SYDE 556/750

Simulating Neurobiological Systems
Lecture 4: Temporal Representations

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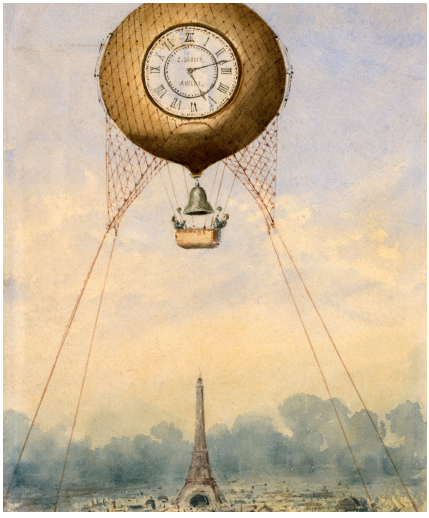
January 22 & 28, 2020



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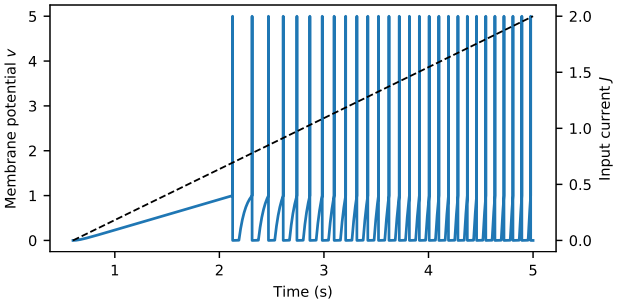
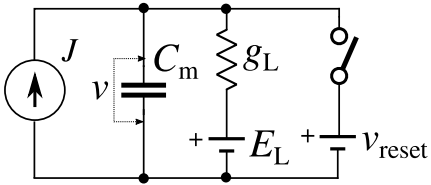
Reminder: The LIF Neuron



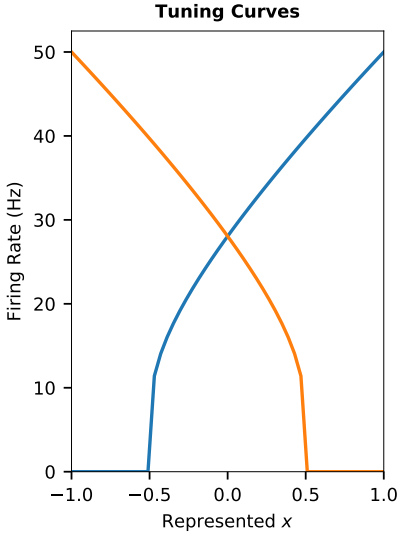


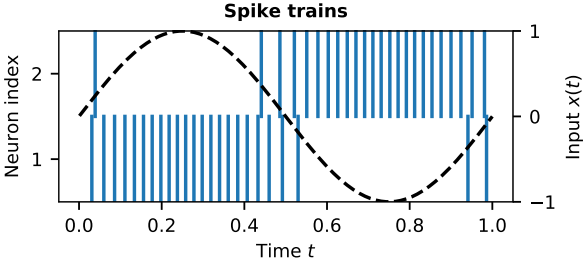
$$\frac{\mathrm{d}}{\mathrm{d}t}v(t) = -\frac{1}{\tau_{\mathrm{RC}}}\big(v(t) - J\big)\,, \qquad \text{if } v(t) < 1\,,$$

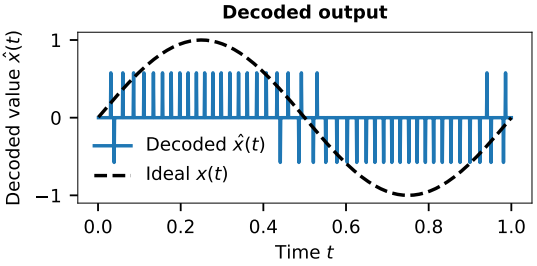
$$v(t) \leftarrow \delta(t - t_{\mathrm{th}})\,, \qquad \text{if } t = t_{\mathrm{th}}\,,$$

$$v(t) \leftarrow 0\,, \qquad \text{if } t > t_{\mathrm{th}} \text{ and } t \geq t_{\mathrm{th}} + \tau_{\mathrm{ref}}\,,$$

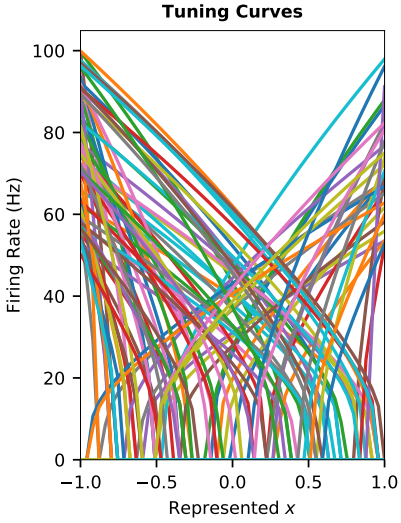
Temporal Decoding of Two Neurons

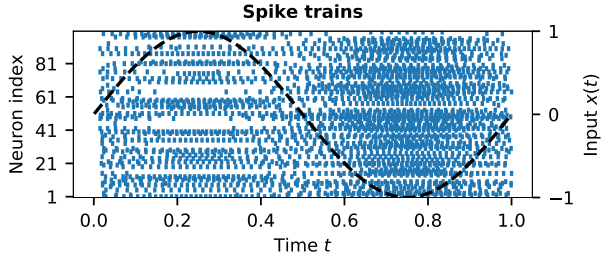


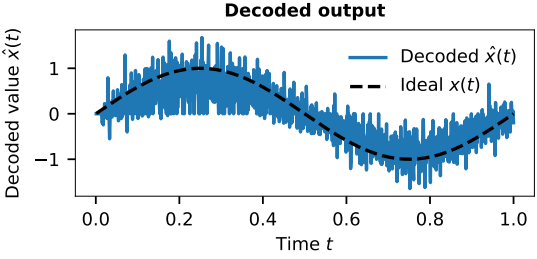




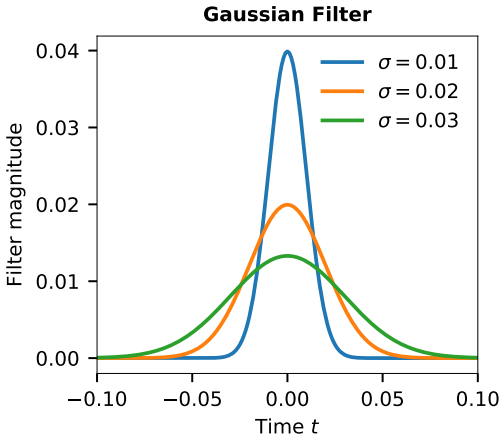
Temporal Decoding of One Hundred Neurons







Filtering by Convolution



Gaussian Filter

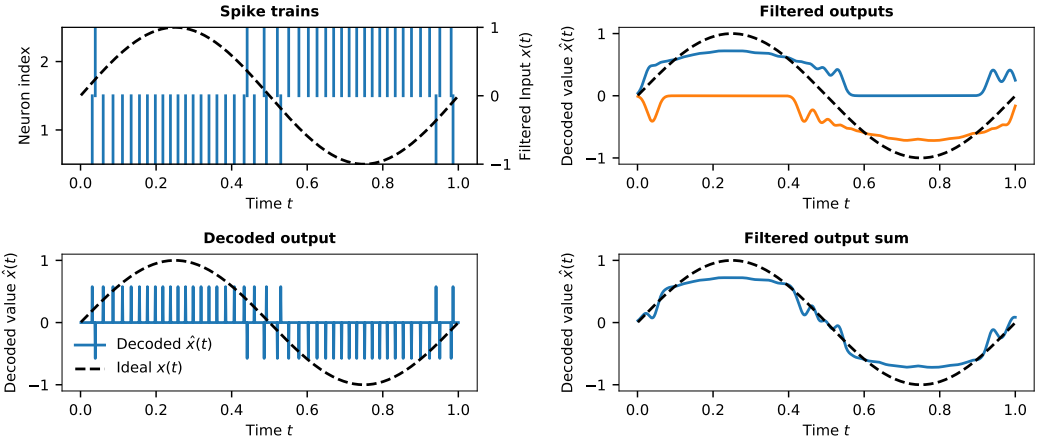
$$h(t) = c \exp\left(\frac{-t^2}{\sigma^2}\right)$$

where c chosen s.t. $\int_{-\infty}^{\infty} h(t)\,\mathrm{d}t = 1$

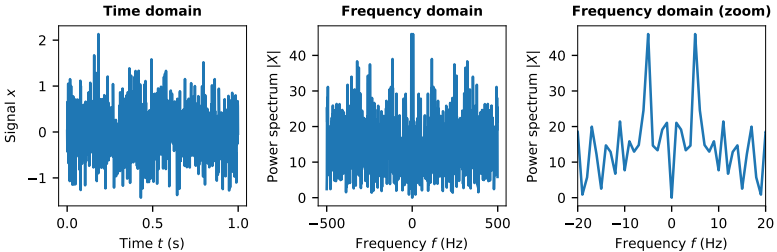
Convolution

$$\big(f * g\big)(t) = \int_{-\infty}^{\infty} f(t-\tau)g(\tau)\,\mathrm{d}t'$$

Filtering a Spike Train

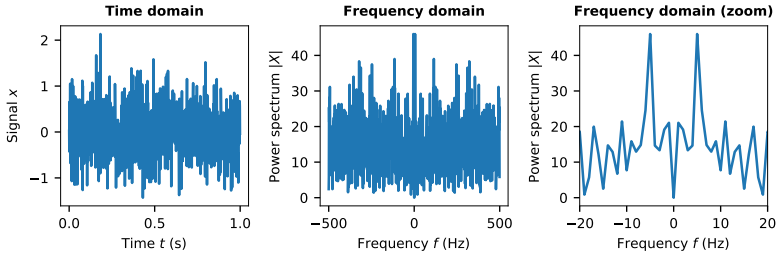


Random Signals

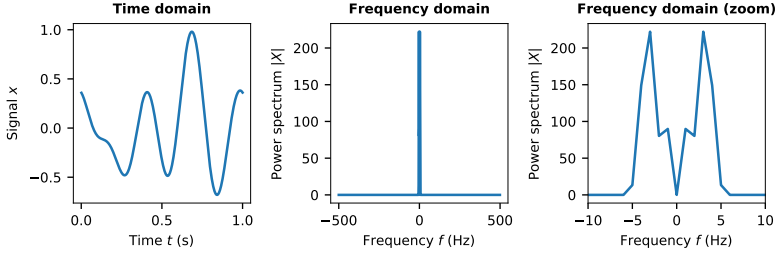


White Noise
(zero mean)

Random Signals

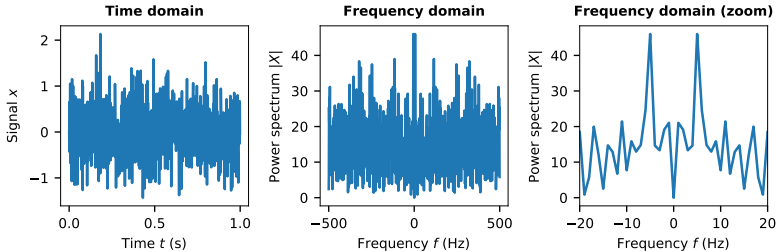


White Noise
(zero mean)

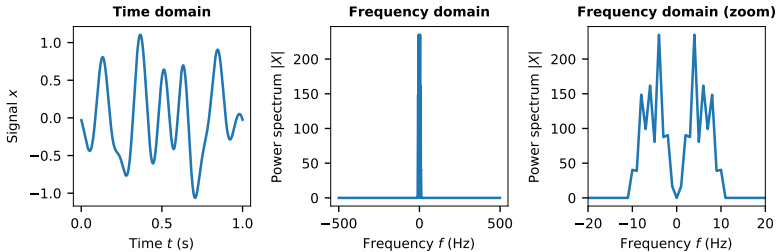


Bandlimited
White Noise
(zero mean,
5 Hz bandwidth)

Random Signals

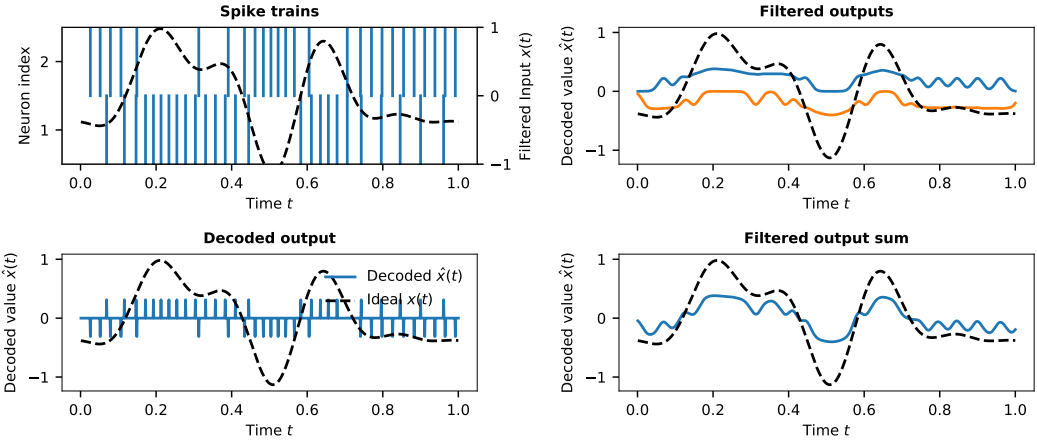


White Noise
(zero mean)

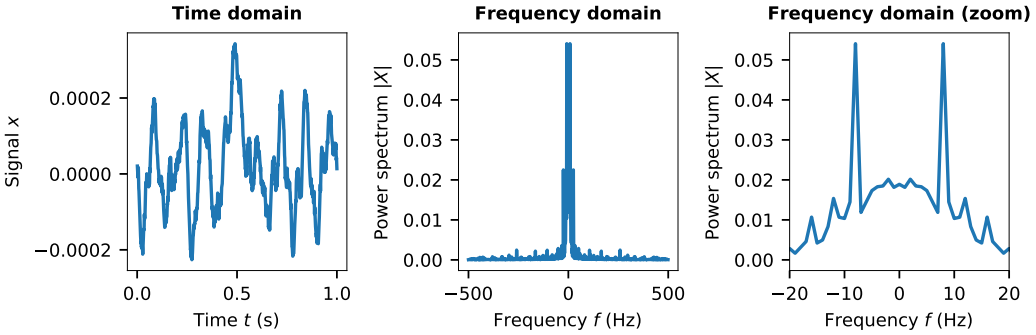


Bandlimited
White Noise
(zero mean,
10 Hz bandwidth)

Filtering a Spike Train for a Random Signal

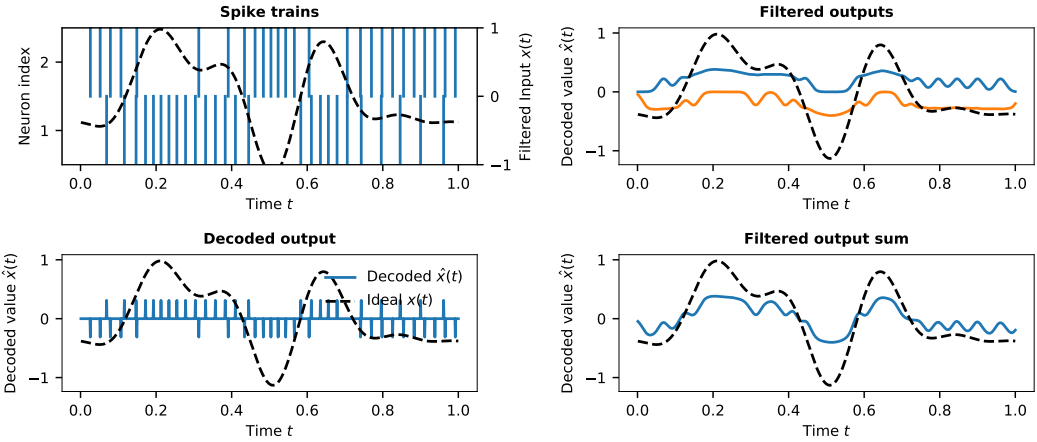


Optimal Filter

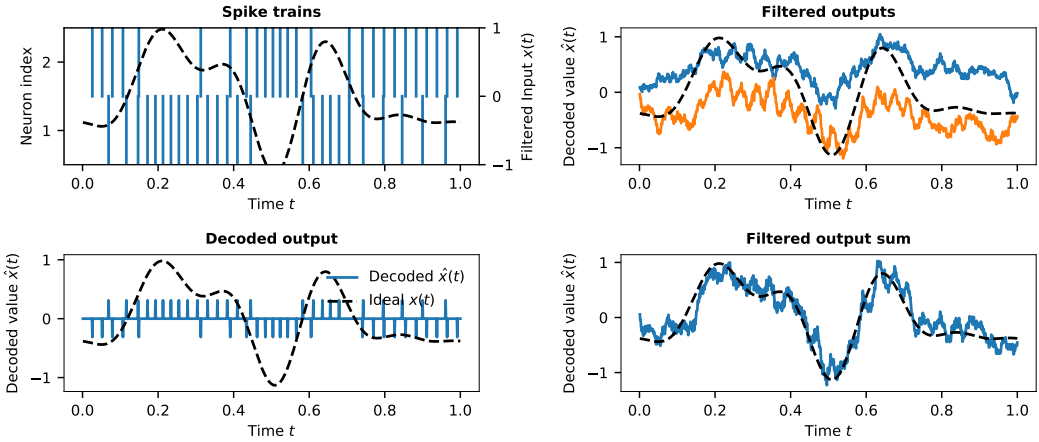


$$H(\omega) = \frac{X(\omega)\overline{R}(\omega)}{|R(\omega)|^2}$$

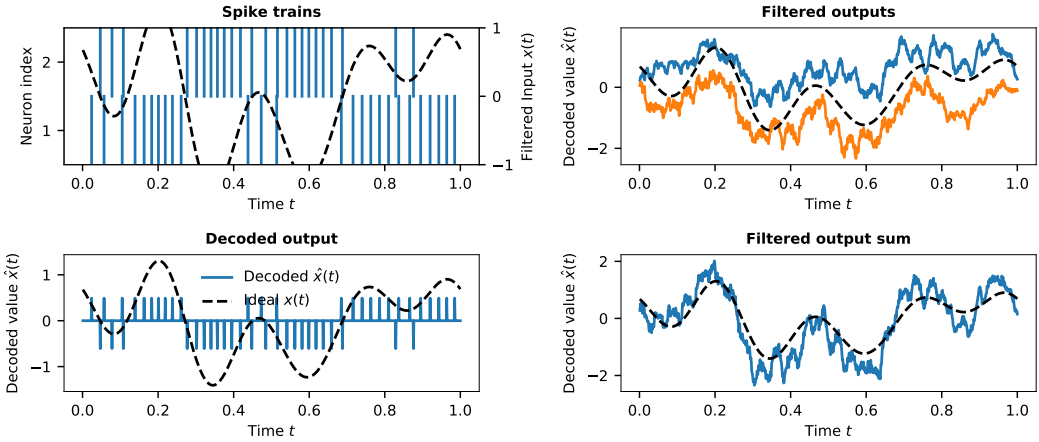
Filtering a Spike Train for a Random Signal (Optimal Filter)



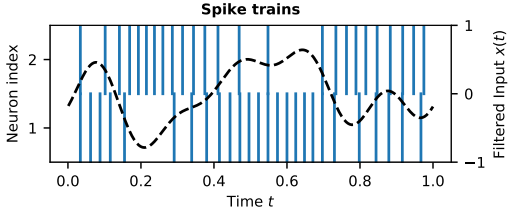
Filtering a Spike Train for a Random Signal (Optimal Filter)

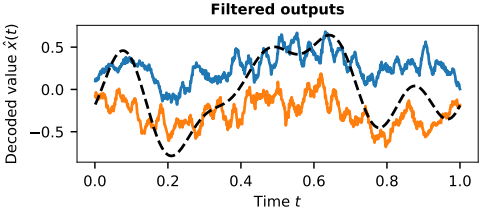


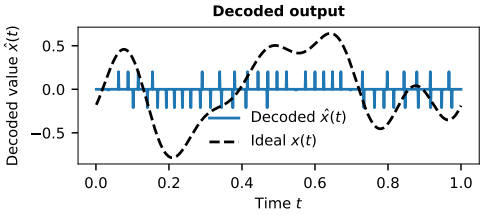
Filtering a Spike Train for a Random Signal (Optimal Filter)

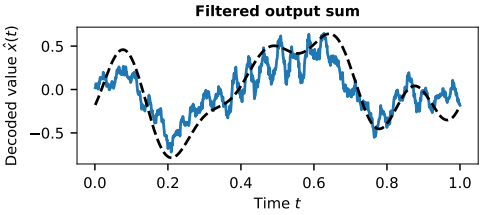


Filtering a Spike Train for a Random Signal (Optimal Filter)

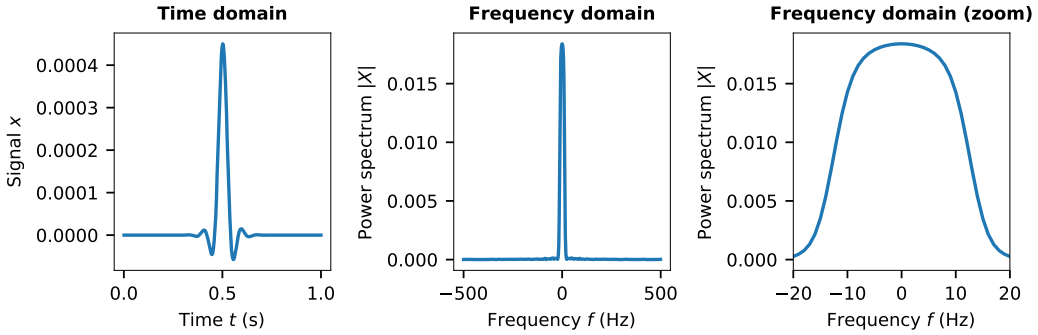






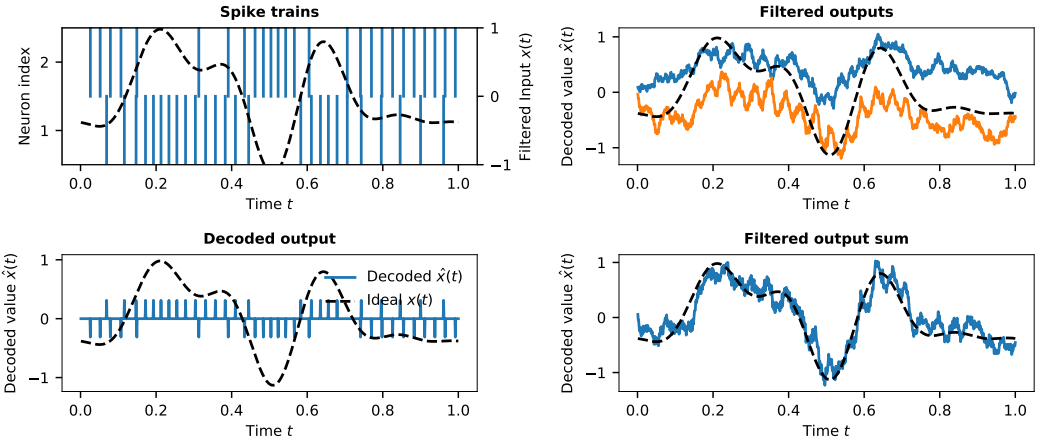


Optimal Filter (Improved)

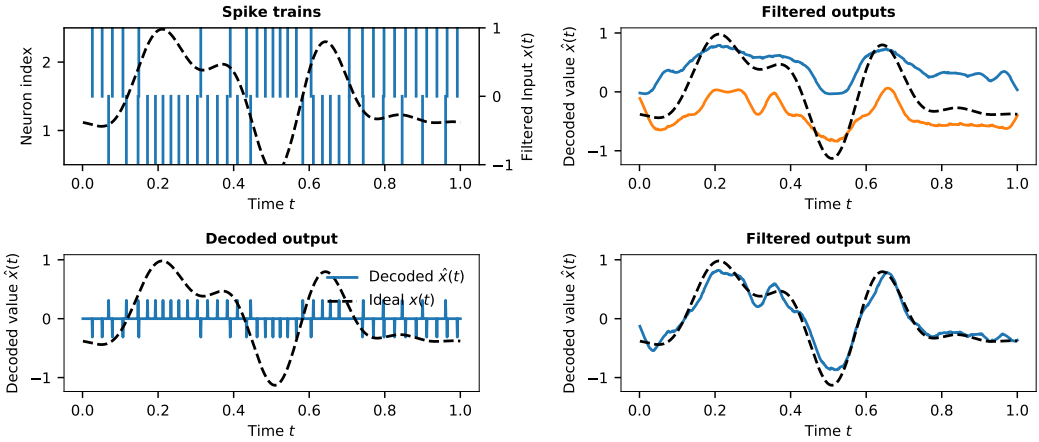


$$H(\omega) = \frac{X(\omega)\overline{R}(\omega) * W(\omega)}{|R(\omega)|^2 * W(\omega)}$$

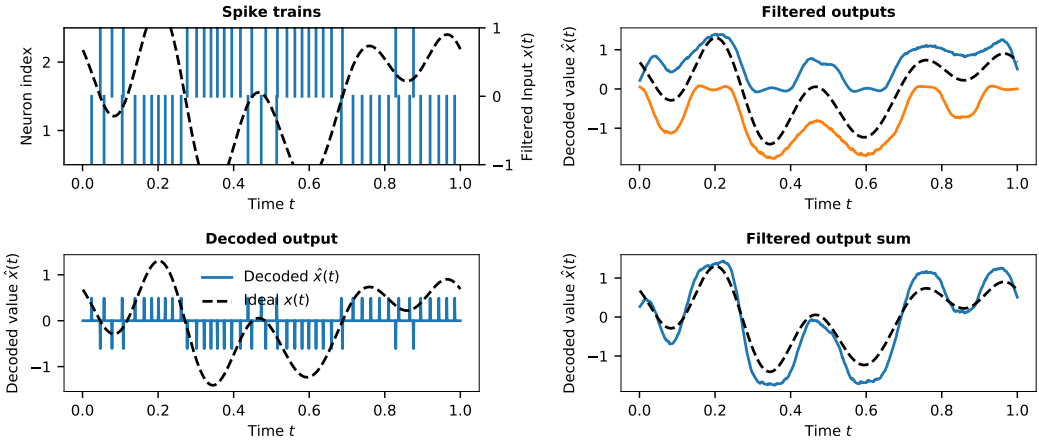
Filtering a Spike Train for a Random Signal (Improved Optimal Filter)



Filtering a Spike Train for a Random Signal (Improved Optimal Filter)



Filtering a Spike Train for a Random Signal (Improved Optimal Filter)



Filtering a Spike Train for a Random Signal (Improved Optimal Filter)

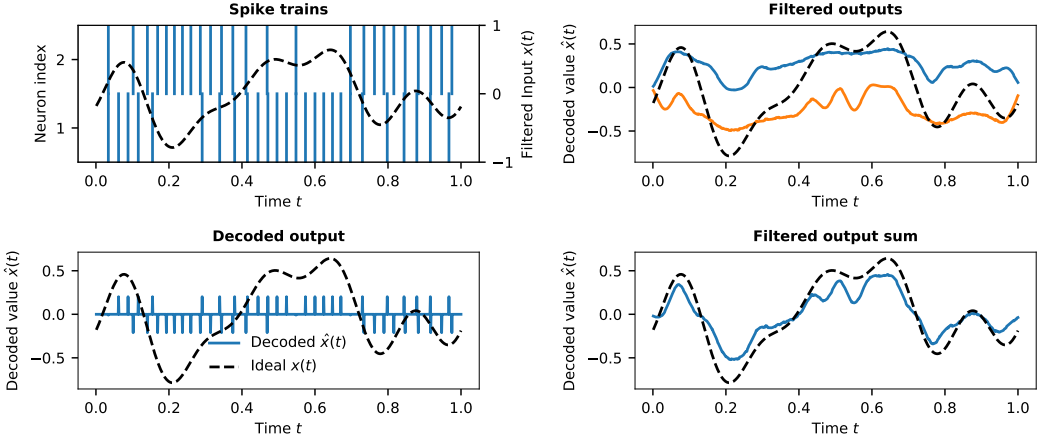


Image sources

Title slide
"Captive balloon with clock face and bell, floating above the Eiffel Tower, Paris, France."
Author: Camille Grávis, between 1889 and 1900.
From Wikimedia.