Chapter 8: Computers That Learn And Adapt

CS105: Great Insights in Computer Science

More Than A Program

• Usually, we think a program is something written by an experienced person.

• Often, the program isn’t complete without “experience” of its own.

• Example: If I had to write a compression program, I could do ok. But, using the character-count statistics from the Gettysburg Address makes it possible to produce the most compact code.
**Machine Learning**

- *Machine learning* is the idea of writing programs that use data (experience) to create better programs than people can write directly.

- *Supervised learning* is a specific problem in which the experience is in the form of labeled examples and the learning system needs to learn to label novel examples.

**Classification: Idea**

- In its simplest form, a learner’s job is to produce a *classifier*.

- A classifier takes objects as input and assigns each one to a *class*.

- Most simply, objects are represented as *vectors of features* and classes are 0/1.
Future Killer?

Example Classifier

- **Input**: A high school student
- **Output**: Will the student drop out of college?
- **Vector of Features**: Score on SATs, grades in Math/English/Science, age, parent’s income, years at current address, height
- **Such a classifier** might be useful as a tool for admissions or financial aid.
Learning: The Problem

- **Input**: A *training set* consisting of *labeled instances*, each of which is a feature vector and a desired class (1 = yes, 0 = no).
- **Output**: A classifier, which we hope will accurately assign new feature vectors to classes.
- A *learning algorithm* is a program that addresses this problem.

Informal to Formal

- Note that problem is not really defined at this point! Whether it does well on new examples isn’t directly measurable.
- One way to make it formal: find classifier with minimum number of mistakes on the training set.
- Usually not enough to create good classifiers: *overfitting*. 
Learning Algorithms

- Decision trees
- Boosting
- Nearest neighbors
- Support Vector Machines
- Neural networks
- Naive Bayesian classifiers
- etc.

Some Applications

- Autonomous driving (camera ⇒ steering wheel)
- Loan applications (age, income ⇒ default?)
- Handwriting recognition (scanner ⇒ digits)
- Speech recognition (audio ⇒ phonemes)
Decision Trees

- Decision trees are another kind of classifier.
- Branch depending on test on attribute value.
- Can build such a tree incrementally and automatically using examples.

ML & Robotics

- Machine learning is almost always grounded in measurable data.
- Computer programs that can collect and use their own data can be quite powerful.
- Essentially, that’s what learning robots are.
- International conference at Rutgers on Epigenetic Robotics!
While True

- What sorts of program would *purposely* have an infinite loop?
- Think about a software-controlled thermostat. It might have a program that looks something like:

```python
def thermostat(low, high):
    while True:
        t = currentTemp()
        if t >= high:
            runAC(4)
        elif t < low:
            runHeat(2)
```

Loop Forever

- operating systems
- user interfaces
- video games
- process controllers
- robots
Robot Basics

• From a software standpoint, modern robots are just computers.
• Typically, they have less memory and processing power than a standard computer.
• Sensors and effectors under software control.

Standard Robots

• Industrial manufacturing robots.
• Research /hobby robots.
• Demonstration robots.
• Home robots.
• Planetary rovers.
• Movie robots.
Manufacturing

- Often arms, little else.
- Part sorting.
- Painting.
- Repeatable actions.

Research / Hobby

- Pioneer
- Handy Board / Lego
- Segbot
- Stanley
Space Exploration

- Sojourner
- Deep Space Agent

Home Robots

- Roomba.
- Mowers.
- Moppers.
- Big in Japan.
- Nursebots.
- Emergency rescue bots, Aibo.
Demonstration Robots

- Honda: Asimo.
- Toyota: lip robot.
- Sony: QRio.

Sensors and Effectors

Sensors:
- bump
- infrared
- vision
- light
- sonar
- sound

Effectors:
- motors
- lights
- sounds
- graphical display
- laser
Simple Learning

- Words: “hello”, “don’t do that”, “sit”, “stand up”, “lie down”, “shake paw”

Trainer: In Words

- For each recognized voice command, there is an associated action program.
- When a voice command is recognized, the corresponding action is taken.
- On “Good Aibo”, nothing needs to change.
- On “Don’t do that”, the most recent command needs a different action program. It is incremented to the next on the list.
Impressive Accomplishment

Honda’s Asimo

- development began in 1999, building on 13 years of engineering experience.
- claimed “most advanced humanoid robot ever created”
- walks 1mph

And Yet…

Asimo is programmed/controlled by people:

- structure of the walk programmed in
- reactions to perturbations programmed in
- directed by technicians and puppeteers during the performance
- no camera-control loop
- static stability
Compare To Kids

Molly
- development began in 1999
- “just an average kid”
- walks 2.5mph even on unfamiliar terrain
- very hard to control
- dynamically stable (sometimes)

Crawl Before Walk

Impressive accomplishment:
- Fastest reported walk/crawl on an Aibo
- Gait pattern optimized automatically
Human “Crawling”

Perhaps our programming isn’t for crawling at all, but for the *desire for movement*!

My Research

How can we create smarter machines?
- Programming
  - tell them exactly what to do
  - “give a man a fish...”
- Programming by Demonstration (supervised learning)
  - show them exactly what do do
  - “teach a man to fish...”
- Programming by Motivation (reinforcement learning)
  - tell them what to want to do
  - “give a man a *taste* for fish...”
Find The Ball Task

Learn:
- which way to turn
- to minimize time
- to see goal (ball)
- from camera input
- given experience.

In Other Words...
- It “wants” to see the pink ball.
- Utility values from seeing the ball and the cost of movement come from the reward function.
- It gathers experience about how its behavior changes the state of the world.
- We call this knowledge its transition model.
- It selects actions that it predicts will result in maximum reward (seeing the ball soon).
- This computation is often called planning.
Exploration/Exploitation

Two roads diverged in a yellow wood,
And sorry I could not travel both
And be one traveler, long I stood
And looked down one as far as I could
To where it bent in the undergrowth;

• In RL: A system cannot make two decisions and be one decision maker---it can only observe the effects of the actions it actually chooses to make. Do the right thing and learn.

RL: Sum Up

• We’re building artificial decision makers as follows:

  • We define perceptions, actions, and rewards (including shaping rewards to aid learning).
  • Learner explores its environments to discover:
    • What actions do
    • Which situations lead to reward
  • Learner uses this knowledge via “planning” to make decisions that lead to maximum reward.