



POLITECNICO
MILANO 1863

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POLITECNICO DI MILANO

RAM&PHM 4.0: Advanced methods for Reliability, Availability, Maintainability, Prognostics and Health Management of industrial equipment

Particle Filtering - exercise session

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Problem 1: estimation of the component degradation state

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Consider a degrading component. The equation describing the time evolution of its degradation indicator, $x(t)$, is:

$$x(t+1) = 0.01x^2(t) + x(t) + 0.001 + \omega(t)$$
$$\omega(t) \sim N(\mu_\omega = 0, \sigma_\omega = 0.001)$$

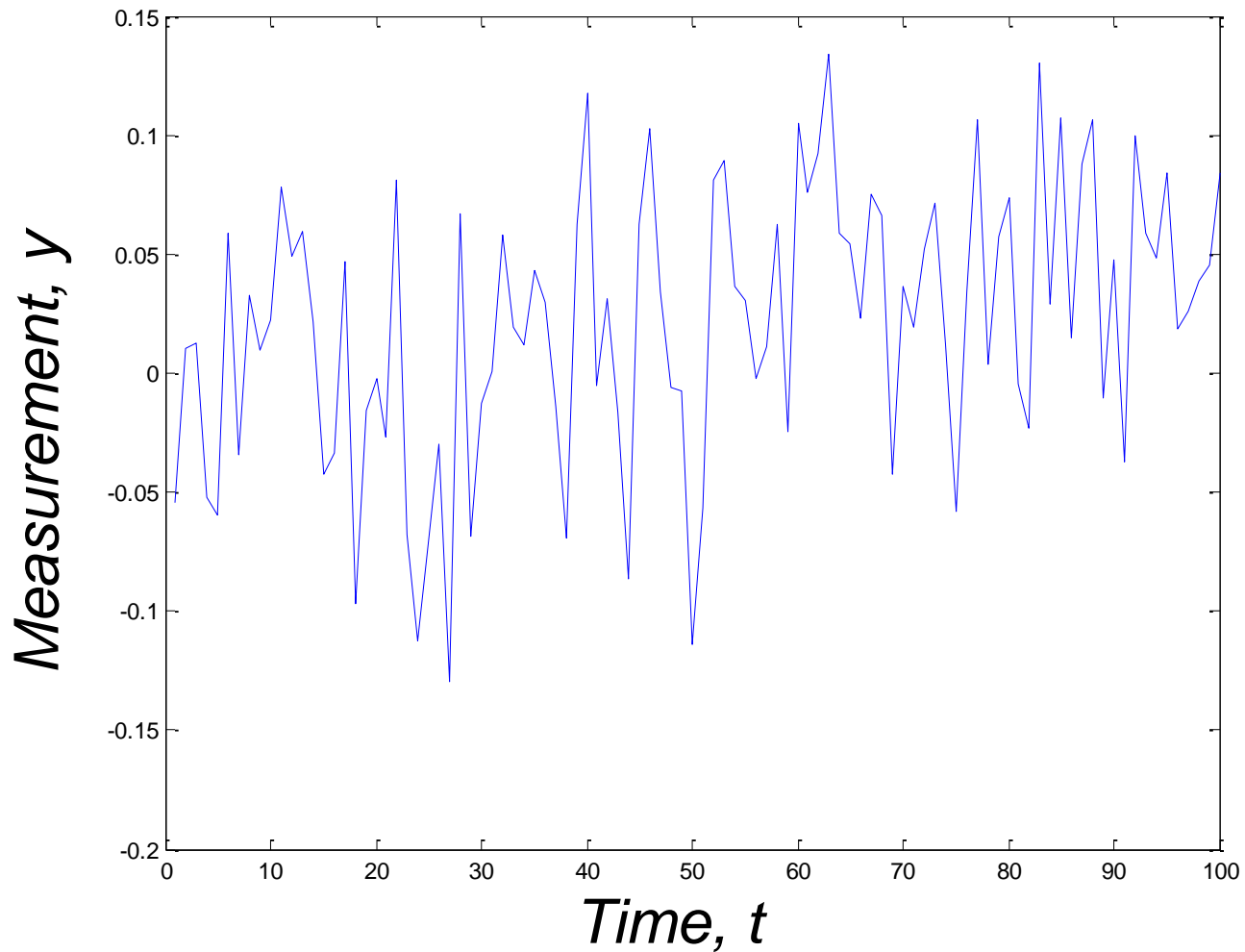
A measurement, y , of the component degradation is obtained through a sensor at time interval $\Delta t = 1$, from time 2. The measurement equation is:

$$y(t) = x(t) + v(t)$$
$$v(t) \sim N(\mu_v = 0, \sigma_v = 0.05)$$

File '**y2_y101.dat**' contains the degradation measurement $y(2), y(3), \dots, y(101)$ collected until the present time $k=101$

You are required to:

- 1) Estimate the probability density function, $p(x(101)|Z(2:101))$ describing the component degradation state at time $k = 101$, its mean value, standard deviation, and the 5 and 95 percentiles of the degradation states. Assume that at time $t=1$ the initial distribution of the degradation state is given by an uniform distribution with range $[0,0.005]$

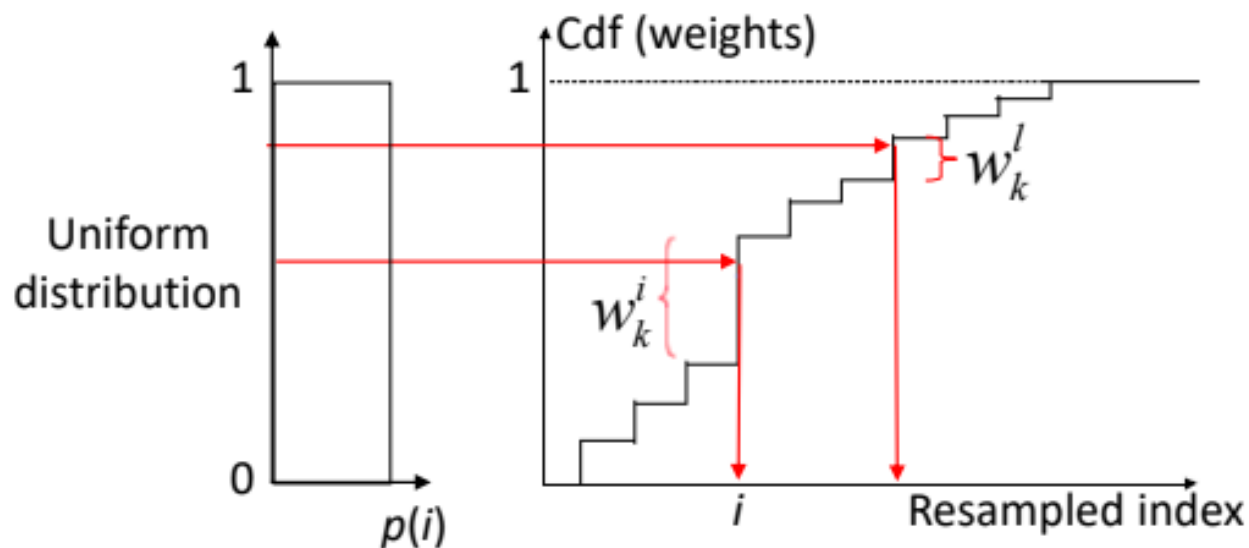


Resampling

- Reduce number of samples with low weights and increase number of samples with large weights (without changing the probability distribution)
- Set of unequally weighted samples \rightarrow set of equally weighted particles

$$\{x_k^i, w_k^i\}_{i=1}^{N_s} \rightarrow \{x_k^{j*}, 1/N_s\}_{j=1}^{N_s}$$

BOOTSTRAP RESAMPLING WITH REPLACEMENT



$$p(x_k^{j*} = x_k^i) = w_k^i$$

Consider the same component in Problem 1. The component fails when its degradation indicator, $x(t)$, exceeds the failure threshold, $x^{th} = 1$.

File '**y2_y40.dat**' contains the degradation measurements $y(2), \dots, y(40)$ collected until the present time $k = 40$.

You are required to:

- a) Estimate the mean value and the standard deviation of the probability density function, $p(RUL_{40})$ describing the component RUL at the present time $k = 40$
- b) Repeat a), assuming that the present time is $k = 401$ and the measurements in file '**y2_y401.dat**' have been collected