Risk in car driving

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Agenda

- Research objectives

- Theoretical and methodological aspects
  
  Risk to propose new device
  → Human-Machine Cooperation approach

- Project examples
  - Embedded driving assistance systems
  - “Roadside driving assistance system”
  - Pre-crash situation analysis

$10^{-3}$ safety-critical systems category
Attempt of risk identification

- Because of driver behavior
  - Lack of attention
  - Bad situation awareness
  - Wrong control
  - Under the influence of drink/drugs
  - No respect of the rules of the road

- Because of road users interaction
  - Different use
  - Different needs
  - Different speeds
  - Different vulnerability
  - ...

- Because of infrastructure characteristics
  - Dangerous roads
  - Dangerous areas
Potential actions

- Legislation and rules of the road
- Modification of driver behavior
  - Authority
  - Information (campaign conducted by government)
  - Education
  - Driving lessons
- Passive driving assistance
  - Passenger compartment, safety belt, airbag
- Active driving assistance
  - ESP
  - ABS
  - ADAS
- Modification of infrastructure
  - Improvement of road geometry
  - Improvement of road information (road markings and signs)
Toward global driving system

Cognitive part

Physical: Posture/movement

Road users

Other events: Meteorological conditions

Passenger compartment

Control/command

Infrastructure

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Toward global driving system

Interruptible control loop
Toward global driving system

**Objectives**

- **Cognitive part**
  - Warning systems
- **Physical part**
  - Diagnosis systems

**DRIVING ENVIRONMENT**

- Infrastructure
- Traffic
- Weather conditions

**Proprioceptive and visual perception**

**WARNING AND CONTROL SYSTEMS**

**Command**

**COMPARTMENT**

**Safety trajectory**

**Diagnosis systems**

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Design and evaluation of Human-Machine System (Millot, 1990)

Process technical characteristics

Context of running: normal or abnormal

Human Operator model (limits, resources)

Analysis of process and commands

Analysis of human prescribed tasks

Model of human prescribed tasks

General model of Human Operator activity (limits, resources)

Validation Improving
HM Interface
HM modes of cooperation

Cognitive activity analysis
Data processing

Records

Real or simulated HM system

Contexts, scenarios

Records to do

Definition of experimental protocols

Objectives of the valuation

HM system

Realization / Integration

HM interfaces specification

Ergonomic criteria

Choice of assistance

Need for assistance

Choice of modes of cooperation

Type of assistance

Information need

Descending phase of conception of the HM system

Ascending phase of valuation of the HM system

Choice of assistance

Type of assistance

Information need

Ergonomic criteria

Decision/Integration

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Objectives of the valuation
Cooperative agent model

- **Know-how**
  - *Internal ability* to solve problems (regarding the process)
    - competences (knowledge, rules, skills)
    - processing abilities (inferences, ...)
  - *External ability* to:
    - get information (from the process and the environment)
    - act (on the process)

- **Know-how-to-cooperate**
  - *Internal ability* to:
    - build up a model of other agents (KH and KHC) and a COFOR
    - deduce the other agents' intentions
    - analyze the task and identify the cooperative forms and structure
    - produce a common plan regarding tasks and coordination
  - *External ability* to communicate (Common Work Space):
    - understanding other agents
    - providing information to other agents
Human-Machine Cooperation: Coordination and Communication

Other fields of application
Experimental dimensions

Definition of system
- Theoretical
  - Study of driving models
  - Study of driving behaviors (flow)
  - Study of infrastructure
  - Study of traffic diagnosis systems
  - Study of alert systems

Driving situation realism
- Low

MATURITY?
- High
- Operational
  - Driver’s acceptability
  - Traffic

Control of experiments (Driver / Driving situation / System) Sample size
- High
- Low
- Needs
  - Technological point of view

Technological point of view
- Needs

Systems
- Study of driver behavior and systems in driving simulator
- Study of driver behavior and systems on private road
- Study of driver behavior and systems on real road
- Study of traffic and systems on real road

Car driving simulator
Experimental procedure

Project presentation/Questionnaires

Passation(s)

Familiarization/Training

Self-confrontation Questionnaires

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Data recording from simulator
Coding and analysis of physiological data
Coding and analysis of actions and verbalizations
Advanced Driver Assistance Systems

Passive Safety

Active Safety

Crash

Safety System soft level
Safety System hard level
Safety Systems after Crash

Normal Driving

Warning Systems

Assistance Systems

Automatic Safety Systems

Safety Systems for minimal crash

Collision avoidance

Pre-Crash

Emergency aid

Passenger protection

ACC
Lane change warning
Braking assistance
Emergency longitudinal and lateral assistance
Seat belt control
Airbag
Stop of motor and Fuel consumption
e-call
Risk to propose new system

Emergence of cognitive functions? Creativity of users?

Objectives

Cognitive part

Physical part

Warning and control systems

Command

Compartement

DRIVING ENVIRONMENT

Infrastructure

Traffic

Weather conditions

Proprioceptive and visual perception

Safety trajectory
Diagnosis and control assistance systems

- **Without assistance**
  - Reference condition

- **Diagnosis mode**
  - Warning message with pictogram
  - Sound signal (2 short beeps)

- **Automatic mode**
  - Warning message with pictogram
  - Sound signal (repetitive beeps)
  - Automatic lateral and longitudinal control
Driving situation example
Experimental scenarios

- Only 12% of drivers accepted to leave the control to the automatic system
  - 46% accepted emergency braking assistance, 33% didn’t accepted assistance system decision but it’s an instinctive reflex
- 23% accepted lateral control assistance system

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Risk to propose new system

**Objectives**

- Cognitive part
- Physical part

**DRIVING ENVIRONMENT**

- Infrastructure
- Traffic
- Weather conditions

**Proprioceptive and visual perception**

**DRIVER**

- Longitudinal control
- Lateral control

**Command**

- Adaptiver cruise control
- Lateral control

**Compartment**

- Safety trajectory
ACC is well accepted by drivers and they think they use it correctly.

They like the task sharing for longitudinal control only.

BUT 71% of drivers think that ACC might cause problems.

ACC use leads to a decrease of mean speed:
- 92% of drivers on highway
- 61% of drivers on major road

BUT during emergency situation some drivers had their feet crossed under the seat!
SARI project: Automatic Road Condition Monitoring to provide Information to Drivers and Road Managers

**AJISE**: Law, Economic, Social and Individual acceptabilities

**RADARR**: Risk to lose control because of **bad weather conditions**

**IRCAD**: Risk to lose control because of **geometric difficulties of the road**

**VIZIR**: Risk to lose control because of lack of visibility/readability
Diagnosis and warning systems

Objectives

Cognitive part

Physical part

Warning systems

Diagnosis systems

DRIVING ENVIRONMENT

Infrastructure  Traffic  Weather conditions

Command

Compartment

Diagnosis systems

Proprioceptive and visual perception

Safety trajectory
Diagnosis and warning systems

Objectives

Driver

Alert system

Variable message signs
Flashes
Button lights
Rumble strips

Risky trajectory

Low or stopped vehicles
Bad weather

Vehicle

Diagnosis system

Speed
Acceleration
Lateral position

Diagnosis system

Safety trajectory

Driving environment

Infrastructure
Traffic
Meteorology

Danger area

Risk to loose control:
geometry (curve), bad weather

Risk to have bad visibility:
crossroad, crest vertical curves

Diagnosis system
Embedded and roadside diagnosis systems

SIREDO

FRAO

Radar

Système vidéo

Laguna CETE Lyon

VACC

LCPC 406
Embedded and roadside diagnosis systems
Experiments with driving simulators

IFFSTAR

LAMIH
Comparison of driver behavior in real and simulated driving environment
Modification of marking

Centreline Rumble Strips (CRS)  Sealed Shoulders (SS)

Experimentations in the field to test adaptive traffic signals impact
Objective data gathering
Subjective data gathering:

ST2: Sciences and technologies for transportation safety
Analysis of driver behavior during pre-crash situation

Realism of the pre-crash situation

No control actions
- Dummy in real pre-crash situation
- Pilot with real pre-crash situation

Experimental data

Data from accidents
- Post mortem data
  - Consequences but little about the origins

Type of data
- Data from accidents
- Experimental data
- Post mortem data

Realism of the driver behavior

Too experienced driver
- Human drivers with simulated pre-crash situation

Too many reconstitutions
- Human drivers who imagine pre-crash situation

ST2: Sciences and technologies for transportation safety
Analysis of driver behavior during pre-crash situation

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ST2 : Sciences and technologies for transportation safety
Analysis of driver behavior during pre-crash situation

Objectives

Cognitive part

Physical part

Safety systems

DRIVING ENVIRONMENT
Infrastructure Traffic Weather conditions

Proprioceptive and visual perception

Command

Compartment

Safety trajectory
Experimental scenarios

50 kilometers

Overtaking

Trees

Truck 1

Truck 2

Tractor

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Driving situation examples
Biomechanical approach
Results from software simulation
## Automation approach

**Example of the Benefit/Cost/Deficit model**

<table>
<thead>
<tr>
<th>Criterion (and units)</th>
<th>Neutral context $s_0$</th>
<th>BCD rule identification for $s_k$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure exercised on the brake pedal (N)</td>
<td>0</td>
<td>$B(s_0, s_k) \rightarrow 0 &lt; s(s_k) \leq 1$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$C(s_0, s_k) \rightarrow 10 &lt; s(s_k) \leq 100$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$D(s_0, s_k) \rightarrow s(s_k) &gt; 100$</td>
</tr>
<tr>
<td>Moment applied on the steering wheel (Nm)</td>
<td>0</td>
<td>$B(s_0, s_k) \rightarrow 0 &lt; s(s_k) \leq 1$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$C(s_0, s_k) \rightarrow 5 &lt; s(s_k) \leq 15$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$D(s_0, s_k) \rightarrow s(s_k) &gt; 15$</td>
</tr>
<tr>
<td>Speed of the steering wheel (m/s)</td>
<td>0</td>
<td>$B(s_0, s_k) \rightarrow 0 &lt; s(s_k) \leq 0.1$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$C(s_0, s_k) \rightarrow 0.5 &lt; s(s_k) \leq 1.5$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$D(s_0, s_k) \rightarrow s(s_k) &gt; 1.5$</td>
</tr>
<tr>
<td>Car speed (Kph)</td>
<td><strong>Speed limit</strong> (50 kph or 90 kph)</td>
<td>$D(s_0, s_k) \rightarrow s(s_k) &gt; Speed_{limit}$</td>
</tr>
<tr>
<td>Distant from line crossing (m)</td>
<td>Centre of the lane (c)</td>
<td>$B(s_0, s_k) \rightarrow c - 0.5 \leq s(s_k) \leq c + 0.5$</td>
</tr>
<tr>
<td>Distant from line crossing (m)</td>
<td></td>
<td>$C(s_0, s_k) \rightarrow 0.8 &lt; s(s_k) &lt; c - 0.5 \text{ or } c + 0.5 &lt; s(s_k) &lt; 2.7$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$D(s_0, s_k) \rightarrow s(s_k) \leq 0.8 \text{ or } 2.7 \leq s(s_k)$</td>
</tr>
<tr>
<td>Time to move from accelerator pedal to brake pedal (s)</td>
<td>0</td>
<td>$B(s_0, s_k) \rightarrow s(s_k) = 0$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$C(s_0, s_k) \rightarrow 0.5 \leq s(s_k) \leq 1$</td>
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<tr>
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<td></td>
<td>$D(s_0, s_k) \rightarrow s(s_k) \leq 0.5$</td>
</tr>
</tbody>
</table>

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Examples of results with this model

Brake pedal load - "Stop" situation

Intervals

Brake pedal load - "Crash" situation

Intervals

Psychological approach

- Comparison between reported and effective behavior → different
- Recall of driving actions:
  - Steering wheel rotation:
    - Position of both hands in the same hemi-space
    - Link with vision
    - Planification (even during emergency situation)
  - Braking / Gearbox use: the most automated gesture
  - Mouvements of protection
Other type of analysis: impact visual perception decision making
What next!

Navigation  Stop & Go  Platoon drive assistance  Anti-collision system

Traffic sign recognition  Lane keeping assistance

Driver monitoring

Cognitive part  Physical part

Warning systems  Safety systems  Comfort

Warning and control systems

Command  Compartment

PC  Phone  Radio DVD

Safety trajectory

DRIVING ENVIRONMENT

Infrastructure  Traffic  Weather conditions

Comfort

Proprioceptive and visual perception

Objectives

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