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!)

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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.

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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. …

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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

$\begin{align*}
\text{non-truck} & \quad \text{hauls-cargo} \quad \text{num-of-wheels} \\
\quad \text{no} & \quad \geq 4 \\
\quad \text{yes} & \quad < 4 \\
\text{relative-height} & \quad \geq 1 \\
\quad & \quad < 1 \\
\text{truck} & \quad \text{non-truck}
\end{align*}$

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 subjective

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)

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 colors 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 among them, and uses it to label new images

User’s Query:

System’s Response:

Feedback: Yes  Yes  Yes  NO!
The Google search engine uses numerous machine learning techniques:
- Spelling corrector: "spehl korector", "phonitick spewling", "Brytny Spears", "Brithney Spears", ...
- Grouping together top news stories from numerous sources (news.google.com)
- Analyzing data from billions of web pages to improve search results
- Analyzing which search results are most often followed, i.e. which results are most relevant

ALVINN, developed at CMU, drives autonomously on highways at 70 mph:
- Sensor input only a single, forward-facing camera

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.

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

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