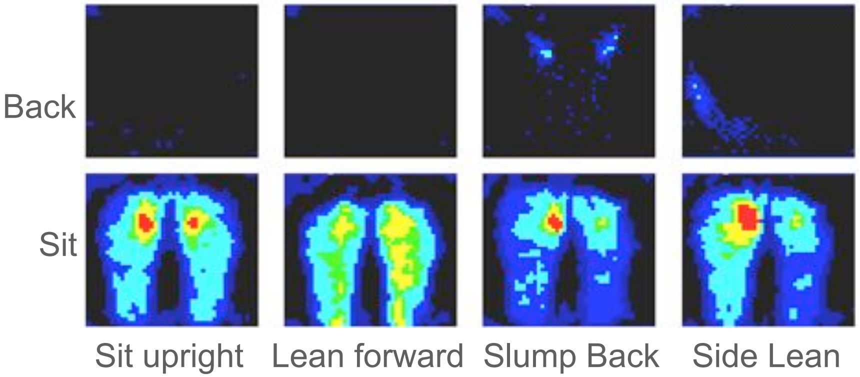
Back Rest

- **Lean Forward**
  - No pressure at the back-mat
  - High pressure at pelvic-bone area

Seat

- **Lean Sidewards**
  - Increased pressure at left shoulder
  - Higher pressure on right thigh, leg and pelvic

Related Work: **Sitting Postures in Office chairs**



Chair-movement recordings
Fenety et al. 2000

The chair as user-interface
Tan et al. 1997, Slivosky et al. 2000, Overbeeke et al. 2001

Posture recognition in chairs
Andreoni 2002, Miller 2002, Ishiyama et al. 2006, Picard & Mota 2003 ("Automated Posture Analysis", see left)

Behaviour: Driver-Vehicle Co-Model :: Implicit Input

Force Sensor Array (FSA) mats

- Two thin sensor mats integrated into the car seat and backrest
- Measuring area of of 430-by-430mm; 1,024 sensors / mat, (32-by-32 matrix)
- Sensing area: 7.94mm²; intersensor distance: 5.74mm, Mat thickness: 1.09mm
- Maximum sampling rate of 10Hz
- Sensor pressure range: 0 ... 26.67kPa (= 0 ... 200mmHg)

Vehicles (Types of Cars / Seat)

- Universality (any car, any seat) of the identification system has to be proved.
- Experiments conducted in different types of car / different types of seats
  Sports car, comfort station wagon, utility car / "normal" seat, body-contoured seat

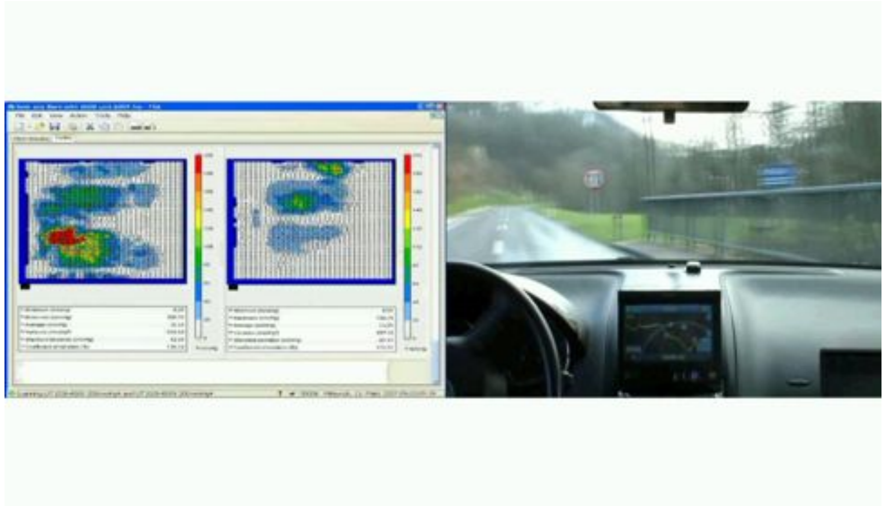
Behaviour: Driver-Vehicle Co-Model :: Implicit Input

Soft Turn Left

Lateral force takes control

Passive style

Less aware?



Hard Turn Right

Leaning against lateral force

Active style

More aware?

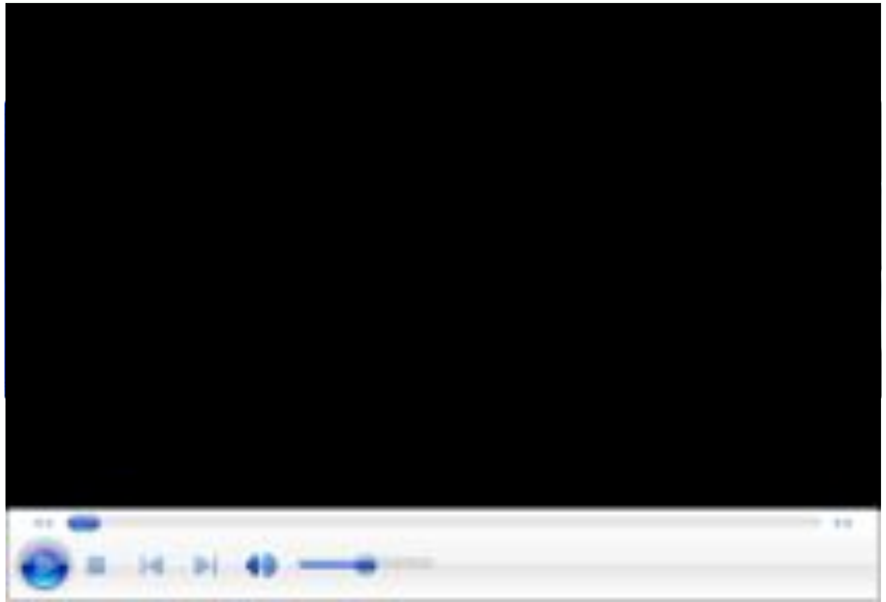
Behaviour: Driver-Vehicle Co-Model :: Implicit Input

Soft Turn Left

Lateral force takes control

Passive style

Less aware?

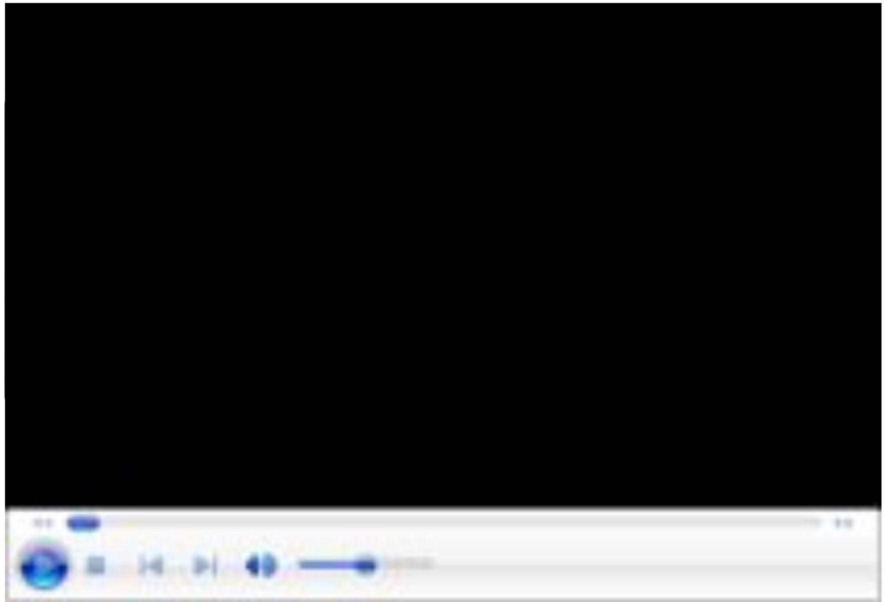


Hard Turn Right

Leaning against lateral force

Active style

More aware?



Driver Identification from Sitting Postures: **Utilized Features**

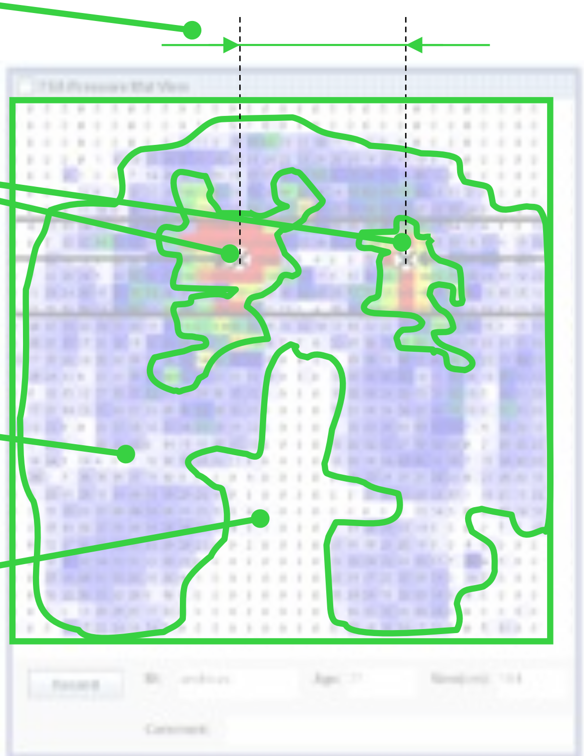
The feature vector (seat) is calculated from the following parameters:
(combination of four individual elements, weight factor experimentally determined)

- **Pelvic Bone Distance**
  - > Distance between the two points on the mat indicating the pelvic bones (center of the left and right areas with highest pressure).

- **High Pressure Area**
  - > All sensors which values exceed 90% of the maximum pressure indicated on the mat.
  - > 1.024 sensors each; scaled to actual persons' traits.

- **Mid to High Pressure Area**
  - > All sensors that values exceed 10 percent of the maximum sensor value.
  - > 1.024 sensors each; scaled to persons' traits.

- **Weight**
  - > Accumulation of pressure values indicated by all 1.024 sensors (calibration before first usage necessary).
  - > Provides no exact weight, but a coarse tendency.



Stimulus: Driver-Vehicle Co-Model :: Subtle Output

Visual and auditory sensory channels for "Car-Driver Feedback"

- Proper choice
  - Bigger part of information in vehicles is delivered via the visual sense
  - Verwey *et al.*: "The most dominant source of danger in vehicles is not looking in the appropriate direction [..]".
  - *Wierda and Aasmann*: "Driving is seeing [..]".
- Services and Appliances in Vehicles
  - Increasing number, operation complexity of Advanced Driver Assistance Systems (ADAS).
  - Infotainment and communication systems, requiring drivers' attention on driving-indepen-dent messages, e.g. cell phone: *(i)* eyes off the road while dialing, and *(ii)* driver is fully engaged by cell phone conversation ➔ concentration on the driving-task is impaired.
  - High cognitive load for the driver ➔ overload situations ➔ operating errors (overlooking information, fail to hear some messages).
- Distracting factors
  - Visual: Glaring/reflecting light, fog, snowfall, day/night vision and light conditions (tunnel)
  - Auditive: Env. (motor, traffic), passenger-communication, cell-phone calls, car stereo

How can these problems be solved?

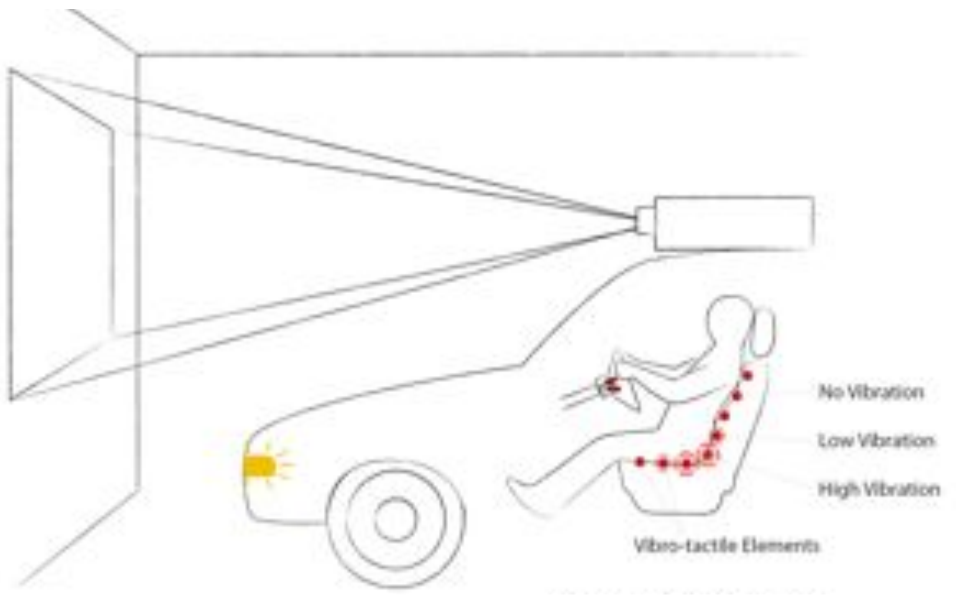
- Introduce new feedback channels (output) ➔ sense of touch (haptics).
- Optimize feedback modalities (visual, auditive, touch) ➔ consider age, gender.
- Multimodal interfaces (stimulate two or more channels simultaneously).

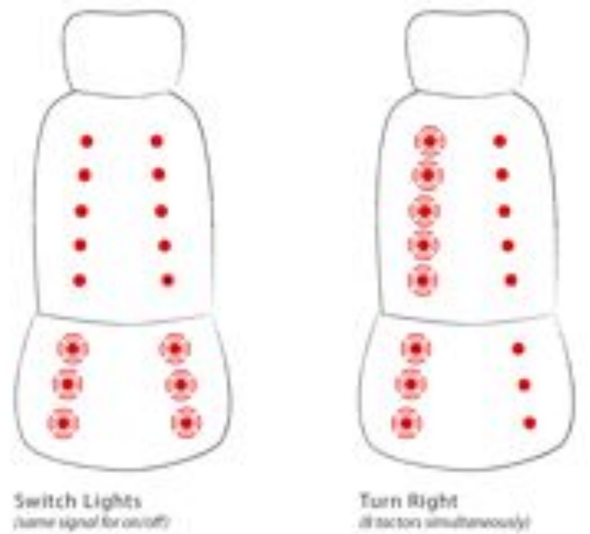
Alois Ferscha

Stimulus: Driver-Vehicle Co-Model :: Vibrotactile Output

Experimental Setting

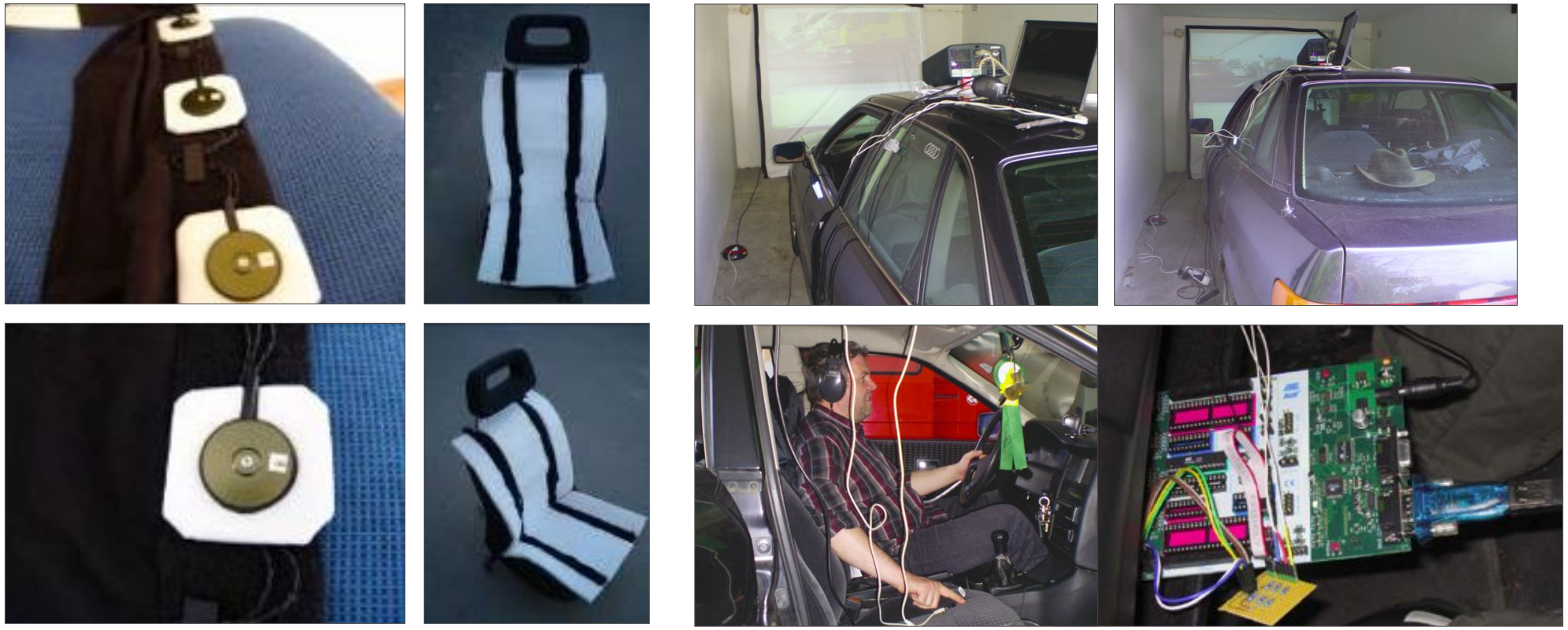
- Vehicle controls (turn/light switch, connected to SW-application (ATmega AVR32).
- Video of test journey (length: *11min.,22sec.)*, replayed on a beamer with head-up display, no abrupt changes of the scenery.
- (44) actions have been tagged; random notification via *(i)* **visual** (superimposed to video), *(ii)* **auditive** (headphone), *(iii)* **haptic** (C2 vibro-tactile actuators) modality.
- Reaction time recorded and stored into database.





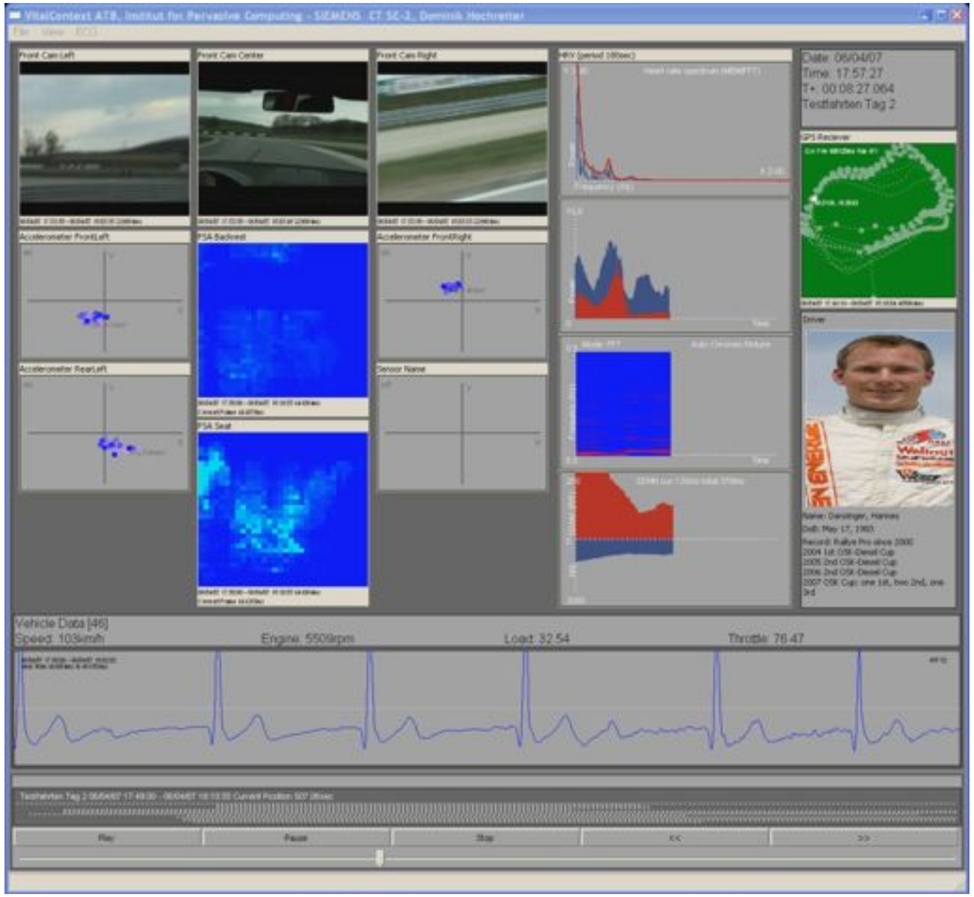
Alois Ferscha

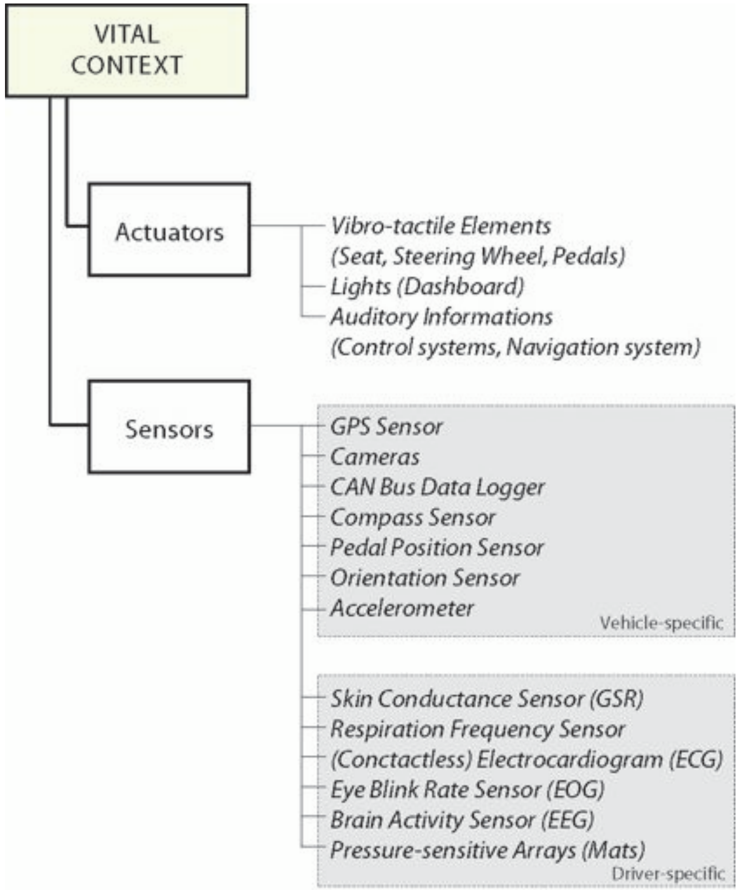
Stimulus: Driver-Vehicle Co-Model :: Vibrotactile Output



Driver Vehicle Co-Model

Experiment Setting: "Collective Driver-Vehicle Co-models (CDVC)„

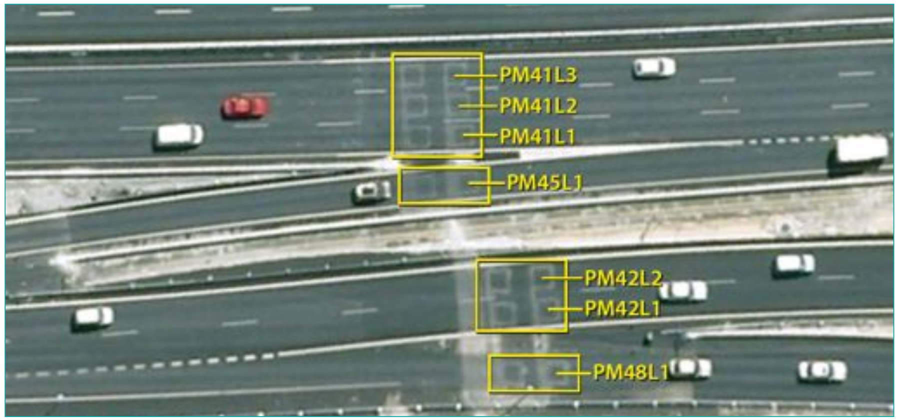




Simulation Experiments : Madrid Motorway M30

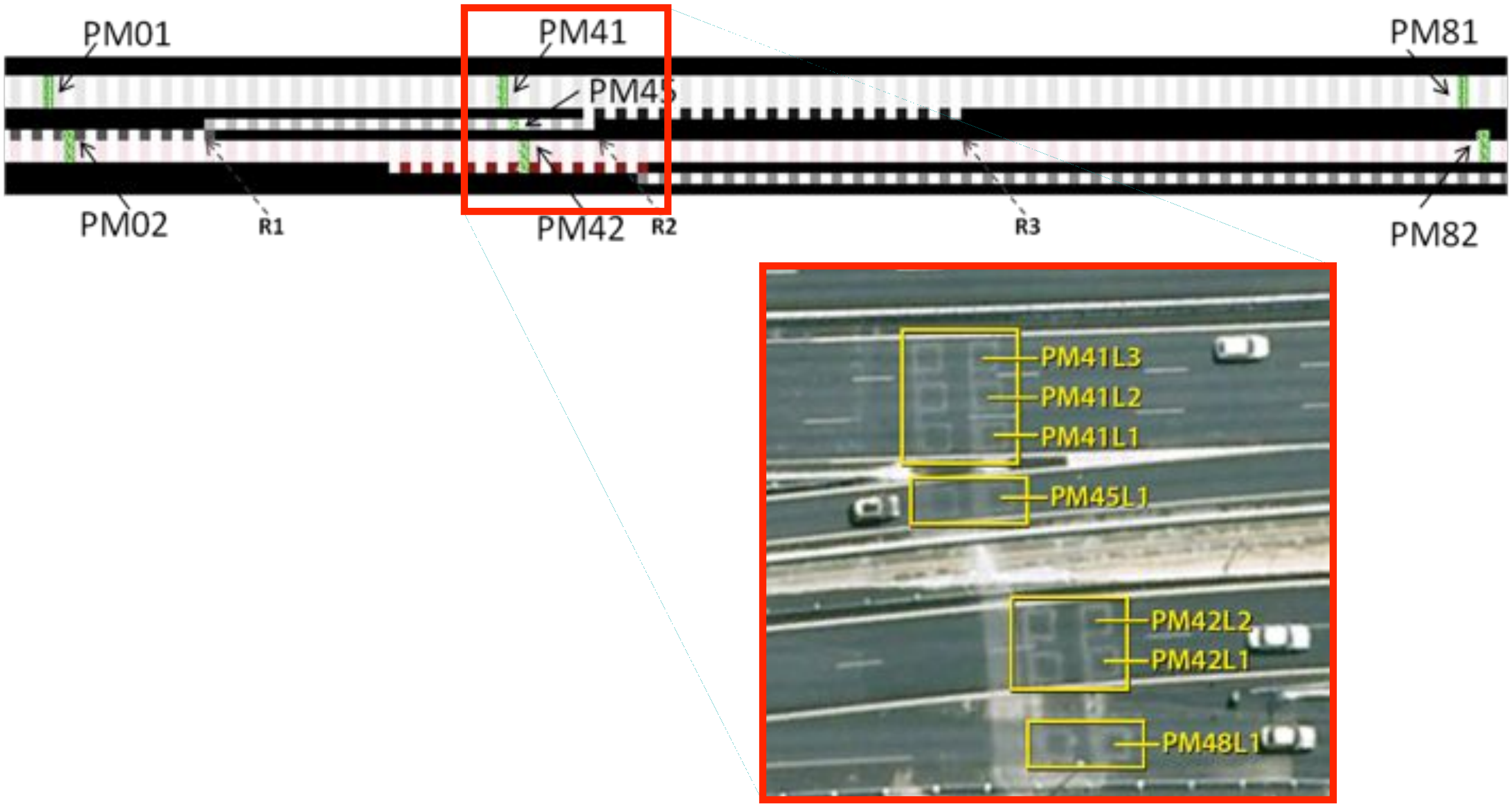
Study the effect of AmI-Technology improving „Merging Lanes“ – based on empirical traffic data

- Detail view of the segment of interest showing induction loop sensors and the entrance ramp
- traffic counters on lane granularity (PM41L1, PM41L2, PM41L3 → later aggregated to PM41)

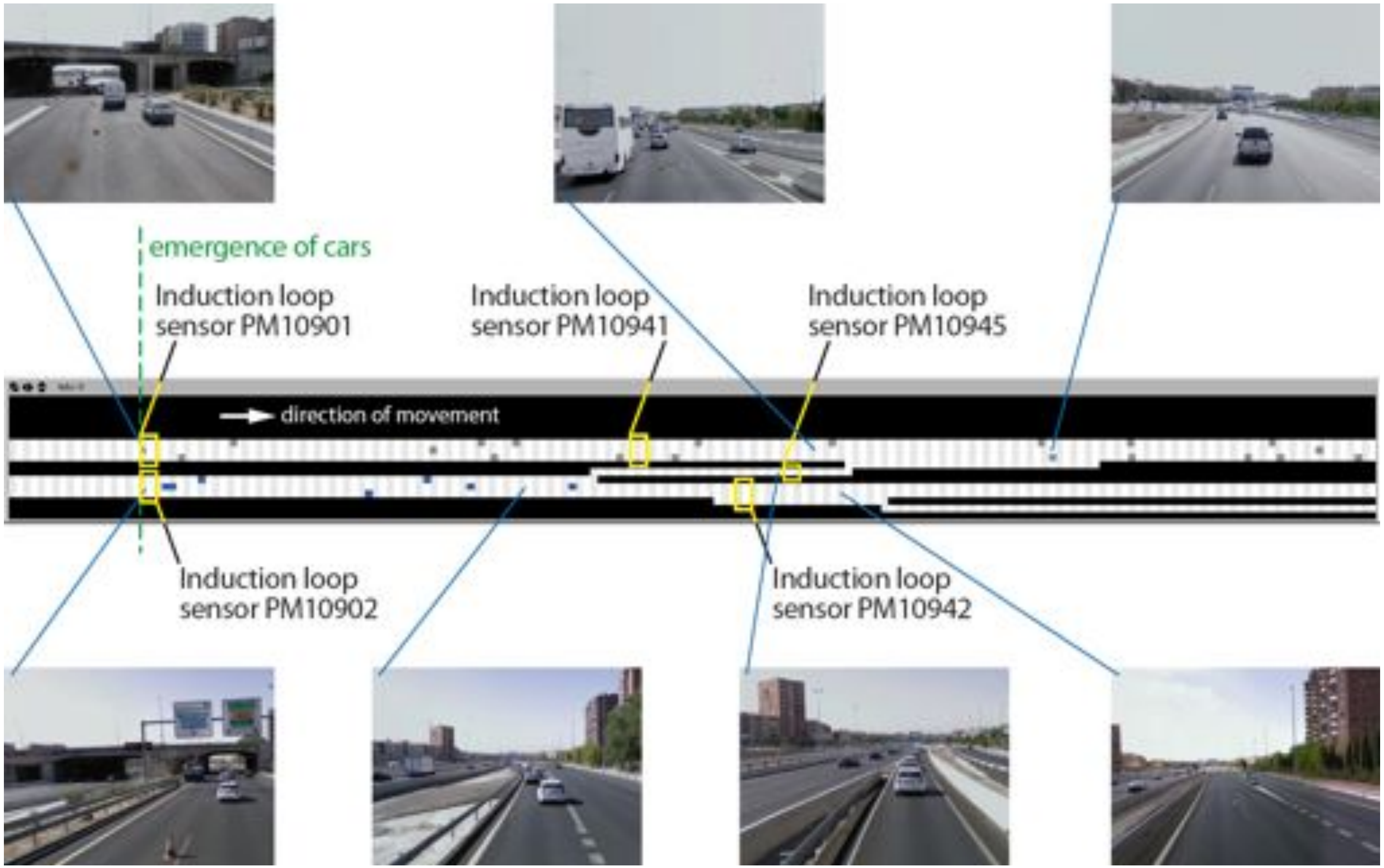
Simulation Experiments : Madrid Motorway M30

- Setting up a cellular automaton model (CA model) for discrete event simulation



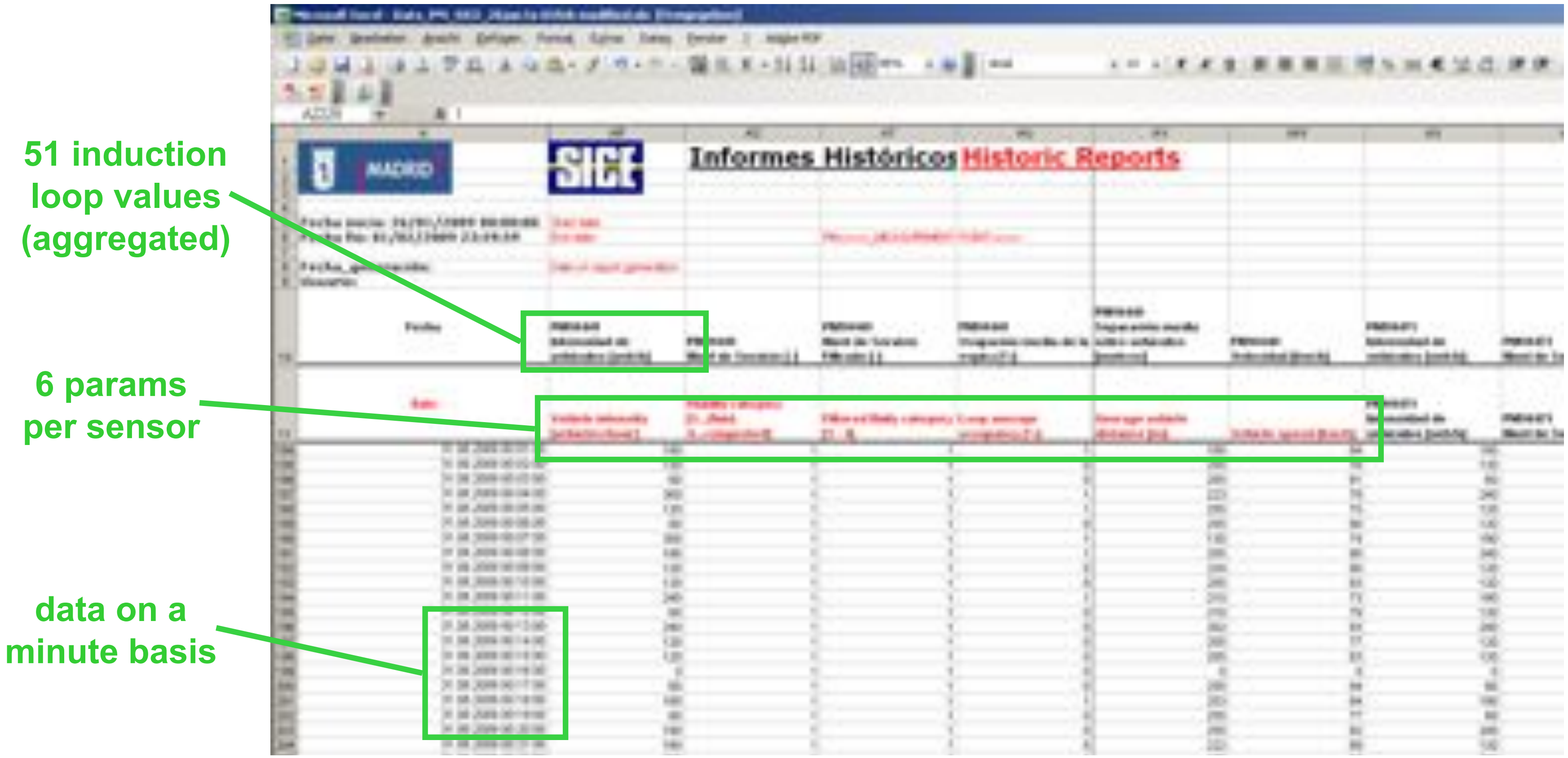
Simulation Experiments : Madrid Motorway M30

- Collecting traffic pattern data traces on the M30 (PM10901 to PM10981=665m)



Simulation Experiments : Madrid Motorway M30

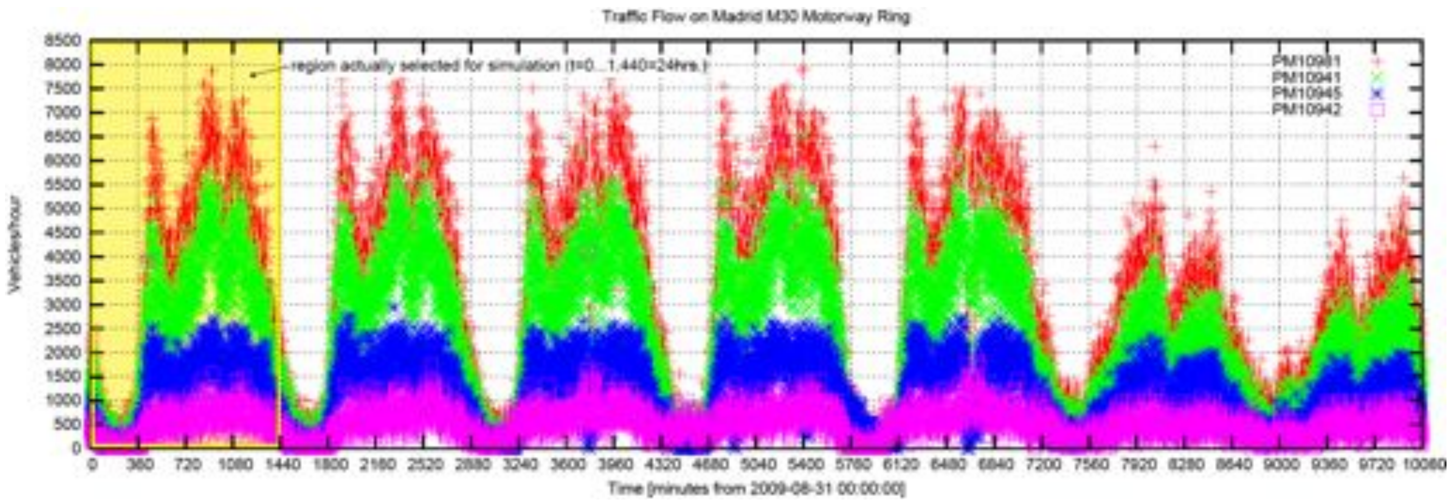
- Traffic data for a segment of 13.2 kilometers, one week (31.08.2009 – 07.09.2009), 10,080 data sets (minute basis), 51 induction loop sensors



Simulation Experiments : Madrid Motorway M30

Identifying traffic flow characteristics

- peak traffic of about 8,000 vehicles/hour on one road (three lanes) → 2,22 vehicles/sec.
- traffic flow gradient repeats day by day (with lower volume on Saturday/Sunday)



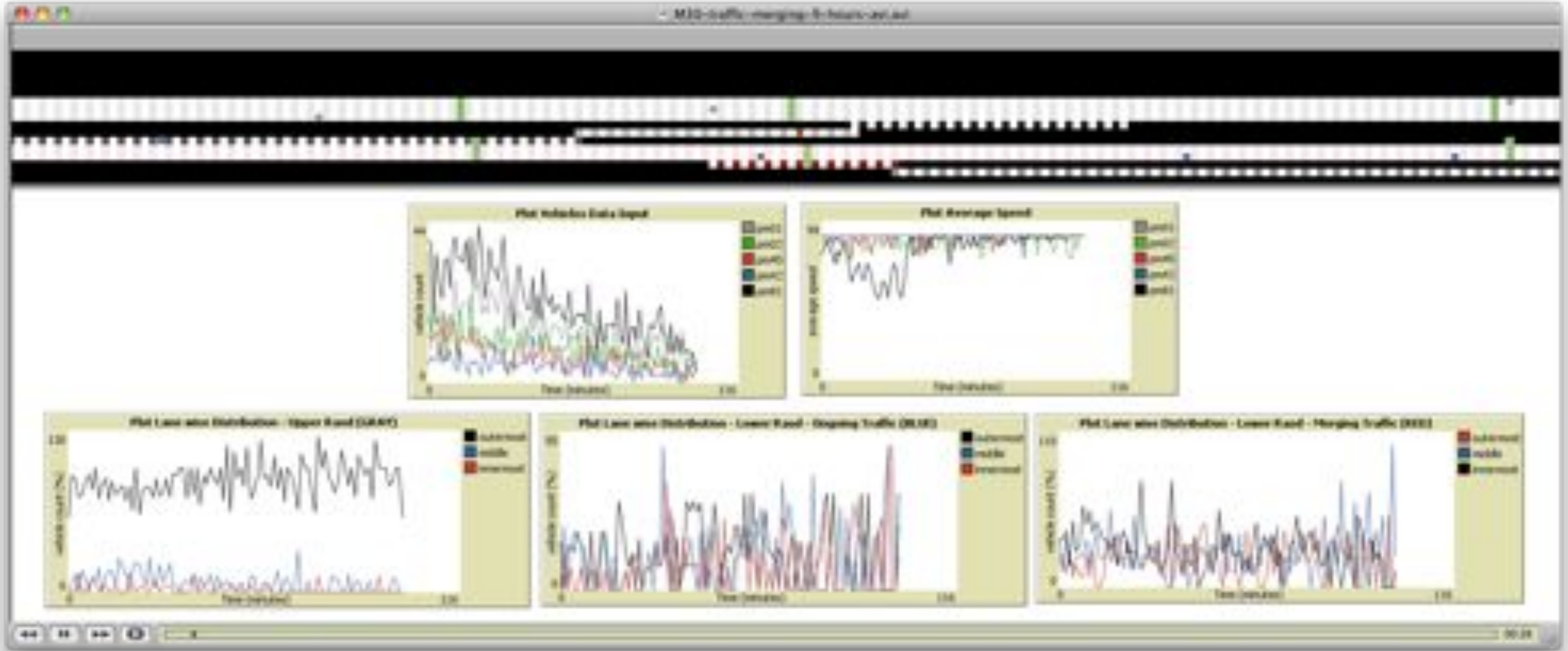
Simulation statistics

- Start time: midnight (00:00:00), end time: midnight (23:59:59) → 1,440 data rows
- Video shows first 9 hours (a simulation run of 25 minutes)
- Speed limit: 90 km/h
- Congestion builds around peak value at 08:00:00

Simulation Experiments : Madrid Motorway M30

Conducting (data-) trace-driven simulation experiments (here with NetLogo, as Video)

120 (2 am): low traffic, no jams



Simulation Experiments : Madrid Motorway M30

Conducting (data-) trace-driven simulation experiments (here with NetLogo, as Video)

300 (5 am): as traffic increases, vehicle count per segment drops

Simulation Experiments : Madrid Motorway M30

Conducting (data-) trace-driven simulation experiments (here with NetLogo, as Video)

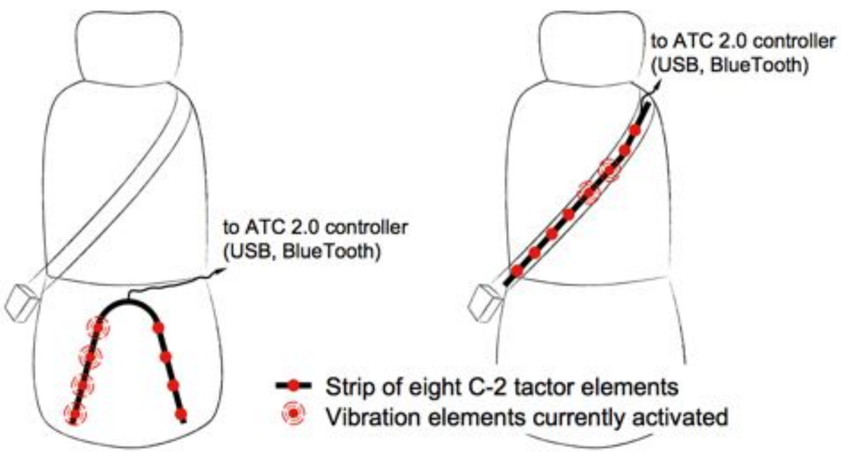
480 (8 am): average speed in segment drops due to lane change frequency > jams emerge

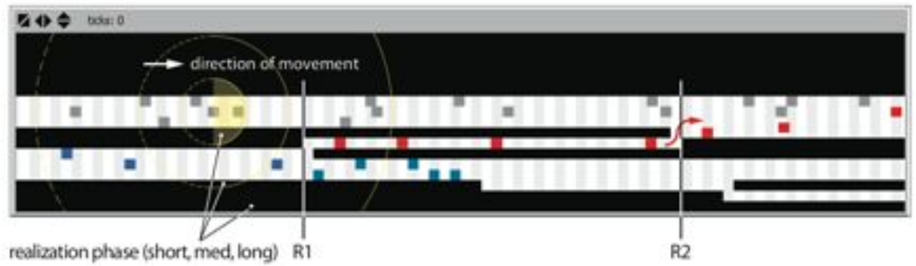
Simulation Experiments : Madrid Motorway M30

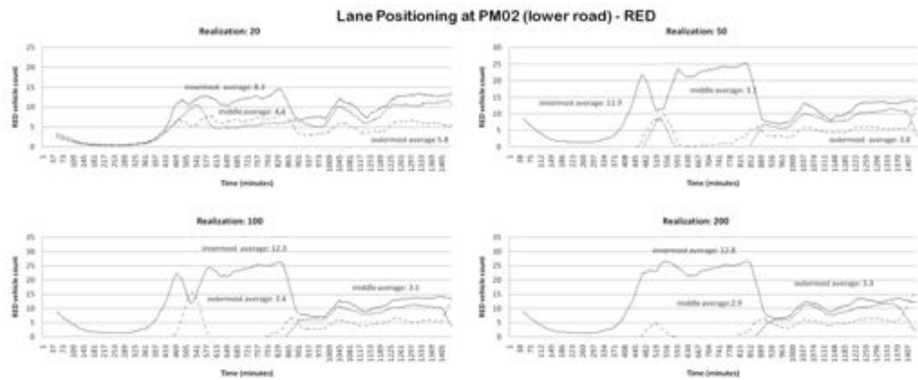
Conducting (data-) trace-driven simulation experiments (here with NetLogo, as Video)

SOCIONICAL (trace driven simulation) model response:

AmI technology (vibrotactile notification indicating „safe to change lane“ far earlier than visually perceived) reduces lane change delays, thus increases overall throuhput in segment
Recommendation: AmI technology can reduce traffic jaming!







Towards a Model for Collective Driver-Vehicle Control Loop

- **Car Crowds as Socio-Technical Systems**
  constituted of many elements that interact and produce "global" behaviour
  = behavior that cannot (easily) be explained in terms of the interactions among the individual elements
- **Approach: Vehicle-Driver Co-Model**
  Implicitely collect emotional / vital state of driver
  - focus: body posture, control interactions, ECG, EMG, EEG

  Feedback from “shared” emotional / vital state
  - focus: vibro-tactile notifications, auditory cues, olfactory stimulation

  Possibly adapt : driving style / driving comfort / vehicle control dynamics
- **Data Driven Simulation: Collective Vehicle-Driver Co-Model**
  “scale up” models, 10^7-10^9 entities
  Case: commuter traffic in Upper Austria (90.000 vehicles)
  Case: commuter traffic on Madrid Motorway (120.000 vehicles)
- **Research Hypothesis**
  “Perceiving the driving style of other drivers, influences the emotional state and hence driving style of the observers..”
  found simulation based evidence
  identified potential of AmI technology to improve

Alois Ferscha

The SOCIONICAL Integration Challenge:

Aspect Oriented Modelling

Individual Models
(describing aspects of individuals, like humans, in a CSTS)
e.g. behavior, intention, trust, plan, goal, "mental elasticity”

Social (Behaviour) Models
(describing individuals as social beings, e.g. being able to communicate)
(analogy: FIPA ACL Agents communication language)
e.g. selfish, cooperative, ..

Population Models
(describing individuals as they link with each other / group together)
e.g. grouping, flocking, leadership, ..

Dispersion Models (Information spread)
(describing information spreads in CSTS constituted by communicating individuals)
e.g. epidemic information spread

The SOCIONICAL Integration Challenge:

Aspect Oriented Modelling

Mobility Models (physical models)
(describing how individuals/entities move (=change place) in a CS-TS)
(evacuation: CA based, traffic: road networks, vehicle movement)

(Evolutionary) Dynamics Models
(describing the dynamics of change a CS-TS is exposed to)
e.g. Linz flood; dynamically rising water level

Domain Models (in which field is the application situated?)
(describing the context within which a CS-TS is situated)
e.g. technical, political, cultural, emergency, transportation, ...

Complex Socio-Technical Systems

ESRC Complexity Research Seminar 6
LSE

July 8, 2010
London, England

Alois Ferscha
(with Andreas Riener, Kashi Zia and Alexei Sharpanskykh)

(supported by the EC under grant SOCIONICAL and OPPORTUNITY)

Univ. Prof. Dr. Alois Ferscha
Universität Linz, Institut für Pervasive Computing
Altenberger Straße 69, A-4040 Linz
ferscha@soft.uni-linz.ac.at

Beliefs of an agent are time-labelled internal representations of structures and processes of the external world created based on communication and observation results received by the agent

(ref: A. S. Rao and M. P. Georgeff. Modeling Rational Agents within a BDI-Architecture. In Proceedings of the 2nd International Conference on Principles of Knowledge Representation and Reasoning)

Trust is an (cognitive and affective) attitude of an agent towards an information source that determines the extent to which information received by the agent from the source influences agent's beliefs.

(ref: Rino Falcone, Cristiano Castelfranchi: Generalizing Trust: Inferencing Trustworthiness from Categories. AAMAS-TRUST 2008.)