The 27th INTERNATIONAL ELECTRIC VEHICLE SYMPOSIUM & EXHIBITION.
Barcelona, Spain
17th-20th November 2013

Driving Cycle and Road Grade on-board prediction for the optimal energy management in EV-PHEVs

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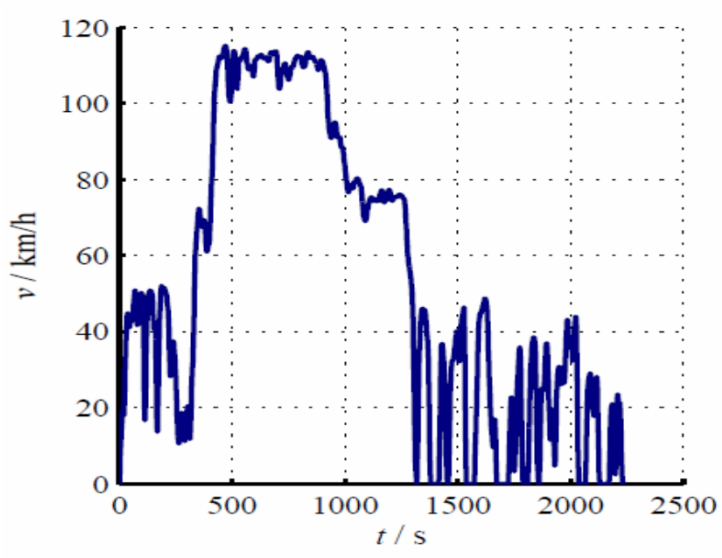
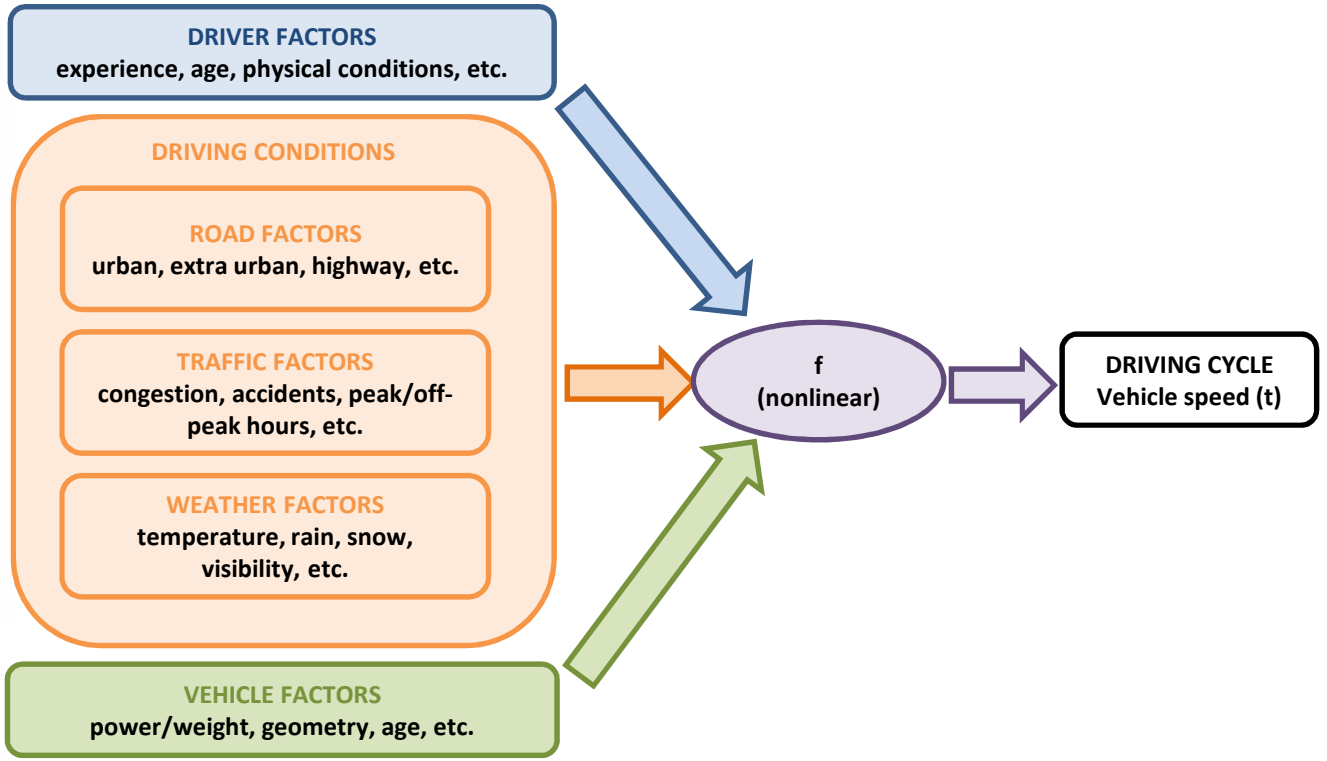
Objective



Driving Cycle of Martorell-Barcelona trip. Courtesy of SEAT.



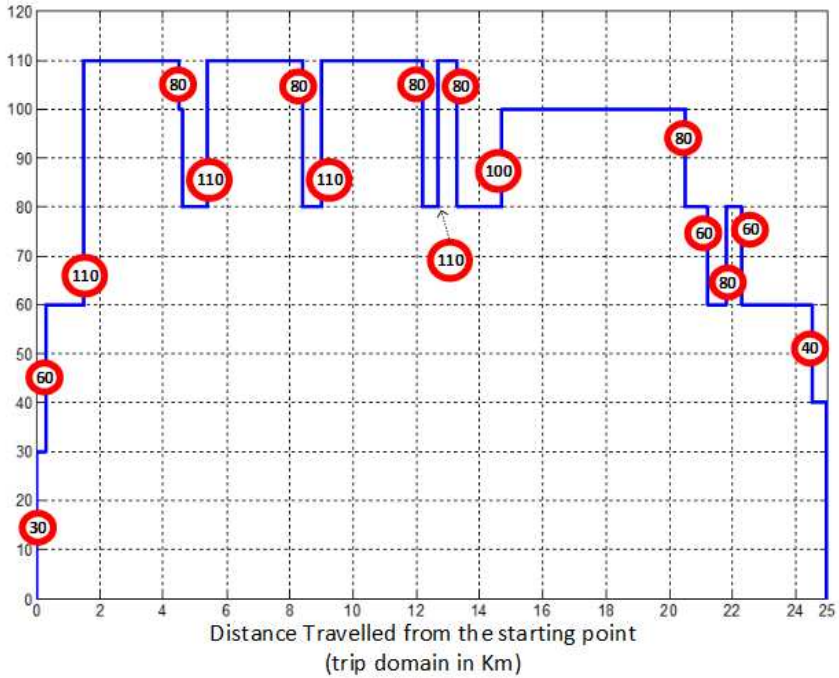
- Driving cycle and road grade on-line prediction over a time horizon.

Precedents

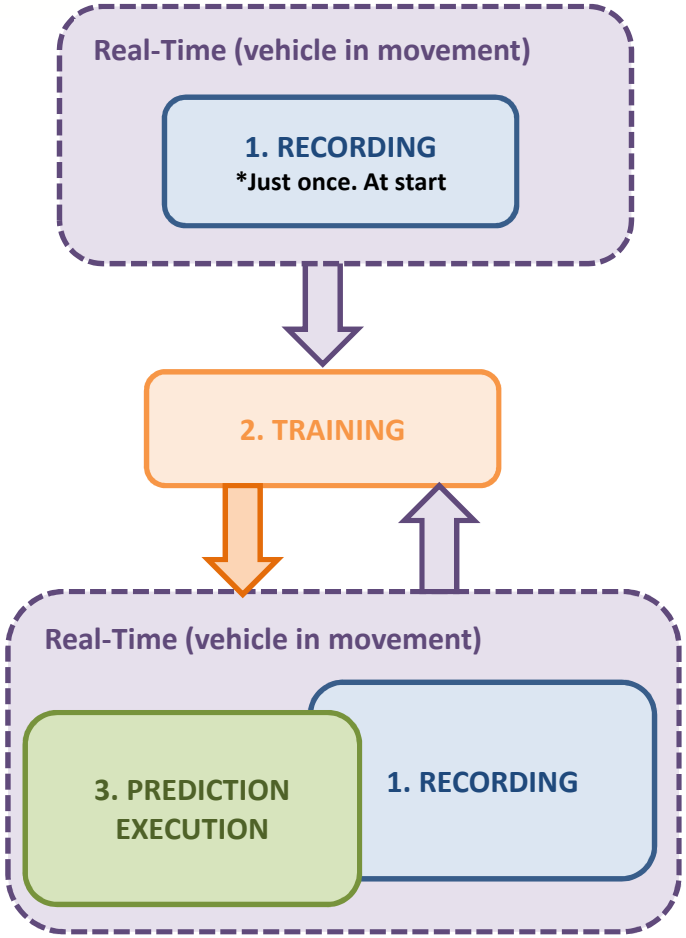
- Research activities only focused on driving conditions (DCOs) real-time prediction.
  1. Obtaining some statistical parameters of the recent past vehicle speed that feed a classification technique (Fuzzy Logic, ANN,…).
  2. Enhancing them with digital maps information and historical route data for building a Reference Driving Cycle (RCD).
- No approach **model the driver/vehicle behavior.**
  - Penalizing the prediction → extra up to 15% fuel consumption reduction can be achieved.

Proposal

- Use an ANN for modeling the driver/vehicle behavior.
  - Processing the **deviation in the trip/distance domain** between a RDC and the vehicle speed. It is only provoked by the driver behavior.
  - The RDC is dynamically and easily constructed using only road/route information:
    - Static → **GIS** (Geographical Information System, digital maps)
    - Dynamic → **GIS + V2X**



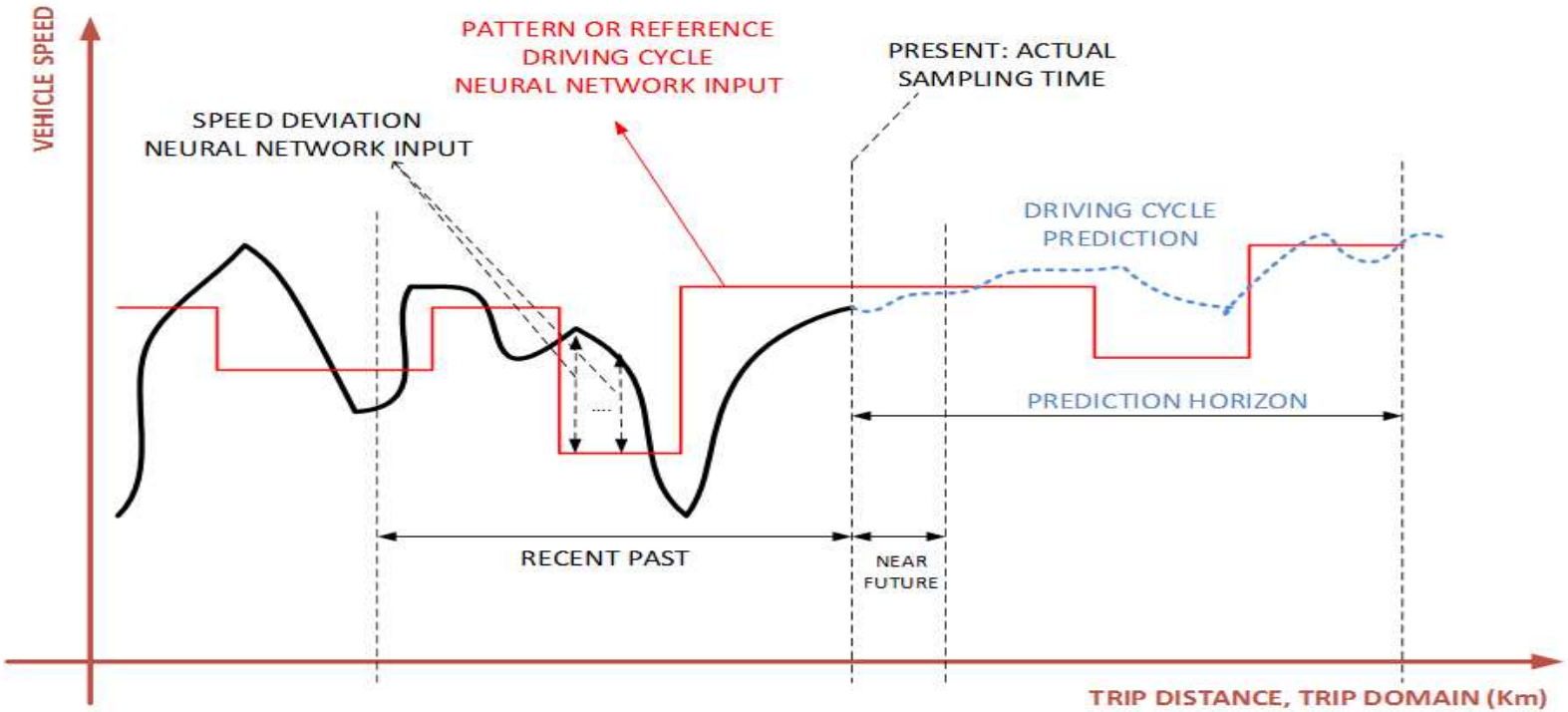
The idea in 3 steps



1. Recording
   - RDCs and driving cycles during usual journeys.
   - In the background.
2. Neural Network Training
   - Based on the speed deviation between the RDC and the vehicle speed **in the trip/distance domain** (not time domain).
   - Off-line task.

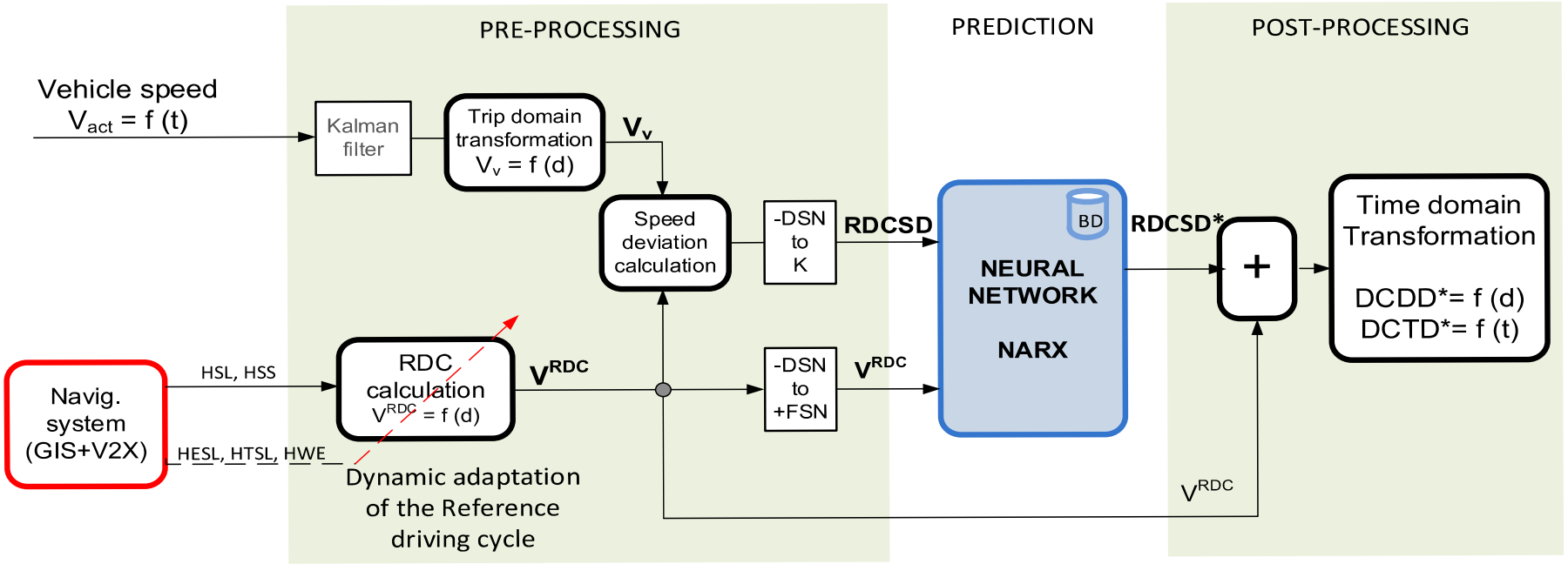
The idea in 3 steps

3. Prediction Execution (I)

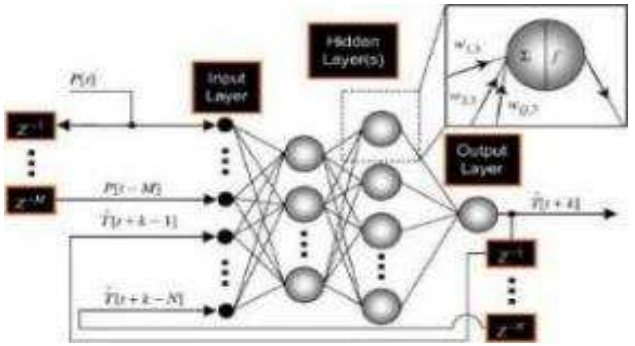


The idea in 3 steps

3. Prediction Execution (II)



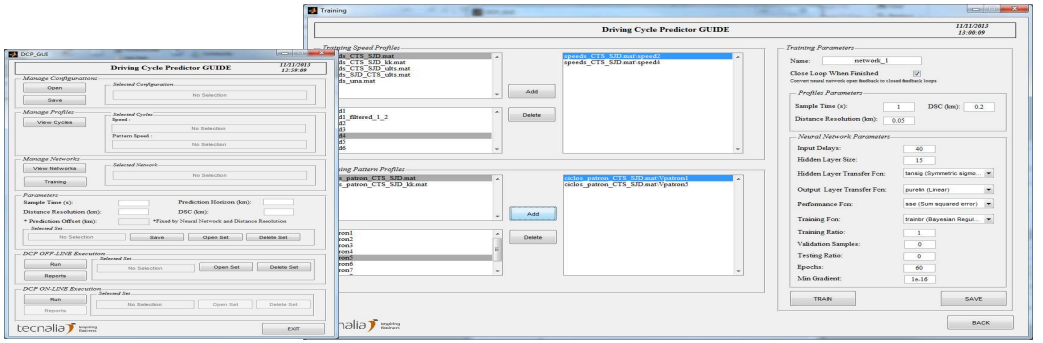
Neural Network

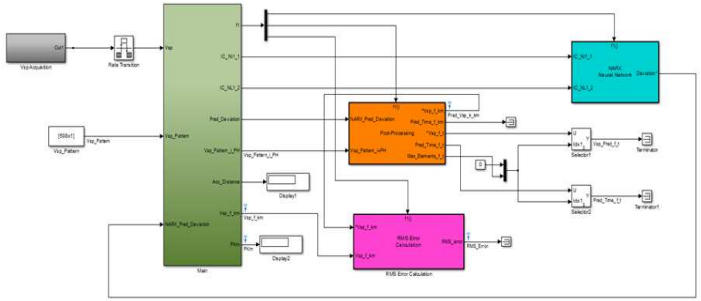


- NARX (Non-linear Autoregressive with exogenous inputs). Widely used in non-linear time series predictions.
- Multilayer net with two delayed inputs, a sigmoid-based hidden layer (7-15 neurons) and pure linear-based output layer (1 neuron).
- Training methods: Bayesian regularization, Levenberg-Marquardt.
- Low computational efforts once trained → embedded into MCUs and DSPs.

Prototype Implementation

- Off-line work
  - MATLAB-Based GUI for training and simulation.
- On-line work
  - Rapid prototyping in a MicroAutobox from dSPACE.
  - Tested in a real SEAT vehicle.
  - CANBus communication for receiving vehicle speed (road/route information **not available yet,** thinking in GIS + ADASYS Protocol).

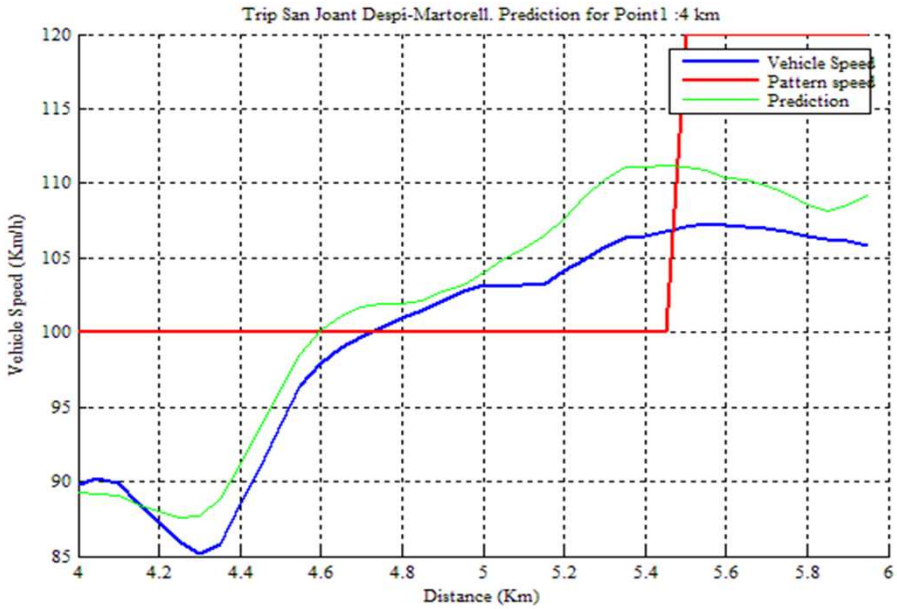


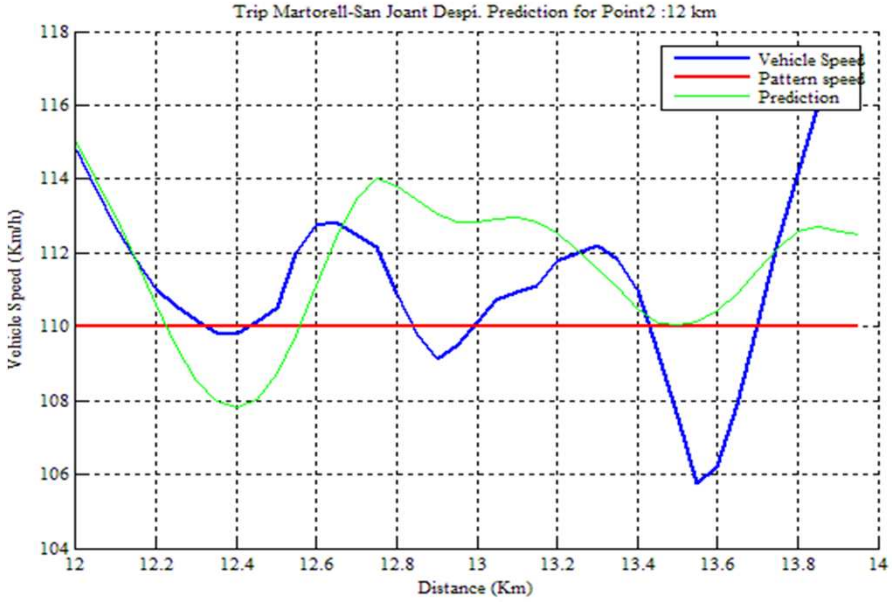


```
/************ Pre-processing ****************************************/
// Distance calculation at each sampe time
IncrKm          = ST[0]*((Vsp[0]+ memoRWork[0])/7200);
aux_Acc_Distance = IncrKm + memoRWork[2];
PKm             = memoRWork[1];
Vsp_km          = memoRWork[3+i-1];

if ( (aux_Acc_Distance-PKm) >= H_Resol[0] ){

    slope = (Vsp[0]- Vsp_km)/(aux_Acc_Distance-PKm);
    n_m   = (uint16_T)round_real((aux_Acc_Distance-PKm)/H_Resol[0]);

    for (j=1; j<=n_m; j++) {
        /************ Generating new values ************************/
        PKm       = memoRWork[1] + H_Resol[0];
        Vsp_km    = memoRWork[3+i-1] + (slope*H_Resol[0]);
        AV_DSC    = Vsp_Pattern[k+Num_DSC];
        diversion = Vsp_Pattern[k] - Vsp_km;

        /* Writting Vsp_f_km and PKm outputs*/
        Vsp_f_km[0] = Vsp_km;
        Pkm[0]      = PKm;

        if (i<d){
            /*Note i and k starts at 1*/
            /************ Filling internal vectors **************/
            memoRWork[3      +i] = Vsp_km;
            memoRWork[3+d    +i] = AV_DSC;
            memoRWork[3+2*d  +i] = diversion;

            //Update Internal vecotrs index
            i++;
```

Results

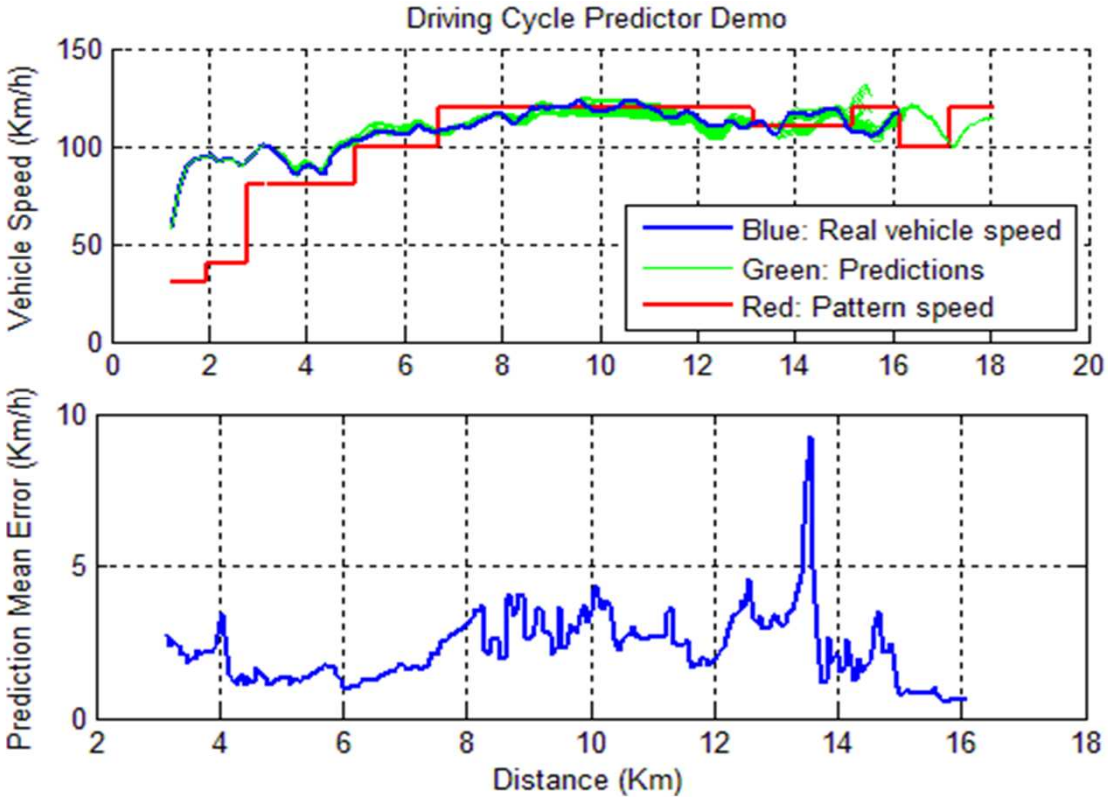
1. Simulation results based on real speed data.
   - Predictions for 4 and 12 kilometric points with 2km prediction horizon





Results

2. In-vehicle testing using a SEAT vehicle.
   - Trip: Martorell - Sant Joan Despí
   - Prediction horizon: 2km
   - Prediction Mean Error lower than 10 km/h



Conclusions

- Driving cycles in the surroundings of Barcelona have been on-line predicted using advanced computational techniques with an average error less than 10km/h.
- Good performances obtained using prediction horizons ranged from 1 to 5km.
- Driving cycles predictions could be used for optimizing different vehicle functions.
  - Among others, energy management in PHEVs, thermal management, transmission controls, eco-driving ADAS.

Acknowledgements

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