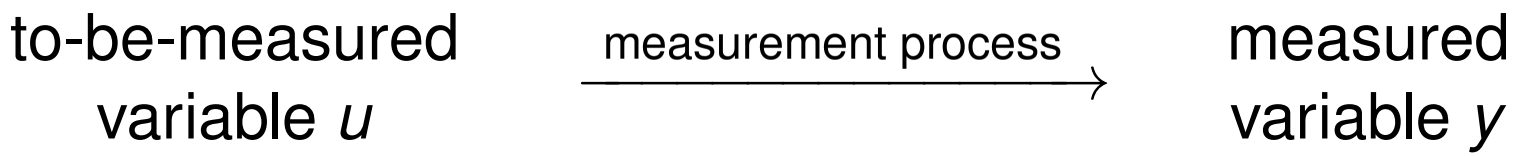
Setup



- the measurement process is a dynamical system
- assumption 1: measured variable is a constant $u(t) = \bar{u}$
  (can be relaxed to "u's change is slower than y's change")
- y is a function of time and depends on both
  - measurement device dynamics and
  - environment dynamics
- assumption 2: measurement process is stable LTI system

Example 1: temperature measurement

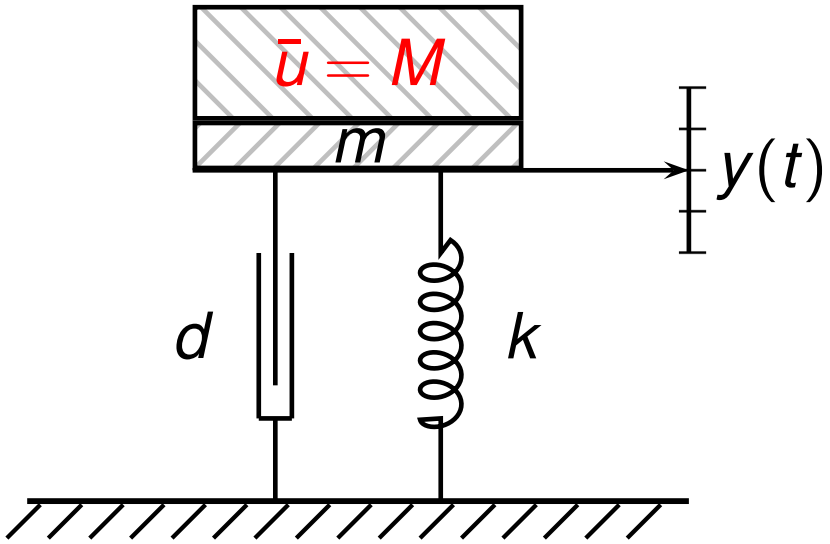
environmental temperature $\bar{u}$ —environment–thermometer heat transfer→ thermometer's reading y

- measurement process: Newton's law of cooling

$$\frac{\mathrm{d}}{\mathrm{d}t}y = a(\bar{u} - y)$$

- the heat transfer coefficient $a > 0$
  depends on thermometer and environment
- first order stable LTI system
- dc-gain of measurement process is 1 (independent of a)

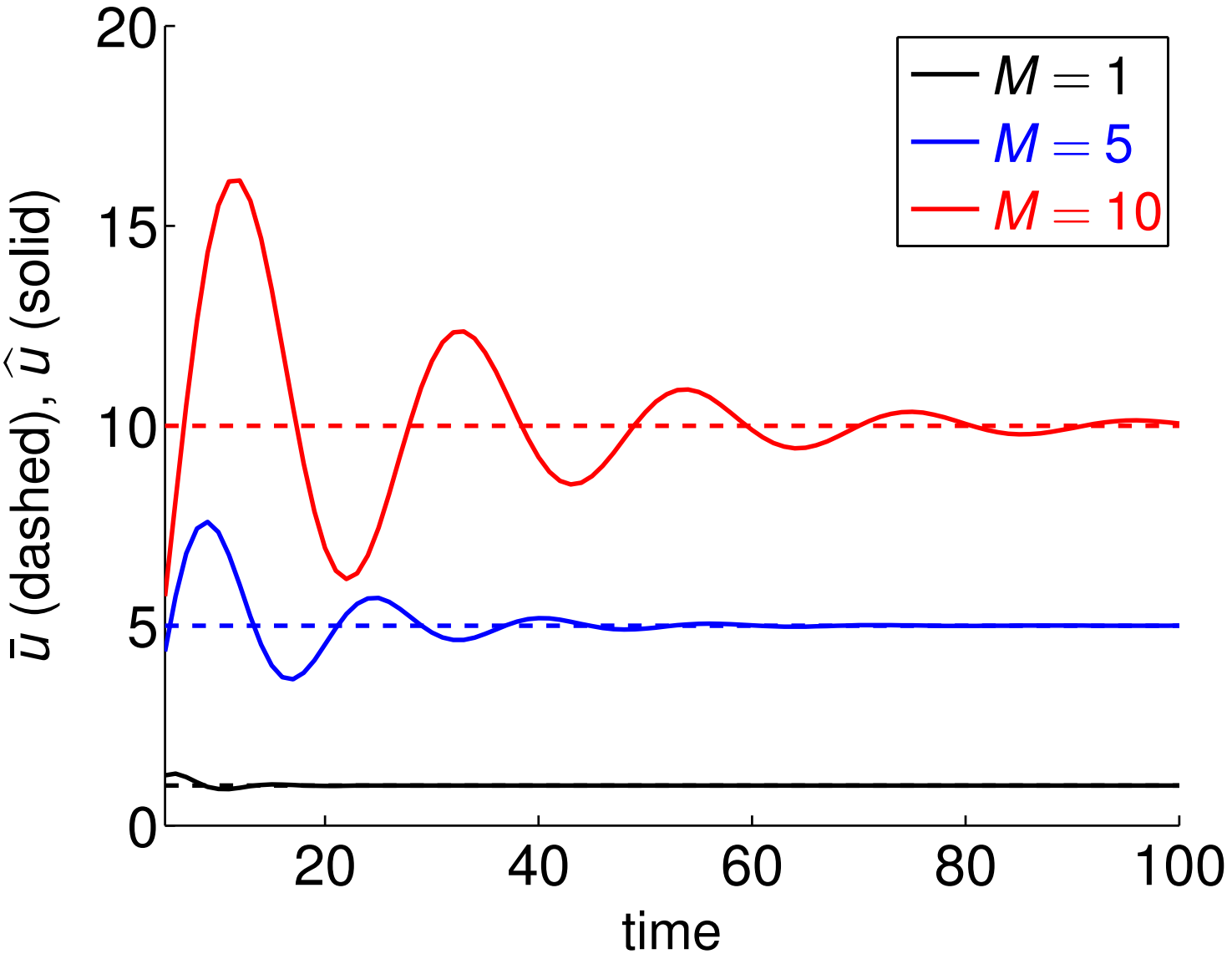
Example 2: weight measurement



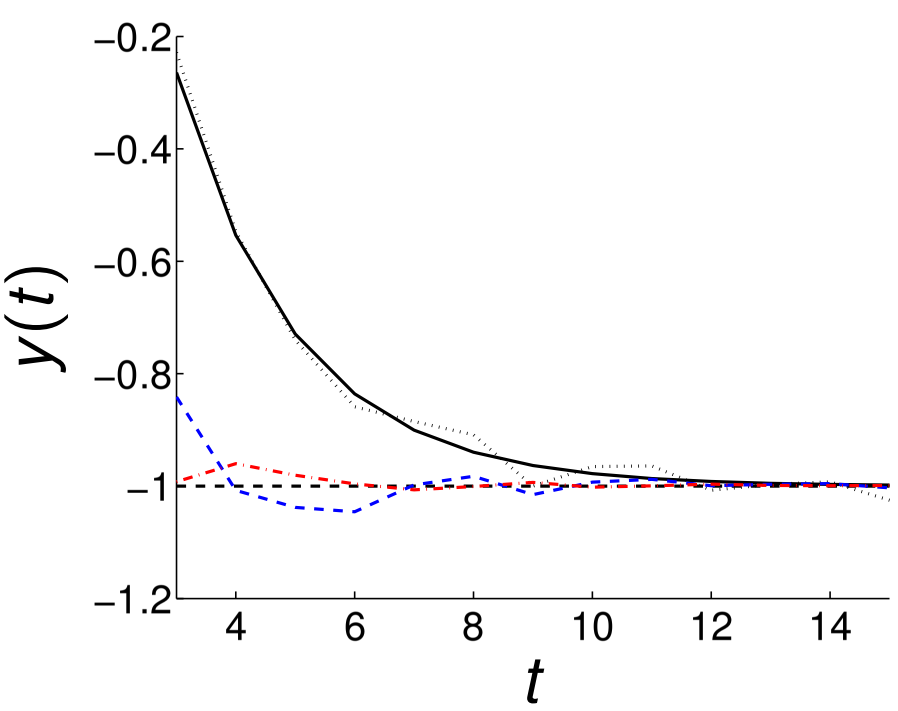
- measurement process

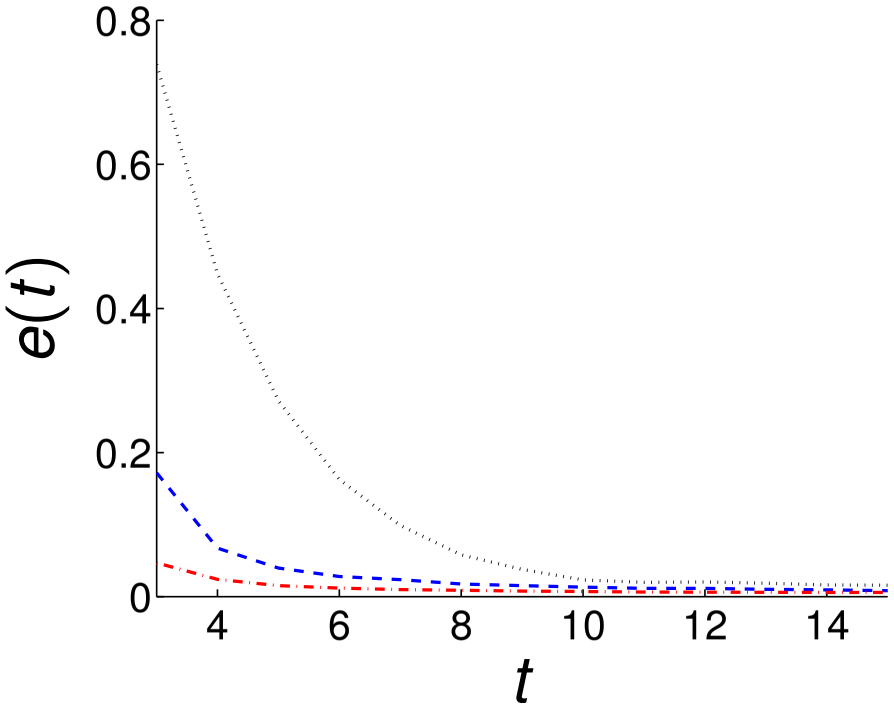
$$(M+m)\frac{\mathrm{d}^2}{\mathrm{d}t^2}y + d\frac{\mathrm{d}}{\mathrm{d}t}y + ky = g\bar{u}$$

- the measurement process dynamics depends on M
- the dc-gain is $-g/k$ (independent of M)


20
15
10
5
0
20
40
60
80
100
time
$\bar{u}$ (dashed), $\hat{u}$ (solid)
$M = 1$
$M = 5$
$M = 10$

Dynamic cooling $a = 0.5$, $x_{\text{ini}} = 1$, $\sigma = 0.02$

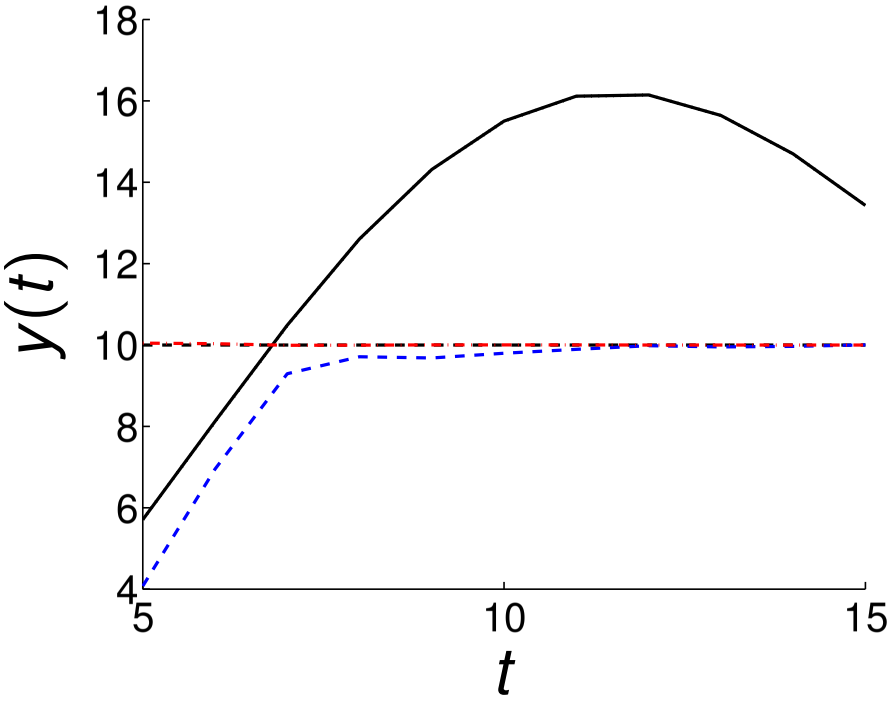


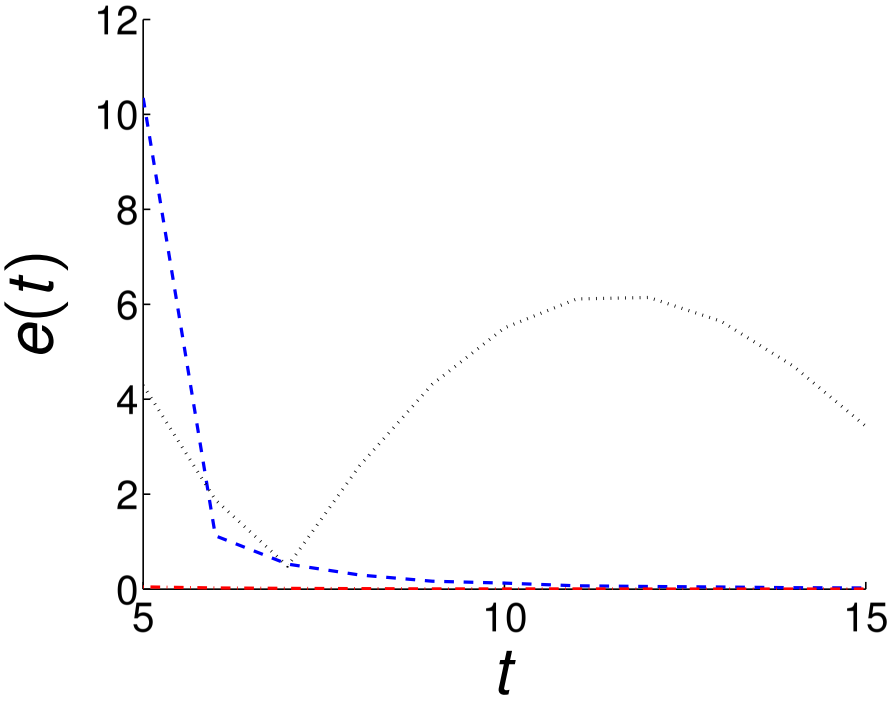


noisy data $\Longrightarrow$ $e(t) \to 0$ as $t \to \infty$ (at different rates!)

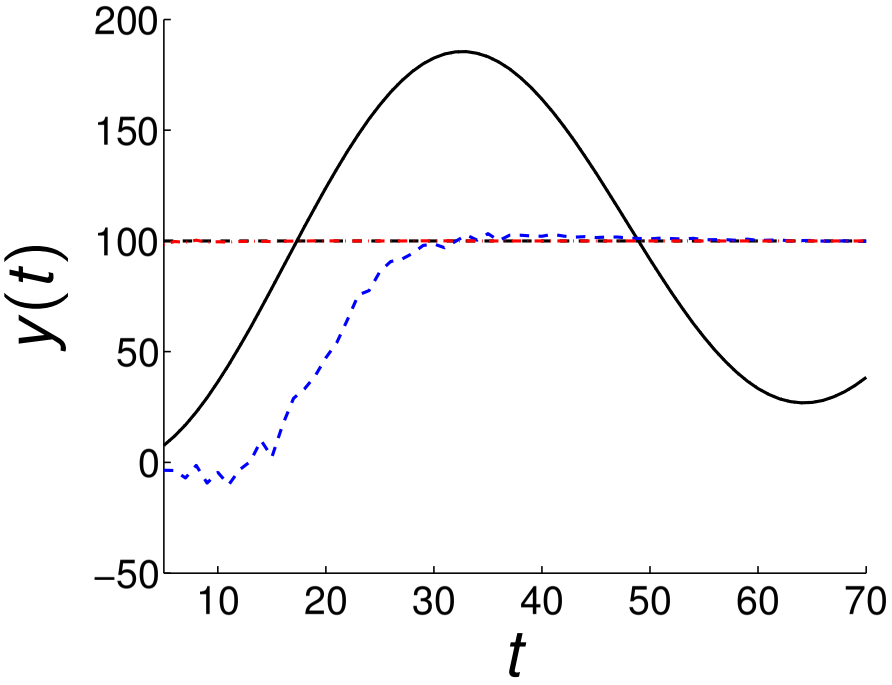
note: Kalman filter is maximum likelihood estimator in this setup

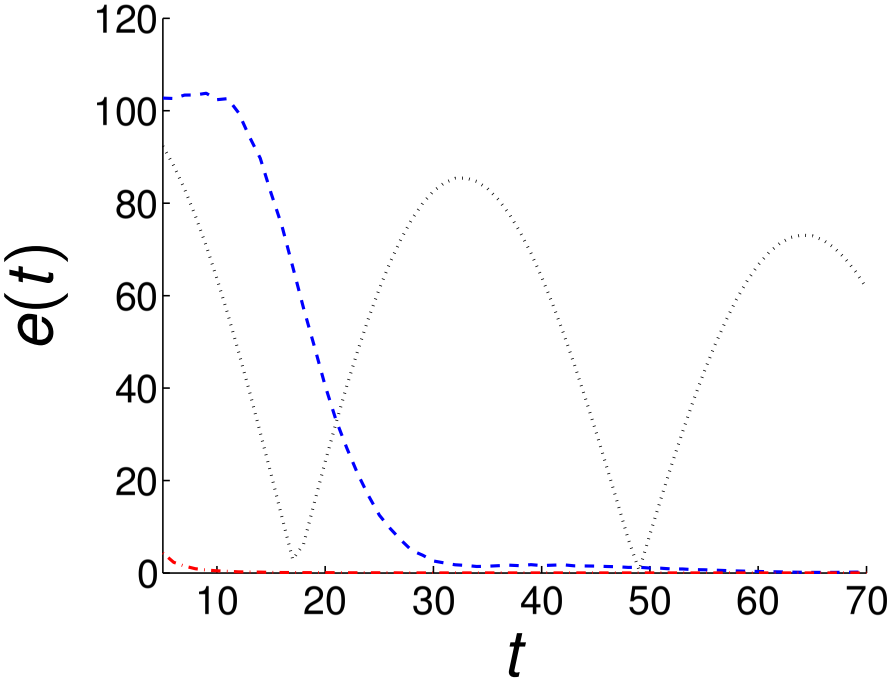
Dynamic weighing $M = 10$





Dynamic weighing $M = 100$





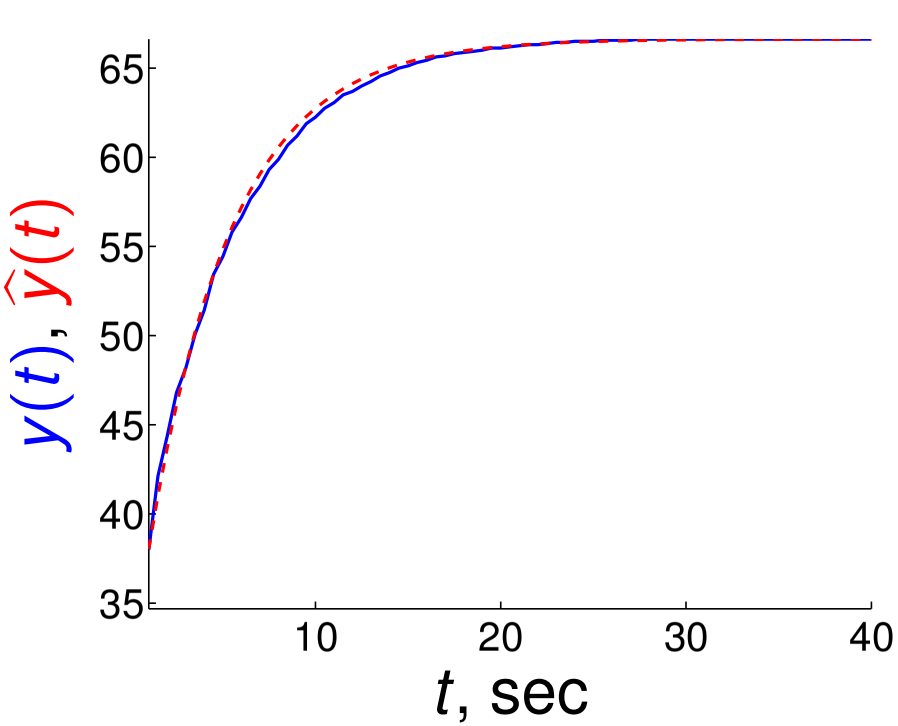
Experiment with Lego NXT Mindstorms

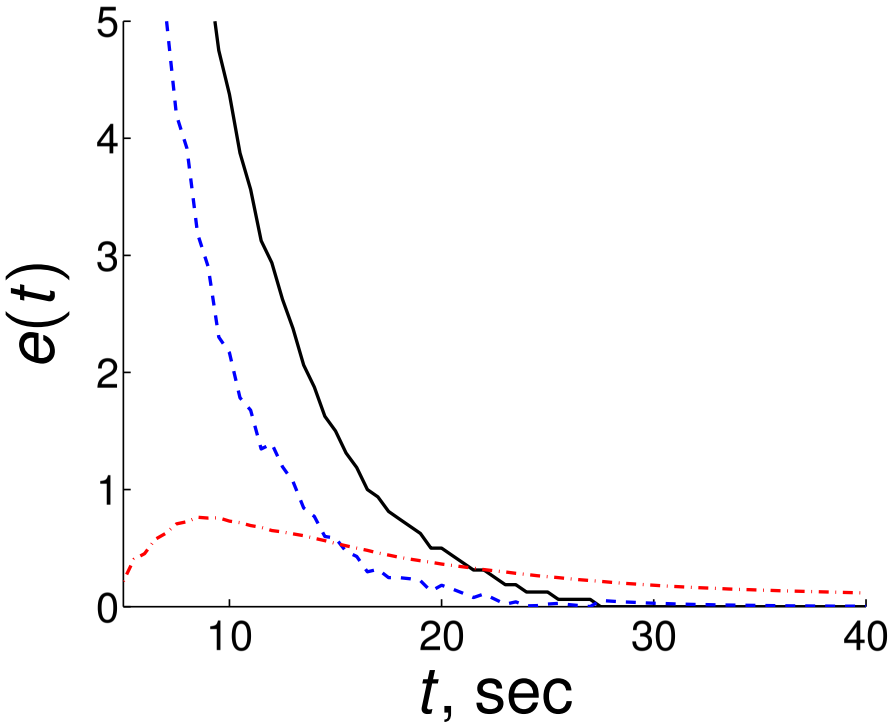
Results with real-life data

model for the KF is fitted using all measurements

$t_s = 0.5$ sec, $\bar{y} = \bar{u} := y(40)$

$f = 0.9$





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