interactIVe

Accident avoidance by active intervention for Intelligent Vehicles

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Artificial Co-Drivers as an Enabling Technology for Future Intelligent Vehicles and Transportation Systems

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interactIVe Final Event

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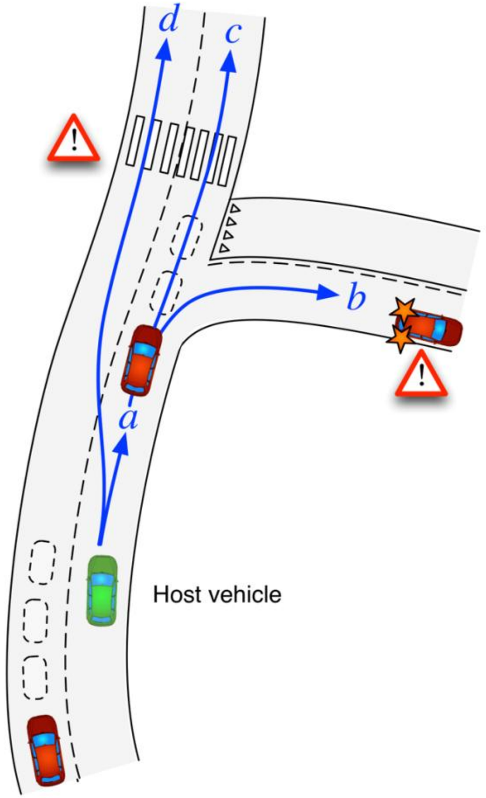
Agenda

- **The “co-driver metaphor”**
  - Genesis of the idea and natural co-drivers
  - Challenges
- **Technologies and design guidelines**
  - Simulation/mirroring theories of cognition
  - Understanding of intentions
  - Reproducing human sensory-motor behaviours
- **The co-driver implementation within interactIVe SP4 (CRF)**
  - Implementation of the building blocks
  - Discussion
- **Impacts of co-driver technology in ITS and future research**
  - Cooperative agents with natural human-peer collaboration
  - Cooperative systems.
  - Learning from rehearsed/share events

“How would a human driver drive?”

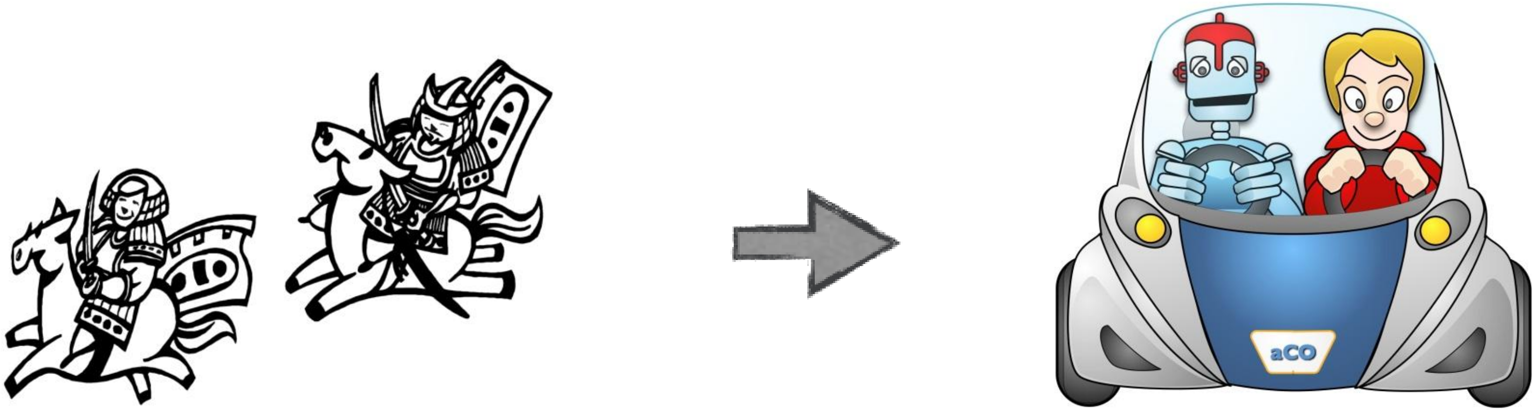


- A ”co-driver” is an intelligent agent which:
  - Produces human-like motor behaviors.
  - Understands human driver intentions.
  - Interacts accordingly.
- Natural co-drivers already exist
  - *e.g.*, horses – the H-metaphor (Flemish, Norman, et. al.)
  - *e.g.*, driving license tutor

Challenges

- It took 500 years to bring Leonardo’s idea to life.

- What do we need to bring the co-driver metaphor to life?



Simulation/mirroring theories of cognition

- Recent theories say that agents with similar sensory-motor system and capable of covert motor activities can use their sensory-motor system to "simulate" observed actions, and thus know the intentions of the observed agent (Hesslow 2002 and 2012; Grush 2004; Hurley 2008; Jeannerod 2001; Decety and Grèzes 2006; Wolpert, Doya, and Kawato 2003).

- Meltzoff says: agents that behave "like-me" have internal states "like-me" (Meltzoff 2007). The "like-me" framework essentially states that one agent "stands in the shoes of another".

- Internal simulations that "re-generate" the observed behavior identify the internal states of the observed agent, and thus the intentions (Haruno, Wolpert, and Kawato 2001; Demiris and Khadhouri 2006).

Human-like sensory-motor systems

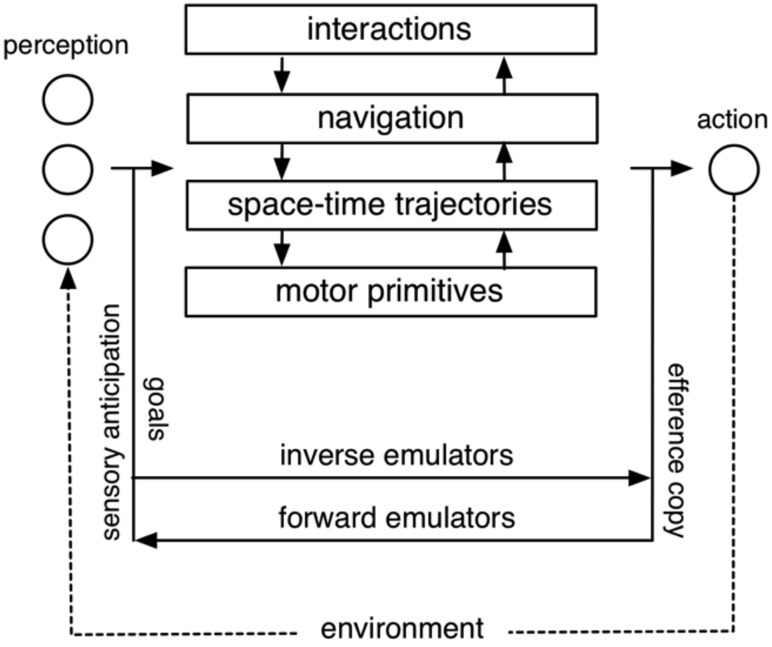
- Humans are organized in hierarchies of subsumptive behaviors (Brooks, 1986; Michon 1985; Hatakka et al. 2002; Hollnagel and Woods 1999, 2005).

- Human cognition is "grounded" (Gibson 1986; Varela, Thompson, and Rosch 1991; Thelen and Smith 1994; Van Gelder 1995; Harvey 1996; Clark 1997; Seitz 2000; Beer 2000; Barsalou 2008) in which the intelligent agent is seen in the loop with the environment, and perception and action are no longer divided.

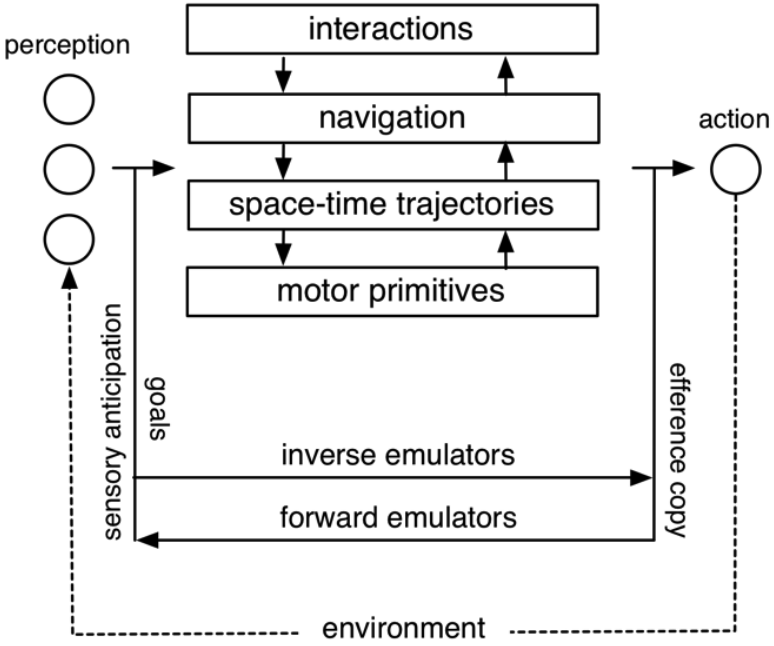
- The traditional paradigm of AI (the computer metaphor: input-processing-output) suffers symbol grounding problems of the abstract amodal symbol systems. It fails in modeling mutual understanding of agents.

Co-driver implementation in interactIVe SP4 (CRF)

- CRF implementation follows theories of mirroring/simulation.
- The architecture is hierarchical, subsumptive behavioral (top), extended with forward and inverse emulators (bottom).

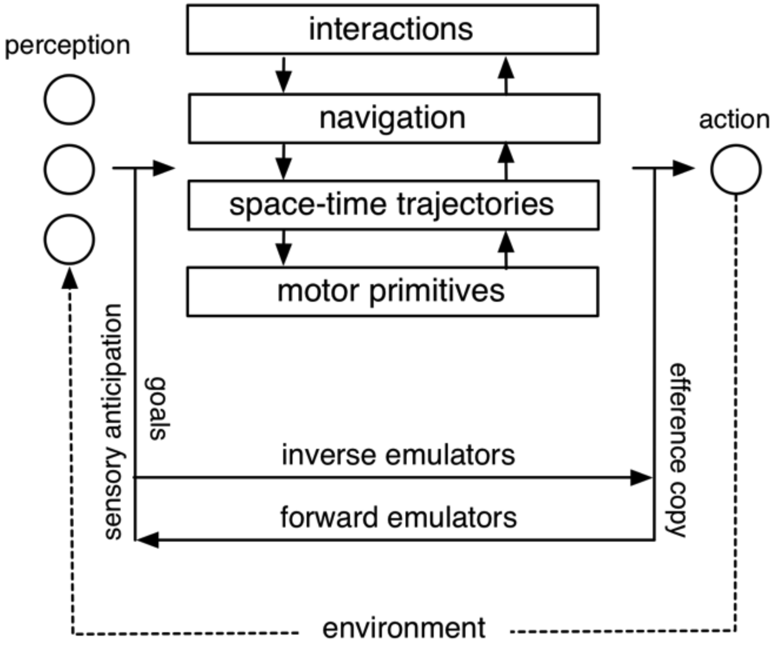


Building blocks/1 - Emulators



- Forward emulators are vehicle dynamics models that neglect high frequencies (not afforded by humans) but consider non-linarites.
- Inverse emulators are minimum jerk/minimum time optimal control plans.

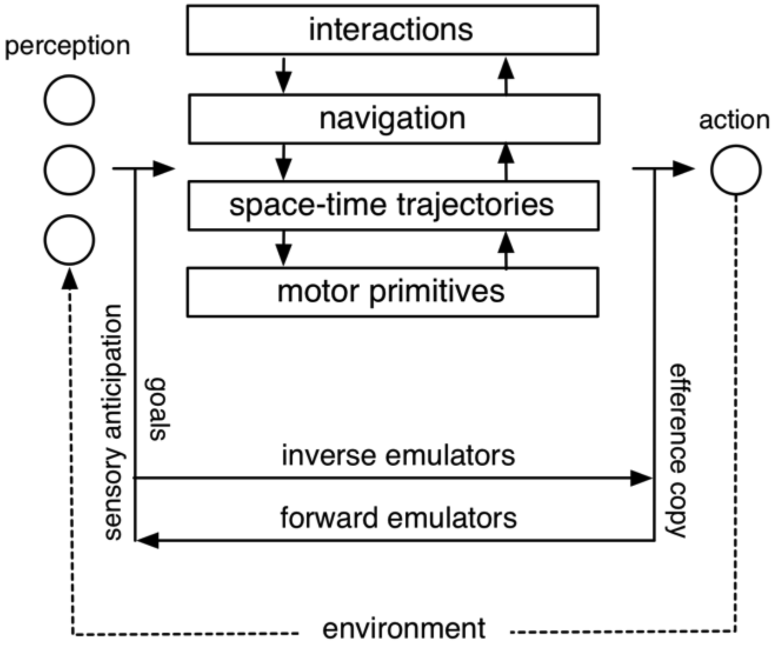
Building blocks/2 – Motor primitives



- Motor primitives are parametric instantiations of inverse emulators that achieve specified goals.

- There are 4 motor primitives:
  - Speed Adaptation (SA)
  - Speed Matching (SM)
  - Lateral Displacement (LD)
  - Lane Alignment (LA).

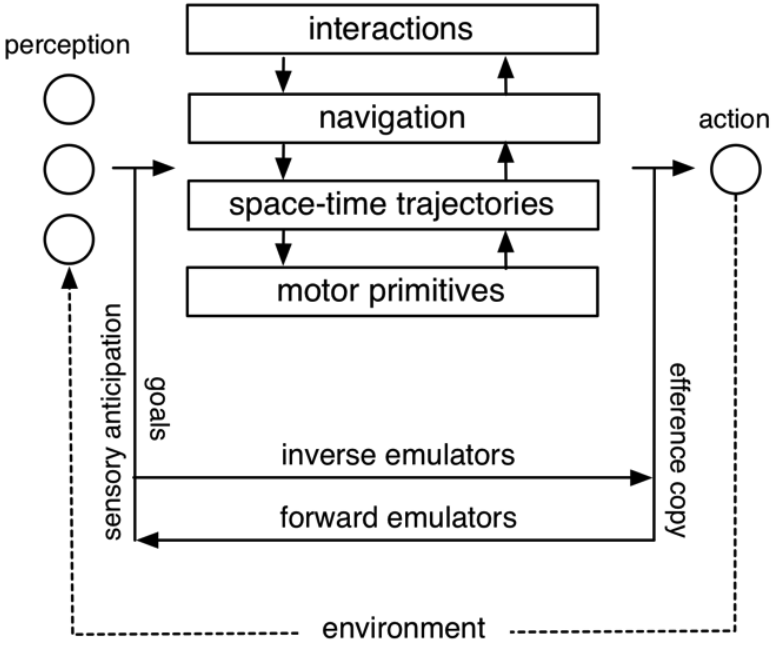
Building blocks/3 - Trajectories



- Space-time trajectories deals with either longitudinal or lateral control to manage one single motor task.

- There are 6 functions:
    - FollowObject (FO)
    - ClearObject (CO)
    - FreeFlow (FF)
    - LaneFollow (LF)
    - LandMarks (LM)
    - Curves (CU)

Building blocks/4 – Navigation hypotheses



perception

interactions

navigation

space-time trajectories

motor primitives

action

sensory anticipation

goals

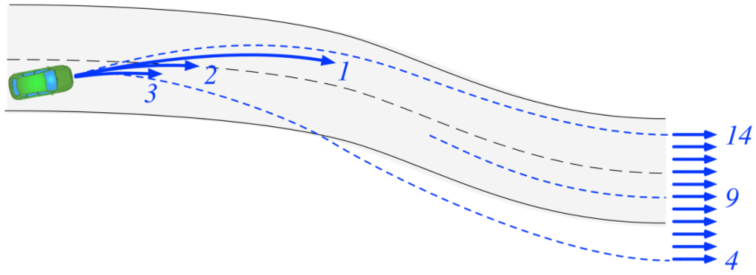
inverse emulators

forward emulators

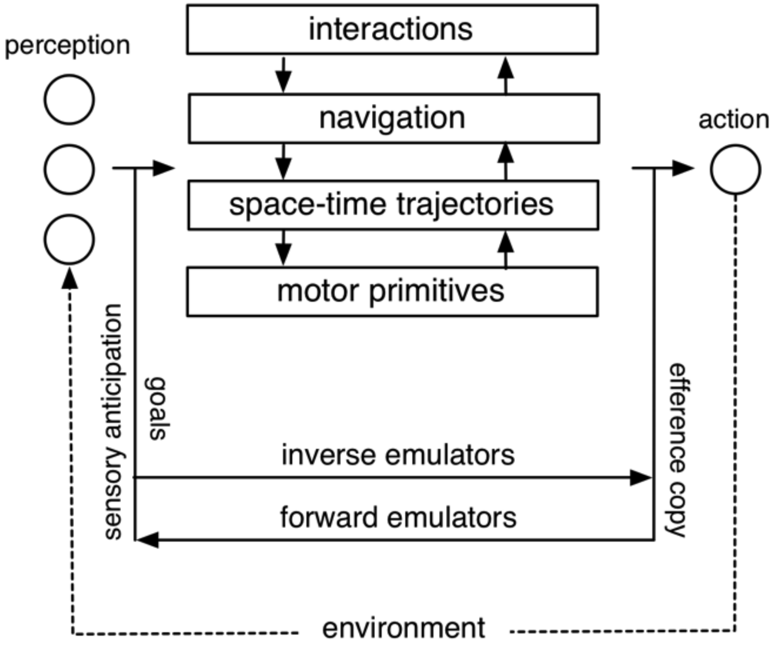
efference copy

environment

- Combines level 2 motor chunks into maneuvers.
- Makes arrays of hypotheses, including incorrect ones that will be used for inference of intentions.
- Example



Building blocks/5/a – Inference of intentions



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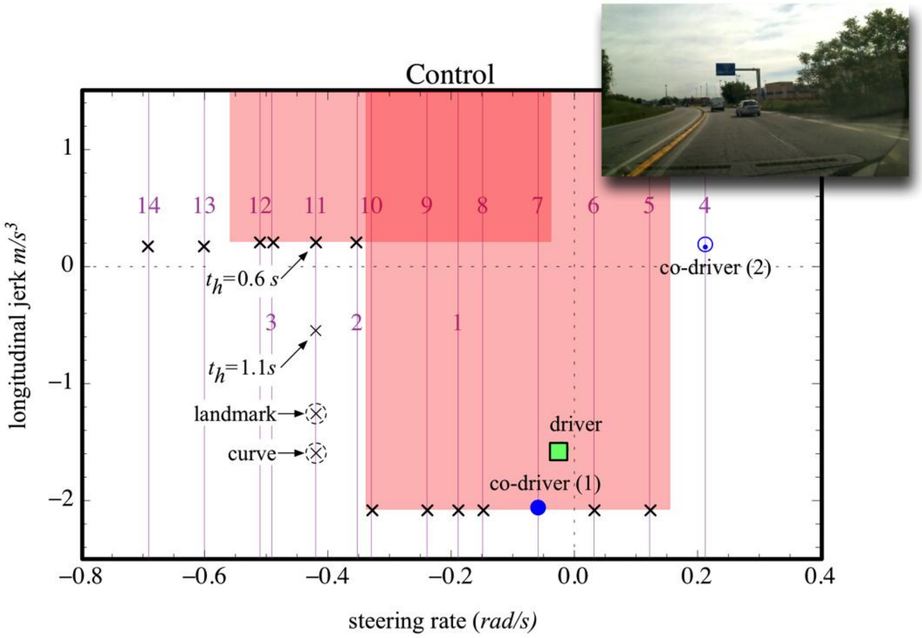
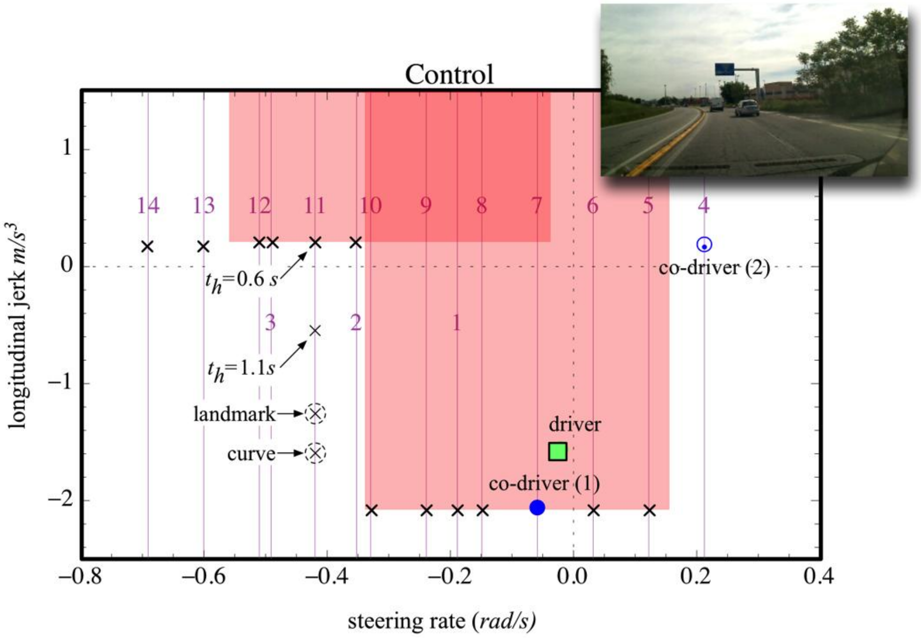
- Compares co-driver motor output of the generated hypotheses with human control.
- Use a saliency approach.



Building blocks/5/b – Interactions

- Interactions are application-dependent (CRF CS is an assistive system)
- Intention is known.
- If it is correct the system does nothing.
- If t is incorrect, the system knows two ways to rectify it.
- The system suggests the longitudinal correction, except when the lateral correction is in lane.



Discussion– User tests

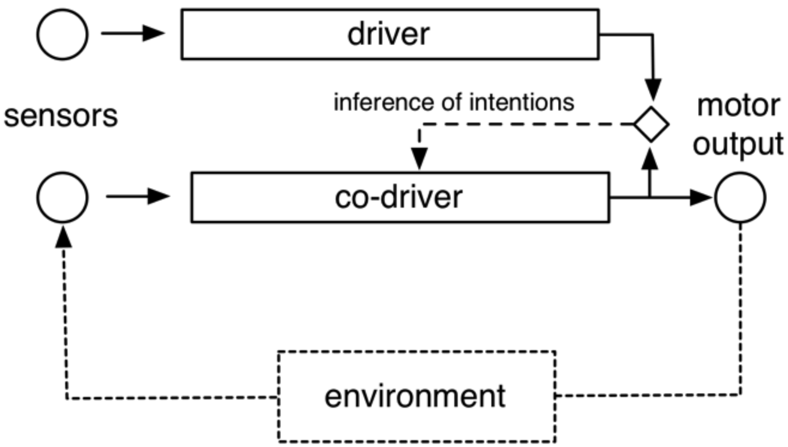
- The system has been tested on a ~50 km road path with ordinary drivers (24 drivers, twice each for a total of 35 hours).

- False alarms were a few (2-4) per trip most due to noise in the perception system. Very few alarms may be ascribed to incomplete/missing/imperfectly designed co-driver behaviors (most of these being due to mismatch between the driving styles, so not critical).

- Collect data will help refine the motor primitives and behaviors built into the system.
- The hierarchical architecture is easily scalable, maintainable and testable.

- Major limitations: the system does not work yet in intersecting roads (has poor understanding of intersecting vehicles intentions).

Impacts of co-driver technology – Joint human-robot system



- Enables Adaptive Automation (offer the appropriate support type and level at any time as a human peer would do)
- Improve execution of maneuvers (substitute human execution with machine execution while preserving the goal – just like chassis control but at navigation-cognitive level)
- Navigate by hints (just like a horse) and largely autonomously until new goals come manifest form the human
- Take over/supervise driver control (under certain conditions)
- Is understandable to other drivers.
- Unified framework for smart (safe, green, comfort) functions.

Impacts of co-driver technology

- Co-drivers enables **cooperative swarm behaviors,** by **exchanging** each other **intentions** they produce **Safety as emergent behavior** (see extra slide).

- **Deliberative Learning.** Co-drivers can use emulators to analyze rare events such accidents besting human expertise in occasional and accident scenarios.

Conclusions

- **It will not take 500 hundred years** (just like was for the helicopter) to bring co-drivers to life.
  - Many building blocks including architecture are clear.
  - Integration and research on other enabling technology are required (but there is a roadmap).

- **Co-driver may revolutionize**:
  - Human-vehicle (robot) interaction and user experience.
  - Cooperative systems (swarms exchanging intentions).
  - Engineering process (form engineering by design to engineering self extendable systems - thanks to deliberative learning).
  - Coping with unforeseen novel situations, including rare ones.
  - Learning interactions (not explained in this presentation).

Major products

- Bertolazzi, E., Biral, F., Lio, M. D., & Galvani, M. (2010). Curve warning driver support systems. A sensitivity analysis to errors in the estimation of car velocity. IEEE Conference on Intelligent Transportation Systems, Proceedings, ITSC (pp. 180–185).

- Da Lio, M, Biral, F., Galvani, M., & Saroldi, A. (2012). Will intelligent vehicles evolve into human-peer robots? IEEE Intelligent Vehicles Symposium, Proceedings (pp. 304–309).

- Saroldi, A., Tango, F., Lio, M. Da, Biral, F., & Galvani, M. (2012). Implementation of a Co-Driver for Continuous Support. 19th ITS World Congress (p. EU–00748). Vienna.

- Bosetti, P., Da Lio, M., & Saroldi, A. (2013). On the Human Control of Vehicles : an Experimental Study of Acceleration. European Transport Research Review, to be published.

- Da Lio, Mauro, Bosetti, P., & Saroldi, A. (n.d.). Artificial Co-Drivers as a Universal Enabling Technology for Future Intelligent Vehicles and Transportation Systems. IEEE Transactions on Intelligent Transportation Systems, submitted.

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- The co-driver has been conceived and developed by University of Trento, implemented with the cooperation of Centro Ricerche Fiat, and integrated in the CRF demonstrator Vehicle. User tests have been carried out by CRF and Lund University.

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Thank you.

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SEVENTH FRAMEWORK
PROGRAMME

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