Welcome to Neuro 140/240!
Biological and Artificial Intelligence
Welcome to Neuro 140!
Biological and Artificial Intelligence

3 - 4:15 Introduction to biological and artificial intelligence

Please interrupt and ask questions

4:15 - 4:20 Short break

4:20 - 5:00 Class logistics, homework, grading, policies
The last machine we ever need to build

Let an ultraintelligent machine be defined as a machine that can far surpass all the intellectual activities of any man however clever. Since the design of machines is one of these intellectual activities, an ultraintelligent machine could design even better machines; there would then unquestionably be an “intelligence explosion,” and the intelligence of man would be left far behind. **Thus the first ultraintelligent machine is the last invention that man need ever make . . .**

I.J.Good, in *Speculations regarding the first ultra-intelligent machine* (1965)
The Turing Test

The Turing test for vision

Kreiman G. Biological and computer vision. Cambridge University Press 2021
Intelligence is the greatest problem in science

If we understand the brain and we understand intelligence ... we could find ways to make us smarter and to build smart machines to help us think

Tomaso Poggio, MIT
Rapid progress in AI
Example: object recognition

Where are the people in this image?
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A flower, as seen by a computer
Formulation of the visual recognition problem
Emergent properties from simple operations

Neural Networks
1. CONVolutional layer
2. NORMalization layer
3. RELU layer
4. POOL layer
5. Weight changes
6. Dropout
7. Deep architectures
Rectifying linear unit (ReLU)
The convolution operation

\[ f(t) * g(t) = \int_{-\infty}^{\infty} f(\tau)g(t - \tau) d\tau \]
Max pooling
Back-propagating errors

\[ E_{total} = E_{o1} + E_{o2} = 0.5[(target_{o1} - o_1)^2 + (target_{o2} - o_2)^2] \]

\[ o_1 = \frac{1}{1 + e^{-net_{o1}}} \]

\[ net_{o1} = h_1 \cdot w_{ho}(1,1) + h_2 \cdot w_{ho}(2,1) + b_{ho} \]

\[ h_1 = \frac{1}{1 + e^{-net_{h1}}} \]

\[ net_{h1} = i_1 \cdot w_{ih}(1,1) + i_2 \cdot w_{ih}(2,1) + b_{ih} \]
Back-propagating errors

\[ E_{\text{total}} = E_{O_1} + E_{O_2} \]

\[ E_{O_1} = 0.5(\text{target}_{O_1} - o_1)^2 \]

\[ \frac{\partial E_{\text{total}}}{\partial (w_{ho2,1})} = \frac{\partial E_{\text{total}}}{\partial o_1} \frac{\partial o_1}{\partial \text{net}_{o1}} \frac{\partial \text{net}_{o1}}{\partial (w_{ho2,1})} \]

\[ \frac{\partial E_{\text{total}}}{\partial o_1} = 2 \times 0.5 \times (o_1 - \text{target}_{O_1}) \]

\[ \frac{\partial \text{net}_{o1}}{\partial (w_{ho2,1})} = h_2 \]

\[ w_{ho}(2,1) \rightarrow w_{ho}(2,1) - \varepsilon \frac{\partial E_{\text{total}}}{\partial w_{ho}(2,1)} \]
Back-propagation

\[ E_{\text{total}} = E_{O_1} + E_{O_2} \]

\[ E_{O_1} = 0.5(\text{target}_{O_1} - o_1)^2 \]

\[ E_{O_2} = 0.5(\text{target}_{O_2} - o_2)^2 \]
Putting it all together

Object classification
1. Cells
2. Labradors
3. Ants
4. Sports cars
5. Roses
6. Ice
Deep convolutional networks
What can deep convolutional networks do?

0. Handwritten digit recognition

1. Classification of large image datasets

2. Better at face recognition than “superrecognizers” and face forensic experts

3. Better at diagnosing breast cancer than radiologists

4. Better than ophthalmologists at diagnosing diabetes of retinopathy. Also, can extract other information such as cardiovascular disease from images of the eye!

5. Classification of plants, galaxies, etc.

6. Extension to other domains
   7a. Speech recognition
   7b. Sentiment analysis of short texts
   7c. Decision-making in health care
   7d. Automatic translation
   7e. Predictive advertising
   7f. Predicting earthquakes
   7g. Predicting protein structure from aminoacid sequence

What can’t deep convolutional networks do?

A lot!
State-of-the-art AI still fails at many tasks

"pig" + 0.005 x = "airliner"
State-of-the-art AI still fails at many tasks
The most powerful computational devices on Earth

\[ a^n + b^n = c^n \quad a, b, c > 0 \text{ int and } n > 2 \]

“… the great events of the world take place in the brain. It is in the brain, and the brain only, that the great sins of the world take place also.” Oscar Wilde
The most precious devices on Earth

**Figure 1**

Past Year Prevalence of Any Mental Illness Among U.S. Adults (2019)

Data Courtesy of SAMHSA

<table>
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<th>Percent</th>
<th>Overall</th>
<th>Female</th>
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<th>26-49</th>
<th>50+</th>
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*Persons of Hispanic origin may be of any race; all other racial/ethnic groups are non-Hispanic.

**Source:** NIMH


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**Consequences**

10.2 million
Approximately 10.2 million adults have co-occurring mental health and addiction disorders.¹

**Impact**

1st
Depression is the leading cause of disability worldwide, and is a major contributor to the global burden of disease.²

-$193 billion
Serious mental illness costs America $193.2 billion in lost earning every year.³

26%
Approximately 26% of homeless adults staying in shelters live with serious mental illness.¹

24%
Approximately 24% of state prisoners have "a recent history of a mental health condition".⁴

90%
90% of those who die by suicide have an underlying mental illness. Suicide is the 10th leading cause of death in the U.S.⁵

---

1 in 100 (2.4 million)
American adults live with schizophrenia.¹

2.6% (6.1 million)
American adults live with bipolar disorder.²

6.9% (16 million)
American adults live with major depression.³

18.1% (42 million)
American adults live with anxiety disorders.⁴

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**Source:** NAMI

https://www.nami.org/Learn-More/Mental-Health-By-the-Numbers
Biophysics of computation

A neuron has three primary components: dendrites, a cell body, and an axon. The dendrites branch out and receive signals from other neurons and arrive to the cell body. The cell body, the globular structure in the middle, contains the cell's DNA and sends the signals received by the dendrites. The axon is a long projection which transmits the electrical signal using voltage changes and various ion channels. Sometimes making connections at the way at the other end of the synapses, neuron's hypothesis is a Hebbian neuron: $f(\sum_i w_i x_i + b)$.

- $x_0$: axon from a neuron
- $w_0$: synapse
- $w_0 x_0$: dendrite
- $w_1 x_1$: cell body
- $w_2 x_2$: output axon
- $f(\sum_i w_i x_i + b)$: activation function
It takes a village
What is the “right” level of abstraction to discover neurobiological algorithms?
Non-human animals are very intelligent and we should learn from them.
David Hubel and Torsten Wiesel

## Neurobiological inspiration

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<th>Neural Networks</th>
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<td>1. Filtering operations (simple cells)</td>
<td>1. CONVolutional layer</td>
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<td>2. Normalization</td>
<td>2. NORMalization layer</td>
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<td>3. Input-output curves</td>
<td>3. RELU layer</td>
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<td>4. Tolerance (complex cells)</td>
<td>4. POOL layer</td>
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<td>5. Plasticity</td>
<td>5. Weight changes</td>
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<td>6. Synaptic failures</td>
<td>6. Dropout</td>
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</tbody>
</table>
Disruptive new technologies in Neuroscience

1. Circuit level diagrams
2. Recording the activity of many neurons
3. Causally interfering with neural activity
1. Circuit level diagrams
2. Recording the activity of many neurons
3. Causally interfering with neural activity
Disruptive Neuroscience 2: Listening to a concert of lots of neurons

1. Recording from many neurons simultaneously
2. Following neurons over prolonged periods of time


Stringer et al Science 2019
Disruptive new technologies in Neuroscience

1. Circuit level diagrams
2. Recording the activity of many neurons
3. Causally interfering with neural activity
Disruptive Neuroscience 3: Causally interfering with neural activity

Millisecond-timescale, genetically targeted optical control of neural activity.
Boyden, Zhang, Bamberg, Nagel, Deisseroth, Nature Neuroscience 2005
CONSCIOUSNESS AND NEUROSCIENCE

Consciousness is an integral part of our everyday experience. It is the subjective awareness of the world around us, and it is the foundation upon which our thoughts and actions are based. In the realm of neuroscience, the study of consciousness has been a challenging and controversial topic, with many different theories and approaches attempting to explain how our brains generate subjective experiences.

One of the most prominent theories of consciousness is the dual-process theory, which posits that there are two distinct systems in the brain that contribute to our conscious experiences: the automatic system (also known as the non-conscious or sub-conscious system) and the controlled system (also known as the conscious or voluntary system). The automatic system is responsible for quick, intuitive responses to stimuli, while the controlled system is responsible for conscious thought and decision-making.

Another theory is the global workspace theory, which proposes that consciousness arises from the binding together of neural activity in different brain regions. According to this theory, the brain's conscious experience is a result of the integration of information from various sensory and cognitive processes.

Despite the many theories and approaches, the exact mechanisms of consciousness remain elusive. However, recent advances in neuroscience, such as the development of new imaging techniques, have provided valuable insights into the neural underpinnings of consciousness.

In conclusion, the study of consciousness is a complex and fascinating field of study. As our understanding of the brain continues to evolve, we can expect that our understanding of consciousness will also continue to expand.

References:
Ascribing feelings to machines

The Tamagotchi effect

Do you take this robot ... NY Times 19Jan2019

Is it evil to push Atlas?
Perils of AI

1. Redistribution of jobs (akin to but perhaps larger than the Industrial Revolution)
2. Unlikely: Terminator-like scenarios
3. Military applications
4. To err is algorithmic (human too)
5. Biases in training data (note that humans have biases too)
6. Lack of “understanding” (note that we do not necessarily understand how humans make decisions either)
7. Social, mental, and political consequences of rapid changes in labor force
8. Rapid growth, faster than development of regulations
Robots don’t play soccer (yet)

Lionel Messi

GO 2015 Finals: Nao-Team versus B-Human

Robocup 2019 Finals: Nao-Team versus B-Human
Example challenge in AI: Understanding humor
Neuro 140: Biological and Artificial Intelligence

Keywords:
- brain
- AI
- vision
- cortex
- neurons
- sensory
- computational
- artificial
- intelligence
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- human
- natural
- medical