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Application of artificial neural network to predict vehicle NOx emission and fuel consumption

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1.Introduction

- Several recent studies have shown that diesel vehicle emission has exceeded standards such as EU 6 by a large margin
- The ever increasingly stringent restrictions over vehicle emission gives rise to the significance of NOx emission prediction to understand, optimise and therefore meet emission standards.

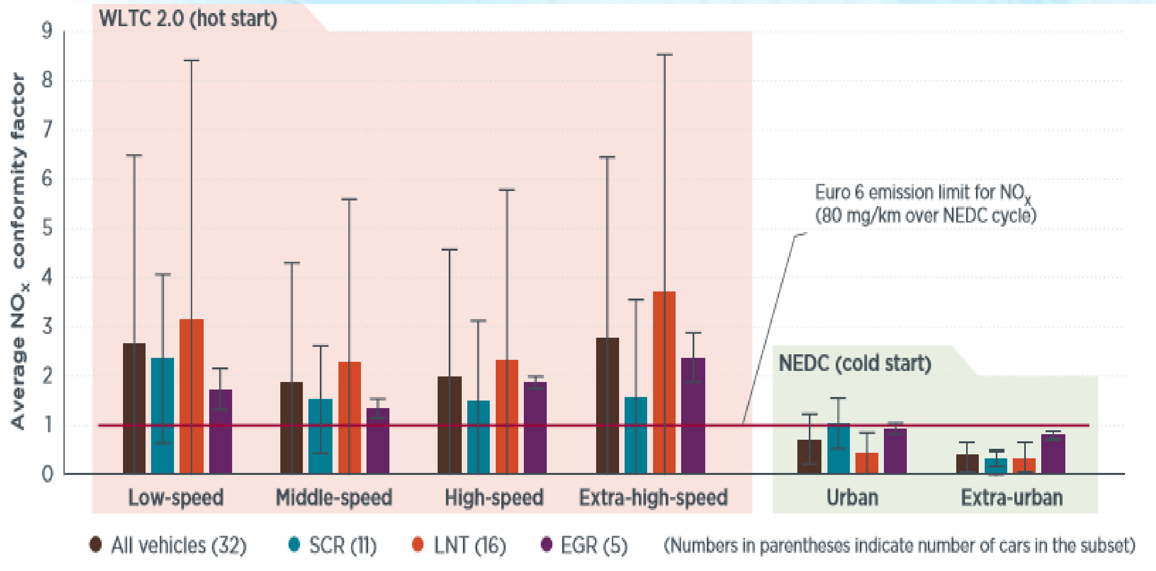

Figure 1. NOx emission of 32 diesel vehicles tested by ADAC (Yang et al., 2015)

VEHICLE NO.	ENGINE SIZE	EXHAUST AFTER-TREATMENT	AVG. NOX EMISSION (G/KM)
1	1.6 T	LNT	0.32
2	2.0 T	SCR	0.24
3	2.0 T	SCR	0.47
4	2.0 T	LNT	0.14
5	1.6 T	EGR	1.29

Table 1. Tested vehicle NOx emissions (LNT: Lean NOx trap, SCR : Selective Catalytic Reduction, EGR: Exhuast Gas Recirculation)

EU 5 NOx standard: 0.18 g/km
EU 6 NOx standard: 0.08 g/km

2.Methodology

- NN structure implemented has 1 input layer, 1 hidden layer and 1 output layer
- Input elements are carefully selected, each of them shares a certain level of similarity with output
- Correlation R, mean square error (MSE) and mean relative error (MRE) are used to assess the quality of regression fitting

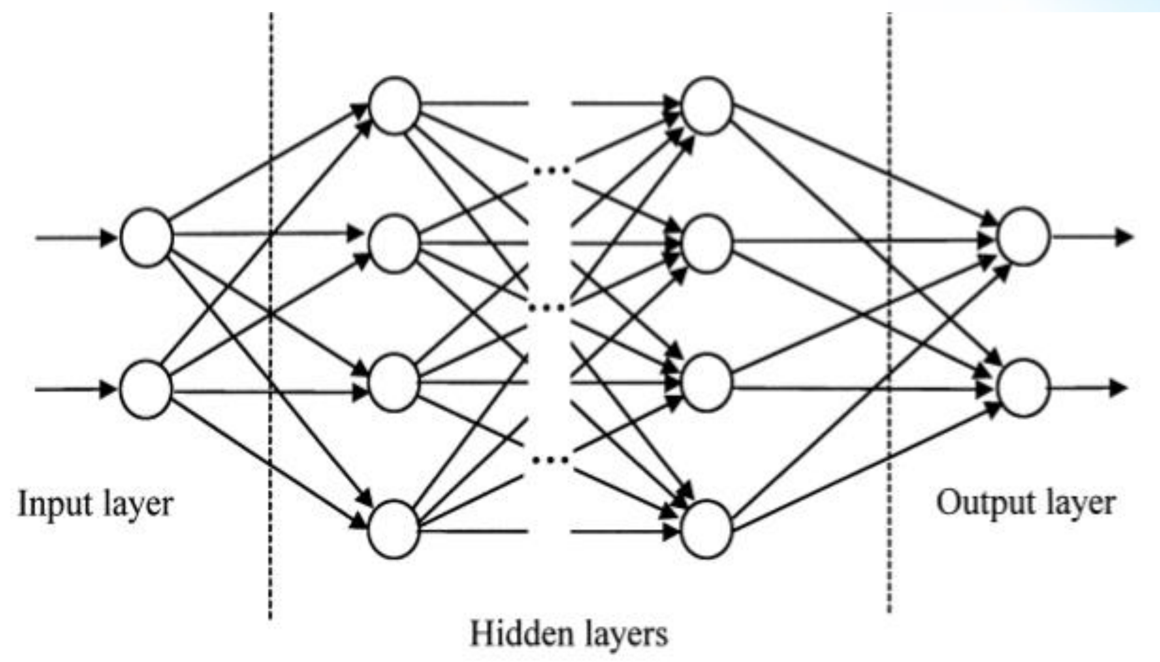

Figure 2. Typical NN structure (Kalogirou, 2000)

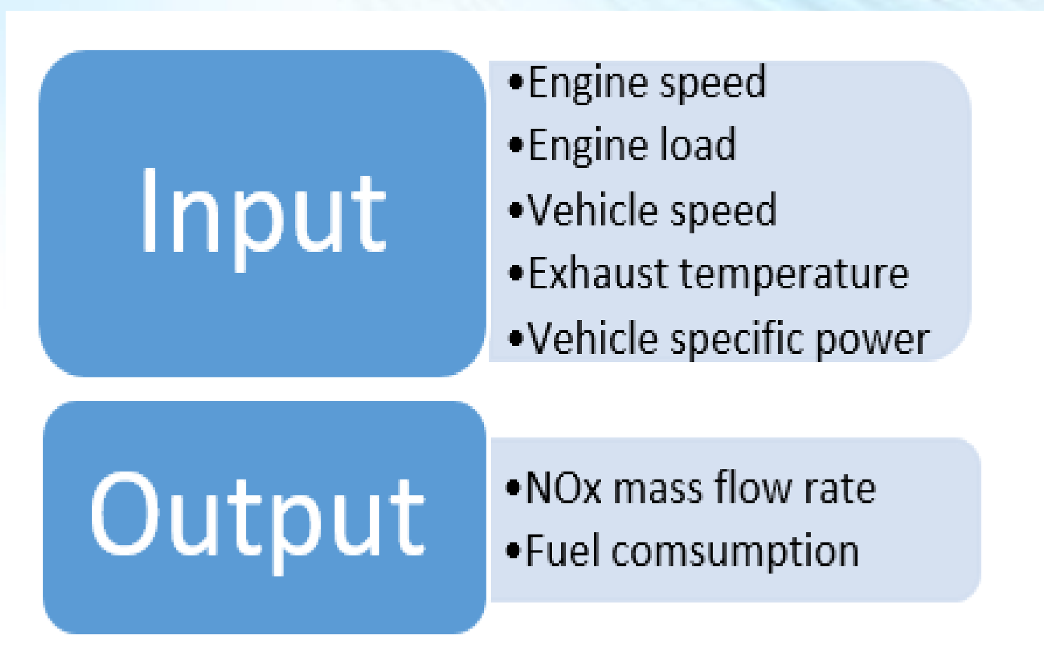

Figure 3. Elements of input and output vectors

3.Neural network improvement

The test using MATLAB nftool default settings does not yield satisfactory results, therefore several improvement techniques are carried out to modify NN structure:

- Initialisation of network weights and biases
- Increase the number of hidden neurons (10 to 100)
- Different training algorithms (Levenberg-Marquardt, Baysian Regularisation, Scaled Conjugate Gradient)
- 5-sec time-frame sampling

4.Results and discussion

Finalised NN structures yield satisfactory results for all 5 vehicle tested, correlation R values are all approximately above 0.78, especially for vehicle 3 (0.910 for NOx emission and 0.934 for fuel consumption)

OUPUT	NOX (R)	FC (R)	NOX (MRE)	FC (MRE)
Vehicle 1	0.823	0.890	100.86%	60.31%
Vehicle 2	0.834	0.872	108.97%	73.54%
Vehicle 3	0.910	0.934	59.34%	38.84%
Vehicle 4	0.786	0.841	113.54%	115.6%

Table 2. Self-trained NOx and fuel consumption correlation R and MRE for 4 vehicles

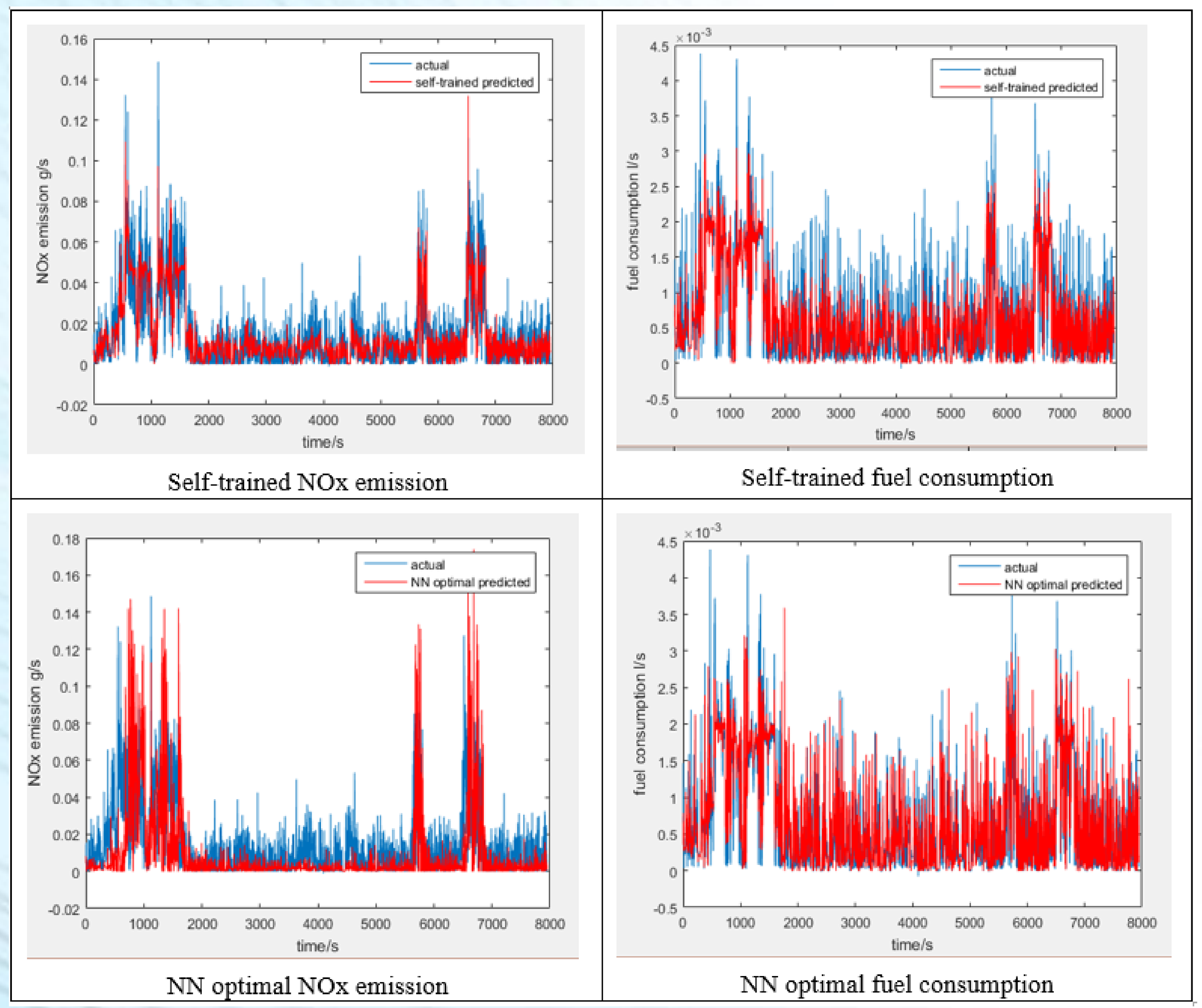

Figure 4. Self-trained and 'NN optimal' regression fitting for NOx and fuel consumption

OUPUT	NOX (R)	FC (R)	NOX (MRE)	FC (MRE)
Self-trained	0.886	0.903	201.74%	83.03%
NN optimal	0.802	0.872	142.27%	86.54%

Table 3. NOx and fuel consumption correlation R and MRE for self-trained and "optimal" NN structure

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