Fonte original: <https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0188553>

key words and phrases: “analysis of the MAP estimator in a real engine”

**Manifold absolute pressure estimation using neural network with hybrid training algorithm**

## **Abstract**

In a modern small gasoline engine fuel injection system, the load of the engine is estimated based on the measurement of the manifold absolute pressure (MAP) sensor, which took place in the intake manifold. This paper present a more economical approach on estimating the MAP by using only the measurements of the throttle position and engine speed, resulting in lower implementation cost by estimating the MAP closely to the simulated MAP values.

## **Introduction**

Electronic fuel injection (EFI) system is expected to be one of the most promising technologies on improving the fuel economy and reducing harmful emissions [[1](https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0188553#pone.0188553.ref001)]. One way to achieve this is by accurately estimating the engine load. There are several types of fuel injection methods being used in modern system of a spark ignition (SI) engine. The most commonly used are the air-flow method or speed-density method. Both methods require estimation of the engine load by estimating the air mass flow rate (AMF) into the engine cylinder [[2](https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0188553#pone.0188553.ref002)]. In the air-flow method, the estimation of cylinder AMF are based on the measurement of the mass air flow (MAF) sensor near the throttle plate. But, in speed-density method, the estimation of the cylinder AMF were based on the measurement by a manifold absolute pressure (MAP) sensor by using combination of look-up tables or polynomial expressions [[3](https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0188553#pone.0188553.ref003)].

With the advancement of computing technology, empirical approach such as artificial neural network was adapted in estimating the manifold pressure as described in [[9](https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0188553#pone.0188553.ref009)]. The neural network approach generally uses the experimental data to predict most of the engine process.

This approach only uses two inputs (throttle position and engine speed) that does not require additional sensor or the MAP sensor to estimate the absolute pressure. The Neural network were chosen because of its capability of learning underlying input/output relationship without requiring the development of an explicit model of the underlying relationship [[10](https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0188553#pone.0188553.ref010), [11](https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0188553#pone.0188553.ref011)].

**In this study, different algorithms were used together to train the neural network to compensate the drawbacks of each other.**

**There are two phases in the development of the neural network, which are training phase and testing phase. The data set are divided into two parts (837 for training phase and 93 for testing phase).**

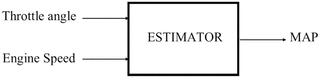
**Artificial neural networks (ANN)**

ANN in most cases can alter its internal structure based on the inside and outside information that feed through the network during the learning phase. ANN consist of an input layer, one or more hidden layer and an output layer. [Fig 1](https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0188553#pone-0188553-g001) shows the general structure of an ANN. For feedforward networks, the mean squared error (MSE) is usually used as the performance function. MSE is the average squared error between the network output, t and the target output, o which is represented by ([1](https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0188553#pone.0188553.e001)).

https://journals.plos.org/plosone/article/file?type=thumbnail&id=info:doi/10.1371/journal.pone.0188553.e001

## **Manifold absolute pressure (MAP) estimation using neural network with hybrid training algorithm**

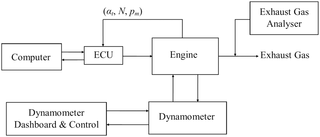
The MAP estimator is based on a multi-layer feed forward neural network which uses the mean squared error (MSE) as its performance function. This network has one hidden layer.



**Fig 2. Two-stage neural network estimator block diagram.**

Based on Fig 2, the network consists of two inputs (throttle angle and engine speed), and one output (MAP). One hidden layer network were used to avoid complication in the network structure and high computation time.

**Regularization is one of the methods that was used in the neural network to improve network generalization and to avoid overfitting.**



**Fig 3. Experimental setup block diagram for data collection.**

By referring to Fig 3, the engine is operated at different speeds and the engine input data which are the throttle angle (αt), engine speed (N) and manifold absolute pressure (pm) are logged into the Engine Control Unit (ECU). The ECU then logged the data into a computer for training the estimator using the proposed methods. There are 1480 data collected from the RFIS as listed in [S1 Table](https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0188553#pone.0188553.s001). 1332 out of 1480 are used for offline network training. Which leaves 148 data for testing the trained network.