A Population Firing Rate Model of Reverberatory Activity in Neuronal Networks

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Abstract
Synaptic activity based on neurotransmitters has been thoroughly described by mathematical models. Most of the existing models, however, disregard asynchronous synaptic transmission, another type of synaptic signal. Asynchronous synaptic transmission has been shown to elevate frequency adaptation of the cell slightly, and take a much longer time to return to resting state than the regular neurotransmitter signal. In this presentation, we will discuss our results in 1) creating firing rate models of neuronal networks incorporating asynchronous synaptic transmission as well as spike frequency adaptation or synaptic depression 2) creating network models with all neurons affecting each other based on the firing rate models 3) analyzing all models. These results emphasize the impact of asynchronous synaptic transmission on neural activity.

Methods

- Equations for population model with spike frequency adaptation

\[
F(x) = \frac{x}{1 - e^{-\alpha}}
\]

\[
\mu(t) = \frac{\mu(t-\Delta t) \mu(t)}{\mu(t) + \mu(t-\Delta t)}
\]

- Coupling terms for both network models

\[
\eta(t) = \frac{\int_{t}^{t+\Delta t} \eta(t) dt}{\Delta t}
\]

- Equations for population model with synaptic depression

\[
F(x) = \frac{x}{1 - e^{-\alpha}}
\]

\[
\mu(t) = \frac{\mu(t-\Delta t) \mu(t)}{\mu(t) + \mu(t-\Delta t)}
\]

- Network adaptation of the spike frequency adaptation model

\[
F(x) = \frac{x}{1 - e^{-\alpha}}
\]

\[
\mu(t) = \frac{\mu(t-\Delta t) \mu(t)}{\mu(t) + \mu(t-\Delta t)}
\]

- Network adaptation of the synaptic depression model

\[
F(x) = \frac{x}{1 - e^{-\alpha}}
\]

\[
\mu(t) = \frac{\mu(t-\Delta t) \mu(t)}{\mu(t) + \mu(t-\Delta t)}
\]

Conclusions

- Neural activity incorporating fast synaptic activity, slow synaptic activity, spike frequency adaptation and synaptic depression can be modeled with population firing rate models
- These models are accurate and robust
- Network models simulate the activity of multiple systems incorporating these factors

Future Work

- Expand on current models by incorporating other kinds of neural activity
- Expand in network models by making them larger, and coupling several networks together

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References