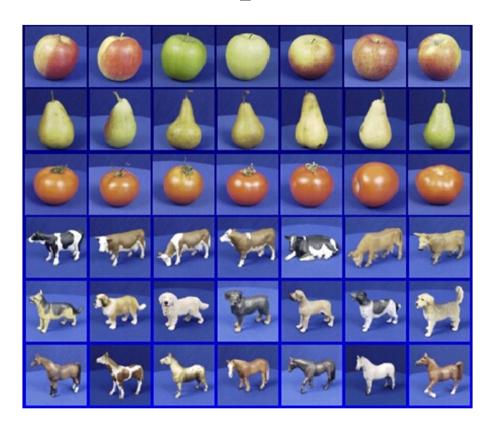# Machine Learning

What is Machine Learning?

- The real question is what is learning?
  - Using past experiences to improve future performance.

- For a machine, experiences come in the form of data.

- What does it mean to improve performance?
  - Learning is guided by an objective, associated with a particular notion of loss to be minimized (or, equivalently, gain to be maximized).

- Why machine learning?
  - We need computers to make informed decisions on new, unseen data.
  - Often it is too difficult to design a set of rules "by hand".
  - Machine learning is about automatically extracting relevant information from data and applying it to analyze new data.

What is the Learning Problem?

- Learning = Improving with experience at some task

  – Improve over task T

  – with respect to performance measure P

  – based on experience E

Example - Visual Object Categorization

We are given categories for these images: What are these?

- A classification problem: predict category y based on image x.
- Little chance to "hand-craft" a solution, without learning.
- Applications: robotics, HCI, web search (a real image Google...)

Supervised Learning

Supervised learning consists of the following basic steps:

Data Collection - Start with training data for which we know the correct outcome provided by a teacher or oracle. In this case: images for which we know the object category.

Representation - Choose how to represent the data.

Modeling - Choose a hypothesis class - a set of possible explanations for the connection between images and categories. This is our model of the problem.

Estimation - Find best hypothesis you can in the chosen class.

Model Selection - We may reconsider the class of hypotheses given the outcome.

Each of these steps can make or break the learning outcome.

Example - Document Classification

- A few labeled web pages with categories: faculty, student, department, course etc.

- Need to automatically classify previously unseen web pages.

- What would be good features to represent these data?

- Feature selection methods allow

Applications of Learning

- Computer vision and robotics:
  - detection, recognition and categorization of objects
  - face recognition
  - tracking objects (rigid and articulated) in video
  - modeling visual attention
- Speech recognition
- Biology and medicine:
  - drug discovery
  - computational genomics (analysis and design)
  - medical imaging and diagnosis
- Financial industry:
  - Fraud detection
  - Credit approval
  - Price and market prediction
- Information retrieval, Web search, Google ads...

Some Issues in Machine Learning

- What algorithms can approximate functions well and when?

- How does number of training examples influence accuracy?

- How does complexity of hypothesis representation impact it?

- How does noisy data influence accuracy?

- What are the theoretical limits of learnability?

- How can prior knowledge of learner help?

- What clues can we get from biological learning systems?

- How can systems alter their own representations?