Portions of this slideshow: Philippe Pasquier

Image credit: Memo Akten, *Deep Meditations* (2018)

Current Topics in Interactive Development - IGME 480

RIT

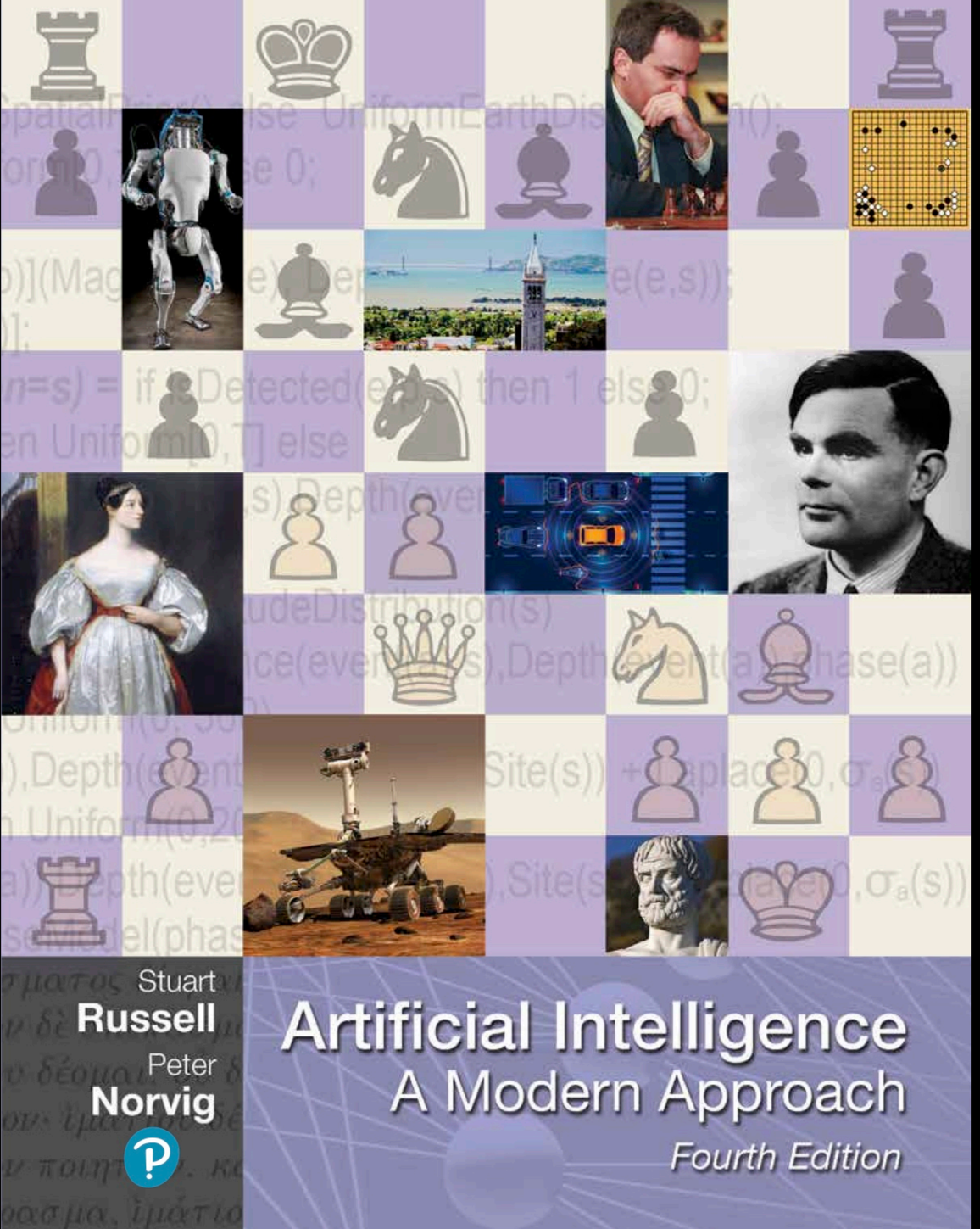
Outline of Today's Lecture

- Artificial Intelligence
- Machine Learning

What is Artificial Intelligence?

What is Artificial Intelligence?

Artificial Intelligence (AI) is a field of study concerned with how agents, situated in an environment (real or virtual) can perceive that environment in some way, take autonomous action and exhibit goal-directed behavior. Typically, intelligent agents also posses the ability to interact and communicate with other agents (including humans).



Russell, S., & Norvig, P. (2020). *Artificial Intelligence: A Modern Approach* (4th edition). Prentice Hall.

“The exciting new effort to make computers think . . . machines with minds, in the full and literal sense.” (Haugeland, 1985)

“[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning …” (Bellman, 1978)

Systems that think and/or act like humans

“The art of creating machines that perform functions that require intelligence when performed by people.” (Kurzweil, 1990)

“The study of how to make computers do things at which, at the moment, people are better.” (Rich and Knight, 1991)

“The study of mental faculties through the use of computational models” (Charniak and McDermott, 1985)

“The study of the computations that make it possible to perceive, reason, and act” (Winston, 1992)

Systems that think and/or act rationally

“A field of study that seeks to explain and emulate intelligent behavior in terms of computational processes.” (Schalkoff, 1990)

“The branch of computer science that is concerned with the automation of intelligent behavior” (Luger and Stubblefield, 1993)

What is Artificial Intelligence?

Some research areas

- **General AI and DAI (Distributed AI)**
  - Autonomous Agents
    - Multi-agent systems
    - Reactive agents (subsumption architecture)
    - Cognitive agents (decision theoretic agents, BDI agents)
    - Hybrid agent architectures
  - Rule-based systems, Expert systems
  - Knowledge representation
- **Machine Learning**
  - Connections approaches (neural networks/deep learning/generative models, SOM)
  - Reinforcement learning
  - Instance-asked learning (KNN)
  - Clustering (K-means, Fuzzy C-means)
  - Probabilistic learning
- **Artificial Life**
  - Evolutionary computing
    - Genetic algorithms
    - Genetic programming
  - Swarm intelligence (flocks, ant colony, stigmergy)
  - Cellular automata
- **Cybernetics and Complex Systems**
  - Emergence, Self-organization, Emergence, Adaptation

What is Artificial Intelligence?

Two Friends with Potted Plant, 1991. Oil on canvas, 60x84 inches.

AARON (Harold Cohen)

Photograph by Becky Cohen

AARON

1975- , Harold Cohen

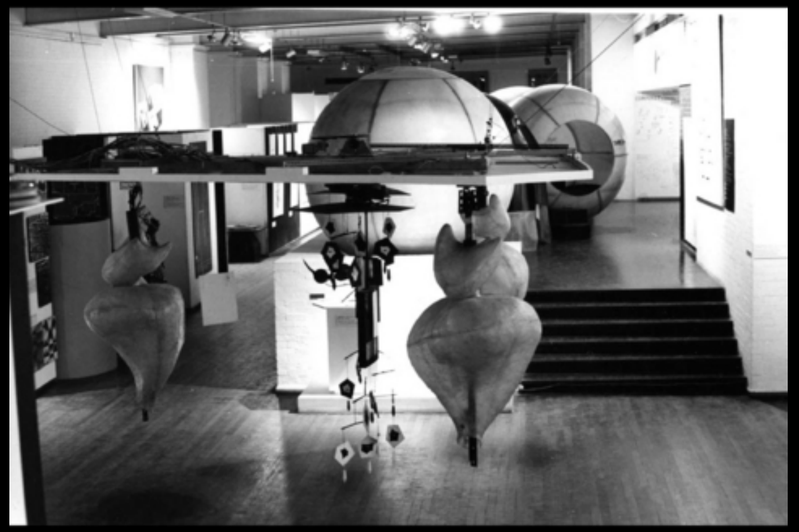
- AARON is a software system developed by Harold Cohen (Professor, UCSD)
- uses AI to generate paintings
- AARON's paintings have been exhibited at the Tate Gallery in London
- Harold Cohen bio: https://visarts.ucsd.edu/people/in-memoriam/harold-cohen.html
- Free (light) version available at: http://www.kurzweilcyberart.com/
    - (also contains a cybernetic poet based on machine learning)

- James Seawright
- *Searcher* (1966)

Light-responsive sculpture
As Seawright describes it, the piece "either seeks or avoids light, depending on the state of internal circuits" (Seawright, 1970, pp. 87-89). However, since the piece both generates and senses light, its resulting behavior is inherently variable and unpredictable as it "frustrat[es] or encourag[es] its own efforts to react to light" (p. 89)

"has a kind of patterned personality... [j]ust as a person you know very well can surprise you, so can these machines"


Colloquy of Mobiles (1968)
Gordon Pask



COLLOQUY OF MOBILES

Gordon Pask

A reactive system composed of 5 rotating mobiles that communicated with each other via light and sound. The goal of communication was to achieve a level of "satisfaction" between the "male" and "female" mobiles. The rotating elements suspended from the ceiling communicated with each other, independent of external influences but people at the exhibition could take part in the conversation between the machines by using flashlights and mirrors to influence the mobiles' learning process.

What is Machine Learning?

What is Machine Learning?

- **What is Learning?**
  - “…to improve automatically with experience…” (Mitchell 1997, pg. 1)
  - The ability to acquire and organize knowledge by building, modifying and organizing internal representations of some external reality.
  - Acquire skills (by gradually improving motor or cognitive skills through repeated practice, sometimes involving little or no conscious thought).
  - Discovering new knowledge by creating hypotheses that explain some data or phenomena
  - The ability to reduce uncertainty about one’s environment

Learning results in changes in behavior that improve competence and/or efficiency.

What is Machine Learning?

Machine learning is a subset of AI concerned with developing computer algorithms that allow machines to **automatically improve through experience**, without being explicitly programmed.

“A computer program is said to **learn** from experience *E* with respect to some class of tasks *T* and performance measure *P*, if its performance at tasks in *T*, as measured by *P*, improves with experience *E* .” (Mitchell 1997)

The ability of machines “to adapt to new circumstances and to detect and extrapolate patterns“ (Russel & Norvig, 2016)

Machine Learning

Introduction to Machine Learning

- How do machines learn? Three basic paradigms:
  - Supervised: a full set of labeled data is provided (i.e. the correct answer) while training an algorithm; the algorithms output is judged as to its correctness; learns a mapping of x to y (x is data, y is label)
  - Unsupervised: data is unlabeled and the algorithm attempts to discern similarities, patterns and differences without any supervision (learns some underlying hidden structure of the data)
  - Reinforcement: an agent learns to achieve a goal by interacting with an uncertain environment using trial and error in order to maximize some notion of cumulative reward (no labeled data used)

Machine Learning

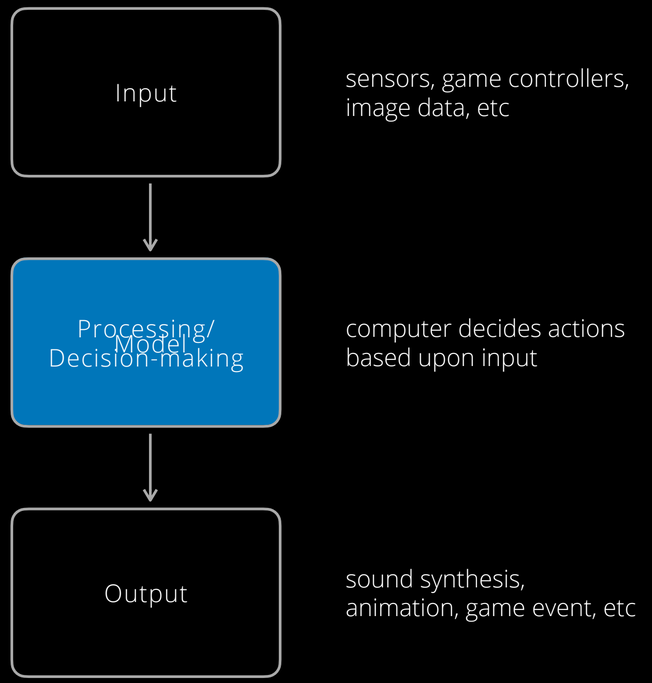
Introduction to Machine Learning

- What kinds of tasks do machines do?
  - Supervised:
    - Classification: assign object/event to one of a given finite set of categories (or “labels”)
    - Prediction/Forecasting (Regression): discerning relationships between input and output variables
  - Unsupervised:
    - Clustering: partition unlabeled examples into distinct subsets, in order to discern similarities within subsets and differences between subsets.
    - Anomaly detection: flagging outliers in a dataset
  - Reinforcement:
    - Problem solving/planning/control: performing actions in an environment in order to achieve a goal

Machine Learning (Pt. 1)

Introduction to Machine Learning

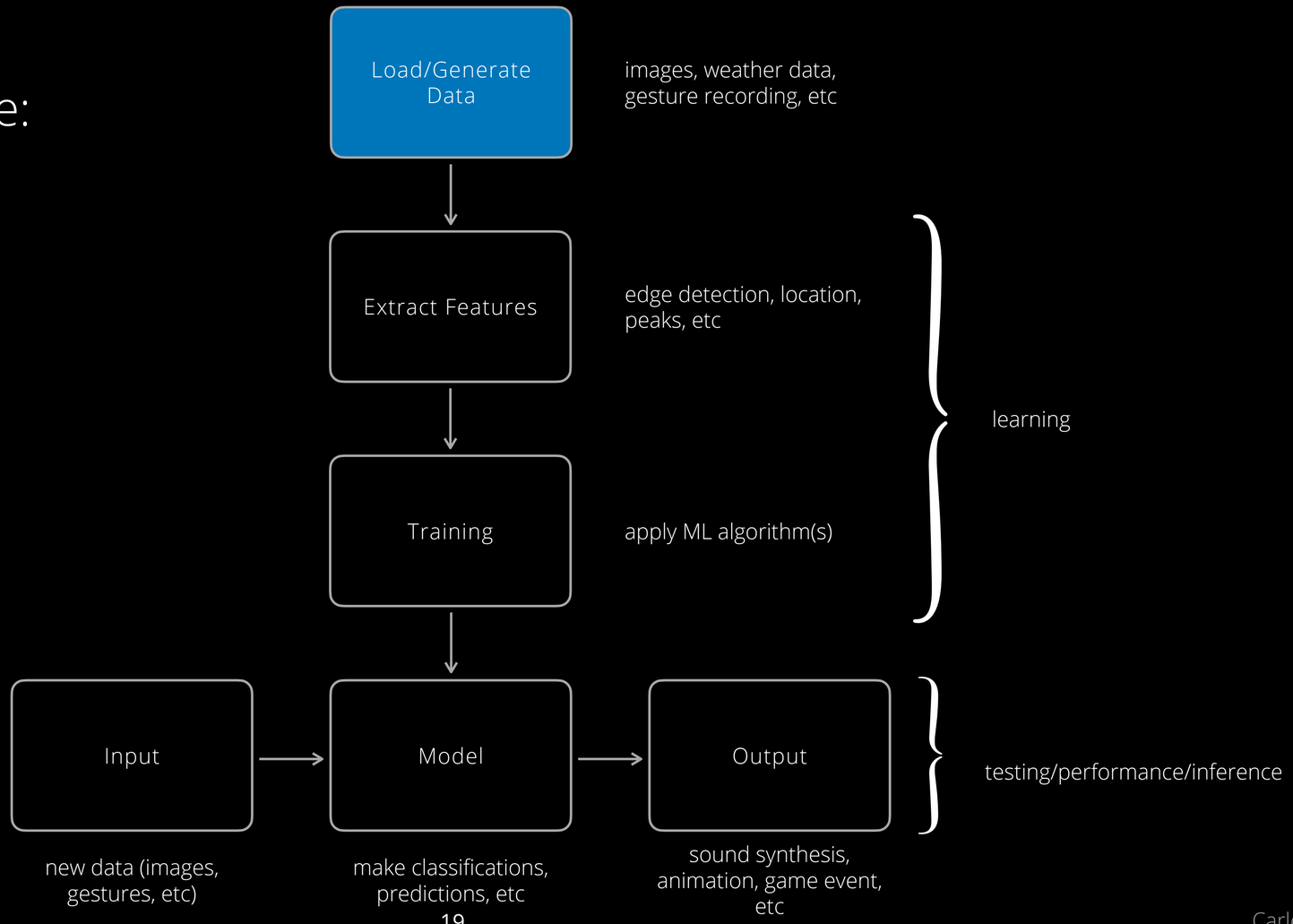
- Machine learning pipeline:



Machine Learning

Introduction to Machine Learning

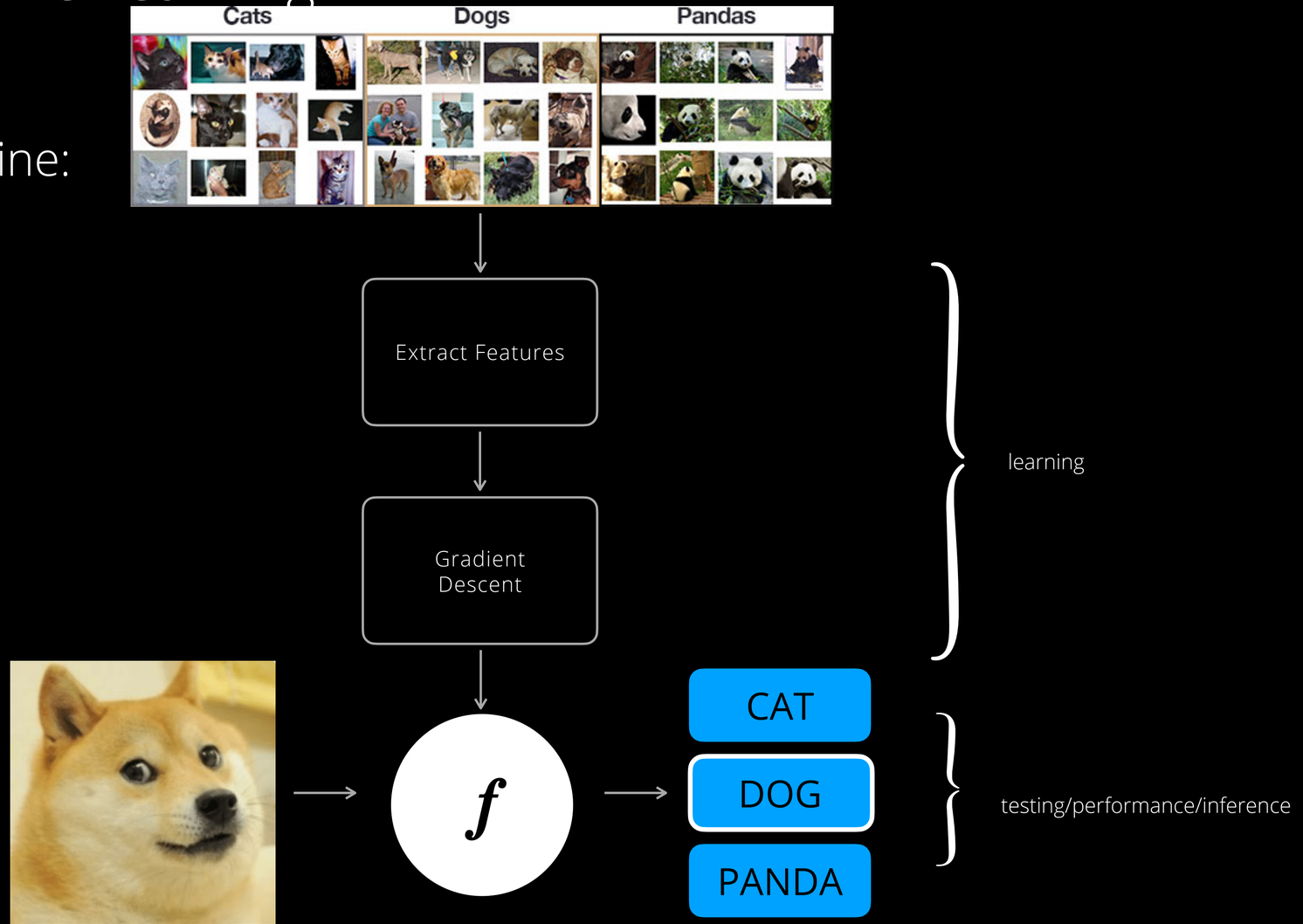
- Machine learning pipeline:



Machine Learning

Introduction to Machine Learning

- Machine learning pipeline:



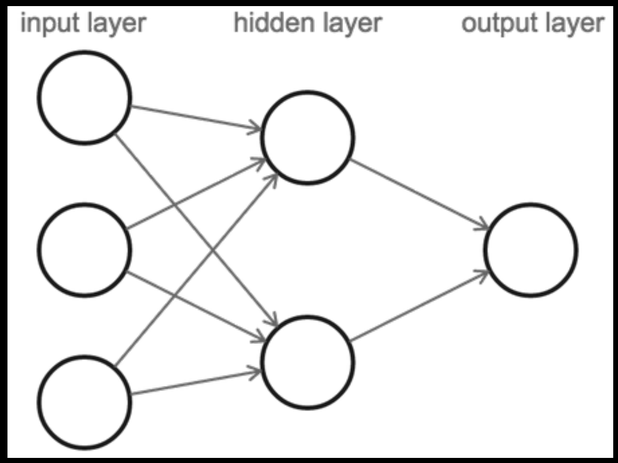
“The original question, ‘Can machines think!’ I believe to be too meaningless to deserve discussion.”

Alan Turing - Turing, A. M. (1950). I.—Computing Machinery and Intelligence. *Mind*, *LIX*(236), 433–460. https://doi.org/10.1093/mind/LIX.236.433

Machine Learning

Introduction to Neural Networks

- What are neural networks (or more specifically, artificial neural networks)?
  - Modeled (somewhat loosely) on biological neurons, neural networks consist of many computational units (each with its own equation), called neurons, connected together (in a network)
  - Model intelligent behavior as an “emergent” property of a large number of simple units rather than from explicitly encoded symbolic rules and algorithms.
  - Neural networks are the paradigm of connectionist systems (connectionism vs. symbolism)



Machine Learning

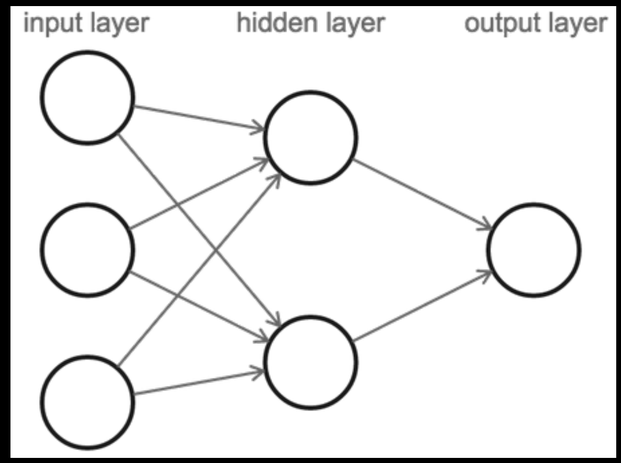
Introduction to Neural Networks

- Many types of neurons and neural networks (too many to list here). For today we will focus on:
  - Perceptron: Initial algorithm for learning simple (single layer) neural networks developed in the 1950's.
  - Feed-forward Networks: More complex algorithm for learning, multi-layer neural networks developed in the 1980's
  - Self-organizing Map: clustering and feature similarities via topological representations

Machine Learning

Introduction to Neural Networks

- Things get interesting when you connect a bunch of neurons together in a network
  - Multi-layer perceptron: input layer -> 1 or more hidden layers -> output layer with with activation being fed forward in the network
  - Hence they are called Multi-layer Feed-forward Networks

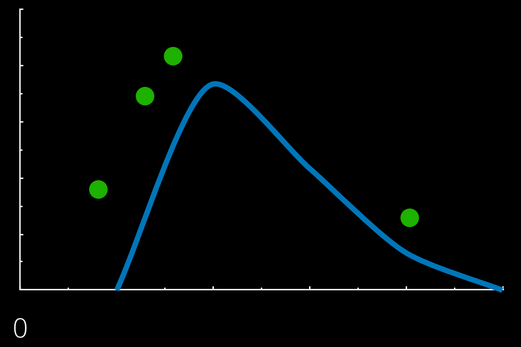


Machine Learning

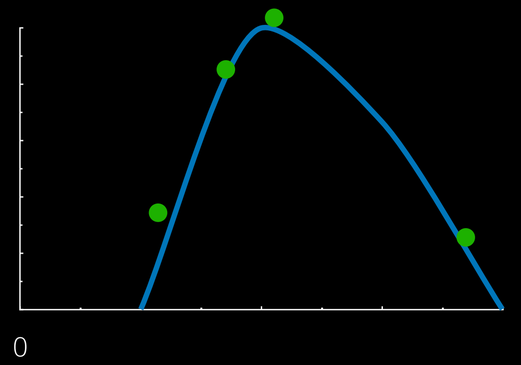
Introduction to Neural Networks

- But how does a neural network actually learn?
  - In order evaluate a candidate solution (i.e. a set of weights), you need to calculate what is known as the loss function (or objective function or cost function) to determine how good a given set of weights are.
  - This means finding values for unknown weights that give the best (usually lowest) loss function score
  - Least squares is a popular loss function, as it rewards models with very small errors

$$(y_1 - \hat{y}_1)^2 + (y_2 - \hat{y}_2)^2 + \ldots + (y_n - \hat{y}_n)^2$$



worse (higher) loss function



better (lower) loss function

Machine Learning

Other Kinds of Machine Learning

- Instance-Based Learning
- Clustering
- Bayesian Learning
- Reinforcement Learning

Machine Learning

Instance-Based Learning

- Instance-based learning techniques construct a general, explicit description of the target function by simply storing the training examples.
- A unique feature of this approach is that any generalization beyond the training data is delayed until a query to the system is made (so there is no real training phase or model constructed). This is distinguished from other approaches where the system tries to generalize the training data before receiving any queries (inference). This is referred to as lazy learning.
- The idea is to determine the class of a query instance given the class of some training instances that are in the neighborhood of the query instance.
- Only used for classification

Machine Learning

Instance-Based Learning

- Instances are points in a multidimensional space (usually Euclidean space)
- A distance metrics function is used for determining the similarity or distance between any two instances. For continuous feature vectors, Euclidian distance is the generic choice:

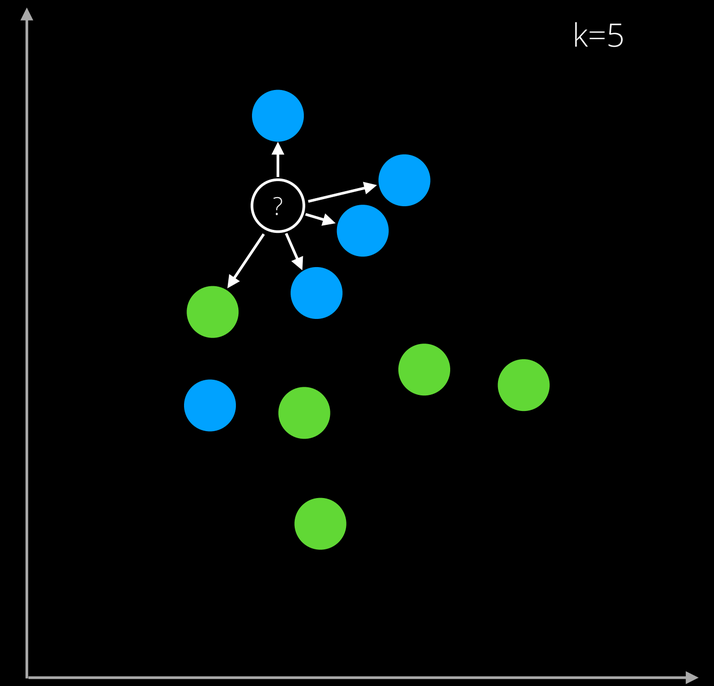
$$d(x_i, x_j) = \sqrt{\sum_{p=1}^{n} (a_p(x_i) - a_p(x_j))^2}$$

Where $a_p(x)$ is the value of the p^{th} feature of example x.

$$\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}.$$

Machine Learning
Instance-Based Learning

- K-Nearest Neighbor
  - Learning by analogy
  - Classification algorithm:
    1. Given an example (*e*), calculate the distance between *e* and all examples in the training set
    2. Select the k closest instances to *e*
    3. Assign *e* to the most common class among its K-nearest neighbors
    4. Return to step 1
  - having K > 1 helps reduce overfitting, making decision boundaries (how it selects a class) less complex (not influenced as much by outlier data points)



Machine Learning
Clustering

- Clustering is the problem of discerning multiple categories in a collection of elements
- A cluster is simply a collection of data points grouped together because of certain similarities.
- Unsupervised clustering is when the categories are not given (i.e. your data is “unlabeled”)
  - Examples:
    - We have the spectrum (frequency information) of 100,000 sounds, are there different types of sounds revealed by their spectrum?
    - We have 15,000 logos, are their different types of logos revealed by their bitmaps?
    - We have thousands of texts, can we group them by thematic similarity?

Machine Learning
Clustering

- K-Means Clustering
  - Each cluster is defined by the centroid (cluster center) of its instances: the average over all the features values
  - Each instance is placed in a cluster according to its distance from each centroid
  - Clusters grow and change shape and their centroids are updated
  - This method is popular because it is simple and relatively computationally efficient.

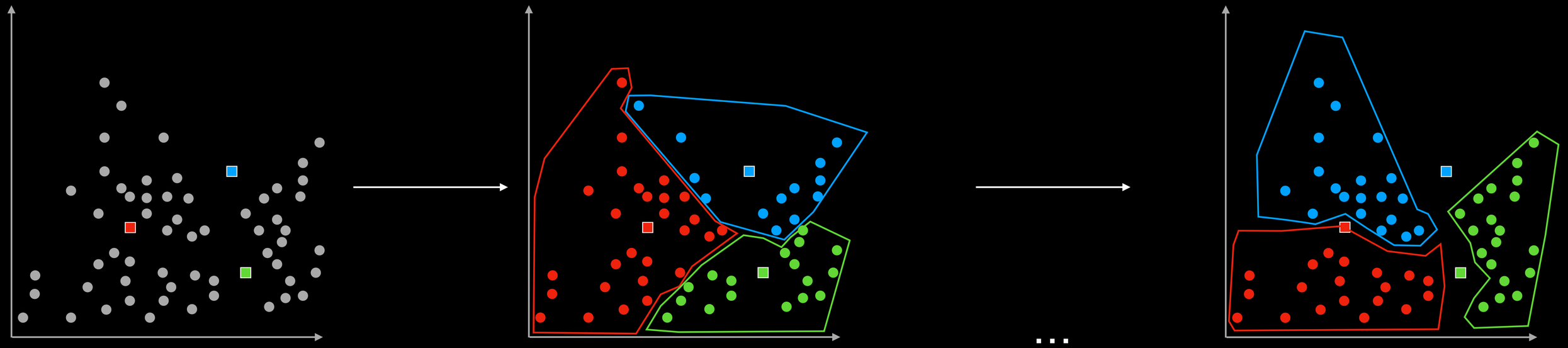
Machine Learning
Clustering

- K-Means Clustering algorithm:
    1. Randomly initialize k centroids for k clusters (number of clusters is defined a priori)
    2. Then for each instance in the dataset:
        i. Calculate the Euclidean distance to each of the centroids
        ii. Assign to the nearest cluster
        iii. Recalculate the centroid for that cluster

        } epoch
    3. Repeat step 2 until none of the instances change cluster (“convergence”)

Machine Learning
Clustering

- Example:



k=3
■■■ = centroids

Machine Learning

Bayesian Learning

- Bayesian Learning uses Bayes' theorem (or Bayes' rule) to determine the conditional probability of a hypotheses given some evidence or observations.
- Bayes' theorem is a mathematical formula used for calculating conditional probabilities
- The idea of Bayesian Learning is to apply Bayes' theorem to learn from the past how to predict the future

$$P(A \mid B) = \frac{P(B \mid A) \cdot P(A)}{P(B)}$$

$P(A)$ = the probability of A occurring
$P(B)$ = the probability of B occurring
$P(A \mid B)$ = the probability of A *given* B
$P(B \mid A)$ = the probability of B *given* A

Machine Learning

Bayesian Learning

- Naive Bayes
  - Formulates a classification decision based upon probabilities (only used for classification)
  - Given the observed feature values for a new instance:
    - What is the probability that it is from class 1, class 2, etc., for all classes

$$P(C_1 \mid x_1, x_2, x_3, \ldots) = ?$$

$$P(C_2 \mid x_1, x_2, x_3, \ldots) = ?$$

x_i are the feature values

  - Computes all these probabilities, then outputs the label for the class with the highest probability
  - It's called "naive" because it assumes that all the features are independent of each other

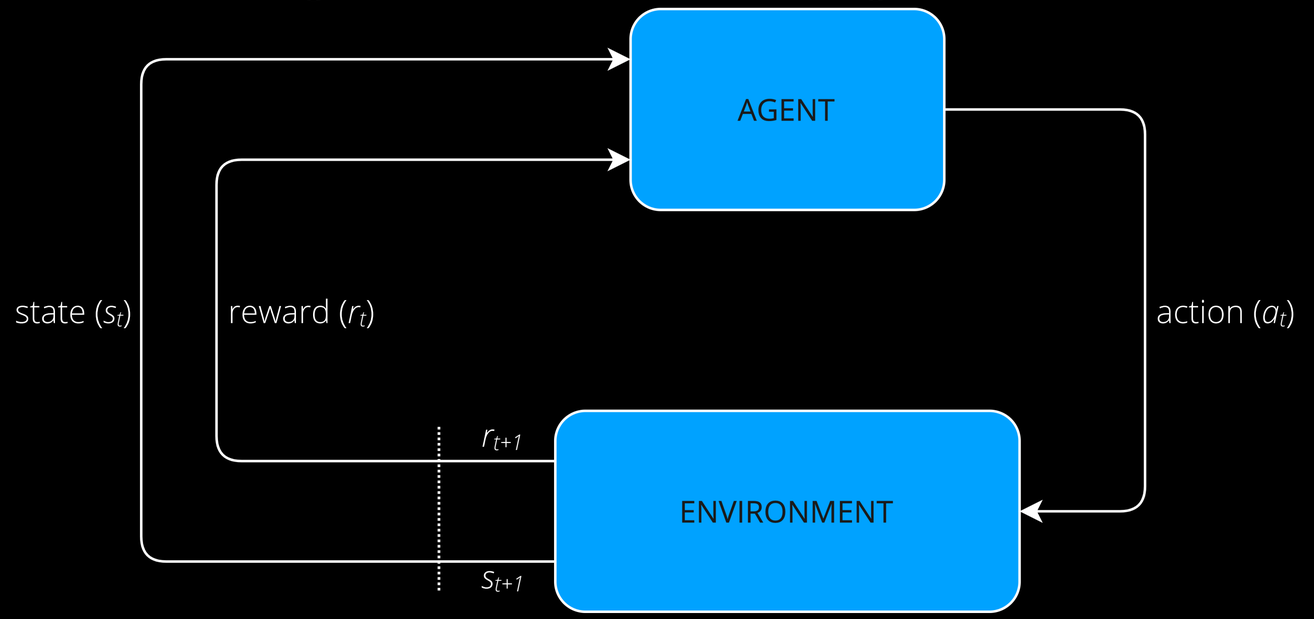
“Consider everything an experiment.”

John Cage - from Ten Rules for Students and Teachers

Machine Learning

Reinforcement Learning

- Reinforcement learning is an area of machine learning concerned with how agents can learn from success and failure in an environment in order to maximize some notion of cumulative reward
- One of the three main paradigms of machine learning (the other two being supervised and unsupervised)



credit: Sutton & Barto (2017)

Machine Learning

Reinforcement Learning

- A RL agent must explicitly explore its environment in order to learn from the consequences of its actions, rather than being explicitly taught. RL agents are not told how to achieve a given task or reach a certain goal but rather are programmed to simply receive rewards or punishments for their actions, to which they must adjust accordingly.
- A RL agent selects its actions on the basis of its past experiences (exploitation) and also by new choices (exploration). To successfully learn then, a RL agent must find a balance between exploration of what is unknown and exploitation of what has already been learned.
- Every RL agent then learns a mapping from states to actions via trial-and-error interactions with a dynamic environment (Harmon and Harmon, 1996). This mapping from perceived environmental states to actions to be taken is referred to as a policy. It can be thought of as the thought process behind picking an action.

Machine Learning

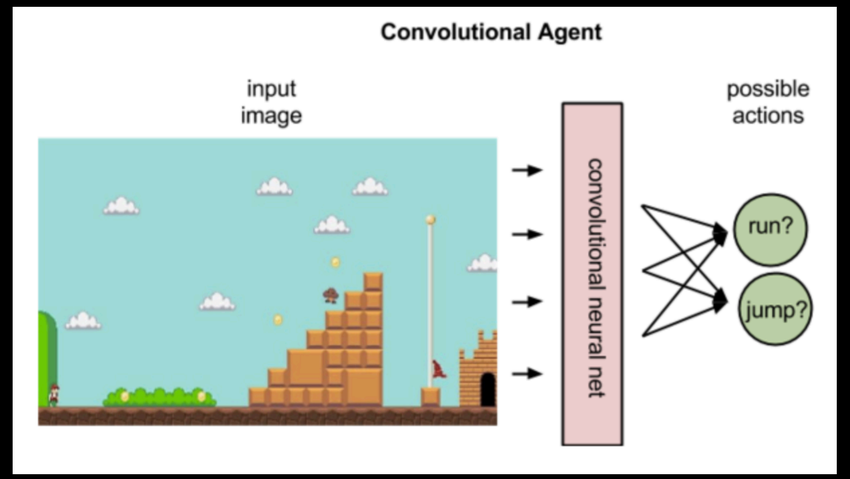
Deep Reinforcement Learning

https://openai.com/blog/gym-retro/

Machine Learning

Deep Reinforcement Learning

- Deep RL combines reinforcement learning with deep NNs
- many RL problems contain high-dimensional data (eg. images or live video) and cannot be solved by “vanilla” RL algorithms
- policy is often represented as a neural network
- an action is taken in the environment and a reward (negative or positive) is used to update the weights

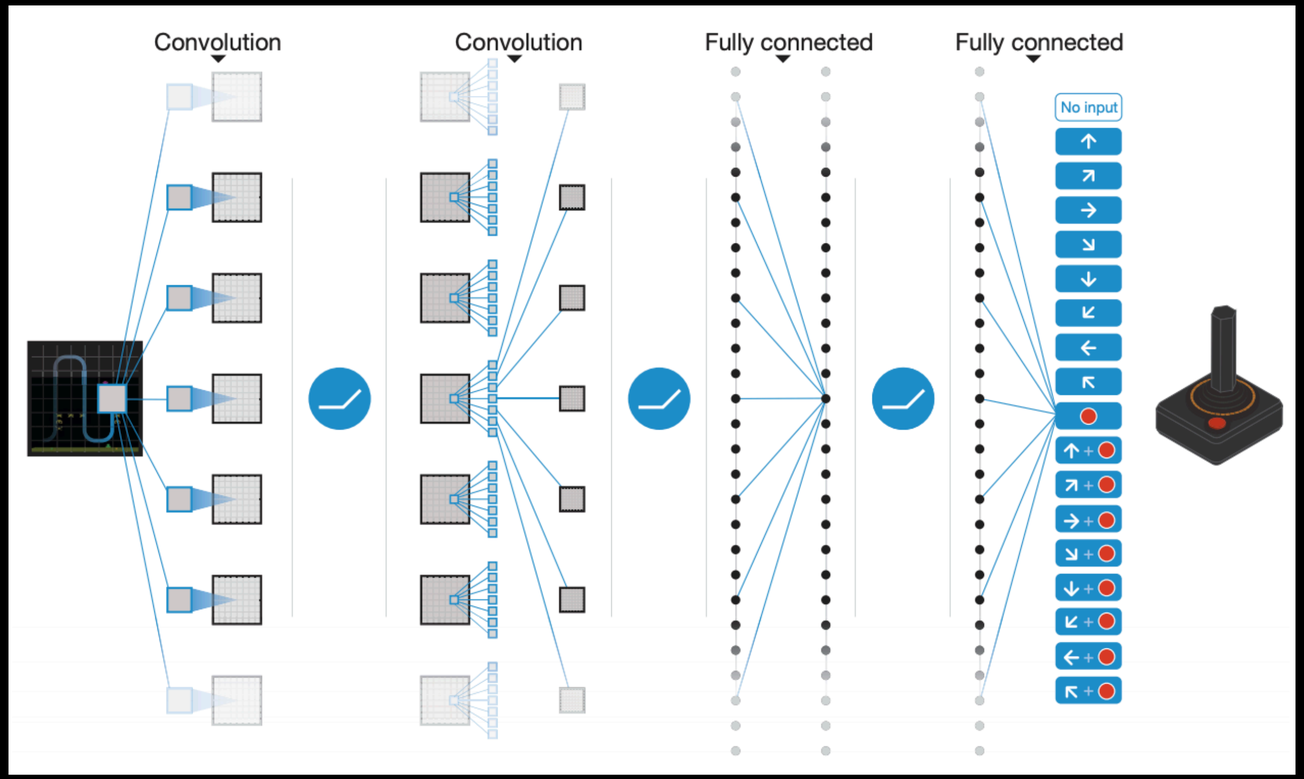


https://wiki.pathmind.com/deep-reinforcement-learning

Machine Learning

Deep Reinforcement Learning

Deep Q-Learning



https://storage.googleapis.com/deepmind-media/dqn/DQNNaturePaper.pdf

“We know not through our intellect but through our experience.”

Maurice Merleau-Ponty