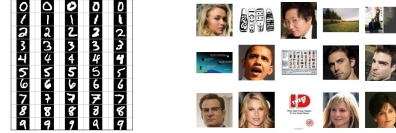# CS 188: Artificial Intelligence
Spring 2010

Lecture 27: Conclusion
4/28/2010

Pieter Abbeel – UC Berkeley

Announcements

- Project 5 due tonight.

- Office hours
  - next week: only Woody and Alex.
  - Next next week: back to normal office hours.
- Contest!!
  - Tournaments every night.
  - **Final tournament: We will use submissions received by Thursday May 6, 11pm.**

Today

- AI applications:
  - Robotics, language, vision

- Where to go next

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Quadruped

- Model as MDP --- but what should the reward function be?
- Reward function trades off 25 features.
- $R(x) = w^\top \phi(x)$

[Kolter, Abbeel & Ng, 2008]

Find the Reward Function for Foot Placements

- $R(x) = w^\top f(x)$

- Find the reward function that makes the demonstrations better than all other paths by some margin

$$\min_{w, \xi \geq 0} \quad \|w\|_2^2 + \sum_i \xi^{(i)}$$
$$\text{s.t.} \quad \forall i, \ \forall x, \ \sum_t w \cdot f(x_t^{(i)}) \geq \sum_t w \cdot f(x_t) + 1 - \xi^{(i)}$$

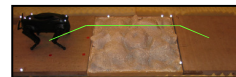- Compare to support vector machine (SVM):

$$\min_{w, \xi \geq 0} \quad \|w\|_2^2 + \sum_i \xi^{(i)}$$
$$\text{s.t.} \quad \forall i, y \ w_{y^*} \cdot f(x_i) \geq w_y \cdot f(x_i) + 1 - \xi^{(i)}$$
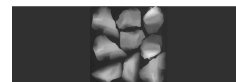
5

High-Level Control

- Demonstrate path across the "training terrain"

- Run apprenticeship learning to find a set of weights w
- Receive "testing terrain" (a height map)

- Find a policy for crossing the testing terrain.
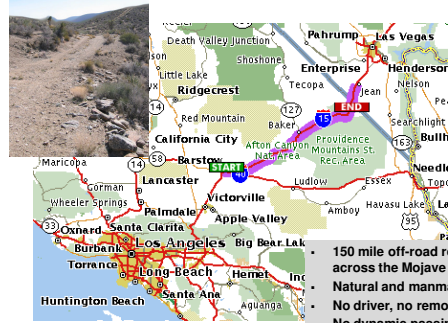
1

Without learning
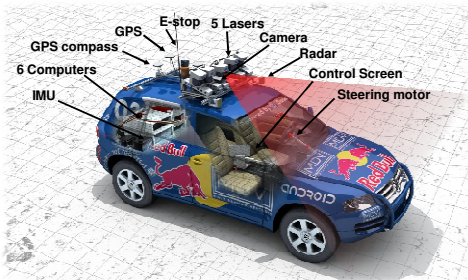

With learned reward function

Autonomous Vehicles

Autonomous vehicle slides adapted from Sebastian Thrun

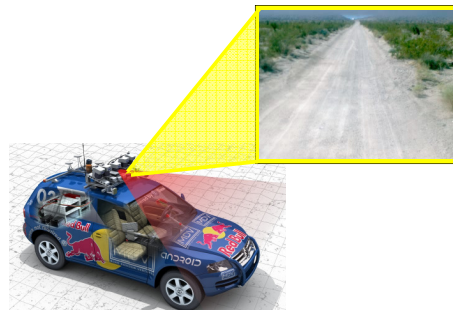### Grand Challenge: Barstow, CA, to Primm, NV

- **150 mile off-road robot race across the Mojave desert**
- **Natural and manmade hazards**
- **No driver, no remote control**
- **No dynamic passing**

Inside an Autonomous Car

GPS
E-stop 5 Lasers
GPS compass   Camera
                     Radar
6 Computers   Control Screen
                     Steering motor
IMU

Sensors: Camera
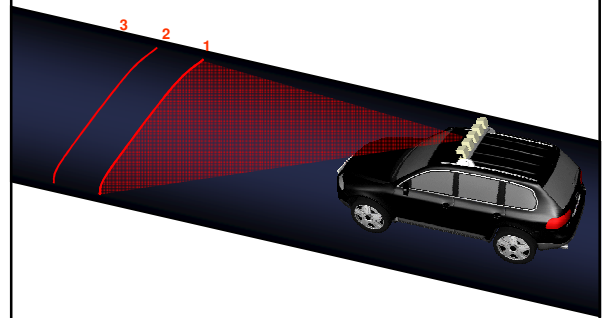
Vision for a Car

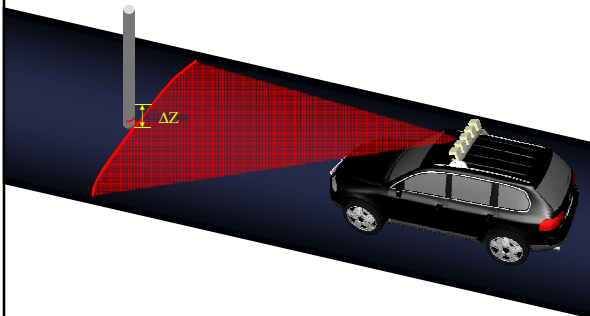

Self-Supervised Vision

- Demo: lidar-and-vision 1.mp4
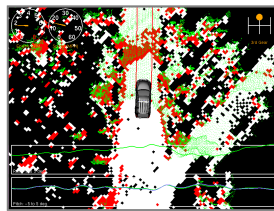
16

Readings: No Obstacles
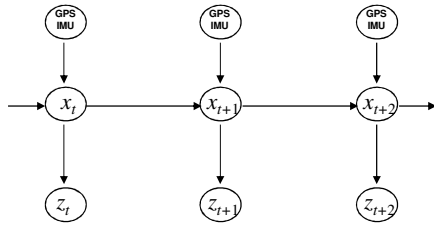

Readings: Obstacles

Obstacle Detection

Trigger if $|Z^i - Z^j| > 15\text{cm}$ for nearby z^i, z^j
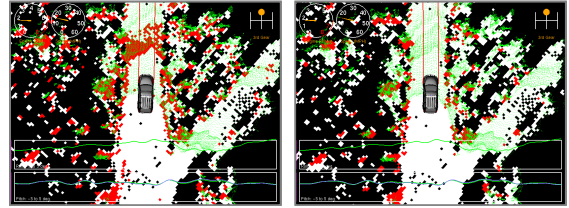

Raw Measurements: 12.6% false positives
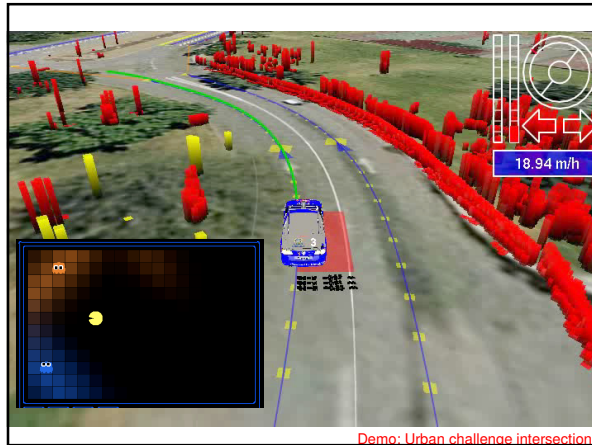
Probabilistic Error Model

HMMs for Detection

Raw Measurements: 12.6% false positives   HMM Inference: 0.02% false positives

---

18.94 m/h

Demo: Urban challenge intersection

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…

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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
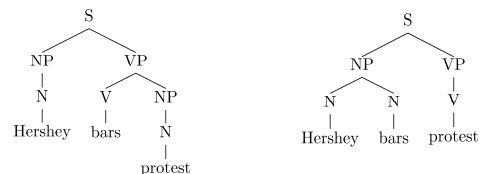

Hershey bars protest

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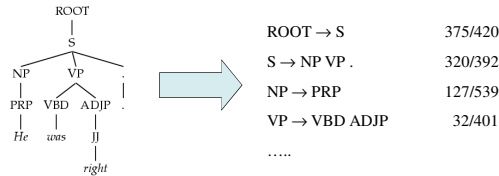
Syntactic Analysis
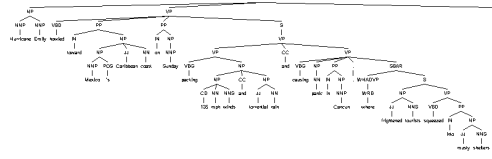
Hurricane Emily howled toward Mexico 's Caribbean coast on Sunday packing 135 mph winds and torrential rain and causing panic in Cancun, where frightened tourists squeezed into musty shelters .
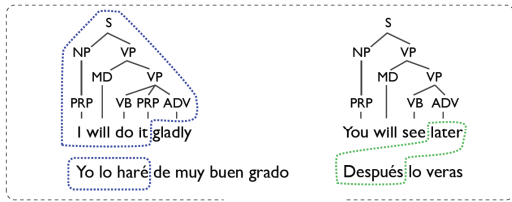
Machine Translation

- 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]
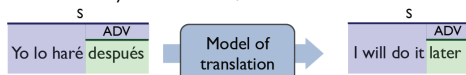
The Problem with Dictionary Look-ups

顶部	/**top**/roof/
顶端	/summit/peak/**top**/apex/
顶头	/coming directly towards one/**top**/end/
盖	/lid/**top**/cover/canopy/build/Gai/
盖帽	/surpass/**top**/
极	/extremely/pole/utmost/**top**/collect/receive/
尖峰	/peak/**top**/
面	/fade/side/surface/aspect/**top**/face/flour/
摘心	/**top**/topping/

Example from Douglas Hofstadter

Machine Translation

A Brief and Biased History
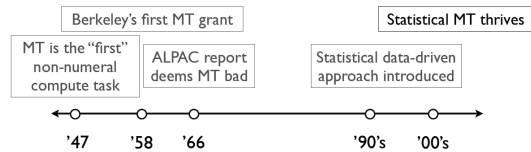
Data-Driven Machine Translation

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:

Yo lo haré pronto
NOVEL SENTENCE → Model of translation → I will do it soon

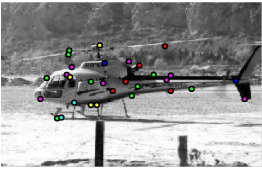
Learning to Translate

CLASSIC SOUPS   Sm.   Lg.

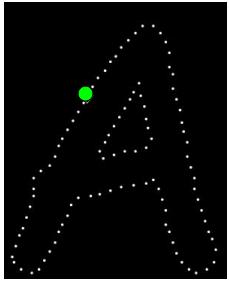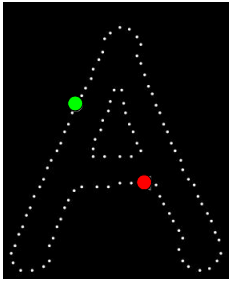| | 57. | House Chicken Soup (Chicken, Celery, Potato, Onion, Carrot) | 1.50 | 2.75 |
58.	Chicken Rice Soup	1.85	3.25
59.	Chicken Noodle Soup	1.85	3.25
60.	Cantonese Wonton Soup	1.50	2.75
61.	Tomato Clear Egg Drop Soup	1.65	2.95
62.	Regular Wonton Soup	1.10	2.10
63.	Hot & Sour Soup	1.10	2.10
64.	Egg Drop Soup	1.10	2.10
65.	Egg Drop Wonton Mix	1.10	2.10
66.	Tofu Vegetable Soup	NA	3.50
67.	Chicken Corn Cream Soup	NA	3.50
68.	Crab Meat Corn Cream Soup	NA	3.50
69.	Seafood Soup	NA	3.50

Example from Adam Lopez

Computer Vision: Object Recognition
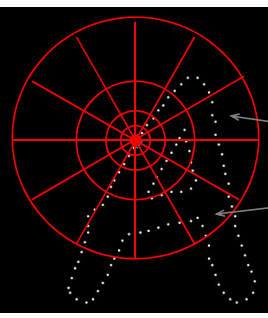
Template   Query

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Comparing Local Regions

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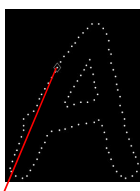## Shape Context
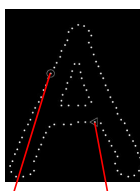
Count the number of points inside each bin, e.g.:
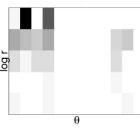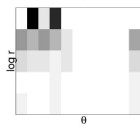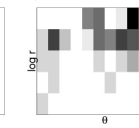
Count = 4

⋮

Count = 10

✦ Compact representation of distribution of points relative to each point

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Shape Context

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Incorporation into nearest neighbors

- Start from two images --- extract contour points
- Compute pairwise cost matrix
  - Cost for difference in histogram
  - Cost difference in tangent direction
- Find lowest cost 1-to-1 matching between two images
- Find the geometric transformation as close as possible to this 1-to-1 matching
- Distance between two images consists of
  - Cost of each of the pairs in the 1-to-1 matching
  - Closeness of geometric transformation and the 1-to-1 matching

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Empirical Evaluation

- Tested their approach on the MNIST dataset.
- As of Dec 2009, more than 50 algorithms have been tested on the database.
- Training set: 60,000 examples.
- Test set: 10,000 examples.
- Error rate: 0.63% using 20,000 training examples and 3-NN.
- At the time of publication, this error rate was the lowest. Currently, the lowest error rate is 0.39%.

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Where to go next?

- Congratulations, you've seen the basics of modern AI
  - … and done some amazing work putting it to use!

- How to continue:
  - Robotics / vision / IR / language: cs189
  - Machine learning: cs281a / cs281b
  - Cognitive modeling: cog sci 131
  - Vision: cs280
  - Robotics: cs287
  - NLP: cs288
  - Optimization: ee127a and ee227a
  - … and more; ask if you're interested

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That's It!

- Happy studying, good luck on the exam and contest, and have a great summer!

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