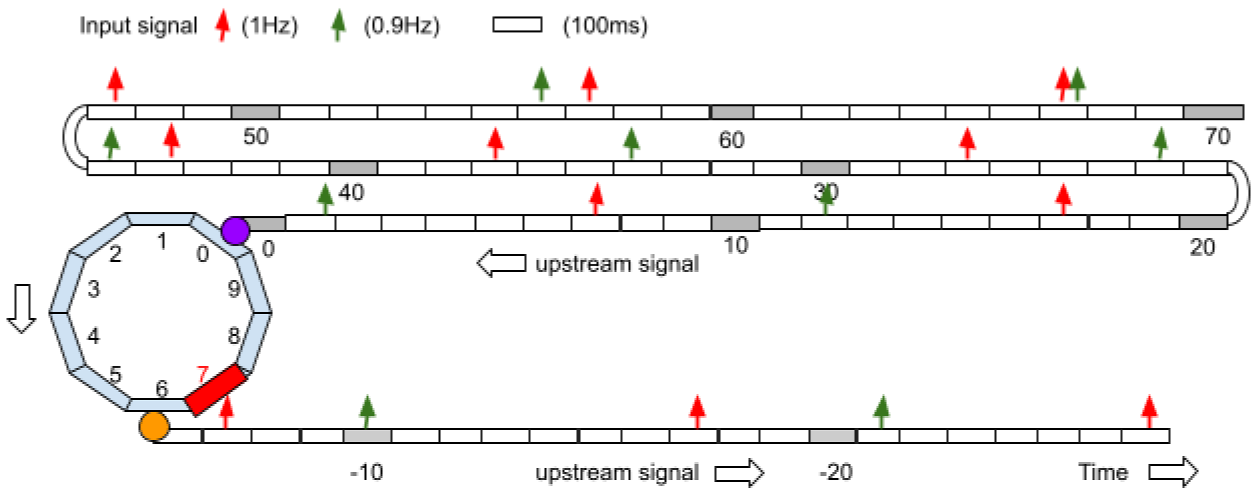
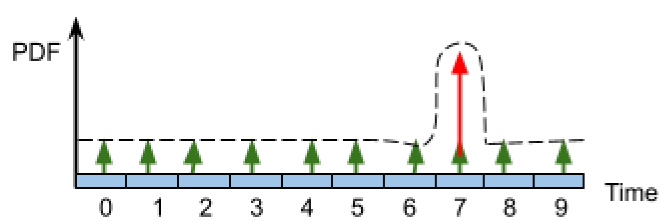
Introduction to Neural Computation without Equations

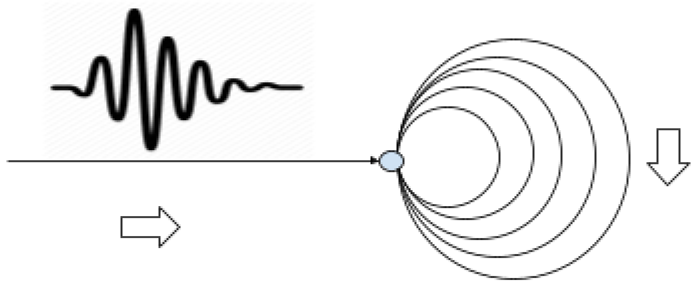
Suppose that a neural circuit receives upstream signals via a neuron (purple) and connects to the downstream network via another (orange). It takes 1s for neural signals to circle around the circuit. Let us also assume that the upstream signals consist of two frequencies: one is firing every 1s (1Hz, as shown in red arrow), and the other firing every 1.1 ms (~0.9Hz, as shown in green arrow). The neuron firing is illustrated as the following diagram where a small block is the equivalent of 100 ms. We can visualize the signal propagation by dragging the signals toward the arrow of the time. The signal propagation along the circuit can be visualized as rotating the circuit.



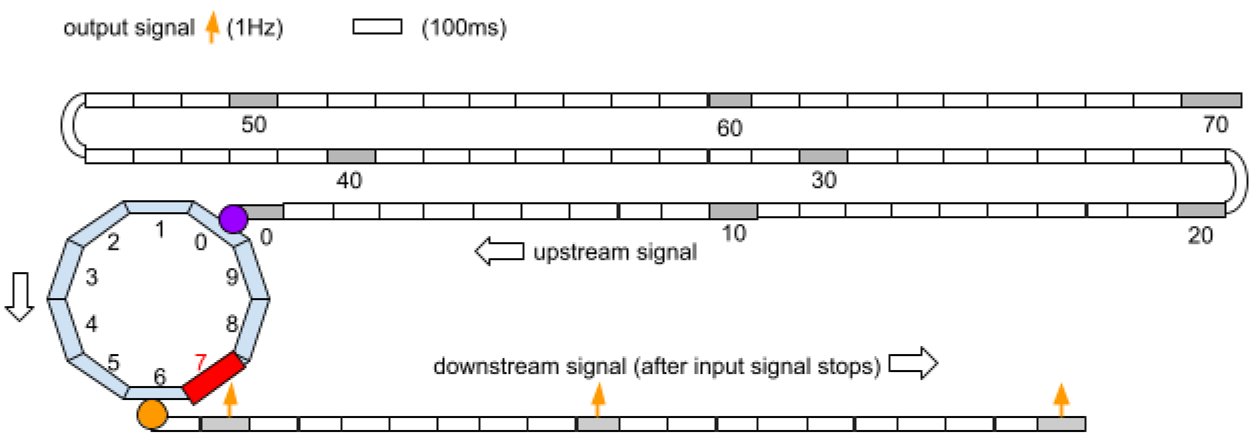
When the input signal lasts, the circuit largely relays the signal to the downstream network. Let us see how it affects the neuron firings around the circuit. The firings resonating with the circuit's frequency (red arrows) always hit the same block (#7 red) while the firings of non-resonating signals (green arrows) spread around the circuit. If we represent the signal circling around the circuit by a probability density function (PDF) by counting the number of neuron firings per unit of time, i.e. 100ms, we will see the 1Hz signal stands out and the non-resonating signal (0.9Hz) becomes background noises. The area under the PDF corresponds to the total number of neuron firings around the circuit, which is powered by the neurons around the circuit and remains largely a constant. Over the time, the circuit will retain only the strength of the signal with resonating frequency (1Hz) of the upstream signals.



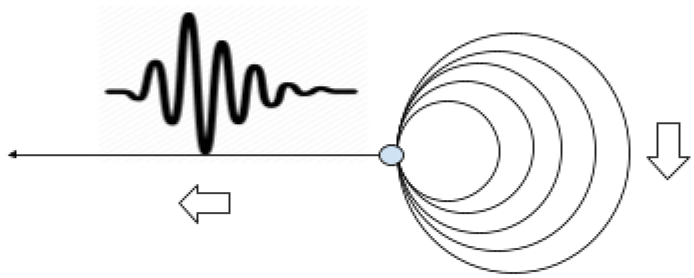
An arbitrarily complex input signal, the intensity of neuron firings as a function of time, can be expressed as a Fourier transform of different frequencies. Each frequency can be stored in a circuit with a matching frequency. Therefore, a cluster of circuits can store the frequency domain representation of an arbitrarily complex input signal.



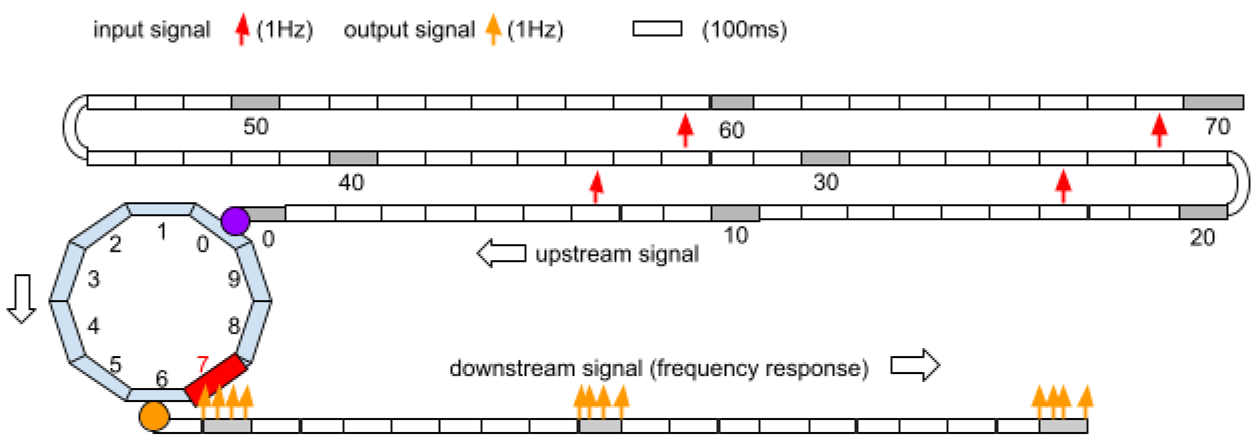
Let us see what happens if the upstream signal stops. The neuron firings of 1Hz signal still circle around the circuit. When the signal arrives at the orange neuron,it will propage to both the next neuron of the circuit and the downstream network. However, the frequency of the signal will be 1Hz and no longer contains other frequencies in the original upstream signals. So, the circuit not only remembers the signal strength of its resonating frequency in its input signals, but also broadcasts the signal strength of a specific frequency.



If a downstream neuron combines the signal from a cluster of neural circuits, it can restore an arbitrary complex input signal in its time domain representation. Imagine an Olympic figure skater whose brain has to give a precise neural signal to each and every voluntary muscle cell. It would require an equivalent of a datacenter to hold 3~4 mins of instructions for trillions of muscle cells and ~1PB/s bandwidth of processing power. This could be easily done through a cluster of neural circuits and circling signals.



If a weak signal with resonating frequency arrives at the circuit and coincides with the circling signal, it will hit the hyper-sensitive area and trigger a strong frequency response. It's the neural basis why we can utter one word at a time even though the muscle memories of all words are simultaneously wired to the muscle cells of the vocal cords.



For spontaneous pattern recognition, symbolic language, reinforcement learning, and the development of abstract concepts, please see page 27, 30, 32, 36.

To appreciate the mathematical power of rotating circles, please see
https://youtu.be/r6sGWTCMz2k

To understand the physical concepts of rotating circles (probability amplitude), please see
https://youtube.com/playlist?list=PLW_HsOU6YZRkdhFFznHNEfua9NK3deBQy