IMoST 2
Final Presentation
Work Package Human Modeling

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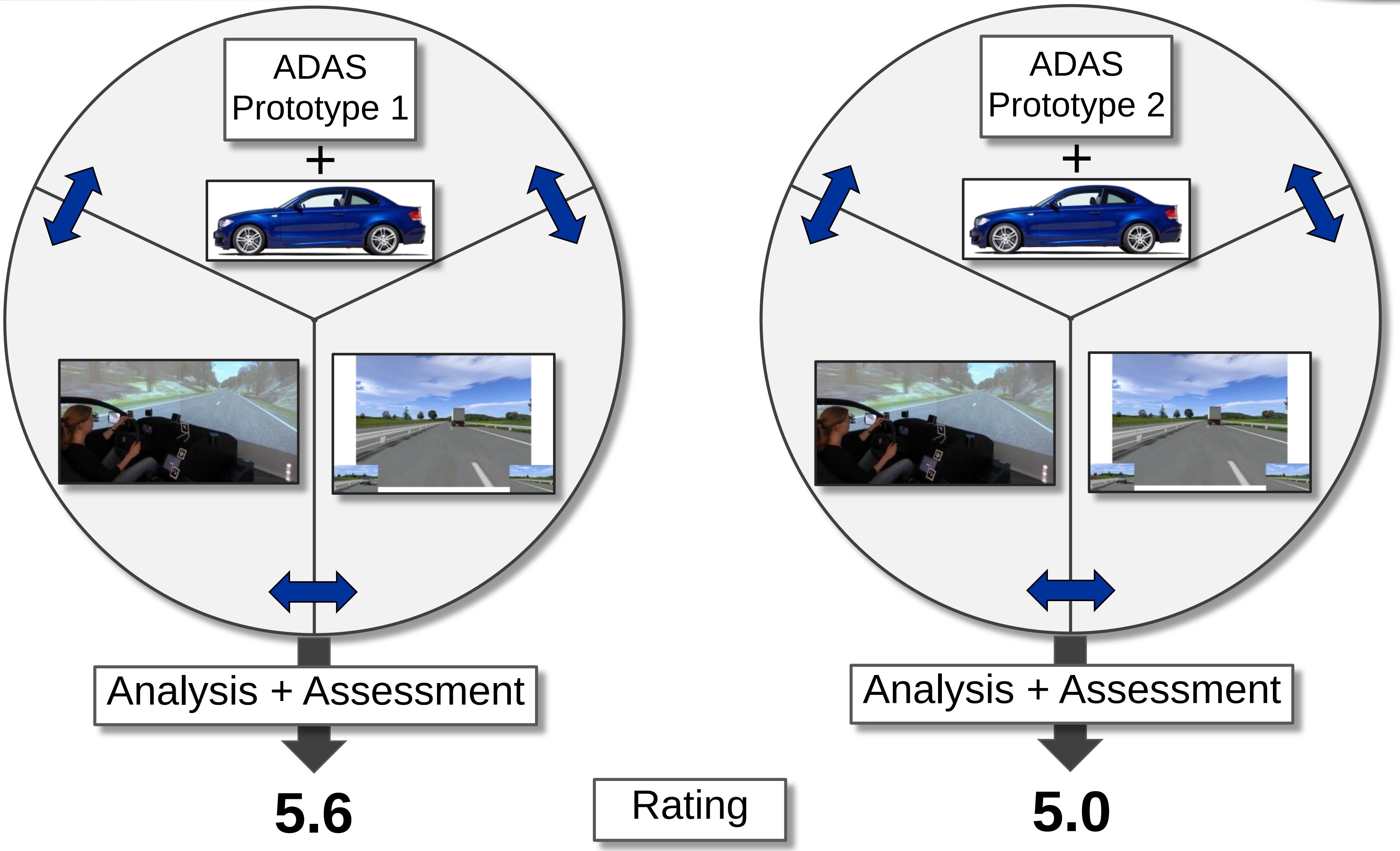
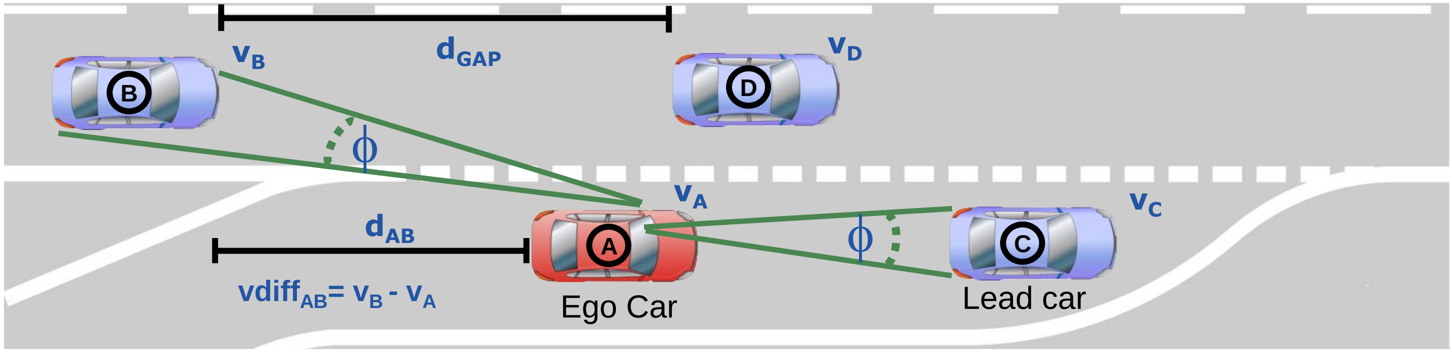
Bayesian Autonomous Driver	Claus Möbus Mark Eilers
Multimodal Perception	Hans Colonius Rike Steenken
Situation Awareness	Martin Baumann David Käthner
Assistenzsystem	Julian Schindler Anna Schieben

IMoST Long Term Goal

Integrated Modeling, Simulation & Analysis Approach



Retrospection: IMoST 1
Highway Merging Scenario without ADAS



- Simulation of a single driving maneuver
  - Scenario variations: gap size, speed and differential speed
- Driver model based on cognitive architecture CASCaS
  - Simulate decision making (which gap) and merging onto the highway
  - Model used angular size / rate of change to estimate gaps (Re-used in IMoST 2)
- Use data from experiments with subjects to set up and also to validate the model's decision making

→ Main Goal IMoST 1: Set up an initial driver model + connection to driving simulator software

→ IMoST 2 has to consider assistance system interaction and further highway scenarios

5 Goals of WP-HM
motivated by Response 3 CoP

Integrated Modelling for Safe Transportation

To enable investigation if drivers will ...

... perceive system (multimodal) signals quickly: "Can system outputs and information be **perceived** by the driver **quickly enough** to enable them to **react appropriately** (e.g. take over request from adaptive cruise control)?“
Multimodal perception (Prof. Dr. Hans Colonius)

... understand what the system is doing: "Does the human-machine interaction of the system **prevent the driver from losing situational awareness** (e.g. keeping the driver in the loop, providing a consistent warning strategy)?“
Situation Awareness (Dr. Martin Baumann)

... still perform relevant tasks adequately: "Are the driver tasks with ADAS support still an essential part of the overall vehicle operation in a way that the driver will not neglect relevant tasks as a result of the use, activation or deactivation of the new system?
Driving Decisions (Dr. Andreas Lüdtke)

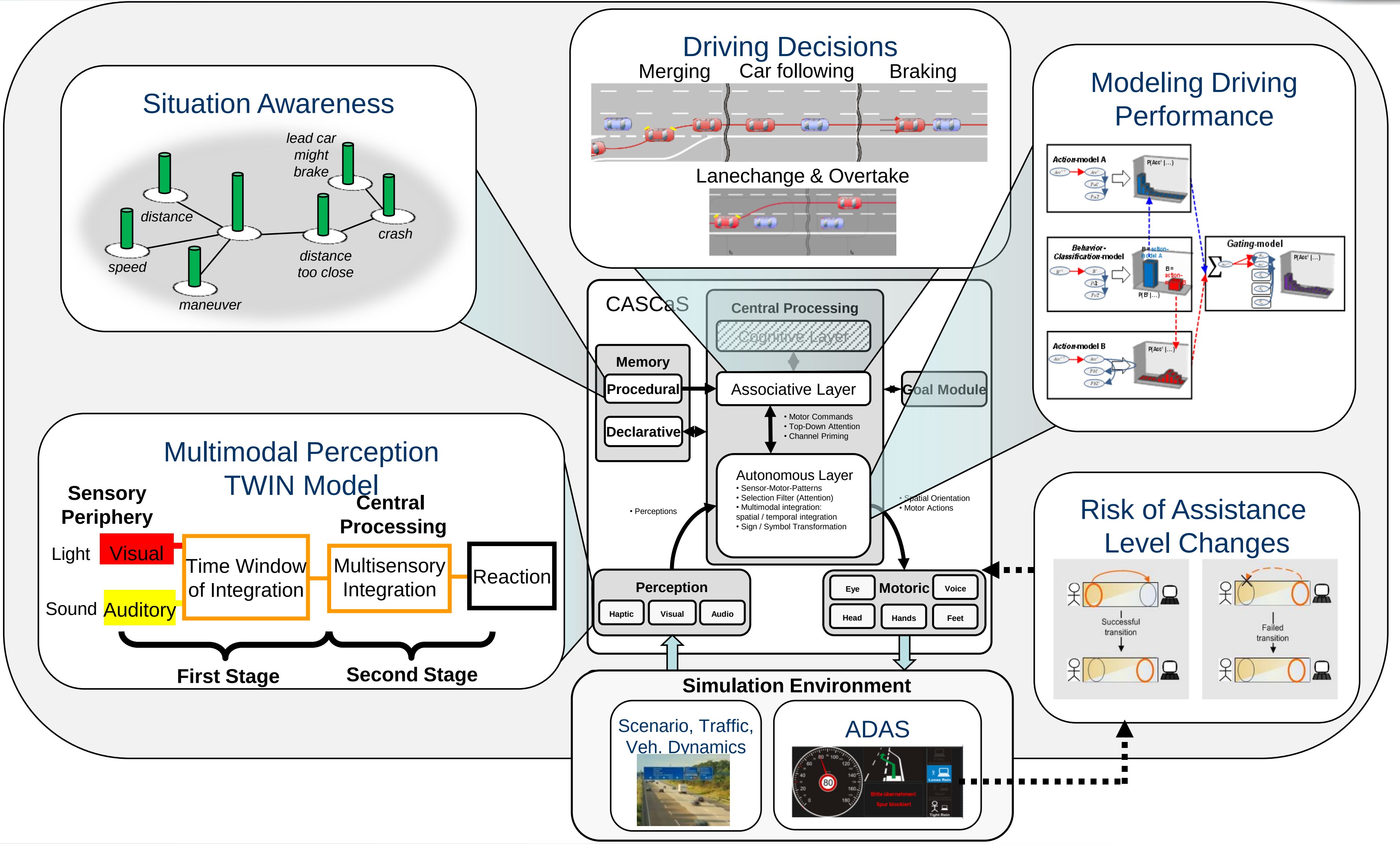
5 Goals of HM
motivated by Response 3 CoP

To enable investigation if drivers will …

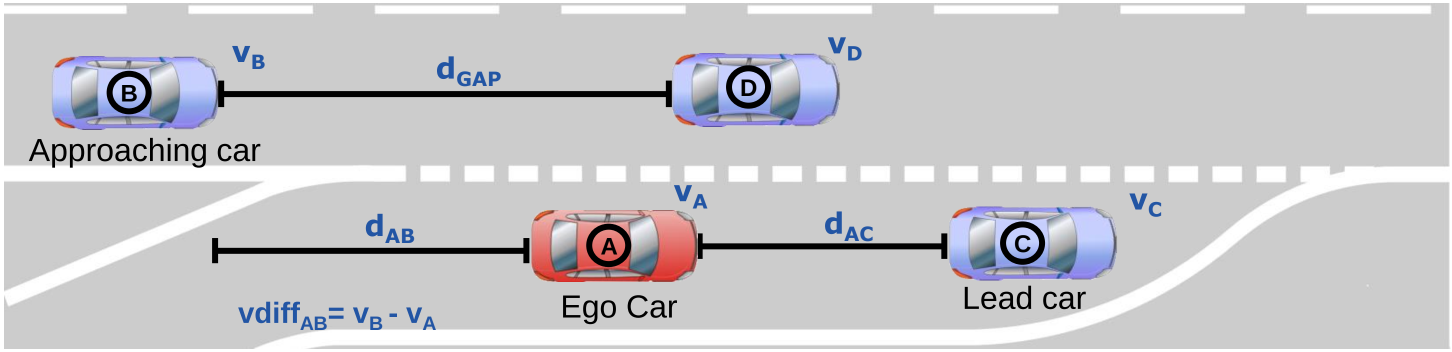
… still be able to control the vehicle: "Did you check if a driving status is no longer controllable by the driver?"
Driving Performance (Prof. Dr. Claus Möbus)

… handle the transition between the assistance levels of the system appropriate: “Which problems might occur with driver intitiated and automation initiated transitions?“
Risk of assistance-level changes (Dr. Frank Flemisch, Dr. Martin Baumann)

Structure of WP-HM
Interaction with WP-EE / WP-AN



Retrospection
Appraisal: The IMoST 1 Driver Model



- Pitfall: simulator view vs. model view on traffic participants
  - f.e. which car is the current lead car was given by simulator
- Single variable usage, no object representation
  - Initially, CASCaS had a very simple memory component only, which could not be exchanged later on in IMoST 1
  - Mental model of the traffic situation was missing (spatial relations + distance / differential speed estimation)
- Gaze modeling not sufficient, fixed views only
  - Windshield (lead car variables + street)
  - Left mirror (variables of cars on right lane)
  - Missing peripheral view → very limited reactive behavior only

→ These drawbacks have all been removed during IMoST 2

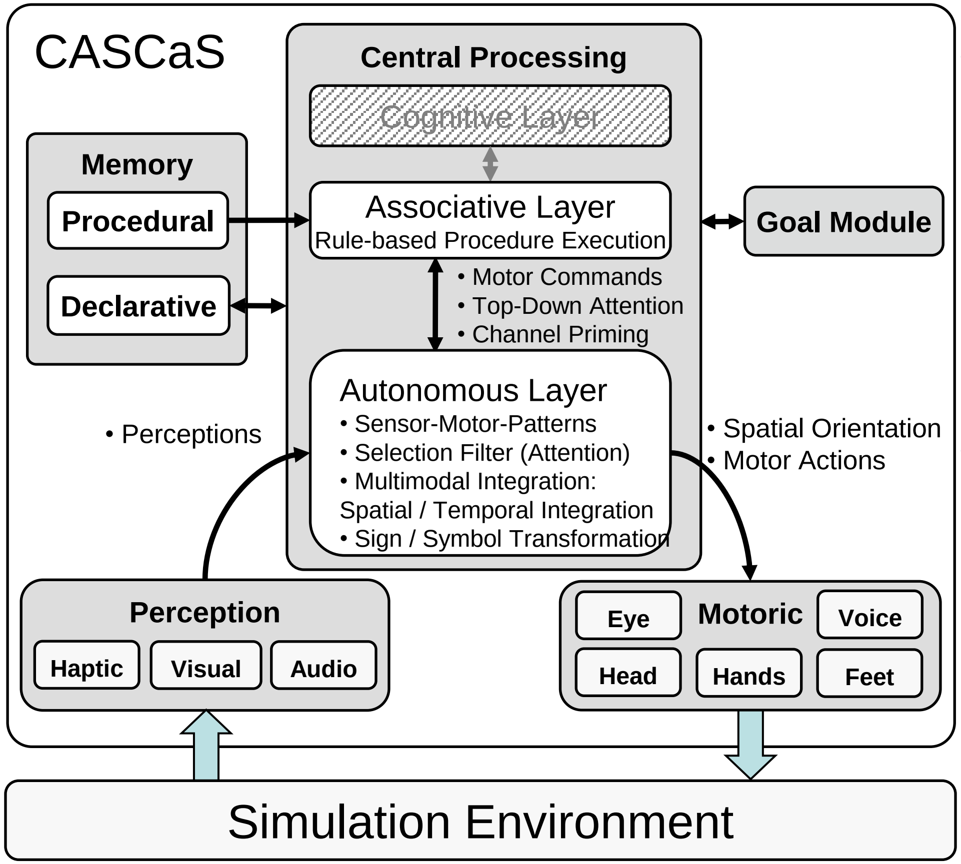
IMoST 2 Driver Model CASCaS Architecture

CASCaS
Modeling & Simulating Human Behavior

Framework which contains (some) cognitive abilities and physiological limits

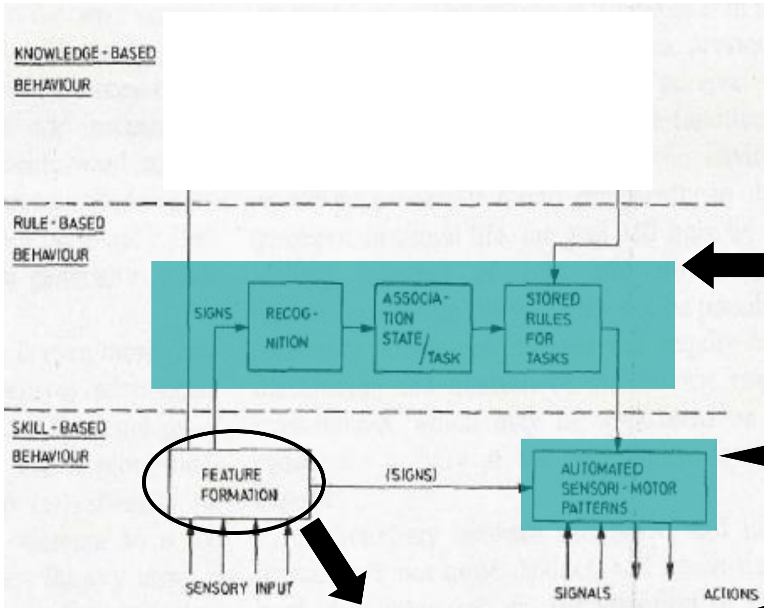
Associative Layer (rule interpreter): simulates goal-oriented human behavior; executes rule-based, conditional action plans stored in procedural memory

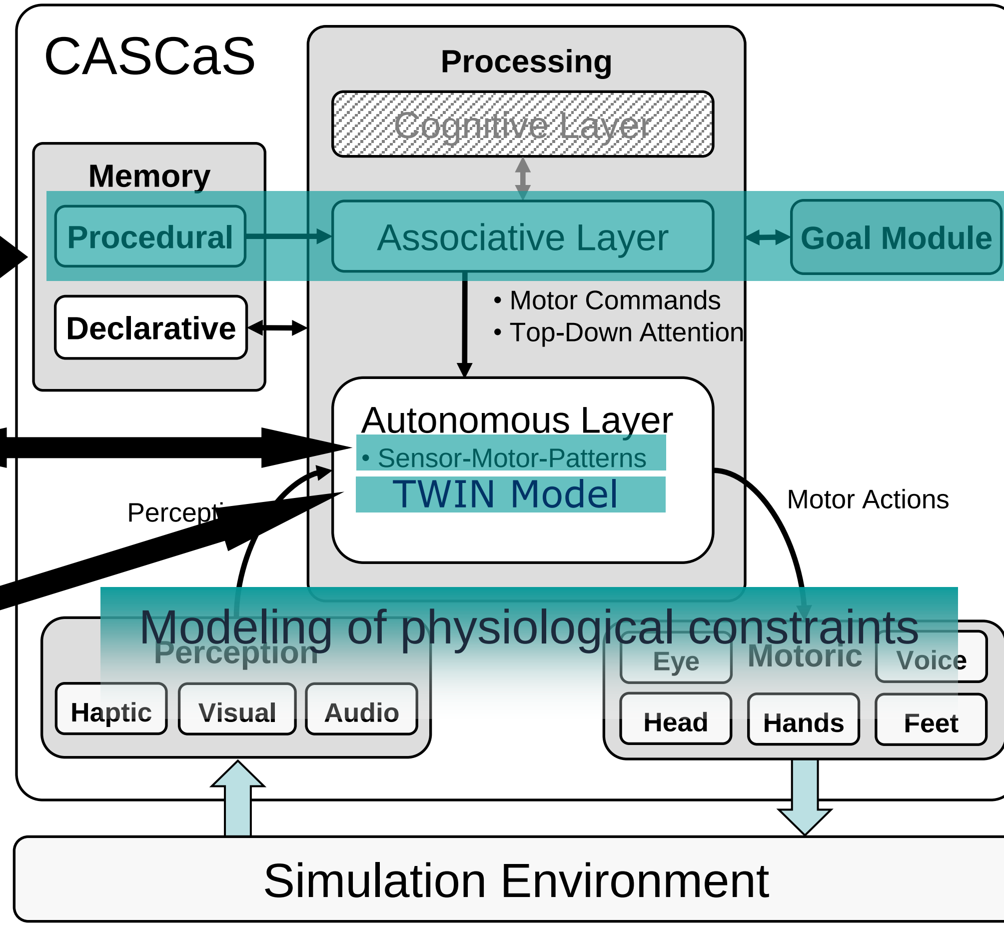
Autonomous Layer simulates highly learned behavior and subconscious cognitive capabilities



- **Top Down Processing** (origin: associative layer, action plan / rule execution):
  - **Rotate Knob, Turn Left:** Motor Commands → Activate Sensor-Motor Pattern → Motor Actions
  - **Look at:** Top-Down Attention → Sensor-Motor Pattern → Motor Action
- **Bottom Up Processing** (origin: perception → autonomous layer):
  - **Perception, Interpretation:** Perceptions → Signs - Symbol Transformation → Declarative Memory
  - **Autonomous Behaviour:** Perceptions → Sensor Motor-Patterns → Motor Actions

Architecture Layout
inspired by Rasmussen (1983)





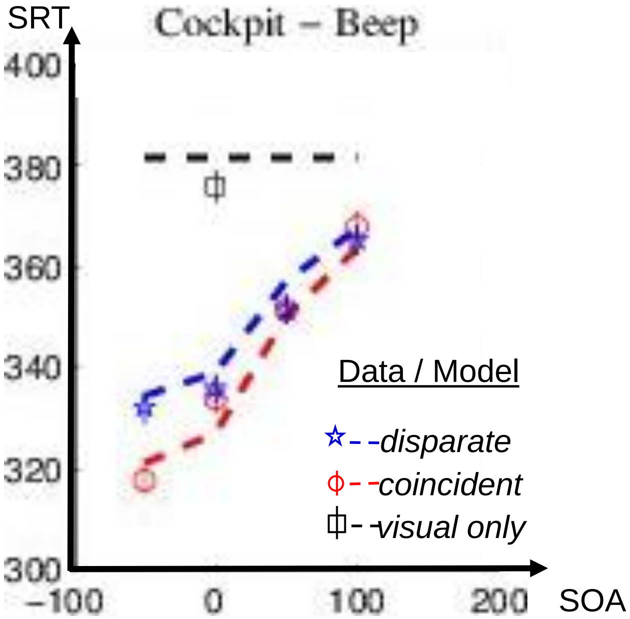
Low-level perception processes:
- object recognition
- detection of movement
- temporal / spatial integration

Fig.1 taken from: Jens Rasmussen (1983). *Skills, Rules and Knowledge; Signals, Signs and Symbols, and Other Distinctions in Human Performance Models*. IEE Transactions on Systems, Man, And Cybernetics Vol. SMC 13, No.3
see also: Michon (1985). *A critical view of driver behavior models: What do we know, what should we do?* In L. Evans & R. C. Schwing (Eds.), Human behavior and traffic safety (pp. 485–520). New York: Plenum Press.

Multimodal perception

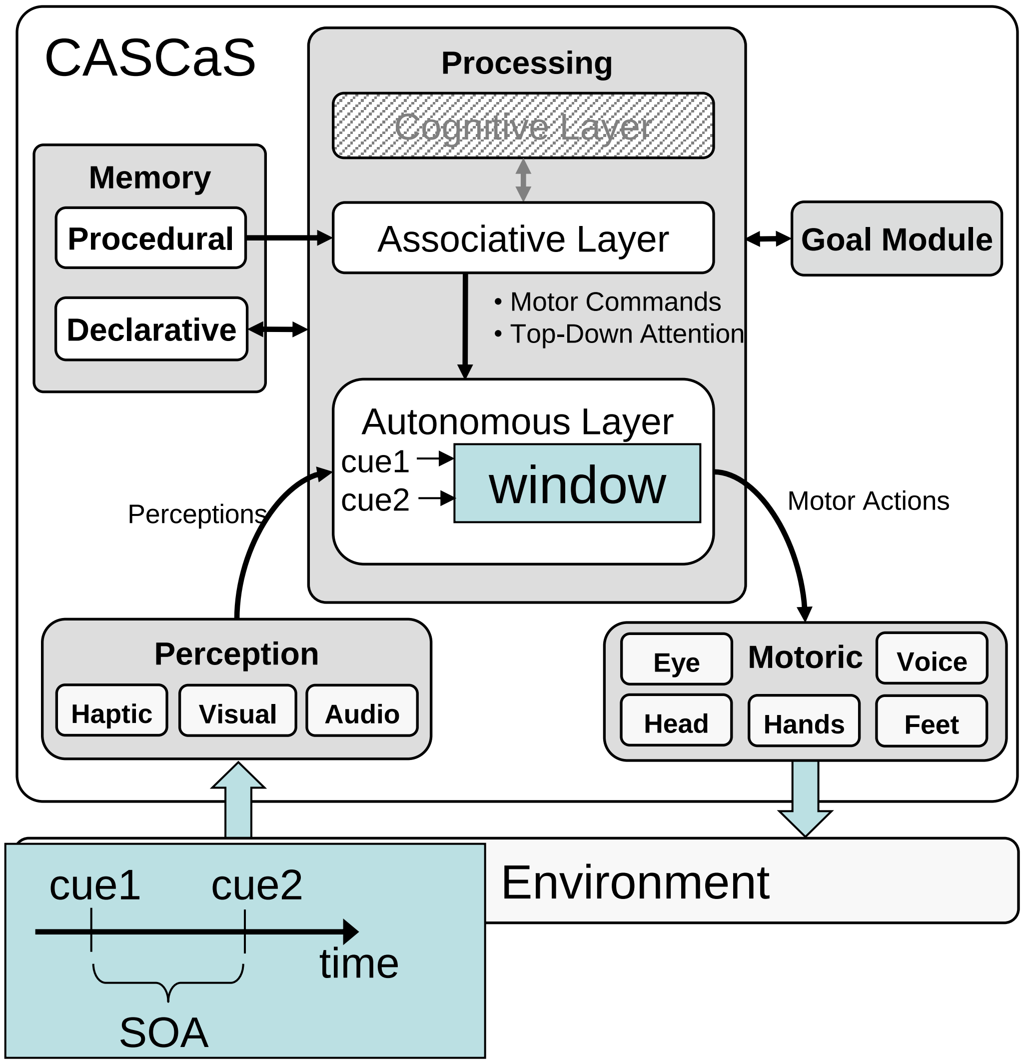
TWIN Model Assumptions

- Modeling reaction time until visual orientation reaction is triggered
  - 1st Stage: Race of the multisensory stimuli from the receptors to the different brain areas
  - 2nd Stage: Spatial integration of the stimuli
- Condition for integration within 2nd stage: stimuli arrive within ~200ms.
- Strength of multisensory integration effect depends on the spatial layout.



Multimodal Perception
CASCaS Integration I

- Why consider multisensory integration a process on the autonomous layer?
  - Even if subject should ignore stimuli, an effect on reaction time is measured
  - Not modelled into perception component, because effect is learned, not physiologically „built-in"
- Implementation: window equals a timer started by any non-target cue
- Cues appear within window
  - Integration possible
  - Effect on reaction time depends on SOA

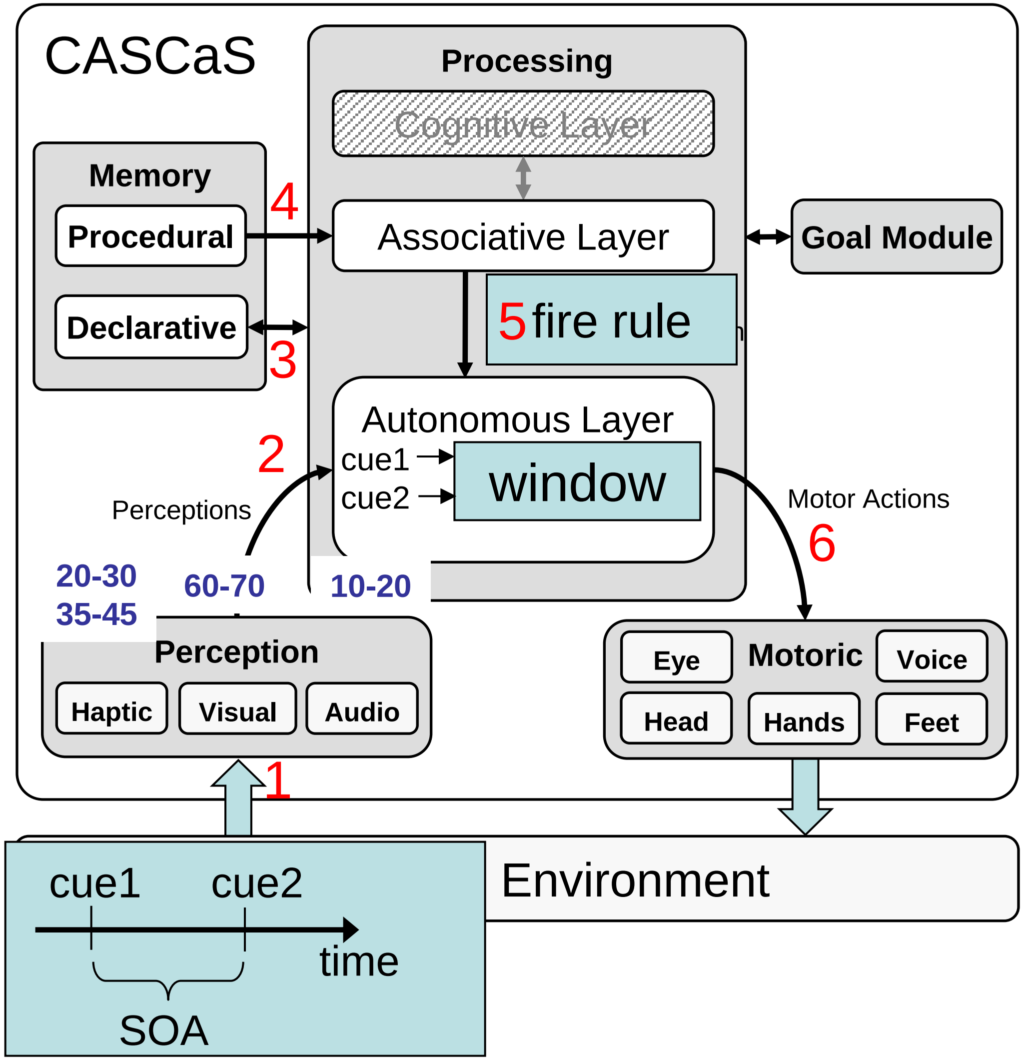


Multimodal Perception

CASCaS Integration II

Data flow in CASCaS

1. Signals from environment
2. Perception *triggers integration* process
3. Integration speeds up *creation of symbol* stored in *working memory*
4. Symbol is used for *production selection*
5. Fired rule triggers sensory motor pattern for eye-head movement
6. execution of orientation reaction

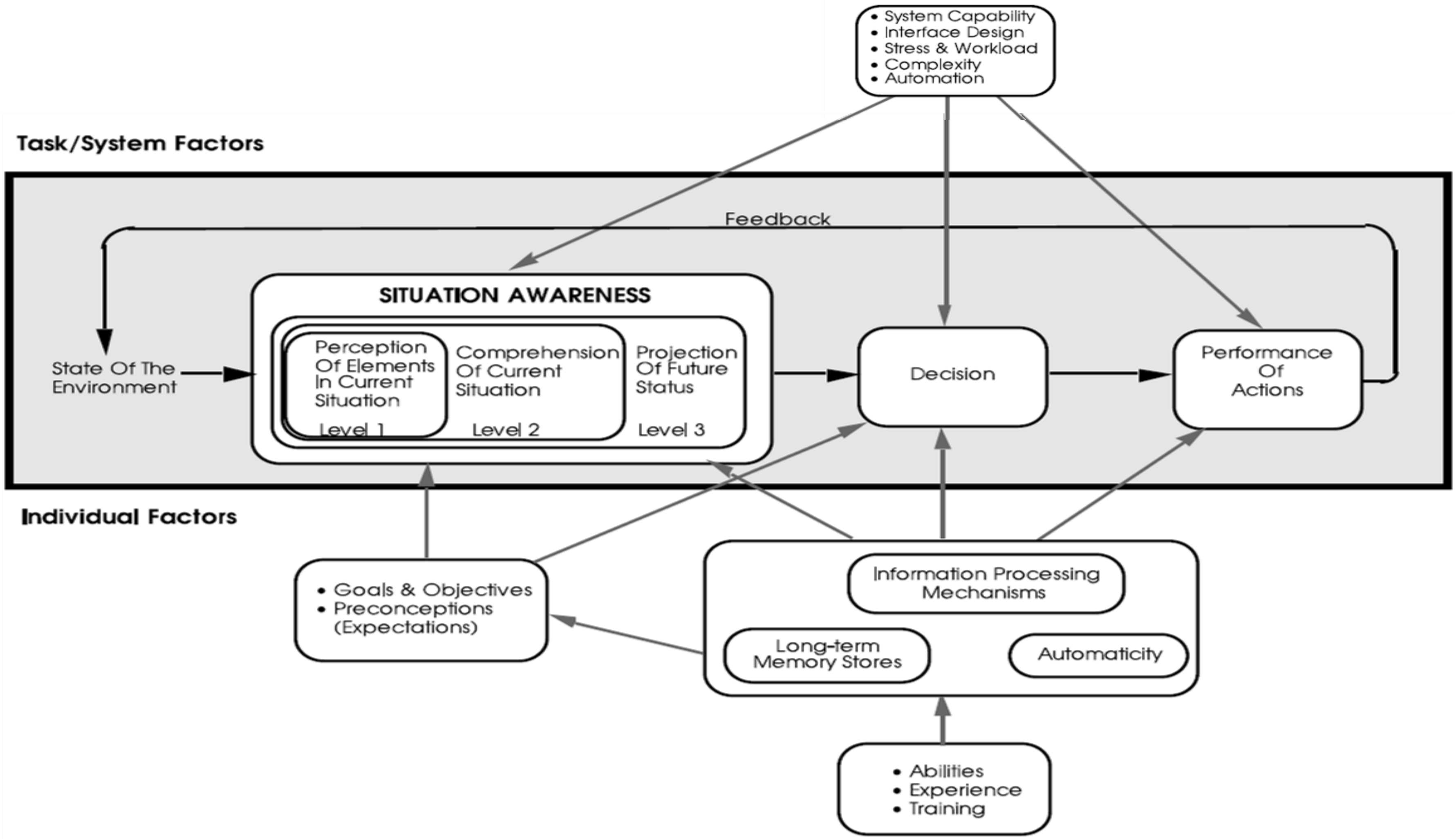


Situation Awareness
Key for decision making

- Precondition for safe driving
  - Coherent and adequate mental representation of the traffic situation

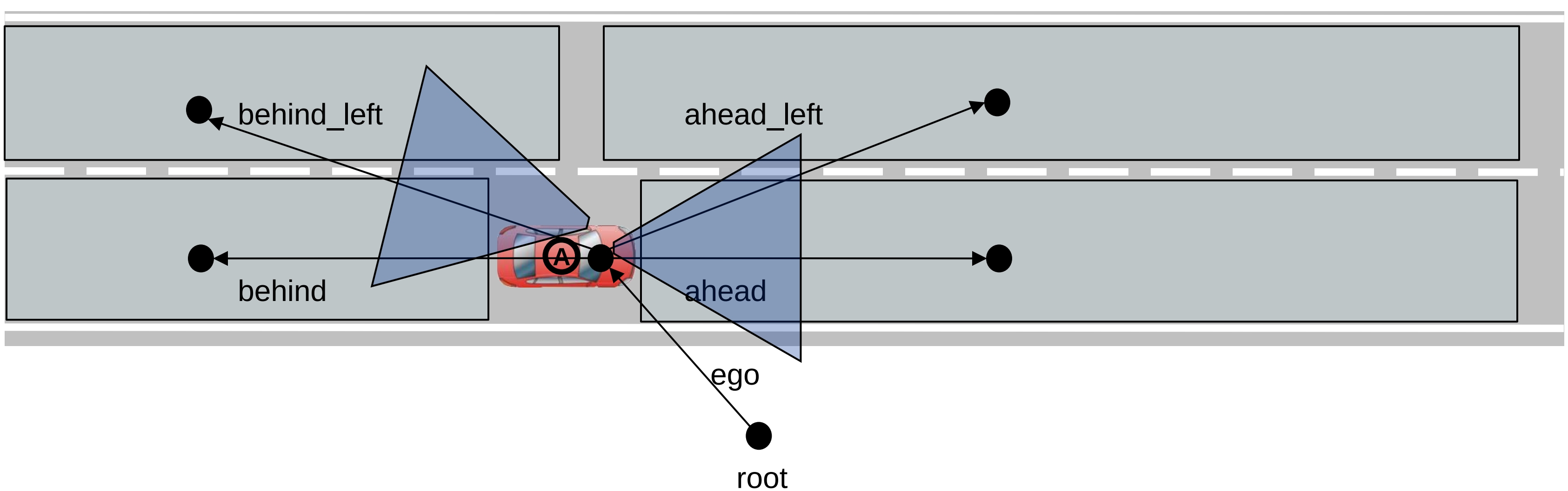
  „Knowing what is going on around you" (Endsley, 2000)
- Main question in ADAS development: Does ADAS (negatively) effect situation awareness?
  - e.g. changes in information aquisition / integration / behavioral change
- Goals for IMoST-2
  - Further develop CASCaS as an engineering tool in terms of situation representation
  - More explicit situation representation compared to IMoST1
    - Objects with features (position, speed, …)
  - Ego-centric spatial representation (Harrison & Schunn, 2003)
  - Step-wise construction of situation representation for representation levels
    - processes work on different levels, each level encoding different kinds information (e.g., Kintsch, 1998; Gernsbacher, 1990)

Situation Awareness
Endsley's (1995) model of situation awareness as reference



Situation Representation
1. Ego-Centric Representation

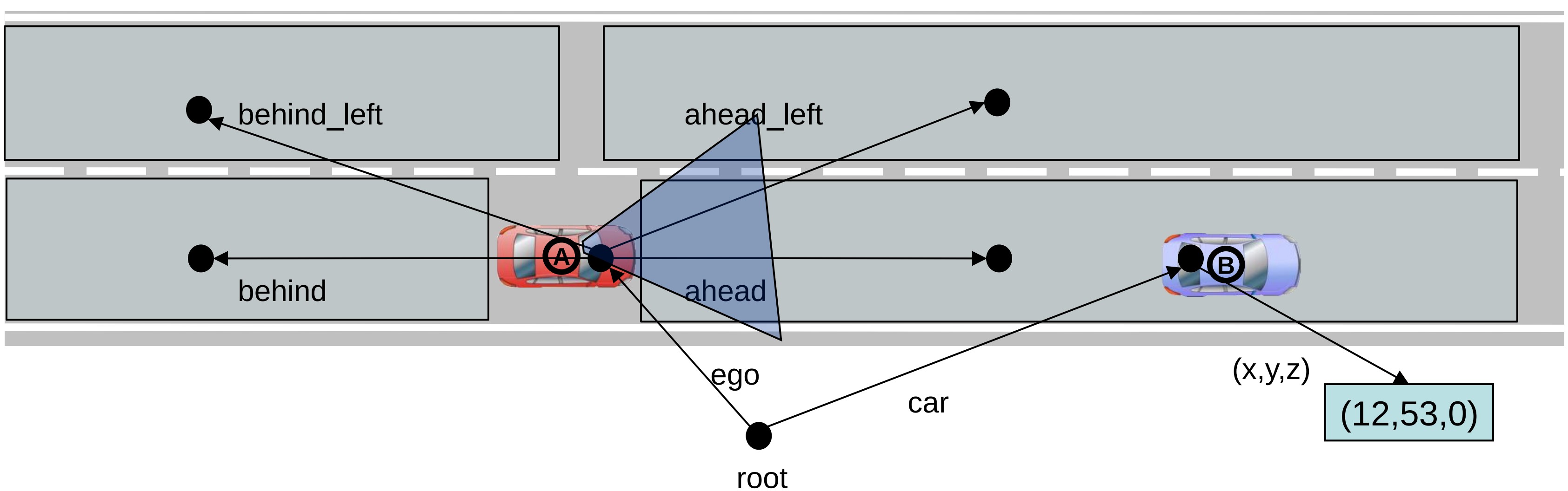
- CASCaS: declarative memory using a semantic network
- Model creates ego-centric spatial representation
  - Splits environment into "zones"
  - Observes surrounding environment through
    - Windshield: direct view, perception uses rel. coordinate
    - Left ext. mirror: indirect view, uses rel. mirror coordinates, OpenGL visibility calculations



Situation Representation

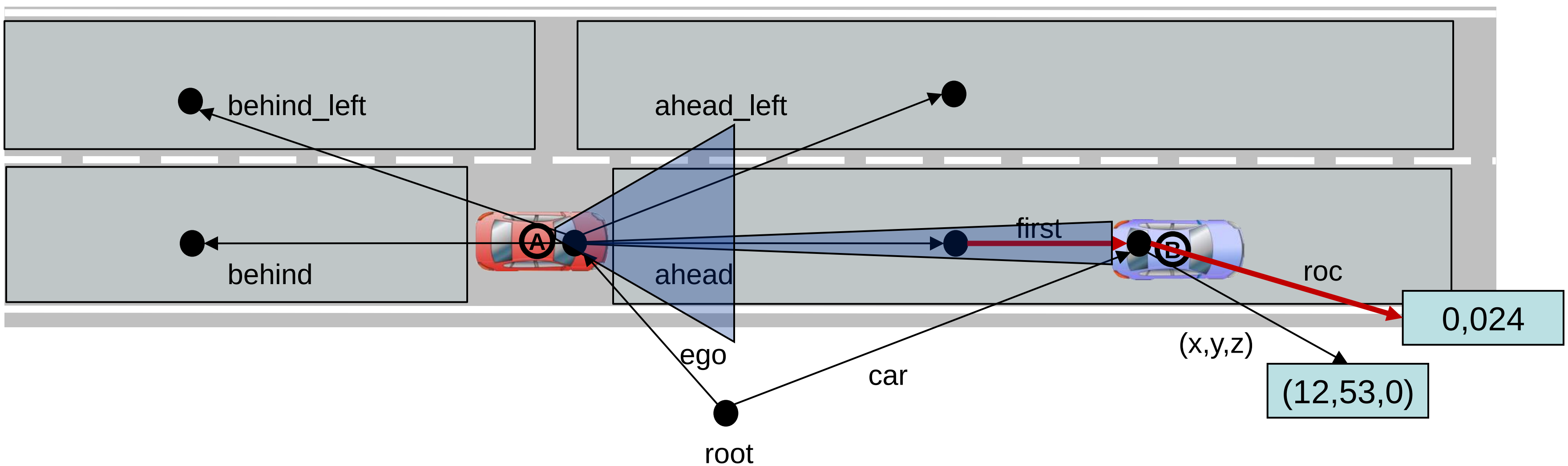
2. Peripheral Vision & Object Detection

- Model observes environment through windshield
  - Peripheral vision detects new object
    - The car is attached to the semantic network using the *object class*
  - Object is stored using relative 3D coordinates
    - Coordinates used for visual gaze direction calculations only
    - Not used for any further cognitive abilities



Situation Representation
3. Object Integration

- Model creates an internal traffic representation
  - Spatial representation: classifies cars in zones using "spatial" association names (first, second)
- Foveal vision to fixate object
  - Additional attributes are perceived, e.g. rate of change of visual angle (movement perception) rad/s

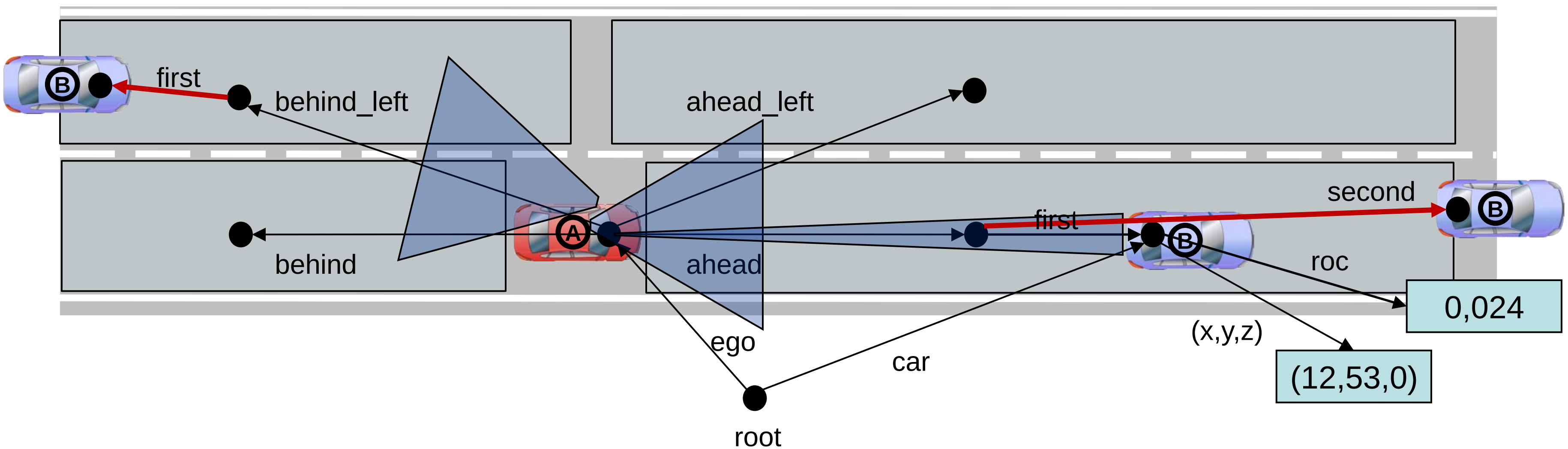


Situation Representation

4. Complex Situations

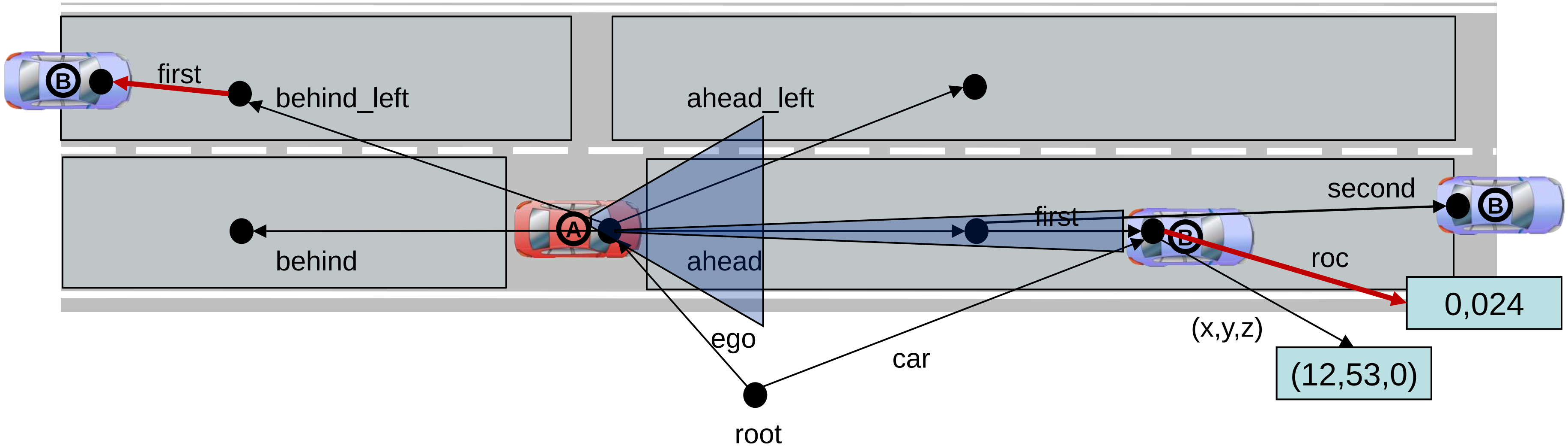
- Model builds explicit traffic representation if necessary
  - Not all cars are always integrated
  - Depends on current intention (goal)
    - e.g. no lane change intention

      → left lane rarely observed

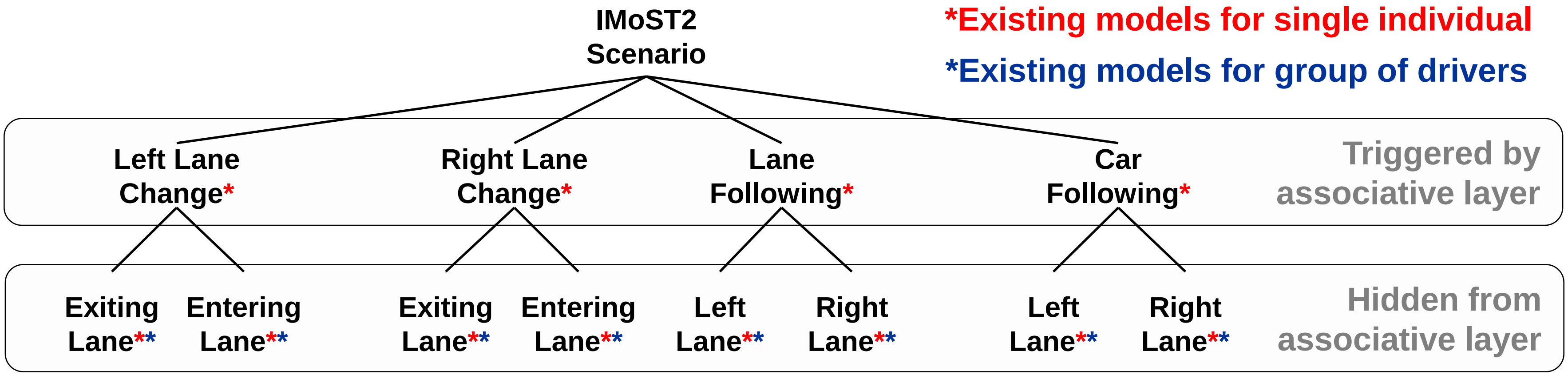


Situation Representation
5. Decision Making

- Model uses angular size and it's rate of change estimations
  - Free-flow → car following / lane change
  - Gap acceptance
- Rule based decision process
  - Currently fixed thresholds taken from data
    - ad hoc modeling may be used to force certain situations
  - Variance in gaze behaviour, distance and speed estimation



Autonomous Layer
Skill hierarchy BAD MoB Model

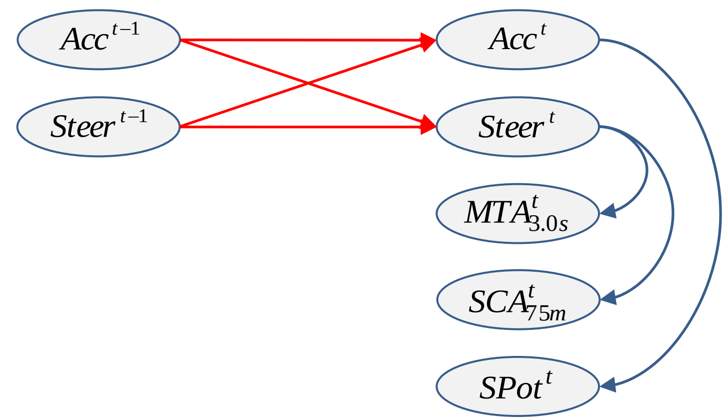


- Experimental data obtained in Experiment 1-2
  - Appr. 1,9 Mio. data samples for learning procedure
  - Eight trials of a single proband (male) are used for learning BAD MoB models of a single individual
  - 18 trials of six probands (3 male, 3 female) are used for learning BAD MoB models of a group of drivers
- Training and validation data
  - 75% of experimental data samples used for learning
  - 25% of experimental data reserved for validation

Autonomous Layer

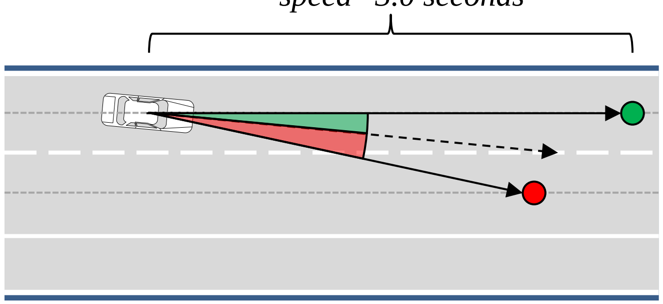
Example *Action*-model: Lane Following

- **Predefined structure for each *Action*-model**
  - Dynamic first order markov naïve Bayesian classifiers (Bayesian Filter)



- **Statistical most relevant percepts obtained from experimental data by machine-learning methods**

- **Pertinent percepts for lateral control:**
  - $\boldsymbol{MTA^{t}_{3.0s}}$: Angle between heading of ego-vehicle and lane point of middle lane in a *time-dependent* distance of speed * 3 seconds (**green**)
  - $\boldsymbol{SCA^{t}_{75m}}$: Angle between heading of ego-vehicle and lane point of slow lane in a constant distance of 75 meters (**red**)

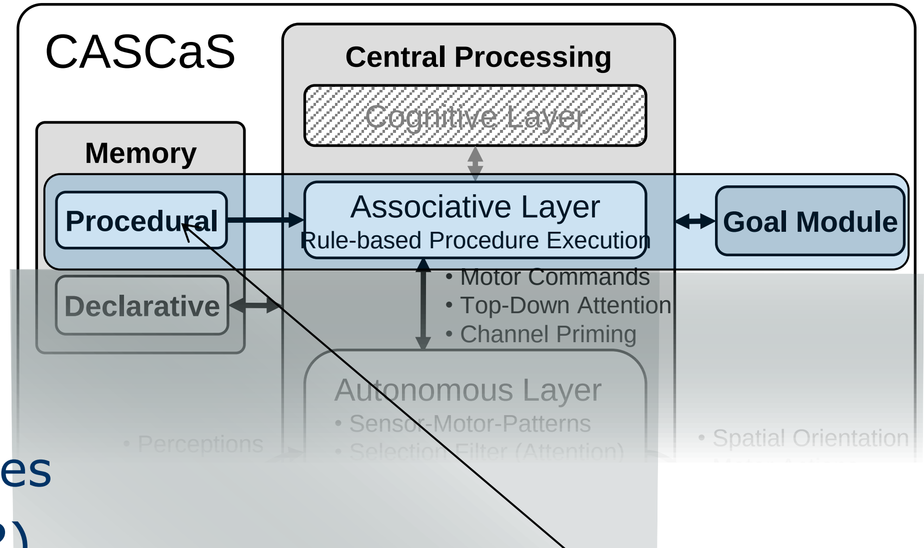


- **Pertinent percepts for longitudinal control:**
  - $\boldsymbol{SPot^{t}}$: Difference between speed limit and current speed of ego-vehicle

IMoST 2 Driver Model Modeling within CASCaS

Modeling within CASCaS
Knowledge Model & Procedure Execution

- Procedure → learned action plans
- Domain-specific knowledge loaded into the architecture
- Goal (What to do next?)
  - Attribute of a rule
  - One goal can have multiple rules
- Rule (How to achieve the goal?)
  - Condition → Action
- Cognitive Cycle:
  - Goal Module selects current goal
  - Associative Layer requests rules from procedural memory
  - Associative Layer executes rule and initiates a new cycle.



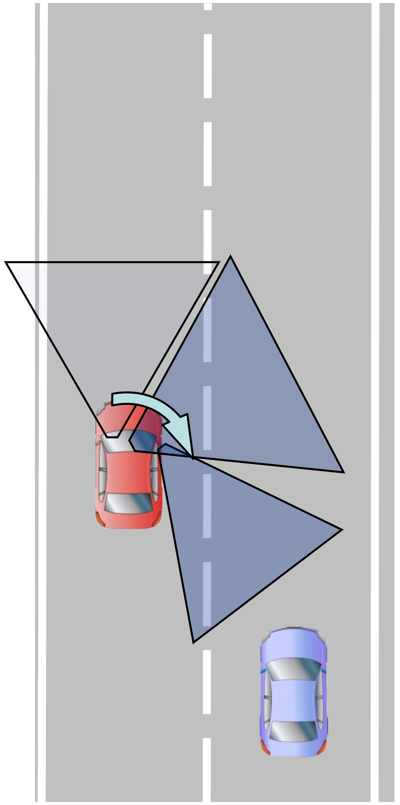

```
rule (id=1, goal=name, type = ...) {
  Condition Part
  →
  Action Part
}
```

Modeling within CASCaS
Example: Lane Change Right

A possible rule to trigger a lane change right

- Assumption: model shifts gaze from windshield to right mirror (goal observe_right_ mirror)

```
rule (id=1, goal=observe_right_mirror, type=regular) {
  //ahead_right, behind_right  objects of type "Car"
  //'none': internal dummy object for none-existence
  Condition ((ahead_right.first == 'none') &&
                 (behind_right.first.ang_size > thr_behind))
 →
  Motor (driver_skills, 'lc_right')
}
```

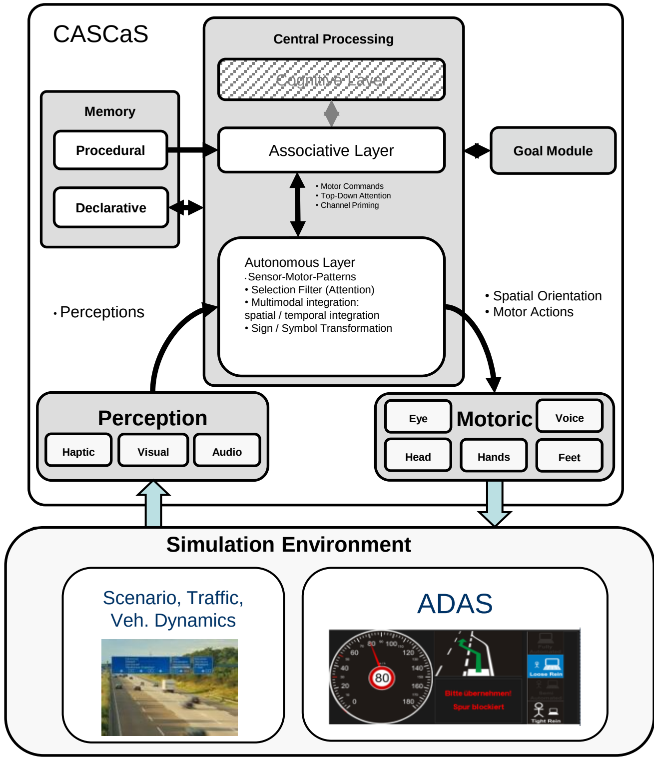


- Peripheral vision → reactive behavior possible using another rule

Modeling within CASCaS
Define Dataflow: Simulator - Model

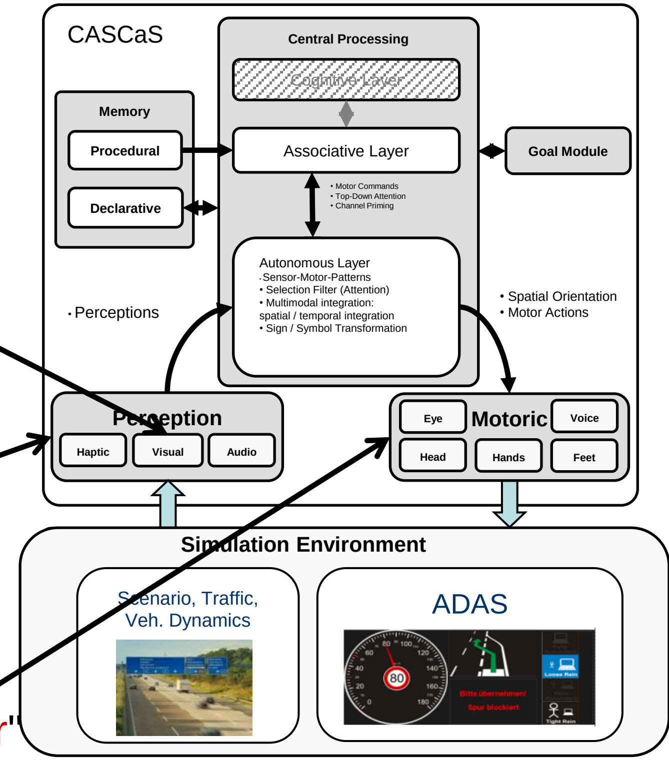
```
<tns:types>
  <tns:type name="Car" type="dynamic" modality="visual">
    <tns:variable name="x" type="double" />
    <tns:variable name="y" type="double" />
    <tns:variable name="z" type="double" />
    <tns:variable name="ang_size" type="double"/>
      ...
  </tns:type>
  ... further data types: sign, mirror, windshield, display
</tns:types>
```

- 3D coordinates used for eye movement time and peripheral view calculations
- Angular size of objects can be perceived through peripheral vision
    - if object is focussed, attribute is used for estimation of movement speed



Modeling within CASCaS
Define Dataflow: Simulator - Model

- variable_definition: define number of objects that can be transmitted from the simulator to CASCaS and vice versa
  - e.g. simulator may have a sensor that can detect 10 cars in parallel
  - does not mean CASCaS can percept all of them in parallel !




```
<tns:types>
  <tns:type name="Car" type="dynamic" modality="visual">
     ...
  </tns:type>
</tns:types>

<variable_definition>
  <variable name="car_1" type="Car" mode="in" >
  <variable name="car_2" type="Car" mode="in" >
  ...
  <variable name="speedometer_display" type="Speedometer"
  <variable name="action" type="Actions" mode="out">
<variable_definition>
```

ADAS Interaction
How to integrate into driver model?

- How to integrate interaction in general:
  - Additional rules which trigger additional actions (e.g. warnings use reactive rules)
  - Extension of procedure according to new cues
    - Alternative rules within the same goal
- What can we do with this modeling?
  - Simulate interaction with changed gaze behaviour
  - Measure impact on maneuver execution
- LDW: reactive rules trigger additional steer left/right actions which override the typical steering behavior.
  - If simulating drivers that are unexperienced with the system, this is a plausible approach
  - Collision warning: could be implemented similar to LDW
- LCA:
  - Full trust in system: rule which initiates lane change directly
  - System as additional cue, integrate with existing procedure

Future Work

- Architectural limits
  - Improve spatial representation model
  - TWIN model generalizations
- Procedure limits
  - Successive rapid lane changes of multiple cars behind produce critical situations which seem unrealistical
  - Current lookahead is one car only
  - Gaze behavior modeling can be improved
    - Scanning patterns in most cases static
    - Drivers look at many more locations
- Further validation (experiments) necessary
  - e.g. maneuver initiation validated using various TTC values only
- ADAS interaction:
  - Current modeling is ad hoc. Partially, due to reduced project duration 3 → 2.5 years. Need further research urgently.
  - Investigate and model behavioral change (adaption process)

IMoST 1 → IMoST 2

IMoST 1 Model	IMoST 2 Model
No peripheral visual perception	Foveal / peripheral visual perception
Gaze behaviour not simulated	Spatial orientation (eye / head movement)
Simple memory model • single variables • leadcar_speed, • leadcar_distance	CASCaS now uses objects • "static": fixed environment (cockpit, mirror) • "dynamic": moving environment (cars,signs...) • perception → processing →memory
Model does not create situation representation	• Builds a spatial representation of surrounding traffic, estimates distances and differential speed
Autonomous layer: PID control	Bayesian Expert Models
No multimodal perception	• TWIN Model assumptions hold in simulator • Basic implementation for haptic / acoustic channels and multimodal integration (not generic enough for ADAS interaction)
Single driving maneuver	Highway: free-flow, car-following, lane change
No ADAS interaction	How to: showcase examples for ADAS interaction