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CS 489/689 Course Notes

Advanced Topics in CS (Neural Networks)

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Last Revision: January 8, 2019

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Abstract

These notes are intended as a resource for myself; past, present, or future students of this course, and anyone interested in the material. The goal is to provide an end-to-end resource that covers all material discussed in the course displayed in an organized manner. These notes are my interpretation and transcription of the content covered in lectures. The instructor has not verified or confirmed the accuracy of these notes, and any discrepancies, misunderstandings, typos, etc. as these notes relate to course's content is not the responsibility of the instructor. If you spot any errors or would like to contribute, please contact me directly.

1 January 7, 2019

1.1 Simulating neurons

To construct neural networks we must first simulate how a biological neuron works.
Ions (positively and negatively charged molecules with excess protons and electrons, respectively) exists outside and inside of a cell and may be moved across the cell membrane.
There exists sodium and potassium **channels** which permits Na+ and K+ ions to move across the cell membrane, respectively. K+ channels move K+ ions out of the cell whereas Na+ channels move Na+ ions into the cell.
Sodium-potassium **pumps** exchange 3 Na+ inside the cell for 2 K+ ions outside the cell. This in effect creates a negative charge inside the cell.

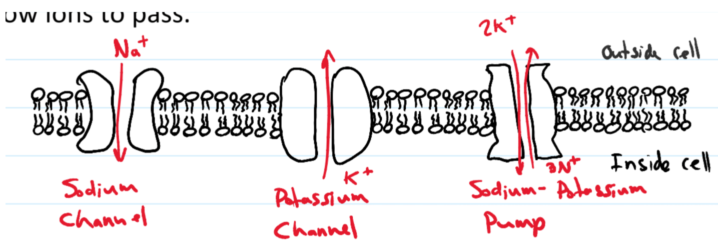

Figure 1.1: Cell membrane with Na+/K+ channels and a sodium-potassium pump. Ions move across the membrane via the channels and pump.

The difference in charge across the membrane induces a voltage difference called the **membrane potential**.
The **action potential** is a spike of electrical activity in neurons. This electrical burst travels along the neuron's **axon** to its **synapse** where it passes signals ot other neurons.
The **Hodgkin-Huxley** model describes how the action potential is effected. Note that both Na+ and K+ ion channels are voltage-dependent: Na+ and K+ move according to the membrane potential as the channelsopen and close with the membrane potential.
Let V be the membrane potential. A neuron usually keeps a membrane potential of around -70mV.
The fraction of K+ channels that are open is n^4, where

$$\frac{dn}{dt} = \frac{1}{t_n(V)}\big(n_\infty(V) - n\big)$$

where $t_n(V)$ is a time constant and $n_\infty(V)$ is the equilibrium solution.

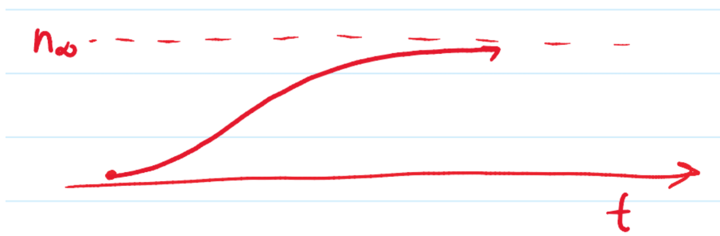

Figure 1.2: n in fraction of K+ channels open over time.