

SYDE 556/750

Simulating Neurobiological Systems
Lecture 3: Representations

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January 14 & 16, 2020



UNIVERSITY OF
WATERLOO

FACULTY OF
ENGINEERING



Visual Cortex



Mapping receptive fields

cell activity

behavior

overall



ongoing



NEF Principle 1: Representation

NEF Principle 1 – Representation

Groups (“populations”, or “ensembles”) of neurons *represent* represent values via nonlinear encoding and linear decoding.

Lossless Codes

INTERNATIONAL ALPHABET FLAGS, PHONETIC ALPHABET, MORSE CODE AND SEMAPHORE ALPHABET															
A ALFA [Flag] [Morse] [Semaphore]	B BRAVO [Flag] [Morse] [Semaphore]	C CHARLIE [Flag] [Morse] [Semaphore]	D DELTA [Flag] [Morse] [Semaphore]	E ECHO [Flag] [Morse] [Semaphore]	F FOXTROT [Flag] [Morse] [Semaphore]	G GOLF [Flag] [Morse] [Semaphore]	H HOTEL [Flag] [Morse] [Semaphore]	I INDIA [Flag] [Morse] [Semaphore]	J JULIETT [Flag] [Morse] [Semaphore]	K KILO [Flag] [Morse] [Semaphore]	L LIMA [Flag] [Morse] [Semaphore]	M MIKE [Flag] [Morse] [Semaphore]	N NOVEMBER [Flag] [Morse] [Semaphore]	O OSCAR [Flag] [Morse] [Semaphore]	P PAPA [Flag] [Morse] [Semaphore]
Q QUEBEC [Flag] [Morse] [Semaphore]	R ROMEO [Flag] [Morse] [Semaphore]	S SIERRA [Flag] [Morse] [Semaphore]	T TANGO [Flag] [Morse] [Semaphore]	U UNIFORM [Flag] [Morse] [Semaphore]	V VICTOR [Flag] [Morse] [Semaphore]	W WHISKEY [Flag] [Morse] [Semaphore]	X XRAY [Flag] [Morse] [Semaphore]	Y YANKEE [Flag] [Morse] [Semaphore]	Z ZULU [Flag] [Morse] [Semaphore]	SEMAPHORE [Flag] [Morse] [Semaphore]					
ALPHABET [Flag] [Morse] [Semaphore]															
NAVAL NUMERAL FLAGS, PHONETIC NUMERALS AND MORSE CODE															
1 ONE [Flag] [Morse]	2 TWO [Flag] [Morse]	3 THREE [Flag] [Morse]	4 FOUR [Flag] [Morse]	5 FIVE [Flag] [Morse]	6 SIX [Flag] [Morse]	7 SEVEN [Flag] [Morse]	8 EIGHT [Flag] [Morse]	9 NINE [Flag] [Morse]	0 ZERO [Flag] [Morse]						
INTERNATIONAL NUMERAL PENNANTS															
1 "Pennant One" [Flag]	2 "Pennant Two" [Flag]	3 "Pennant Three" [Flag]	4 "Pennant Four" [Flag]	5 "Pennant Five" [Flag]	6 "Pennant Six" [Flag]	7 "Pennant Seven" [Flag]	8 "Pennant Eight" [Flag]	9 "Pennant Nine" [Flag]	0 "Pennant Zero" [Flag]						
NAVAL SPECIAL FLAGS AND PENNANTS															
International Answer [Flag] [Morse] [Semaphore]	Code [Flag] [Morse] [Semaphore]	Black Pennant [Flag] [Morse] [Semaphore]	Corpus [Flag] [Morse] [Semaphore]	Designation [Flag] [Morse] [Semaphore]	Division [Flag] [Morse] [Semaphore]	Emergency [Flag] [Morse] [Semaphore]	Flotilla [Flag] [Morse] [Semaphore]	Formation [Flag] [Morse] [Semaphore]							
Interrogative [Flag] [Morse] [Semaphore]	Negative [Flag] [Morse] [Semaphore]	Preparative [Flag] [Morse] [Semaphore]	Port [Flag] [Morse] [Semaphore]	Speed [Flag] [Morse] [Semaphore]	Squadron [Flag] [Morse] [Semaphore]	Starboard [Flag] [Morse] [Semaphore]	Station [Flag] [Morse] [Semaphore]	Submarine [Flag] [Morse] [Semaphore]							
Tow [Flag] [Morse] [Semaphore]	First Subtittle [Flag] [Morse] [Semaphore]	Second Subtittle [Flag] [Morse] [Semaphore]	Third Subtittle [Flag] [Morse] [Semaphore]	Fourth Subtittle [Flag] [Morse] [Semaphore]											

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0

Encoding: $a = f(x)$

Decoding: $x = f^{-1}(a)$

Binary numbers: Nonlinear encoding, linear decoding

- Represent a natural number between 0 and $2^n - 1$ as n binary digits.
- **Nonlinear encoding**

$$a_i = (f(x))_i = \begin{cases} 1 & \text{if } x - 2^i \lfloor \frac{x}{2^i} \rfloor > 2^{i-1}, \\ 0 & \text{otherwise.} \end{cases}$$

- **Linear decoding**

$$x = f^{-1}(\mathbf{a}) = \sum_{i=0}^{n-1} 2^i a_i = \mathbf{F}\mathbf{a} = \begin{pmatrix} 1 & 2 & \dots & 2^{n-1} \end{pmatrix} \begin{pmatrix} a_0 \\ a_1 \\ \vdots \\ a_{n-1} \end{pmatrix}.$$

- This is a **distributed code**. But, **not robust** against additive noise!

Lossy codes

- ▶ **Lossy code**

Inverse f^{-1} does not exist, instead *approximate* the represented value

Encoding: $\mathbf{a} = f(\mathbf{x})$

Decoding: $\mathbf{x} \approx g(\mathbf{a})$

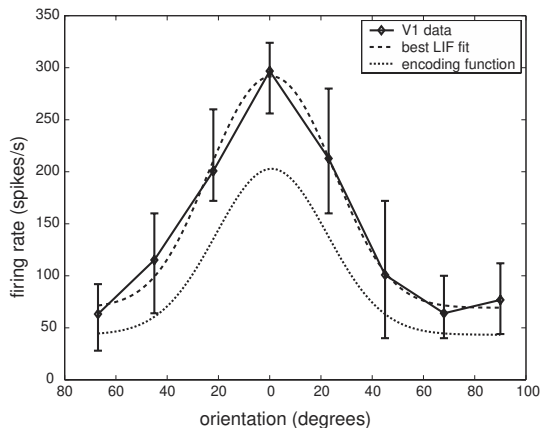
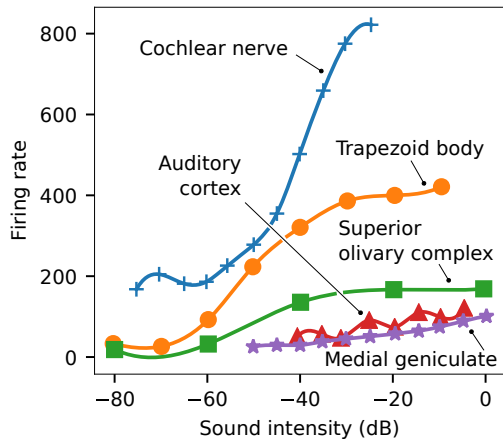
- ▶ **Examples**

- ▶ Audio, image, and video coding schemes (MP3, JPEG, H.264)

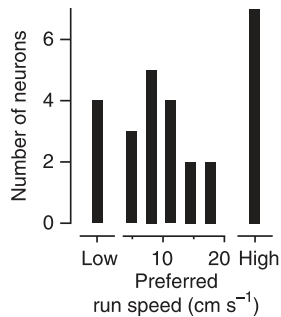
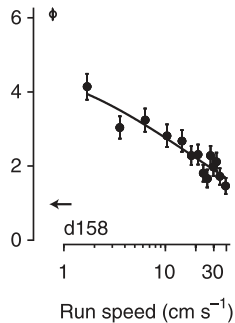
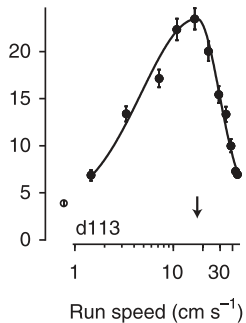
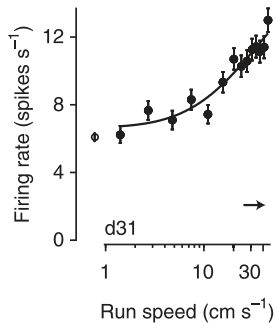
- ▶ Basis transformation onto first n principal components (PCA)

- ▶ **Neural Representations**

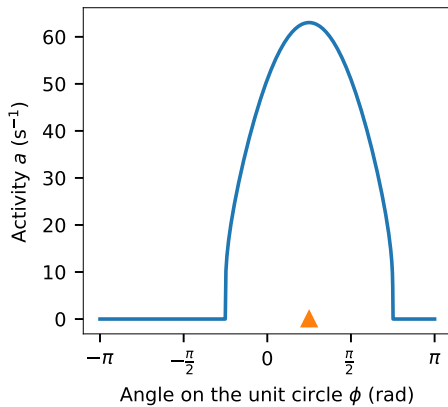
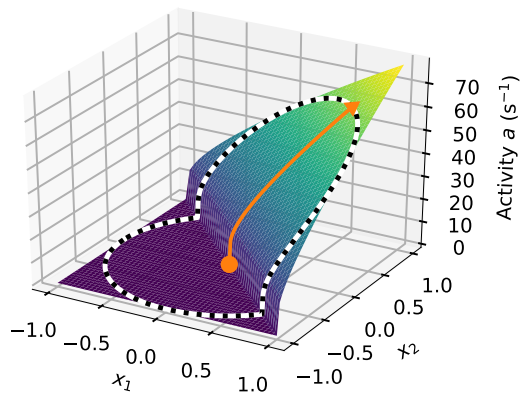
Tuning curves (I)



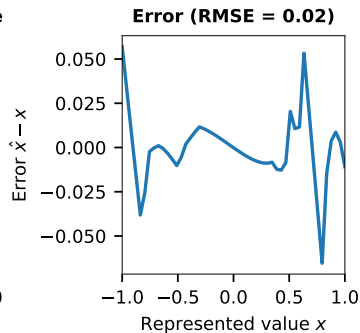
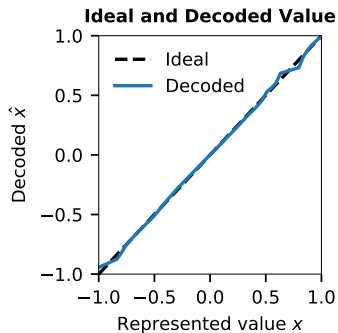
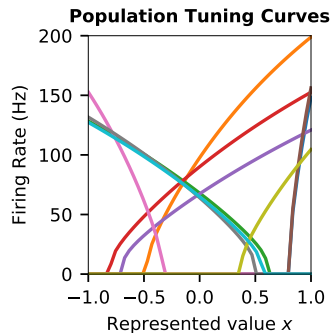
Tuning curves (II)



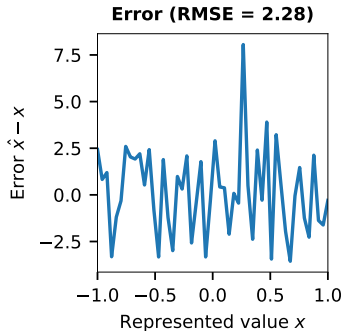
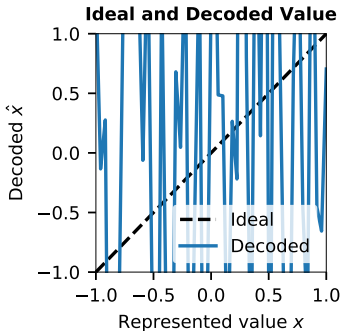
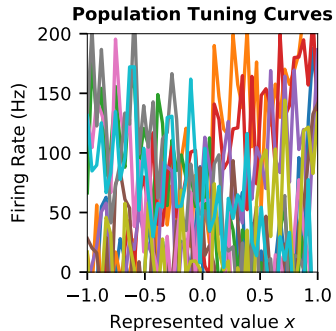
Preferred Directions in Higher Dimensions: Representing 2D Values



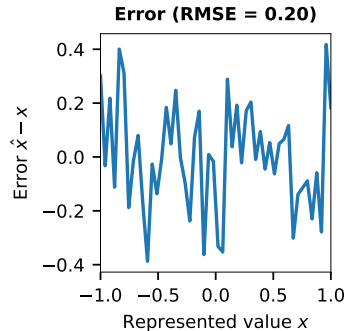
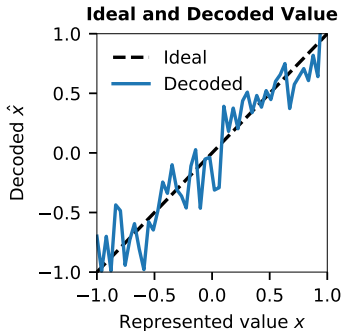
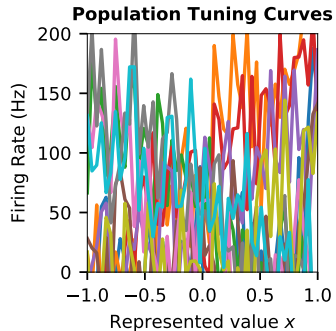
Decoding Without Taking Noise Into Account



Decoding Noisy \mathbf{A} Without Taking Noise Into Account



Decoding Noisy \mathbf{A} Accounting for Noise



Administration

- ▶ **Assignment 1 has been released.**

The due date has been adjusted to January, 30.

- ▶ Some new potential times for office hours

Mon 15:30–16:30, Mon 16:30–17:30, Tue 15:00–16:00,

Thu 11:30–12:30 (current slot), Thu 12:30–13:30

Image sources

Title slide

“The Ultimate painting.”

Author: Clark Richert.

From Wikimedia.