Knowledge-based Reconfiguration of Driving Styles for Intelligent Transport Systems

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Outline

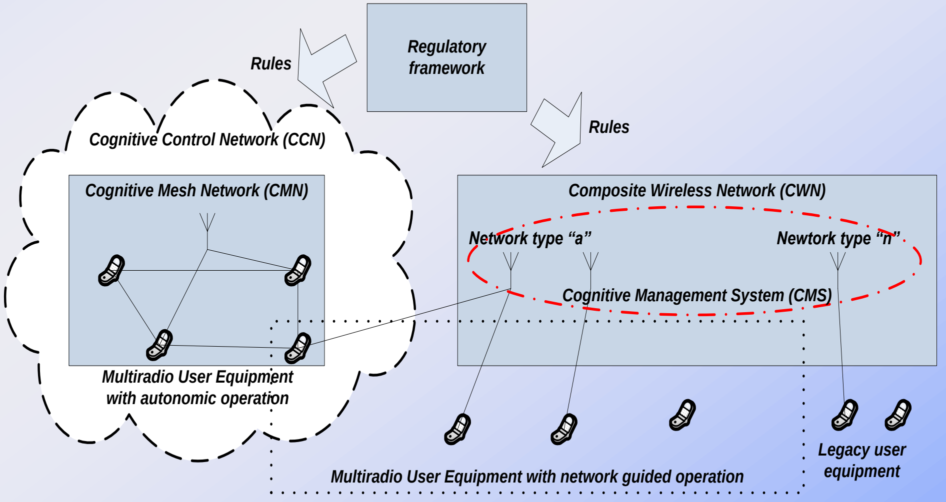
- Overview of trends in telecommunications
  - The Future Internet (FI) era
- Motivation for research in Intelligent Transportation Systems (ITS)
  - Trends and challenges
- Reconfiguration of driving styles
  - A-drive functionality
    - Description
    - Formulation
    - Indicative results
- Summary and Conclusions

Overview of trends in telecommunications

- Enormous advances in telecommunications
  - Research and development projects
  - Work performed in international fora
  - Creative competition among manufacturers
- As a result?
  - Innumerable innovations
    - Powerful infrastructures
      - Increasingly high data rates
    - Intelligent management platforms
- Versatile novel applications assure the success and usefulness of innovations
  - Legacy (conventional) access network technologies
    - Coexist and cooperate with currently emerging and new standards.
      - Wireless wide area networking technologies
      - Broadcasting technologies
      - Wireless networking technologies of a shorter range
      - Wireless ad hoc networks and wireless sensor networks

The Future Internet (FI) era

- Characteristics of the Future Internet (FI)
  - Powerful network infrastructures
  - Potential to provide multiple, advanced applications, services and content, by exploiting the powerful infrastructure
  - "Green" infrastructures in terms of efficient energy usage
  - Advances in the business model, socio-economics and security



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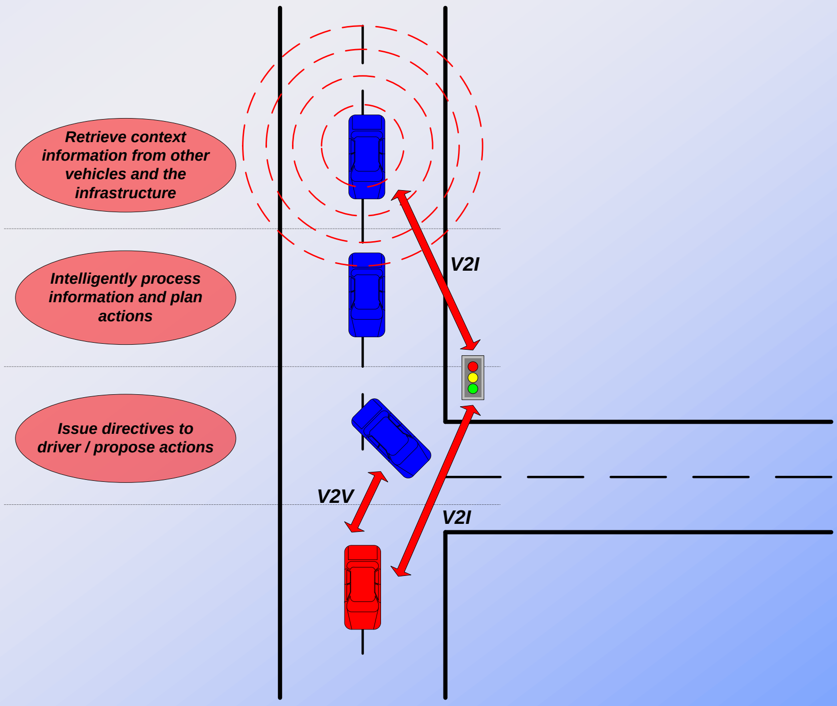
Intelligent Transportation Systems (1/4)

- Increased utilization of vehicles
  - Traffic congestions
  - Pollution
  - Degradation of life quality
  - Emergencies / accidents
- Extensive use of telecommunications systems inside vehicles
- Transportation is facilitated by means of newly introduced, revolutionary telecommunication techniques and gadgets
  - Improvement of the driver’s safety
  - Improvement of the passengers’ quality of life through entertainment.



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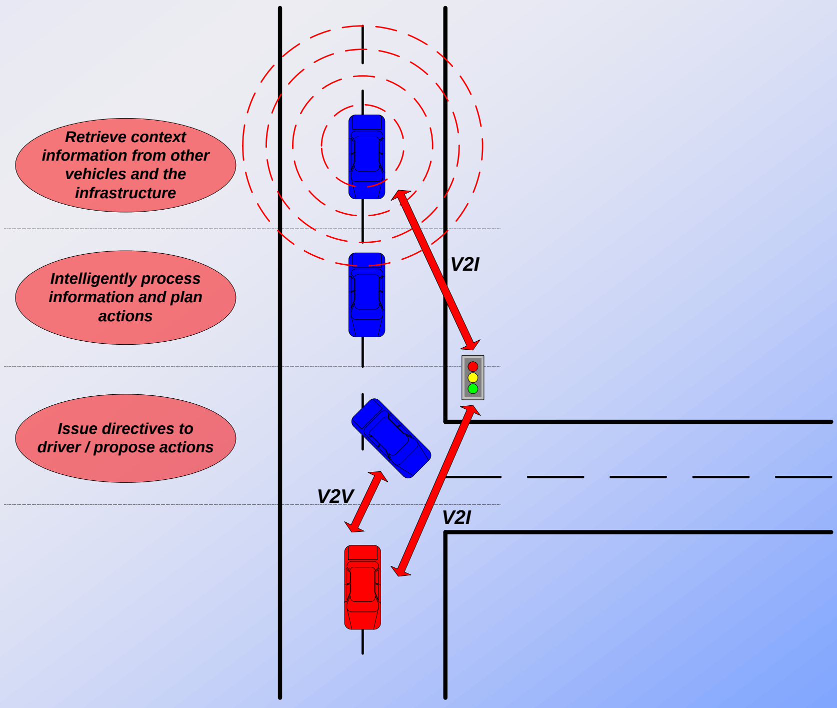
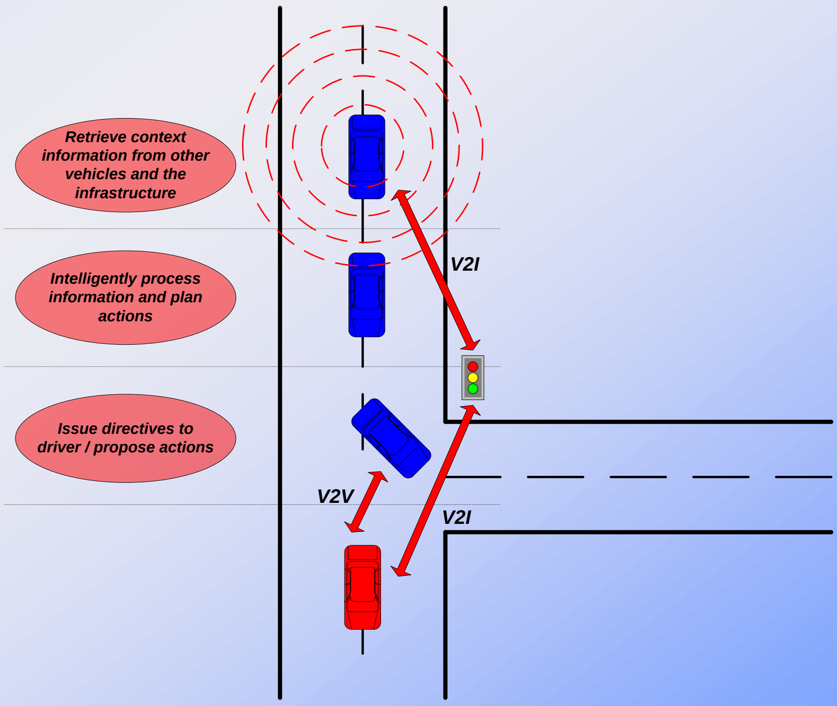
Intelligent Transportation Systems (2/4)

- Research issues
  - Traffic assessment and management
  - In-vehicle and on-road safety management
  - Driver modeling
  - Emergency management
  - Environmental effects of transportation
  - Application of technologies like sensor networks or network entities' control techniques



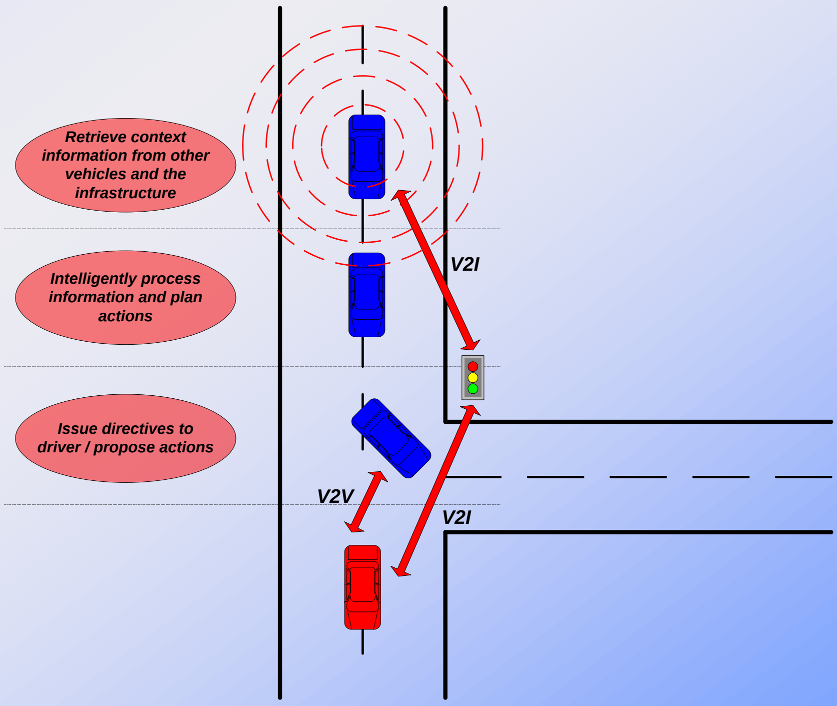
Intelligent Transportation Systems (3/4)

- Indicative ITS
  - The blue vehicle is helped to avoid an emergency situation caused by the red vehicle
  - After gathering the necessary information, the blue vehicle's intelligent management system that is part of its ITS, informs the driver that he should slow down and potentially make a turn, so as to avoid any unwanted implications.
  - Intelligence lies in the ITS proactive decision upon alternatives, which would otherwise be feasible only after the driver could see/understand the emergency.



Intelligent Transportation Systems (4/4)

- Challenges
  - Traffic needs to be assessed in real-time
  - Distributed solutions
  - Real-time collection of context information and solution of optimization problems
  - Increase of the level of intelligence embedded in vehicles
    - Extensive navigation assistance
    - Monitoring their own systems and behavior
    - Reconfiguring their operating parameters
    - Alerting the driver when action is required



Reconfiguration of driving styles: the concept

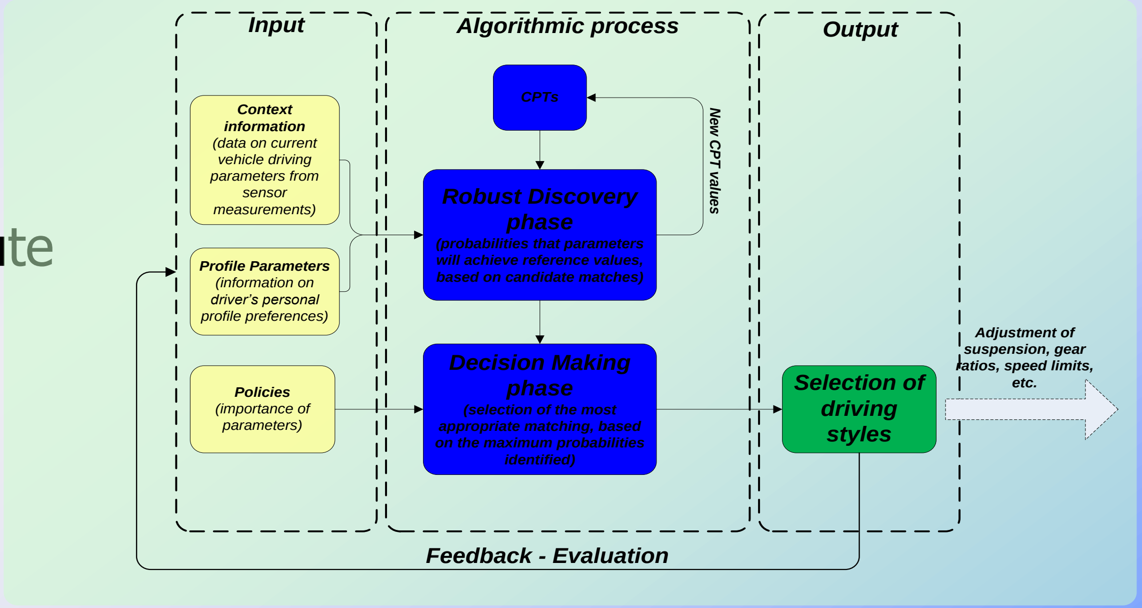
- What is a driving style in general?
  - A combination of parameters, such as vehicle reaction, control, gearbox changes, suspension adjustments, etc.
- Why to dynamically change it?
  - Dynamic reconfiguration of vehicle's driving style is necessary, due to change of parameters
    - Driving mood (fatigue)
    - Road condition
    - Driver's experience
  - A system that can increase the reliability of the decisions is required.
  - The system should provide the probability that some parameters will achieve certain values, based on specific matches.
- **Goal: the automatic reconfiguration of the driving style parameters based on a set of criteria**

Business case

- 1. A set of drivers that may drive a certain vehicle is assumed (in the case of a family, usually one of them is the most frequent driver), as well as a set of driving styles.
  - The drivers and the driving styles are associated with specific parameters,
    - i.e. (a) context information deriving from measurements obtained from the vehicle's sensors
    - data on the driver's personal profile parameters
    - data associated with style related parameters
    - A set of overarching policies reflects driver/styles preferences, in the form of weights (importance) attributed to the aforementioned parameters.
- 2. The manner in which a driver operates the vehicle can change from time to time.
  - Change of the personal profile parameters.
  - Thus, a change in the driving style of the vehicle may be desirable (change of suspension adjustments, gear ratios, speed of vehicle reaction, etc.).
- 3. Goal of functionality
  - Interact, on behalf of the driver, with all candidate driving styles and find and propose an optimum match

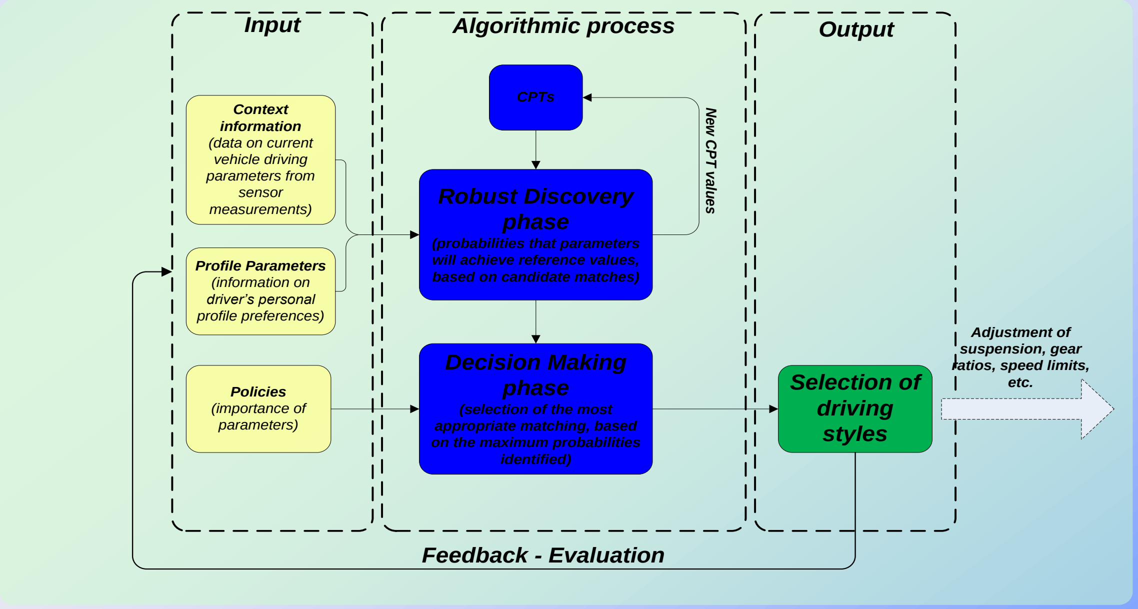
Business case and *a-drive* description (1/3)

- Input
  - personal profile parameters
  - vehicle sensor measurements and
  - policies which attribute importance to the parameters through numerical weights.



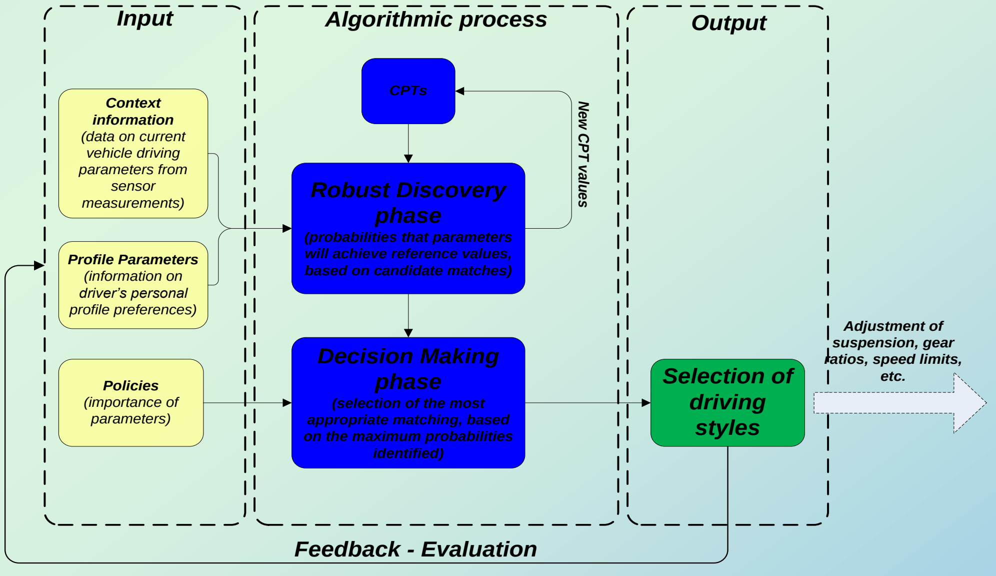
Business case and *a-drive* description (2/3)

- Output
  - Optimum matching among drivers and driving styles



Business case and *a-drive* description (3/3)

- Solution in phases
  - Robust discovery
    - aims at maximizing the probabilities that the parameters will reach certain values,
      - Bayesian based model
  - Decision making
    - Steps on those probabilities and finds the optimum matching considering also the importance of the parameters.



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A-drive formal description (1/3)

- Input
  - The set of the potential vehicle's drivers is PD.
  - D is defined for representing the driver. D can take values 1 to $|PD|$.
  - The set of candidate driving styles is denoted as CDS.
  - DS is defined for representing the driving style. DS can take values 1 to $|CDS|$.
  - The set of parameters is denoted as N.
  - Each parameter, j $(j=1,\ldots,N)$, can refer to a specific aspect, e.g. mean driving speed, age, gender, etc. Finally, the importance of each parameter, j $(j=1,\ldots,N)$ is indicated by a weight value w_j.
  - The sum of the w_j weights, over all $j=1,\ldots,N$, will be 1.
  - Variable i is defined for representing the driving style.
  - Variable v_j $(j=1,\ldots,N)$ depicts the value of the j-th parameter.
  - Each variable V_j is associated with a set of reference values $\mathrm{R}V_{ij}$ $(i \in CDS)$.
  - Variable v_j can take a value among those in $\mathrm{R}V_{ij}$, when driving style i is considered.
  - The knowledge that needs to be developed relies on conditional probabilities, which have the form $\Pr\left[V_j = rv_{ij}^k \mid DS = i\right]$, where $rv_{ij}^k \in RV_{ij}$ denotes the k-th reference value for the j-th parameter when driving style i is considered.

A-drive formal description (2/3)

- Solution: robust discovery
  - The goal of this process is to identify the most probable parameter values.
  - For this purpose, *a-drive* collects evaluations made for the CDS driving styles.
  - Let us assume that the most recent evaluation indicates that driving style i can achieve rv_{ij}^{coll} regarding parameter j.
  - Let dif_{ij} be the difference between the maximum and the minimum reference value in RV_{ij}.
  - Then, for each reference value, $rv_{ij}^{k} \in RV_{ij}$, there can be a correction factor $cor_{ij}^{k} = 1 - \left(\left| rv_{ij}^{k} - rv_{ij}^{coll} \right| / dif_{ij} \right)$.
  - Since $0 \leq cor_{ij}^{k} \leq 1$, a value close to one means that the reference and collected values are close
  - New conditional probabilities

$$\Pr\left[V_j = rv_{ij}^{k} \middle| DS = i\right]_{new} = nf_{ij} \cdot cor_{ij}^{k} \cdot \Pr\left[V_j = rv_{ij}^{k} \middle| DS = i\right]_{old}$$

Parameter nf_{ij} is a normalizing factor for guaranteeing that all the “new” probabilities will sum up to one

A-drive formal description (3/3)

- Solution: decision making
  - Selection of driving styles that have high probability of achieving the most appropriate parameter values (thus living up to the driver expectations).

$$OF_i = \sum_j \left\{ \max(\Pr\left[V_j = rv_{ij}^k \mid DS = i\right]) \right\} \cdot w_j \qquad (4), \text{ where } i \in CDS, \; (j = 1,\ldots,N)$$

and $rv_{ij}^k \in RV_{ij}$ denotes the k-th reference value for the j-the parameter when driving style i is considered.

The driving style with the highest OF_i value should be selected

Each driving style corresponds to a specific combination

- suspension adjustment
- gear ratios
- speed limits

steering wheel reciprocation.

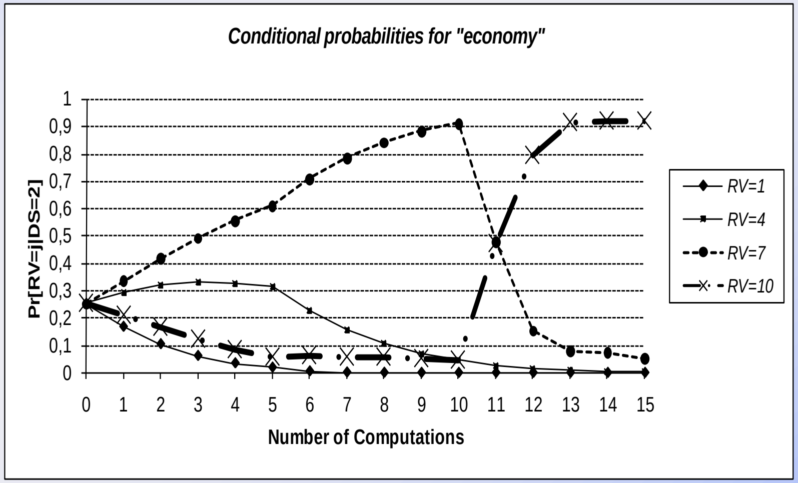
Indicative scenario and results (1/2)

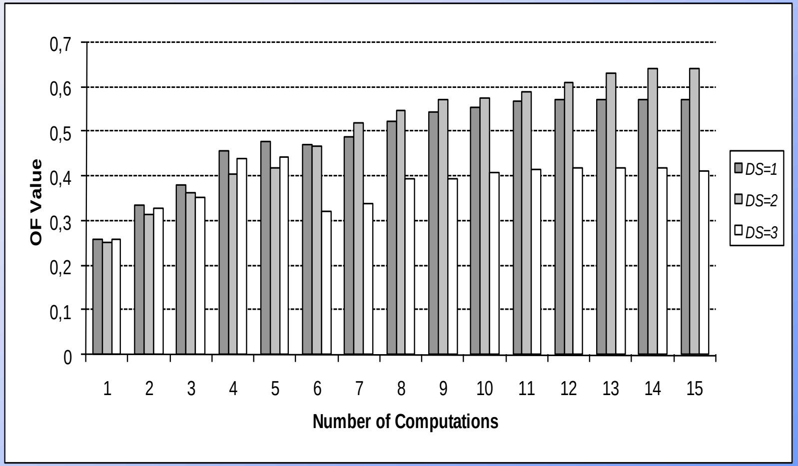
- Scenario description
  - Gradual development of knowledge and the impact of the continuous change of a driver (who gradually drives more smoothly - less aggressively) on the decision making process.

  - 3 different driving styles are assumed
    - Comfort, normal and sport.
      - Parameter values (obtained either through sensors or inserted by the driver during the evaluation process)
      - 15 computations are split in 3 phases (each one lasting for 5 computations).
      - The second driving style exhibits a better performance in each subsequent phase, implying that it is more suitable.

Indicative scenario and results (2/2)

Parameters	$DS = 1$			$DS = 2$			$DS = 3$		
	1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Mean driving speed	7	6	5	7	6	8	7	6	4
Frequency of gear changes	8	7	6	8	7	9	8	7	5
Mean level of rev/min	8	7	6	8	7	9	8	7	5
Economy	6	8	7	6	8	9	6	8	5
Comfort	5	7	6	5	7	8	5	7	5





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Summary, conclusions and future work (1/2)

- Summary
  - Recent advances in telecommunications
    - Migration towards the FI
    - Novel applications
    - Transportation is an area of increased interest

- Conclusions
  - Reconfiguration of driving styles: a-drive functionality
  - Provision of fast and reliable solutions
    - A-drive can:
      - adapt to parameter changes fast and successfully
      - propose the most suitable driving style whilst driving a vehicle based on knowledge, experience and enhanced decision-making

Summary, conclusions and future work (2/2)

- Extensions – future work
  - Further machine learning techniques that could create collective knowledge
  - The potential to change the importance (weights) attributed to the parameters during the robust discovery phase and then test the system's response.
  - Integration of the concept of in-vehicle intelligence in larger management functionality for ITS that could exploit several novel concepts, such as issuing directives to the drivers in tackling emergency situations, amending traffic lights and taking other useful decisions during a vehicle's ride.

Indicative related publications

- *G. Dimitrakopoulos, G. Bravos, M. Nikolaidou and D. Anagnostopoulos, "A Proactive, Knowledge-Based Intelligent Transportation System based on Vehicular Sensor Networks", IET Intelligent Transport Systems journal, vol. 7, Issue:4, pp 454 - 463, December 2013.*
- *G. Dimitrakopoulos, P. Demestichas, V. Koutra, "Intelligent Management Functionality for Improving Transportation Efficiency by means of the Car Pooling Concept", IEEE Transactions on Intelligent Transportation Systems, vol 13, issue 2, June 2012, pp. 424-436.*
- *G. Dimitrakopoulos, P. Demestichas, "Intelligent Transportation Systems based on Cognitive Networking Principles", IEEE Vehicular Technology Magazine (VTM), March 2010.*
- *M.Mueck, A.Piipponen, G.Dimitrakopoulos, et al., "ETSI Reconfigurable Radio Systems – Status and Future Directions on Software Defined Radio and Cognitive Radio Standards", IEEE Communications Magazine, September 2010.*

Thank you!

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