Man-Machine Systems for Autonomous Vehicles in Driving Simulation

The ANR CoCoVeA project

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OPAL-RT TECHNOLOGIES

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THE AUTONOMOUS VEHICLE: WHAT FOR ?

Comfort:

- Increase mean driving speed (smaller inter-distances)
- Solution to park problems
- Reduction of traffic jams

Safety:

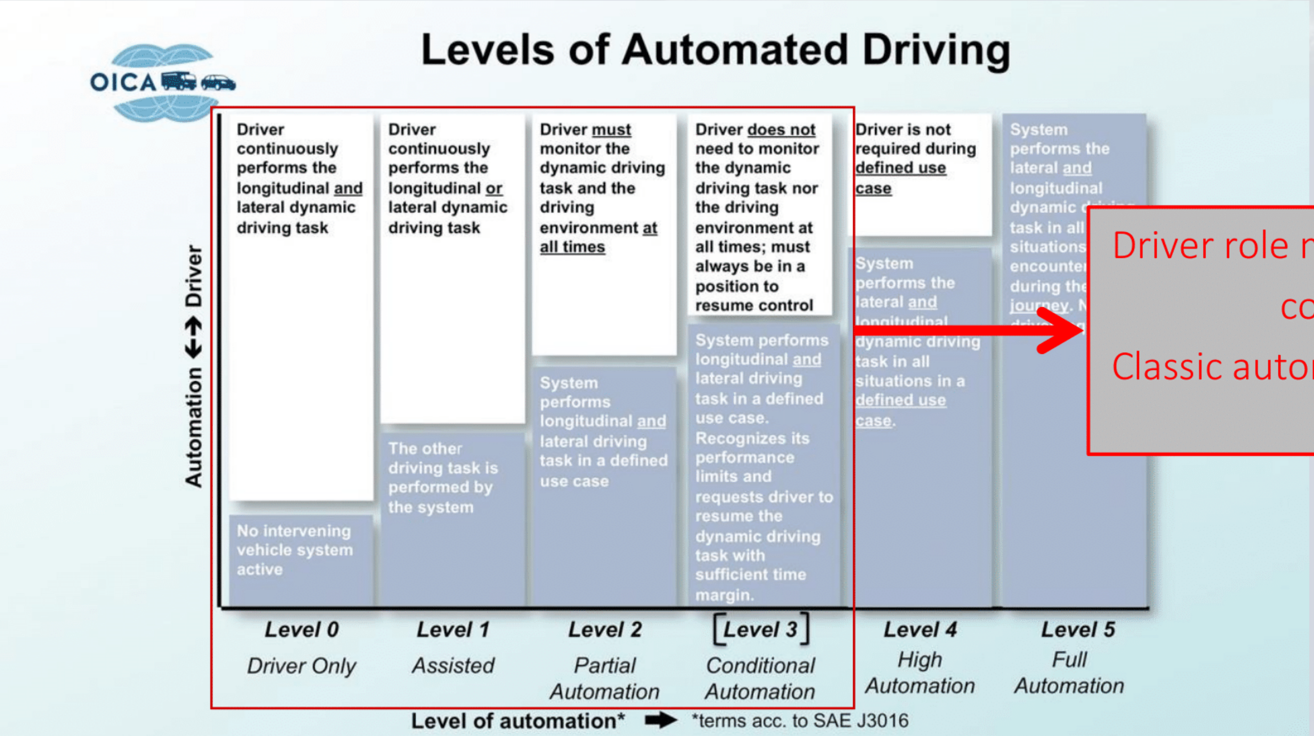
- Reduction of accidents number and severity
- Reduction of driving infractions (speeding, behavior …)

Economy - society:

- Better energetic efficiency
- "Better" use of time spent in vehicles
- Car sharing (shared use)
- Mobility challenges (silver-economy & disabled)

AUTOMATED DRIVING

Large increase of automation level



Driver role modification:

control → supervision

Classic automation issues

DRIVING AUTOMATION REQUIREMENTS

Perceive the environment & locate the vehicle

- GNSS, SLAM, vision, radar, lidar, communication V2V, V2X, …

Trajectory planning

- Potential fields method, graphs, interpolation, …

Control the movement of the vehicule on this trajectory

- Automatic control (optimal control: backstepping, MPC, …)

Manage the situation dynamics

- Mobiles (vehicles, pedestrians …)
  - Impact on trajectory & control
- Automation levels
  - Engage/ Disengage automation
  - Manual recovery

→ Interactions with the driver

CONTEXT, NEEDS & CHALLENGES

Context

- Increase of systems number and of their complexity (from information to driving automation)
- More information to communicate to the driver
- Interactions with the driver through several different modalities (visual, sound, haptics)

CONTEXT, NEEDS & CHALLENGES

Context

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CONTEXT, NEEDS & CHALLENGES

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CONTEXT, NEEDS & CHALLENGES

Context

- Increase of systems number and of their complexity (from information to driving automation)
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Needs: Cooperation between driver & vehicle

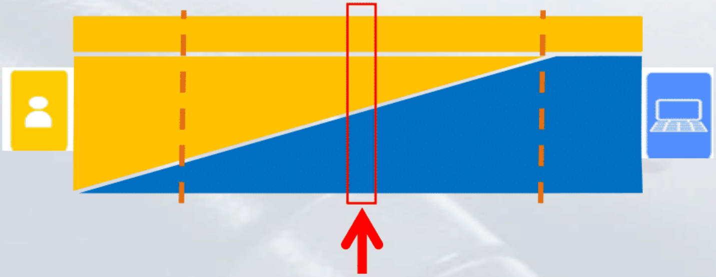
- Good understanding and anticipation of systems' actions
- Current Automation Level awareness
- Processing capacity and attention management (saturation, vigilance decrease)
- Fast reaction time (manual control resume)

Challenges

- Safety: assist the driver without bad side effects
- Acceptability : provide a real assistance (use complexity issue)

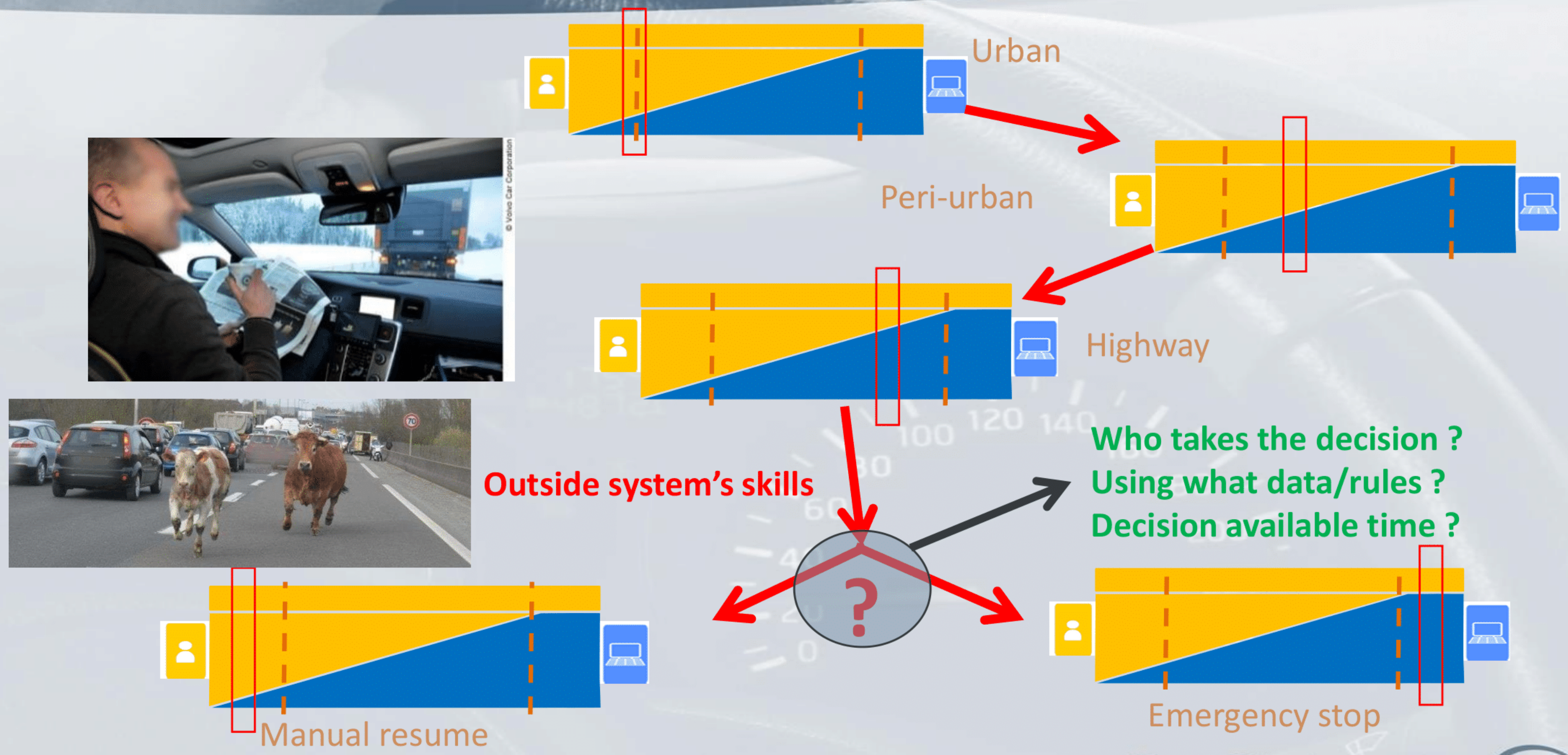
THE PROJECT AND ITS AIMS
TWO MAIN QUESTIONS

- The automation level control (task sharing) and the authority management between the driver and the systems
  - e.g. : Management of transitions:
    - Automated -> Manual
    - Manual -> Automated



- What information and how to exchange between the system & the driver (information load)
  - e.g. : underload (disengagement risk), overload (saturation risk)

Example : Automation Levels during a small trip



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THE PROJECT AND ITS AIMS
MAIN CHALLENGES

Scientific challenges

- Driver state assessment (WL, attention, vigilance …)
- Fitting between driver state regarding driving context induced demands
- Human-Machine Cooperation & control sharing
- Dynamic task allocation methods and automation level control

Technologic challenges

- How to design a cooperation system between driver and automated system ?
- How to organize the information flow between driver & system on multi-modal HMI ?

THE PROJECT: CONSORTIUM AND PLANNING

Partnership

- Three academics
- Five companies

Budget

- Global : 2.954.289 €
- ANR funding : 999.248 €

Calendar

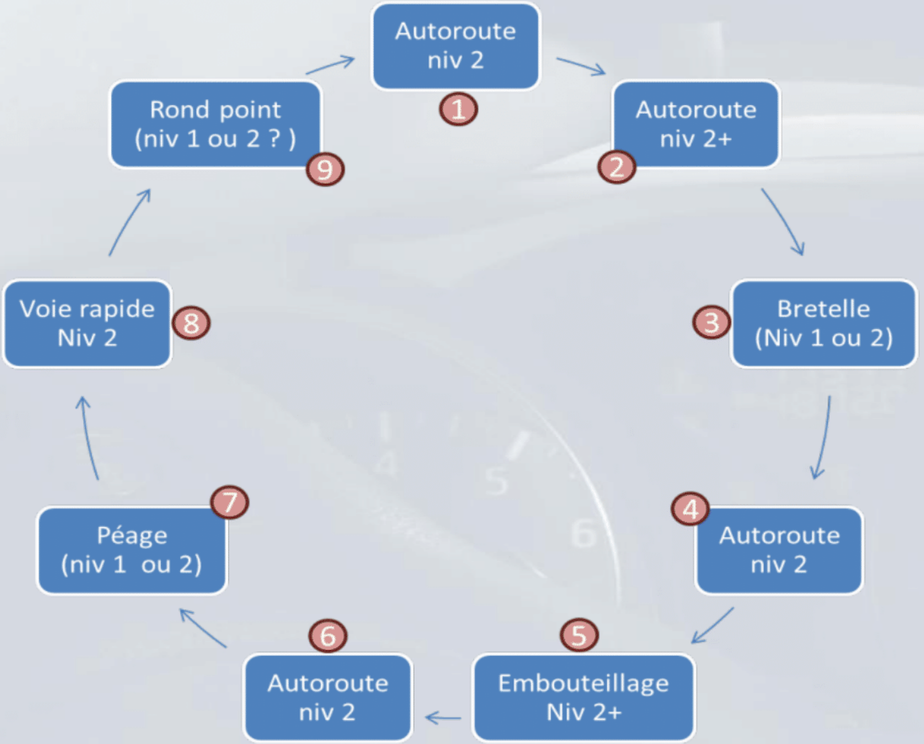
- Kick off: November 2013
- Duration: 48 months

WORK PACKAGES AND STRUCTURE

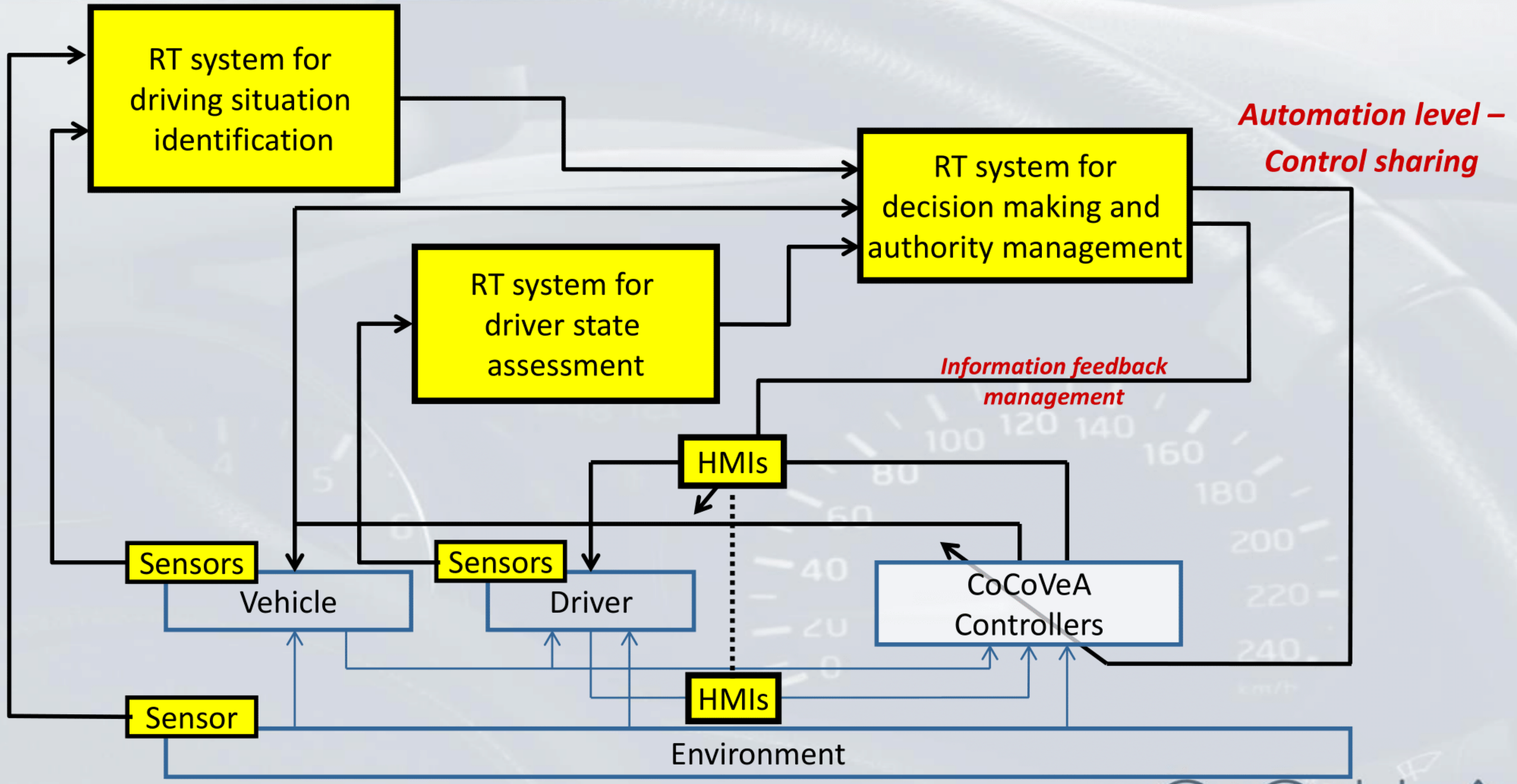
7 main work packages

2. Specifications, scenarios & architecture
3. Design of control sharing and automation levels modulation
4. Design of HMIs and information management mechnisms
5. Data collection and perception
6. Prototyping & functional assessment in driving simulator
7. Deployment on real vehicle
8. Experimentations for functional validation

2. USE CASES


Autoroute niv 2
1
Autoroute niv 2+
2
Bretelle (Niv 1 ou 2)
3
Autoroute niv 2
4
Embouteillage Niv 2+
5
Autoroute niv 2
6
Péage (niv 1 ou 2)
7
Voie rapide Niv 2
8
Rond point (niv 1 ou 2 ?)
9

2. GLOBAL ARCHITECTURE



3. STATE CHART

Used for authority management

Implements the mechanisms for automation level modification (OICA LoA) and their associated conditions

- Driver state (Paying attention, hands on the wheel …)
- Driving situation (road kind, speed, speed limit …)
- Actions on the car controls (HMI, gas & brake pedal, steering wheel …)
- System skills (inside or outside the system skills domain)

3. STATE CHART

Used fo

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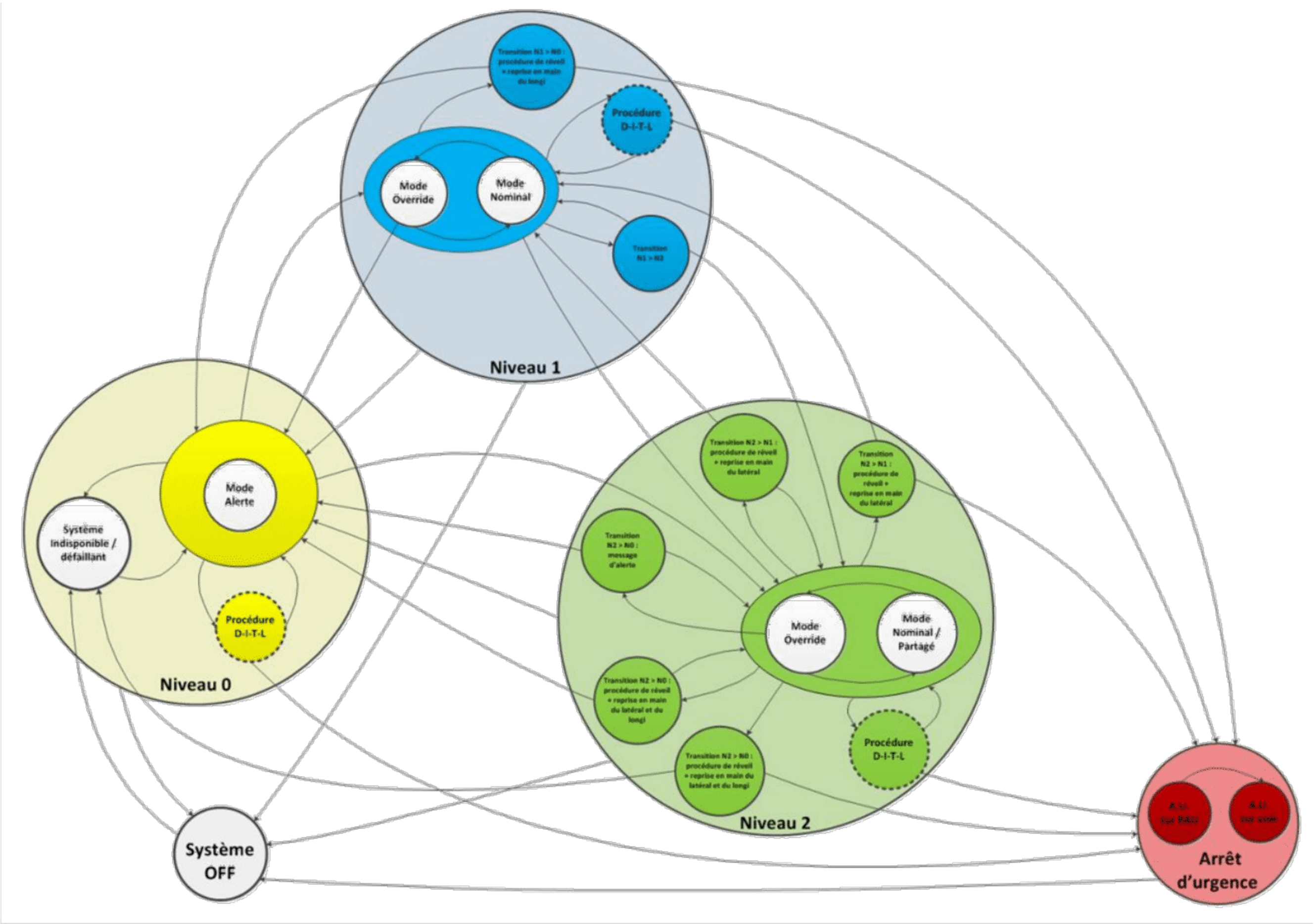
- Driver s
- Driving
- Actions ...)
- System

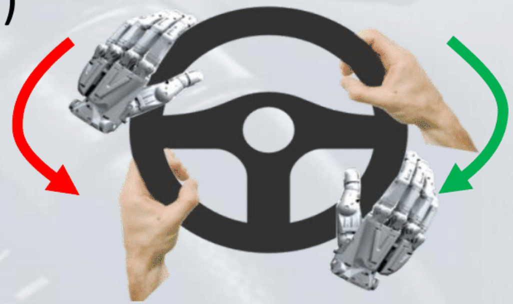


3. DRIVER / SYSTEM COOPERATION

Managing interferences is a critical issue

Studies about LKA (Lane Keeping Assistance)

- Tend to increase the number of collisions (Griffiths et al, 2005)
  - Vigilance problems, over-trust (lack of reaction toward risk)
  - "Conflict" management



Conflict : two possible strategies

- Driver Action ➔ system disengage
- Continuous Shared Control ➔ mutual "understanding"

Requires a model / an architecture

- A hierarchical driving task (Michon 1985)

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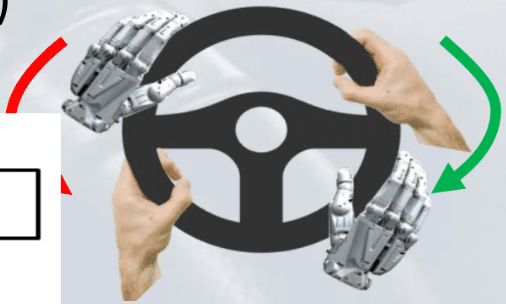

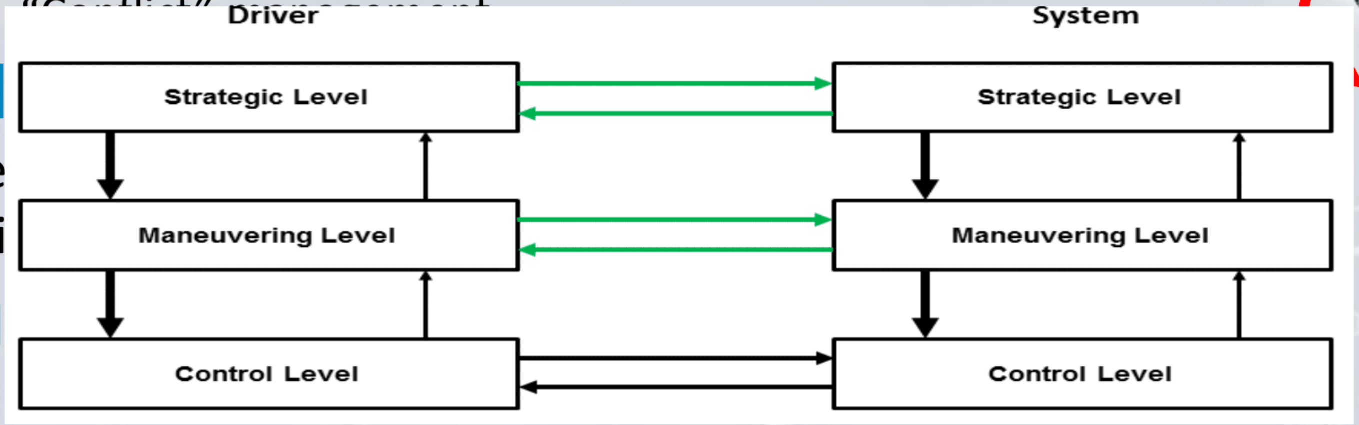

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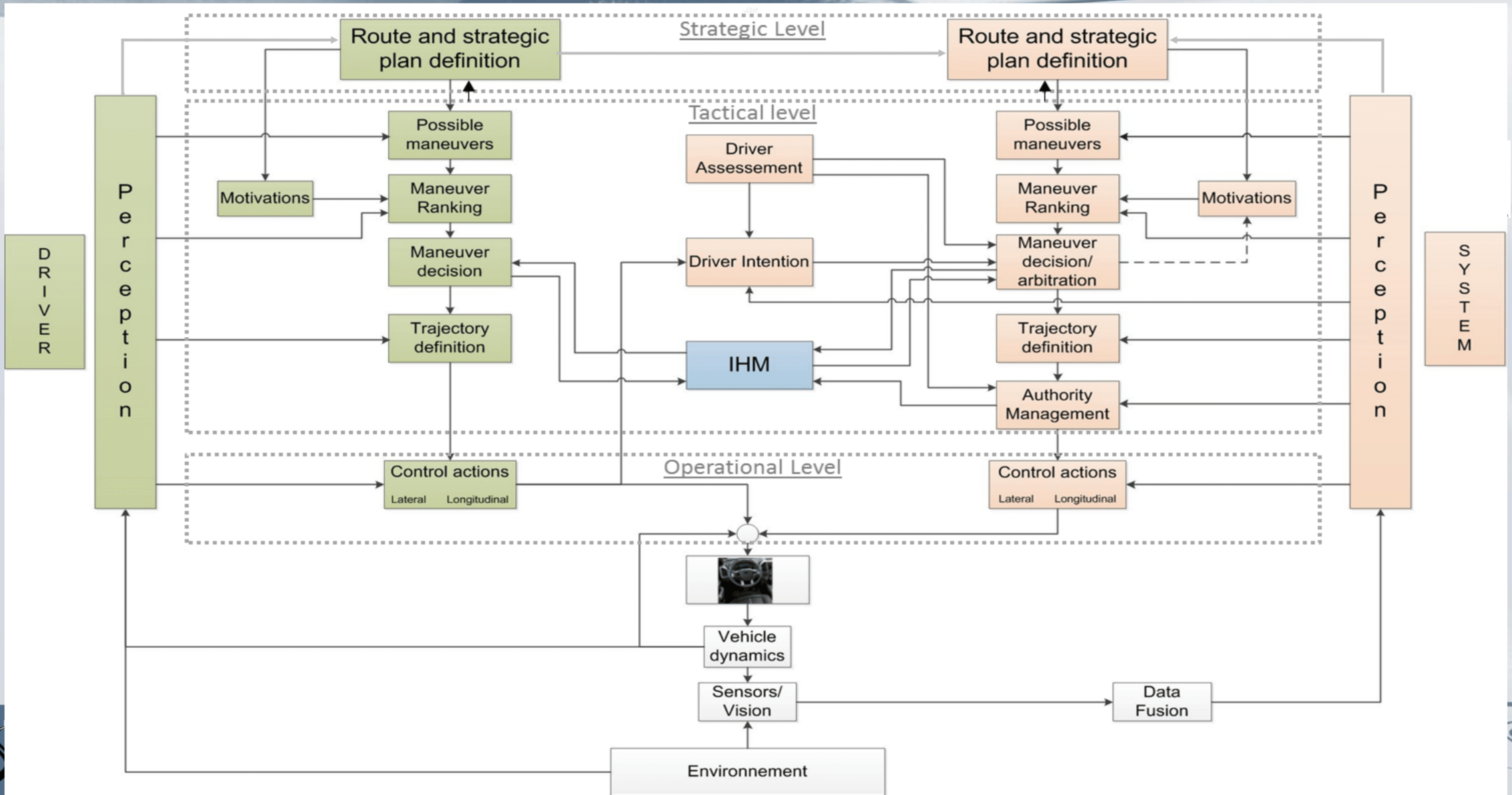
Cooperation is designed for each model level

3. MULTI-LEVEL COOPERATION ARCHITECTURE



4. DRIVER-VEHICLE INTERACTIONS

Bi-directional haptic communication

- Steering wheel (torque feedback)
- Gas pedal (Force feedback)

Visual HMI

- Especially designed to fit the use cases, the state chart and the selected cooperation modalities

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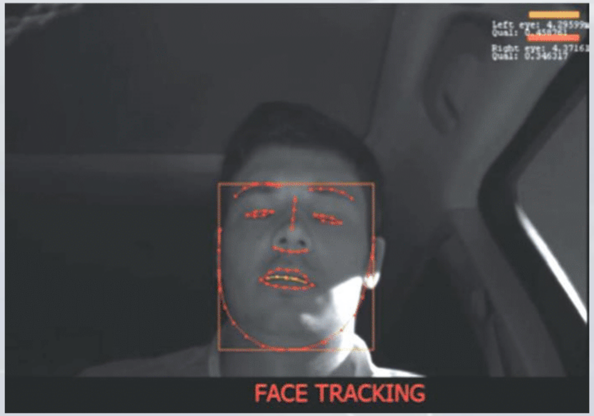
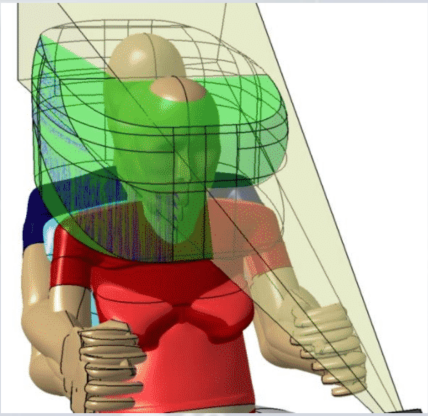
5. DRIVER MONITORING

Aims:

- Measure driver's vigilance and attention levels
- Be sure that the driver's has its hands on the wheel

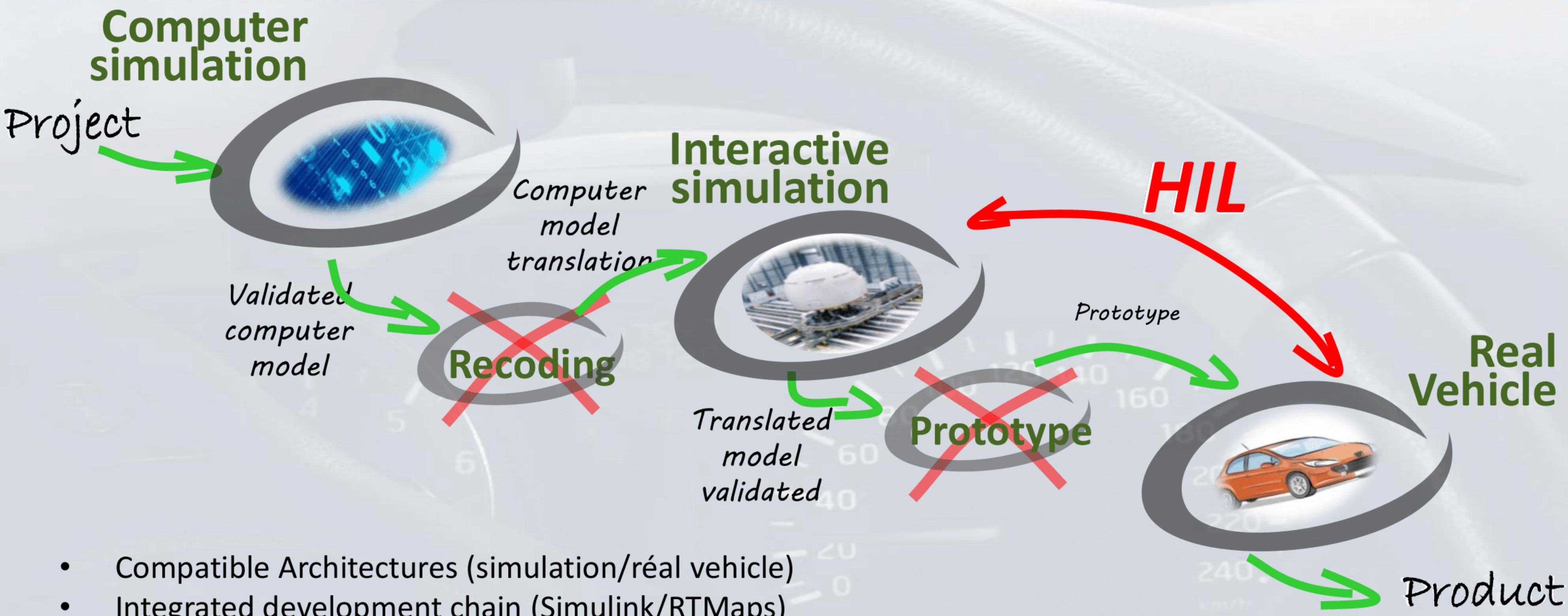




Method:

- Integration of a Driver Monitoring system (image processing based)
- Steering wheel equipped with capacitive sensors

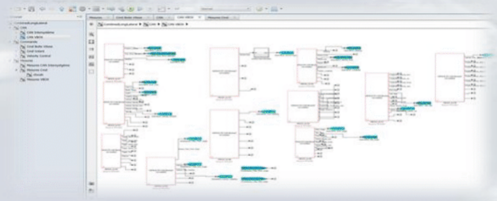
6. DEVELOPEMENT / VALIDATION STEPS



- Compatible Architectures (simulation/réal vehicle)
- Integrated development chain (Simulink/RTMaps)

PROTOTYPING AND VALIDATION ARCHITECTURE

Architecture of the CoCoVeA system



Simulink prototyping

Rapid prototyping:

- I/O : Offline data
- Matlab/Simulink (no Real Time)
- Validation on SHERPA driving simulator
- Limited HIL

SHERPA specific:

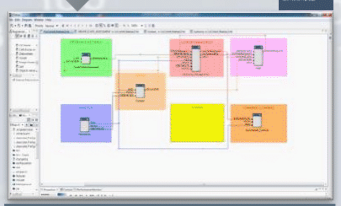
- Driver Monitoring
- HMI
- Hands sensor

SHERPA - LAMIH

Validation

Validation

Compatible architectures



Implémentation sur RTMaps

Portage :

- I/O : Simulated sensors (SENSOR)
- RTMaps (Real Time)
- Validation on SHERPA
- Full HIL (CAN)

C1 specific:

- Video camera
- LIDAR
- GPS RTK
- IMU

Citroën C1-ENSIAME

Validation

Integration :

- I/O : Real sensors
- RTMaps (Real Time)
- Real vehicle validation
- Full HIL (CAN)

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DEMONSTRATOR ON SHERPA

Main characteristics :

- Instrumented Peugeot 206
- 6 axis dynamic platform
- 240° front display & 3 rearview mirrors
- SCANeR Studio software
- Specific interfaces for Matlab/Simulink & RTMaps for ADAS prototyping
- Specific equipments: glass cockpit, instrumented steering wheel, FF gas pedal, driver monitoring, eye tracking

7. DEMONSTRATOR ON C1-ENSIAME

C1-ENSIAME:

- Autonomous vehicle test platform of ENSIAME (Engineer school)
- Integration of driver system cooperation, especially the haptic shared control

VIDEO OF THE SYSTEM IN SHERPA

RESULTS SYNTHESIS

CoCoVeA allowed to:

- Define a multi-level cooperation architecture
- Identify the driver's informational needs to perform his driving task and this according to the automation level (shared driving, supervision, delegation, resume control)
- Define the HMI mechanisms for providing this information to the driver and collecting his instructions
- Define the driver's monitoring requirements (in manual and automated driving)
- Define the switching mechanisms between driving modes and the conditions associated with these transitions
- Prototype all the work in the form of an integrated system on a driving simulator
- Prototype part of this work on real vehicles
- Evaluate prototypes on driving simulators

CONCLUSION

Automated vehicle

- Challenges are not technics related only !
- The driver role has to be redefined and will change depending on the technical progresses
    - Conflict / Authority ; Transitions ?
    - Training ?
    - Skills erosion ?
    - …
- These studies would be impossible without an adapted architecture for development & test
    - Assets of simulation (computer based and interactive)
    - Huge potential of a common system architecture

Thank you for your attention

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