Figures and figure supplements

Visualization of currents in neural models with similar behavior and different conductance densities

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Figure 1. Landscape optimization can be used to find models with specific sets of features. (A) Example model bursting neuron. The activity is described by the burst frequency and the burst duration in units of the period (duty cycle). The spikes detection threshold (red line) is used to determine the spike times. The ISI threshold (cyan) is used to determine which spikes are bursts starts (bs) and bursts ends (be). The slow wave threshold (blue line) is used to ensure that slow wave activity is separated from spiking activity. (B) Example model spiking neuron. We use thresholds as before to measure the frequency and the duty cycle of the cell. The additional slow wave thresholds (purple) are used to control the waveform during spike repolarization.

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Figure 2. Currentscape of a model bursting neuron. A simple visualization of the dynamics of ionic currents in conductance-based model neurons. (A) Membrane potential of a periodic burster. (B) Percent contribution of each current type to the total inward and outward currents displayed as pie charts and bars at times $T_1$ and $T_2$. (C) Percent contribution of each current to the total outward and inward currents at each time stamp. The black filled curves on the top and bottom indicate total inward outward currents respectively on a logarithmic scale. The color curves show the time evolution of each current as a percentage of the total current at that time. For example, at $t = T_1$ the total outward current is $\approx 2.5 \text{nA}$ and the orange shows a large contribution of $KCa$. At $t = T_2$ the total outward current has increased to $\approx 4 \text{nA}$ and the $KCa$ current is contributing less to the total.

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Figure 3. Membrane potential $V$ distributions. (A) Distribution of membrane potential $V$ values. The total number of samples is $N = 2.2 \times 10^6$. Y-axis scale is logarithmic. The area of the dark shaded region can be used to estimate the probability that the activity is sampled between $-50mV$ and $-40mV$, and the area of the light shaded region is proportional to the probability that $V(t)$ is sampled between $-30mV$ and $20mV$. The area of the dark region is 20 times larger than the light region. (B) The same distribution in (A) represented as a graded bar. (C) Distribution of $V$ as a function of $V$ and $gNa$, and waveforms for several $gNa$ values. The symbols indicate features of the waveforms and their correspondence to the ridges of the distribution of $V$. (D) Waveforms under two conditions and their correspondence to the ridges of the distribution of $V$. The ridges were enhanced by computing the derivative of the distribution along the $V$ direction.

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**Figure 3—figure supplement 1.** Probability distributions of membrane potential. (A) The black trace corresponds to the membrane potential \( V(t) \) during a spike within a burst (total time 5.4 msec). The y-axis is split into four equally sized bins (in colors) that span the full range of \( V \) values.

Figure 3—figure supplement 1 continued on next page
(\min V = -60\text{mV} \text{ and } \max V = 28\text{mV}). \text{ The probability that } V(t) \text{ is observed in a given bin at a random instant is proportional to the total time } V(t) \text{ spends at that bin. This is indicated in colors by the preimage of each bin. (B) The total time spent in each bin can be interpreted as a coarse-grained probability distribution of } V(t). \text{ (C) (top) Membrane potential } V, \text{ more bins and their pre-images. (bottom) Probability distribution of } V. \text{ (D) Idem for 50 bins. Note that the probability distribution of } V(t) \text{ displays sharp peaks for values of } V \text{ where local maxima (or minima) in time occur. This effect is more noticeable as the number of bins is increased.}

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Figure 4. Currentscapes of model bursting neurons. (top) Maximal conductances of all model bursters. (bottom) The panels show the membrane potential of the cell and the percent contribution of each current over two cycles.

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Figure 5. Response to current injections and interspike-intervals (ISI) distributions of model (a). (A) (top) Control traces (no current injected 0nA), regular bursting (0.8nA), irregular bursting 1.95nA. (B) (top) Fast regular bursting (f > 6Hz), quadruplets (3.45nA), doublets (3.75nA) and singlets (4.5nA) (tonic spiking). (C) ISI distributions over a range of injected current.

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Figure 6. ISI distributions of the six model bursting neurons over a range of injected current. The panels show all ISI values of each model burster over a range on injected currents (vertical axis is logarithmic). All bursters transition into tonic spiking regimes for injected currents larger than $5 \text{nA}$ and the details of the transitions are different across models.

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Figure 7. Effects of decreasing maximal conductances: inward currents. The figure shows the membrane potential $V$ of all model cells as the maximal conductance $g_i$ of each current is gradually decreased from 100% to 0%. Each panel shows 11 traces with a duration of 3 s. Dashed lines are placed at 0mV and −50mV. The shading indicates values of maximal conductance for which the activity the models differs the most.

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Figure 8. Effects of decreasing maximal conductances: outward currents. The figure shows the membrane potential $V$ of all model cells as the maximal conductance $g_i$ of each current is gradually decreased from 100% to 0%. Each panel shows 11 traces with a duration of 3 s. Dashed lines are placed at 0mV and −50mV. The shading indicates values of maximal conductance for which the activity the models differs the most.

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Figure 9. Decreasing CaT in model (f). The figure shows the traces and the currentscapes of model (f) as CaT is gradually decreased. Top panels show 1 second of data, center panels show 0.1 seconds and the bottom panels show 2 seconds (see full traces in Figure 8).

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**Figure 10.** Complete removal of one current: inward currents. The figure shows the traces and currentscapes for all bursters when one current is completely removed.

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Figure 11. Complete removal of one current: outward currents. The figure shows the traces and currentscapes for all bursters when one current is completely removed.

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Figure 12. Changes in waveform as currents are gradually removed. Inward currents. The figure shows the ridges of the probability distribution of $V(t)$ as a function of $V$ and each maximal conductance $p(V, g_i)$. The ridges of the probability distributions appear as curves and correspond to values of $V$ where the system spends more time, such as extrema. The panels show how different features of the waveform such as total amplitude, and the amplitude of each spike, change as each current is gradually decreased.

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Figure 13. Changes in waveform as currents are gradually removed. Outward and leak currents. The figure shows the ridges of the probability distribution of $V(t)$ as a function of $V$ and each maximal conductance $\rho(V, g_i)$. See Figure 12.
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Figure 14. Changes in waveform of current shares as one current is gradually decreased. The panels show the probability distribution of the share of each current $C_i(t)$ for model (f) as $CaT$ is decreased (see Figure 14—figure supplement 1).

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Figure 14—figure supplement 1. Probability distributions of currents shares. The Figure shows the relationship between the currentscapes and the distributions of current shares. (A) Distribution of A current share to the total outward current for 1001 values of gCaT between 0% and 100%. (B) Share...
of A current as a time series. The A current contributes with more than 50% of the outward current for most of the time. At 70%gCaT the cell spikes tonically and the A contributes 50% of the outward current most of the time. The symbols indicate features in the waveform that are mapped to ridges in the distribution. (C) Currentscapes. (D) Idem (B) but for KCa. Notice the share of KCa decreasing as gCaT → 0. (E) Distribution of KCa current share to the total outward current for 1001 values of gCaT between 0% and 100%.

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**Figure 15.** Changes in waveform of current shares as each current is gradually decreased. The panels show the probability distribution of the share of each current $C_i(t)$ for model (c) as each current is decreased.

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