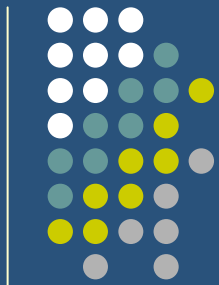
Compression of Spike Data using the Self-Organizing Map

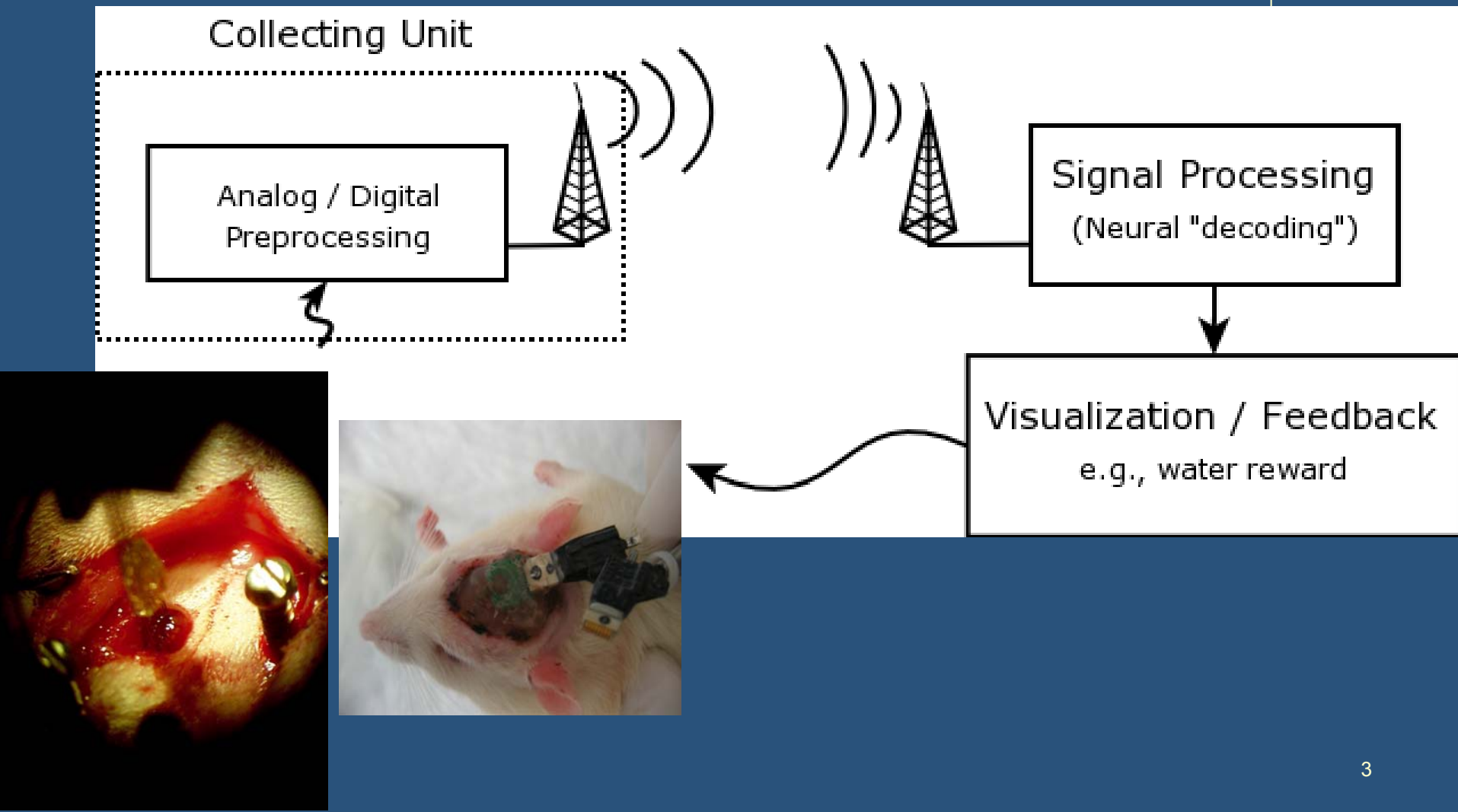
Justin C. Sanchez, Ph.D.
Antonio R. C. Paiva
Jose C. Principe, Ph.D.
Computational NeuroEngineering Laboratory
Department of Pediatrics Division of Neurology
Department of Electrical and Computer Engineering
University of Florida
justin@cnel.ufl.edu

Motivation

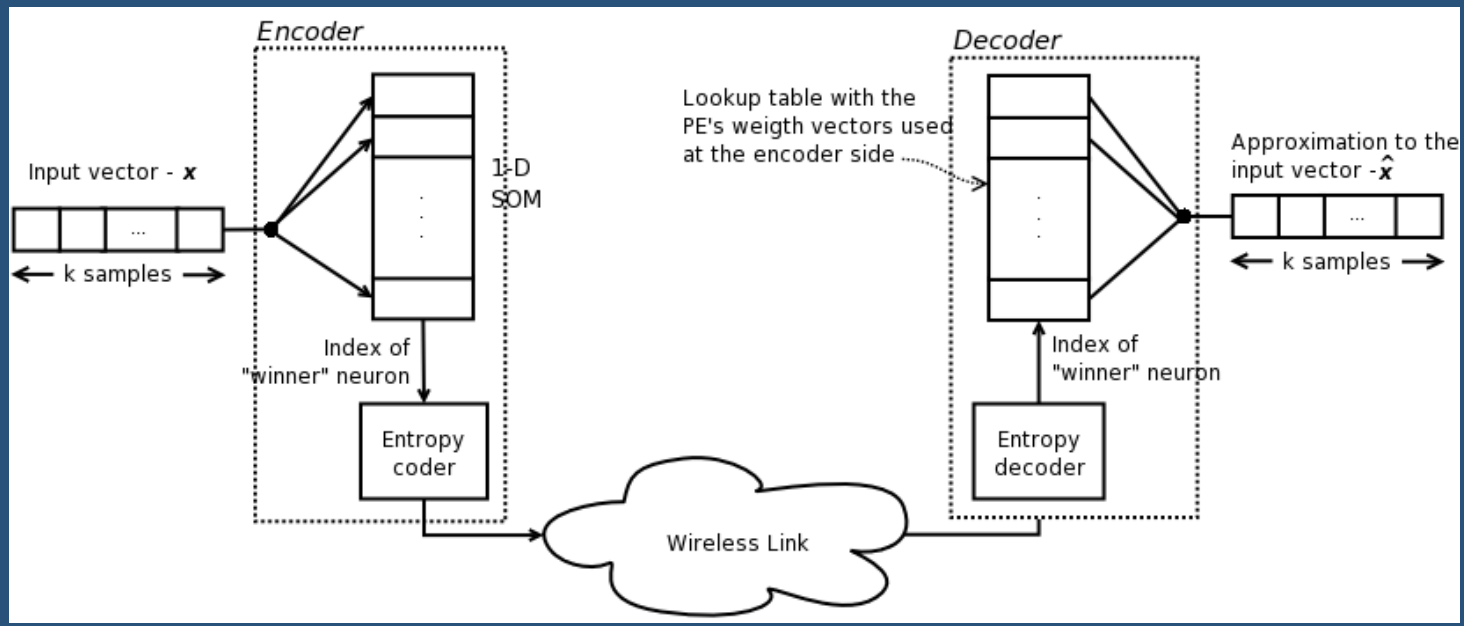


- Wireless links for electrophysiology have limitations on the available bandwidth.
  - 32ch @ 20kHz, 16 bits ~ 10Mbps
  - 32ch snips, 100 spikes/s, 32 samples, 16 bits ~ 1.6Mbps
  - 32ch bin, 8 bits ~ 240bps
- Gap in approaches: high or low data rates
- Preserve as much information as possible for sorting at a later time.

The wireless Brain Machine Interface Paradigm



Conceptual diagram of Encoding/Decoding process



- In this method, compression is achieved in two steps:
  - Quantization through the application of the SOM; k samples is represented by an index
  - Entropy coding of the indices.

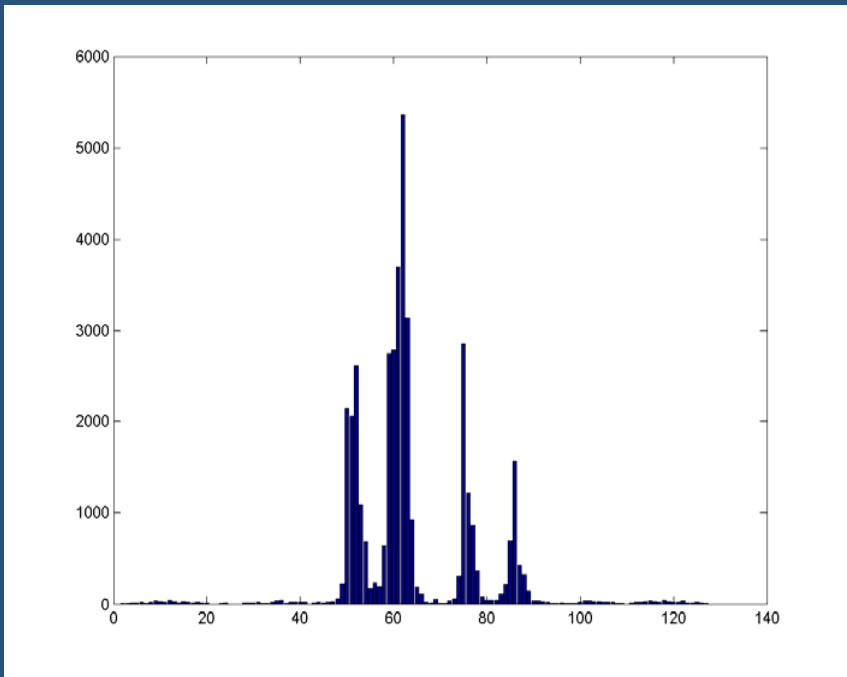
Compression through the SOM

- Local framework - preserve the topology of the data using neighborhood links between PEs
- Compression through the SOM is *lossy*:
  - Many-to-one mapping;
  - Choose nearest neighbor to minimize the quantization error.
- Compression ratio is constant:
  - If each sample has *b* bits, with *k* samples per vector, and a SOM with N vectors, the compression ratio (just due to the SOM) is

$$\frac{kb}{\lceil \log_2 N \rceil} : 1$$

Entropy coding

- Why use entropy coding?
  - Because of non-uniform distribution of the *indices* of the firing PEs.



Entropy coding

- Calculate the entropy of the indices, at the output of the SOM, with

$$h = -\sum_{i=1}^{N} p_i \log_2 p_i$$

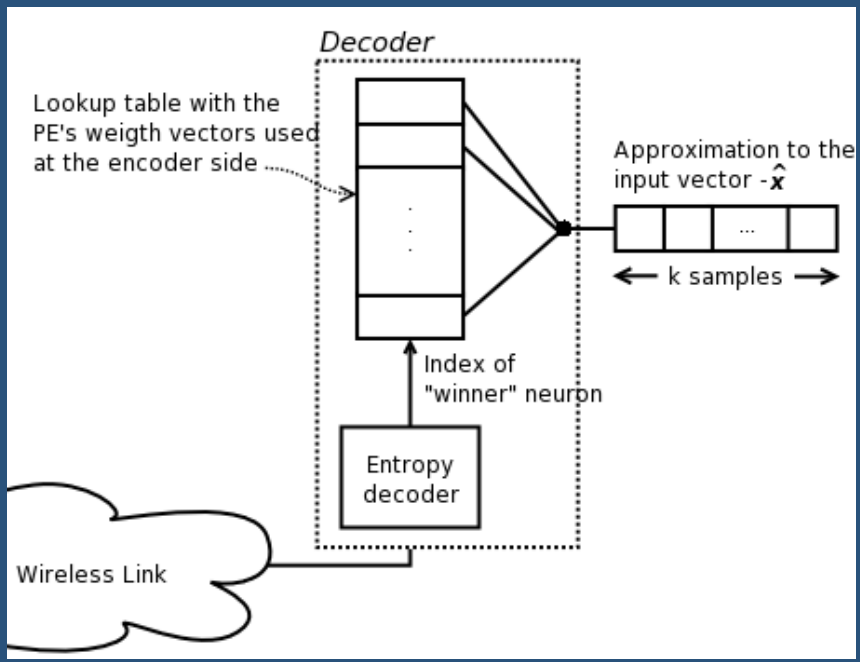
where *p* is the "probability" of the *i* th index.

- Final compression ratio is:

$$(k \times N \times 8)/h$$

Vector length (*k*), # of PEs (*N*)

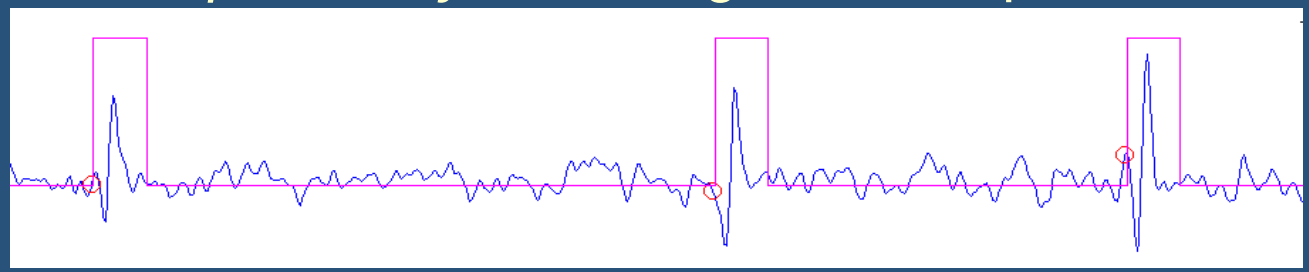
Decoding process



1. Entropy decode;
2. Use index to fetch vector of winning PE in table;
3. Concatenate vector to the output.

Training/Testing Sets

- Training:
  - Equal amount of training samples from each channel;
  - Selected *spikes only* assuming width of spike of 27 samples;

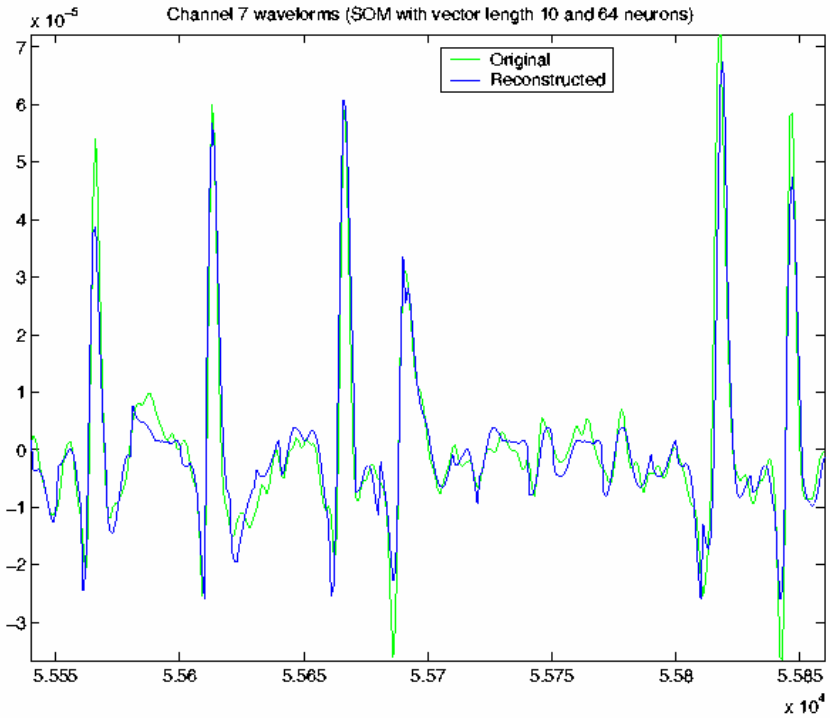


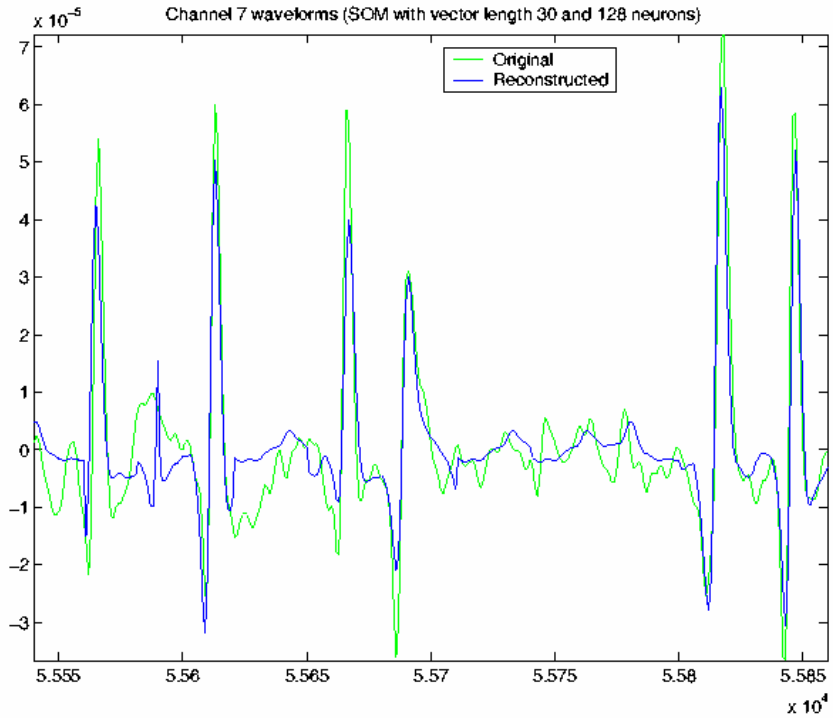
  - 2x(4000 spikes)x27+(2% noise samples) ≈ 110,000 samples;
  - Designed to reconstruct spikes, but be noise aware.
- Testing:
  - 400,000 samples from each channel (outside the training set).

Results

Input dimension	No. of PEs	Channel 6		Channel 7	
		Bitrate (kbits/sec)	Compression ratio	Bitrate (kbits/sec)	Compression ratio
10	32	4.14	37.7 : 1	3.76	41.6 : 1
	64	5.44	28.7 : 1	4.96	31.5 : 1
	128	6.73	23.2 : 1	6.18	25.3 : 1
20	64	1.71	91.6 : 1	1.27	123.2 : 1
	128	2.21	70.7 : 1	1.95	80.0 : 1
	256	2.75	56.9 : 1	2.34	66.9 : 1
30	128	1.02	152.8 : 1	0.84	186.7 : 1
	256	1.44	108.7 : 1	1.22	128.4 : 1

Reconstructions vs Vector Length





Conclusions

- Compression ratio provides a balance between the fidelity of the reconstruction versus the desired/allowable bitrate in the communication link.

- Future work:
  - Exploring changes to the SOM to minimize reconstruction error;
  - Quantify the effects of quantization in spike detection and spike sorting.