Tuning and Validation of Driver's Model

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Main Contents

- Main Issues of DVE Framework
- Parameters, Variables and their Selection
- The Methodology for Tuning and Validation
- Experimental design and driving simulator set-up
- Data Analysis and Results
- Conclusions and future Steps

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Overview of DVE Framework

- Driver's Behavioural Model in AIDE-SP1 is based on the IPS (= Information Processing Systems) paradigm
- The most suitable model for representing driver's behaviour during performances of activities, is the *Task Analysis* approach
- The number of basic elements is:
  - **Elmentary functions**, which represent the basic activity that can not be further subdivided into simpler components
  - **Elementary task**, which are tasks made of elementary functions only
  - **Complex task**, which are tasks made of a combination of Elementary Tasks and Elementary Functions
- Two types of driver's behaviour:
  - **Normative** $\Rightarrow$ it implies very low or zero level of impairment and no behavioural adaptation
  - **Descriptive** $\Rightarrow$ it represents a more realistic condition that considers Driver Error Propensity (DEP) and behavioural adaptation

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Parameters and Variables used by DVE

- Descriptive driver behaviour is identified by a number of *parameters* that enable to modify and adapt the way in which cognitive functions (*Perception, Interpretation, Planning, Execution*) are developed and actions are performed
- Five parameters have been selected:
  - Attitude / personality (ATT)
  - Experience / competence (EXP)
  - Task Demand (TD)
  - Driver's State (DS)
  - Situation Awareness (SA)
  - Intentions / goals (INT)
- Each of these parameters are charatectised by a number of variables, which are related one another by a guessed relationship to be evaluated

Selection of Parameters and Variables

- Based on the work carried out for the definition of DVE modeling and for the implementation of SSDRIVE simulator, as well as on the study performed in SP3, the following parameters have been chosen for validation and tuning of the related models: Distraction and Task Demand
- Moreover, also the prediction of driver's intention (DIP) has been explored
- The main goals of our work has been:
  - Assessment of the efficacy of the formulation predicting TD and DIS through machine learning (ML) approach
  - Proposal of a new formulation for these two parameters, according to literature review and ML results
- **In particular, we focus this presentation on DIS parameter (time constraints, best performances found, etc.) and on DIP**

The DIS and DIP Parameters

- DIS has been selected because of its importance in determining Situation Awareness (SA) parameter, a key indicator both for DVE Modelling (SP1) and for Real Time Measurable Parameters (SP3)
- Formal definition of DIS = Cognitive load or shift of visual attention away from the road ahead, induced by an external event or a secondary task
- For descriptive driver's behaviour investigation, the driver's error propensity (DEP) indicator is fundamental; associated with it, we have considered the DIP parameter, as a "pre-condition" for DEP evaluation
- Formal definition of DIP = Prediction of Driver's Intention (e.g. of acting a lane-change maneuver)

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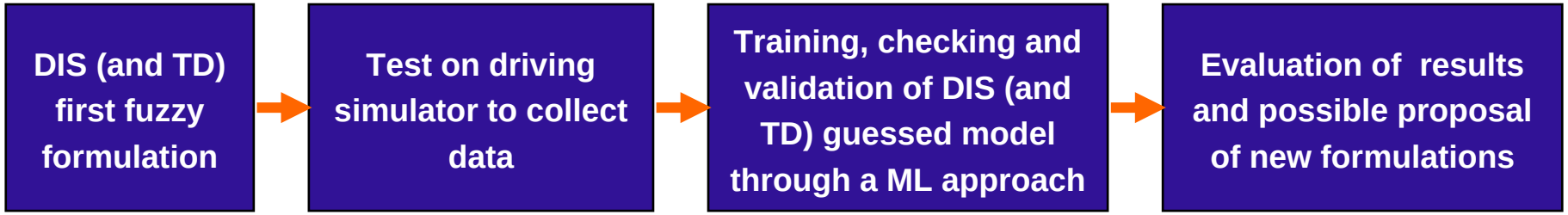
The Methodolgy: following a ML Approach (#1)

- The first formulation guessed for DIS (and TD, even if not considered here) was a fuzzy formulation
- Following a ML approach, a validation and tuning activity has been carried out and the following techniques have been adopted
  - Fuzzy Logic (FL)
  - Adaptive-Network-based Fuzzy Inference Systems (ANFIS)
  - Neural Network (NN)



The Methodolgy: following a ML Approach (#2)

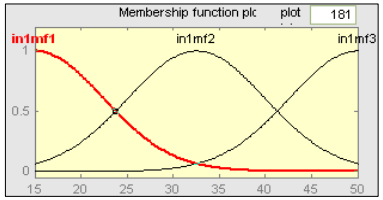
- All in all, it is an inductive approach for design and development of algorithms that allow a system to "learn“ by extracting out rules and patterns from a data set

- For the application to DVE parameters:
  - Training, checking and testing of DIS
  - Use of specific input data-set, in order to determine membership functions, according to target output
  - Definition and implementation of a specific (and perhaps more accurate) relationship among the variables characterizing the parameter under examination

Overview of Method & Approach (#1)

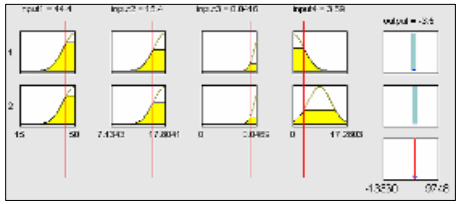
- **Fuzzy Logic Modelling**
  - FL is a non-linear mapping of an input space (*feature*) to an output space. So it handles simultaneously numerical data and linguistic knowledge
  - Between IN and OUT, there is a sort of ”black-box”, where any number of things can be inside (from FIS to expert systems, from linear systems to Neural Networks)

MBF



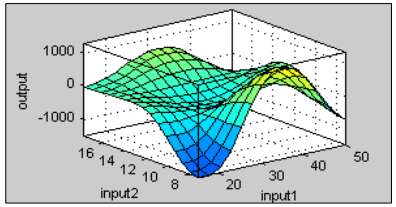
MBFs mapping “input 1” to the output of the FIS

Rules

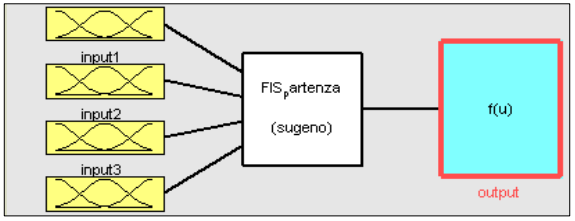


Rules relating FIS INs to the OUT

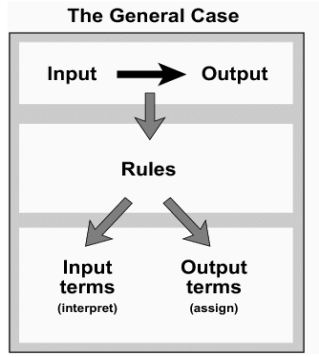
Output space

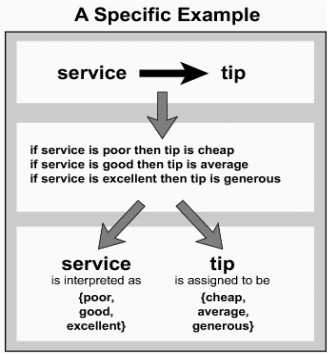


OUT space of the FIS



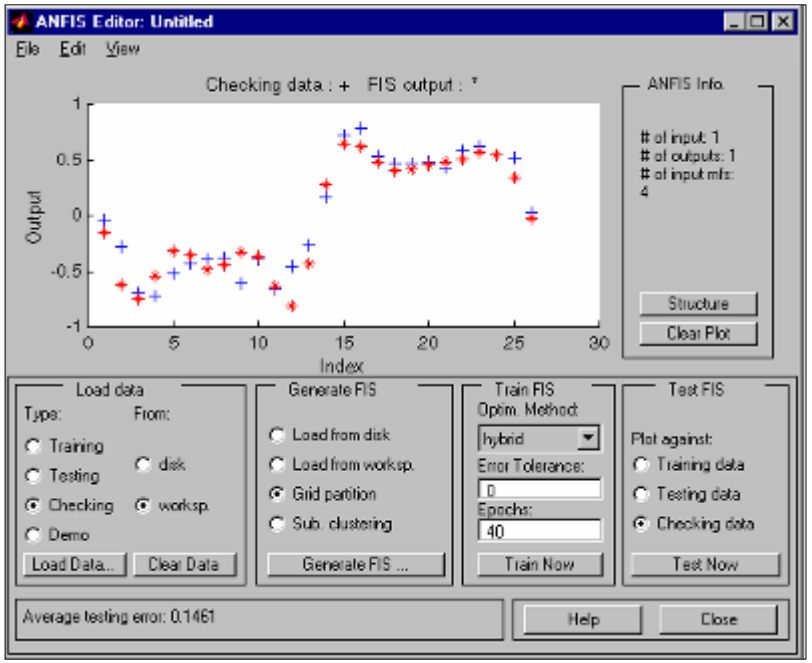
FIS with 4 iINs (left) and 1 OUT(right): in the centre, Rules’ block relating inputs to output.





Overview of Method & Approach (#2)

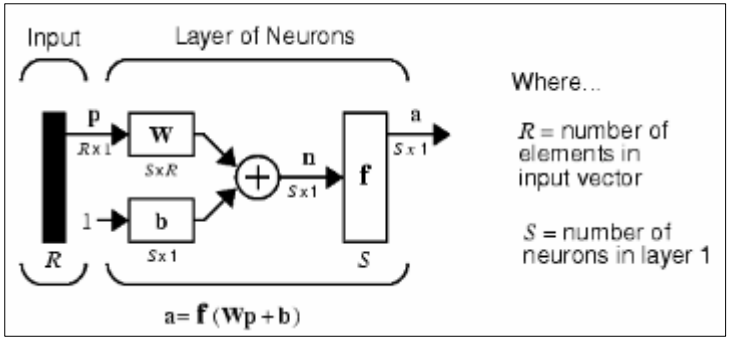
- **Adaptive-Network-based Fuzzy Inference Systems Modelling**
  - MBF are defined arbitrarly by human experts in FIS
  - Tuning of these MBFs has to be done manually
  - ANFIS is neuro-adaptive learning techniques providing a method for the Fuzzy Inference System to learn information about a dataset
  - Using a given IN/OUT data-set, the parameters of MBFs are tuned by a *back-propagation* algorithm, combined with the *least-squared-error* method
  - This allow the FIS to learn from data we want to model



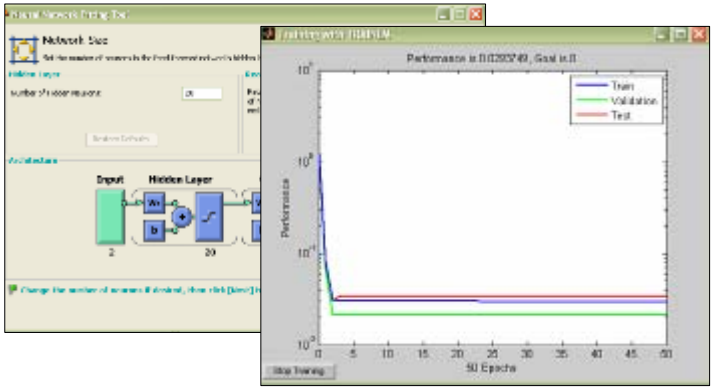
ANFIS editor toolbox in Matlab®

Overview of Method & Approach (#3)

- **Neural Networks Modelling**
  - An Artificial Neural Networks (ANN) system is an information processing paradigm, that is inspired by biological nervous system (the brain) and it consists in a large number of highly interconnected processing elements, working together to solve specific problems
  - It is possible to train an ANN to perform a particular function by adjusting the values of the connections (weights) between elements
  - Usually, ANN are trained so that a particular input leads to a specific target output
  - Nowadays (A)NN are used in several fields of applications, such as: aerospace, automotive, banking, medical, robotics, etc.



An example of Neuron Architecture



Neural Network fitting toolbox in Matlab®

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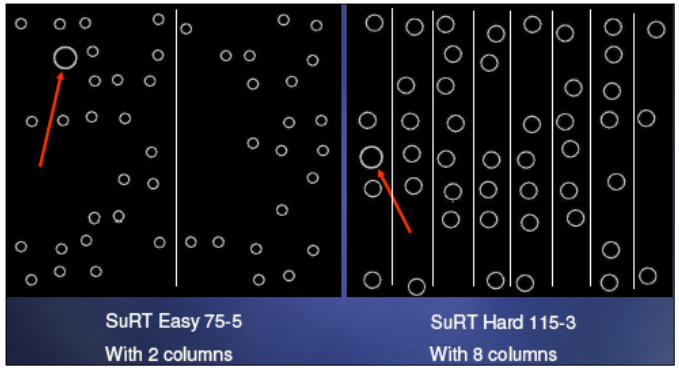
Test on driving simulator: overview

- **Overview**
- An experiment on the University of Modena and Reggio Emilia driving simulator was conducted.
- Driver, Vehicle and Environment data were collected for the **training**, **tuning** and **validation** of DVE's Driver Model parameters.

UNIMORE driving simulator: AIDE experiment setup

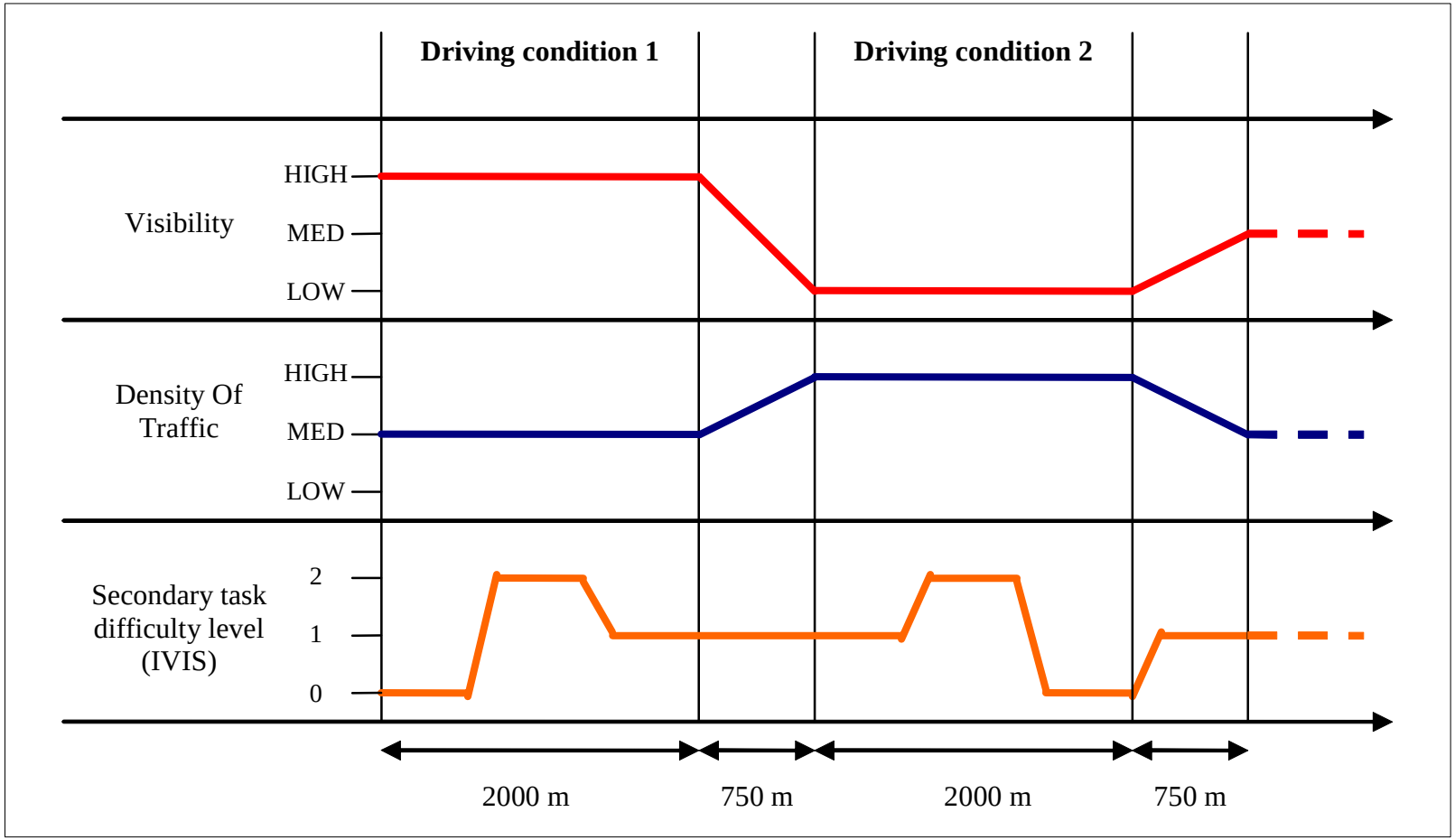
Experimental setup

- **Participants and test design**
- Twelve participants between 19 and 40 years of age were involved.
- Drivers were asked to drive for 40 minutes in a scenario with three different (High, Medium and Low) Visibility and Traffic conditions randomly presented.
- An LCD monitor simulating the activation of an IVIS was placed nearby the driver's seat, randomly presenting a visual task with two degrees of difficulty.



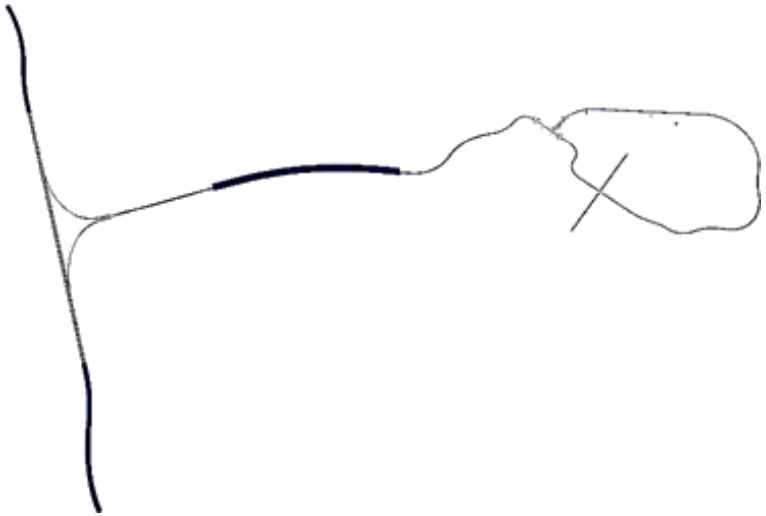
Scenario with bad VISibility and bad Density of Traffic (left), acceptable VISibility and good Density of Traffic (centre) and Look and find task reproduced on the on-board touch screen (IVIS task)

Driving scenario and events 1/2



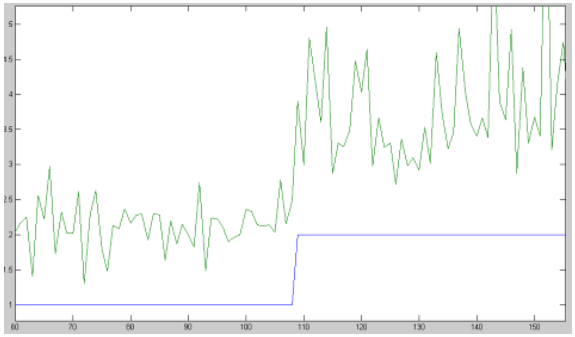
Driving scenario and events 2/2

VISIBILITY [meters]			DENSITY of TRAFFIC [vehicles/km]			IVIS (secondary task difficulty)	
LOW	*MEDIUM*	*HIGH*	*LOW*	*MEDIUM*	*HIGH*	*LOW*	*HIGH*
>=70 e <100	>=100 & <1000	>=1000 e <=5000	>=15 e <20	>=20 e <35	>=35 e <50	1	2

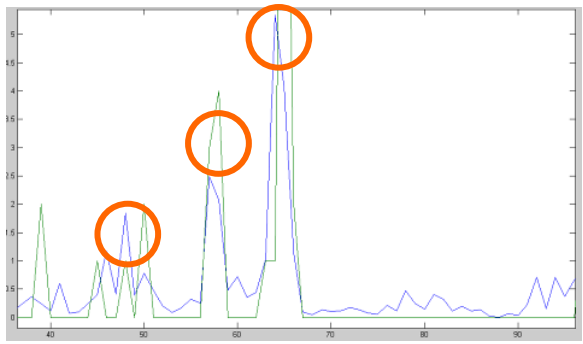


Experiment results: data recorded

- Data related to Driver, Vehicle and Environment were recorded during the simulation, in particular:
  - **Driver and Vehicle**: Standard Deviation (SD) of steering angle, SD of speed, SD of lateral position, Steering Reversal Rate, Time to Line Crossing, Deceleration Jerks, SD of acceleration and Driver's secondary task reaction time
  - **Environment**: Visibility, Density of Traffic



Driver reaction time performing the secondary task (green line) in comparison with the task's degree of difficulty



SD of speed (blue line) in comparison with Deceleration jerks (green) when Visibility is Low and Density of Traffic is High (red circles)

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Data Preparation and Analysis

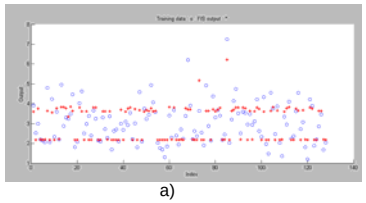
- Based on correlation matrix and results from experiments, DIS has been regarded as function of the number of active IVIS devices (IVIS) and of the Standard Deviation of Steering Angle (SDSA): *DIS = f(IVIS , SDSA)*
- The measure used as target output has been the *reaction time,* taken by subjects in performing a secondary task during driving sections at simulator, following the HASTE protocol
- Two models of DIS have been analyzed and then compared: one obtained by ANFIS and another designed by ANN
- For DIP parameter, other specific tests have been performed, selecting two types of different maneuvers to be recognized (plus free-ride mode):
  - Lane-change (LC)
  - Car-following (CF)
  - Free-ride (FR)

Main Results – ANFIS for DIS

- After testing different combinations, (IVIS, SDSA / Treac) has been selected

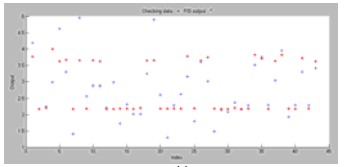
- Features of ANFIS:
  - Grid-partition of IN data
  - Radius of Influence = 0.2
  - Error Tolerance = 0.01
  - Epochs of Training = 100

- Results
  - Error Testing = 0.4
  - Satisfactory, but not good enough; another model, using NN, has been tested



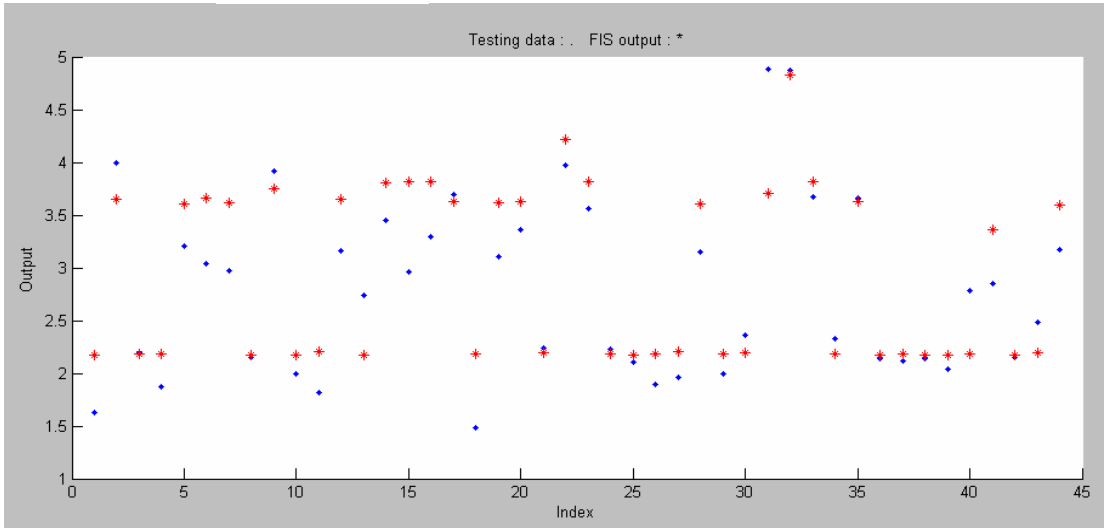
a)

Training



b)

Checking



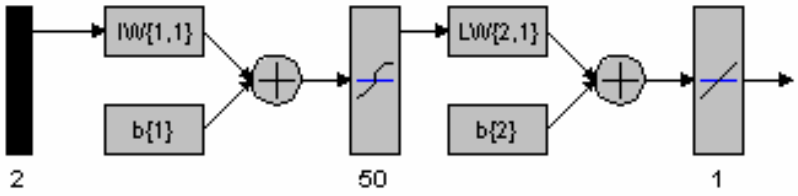
Testing

Main Results – ANN for DIS (#1)

- A specific NN architecture has been selected with the following features:
  - Output Layer = 1
  - Output Neuron = 1
  - Hidden Layer = 1
  - Hidden Neurons = 50
  - Maximum number of epochs for training = 500
  - Error tolerance = 0.01

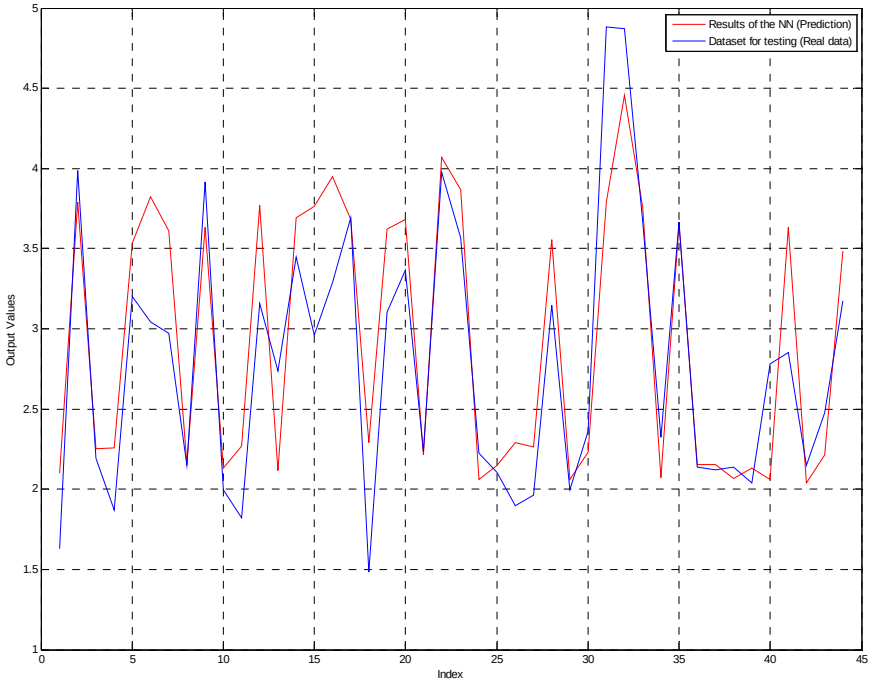
- The network is a **Feed-forward Back-propagation**, using "**Lavenberg-Marquardt**" technique for Training (best performances)

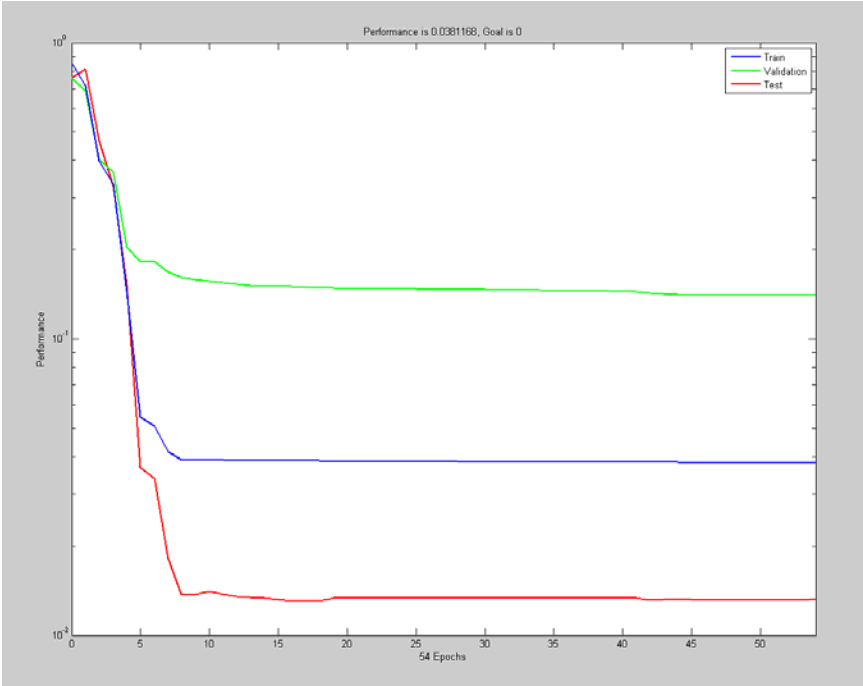
- Network topology is shown

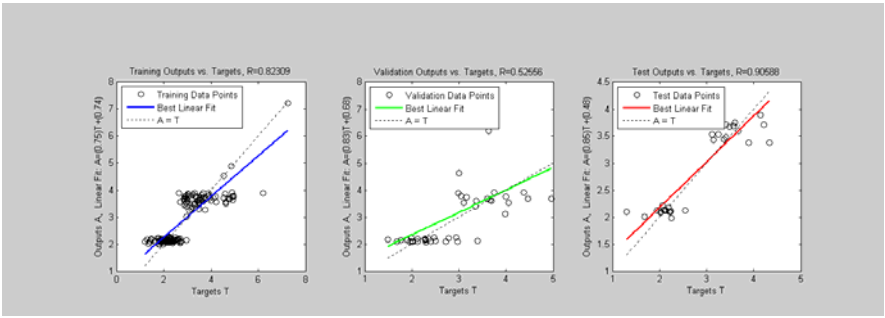


Main Results – ANN for DIS (#2)

- The MSE value is 0.33 and the fit of the predicted data (RED) respect to the real test data (BLUE) appears good (<0.67).







Task Demand and Distraction viewer

- As a result of the tuning and validation of Task Demand and Distraction, a viewer of these driver model parameters was developed using Matlab Simulink, DynaAnimation and Altia software.

- The viewer displays the effects of Driver, Vehicle and Environment conditions on Task Demand and Distraction developed through the Simulink Neural Network toolbox.

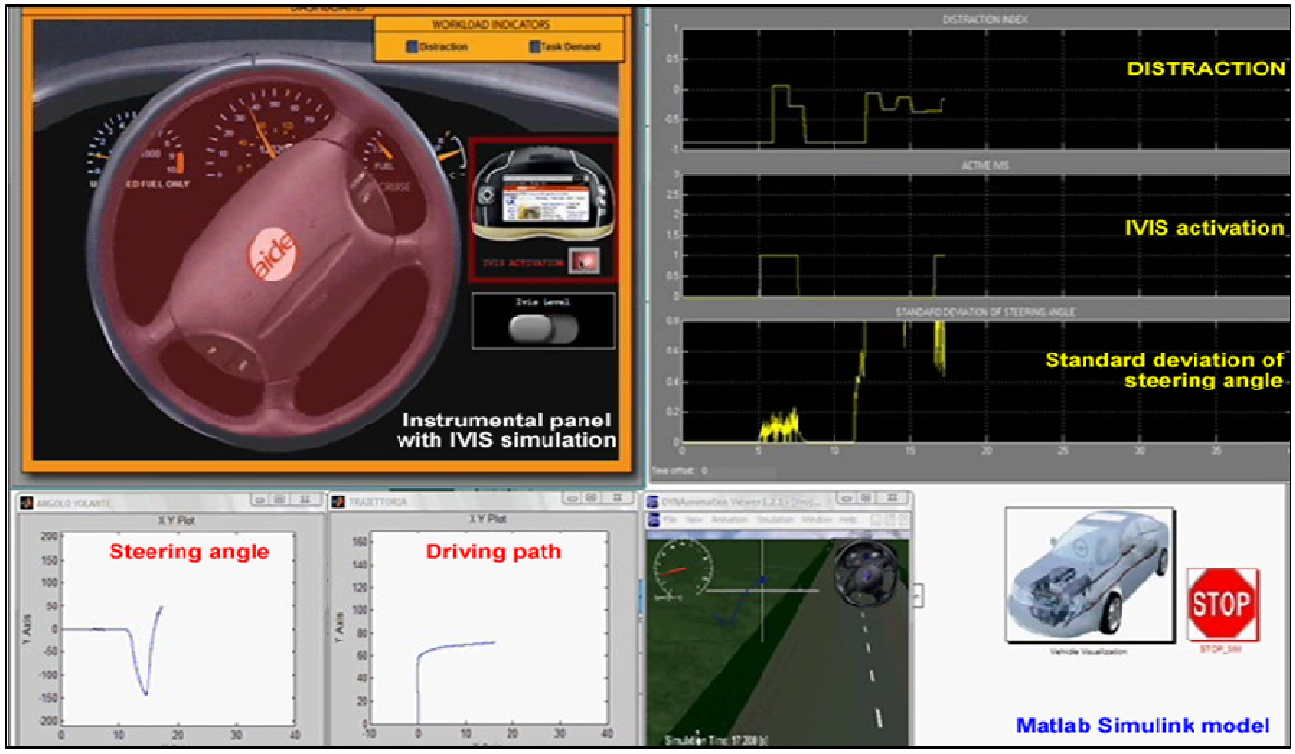
Task Demand viewer

- Task Demand viewer allows to monitor the effort spent by the driver to keep the lane

Task Demand level viewer

Distraction viewer

- Distraction displays the level of drivers' distraction induced by an IVIS.



Distraction level viewer

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Summary and Conclusions (#1)

- Based on the DVE framework, developed in WP1 of AIDE-SP1, some parameters and variables describing the driver's behaviour, have been selected: DIS and DIP, in particular
- After the intial proposal, a deeper investigation has been carried on, about the relationships among variables characterising the parameters for the description of driver's behaviour
- This activity of validation and tuning has been conducted making some hyphotesis of modelling, by means a machine learning approach: starting from initial fuzzy relationships, ANFIS and ANN approaches have been explored
- Data set for training, checking and testing have been derived by appropriate experiments performed at the static driving simulator at UNIMORE, with "real" human subjects
- Quite good results have been found for both the approaches

Summary and Conclusions (#2)

- Especially considering a Neural Network model for DIS, prediction fits real data in a good way; the input is constituted by Number of active IVIS devices and steering behaviour and target is Reaction Time in performing secondary task
- This is a very important results, since DIS is related just to the driver's distraction caused by IVIS; based on our model, it is possible to estimate and assess it, using parameters easily collectable directly on-board vehicle (see also the work done in SP3)

Next Steps

- Even if the AIDE project is going to the end, some works still remain to do and further investigations are possible
- Wider evaluation of network model for DIS, both on type and topology point of view
- Enlarging the same investigation to other meaningful parameters, in order to model them and intergrate them in a unique driver's behavioural model
- Creating a link between DEP parameter, which is related to driver's error making, and the DIS parameter, related to explore and predict the driver's intention (manouver)
- Integration of the complete driver's behavioural model into the SSDRIVE simulator, developed by WP3 in SP1
- Integration and development of such a model on car prototype for a "real-time" use and assessment (for example, the assessment of driver's distraction or driver's propensity to make an error, can contribute to enhance the efficacy of the warning criteria of ADAS applications).