
Announcements

- ❖ Final exam

- ❖ Aug. 6, 8am-9:40am
- ❖ Open book, open notes
- ❖ No communication

- ❖ Still some questions?

- ❖ Piazza
- ❖ OH today 1pm-2pm

- ❖ Course evaluation

Ve492: Introduction to Artificial Intelligence

Final Review



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Slides adapted from <http://ai.berkeley.edu>, AIMA, UM, CMU

Probability

- ❖ For each of the following statements, either prove it is true or give a counterexample.
 - ❖ If $P(a \mid b, c) = P(b \mid a, c)$, then $P(a \mid c) = P(b \mid c)$
 - ❖ If $P(a \mid b, c) = P(a)$, then $P(b \mid c) = P(b)$
 - ❖ If $P(a \mid b) = P(a)$, then $P(a \mid b, c) = P(a \mid c)$

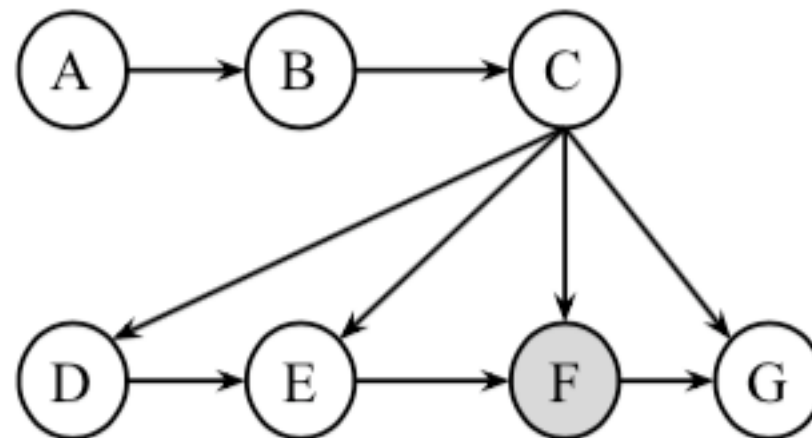
Bayes Rule

Consider two medical tests, A and B, for a virus. Test A is 95% effective at recognizing the virus when it is present, but has a 10% false positive rate (indicating that the virus is present, when it is not). Test B is 90% effective at recognizing the virus, but has a 5% false positive rate. The two tests use independent methods of identifying the virus. The virus is carried by 1% of all people. Say that a person is tested for the virus using only one of the tests, and that test comes back positive for carrying the virus.

- ❖ Which test returning positive is more indicative of someone really carrying the virus? Justify your answer mathematically.

Bayes' Net

- ❖ Write the joint distribution of the following Bayes' net

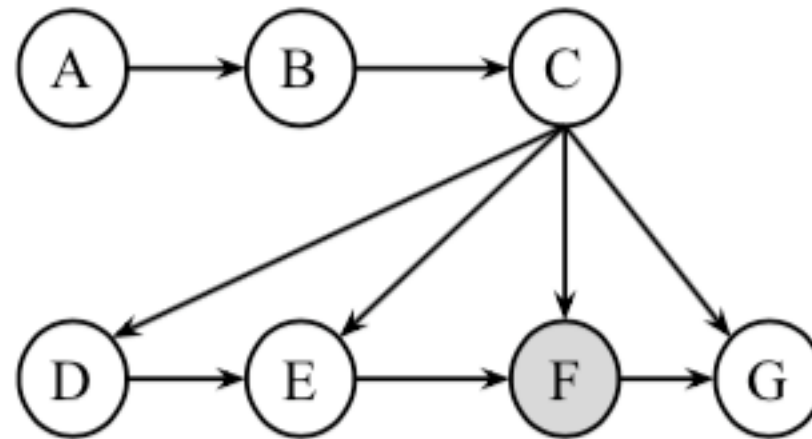


- ❖ How many values does the joint distribution have?
- ❖ How many parameters does the Bayes' net have?

D-Separation

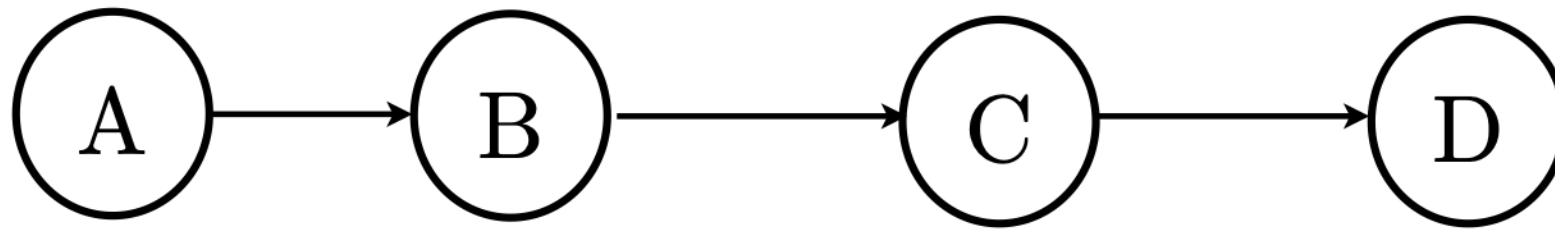
- ❖ Check Bayes applet

Inference



- ❖ Run Variable Elimination to compute $P(B, D | + f)$ with order A, C, E, G
- ❖ What is the size of the largest generated factor?
- ❖ Find the best ordering for Variable Elimination
- ❖ What is the cutset for this graph?

Sampling



$P(A)$	
$-a$	$3/4$
$+a$	$1/4$

$P(B A)$		
$-a$	$-b$	$2/3$
$-a$	$+b$	$1/3$
$+a$	$-b$	$4/5$
$+a$	$+b$	$1/5$

$P(C B)$		
$-b$	$-c$	$1/4$
$-b$	$+c$	$3/4$
$+b$	$-c$	$1/2$
$+b$	$+c$	$1/2$

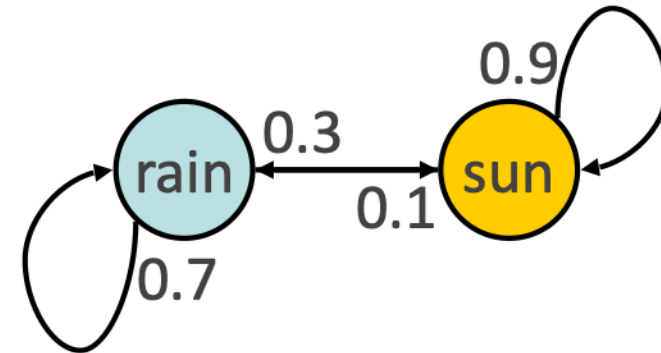
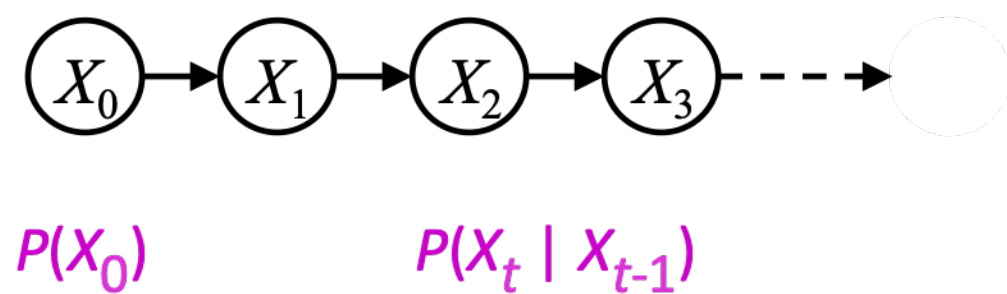
$P(D C)$		
$-c$	$-d$	$1/8$
$-c$	$+d$	$7/8$
$+c$	$-d$	$5/6$
$+c$	$+d$	$1/6$

Samples

$+a$	$+b$	$-c$	$-d$
$+a$	$-b$	$+c$	$-d$
$-a$	$+b$	$+c$	$-d$
$-a$	$-b$	$+c$	$-d$
$+a$	$-b$	$-c$	$+d$
$+a$	$+b$	$+c$	$-d$
$-a$	$+b$	$-c$	$+d$
$-a$	$-b$	$+c$	$-d$

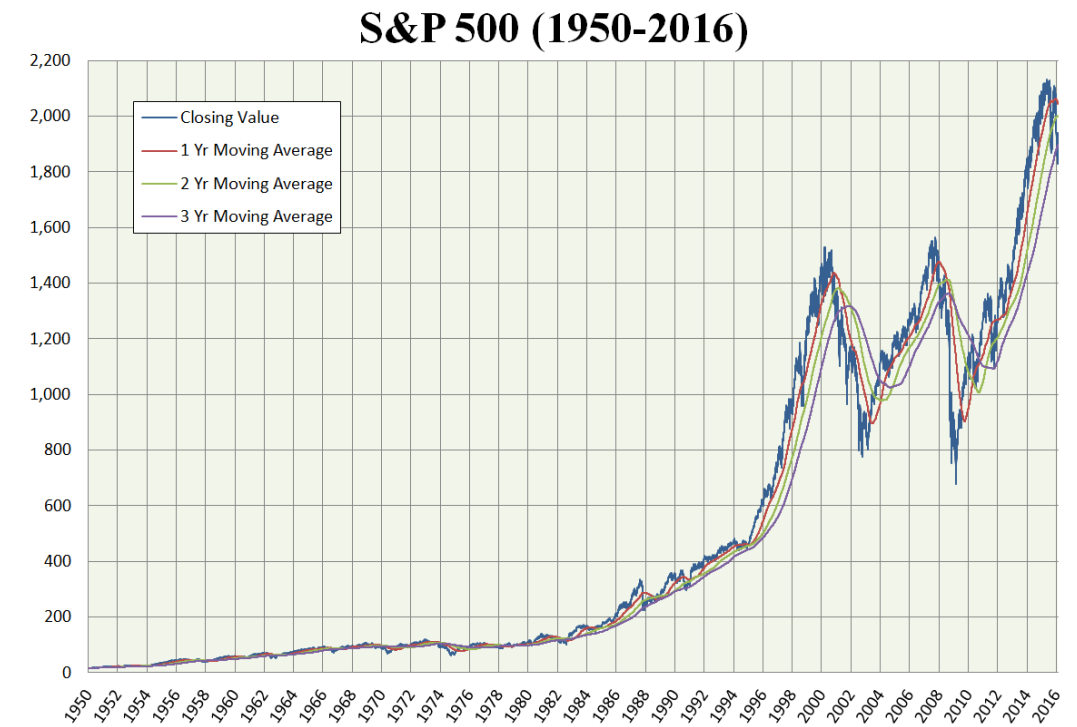
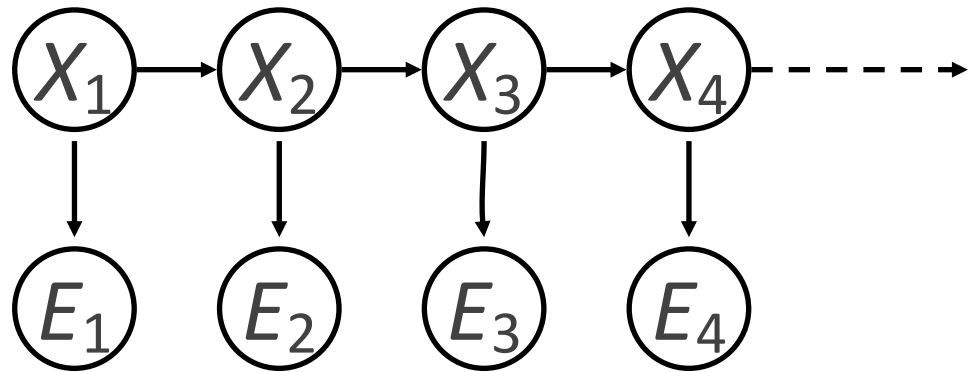
- ❖ Estimate $P(+c | +a, -d)$ via rejection sampling
- ❖ Estimate $P(-a | +b, -d)$ via likelihood weighting

Markov Chain

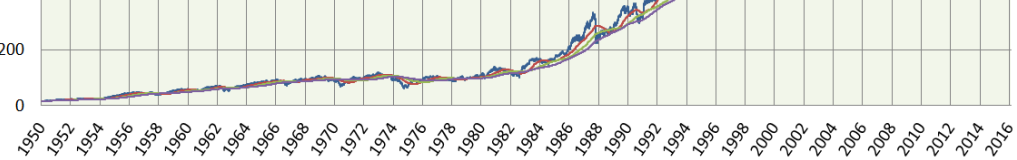


- ❖ What is the probability of $P(X_t)$?
- ❖ What is the stationary distribution for the weather example?

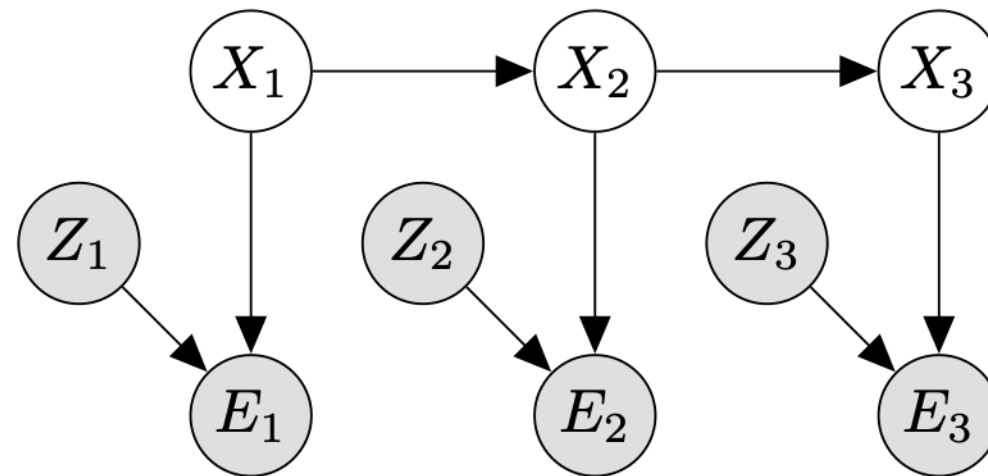
Hidden Markov Model



Wikipedia

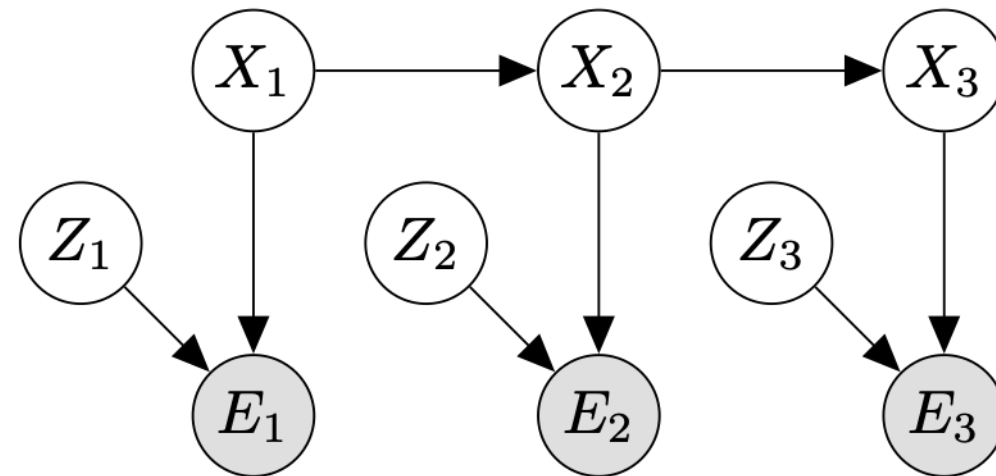
- ❖ Financial investment
 - ❖ X = market condition: bull, bear
 - ❖ E = price evolution of some index: up, down
 - ❖ Label past data into bull vs bear
 - ❖ Use historical data to estimate transition/emission probabilities
- 
- A line chart showing the historical evolution of a stock market index from 1950 to 2016. The x-axis represents years from 1950 to 2016 in two-year increments. The y-axis represents the index value from 0 to 200. Multiple colored lines (blue, red, green, orange) represent different indices, all showing a general upward trend with significant fluctuations. A notable sharp decline is visible around 1980, followed by a recovery and another decline around 2008.
- Wikipedia

Hidden Markov Model



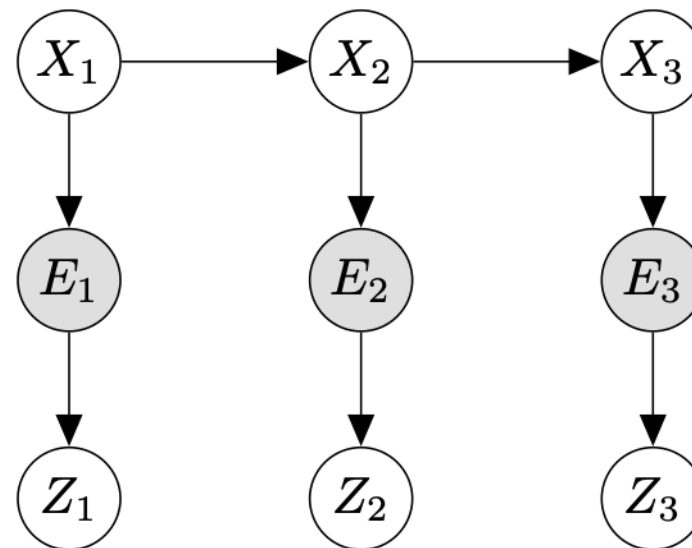
- ❖ Adapt the forward algorithm to this variant of HMM
 - ❖ Predict step
 - ❖ Update

Hidden Markov Model



- ❖ Adapt the forward algorithm to this variant of HMM
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 - ❖ Update

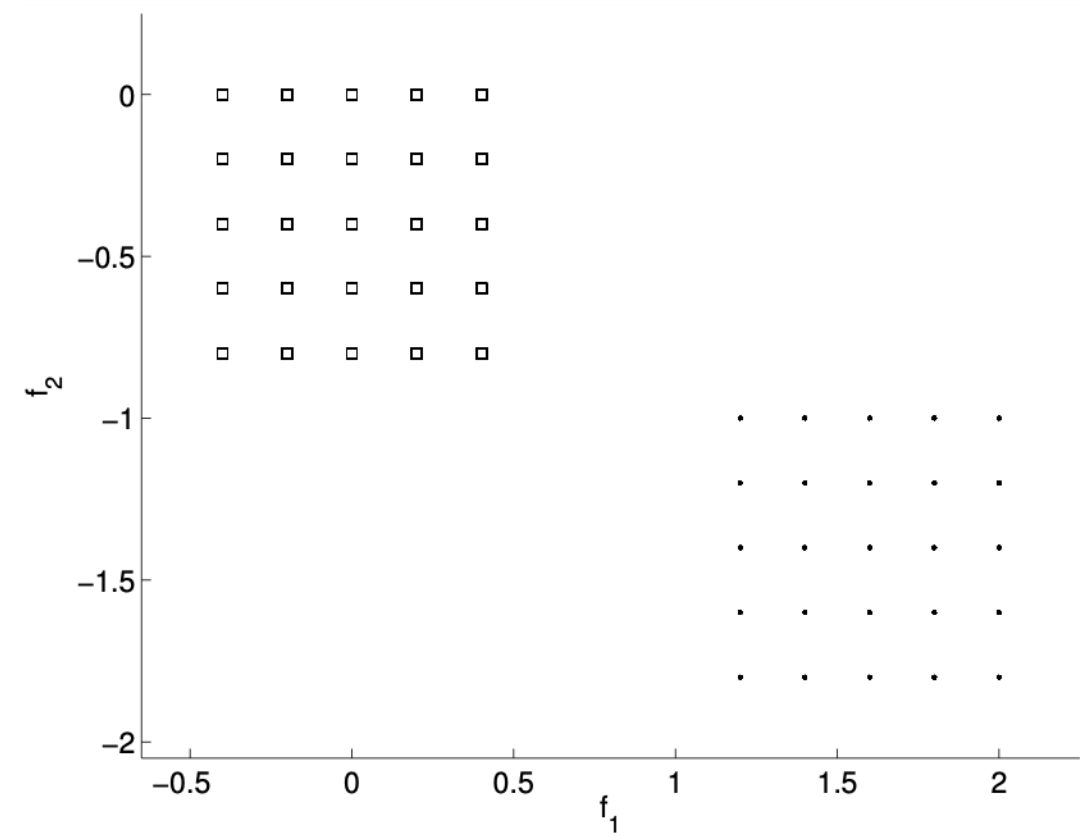
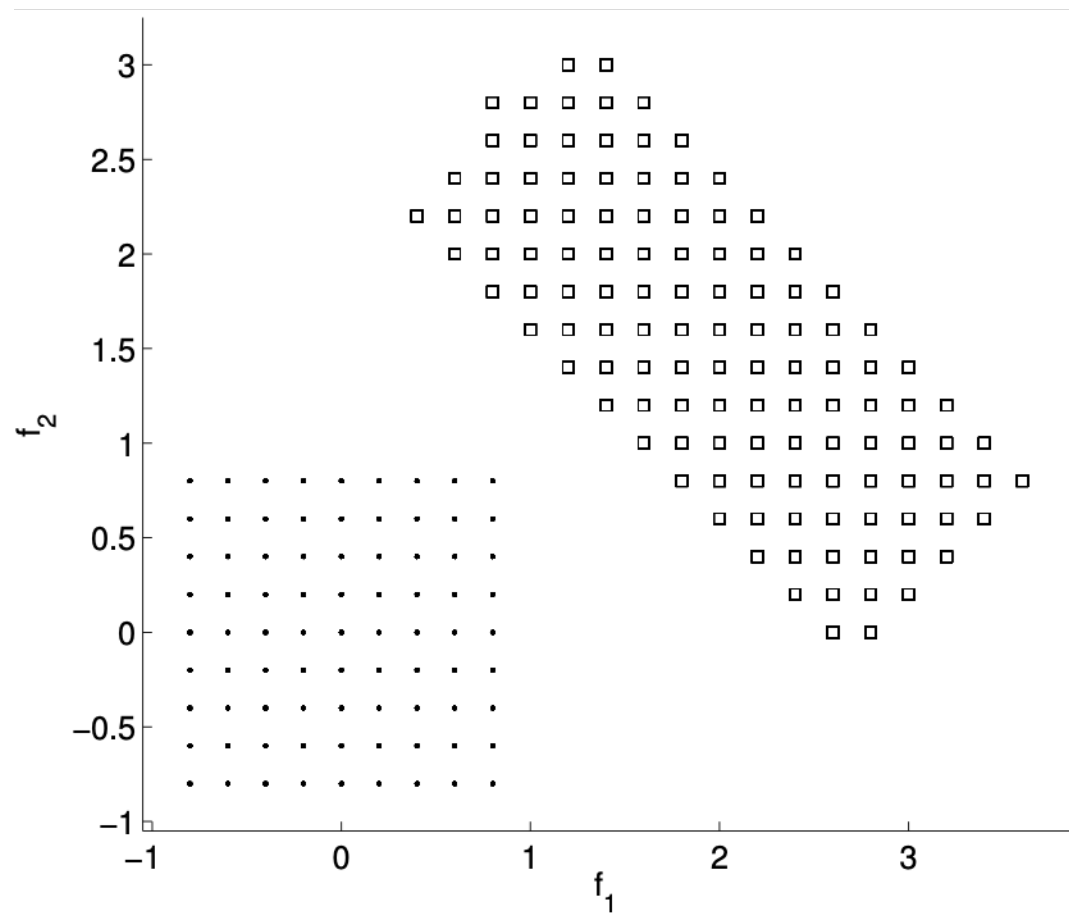
Hidden Markov Model



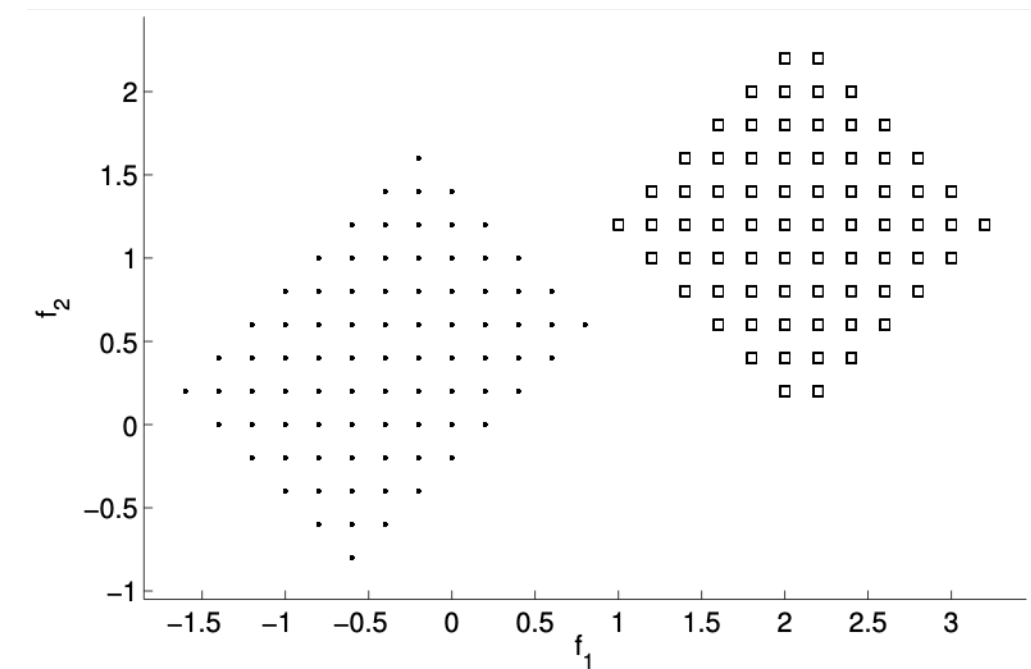
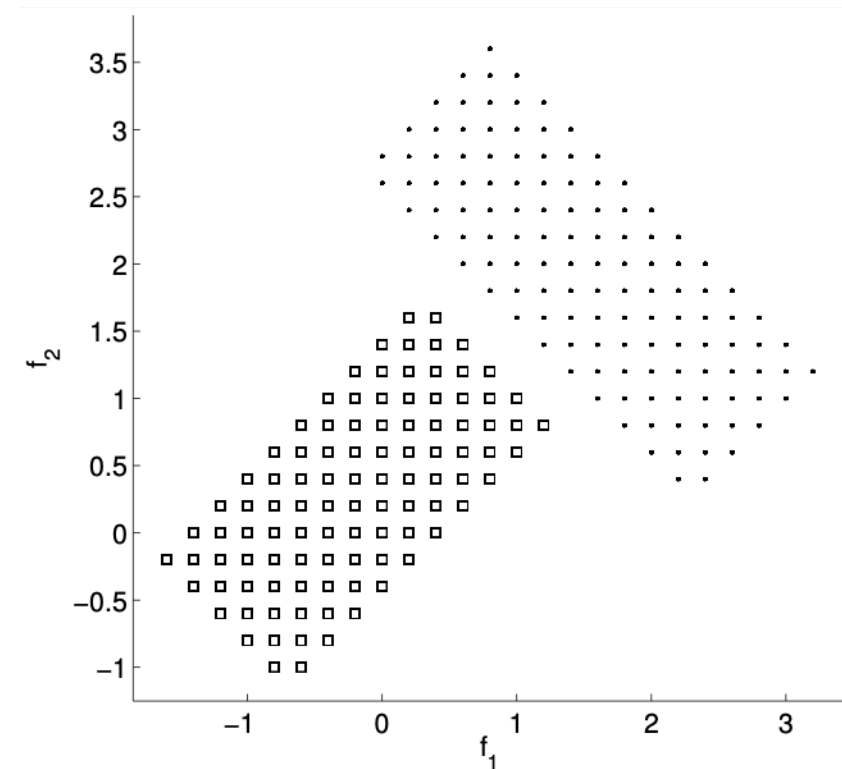
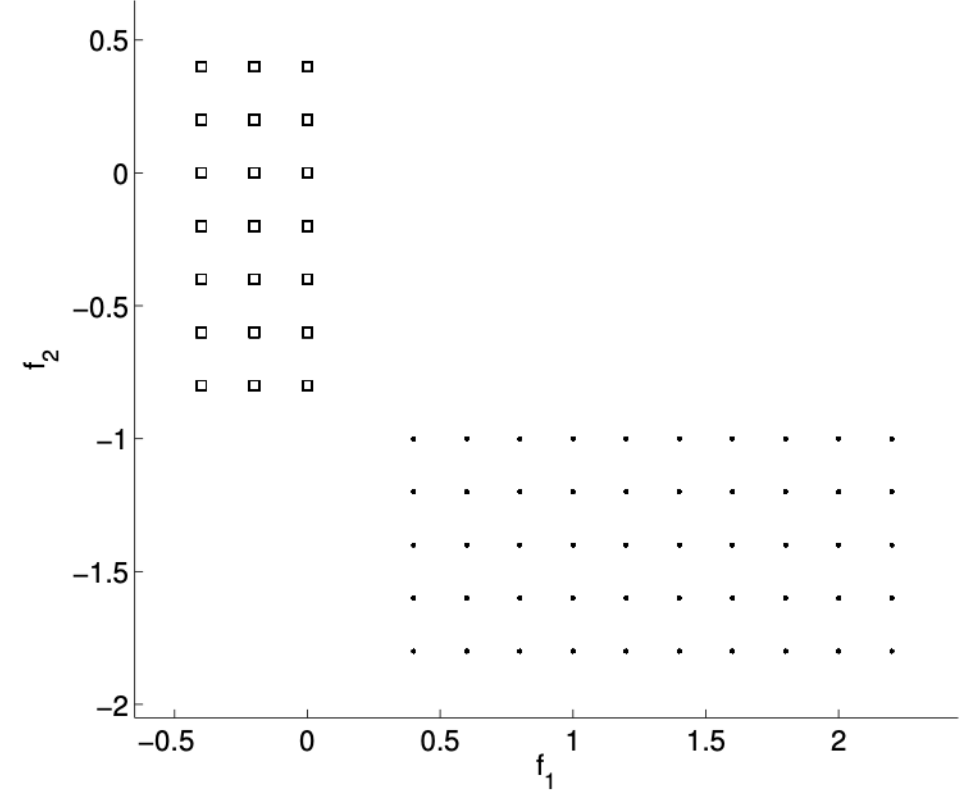
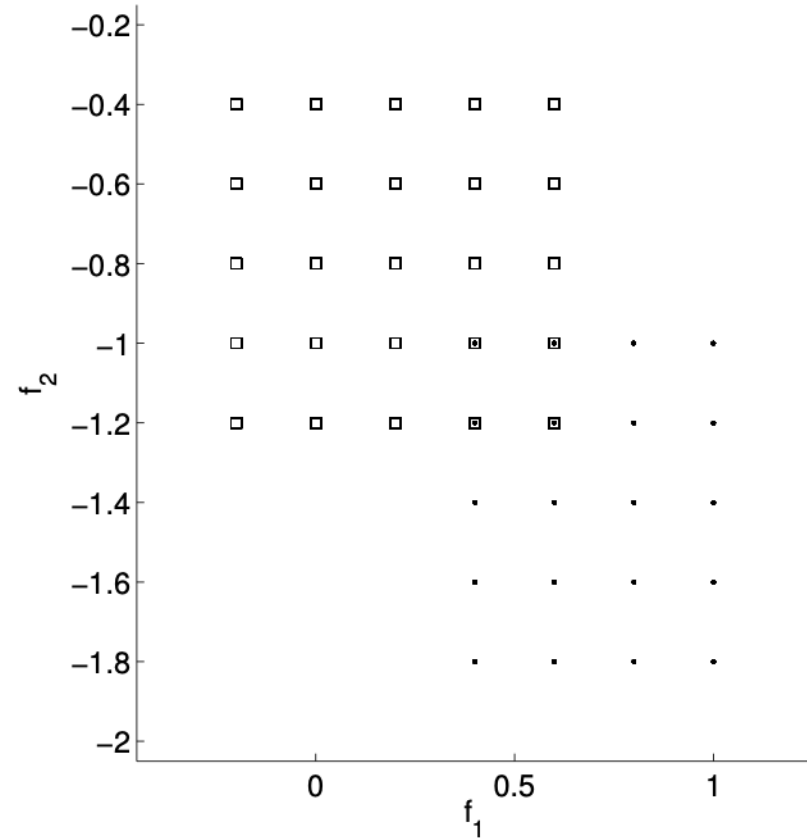
- ❖ Adapt the forward algorithm to this variant of HMM
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Naïve Bayes

- ❖ Which of the following binary classification problems satisfy the assumption made in Naïve Bayes?



Naïve Bayes ctd.



Discriminative Learning

For a binary classification problem, we choose the following model $\mathbb{P}(y = +1|x) = \Phi(w \cdot x)$ where Φ is the CDF of a standard normal distribution.

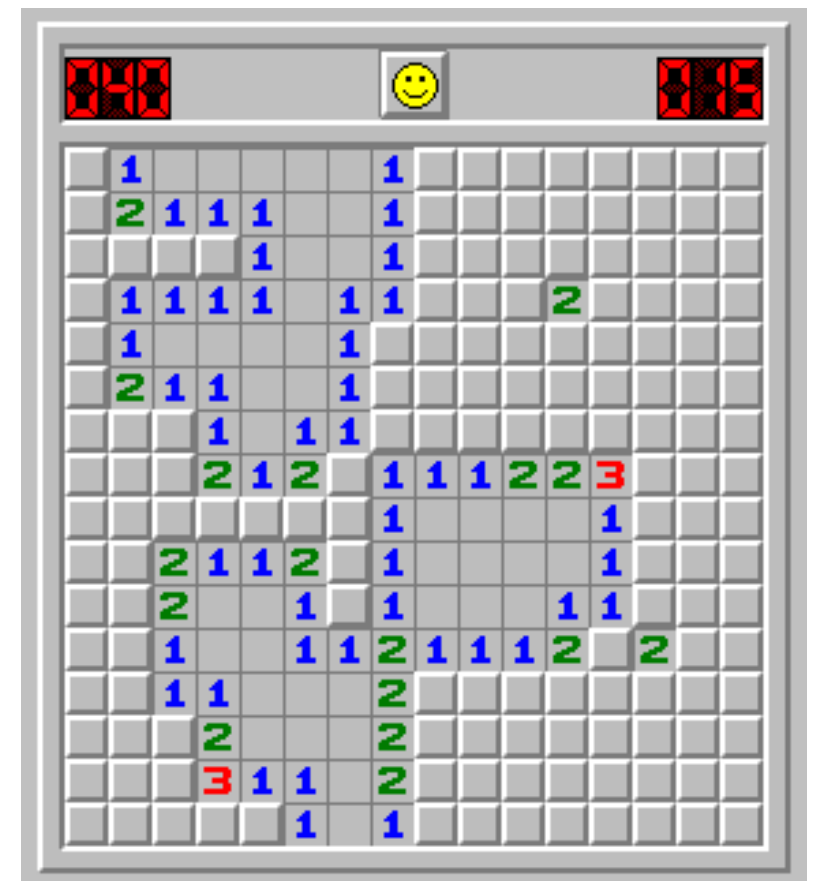
- ❖ What is the decision boundary?
- ❖ Formulate the optimization problem to be solved to find w
- ❖ Formulate the stochastic gradient method to solve that problem

Propositional Logic

- ❖ Which of the following are correct?
 - ❖ $\text{False} \models \text{True}$
 - ❖ $\text{True} \models \text{False}$
 - ❖ $(A \wedge B) \models (A \Leftrightarrow B)$
 - ❖ $(A \vee B) \wedge (\neg C \vee \neg D \vee E) \models (A \vee B)$
 - ❖ $(A \vee B) \wedge \neg(A \Rightarrow B)$ is satisfiable
 - ❖ $(A \Leftrightarrow B) \wedge (\neg A \vee B)$ is satisfiable
 - ❖ $(A \Leftrightarrow B) \Leftrightarrow C$ has the same number of models as $(A \Leftrightarrow B)$ for any fixed set of proposition symbols that includes A, B, C

Application: Propositional Logic

- ❖ Minesweeper: Let $X_{i,j}$ be true iff square $[i, j]$ contains a mine.
- ❖ Write down the assertion that exactly two mines are adjacent to $[1,1]$ as a sentence involving some logical combination of $X_{i,j}$ propositions.
- ❖ Generalize your assertion by explaining how to construct a CNF sentence asserting that k of n neighbors contain mines
- ❖ Explain precisely how an agent can use DPLL to prove that a given square does (or does not) contain a mine.



First-Order Logic

- ❖ For each of the following sentences in English, decide if the accompanying first-order logic sentence is a good translation. If not, explain why not and correct it.

- ❖ No two people have the same social security number.

$$\neg \exists x, y, n \text{ Person}(x) \wedge \text{Person}(y) \Rightarrow [\text{HasSS\#}(x, n) \wedge \text{HasSS\#}(y, n)]$$

- ❖ John's social security number is the same as Mary's.

$$\exists n \text{ HasSS\#}(\text{John}, n) \wedge \text{HasSS\#}(\text{Mary}, n)$$

- ❖ Everyone's social security number has nine digits.

$$\forall x, n \text{ Person}(x) \Rightarrow [\text{HasSS\#}(x, n) \wedge \text{Digits}(n, 9)]$$

Classic Planning

A monkey is in a room with some bananas hanging out of reach from the ceiling. A box is available that will enable the monkey to reach the bananas if he climbs on it. Initially, the monkey is at *A*, the bananas are at *B*, and the box is at *C*. The monkey and the box have height *Low*, but if the monkey climbs onto the box he will have height *High*, the same as the bananas. The actions available to the monkey include *EatBananas* if the monkey and the bananas are at the same location and height, *Go* from one place to another, *Push* an object from one place to another, and *ClimbUp* onto or *ClimbDown* from an object.

- ❖ Write down the initial state description
- ❖ Write down the STRIPS definitions of the five actions.

