THE UNIVERSITY OF WARWICK

Model Based Emissions Control

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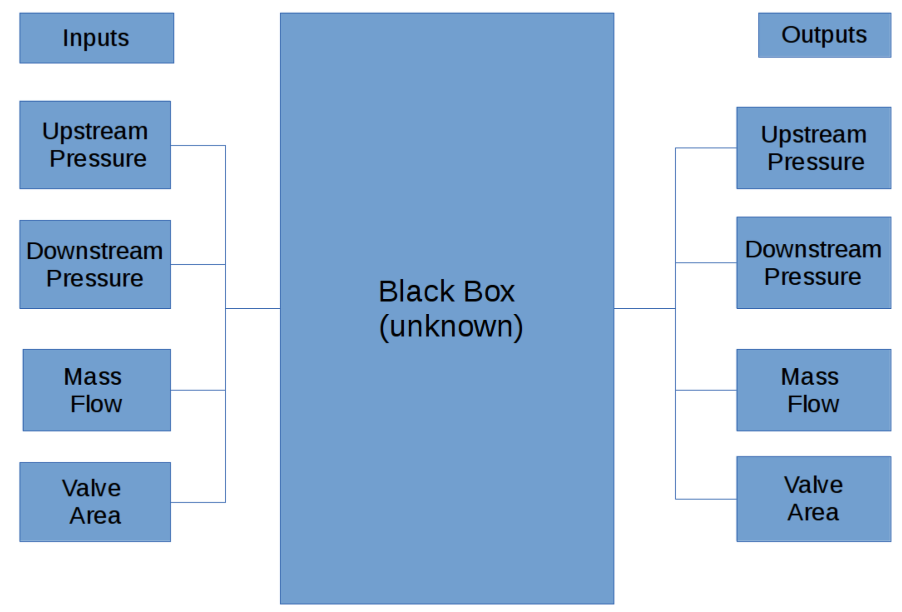
Introduction

A common problem in the industrial world is that of reverse engineering. One has some input and output data streams with possible noise associated from an unknown model, effectively a black box, and one wants to find a method that calculates the latter from the former.
A method is explained below that performs this in certain circumstances.

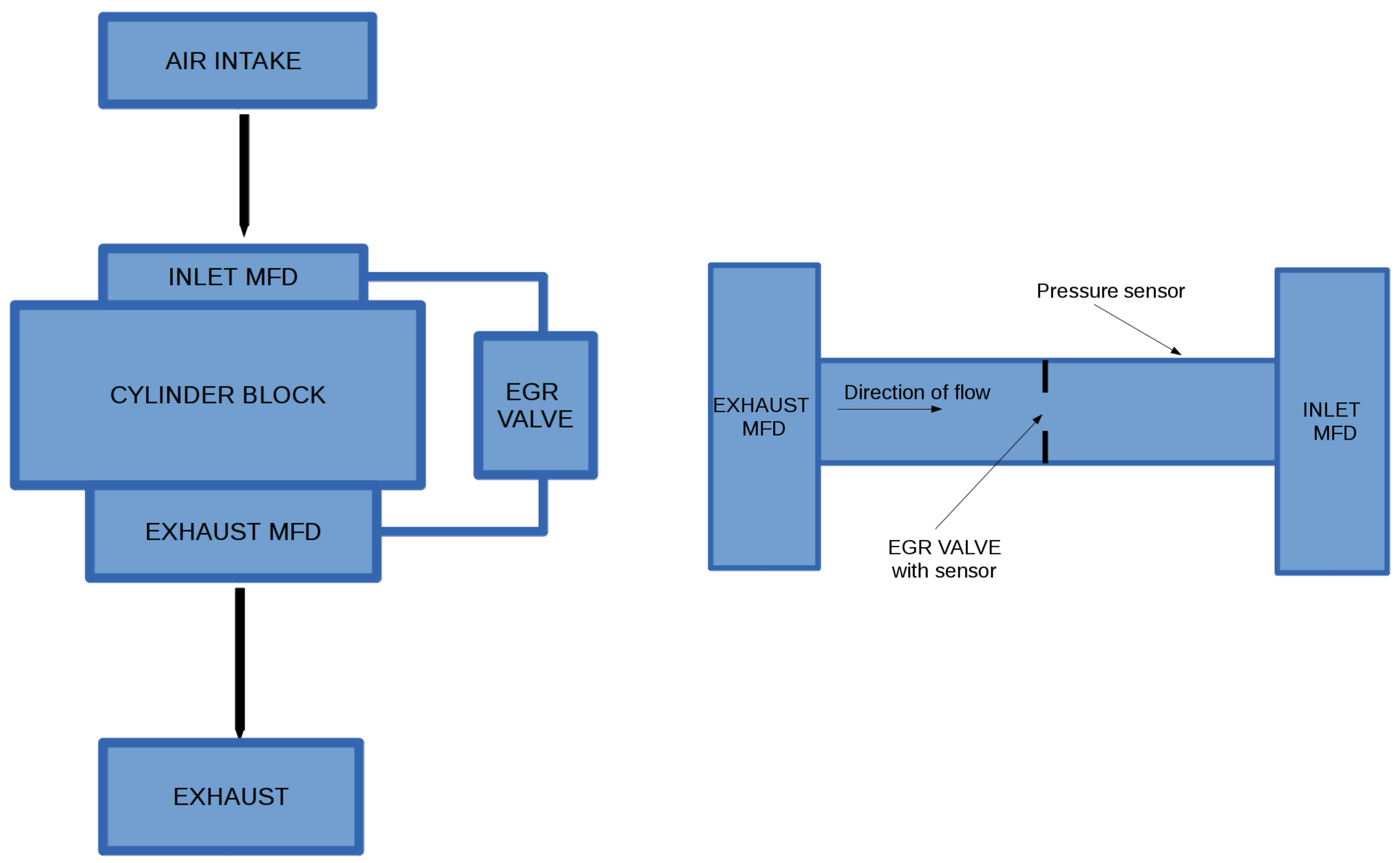
Black Box System



Application: E.G.R. Valve system

One such application is the exhaust gas recirculation system in a car engine. For emissions control, accurate estimates of the mass flow and valve area are highly desirable. In order to produce these estimates, the ECU evaluates an unknown method, that we replicate with some success.

Engine Schematic



Least Squares Approximation

Suppose one has a collection of points $\{x^i, y^i\}_{i=1}^N \subset \mathbb{R}^{2d}$. One aims to find the function $f : \mathbb{R}^d \to \mathbb{R}^d$ that minimises the squared distance:

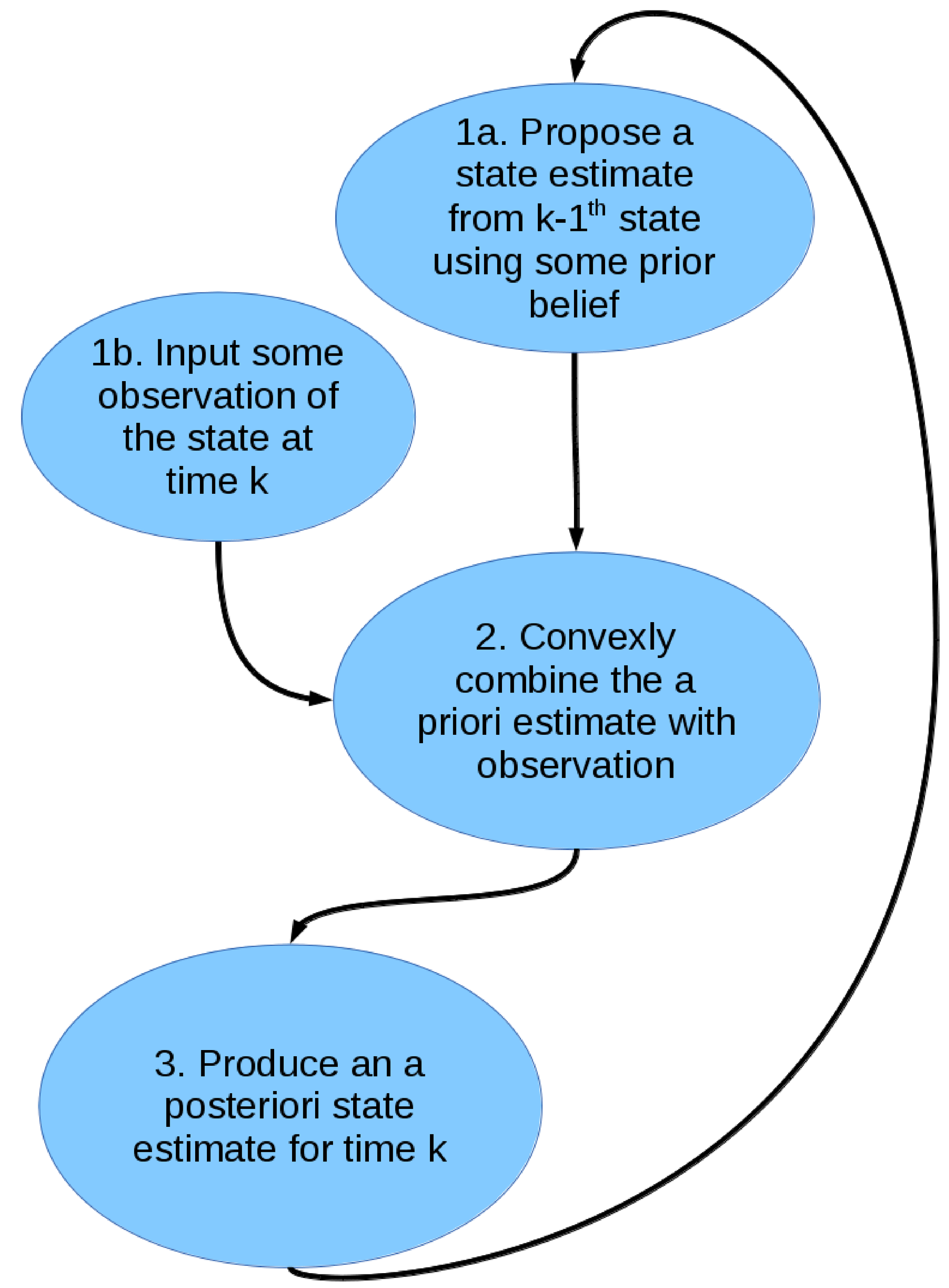
$$\sum_{i=1}^{N} \left| f(x^i) - y^i \right|^2$$

Numerical Application of LSA

For numeric implementation, one must choose a basis $\{\phi_j\}_{j=1}^K$ of a finite dimensional space. Any basis can be chosen, but certain ones have properties which will produce a more appropriate result. This basis approximates the system above and reduces it to a finite dimensional linear problem by:

$$\sum_{i=1}^{N} |f(x^i) - y^i|^2 = \sum_{i=1}^{N} \left| \sum_{j=1}^{K} a_j \phi_j(x^i) - y^i \right|^2 = \|\mathbf{Ca} - \mathbf{y}\|_2$$

Kalman Filtering

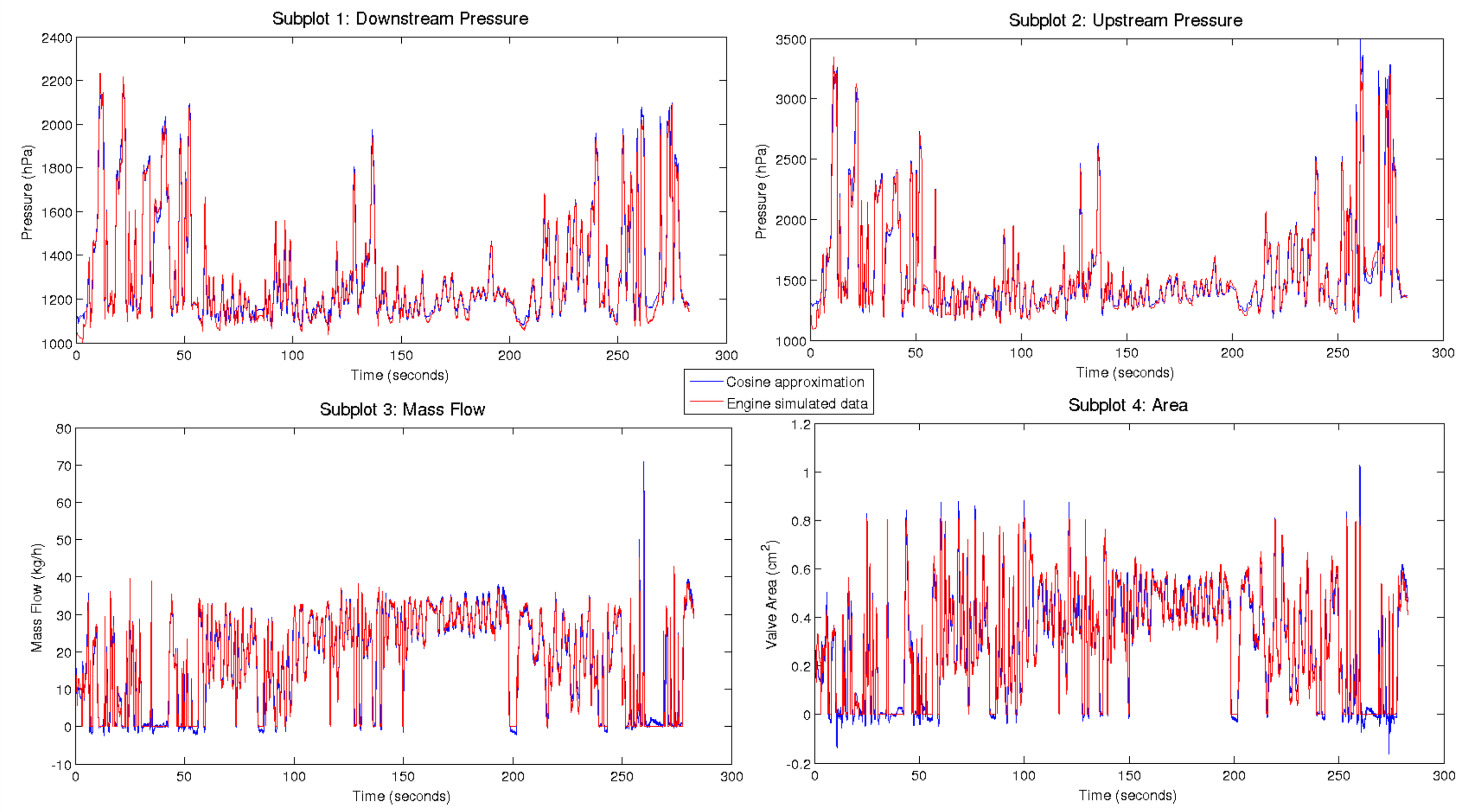


E.G.R. Simulations

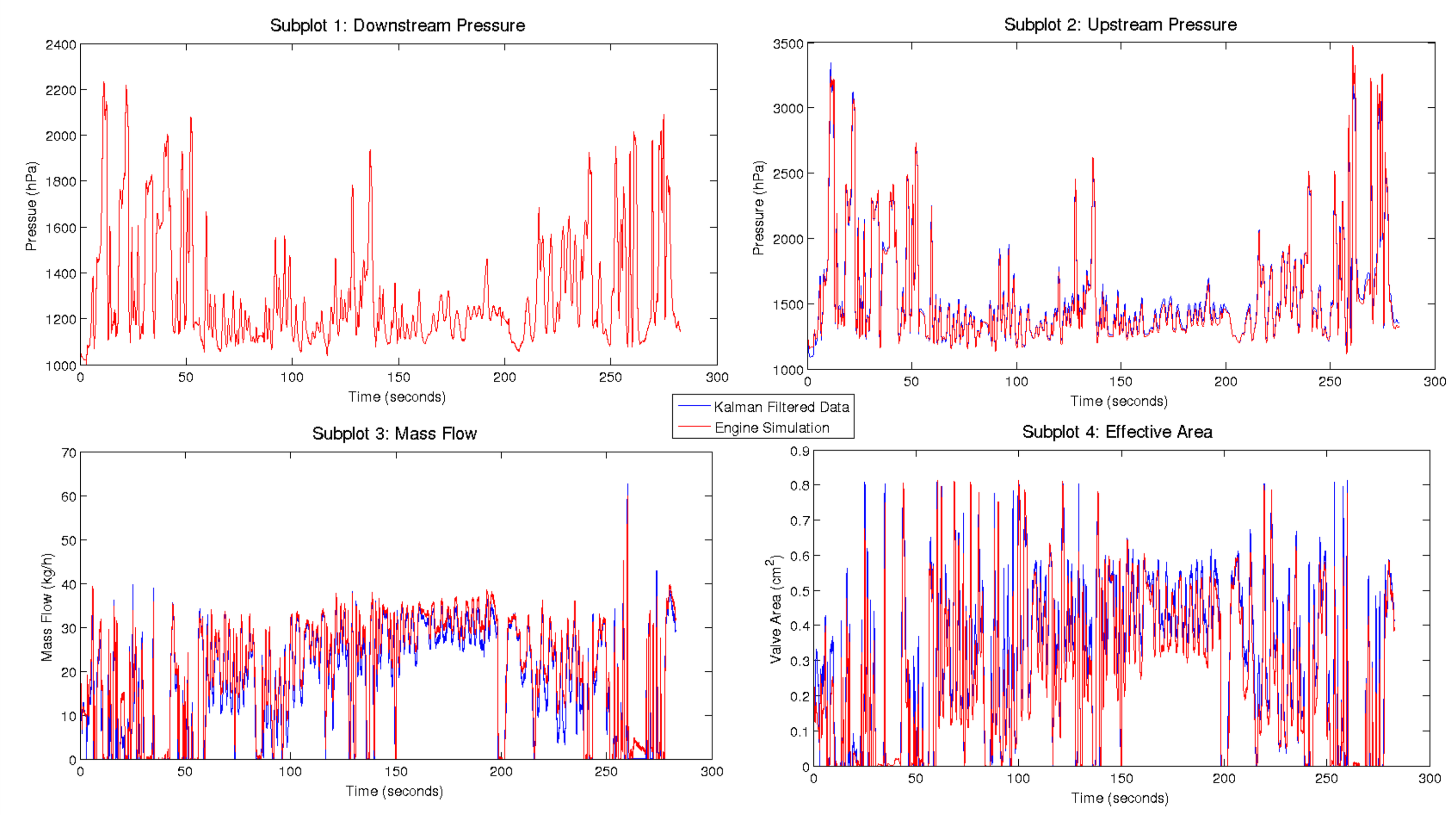
We chose a basis consisting of cosine functions with finitely many frequencies in $\mathbb{R}^4$ to approximate each coordinate direction,

$$\cos\left(\frac{x_1 - s_1}{2n_1\pi} i\right) \cos\left(\frac{x_2 - s_2}{2n_2\pi} j\right) \cos\left(\frac{x_3 - s_3}{2n_3\pi} k\right) \cos\left(\frac{x_4 - s_4}{2n_4\pi} l\right)$$

Approximation in Cosine Basis



Kalman Filtered Outputs



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