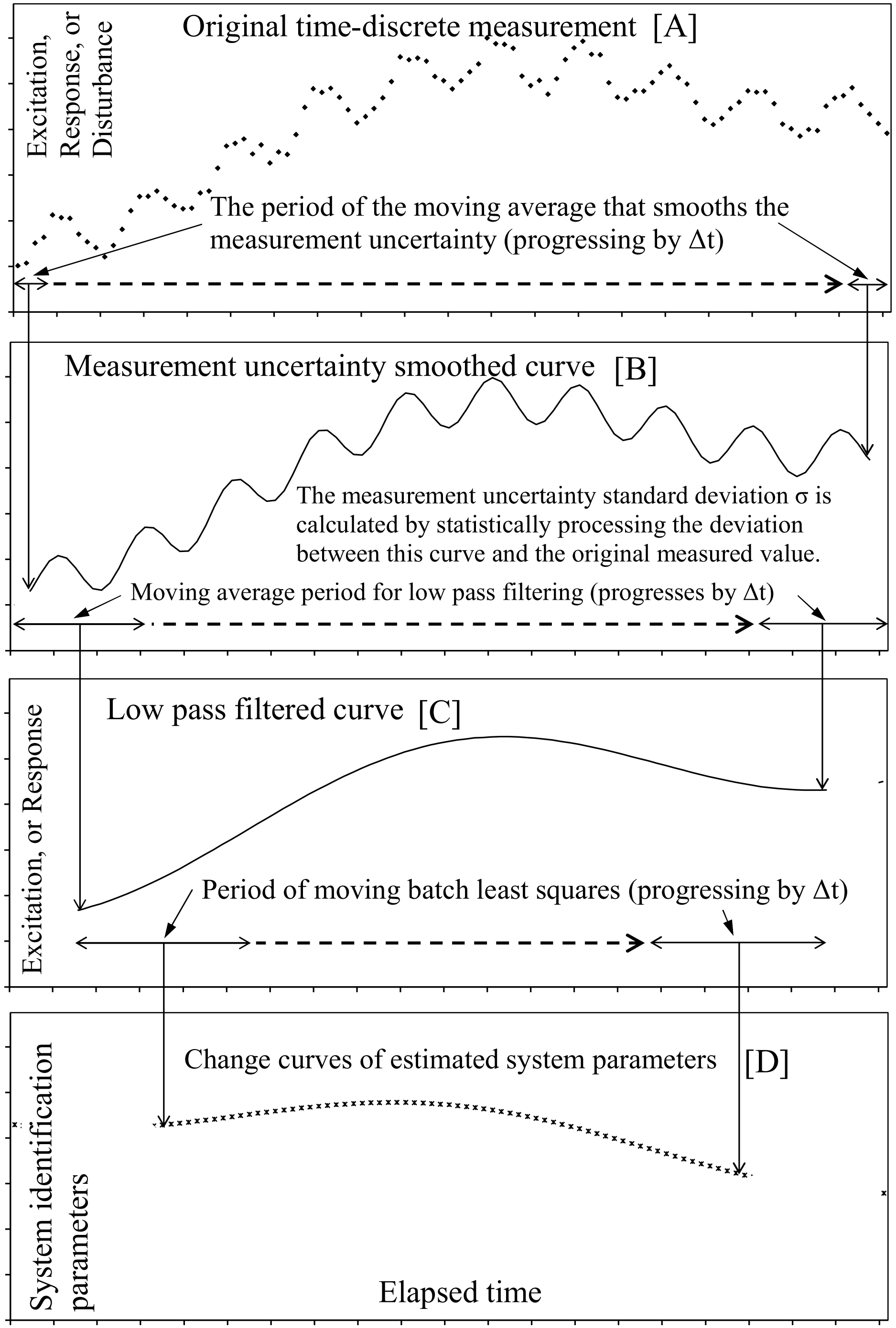
Moving Least Squares Method, Low-pass Filter, and Measurement Uncertainty Smoothing Curve



(Above diagrams from Reference 112)

For ventilation measurements in multi-zone building systems, a formula was derived based on the least squares method to estimate the average inter-zone airflow rates over the measurement period. This formula was then transformed using Woodbury's matrix inversion lemma to derive a recurrence formula to successively estimate the airflow rate etc. for each time step Δt.(Reference 13,26,99)

However, the recursive least squares did not produce reasonable results.(Ref.17) On the other hand, applying least squares to a period of a few hours that was a part of a measurement period of several days, and shifting this period by Δt was successful.(Ref.35)

For example, the dotted curve [A] represents gas concentration measured at one-minute intervals. A moving average over several minutes is applied to the data [A] to obtain curve [B], which smooths the measurement uncertainty. The deviation of the data [A] from curve [B] is statistically processed over the entire measurement period to obtain the measurement uncertainty standard deviation σ. (Ref.111)

All measured data are low-frequency filtered by a moving average to obtain the curve [C]. The moving average period is several minutes for ventilation measurements and about 8 hours for heat transfer measurements. If rectangular heating is used, a double moving average is also applied. (Ref.139)

Then, the moving least squares method is applied. The length of this period is the time it takes for gas generation in each zone to cycle through all zones. For example, the obtained ventilation flow rate change curve is shown as [D].

In addition, the necessary magnitude of excitation (Ref.141) and the optimal damping period (Ref.98) were also studied.