Analysis of spectro-temporal receptive fields in an auditory neural network

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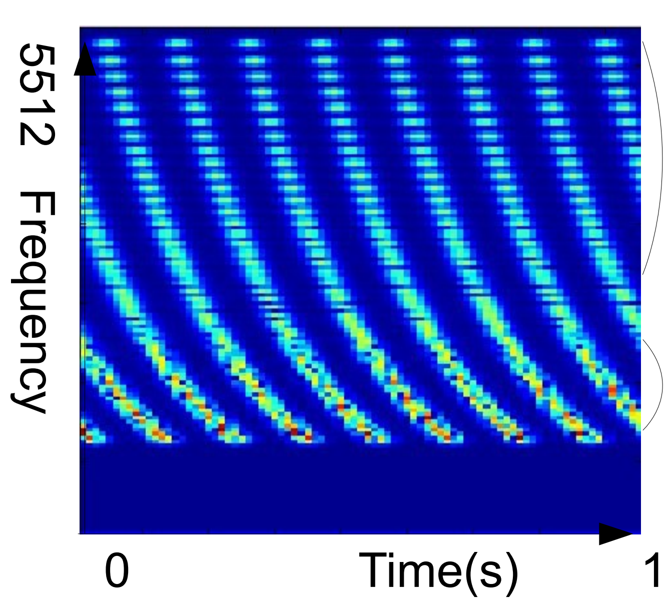
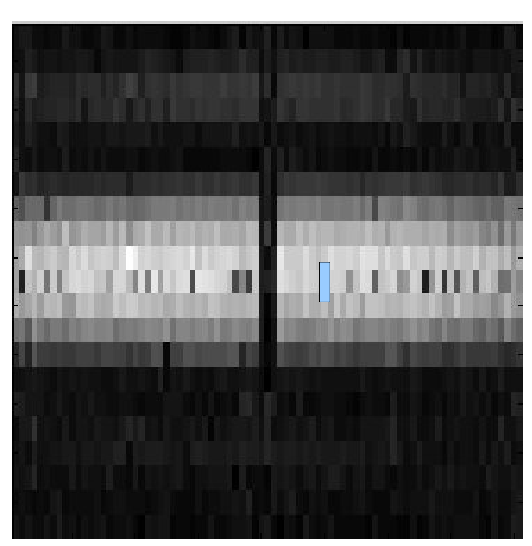
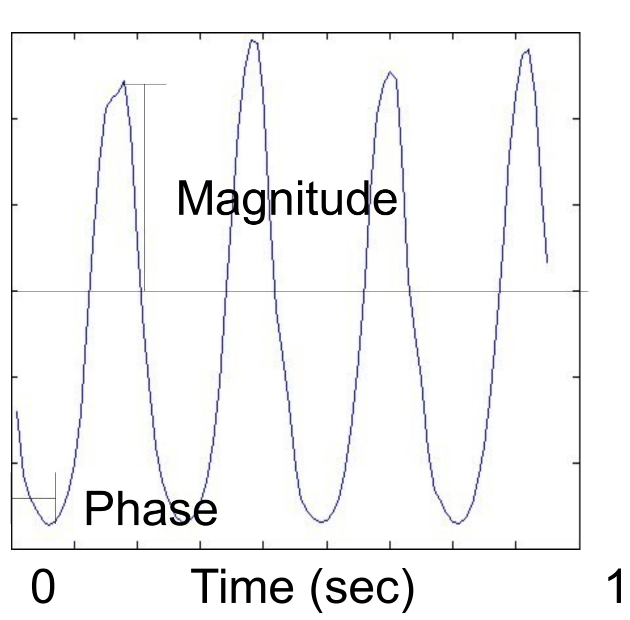
Abstract

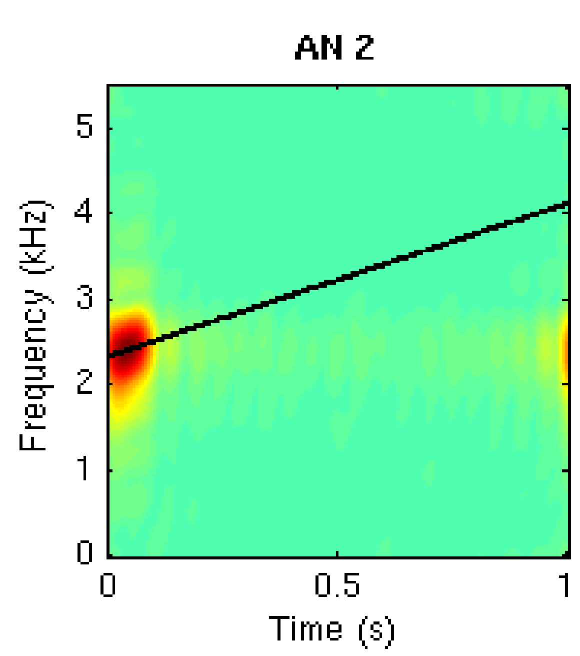
Neural networks have been utilized for a vast range of applications, including computational biology. But the validity of these models remains in question. In the models of the auditory cortex, for example, the properties of neuronal populations are hard to fully characterize with traditional methods such as tuning curves. Spectro-temporal receptive fields (STRFs), which describe neurons in both the spectral and temporal domains, have been obtained in a variety of animals, but have not been adequately studied in computational models. The aim of this project is to address these issues by generating the spectro-temporal receptive fields on a basic, neural network model of the early auditory processing stages in the brain. This novel use of STRFs can be used as a means of comparison between a model and its biological counterpart.

Generating STRFs

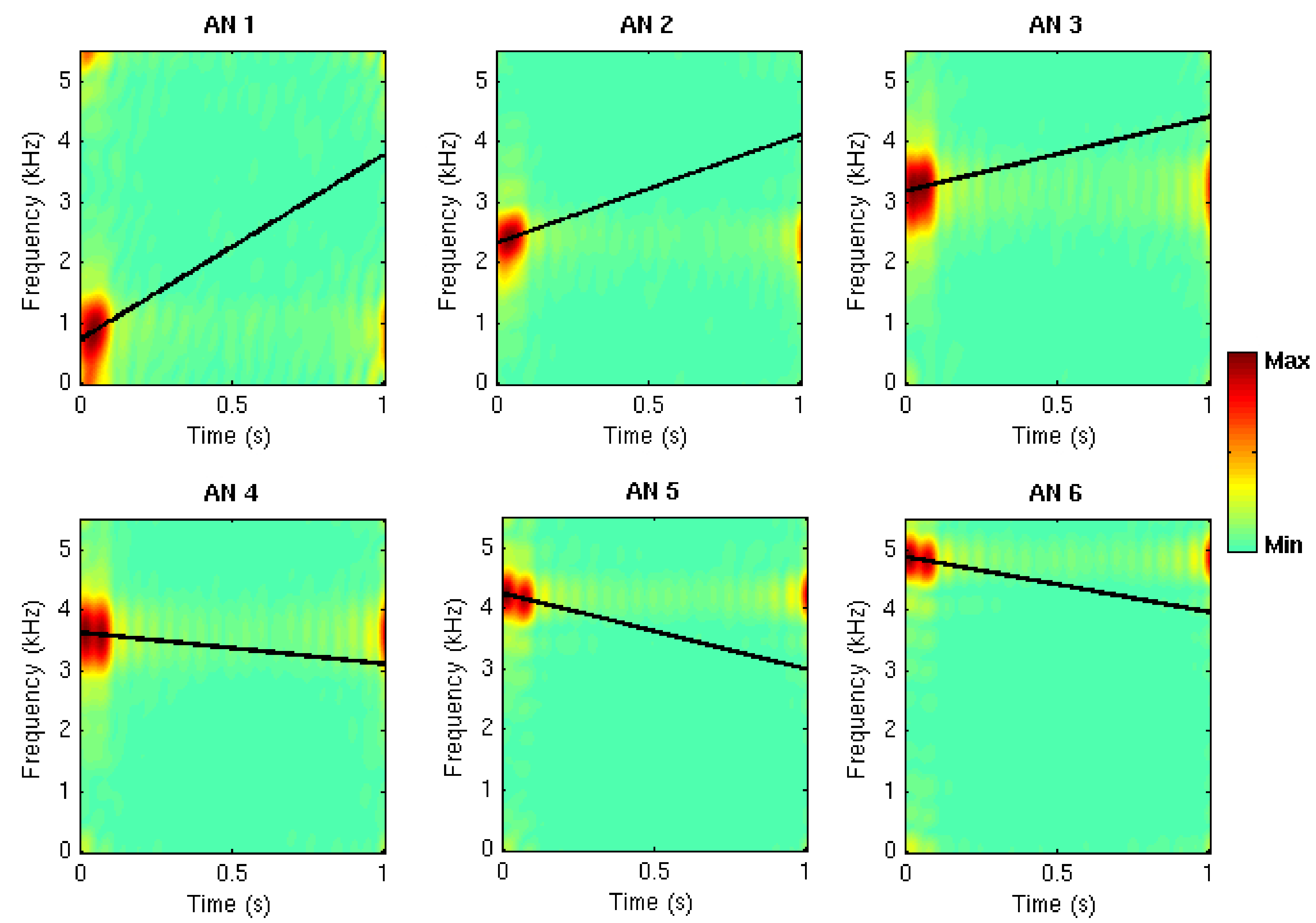








Results



Discussion

The receptive fields for the six different artificial neurons are plotted in the figure. The abscissa represents time after stimulus onset and the ordinate represents frequency. The bright area of the graph shows where the artificial neuron responds with greatest intensity. The dark area shows where artificial neuron does not respond to, or responds very weakly to. The graphs show that the artificial neurons are responding to distinct frequency ranges. For instance, the STRF for AN 1 shows that the second artificial neuron responds strongly to frequencies up to 1310 Hz. As the artificial neurons are connected to higher frequency input units, the receptive fields show that the artificial neuron also responds to higher frequencies. This result agrees with the hypothesized outcome.

Applications

Receptive fields have been extensively analyzed in both animals and neural networks in the visual domain. In the auditory domain, spectro-temporal receptive fields (STRFs) describe both the spectral and temporal aspects of a neuron. The STRFs have been used in many types of animals, but have not been explored in a computational model. This project describes the construction of a neural network of basic auditory processing and the subsequent testing using STRFs. The neural network could also serve as a starting point in investigating new therapies for hearing loss. One possible cortical level treatment for hearing loss is electrode stimulation, where small electrical currents are delivered to parts of the brain. Another type of treatment is transcranial magnetic stimulation (TMS). Both of these therapies can be first tested in neural networks by simulating the effect of brain stimulation. Researchers would be able to quickly validate the use of the therapy by examining the properties of the artificial neurons through STRFs.

Linear Model

The current neural network is a two-layer, forward feeding and linear model of the early auditory processing stages in the brain. The first layer is the input layer. The input to the neural network is a spectrogram, a graph of frequency v. time, which was converted from a waveform of the sound stimulus using a Fourier transform. The first layer receives one timestep of auditory information at a time. A timestep is about 12 ms of auditory information. The second layer is the output layer, a matrix product of the input vector and weight vector. The weights between the two layers were first set at random values, then trained using Oja's rule. After the weights were trained, they were plotted and analyzed.

Temporal Model

This neural network is also a two-layer forward feeding and receives time-delayed inputs from multiple timesteps ago. Each of these timesteps composes the entire first layer, which becomes 387 units long (three timesteps each of 129 units).Using this configuration, the neural network was trained using Oja's rule. As with the linaer model, the weights between the first and second layers of the model were originally set at zero-centered, normally distributed, random values. In addition, the connections between the artificial neurons are be created nor eliminated; they are only modified.