Learning Systems

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Outline

- Overview of Machine Learning
  - Definition
  - Examples
  - Where is This Headed?

Part I:

Overview of Machine Learning

Machine Learning: Defining Question

- The field of Machine Learning seeks to answer the question:
  "How can we build computer systems that automatically improve with experience, and what are the fundamental laws that govern all learning processes?"

Machine Learning Tasks

- The question covers a broad range of learning tasks, such as:
  - How to design autonomous mobile robots that learn to navigate from their own experience?
  - How to data mine historical medical records to learn which future patients will respond best to which treatments?
  - How to build search engines that automatically customize to their user's interests?

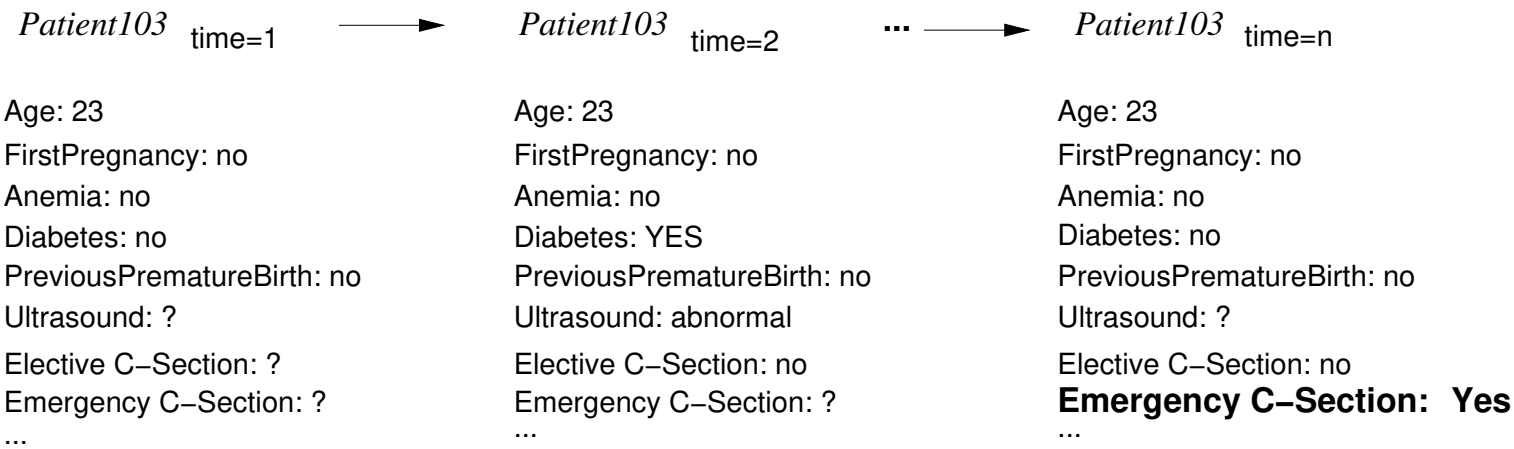
What Is a Learning Problem?

- A *Learning Problem* is defined in terms of a:
  - — Task T
  - — Performance metric P
  - — Type of experience E
- *We say that a machine learns if the system reliably improves its performance P at task T, following experience E*
- Depending on how we specify T, P, and E, the learning task might also be called by names such as data mining, autonomous discovery, database updating, programming by example, etc.

Place of Machine Learning within Computer Science

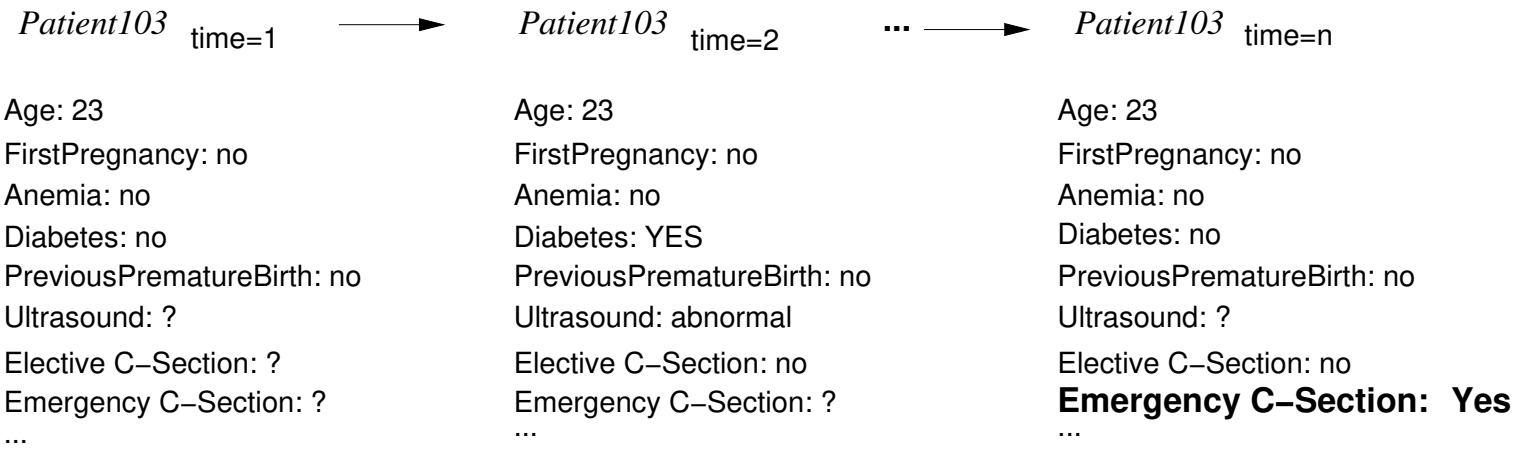
- *The application is too complex for people to manually design the algorithm*
  - Software for sensor-base perception tasks, such as speech recognition and computer vision
  - All of us can easily label which photographs contain a picture of our mother, but none of us can write down an algorithm to perform this task
- *The application requires that the software customize to its operational environment after it is fielded*
  - One example of this is speech recognition systems that customize to the user who purchases the software
  - Machine learning here provides the mechanism for adaptation
- The machine learning niche within the software world is growing rapidly:
  - Bookstores that customize to your purchasing preferences
  - Email readers that customize to your particular definition of spam
  - ...

Example Learning Problem I



- Given:
  - 9714 patient records, each describing a pregnancy and birth
  - Each patient record contains 215 features
- Learn to predict:
  - Classes of future patients at high risk for *Emergency Cesarean Section*

Example Learning Results I



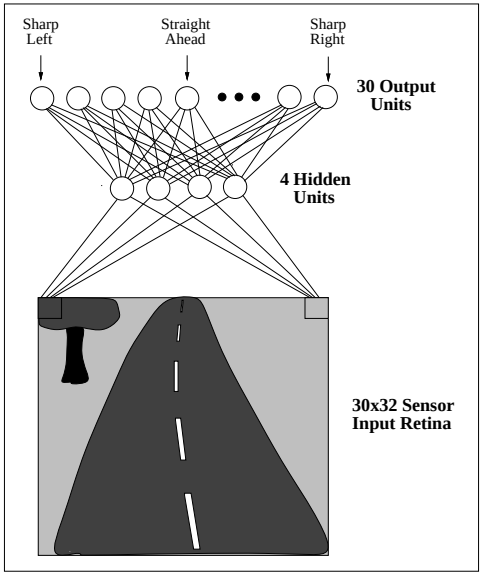
- One of 18 learned rules:

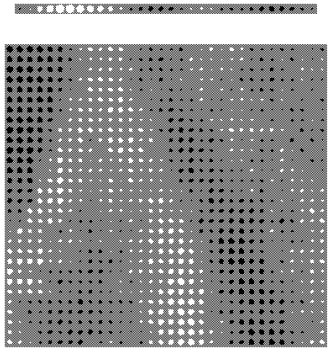
```
If   No previous vaginal delivery, and
     Abnormal 2nd Trimester Ultrasound, and
     Malpresentation at admission
Then Probability of Emergency C-Section is 0.6

Over training data: 26/41 = .63,
Over test data: 12/20 = .60
```

Example Learning Problem II

ALVINN [Pomerleau] drives 70 mph on highways





Applications in Security

- **Network Intrusion Detection:**
  - Learn to recognize intrusion attempts from observing examples of intrusions
  - Learn to describe normal traffic so that anomalous behavior can be uncovered
  - State-of-the-art approaches has achieved a detection rate of 71% with only 50 false alarms per week when tested on the DARPA Intrusion Detection Evaluation Benchmark
- **Bio-surveillance:**
  - A variety of US government efforts to detect and track disease outbreaks now use machine learning
  - *RODS project:*
    - Real-time collection of admissions reports to emergency rooms across western Pennsylvania
    - The use of machine learning software to learn the profile of typical admissions so that it can detect anomalous patterns of symptoms and their geographical distribution

Where is This Headed?

- **Today:** *tip of the iceberg*
  - — First-generation algorithms: neural nets, decision trees, regression ...
  - — Applied to well-formated database
  - — Budding industry

- **Opportunity for tomorrow:** *enormous impact*
  - — Learn across full mixed-media data
  - — Learn across multiple internal databases, plus the web and news-feeds
  - — Learn by active experimentation
  - — Learn decisions rather than predictions
  - — Cumulative, lifelong learning
  - — Programming languages with learning embedded?