Final Seminar

DRIVER SUPPORT WARNING
(« Black spots » warning, Rollover)

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Objectives

✓ Develop innovative systems to increase safety of heavy vehicles:
  - Pre-trip application: detection of black spots of infrastructure,
  - On-board system: prediction of rollover.

✓ Risk detection ➔ Warning to the driver ➔ Proposition of recommended speed
“BLACK SPOTS” WARNING APPLICATION
Objectives

✓ Develop a warning system to increase safety of heavy vehicles,

✓ Pre-trip application:
  – Detection of the risky areas of infrastructure,
  – Proposition of a speed profile adapted to infrastructure characteristics.

✓ On-trip application:
  – Comparison between the safety speed and the real speed ➔ warning.
Two complementary approaches

- Macroscopic level:
  - Accidents database analysis ➔ risky area,
  - Type of heavy vehicles involved in accidents ➔ risky trucks.

- Microscopic level:
  - Numerical simulations ➔ thresholds values for infrastructure characteristics (crossfall, slope, skid resistance…).
  - Maximum speed.
Macroscopic level

✓ Typology of HGV accidents:

- Tractor semi-trailer
  - 50% of heavy vehicles traffic,
  - 60% of accidents in curves,
  - 46% of accidents in straight line.

- HGV + trailer
  - 5% of heavy vehicles traffic,
  - 22% of accidents in curves,
  - 22% of accidents in straight line.

- Type of accident
  - HGV alone 2/3 rollover,
  - HGV - passenger car 1/2 front/front collision.

The most frequent HGV involved in accidents

The most dangerous HGV
Macroscopic level

✓ Infrastructure ⇔ tractor semi-trailer accidents:
  − Curves
    • small radius of curvature, weak skid resistance on primary roads,
    • high radius of curvature, weak skid resistance lying on secondary roads and rural highways,
    • Large curves in descent,
    • Curves with reverse crossfall.
  − Roundabouts,
  − Ramps.

✓ Infrastructure database requirements:
  − Radius of curvature,
  − Longitudinal slope,
  − Crossfall,
  − Skid resistance (SFC),
  − Category of road.

Minimum data needed for the application
Microscopic level

- Numerical simulations using PROSPER software
  - 5 axles tractor semi-trailer,
  - Fully loaded and empty,
  - Combination of values for infrastructure characteristics
    - SFC: 0.4 / 0.6 / 0.8,
    - Radius: 100 to 600 m,
    - Crossfall: 3% to 7%,
    - Slope: 0 to 7%.

- Thresholds values
- Abacus: $V_{\text{max}} = f(\text{geometry}, \text{SFC}, \text{load})$
Black spot algorithm

Road category

Load of the vehicle

Radius of curvature R

Abs(R) > 600

Sign(radius) * Sign(crossfall > 0)

Abs(R) < 600 m

Slope and length of the section

Slope > 5% & length > 1500 m

Slope > 5% & length < 1500 m

Slope < 5%

Vmax = f(Crossfall, SFC)

LOAD

INFRASTRUCTURE CHARACTERISTICS

SPEED RECOMMENDATION

LEVEL OF RISK
Some experimental results

Road 5

Speed (km/h)

Recommended speed
Speed driver 1
Speed driver 2

DISTANCE (km)

CURVES

ROUNDABOUTS
Concluding remarks

✓ Detection of “black spots”
  – Good accuracy of the method,
  – Dangerous areas detected,

✓ Overestimation of the Vmax due to:
  – SFC values non available,
  – Generic truck model,
  – Fixed load.

✓ Next steps
  – Improvement of the accuracy of the simulations,
  – Complete the road database.
ROLLOVER RISK APPLICATION
Objectives

• Develop on-board concepts design of systems to increase safety.

• To prevent in real time the rollover risk (Alarm to the driver)

⇒ Recommended speed calculation
Use Cases

• Truck driver provides information during tour: (the driver is informed about driving relevant status and status changes given by the database..)
• Reliable safety warnings in vehicle
• Give recommended speed to avoid any accident during journey
• ...

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Methodology

Since we do not have sensors, the following states have been off-line estimated:

- Estimation of impact forces,
- Estimation of the Center of gravity height,
- Recommended speed calculation,
- Lateral acceleration $\Rightarrow \text{Acc}=V^2/R$. 
**Rollover risk prediction**

The rollover risk is detected when one of the wheels of the same axle leaves the ground

\[ LTR = \left| \frac{F_{zL} - F_{zR}}{F_{zL} + F_{zR}} \right| = \frac{2m_2}{m \cdot T} \left| h_0 + h \cos \phi \right| \cdot \frac{a_y}{g} + h \sin \phi < R_{\text{lim}} = 1 \]

- \( m \): total mass,
- \( m_2 \): sprung mass
- \( T \): distance between Wheels of the axel
- \( a_y \): lateral acceleration,
- \( \phi \): roll angle
- \( h_0 \): roll axis height
- \( H = (h_0 + h \cdot \cos \phi) \): center of gravity height
Selected Truck Model

Tractor/Semi-trailer model

Inputs: Road profile, skid resistance, radius of curvature, Longitudinal and transverse slope.

\[ M(q)q + C(q,q)q + G(q) = F_g \in \mathbb{R}^{12} \]

\[ q = [x, y, z, \phi, \psi, \psi, q_1, q_2, q_3, q_4, q_5, q_6]^T \]

\( F_g \) : Forces vector (internal and applied)
- Tyres forces
- Suspensions forces
Tractor/Semi-trailer model description

Engine Torque
- Couple Moteur
- M3(:,1),couple
- [t, Vc]

Vehicle speed
- Vitesse correvit

Infrastructure Data Base
- Braquage2
- Pente
- Uni
- Devers

Dynamic States
- Etats Dynamiques
- (Positions, Speeds, accelerations)

Modele PL/Infrastructure
- Interactions Pneumatique/Chaussee

Clock
- temps
- 0
<table>
<thead>
<tr>
<th>INPUTS</th>
<th>OUTPUTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road data:</td>
<td>Vehicle positioning (X, Y and Z)</td>
</tr>
<tr>
<td>Radius of curvature, Longitudinal and</td>
<td>Longitudinal, lateral and vertical</td>
</tr>
<tr>
<td>transverse slope, Skid resistance, road</td>
<td></td>
</tr>
<tr>
<td>profile, GPS</td>
<td></td>
</tr>
<tr>
<td>Steering angle</td>
<td>Roll, pitch and yaw angle</td>
</tr>
<tr>
<td>Engine Torque</td>
<td>Suspension deflections</td>
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<tr>
<td></td>
<td>Vertical displacements of the wheels</td>
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<td></td>
<td>Impact forces (Fx, Fy and Fz)</td>
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<td></td>
<td>Vehicle speeds</td>
</tr>
<tr>
<td></td>
<td>(Vx, Vy and Vz)</td>
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<tr>
<td></td>
<td>Vehicle accelerations</td>
</tr>
<tr>
<td></td>
<td>(Ax, Ay and Az)</td>
</tr>
</tbody>
</table>
Rollover Risk Predictive System

- Speed reducing
- Route changing

Map database
GPS

Rollover predictive system

Speed limits
Acceleration limits
Rollover risk
Acceleration limit

\[ a_y \leq \frac{g m T}{2 m_2 H} - \frac{g h \sin(\phi)}{H} \]

\[ a_y = \frac{V^2}{R} \]

\[ V \leq \sqrt{R \left( \frac{g m T}{2 m_2 H} - R \frac{g h \sin(\phi)}{H} \right)} \]

Recommended speed

\[ V_{\text{max}} = \sqrt{R \left( \frac{g m T}{2 m_2 H} - R \frac{g h \sin(\phi)}{H} \right)} \]

\[ R : \text{Radius of curvature} \]
Rollover warning integration

Collected data (from CAN bus):

- **BreakPedalPos** - % of fully pressed
- **CurrentGear** - gear nr (maximum 12)
- **SteeringWheelAngle** – radians ➔ Used
- **VehicleSpeed** - km/h ➔ Used
- **YawRate** - rad/s ➔ Used
- **FuelRate** - instant l/h
- **GPS_Latitude** - decimal degrees N
- **GPS_Longitude** - decimal degrees E
- **GPS_Speed** - m/s ➔ Used
- **GPS_Altitude** - m (uncalibrated)
- **GPS_Time** - seconds since 1970
- **CummulatedFuelRate** - fuel used since the logging started observe! Unit in dl
Rollover warning integration

No Action

Off line study along the route

Recommended speed (Rsp)

Asp>Rsp

YES

Rollover risk

ALARM

Actual measured speed (Asp)

Speed reducing
Experimental results
Experimental results

Route 3

Steer wheel angle (rad)

Time (s)
Experimental results
Experimental results
Experimental results
Experimental results
Experimental results

Rollover risk zone
Experimental results
Conclusion

• The dynamic states of the vehicle are estimated, the recommended speed is calculated and the alarm is sent to the driver.

• Some false alarms are occurs. This is due to the fact that:
  1- the calculation is done off-line and not in real time
    ➔ The vehicle dynamics can be changed during the trip.
  2- The road data base is incomplete (SFC value)
  3- The vehicle parameters are not known

• Adding some sensors (measures) are necessary to have robust speed calculation and reducing false alarms.