Signal Reconstruction from Sampled Data Using Neural Network

Poster presentation by
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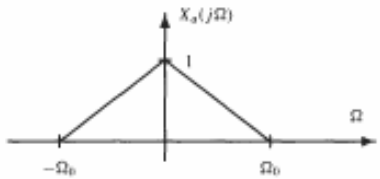
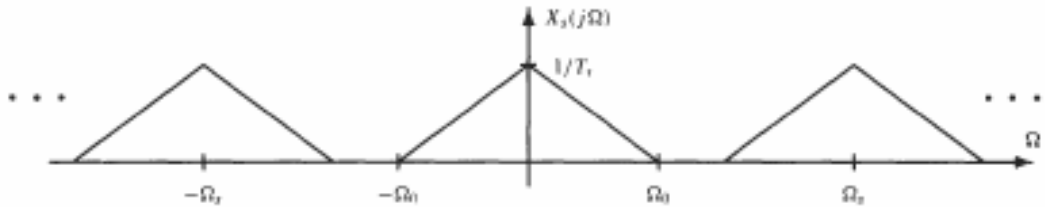
Sampling and Reconstruction

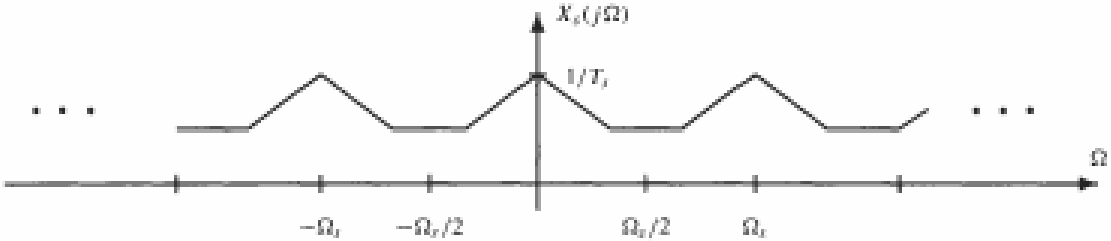
For the following signal:



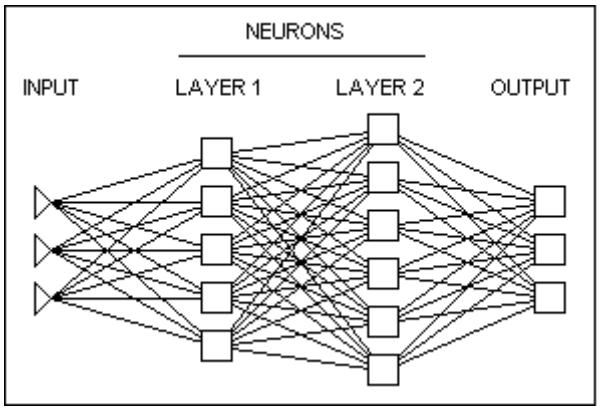
- Sampling above Nyquist sampling rate:

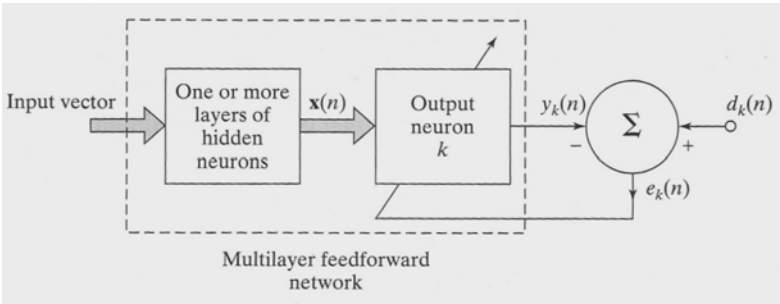


- Sampling below Nyquist sampling rate – aliasing:



Neural Network



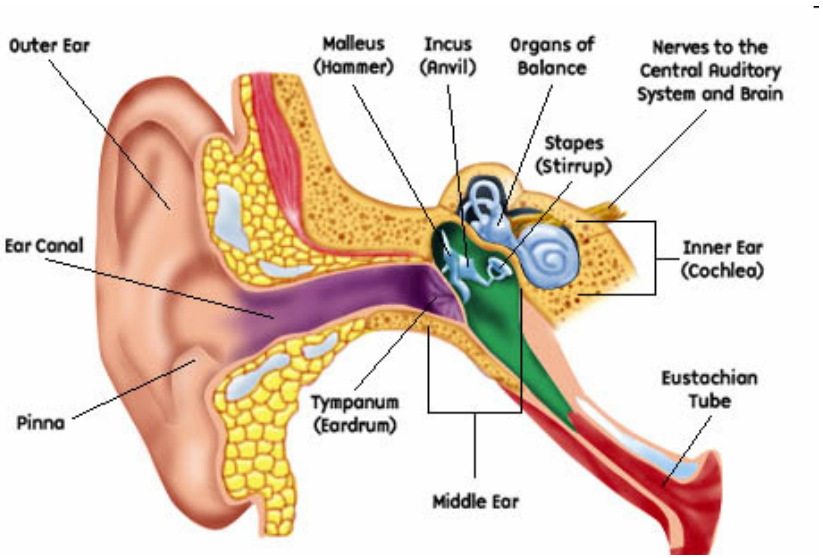


A Neural Network generally maps a set of inputs to a set of outputs after a training procedure on a finite set of input-output examples.

Training is the act of presenting the network with some sampled data and modifying the weights to better approximate the desired output

The Human auditory system

- A very complex system with the phenomena of:
  - Sensitivity to log-spectrum - Octaves
  - Critical bands
  - Threshold of hearing
  - Masking



The Paper:

"SIGNAL RECONSTRUCTION FROM SAMPLED DATA USING NEURAL NETWORK"

Akihito Sudou, Pitoyo Hartono, Ryo Saegusa, Shuji Hashimoto

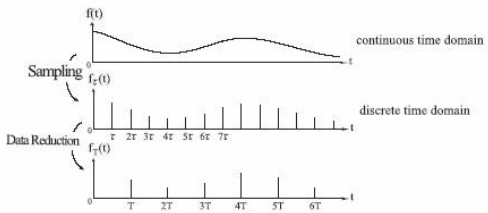


Figure 1: Sampling and Data Reduction

- A signal sampled with Nyquist rate underwent data reduction.
- Reconstruction was made both with a linear perceptron and a multilayered perceptron (with one hidden layer).
- For comparison a reconstruction using FIR filter with sinc was made.
- The NN did the training by minimizing the MSE.
- Two experiments were made:
  - Comparing the errors between the different reconstructions and the original signal for different data reduction rates.
  - Comparing the results of the different reconstructions while changing the number of inputs to the NN and the data reduction rate.

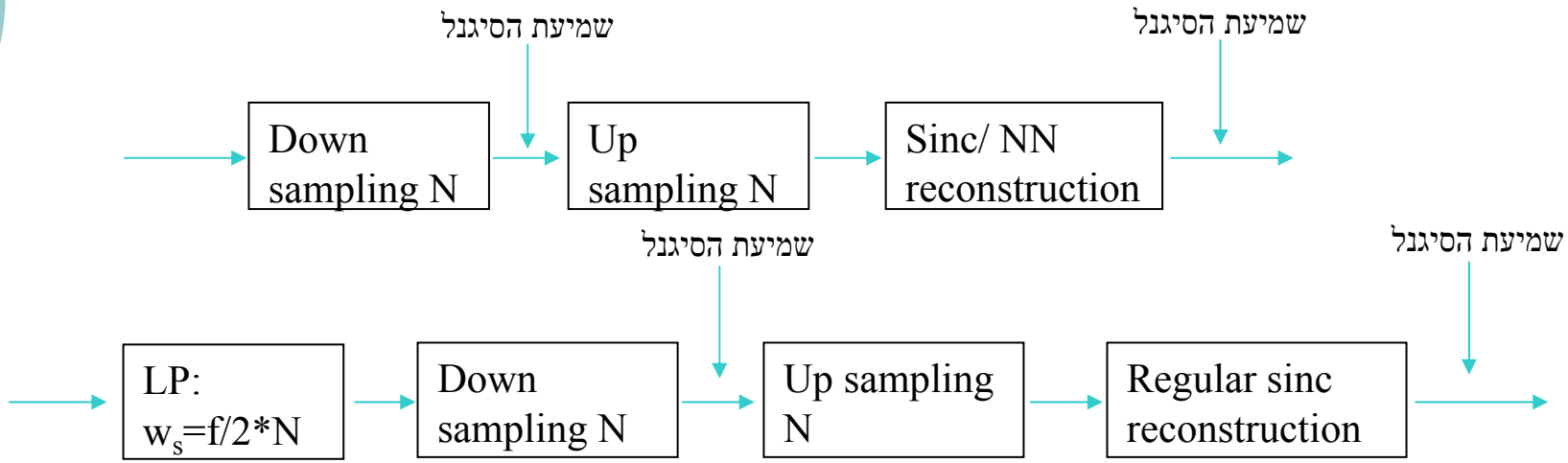
Results from the paper:

Note: the criteria for a good reconstruction was the average MSE not the sound quality.

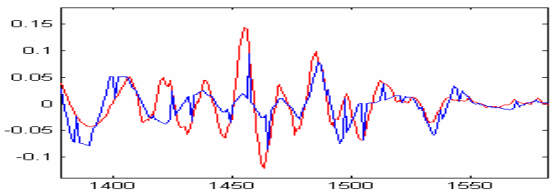
- The experiment showed that the perceptron achieved better reconstruction then the FIR reconstruction. Also it was shown that for larger data reduction the mistake in the reconstruction is larger.
- They didn't see a meaningful difference in the reconstructions by the linear perceptron and the multi-layer perceptron with one hidden layer.
- The second experiment showed that using a perceptron with larger number of inputs improves the reconstruction

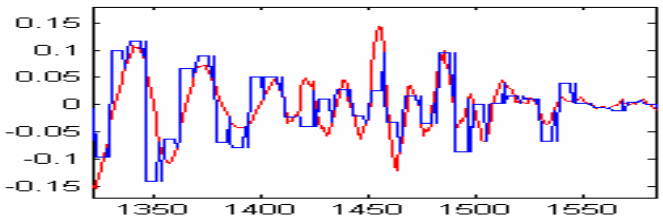
Time Domain

- We are using 2 signals: speech and musical.

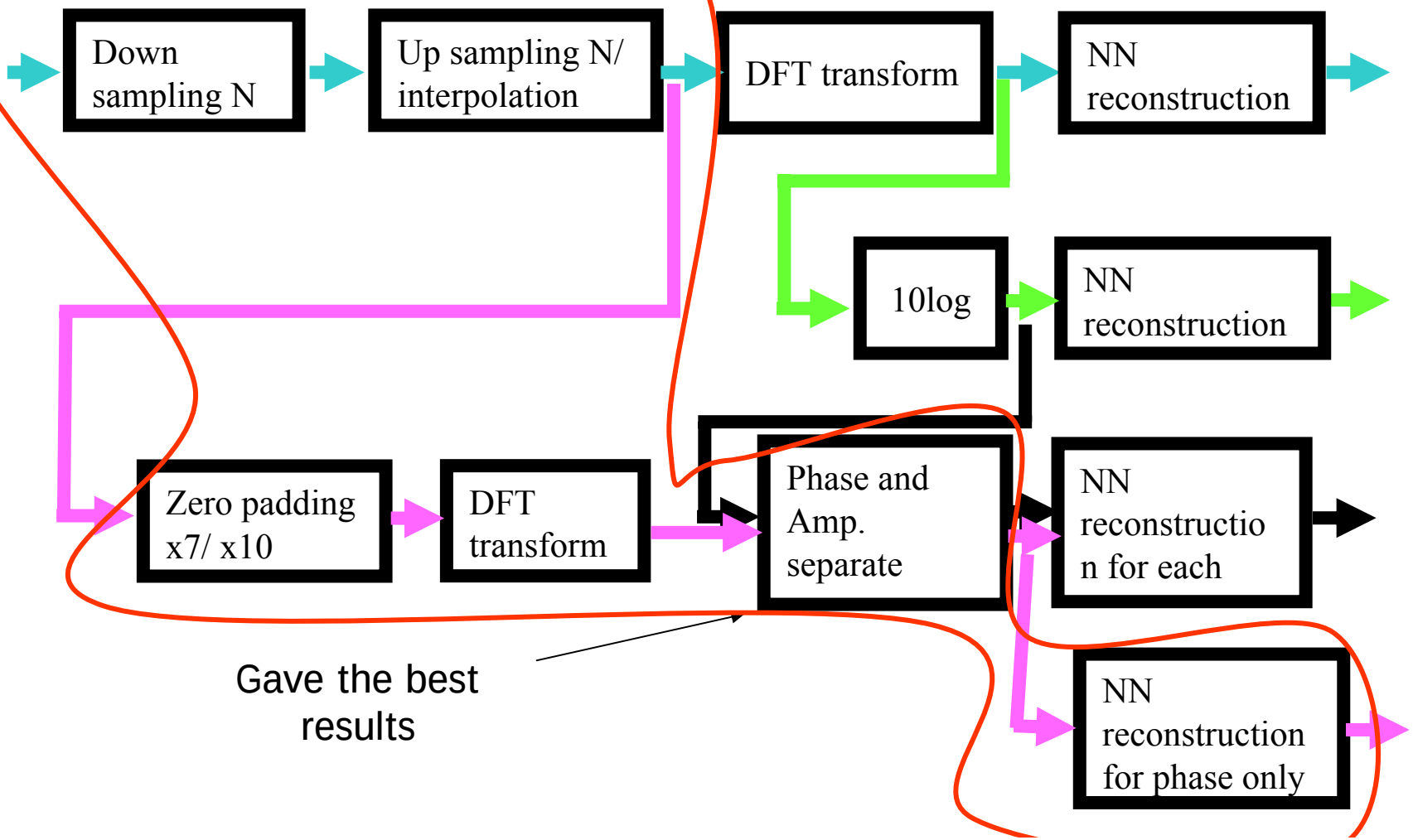


- up sampling does zero interpolation and is probably not optimal for the reconstruction. We tried other types of interpolation- linear: nearest neighbor:



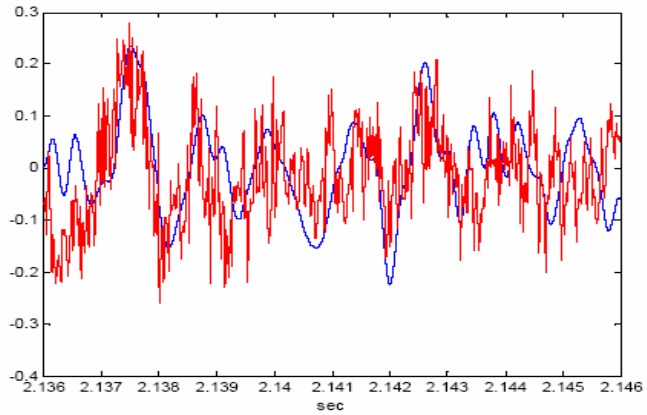


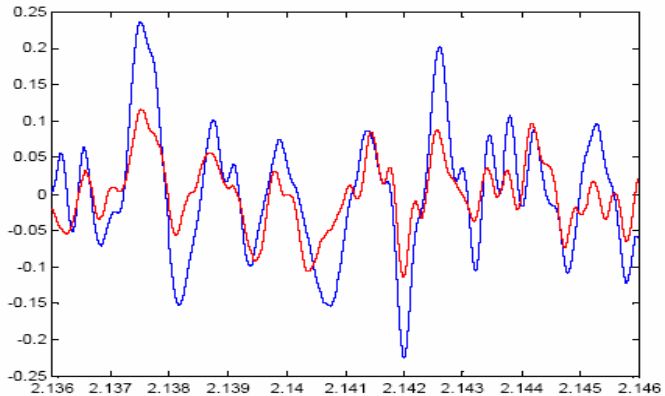
Frequency Domain



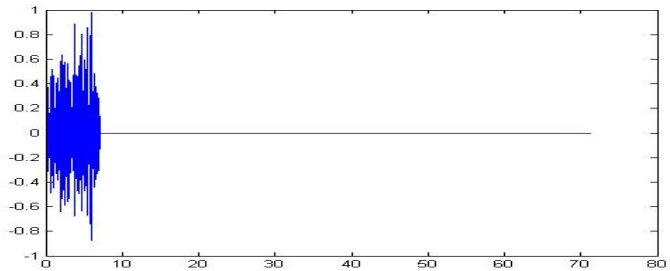
Phase and amplitude reconstruction vs. only phase reconstruction:

- Red- the reconstructed signal
- Phase and amplitude reconstruction and then combination
- Using the unreconstructed amplitude and the reconstructed phase.
- We can see that the amplitude reconstruction adds a lot of noise.





Zero padding



- Zero padding is actually a way to increase the frequency resolution.
- We did only phase reconstruction and used either the original (non-reconstructed amplitude) or the average amplitude.
- The average amplitude showed better results
- We used PESQ and our hearing as an estimate for the quality of reconstruction here are the best results that we got for the speech signal.

	PESQ	Comp. rate
L=30 segl=0.1 pad=7	1.679	1.276
L=30 segl=0.1 pad=6	1.677	1.413
L=10 segl=0.1 pad=7	1.670	2.305
L=20 segl=0.1 pad=7	1.685	1.643
L=30 segl=1 pad=7	1.716	3.297
L=30 segl=0.5 pad=7	1.689	2.803

Sending and receiving:

- Sending:

Down sampling, interpolation, Zero padding → FFT transform, 10log, phase and amplitude separation → NN training on the phase and saving the weights →

Sending: l- length of the signal after down sampling, N- down sampling rate, type of the interpolation, zero padding rate, L- window length, segment length, down sampled signal, weights in the correct order.

- Receiving:

Interpolation, Zero padding → FFT transform, 10log, phase and amplitude separation → Phase reconstruction using the weights received, finding the average amplitude → Composing the signal from the reconstructed phase and the average amp.

→ Noise reduction in time domain

Conclusions

- The reconstructed signals are very noisy and need a lot of noise reduction processing if a good quality of sound is required but if the goal is only to understand the sentence spoken the quality is good enough.
- This method proved to be not useful as a compression method because there are much better ways of compression that deliver a much better sound quality after decompression.