Introduction

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- Intelligence is essential to us. We call ourselves *Homo sapiens*—man the wise
- Our brain can perceive, understand, predict, and manipulate a world, which is one of the greatest scientific mysteries

- Artificial Intelligence: build an intelligent agent that can perceive and perform in its environment, while optimizing its outcome

- One of the most interesting and fastest-growing fields (especially in the last decade)
- Over a trillion dollars a year in revenue (= Netherlands's GDP, 17th in the world)
- AI expert Kai-Fu Lee predicts AI's impact will be "more than anything in the history of mankind"
- Not like other fields such as physics, AI research is still wide open

- By 2019, AI has reported to exceed human-level performance on various domains.
- Computer vision: ImageNet object detection
- Language processing: speech recognition in a limited domain
- Biology: skin cancer detection, prostate cancer detection, protein folding, and diabetic retinopathy diagnosis
- Games (classic and video): chess, Go, poker, Pac-Man, Jeopardy!, Quake III, Dota 2, StarCraft II, various Atari games

- Major improvements have been achieved in many other domains: autonomous vehicles (ground and air), planning and scheduling, recommendations, medicine discovery, climate change, ...

- These successes have stimulated huge interest in AI in both academia and industry
- AI papers increased 20-fold between 2010 and 2019 to 20,000 a year; The most popular category is machine learning
- Course enrollment increased 5-fold in the U.S. and 16-fold internationally from a 2010 baseline. AI is the most popular specialization in CS
- AI startups increased 20-fold in the U.S. to over 800
- Machine Learning (especially Deep Learning) is responsible for most of these developments

- Supervised learning
- Reinforcement learning
- Unsupervised learning

- Supervised Learning and Reinforcement Learning contribute to most successes
- Computer vision: ImageNet object detection
- Language processing: speech recognition in a limited domain
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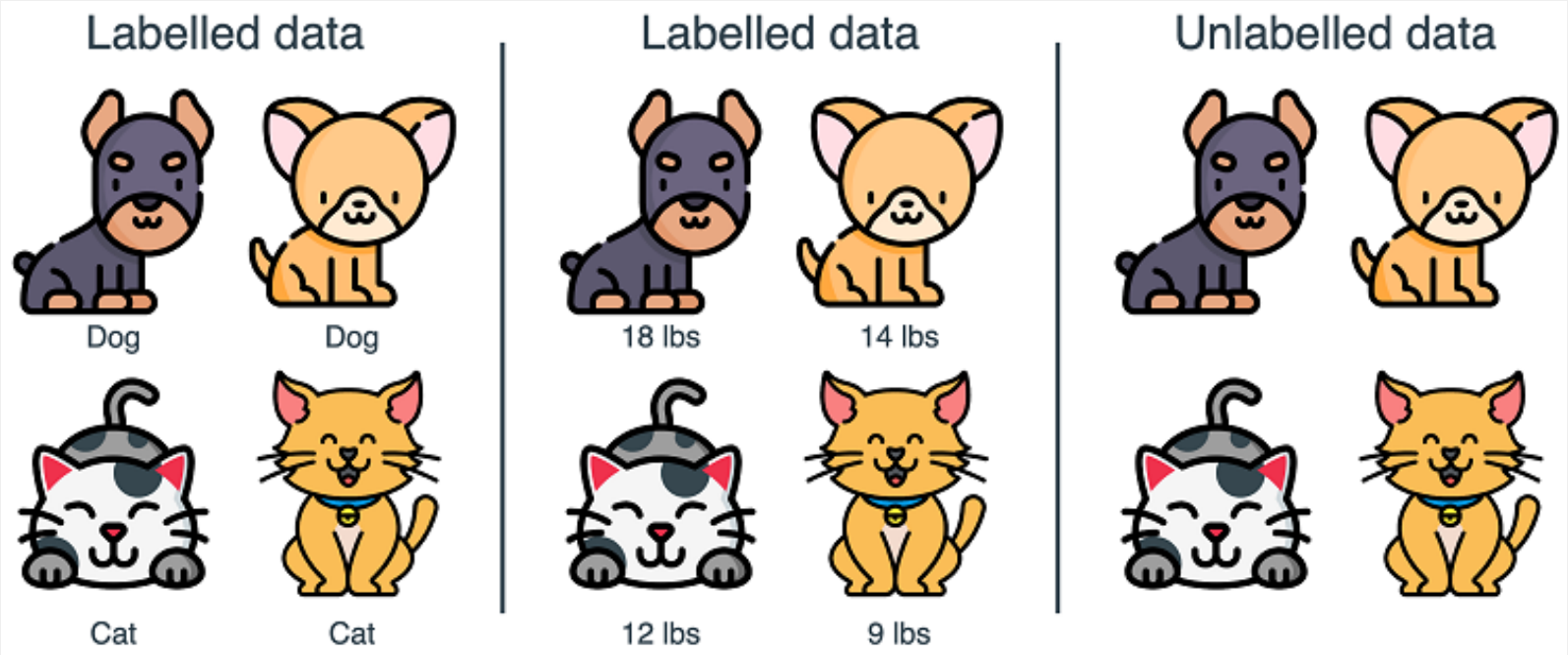
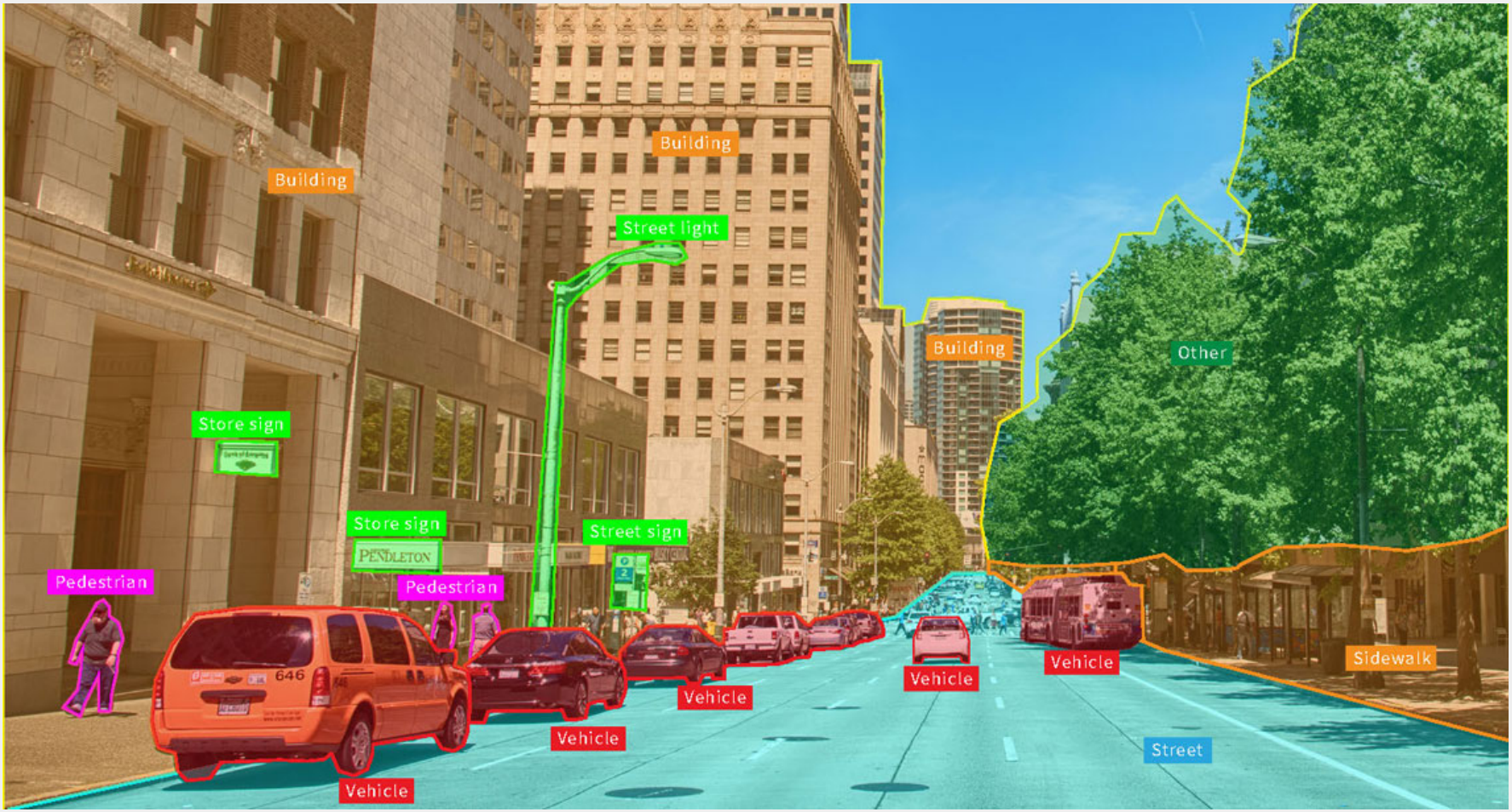
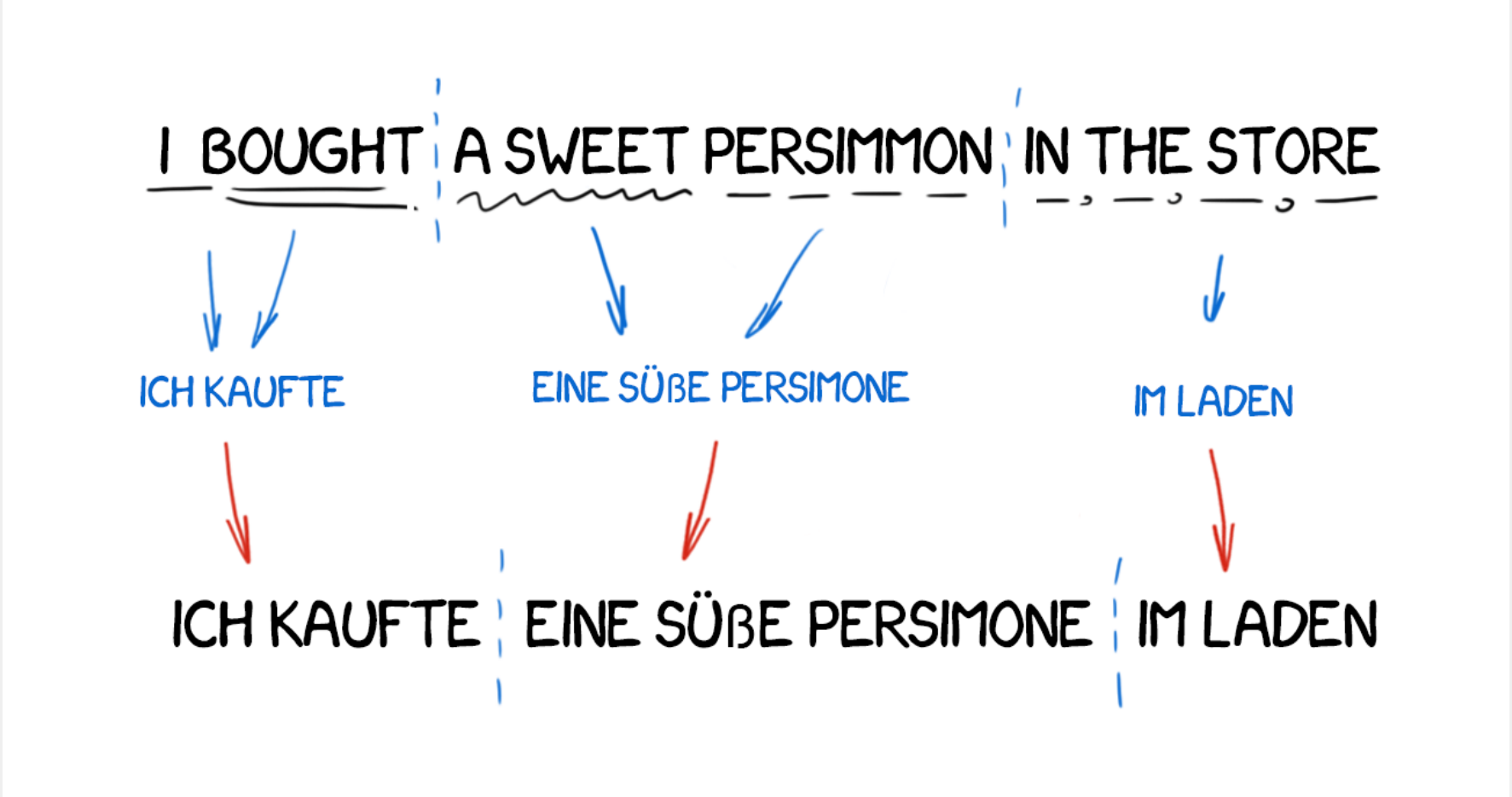
- Uses labelled data, hence "supervised"



Supervised Learning: Labelled Data




I BOUGHT
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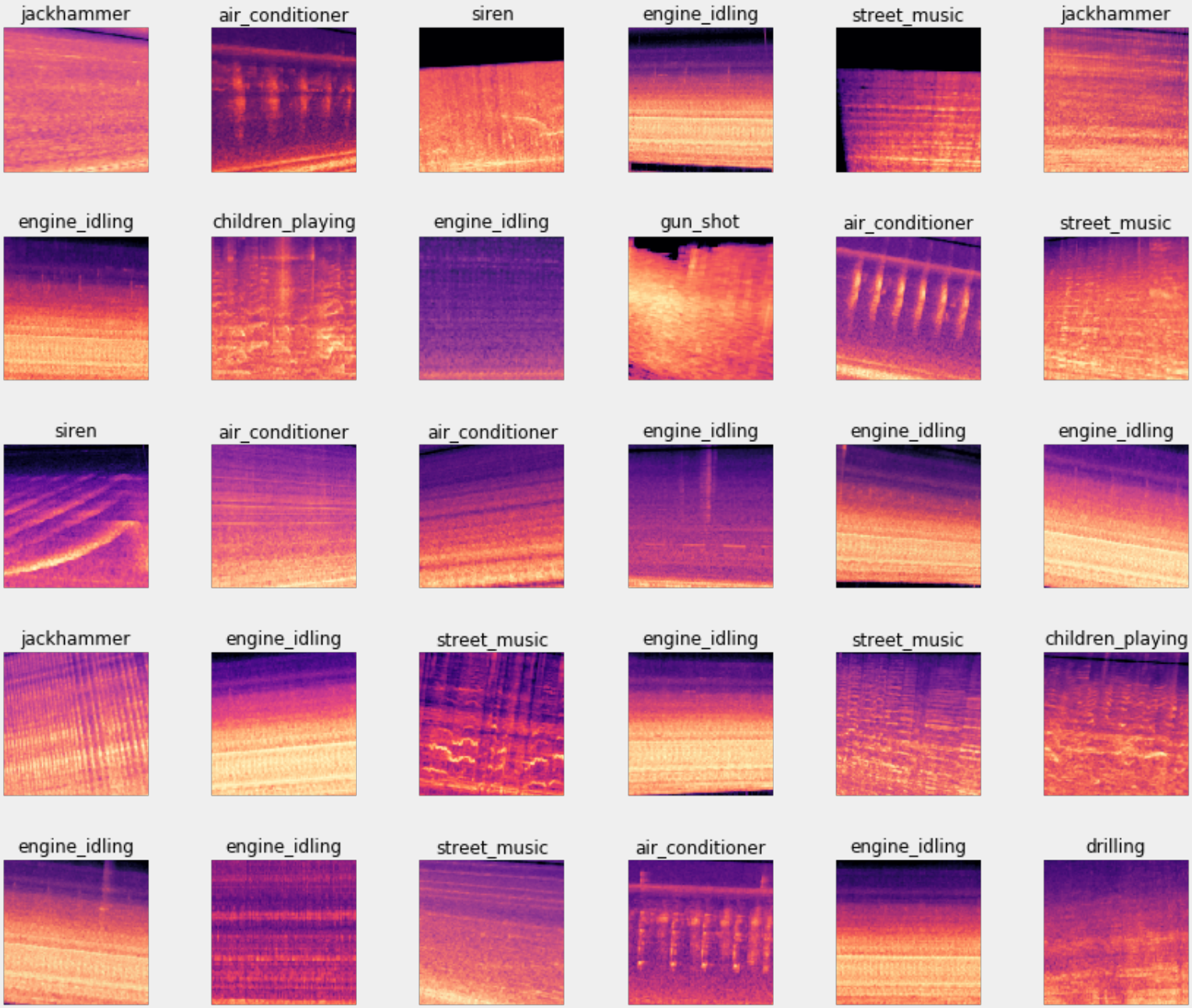
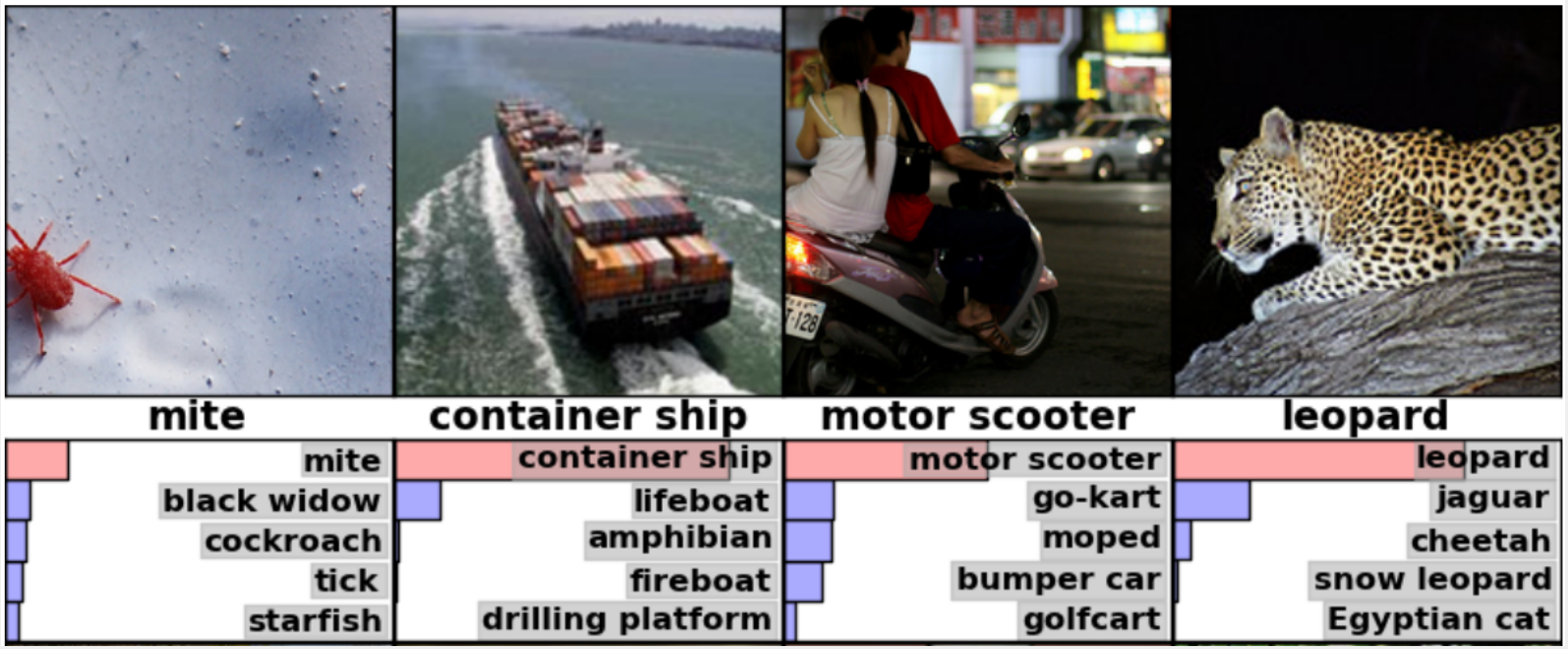
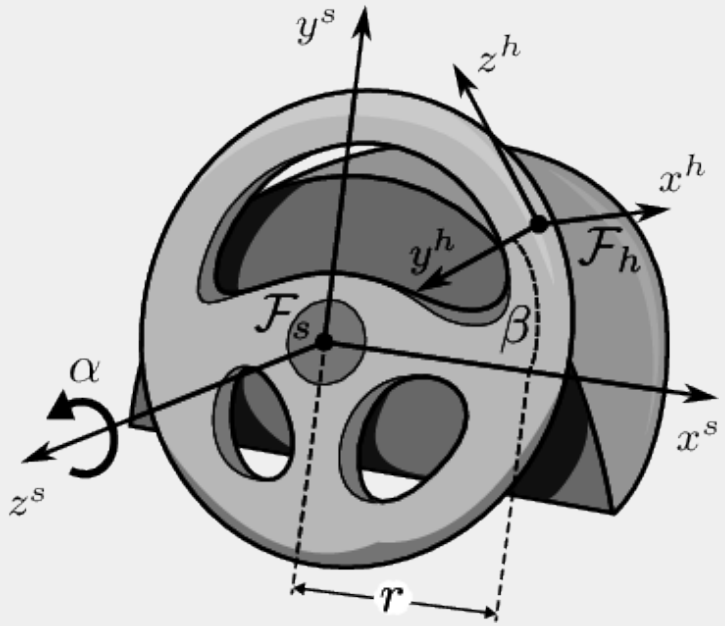
Supervised Learning: Labelled Data



- Classification: predict categorical labels (discrete values)
- E.g., ImageNet: 1,000 object classes (categories), 1M+ images, labels are crowd-sourced



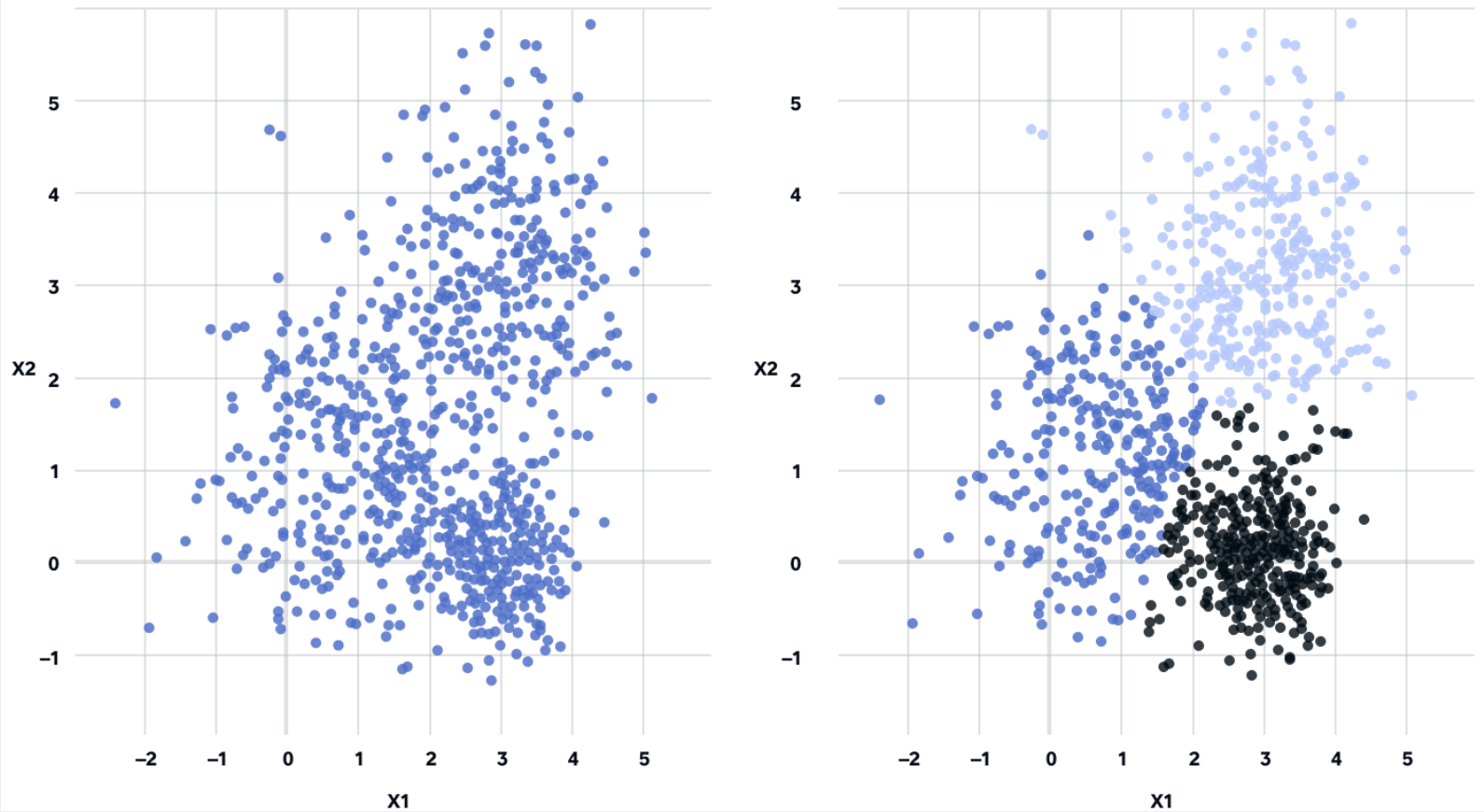
- Regression: predict numerical labels (continuous values)
- E.g., stock price, temperature, continuous control commands, etc.



- Training set: train a model
- Validation set: tune a model through its hyperparameters
- Test set: test a model
- Example ratio: 6:2:2

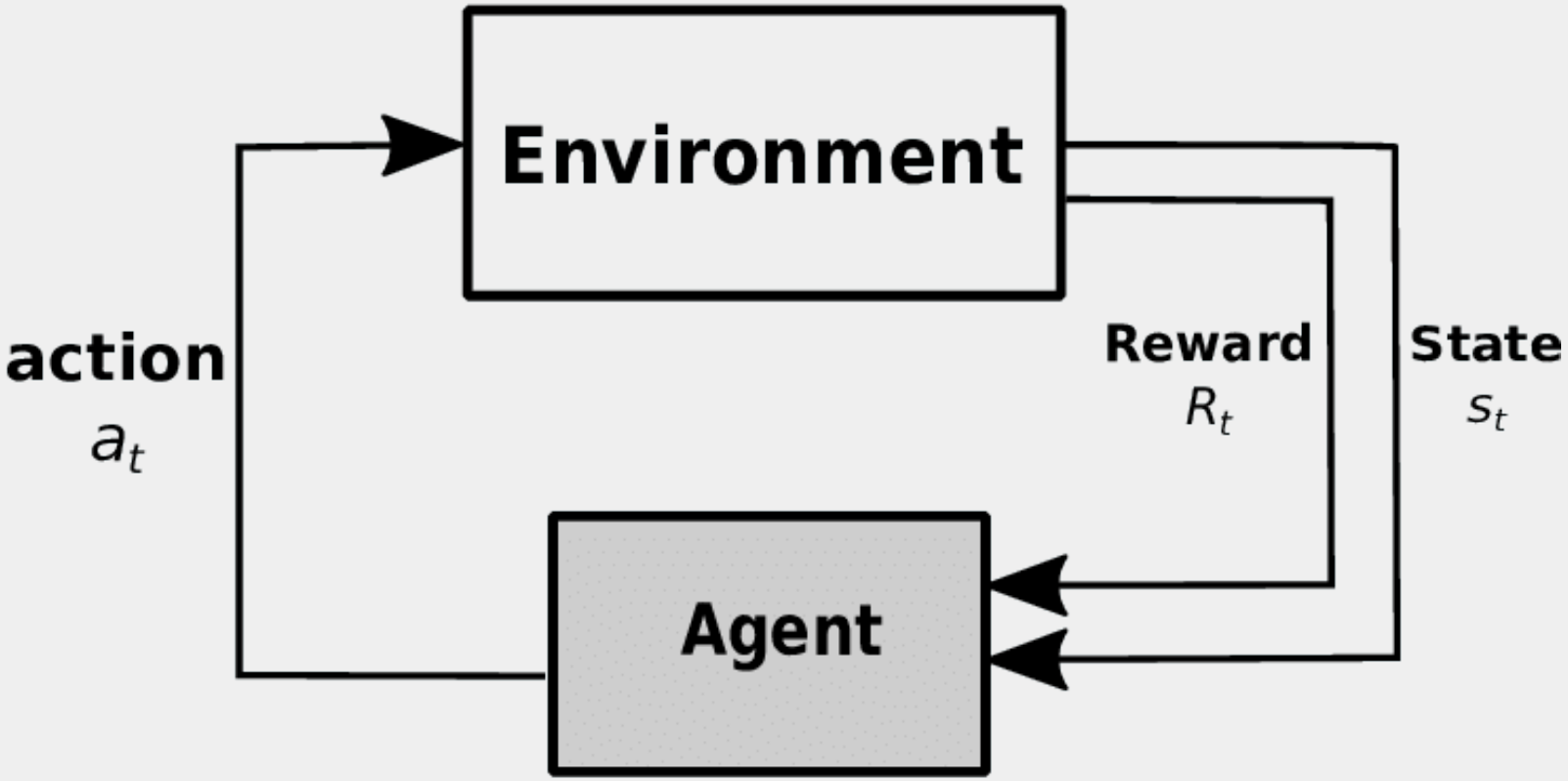
- Assumption 1: training and test data are from the same distribution (the distribution is usually unknown)

- Assumption 2: training and test data are i.i.d. (independent and identically distributed)

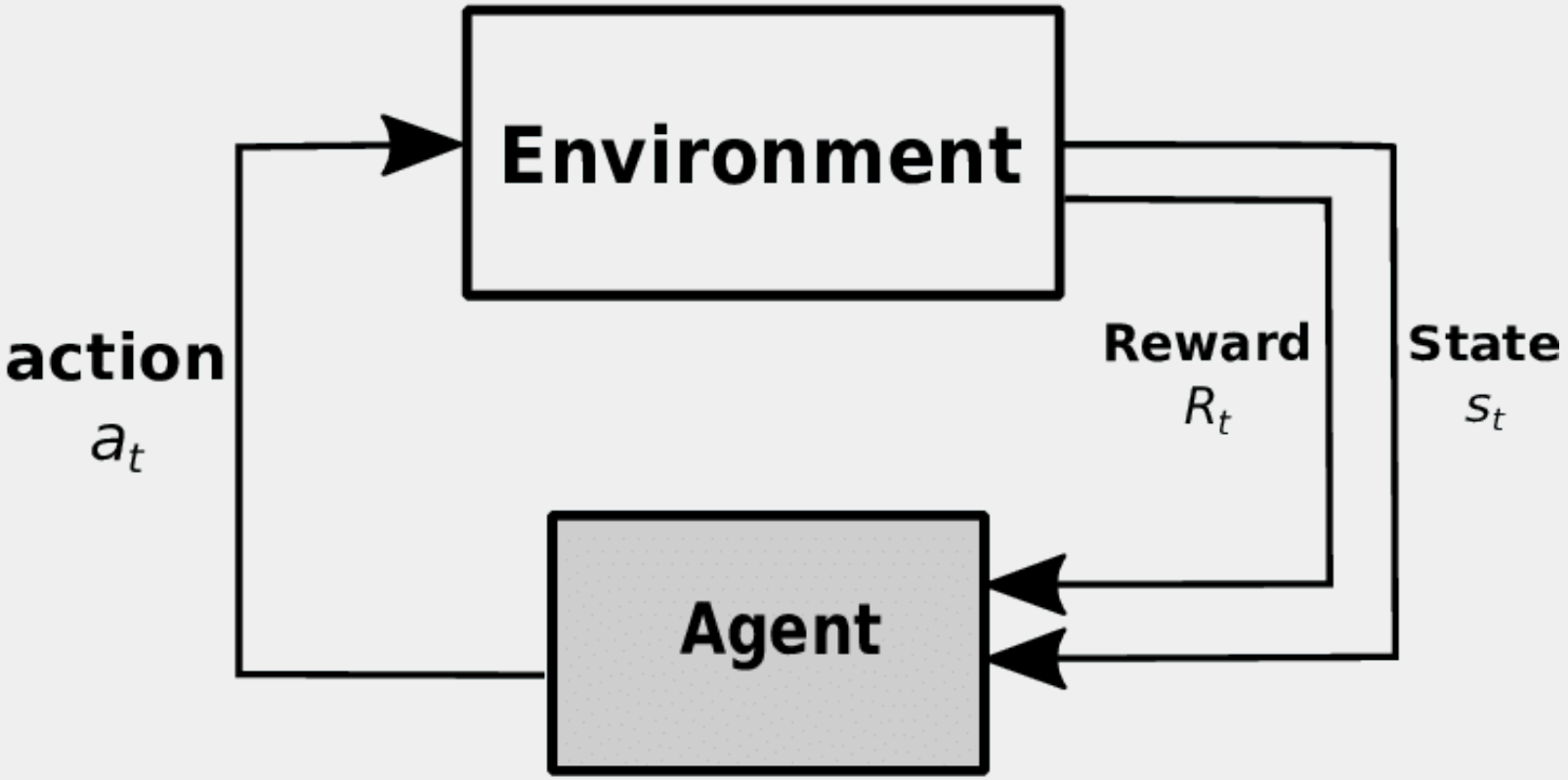


- Note: non-i.i.d. data may or may not break supervised learning

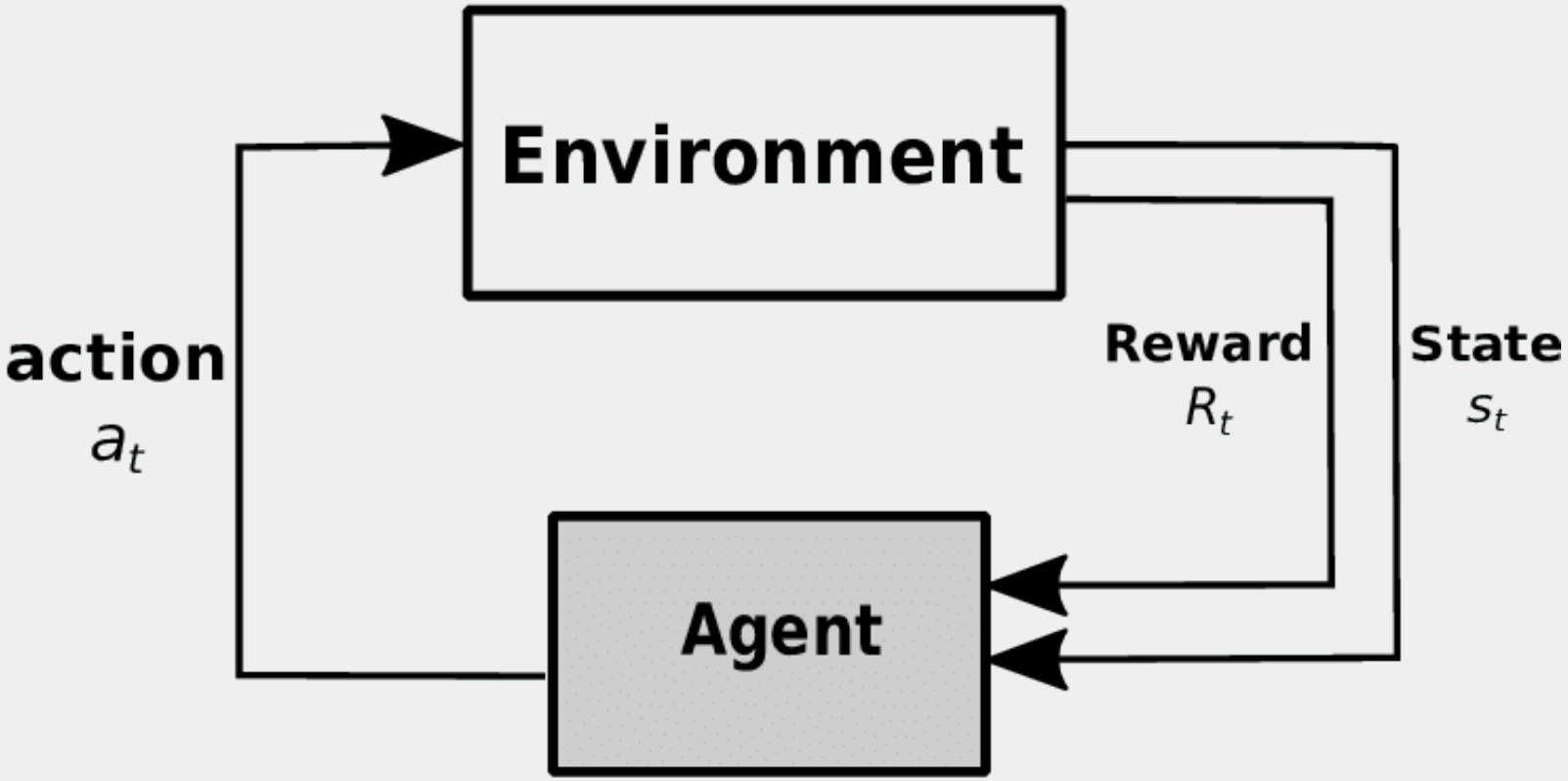
- Sequential decision making: interactions between Agent and Environment



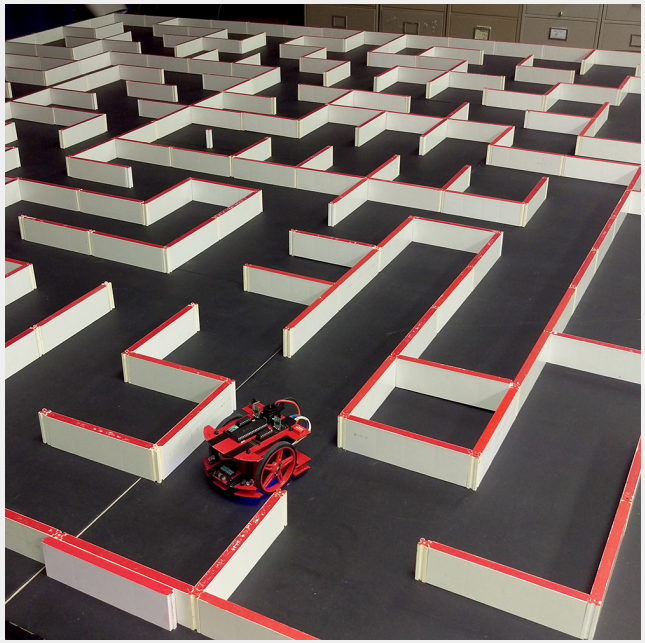
- Agent chooses an action to execute in the current state of Environment



- Environment provides reward to Agent and transits Agent to the next state



- Agent perceives its environment, performs a sequence of actions, observes their "rewards," and learns an optimal policy
- E.g., Go, robot and maze, Atari game, etc.

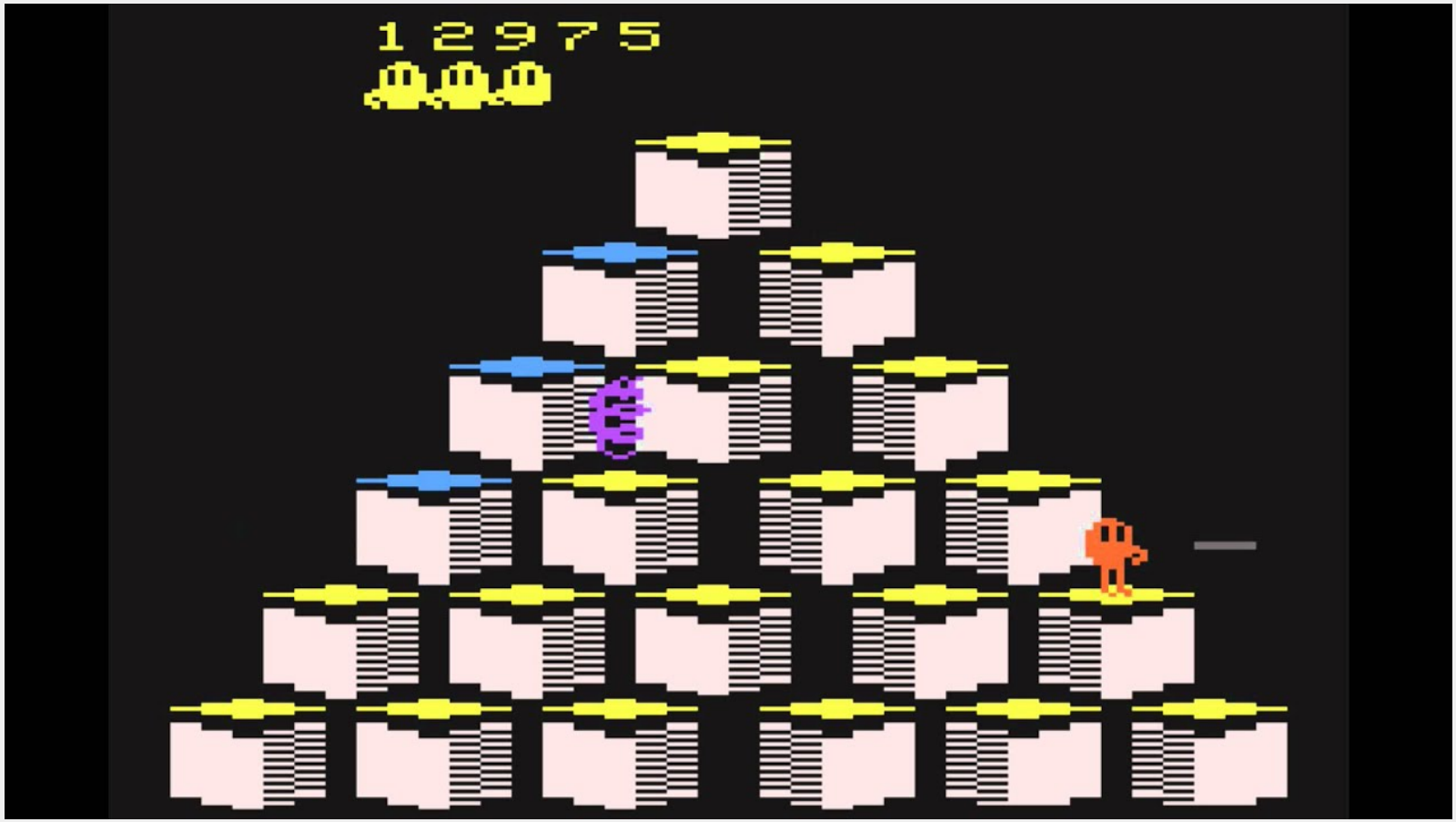


- Supervised learning
  - Solve the recognition problem
  - Assume i.i.d. data
  - Cannot pass human performance (i.e., ground truth)
    - Although for ImageNet: human 5% error, best model 3.57% error
- Reinforcement learning
  - Solve the decision problem
  - Learn via trial and error, no explicit supervisor only indirect, delayed feedback
  - Action order (time) matters $\rightarrow$ non-i.i.d. data
    - E.g., autonomous driving via a front-facing camera (image at t affects action at $t+1$ then affects image at $t+1$)
  - Superhuman potential

- Pros:
  - powerful (if works)
  - supervised learning is easy to set up, even without domain knowledge
- Cons:
  - blackbox (no human-interpretable features)
  - difficult to defend adversarial attacks
  - data hungry
  - computation intensive
  - hyperparameter search is tedious

- Steering angle prediction = 90k images + 3080 (GPU) + 16 hours

- Q-bert: DQN (algorithm) + 3070 TI (GPU) + 2–3 hours



- Atari games (link)
- AlphaZero (link), AlphaGo documentary (link)
- AlphaStar (link)
- AlphaFold (link)
- OpenAI Five (link)
- Hide and Seek (link)
- Rubik's Cube (link)
- Gran Turismo 7 (link)

- Weizi Li, David Wolinski, Julien Pettré, and Ming C. Lin, "Biologically-Inspired Visual Simulation of Insect Swarms," Computer Graphics Forum (Proc. Eurographics), 34(2):425–434, 2015.