Center for Embedded Systems
An NSF Industry/University Cooperative Research Center

Environmental information and multi-sensor data fusion based performance estimations for smart cars

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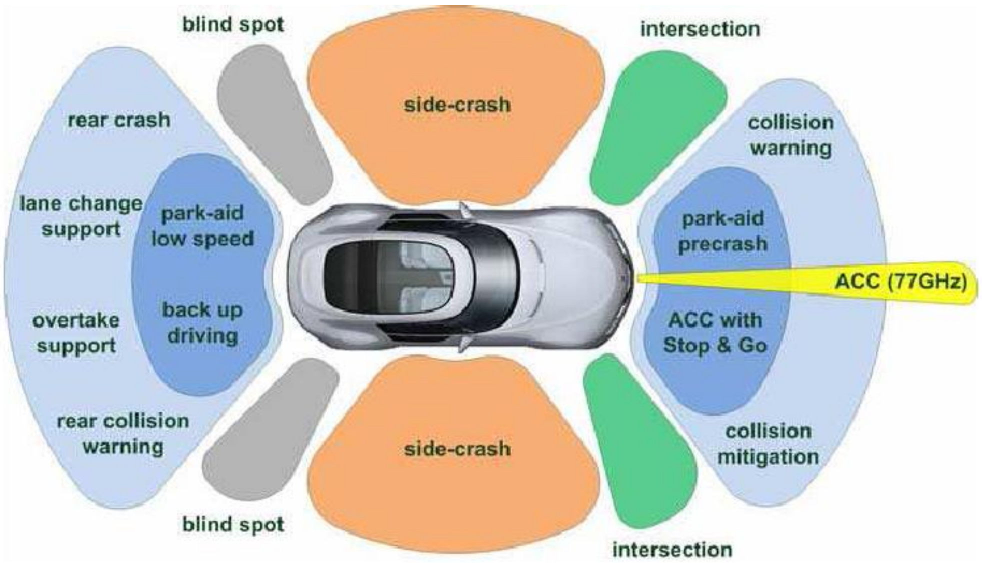
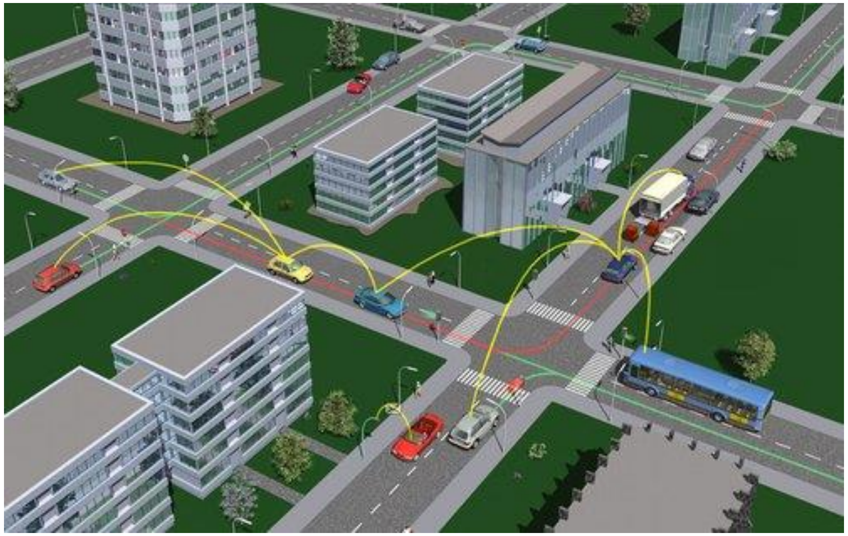
Project Overview and Description

- Modern cars employ hundreds of sensors for situational and environmental information → **Multi-sensor data fusion**
- Beyond the growth in tradition signals there is and will be a rapid growth in connectivity → **Internet, Cloud, V2V**

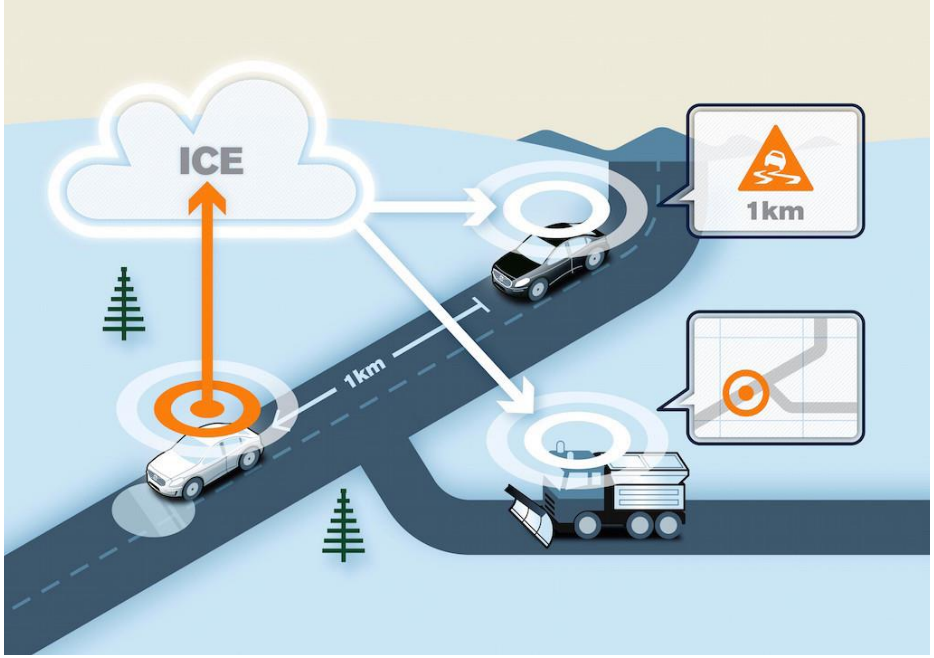
How can we efficiently combine these data sources?





Project Overview and Description

- **Use case:** Coefficient of friction
- **Vision/Temperature Based Methods:**
  - Performance/reliability is affected by the intensity of light
- **Tire Tread Based Methods:**
  - Cost, technical challenges and signal conditioning
- **Wheel Dynamics Based Methods:**
  - Estimation based on ABS/TCS is generally inadequate



Approach

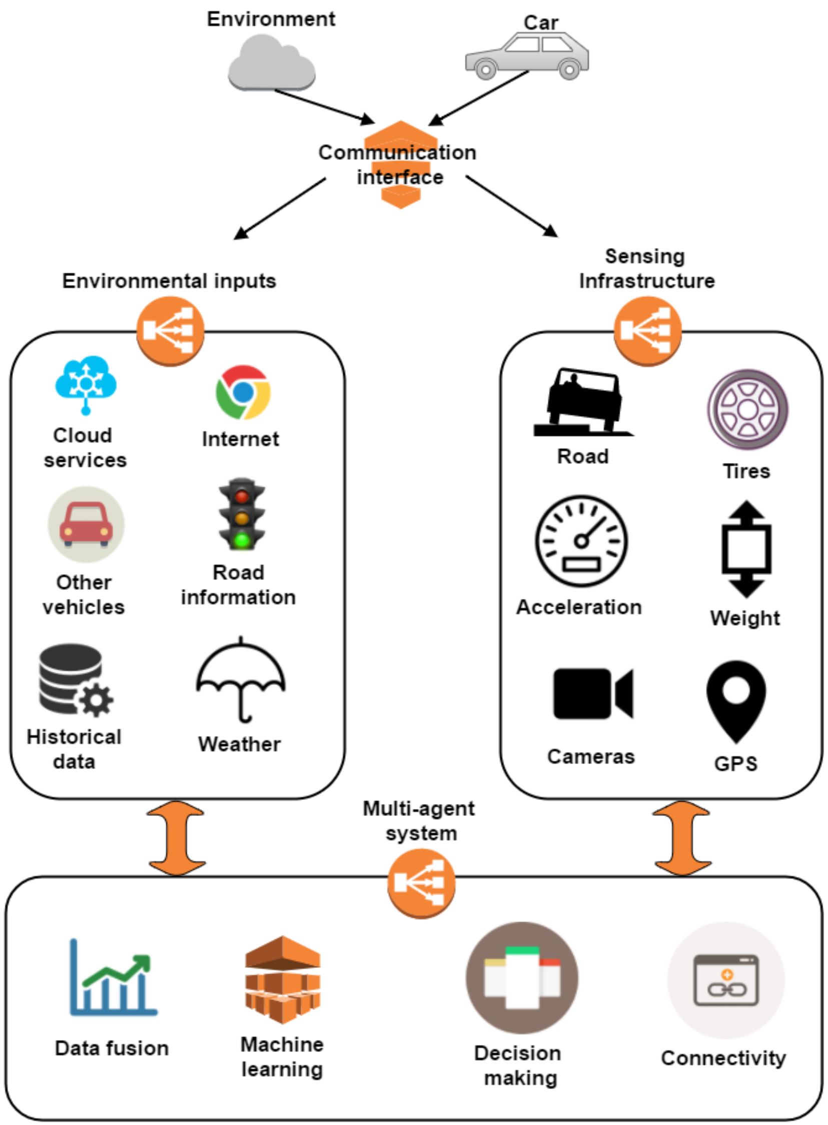
- **The proposed project:**
  - Will merge data from multiple on vehicle sensors as well as environmental information
  - Will explore static and dynamic changes both on the vehicle and the environment
  - Employ reflective and deliberative information gathering
  - Propose an MSDF framework for fusing data from different types of sensors and inputs

Project Tasks/ Deliverables

	Description	Date
1	Review of data fusion method and extraction of friction models	12/2016
2	Design and implementation of the data fusion techniques targeting coefficient of friction	4/2017
3	Evaluation of different scenarios in simulations	6/2017
4	Evaluation of the estimator performance with experimental data	8/2017

Executive Summary

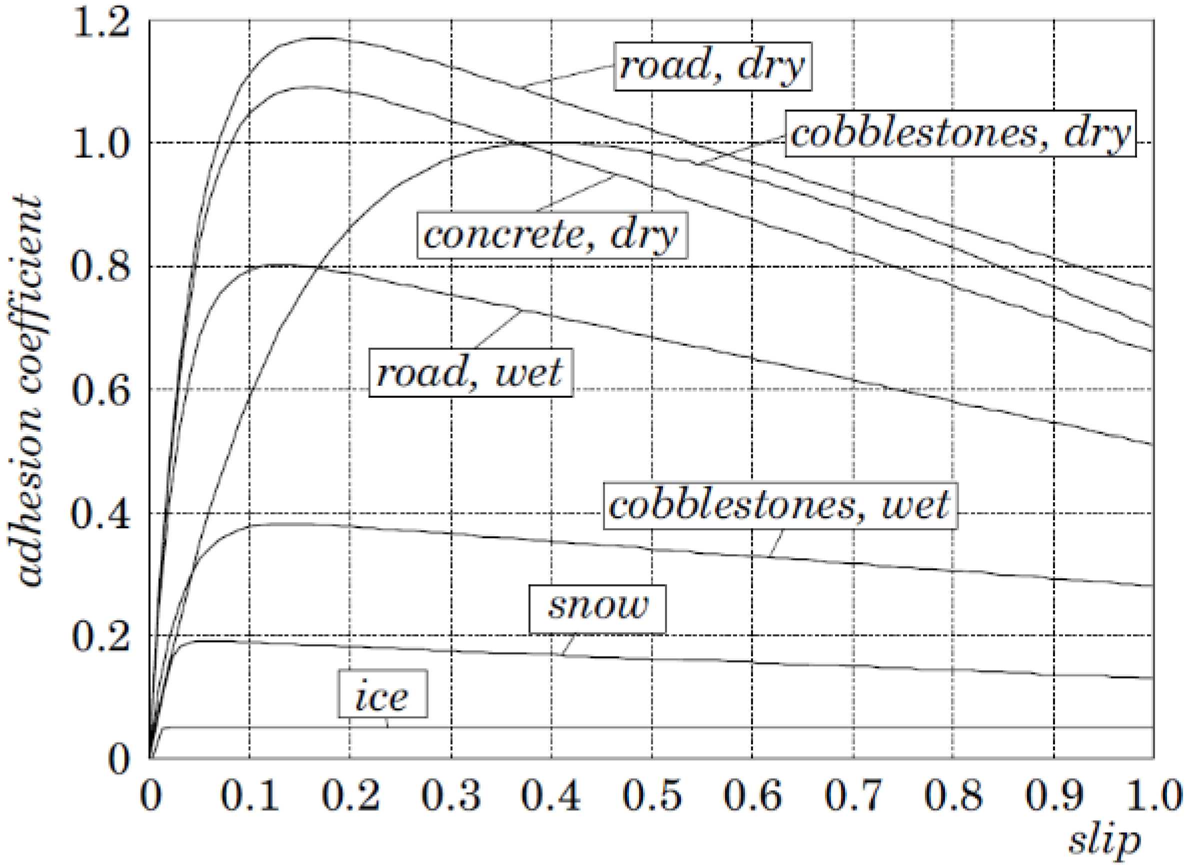
- Collect data and inputs from on-vehicle sensors and environmental sources
- Merge estimations (other cars, internet) and employ efficient data fusion techniques
- Explore and address static and dynamic changes both on the vehicle and the environment (sensor/application failure, internet connectivity error etc.)
- Explore adaptive learning (historical data) methodologies and compare data and model driven techniques



REMAINING SLIDES For poster session ONLY (as many as you'd like)

TECHNICAL DETAIL

Friction Coefficient



- Parameters that can affect friction coefficient:
  - Tires
  - Weights
  - Size
  - Temperature
  - Road conditions
  - Weather
  - Etc.

U. Kiencke, L. Nielsen, Automotive control systems, 2nd Edition, Springer, Berlin, 2005

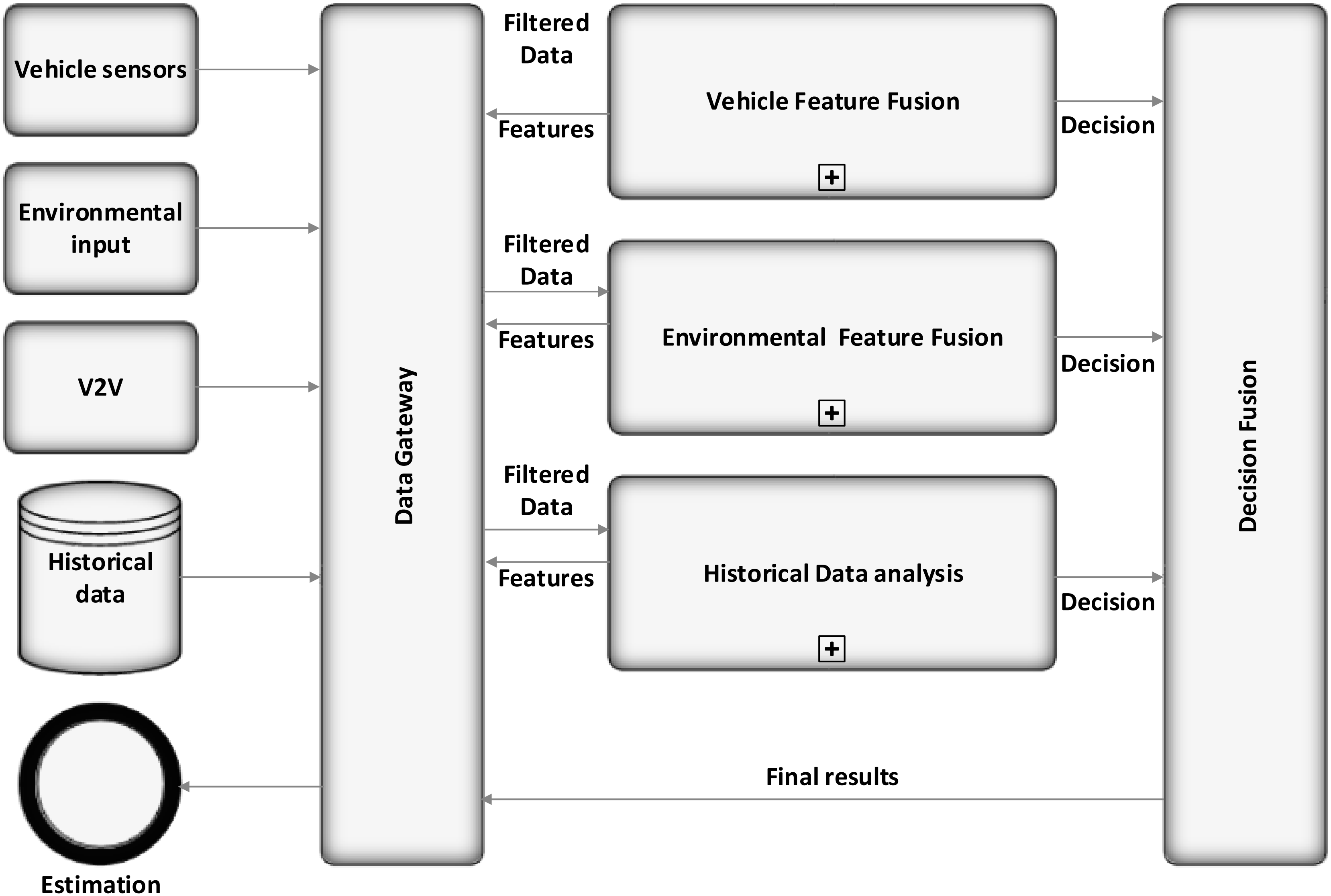
Current Solutions

Category	Special Sensors	Sensor reliability	Vulnerability	Cost
Vision/Temperature	Optical/Temperature	Need clear vision	Snow, ice	High
Tire tread	Strain sensor	-	Sensor noise	High
Wheel dynamic	-	-	High frequency disturbances	Low
Vehicle dynamics	D-GPS	Need line of sight	Slow reaction in rapid changes	Medium
	Inertial	-	Not good performance	Low

Differentiators

- Studies that investigate the performance of separate subsystems using simulation approaches, they rely on experimental methods.
- As authentic and valuable this approach is, it lacks flexibility in investigating fusion paradigms and sensor-sets.
- In this project we will also employ discrete event simulation to evaluate the performance of fusion architectures.

Framework Overview



Environmental Information

Weather information
Precipitation
Surface temperature
One hour prognosis
Air temperature
Humidity
Max wind speed
Sublimation

Road slipperiness
Precipitation (rain/sleet) on a frozen road surface
Precipitation (snow) on a frozen road surface
Precipitation (snow/sleet) on a warm road surface
Snowfall together with hoarfrost
Hoarfrost and low visibility
Freezing dew followed by hoarfrost
Strong formation of hoarfrost
Weak formation of hoarfrost
Drifting snow
Watercover which freezes

Matters to be explored:

- Predict the extent of slipperiness
- Calculate the ideal velocity

Reflective and deliberative information gathering

- By being ***deliberative***, an agent *intentionally* and *selectively* chooses how to gather information
  - Partially Observable Markov Decision Process
  - Active Sensing POMDP

- By being ***reflective***, an agent *self-evaluates* its informational needs and performance in order to understand its needs
  - Reflection for the Active Sensing POMDP

- A POMDP models an agent decision process in which it is assumed that the agent must maintain a probability distribution over the set of possible states

Vehicle to X communication

- Utilize multi-agent framework built in Year 7 of CES
  - Integrate Internet ,cloud and GPS information exchange
- Research challenges:
  - Number of vehicles exchanging information (communication depth)
  - Normalized information (each vehicle calculates friction in a different way)
  - Accuracy and comparison with on-vehicle sensors

Image sources: https://www.dcaiti.tu-berlin.de/research/simulation/