

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  <small>Alphabet: 1st letter</small>	B BRAVO  <small>Alphabet: 2nd letter</small>	C CHARLIE  <small>Alphabet: 3rd letter</small>	D DELTA  <small>Alphabet: 4th letter</small>	E ECHO  <small>Alphabet: 5th letter</small>	F FOXTROT  <small>Alphabet: 6th letter</small>	G GOLF  <small>Alphabet: 7th letter</small>	H HOTEL  <small>Alphabet: 8th letter</small>	I INDIA  <small>Alphabet: 9th letter</small>	J JULIETT  <small>Alphabet: 10th letter</small>						
K KILO  <small>Alphabet: 11th letter</small>	L LIMA  <small>Alphabet: 12th letter</small>	M MIKE  <small>Alphabet: 13th letter</small>	N NOVEMBER  <small>Alphabet: 14th letter</small>	O OSCAR  <small>Alphabet: 15th letter</small>	P PAPA  <small>Alphabet: 16th letter</small>	Q QUEBEC  <small>Alphabet: 17th letter</small>	R ROMEO  <small>Alphabet: 18th letter</small>	S SIERRA  <small>Alphabet: 19th letter</small>	T TANGO  <small>Alphabet: 20th letter</small>						
U UNIFORM  <small>Alphabet: 21st letter</small>	V VICTOR  <small>Alphabet: 22nd letter</small>	W WHISKEY  <small>Alphabet: 23rd letter</small>	X XRAY  <small>Alphabet: 24th letter</small>	Y YANKEE  <small>Alphabet: 25th letter</small>	Z ZULU  <small>Alphabet: 26th letter</small>	SEMAPHORE ALPHABET      									

A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
S
T

U
V
W
X
Y
Z

1
2
3
4
5
6
7
8
9
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.

Binary numbers: Nonlinear encoding, linear decoding

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

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

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- **Linear decoding**

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

Binary numbers: Nonlinear encoding, linear decoding

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- This is a **distributed code**.

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

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- ▶ **Examples**

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

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

Lossy codes

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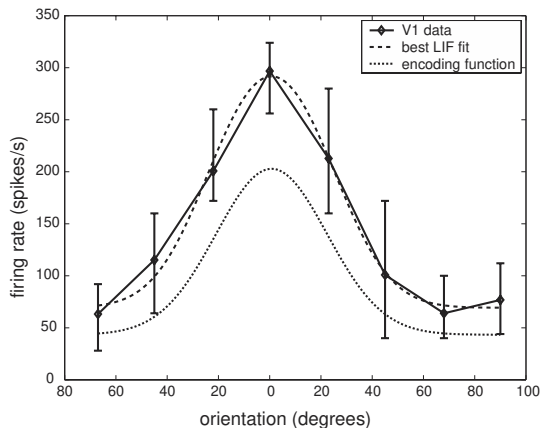
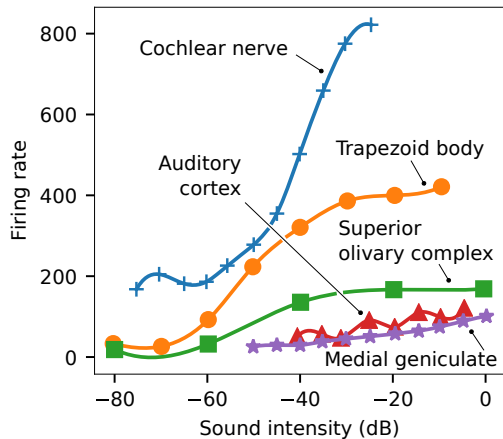
- ▶ **Examples**

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

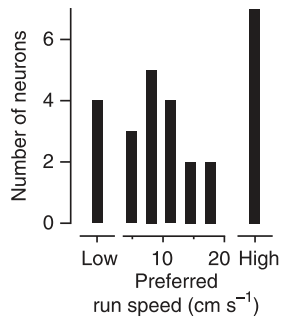
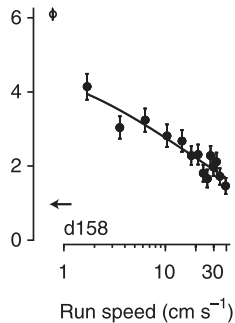
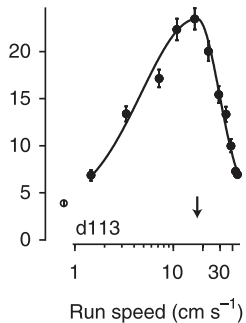
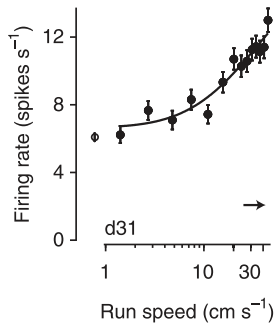
- ▶ Basis transformation onto first n principal components (PCA)

- ▶ **Neural Representations**

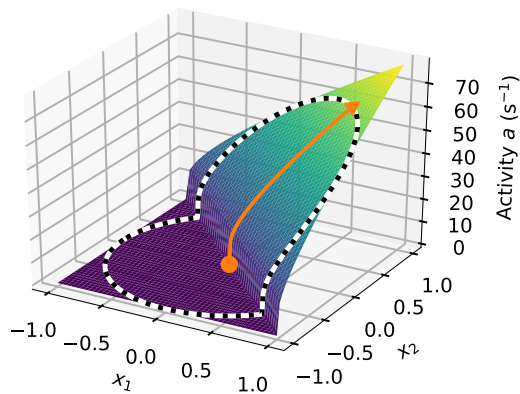
Tuning curves (I)



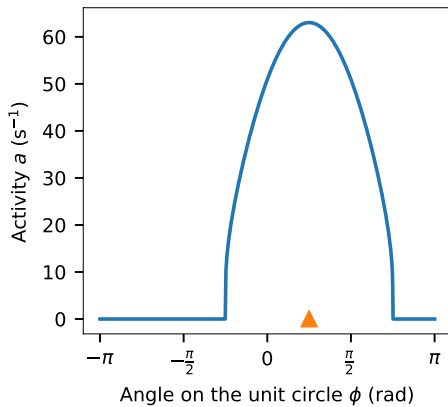
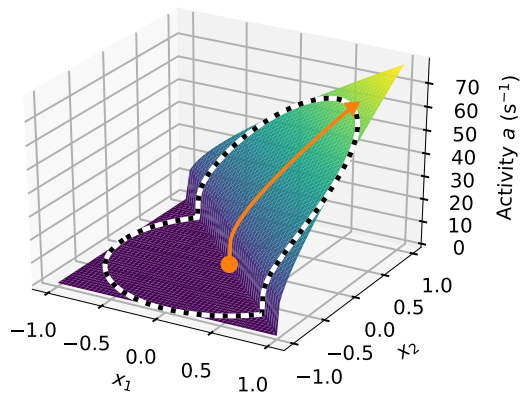
Tuning curves (II)



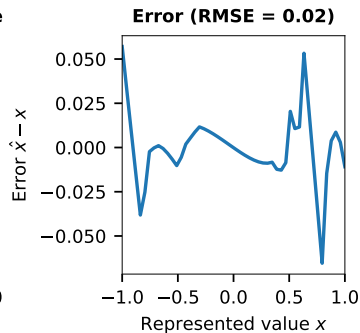
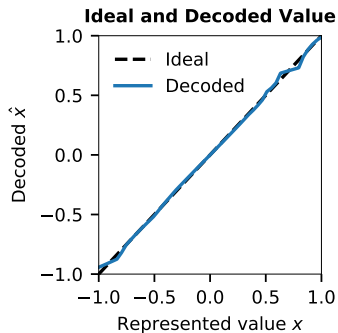
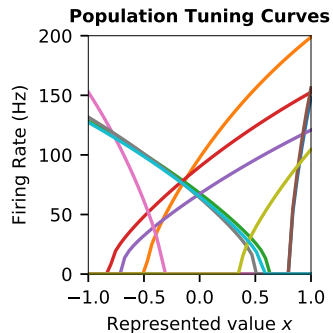
Preferred Directions in Higher Dimensions: Representing 2D Values



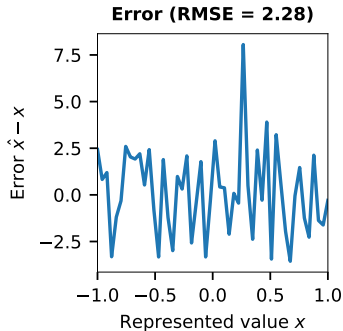
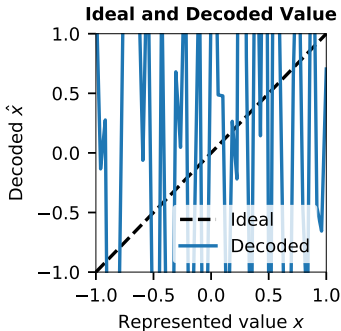
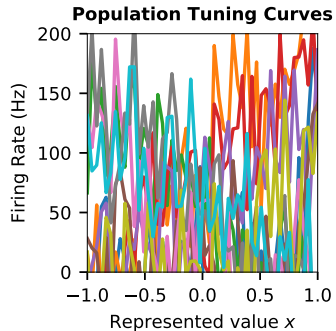
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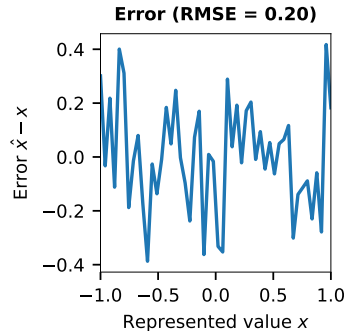
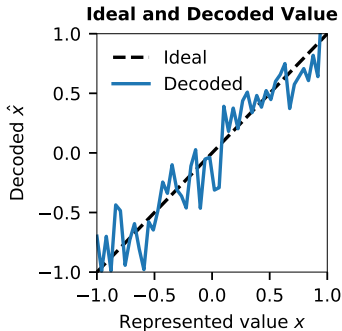
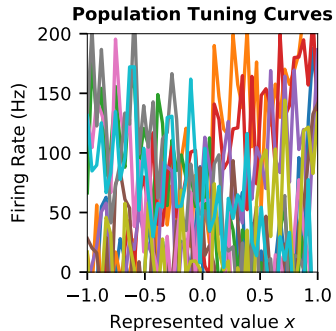
Decoding Without Taking Noise Into Account



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.