

# Outline

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- Why Machine Learning?
- What is a well-defined learning problem?
- An example: learning to play checkers
- What questions should we ask about Machine Learning?

# Why Machine Learning

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- Recent progress in algorithms and theory
- Growing flood of online data
- Computational power is available
- Budding industry

Three niches for machine learning:

- Data mining : using historical data to improve decisions
  - medical records → medical knowledge
- Software applications we can't program by hand
  - autonomous driving
  - speech recognition
- Self customizing programs
  - Newsreader that learns user interests

# Typical Datamining Task

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Data:

<i>Patient103</i> time=1	→	<i>Patient103</i> time=2	...	→	<i>Patient103</i> time=n
Age: 23		Age: 23			Age: 23
FirstPregnancy: no		FirstPregnancy: no			FirstPregnancy: no
Anemia: no		Anemia: no			Anemia: no
Diabetes: no		Diabetes: YES			Diabetes: no
PreviousPrematureBirth: no		PreviousPrematureBirth: no			PreviousPrematureBirth: no
Ultrasound: ?		Ultrasound: abnormal			Ultrasound: ?
Elective C-Section: ?		Elective C-Section: no			Elective C-Section: no
Emergency C-Section: ?		Emergency C-Section: ?			<b>Emergency C-Section: Yes</b>
...		...			...

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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

# Datamining Result

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## Data:

<i>Patient103</i> time=1	→	<i>Patient103</i> time=2	...	→	<i>Patient103</i> time=n
Age: 23		Age: 23			Age: 23
FirstPregnancy: no		FirstPregnancy: no			FirstPregnancy: no
Anemia: no		Anemia: no			Anemia: no
Diabetes: no		Diabetes: YES			Diabetes: no
PreviousPrematureBirth: no		PreviousPrematureBirth: no			PreviousPrematureBirth: no
Ultrasound: ?		Ultrasound: abnormal			Ultrasound: ?
Elective C-Section: ?		Elective C-Section: no			Elective C-Section: no
Emergency C-Section: ?		Emergency C-Section: ?			<b>Emergency C-Section: Yes</b>
...		...			...

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## 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:  $12/20 = .60$

# Credit Risk Analysis

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## Data:

<i>Customer103:</i> (time=t0)	<i>Customer103:</i> (time=t1)	...	<i>Customer103:</i> (time=tn)
Years of credit: 9	Years of credit: 9		Years of credit: 9
Loan balance: \$2,400	Loan balance: \$3,250		Loan balance: \$4,500
Income: \$52k	Income: ?		Income: ?
Own House: Yes	Own House: Yes		Own House: Yes
Other delinquent accts: 2	Other delinquent accts: 2		Other delinquent accts: 3
Max billing cycles late: 3	Max billing cycles late: 4		Max billing cycles late: 6
Profitable customer?: ?	Profitable customer?: ?		<b>Profitable customer?: No</b>
...	...		...

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## Rules learned from synthesized data:

If Other-Delinquent-Accounts > 2, and  
Number-Delinquent-Billing-Cycles > 1  
Then Profitable-Customer? = No  
[Deny Credit Card application]

If Other-Delinquent-Accounts = 0, and  
(Income > \$30k) OR (Years-of-Credit > 3)  
Then Profitable-Customer? = Yes  
[Accept Credit Card application]

# Other Prediction Problems

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## Customer purchase behavior:

<i>Customer103:</i> (time=t0)	<i>Customer103:</i> (time=t1)	...	<i>Customer103:</i> (time=tn)
Sex: M	Sex: M		Sex: M
Age: 53	Age: 53		Age: 53
Income: \$50k	Income: \$50k		Income: \$50k
Own House: Yes	Own House: Yes		Own House: Yes
MS Products: Word	MS Products: Word		MS Products: Word
Computer: 386 PC	Computer: Pentium		Computer: Pentium
Purchase Excel?: ?	Purchase Excel?: ?		<b>Purchase Excel?: Yes</b>
...	...		...

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## Customer retention:

<i>Customer103:</i> (time=t0)	<i>Customer103:</i> (time=t1)	...	<i>Customer103:</i> (time=tn)
Sex: M	Sex: M		Sex: M
Age: 53	Age: 53		Age: 53
Income: \$50k	Income: \$50k		Income: \$50k
Own House: Yes	Own House: Yes		Own House: Yes
Checking: \$5k	Checking: \$20k		Checking: \$0
Savings: \$15k	Savings: \$0		Savings: \$0
Current-customer?: yes	Current-customer?: yes		<b>Current-customer?: No</b>

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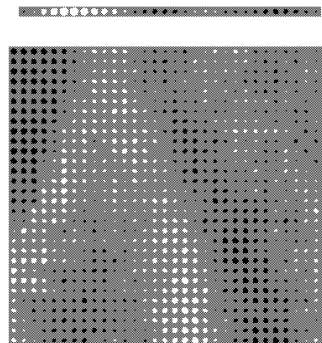
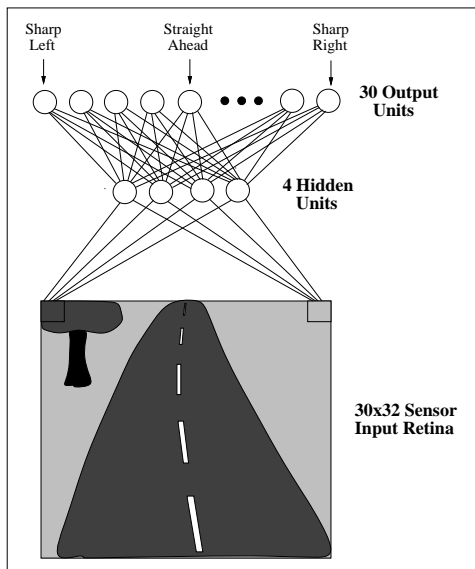
## Process optimization:

<i>Product72:</i> (time=t0)	<i>Product72:</i> (time=t1)	...	<i>Product72:</i> (time=tn)
Stage: mix	Stage: cook		Stage: cool
Mixing-speed: 60rpm	Temperature: 325		Fan-speed: medium
Viscosity: 1.3	Viscosity: 3.2		Viscosity: 1.3
Fat content: 15%	Fat content: 12%		Fat content: 12%
Density: 2.8	Density: 1.1		Density: 1.2
Spectral peak: 2800	Spectral peak: 3200		Spectral peak: 3100
Product underweight?: ??	Product underweight?: ??		<b>Product underweight?: Yes</b>
...	...		...

# Problems Too Difficult to Program by Hand

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ALVINN [Pomerleau] drives 70 mph on highways



# Software that Customizes to User

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<http://www.wisewire.com>

# Where Is this Headed?

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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 newsfeeds
- Learn by active experimentation
- Learn decisions rather than predictions
- Cumulative, lifelong learning
- Programming languages with learning embedded?

# Relevant Disciplines

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- Artificial intelligence
- Bayesian methods
- Computational complexity theory
- Control theory
- Information theory
- Philosophy
- Psychology and neurobiology
- Statistics
- ...

# What is the Learning Problem?

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Learning = Improving with experience at some task

- Improve over task  $T$ ,
- with respect to performance measure  $P$ ,
- based on experience  $E$ .

E.g., Learn to play checkers

- $T$ : Play checkers
- $P$ : % of games won in world tournament
- $E$ : opportunity to play against self

# Learning to Play Checkers

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- $T$ : Play checkers
- $P$ : Percent of games won in world tournament
- What experience?
- What exactly should be learned?
- How shall it be represented?
- What specific algorithm to learn it?

# Type of Training Experience

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- Direct or indirect?
- Teacher or not?

A problem: is training experience representative of performance goal?

# Choose the Target Function

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- $ChooseMove : Board \rightarrow Move$  ??
- $V : Board \rightarrow \mathfrak{R}$  ??
- ...

## Possible Definition for Target Function $V$

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- if  $b$  is a final board state that is won, then  $V(b) = 100$
- if  $b$  is a final board state that is lost, then  $V(b) = -100$
- if  $b$  is a final board state that is drawn, then  $V(b) = 0$
- if  $b$  is not a final state in the game, then  $V(b) = V(b')$ , where  $b'$  is the best final board state that can be achieved starting from  $b$  and playing optimally until the end of the game.

This gives correct values, but is not operational

# Choose Representation for Target Function

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- collection of rules?
- neural network ?
- polynomial function of board features?
- ...

# A Representation for Learned Function

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$$w_0 + w_1 \cdot bp(b) + w_2 \cdot rp(b) + w_3 \cdot bk(b) + w_4 \cdot rk(b) + w_5 \cdot bt(b) + w_6 \cdot rt(b)$$

- $bp(b)$ : number of black pieces on board  $b$
- $rp(b)$ : number of red pieces on  $b$
- $bk(b)$ : number of black kings on  $b$
- $rk(b)$ : number of red kings on  $b$
- $bt(b)$ : number of red pieces threatened by black (i.e., which can be taken on black's next turn)
- $rt(b)$ : number of black pieces threatened by red

# Obtaining Training Examples

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- $V(b)$ : the true target function
- $\hat{V}(b)$  : the learned function
- $V_{train}(b)$ : the training value

One rule for estimating training values:

- $V_{train}(b) \leftarrow \hat{V}(Successor(b))$

# Choose Weight Tuning Rule

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## LMS Weight update rule:

Do repeatedly:

- Select a training example  $b$  at random

1. Compute  $error(b)$ :

$$error(b) = V_{train}(b) - \hat{V}(b)$$

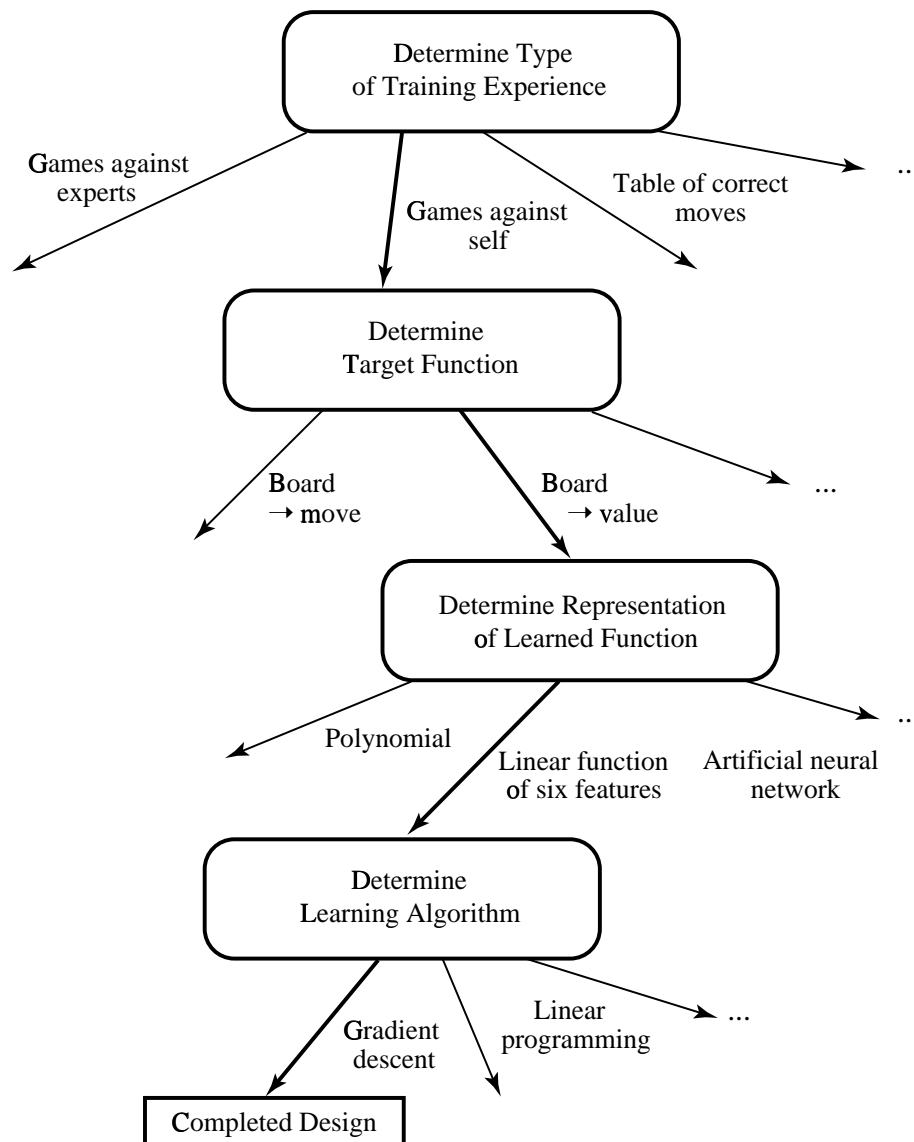
2. For each board feature  $f_i$ , update weight  $w_i$ :

$$w_i \leftarrow w_i + c \cdot f_i \cdot error(b)$$

$c$  is some small constant, say 0.1, to moderate the rate of learning

# Design Choices

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# Some Issues in Machine Learning

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- 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?