CSCE 478/878 Lecture 0: Administrivia

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Welcome to CSCE 478/878!

- Please check off your name on the roster, or write your name if you're not listed
- Policy on sit-ins: You may sit in on the course without registering, but not at the expense of resources needed by registered students
  - Don't expect to get homework, etc. graded
  - If there are no open seats, you may have to surrender yours to someone who is registered
- You should have 2 handouts:
  1. Syllabus
  2. Copies of slides
- In addition, check out Homework 0 on the web (mandatory!)

Machine Learning Lecture 1: Introduction

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Adapted from *Future Problem Solvers* lecture, January 2004

What is Machine Learning?

- Building machines that automatically *learn* from experience
  - Important research goal of artificial intelligence
- (Very) small sampling of applications:
  - Data mining programs that learn to detect fraudulent credit card transactions
  - Programs that learn to filter spam email
  - Autonomous vehicles that learn to drive on public highways
  - Recognizing handwritten characters for mail and check sorting
  - Modeling users to aid web browsing, shopping, etc.

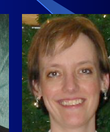
What is Learning?

- Many different answers, depending on the field you're considering and whom you ask
  - AI vs. psychology vs. education vs. neurobiology vs. …

Does Memorization = Learning?

- Test #1: Thomas learns his mother's face

Memorizes:



But will he recognize:

Thus he can generalize beyond what he's seen!

Does Memorization = Learning? (cont'd)

- Test #2: Nicholas learns about trucks & combines

Memorizes:

But will he recognize others?

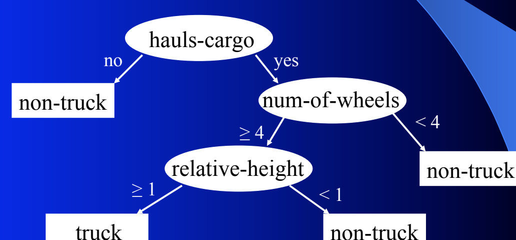
So learning involves ability to generalize from labeled examples
In contrast, memorization is trivial, especially for a computer)

Again, what is Machine Learning?

- Given several *labeled examples* of a *concept*
  - E.g. trucks vs. non-trucks
- Examples are described by *features*
  - E.g. *number-of-wheels* (integer), *relative-height* (height divided by width), *hauls-cargo* (yes/no)
- A machine learning algorithm uses these examples to create a *hypothesis* that will *predict* the label of new (previously unseen) examples
- Similar to a very simplified form of human learning
- Hypotheses can take on many forms

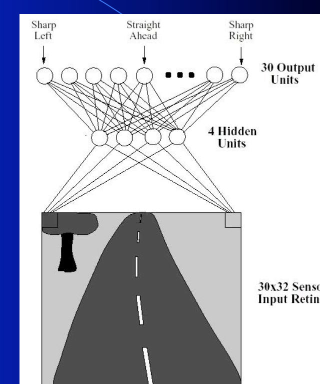
Hypothesis Type: Decision Tree

- Very easy to comprehend by humans
- Compactly represents if-then rules



Hypothesis Type: Artificial Neural Network

- Designed to simulate brains
- "Neurons" (processing units) communicate via connections, each with a numeric weight
- Learning comes from adjusting the weights



Other Hypothesis Types

- Nearest neighbor
  - Compare new (unlabeled) examples to ones you've memorized
- Support vector machines
  - A new way of looking at artificial neural networks
- Bagging and boosting
  - Repeatedly apply your favorite learning algorithm and combine the results
- Bayesian approaches
  - Build probabilistic models of the concept
- Many more
  - See your local machine learning instructor for details

Why Machine Learning?

- (Relatively) new kind of capability for computers
  - Data mining: extracting new information from medical records, maintenance records, etc.
  - Self-customizing programs: Web browser that learns what you like and seeks it out
  - Applications we can't program by hand: E.g. speech recognition, handwriting recognition, autonomous driving

Why Machine Learning? (cont'd)

- Understanding human learning and teaching:
  - Mature mathematical models might lend insight
- The time is right:
  - Recent progress in algorithms and theory
  - Enormous amounts of data and applications
  - Substantial computational power
  - Growing industry (e.g. Google's and other companies' research groups)

Why Machine Learning? (cont'd)

- Many old real-world applications of AI were *expert systems*
  - Essentially a set of if-then rules to emulate a human expert
  - E.g. "If medical test A is positive and test B is negative and if patient is chronically thirsty, then diagnosis = diabetes with confidence 0.85"
  - Rules were extracted via interviews of human experts

Machine Learning vs. Expert Systems

- ES: Expertise extraction tedious; ML: Automatic
- ES: Rules might not incorporate intuition, which might mask true reasons for answer
  - E.g. in medicine, the reasons given for diagnosis x might not be the objectively correct ones, and the expert might be unconsciously picking up on other info
  - ML: More "objective"

Machine Learning vs. Expert Systems (cont'd)

- ES: Expertise might not be comprehensive, e.g. physician might not have seen some types of cases
- ML: Automatic, objective, and data-driven
  - *Though it is only as good as the available data*

Relevant Disciplines

- AI: Learning as a search problem, using prior knowledge to guide learning
- Probability theory: computing probabilities of hypotheses
- Computational complexity theory: Bounds on inherent complexity of learning
- Control theory: Learning to control processes to optimize performance measures
- Philosophy: Occam's razor (everything else being equal, simplest explanation is best)
- Psychology and neurobiology: Practice improves performance, biological justification for artificial neural networks
- Statistics: Estimating generalization performance

More Detailed Example: Content-Based Image Retrieval

Given database of hundreds of thousands of images

How can users easily find what they want?

One idea: Users query database by image *content*

– E.g. "give me images with a waterfall"

Content-Based Image Retrieval (cont'd)

One approach: Someone annotates each image with text on its content

– Tedious, terminology ambiguous, maybe subjectiv

Better approach: *Query by example*

– Users give examples of images they want

– Program determines what's common among them and finds more like them

Content-Based Image Retrieval (cont'd)

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Content-Based Image Retrieval (cont'd)

- User's feedback then labels the new images, which are used as more training examples, yielding a new hypothesis, and more images are retrieved

How Does the System Work?

For each pixel in the image, extract its color + the colo of its neighbors

These colors (and their relative positions in the image) are the features the learner uses (replacing e.g. *number of-wheels*)

A learning algorithm takes examples of what the user wants, produces a hypothesis of what's common amon them, and uses it to label new images

Other Applications of ML

The Google search engine uses numerous machine learning techniques

- Spelling corrector: "spehl korector", "phonitick spewling", "Brytney Spears", "Brithney Spears", …
- Grouping together top news stories from numerous sources (news.google.com)
- Analyzing data from billions of web pages to improve searc results
- Analyzing which search results are most often followed, i.e which results are most relevant

Other Applications of ML (cont'd)

ALVINN, developed at CMU, drives autonomously on highways at 70 mph

- Sensor input only a single, forward-facing camera

Other Applications of ML (cont'd)

SpamAssassin for filtering spam e-mail

Data mining programs for:

- Analyzing credit card transactions for anomalies
- Analyzing medical records to automate diagnoses

Intrusion detection for computer security

Speech recognition, face recognition

Biological sequence analysis

Each application has its own representation for feature learning algorithm, hypothesis type, etc.

Variations on the Theme

- Classification vs. regression
  - Discrete- vs. real-valued labels
- Supervised vs. semi-supervised vs. unsupervised
  - How many of the training examples are labeled (all of it vs. some of it vs. none of it)
  - There's use to be made of unlabeled data!
- Noise in attributes and/or labels
- We'll emphasize binary classification, fully supervised, noise-free

Conclusions

- ML started as a field that was mainly for research purposes, with a few niche applications
- Now applications are very widespread
- ML is able to automatically find patterns in data that humans cannot
- However, still *very far* from emulating human intelligence!
  - Each artificial learner is task-specific