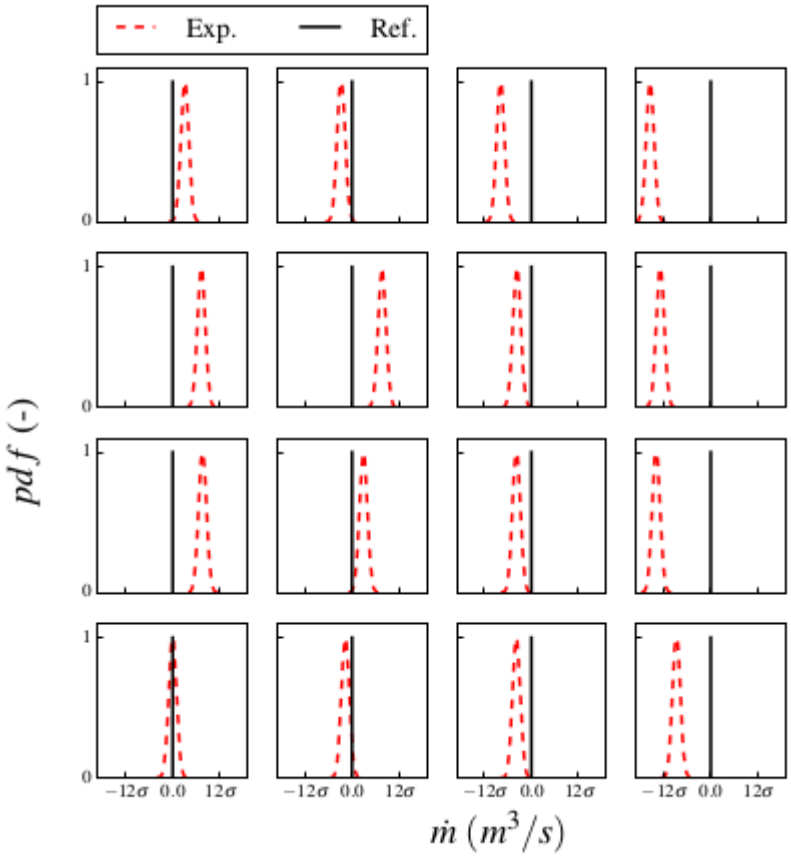
Bayesian calibration of ultrasonic flow meters for industrial applications

Ultrasonic transit-time flow meters are instruments used to measure flow rates in a variety of industrial applications, from pipes to stacks. They are able to measure the flow speed by computing the transit time of an impulse traveling between two sensors. These instruments are able to measure the flow rate with a very small error.

However, if the flow in the pipe undergoes some sort of disturbance, its velocity profile will be disturbed as well thus causing the flow meter to have larger errors. The uncertainty due to repeatability associated with the flow meter measurements is, nonetheless, very small and most of the time the instrument is not able to capture the true value of the flow rate as shown in the figure below.



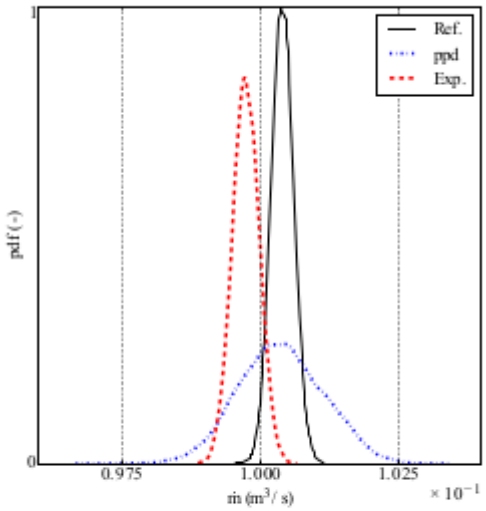
This causes the instrument to provide misleading values of the uncertainty associated with its measurements and, in combination with larger errors due to flow disturbances, can severely impair the flow meter performance.

TU Delft applied Bayesian techniques to this problem in order to overcome this problem and provide a realistic estimate of the uncertainty associated with ultrasonic flow meter measurements.
Bayesian techniques are slowly finding their way in the metrology community and provide a way to update an a-priory estimate of the uncertainty about a certain quantity of interest once more data becomes available.

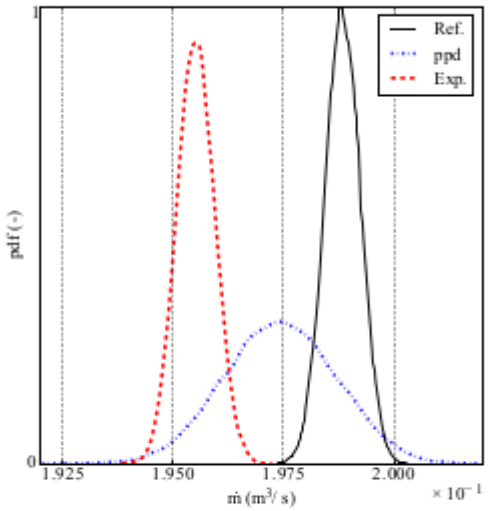
The two fundamental ingredients to Bayesian calibration are the availability of data and of a statistical model. In this project, the data are acquired through an experiment in collaboration with the Dutch Metrology Institute (VSL), while the model is a combination of Computational Fluid Dynamics (CFD) and some post-processing techniques allowing to reproduce the behaviour of an ultrasonic flow meter.

By combining the acquired data and the model with the use of Bayes theorem, it is possible to come up with an updated estimate of the uncertainty associated with ultrasonic flow meter measurements as well as an updated estimate of the error.

Below is an example of the outcome of this method for two different flow condtions.



(a) Comparison of posterior on flow rate with flow meter measurement for $x/D = 4.0$, $Re_b = 5.3 \cdot 10^4$ and $\alpha = 0\pi$.



(b) Comparison of posterior on flow rate with flow meter measurement for $x/D = 4.0$, $Re_b = 1.05 \cdot 10^5$ and $\alpha = 0\pi$.

This methodology can be used to improve current calibration techniques or in place of standard calibration techniques in order to have a more realistic estimate of the uncertainty associated with ultrasonic flow meter measurements.