CS 188: Artificial Intelligence
Fall 2009

Advanced Applications:
Robotics / Vision / Language

Dan Klein – UC Berkeley
Many slides from Pieter Abbeel, John DeNero

Announcements

- Contest: amazing stuff – 59 teams!
  - Final qualifying tournament almost done running!
  - Congrats to current qualifiers!
    - Send us your info ASAP
  - Tonight: seeding tournament
  - Wednesday NOON: final tournament
  - Thursday: final results in class!
Today

Motivating Example

- How do we specify a task like this?

[Demo: autorotate / tictoc]
Autonomous Helicopter Flight

- **Control inputs:**
  - \( a_{\text{lon}} \): Main rotor longitudinal cyclic pitch control (affects pitch rate)
  - \( a_{\text{lat}} \): Main rotor latitudinal cyclic pitch control (affects roll rate)
  - \( a_{\text{coll}} \): Main rotor collective pitch (affects main rotor thrust)
  - \( a_{\text{rud}} \): Tail rotor collective pitch (affects tail rotor thrust)

Autonomous Helicopter Setup

On-board inertial measurement unit (IMU)

Send out controls to helicopter
Helicopter MDP

- **State:** \( s = (x, y, z, \phi, \theta, \psi, \dot{x}, \dot{y}, \dot{z}, \dot{\psi}, \dot{\theta}, \dot{\psi}) \)

- **Actions (control inputs):**
  - \( a_{\text{lon}} \): Main rotor longitudinal cyclic pitch control (affects pitch rate)
  - \( a_{\text{lat}} \): Main rotor latitudinal cyclic pitch control (affects roll rate)
  - \( a_{\text{coll}} \): Main rotor collective pitch (affects main rotor thrust)
  - \( a_{\text{rud}} \): Tail rotor collective pitch (affects tail rotor thrust)

- **Transitions (dynamics):**
  - \( s_{t+1} = f(s_t, a_t) + w_t \)

  \([f \text{ encodes helicopter dynamics}]
  \[w \text{ is a probabilistic noise model} \]

- Can we solve the MDP yet?

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Problem: What’s the Reward?

- **Rewards for hovering:**
  \[
  R(s) = -(\alpha_x(x - x^*)^2 + \alpha_y(y - y^*)^2 + \alpha_z(z - z^*)^2 + \alpha_{\dot{x}}(\dot{x} - \dot{x}^*)^2 + \alpha_{\dot{y}}(\dot{y} - \dot{y}^*)^2 + \alpha_{\dot{z}}(\dot{z} - \dot{z}^*)^2)
  \]

- **Rewards for “Tic-Toc”?:**
  - Problem: what’s the target trajectory?
  - Just write it down by hand?

[demo: hover]
[demo: bad]
**Apprenticeship Learning**

- Goal: learn reward function from expert demonstration
- Assume $R(s) = w \cdot f(s)$
- Get expert demonstrations $s = (s_0, s_1, \ldots s_n)$
- Guess initial policy $\pi_0$
- Repeat:
  - Find $w$ which make the expert better than $\{\pi_0, \pi_1, \ldots, \pi_{i-1}\}$
  - $w_i \leftarrow$ distinguish $(\pi^*, \{\pi_0, \pi_1, \ldots, \pi_{i-1}\})$
  - Solve MDP for new weights $w$:
    - $\pi_i \leftarrow$ solve $(MDP(w_i))$

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**Pacman Apprenticeship!**

- Demonstrations are expert games
- Features defined over states $s$
- Score of a state given by:
  - $w \cdot f(s)$
- Learning goal: find weights which explain expert actions
Helicopter Apprenticeship?

Probabilistic Alignment

Intended trajectory
\[ z_{t+1} = f(z_t) + \omega_t \]

Expert demonstrations
\[ y_j = z_{\tau_j} + \nu_j \]

Time indices

- Intended trajectory satisfies dynamics.
- Expert trajectory is a noisy observation of one of the hidden states.
  - But we don’t know exactly which one.
Alignment of Samples

- Result: inferred sequence is much cleaner!

Final Behavior
What is NLP?

- **Fundamental goal:** analyze and process human language, broadly, robustly, accurately…
- **End systems that we want to build:**
  - Ambitious: speech recognition, machine translation, information extraction, dialog interfaces, question answering…
  - Modest: spelling correction, text categorization…

Problem: Ambiguities

- **Headlines:**
  - Enraged Cow Injures Farmer With Ax
  - Hospitals Are Sued by 7 Foot Doctors
  - Ban on Nude Dancing on Governor's Desk
  - Iraqi Head Seeks Arms
  - Local HS Dropouts Cut in Half
  - Juvenile Court to Try Shooting Defendant
  - Stolen Painting Found by Tree
  - Kids Make Nutritious Snacks

- **Why are these funny?**
Parsing as Search

Grammar: PCFGs

- Natural language grammars are very ambiguous!
- PCFGs are a formal probabilistic model of trees
  - Each “rule” has a conditional probability (like an HMM)
  - Tree’s probability is the product of all rules used
- Parsing: Given a sentence, find the best tree – search!

```
ROOT  \\
   ↓  \\
S  \\
  \\
NP  VP  \\
  \\
   NP  \\
   V  NP  \\
   \\
     N  \\
Hershey  bars  N  \\
     protest  \\

ROOT  \\
   ↓  \\
S  \\
  \\
NP  VP  \\
  \\
   NP  \\
   V  \\
   \\
     N  \\
Hershey  bars  V  \\
     protest  \\

```

```
ROOT \rightarrow S 375/420
S \rightarrow NP VP . 320/392
NP \rightarrow PRP 127/539
VP \rightarrow VBD ADJP 32/401
.....
```
Hurricane Emily howled toward Mexico’s Caribbean coast on Sunday packing 135 mph winds and torrential rain and causing panic in Cancun, where frightened tourists squeezed into musty shelters.

Machine Translation

- Translate text from one language to another
- Recombines fragments of example translations
- Challenges:
  - What fragments? [learning to translate]
  - How to make efficient? [fast translation search]
The Problem with Dictionary Look-ups

Example from Douglas Hofstadter

A Brief and Biased History

When I look at an article in Russian, I say: “This is really written in English, but it has been coded in some strange symbols. I will now proceed to decode.”

“Machine Translation” presumably means going by algorithm from machine-readable source text to useful target text... In this context, there has been no machine translation...

Warren Weaver

John Pierce

Berkeley's first MT grant

MT is the “first” non-numeral compute task

ALPAC report deems MT bad

Statistical MT thrives

Statistical data-driven approach introduced

'47 '58 '66 '90's '00's
Data-Driven Machine Translation

Target language corpus:
- I will get to it soon
- See you later
- He will do it

Sentence-aligned parallel corpus:
- Yo lo haré mañana
- I will do it tomorrow
- Hasta pronto
- See you soon
- Hasta pronto
- See you around

Machine translation system:

Learning to Translate

<table>
<thead>
<tr>
<th>CLASSIC SOUPS</th>
<th>Sm.</th>
<th>Lg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>57. 青椒肉粥</td>
<td>House Chicken Soup (Chicken, Celery, Potato, Onion, Carrot)</td>
<td>1.50</td>
</tr>
<tr>
<td>58. 豆腐蒸湯</td>
<td>Chicken Rice Soup</td>
<td>1.85</td>
</tr>
<tr>
<td>59. 麻婆豆腐</td>
<td>Chicken Noodle Soup</td>
<td>1.85</td>
</tr>
<tr>
<td>60. 重庆小面</td>
<td>Cantonese Wonton Soup</td>
<td>1.50</td>
</tr>
<tr>
<td>61. 麻辣香锅</td>
<td>Tomato Clear Egg Drop Soup</td>
<td>1.65</td>
</tr>
<tr>
<td>62. 佛跳墙</td>
<td>Regular (Wonton) Soup</td>
<td>1.10</td>
</tr>
<tr>
<td>63. 热带水果汤</td>
<td>Hot &amp; Sour Soup</td>
<td>1.10</td>
</tr>
<tr>
<td>64. 粤菜拼盘</td>
<td>Egg Drop Soup</td>
<td>1.10</td>
</tr>
<tr>
<td>65. 咸汤</td>
<td>Egg Drop (Wonton) Mix</td>
<td>1.10</td>
</tr>
<tr>
<td>66. 抱罗粉</td>
<td>Tofu Vegetable Soup</td>
<td>NA</td>
</tr>
<tr>
<td>67. 麻婆豆腐</td>
<td>Chicken Corn Cream Soup</td>
<td>NA</td>
</tr>
<tr>
<td>68. 高汤玉米面</td>
<td>Crab Meat Corn Cream Soup</td>
<td>NA</td>
</tr>
<tr>
<td>69. 海鲜粥</td>
<td>Seafood Soup</td>
<td>NA</td>
</tr>
</tbody>
</table>

Example from Adam Lopez
The HMM Model

E:
Thank you, I shall do so gladly.

A:

F:
Gracias, lo haré de muy buen grado.

Model Parameters

Emissions: \( P(F_1 = \text{Gracias} \mid E_{A1} = \text{Thank}) \)  
Transitions: \( P(A_2 = 3 \mid A_1 = 1) \)

Levels of Transfer

interlingua
semantics
syntax
phrases
words
SOURCE

TARGET

interlingua
semantics
syntax
phrases
words

\( P(\text{I will do it tomorrow} \mid \text{Yo lo haré mañana}) = 0.8 \)

<table>
<thead>
<tr>
<th>English (E)</th>
<th>P(E \mid \text{mañana})</th>
</tr>
</thead>
<tbody>
<tr>
<td>tomorrow</td>
<td>0.7</td>
</tr>
<tr>
<td>morning</td>
<td>0.3</td>
</tr>
</tbody>
</table>

English (E) | P(E \mid \text{will do it}) |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>will do it</td>
<td>0.8</td>
</tr>
<tr>
<td>will do so</td>
<td>0.2</td>
</tr>
</tbody>
</table>
Machine Translation

Machine translation system:

A Statistical Translation Model

Synchronous Derivation

A Statistical Model

Translation model components
factor over applied rules

How well are these rules
supported by the data?

Language model factors over n-grams

How well is this output sentence
supported by the data?

Synchronous Grammar Rules

S → (Yo lo haré ADV ; I will do it ADV)
ADV → (después ; later)
Example Syntax-Based Translation

foreign:  ورفض إبراهيم الدلامة أي صريحات فور وصوله إلى المقامة.

tac-lang: urFD albaZ aladam laZ tSryfat fur wSulh ab almglTz.

bckfltr: urFD AlbaZ AladAb Alay tSryFat fur wSulh Almgt.

Tune: ntw: ol @ ol baz declined to make any statements upon his arrival in the province.

[demo: MT]