Reduction to Classification

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University of Colorado Boulder
LECTURE 13

Busy Week

Content Questions

Content Questions

Content Questions

Content Questions

Content Questions

Content Questions

Content Questions

Content Questions

Content Questions

Content Questions

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Administrivia

- How is the course going?
- What do you like?
- What don't you like?
- What should we do for an undergrad section?

Administrivia

- Boosting Due on Friday
- Midterm Next Week: 1.5 Hours
- Project Meetings
-

Defining a Code Book

- Want to decide whether a name is German, Argentine, or Chinese
- Using ECOC
- What do we need first?

Defining a Code Book

- Want to decide whether a name is German, Argentine, or Chinese
- Using ECOC
- What do we need first?

Class	b_1	b_2	b_3	b_4
Chinese	1	0	0	1
German	0	0	1	0
Argentine	1	1	1	0

Training Data

German	Chinese	Argentine
Mann	Cao Xueqin	Puig
Goethe	Lu Xun	Borges
Grass	Gao Xingjian	Cortazar

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What are the training examples for each classifier?

Training Data

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What are the training examples for each classifier?

Training Examples

	h_1	h_2	h_3	h_4

Training Examples

	h_1	h_2	h_3	h_4
Mann	-	-	+	-
Goethe	-	-	+	-
Grass	-	-	+	-

Training Examples

	h_1	h_2	h_3	h_4
Mann	-	-	+	-
Goethe	-	-	+	-
Grass	-	-	+	-
Cao Xue	+	-	-	+
Lu Xun	+	-	-	+
Gao Xingjian	+	-	-	+

Training Examples

	h_1	h_2	h_3	h_4
Mann	-	-	+	-
Goethe	-	-	+	-
Grass	-	-	+	-
Cao Xue	+	-	-	+
Lu Xun	+	-	-	+
Gao Xingjian	+	-	-	+
Puig	+	+	+	-
Borges	+	+	+	-
Cortazar	+	+	+	-

Classification

Class	b_1	b_2	b_3	b_4
Chinese	1	0	0	1
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Classification

Class	b_1	b_2	b_3	b_4
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- $(0, 0, 0, 1) \rightarrow$
-

Classification

Class	b_1	b_2	b_3	b_4
Chinese	1	0	0	1
German	0	0	1	0
Argentine	1	1	1	0

- $(0, 0, 0, 1) \rightarrow$ German
-

Classification

Class	b_1	b_2	b_3	b_4
Chinese	1	0	0	1
German	0	0	1	0
Argentine	1	1	1	0

- $(0, 0, 0, 1) \rightarrow$ German
- $(0, 1, 0, 1) \rightarrow$

Classification

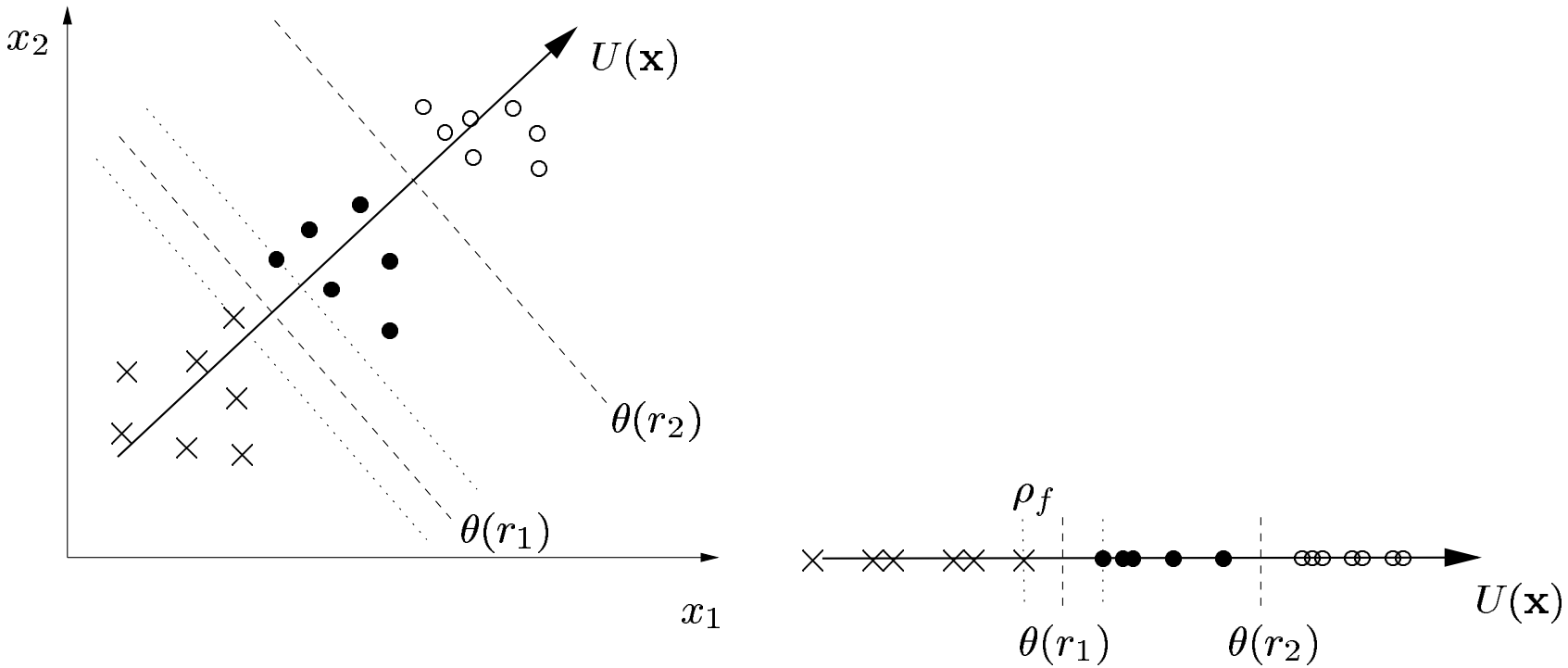
Class	b_1	b_2	b_3	b_4
Chinese	1	0	0	1
German	0	0	1	0
Argentine	1	1	1	0

- $(0, 0, 0, 1) \rightarrow$ German
- $(0, 1, 0, 1) \rightarrow$ Chinese

Bottom Line

- Understand what your algorithm is doing when you ask it to multi class
- Features and training imbalance matter more than ever
- Debugging is often easier if **you** binarize the problem

SVM Ranking


x_2
$U(\mathbf{x})$
$\theta(r_2)$
$\theta(r_1)$
x_1
ρ_f
$U(\mathbf{x})$
$\theta(r_1)$
$\theta(r_2)$

Real(-ish) Data

Sets of five movies ranked by users

```
# Big Lebowski, The
1 qid:375 1:0.04 2:0.01 3:1.1 4:0.0 5:1.0 6:0.0 7:0.0
# School of Rock, The
2 qid:375 1:0.06 2:-0.00 3:0.7 4:0.0 5:1.0 6:0.0 7:0.0
 # While You Were Sleeping
3 qid:375 1:0.03 2:-0.01 3:0.04 4:0.0 5:1.0 6:0.0 7:0.0
# Clockwise
4 qid:375 1:-0.01 2:-0.02 3:0.04 4:0.0 5:1.0 6:0.0 7:0.0
 # Enchanted April
5 qid:375 1:0.02 2:-0.02 3:0.7 4:0.0 5:0.0 6:0.0 7:1.0
```

1: Year of the movie ($\mu = 1987$, var=266)

Real(-ish) Data

Sets of five movies ranked by users

```
# Big Lebowski, The
1 qid:375 1:0.04 2:0.01 3:1.1 4:0.0 5:1.0 6:0.0 7:0.0
# School of Rock, The
2 qid:375 1:0.06 2:-0.00 3:0.7 4:0.0 5:1.0 6:0.0 7:0.0
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3 qid:375 1:0.03 2:-0.01 3:0.04 4:0.0 5:1.0 6:0.0 7:0.0
# Clockwise
4 qid:375 1:-0.01 2:-0.02 3:0.04 4:0.0 5:1.0 6:0.0 7:0.0
 # Enchanted April
5 qid:375 1:0.02 2:-0.02 3:0.7 4:0.0 5:0.0 6:0.0 7:1.0
```

2: Length of the movie ($\mu = 108$, var=569)

Real(-ish) Data

Sets of five movies ranked by users

```
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1 qid:375 1:0.04 2:0.01 3:1.1 4:0.0 5:1.0 6:0.0 7:0.0
# School of Rock, The
2 qid:375 1:0.06 2:-0.00 3:0.7 4:0.0 5:1.0 6:0.0 7:0.0
 # While You Were Sleeping
3 qid:375 1:0.03 2:-0.01 3:0.04 4:0.0 5:1.0 6:0.0 7:0.0
# Clockwise
4 qid:375 1:-0.01 2:-0.02 3:0.04 4:0.0 5:1.0 6:0.0 7:0.0
 # Enchanted April
5 qid:375 1:0.02 2:-0.02 3:0.7 4:0.0 5:0.0 6:0.0 7:1.0
```

3: Rating ($\mu = 6.4$, var=1.4)

Real(-ish) Data

Sets of five movies ranked by users

```
# Big Lebowski, The
1 qid:375 1:0.04 2:0.01 3:1.1 4:0.0 5:1.0 6:0.0 7:0.0
# School of Rock, The
2 qid:375 1:0.06 2:-0.00 3:0.7 4:0.0 5:1.0 6:0.0 7:0.0
 # While You Were Sleeping
3 qid:375 1:0.03 2:-0.01 3:0.04 4:0.0 5:1.0 6:0.0 7:0.0
# Clockwise
4 qid:375 1:-0.01 2:-0.02 3:0.04 4:0.0 5:1.0 6:0.0 7:0.0
 # Enchanted April
5 qid:375 1:0.02 2:-0.02 3:0.7 4:0.0 5:0.0 6:0.0 7:1.0
```

4: Action (binary)

Real(-ish) Data

Sets of five movies ranked by users

```
# Big Lebowski, The
1 qid:375 1:0.04 2:0.01 3:1.1 4:0.0 5:1.0 6:0.0 7:0.0
# School of Rock, The
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 # Enchanted April
5 qid:375 1:0.02 2:-0.02 3:0.7 4:0.0 5:0.0 6:0.0 7:1.0
```

5: Comedy (binary)

Real(-ish) Data

Sets of five movies ranked by users

```
# Big Lebowski, The
1 qid:375 1:0.04 2:0.01 3:1.1 4:0.0 5:1.0 6:0.0 7:0.0
# School of Rock, The
2 qid:375 1:0.06 2:-0.00 3:0.7 4:0.0 5:1.0 6:0.0 7:0.0
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3 qid:375 1:0.03 2:-0.01 3:0.04 4:0.0 5:1.0 6:0.0 7:0.0
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 # Enchanted April
5 qid:375 1:0.02 2:-0.02 3:0.7 4:0.0 5:0.0 6:0.0 7:1.0
```

6: Documentary (binary)

Real(-ish) Data

Sets of five movies ranked by users

```
# Big Lebowski, The
1 qid:375 1:0.04 2:0.01 3:1.1 4:0.0 5:1.0 6:0.0 7:0.0
# School of Rock, The
2 qid:375 1:0.06 2:-0.00 3:0.7 4:0.0 5:1.0 6:0.0 7:0.0
 # While You Were Sleeping
3 qid:375 1:0.03 2:-0.01 3:0.04 4:0.0 5:1.0 6:0.0 7:0.0
# Clockwise
4 qid:375 1:-0.01 2:-0.02 3:0.04 4:0.0 5:1.0 6:0.0 7:0.0
 # Enchanted April
5 qid:375 1:0.02 2:-0.02 3:0.7 4:0.0 5:0.0 6:0.0 7:1.0
```

7: Drama (binary)

Fitting an SVM

- SVM-RANK
- Five support vectors
- Weight vector

$$w = \langle 0.02, 0.03, -1.82, -2.30, -0.05, 1.73, 1.84 \rangle \quad (1)$$

Predictions

$$w = \langle 0.02, 0.03, -1.82, -2.30, -0.05, 1.73, 1.84 \rangle \quad (2)$$

```
# Paper Chase
1:-0.06 2:0.0 3:0.53 4:0.0 5:0.0 6:0.0 7:1.0
# Seconds
1:-0.08 2:-0.01 3:0.74 4:0.0 5:0.0 6:0.0 7:1.0
#Smokey and the Bandit II
1:-0.03 2:-0.02 3:-1.43 4:1.0 5:1.0 6:0.0 7:0.0
# CB4
1:0.02 2:-0.03 3:-0.73 4:0.0 5:1.0 6:0.0 7:0.0
#Sideways
1:0.06 2:0.03 3:1.09 4:0.0 5:1.0 6:0.0 7:1.0
```

- Paper Chase:

- Paper Chase: $-0.01 \cdot -0.06 + 0.07 \cdot 0.00 + -1.95 \cdot 0.53 + -2.28 \cdot 0.00 + -0.07 \cdot 0.00 + 1.57 \cdot 0.00 + 1.87 \cdot 1.00 = 0.84$

- Paper Chase: $-0.01 \cdot -0.06 + 0.07 \cdot 0.00 + -1.95 \cdot 0.53 + -2.28 \cdot 0.00 + -0.07 \cdot 0.00 + 1.57 \cdot 0.00 + 1.87 \cdot 1.00 = 0.84$
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- Smokey and the Bandit II:

- Paper Chase: $-0.01 \cdot -0.06 + 0.07 \cdot 0.00 + -1.95 \cdot 0.53 + -2.28 \cdot 0.00 + -0.07 \cdot 0.00 + 1.57 \cdot 0.00 + 1.87 \cdot 1.00 = 0.84$
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- Smokey and the Bandit II: $-0.01 \cdot -0.03 + 0.07 \cdot -0.02 + -1.95 \cdot -1.43 + -2.28 \cdot 1.00 + -0.07 \cdot 1.00 + 1.57 \cdot 0.00 + 1.87 \cdot 0.00 = 0.44$

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- Seconds: $-0.01 \cdot -0.08 + 0.07 \cdot -0.01 + -1.95 \cdot 0.74 + -2.28 \cdot 0.00 + -0.07 \cdot 0.00 + 1.57 \cdot 0.00 + 1.87 \cdot 1.00 = 0.43$
- Smokey and the Bandit II: $-0.01 \cdot -0.03 + 0.07 \cdot -0.02 + -1.95 \cdot -1.43 + -2.28 \cdot 1.00 + -0.07 \cdot 1.00 + 1.57 \cdot 0.00 + 1.87 \cdot 0.00 = 0.44$
- CB4:

- Paper Chase: $-0.01 \cdot -0.06 + 0.07 \cdot 0.00 + -1.95 \cdot 0.53 + -2.28 \cdot 0.00 + -0.07 \cdot 0.00 + 1.57 \cdot 0.00 + 1.87 \cdot 1.00 = 0.84$
- Seconds: $-0.01 \cdot -0.08 + 0.07 \cdot -0.01 + -1.95 \cdot 0.74 + -2.28 \cdot 0.00 + -0.07 \cdot 0.00 + 1.57 \cdot 0.00 + 1.87 \cdot 1.00 = 0.43$
- Smokey and the Bandit II: $-0.01 \cdot -0.03 + 0.07 \cdot -0.02 + -1.95 \cdot -1.43 + -2.28 \cdot 1.00 + -0.07 \cdot 1.00 + 1.57 \cdot 0.00 + 1.87 \cdot 0.00 = 0.44$
- CB4: $0.01 \cdot 0.02 + 0.07 \cdot -0.03 + -1.95 \cdot -0.73 + -2.28 \cdot 0.00 + -0.07 \cdot 1.00 + 1.57 \cdot 0.00 + 1.87 \cdot 0.00 = 1.35$

- Paper Chase: $-0.01 \cdot -0.06 + 0.07 \cdot 0.00 + -1.95 \cdot 0.53 + -2.28 \cdot 0.00 + -0.07 \cdot 0.00 + 1.57 \cdot 0.00 + 1.87 \cdot 1.00 = 0.84$
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- Sideways: $-0.01 \cdot 0.06 + 0.07 \cdot 0.03 + -1.95 \cdot 1.09 + -2.28 \cdot 0.00 + -0.07 \cdot 1.00 + 1.57 \cdot 0.00 + 1.87 \cdot 1.00 = -0.32$

- Paper Chase: $-0.01 \cdot -0.06 + 0.07 \cdot 0.00 + -1.95 \cdot 0.53 + -2.28 \cdot 0.00 + -0.07 \cdot 0.00 + 1.57 \cdot 0.00 + 1.87 \cdot 1.00 = 0.84$
- Seconds: $-0.01 \cdot -0.08 + 0.07 \cdot -0.01 + -1.95 \cdot 0.74 + -2.28 \cdot 0.00 + -0.07 \cdot 0.00 + 1.57 \cdot 0.00 + 1.87 \cdot 1.00 = 0.43$
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- CB4: $0.01 \cdot 0.02 + 0.07 \cdot -0.03 + -1.95 \cdot -0.73 + -2.28 \cdot 0.00 + -0.07 \cdot 1.00 + 1.57 \cdot 0.00 + 1.87 \cdot 0.00 = 1.35$
- Sideways: $-0.01 \cdot 0.06 + 0.07 \cdot 0.03 + -1.95 \cdot 1.09 + -2.28 \cdot 0.00 + -0.07 \cdot 1.00 + 1.57 \cdot 0.00 + 1.87 \cdot 1.00 = -0.32$

What's the predicted ranking?

Ranking

Predicted Rank

1. Sideways
2. Seconds
3. Smokey and the Bandit II
4. The Paper Chase
5. CB4

Ranking

Predicted Rank	True Rank
1. Sideways	1. Sideways
2. Seconds	2. Smokey and the Bandit II
3. Smokey and the Bandit II	3. Seconds
4. The Paper Chase	4. The Paper Chase
5. CB4	5. CB4

Ranking

Predicted Rank	True Rank
1. Sideways	1. Sideways
2. Seconds	2. Smokey and the Bandit II
3. Smokey and the Bandit II	3. Seconds
4. The Paper Chase	4. The Paper Chase
5. CB4	5. CB4

How many errors is this?

Ranking to Regression

- Using SVMs to predict a value
- Ranking that value
- What if we care about actual value and not just relative order?
- Regression!