Today's Reading

Today's assigned "reading" is twofold:

1. Reprise Peter Norvig's September 23, 2010, talk, "The unreasonable effectiveness of data," UBC Computer Science Distinguished Lecture Series. (video)
2. Peter Norvig's "On Chomsky and the two cultures of statistical learning." (on line essay)

Noam Chomsky was one of six presenters in the "Keynote Panel: The Golden Age – A Look at the Original Roots of Artificial Intelligence, Cognitive Science, and Neuroscience" at the MIT150 Celebration Symposium: Brains, Minds, and Machines, May 3–5, 2011. Norvig's essay is in response to an answer Chomsky gave to a question posed by Steven Pinker, the panel moderator

Those specifically interested in linguistics and philosophy are encouraged to explore further by listening to the presentations by both Chomsky and Barbara Partee. Also included in the panel are AI pioneers Marvin Minsky and Patrick Winston and neuroscientists/biologists Emilio Bizzi and Sydney Brenner.

Today's Learning Goals

1. To extend our notion of language to include knowledge representation (KR) and reasoning
2. To distinguish two aspects of an intelligent system's KR:
   - knowledge of the 3D world (objective, external knowledge)
   - knowledge of itself as a problem solver (subjective, internal knowledge)
3. To introduce the Bayesian interpretation of probability and associated statistical inference
4. To identify three exemplar approaches to KR based, respectively, on structured, semi-structured and unstructured "big data" knowledge bases

Methodological Issues (Across Disciplines)

- What problems do each discipline address?
- What questions do each discipline ask about those problems?
- What tools and techniques do each discipline use to answer these questions?
- What defines "success" in each discipline?

Note: Arguably, the core disagreement between Chomsky and Norvig, as reflected in today's reading, "On Chomsky and the two cultures of statistical learning," is a disagreement about the answer to the question, "What defines success?"

AI deals with knowledge representation (KR). Intelligent systems need to represent both knowledge of the 3D world (external knowledge) and knowledge about themselves as problem solvers (internal knowledge).

Knowledge Representation (KR): Key Issues

Questions to ask of any KR scheme are:

1. What *"language"* is being used?
2. What *knowledge* is represented explicitly by a given set of expressions in the language?
3. What *inference mechanism* is available to make explicit knowledge which is implicit, but not yet explicit, in the given set of expressions?

Inference mechanisms can be thought of as methods to reason about (or calculate with) knowledge in order to make explicit that which is only implicit

Suppose we have a group of n people. The number of distinct ways in which birthdays can occur (allowing for repetitions) is 365^n. Of these ways, only

$$365 \times 364 \times \ldots \times (365 - (n-1))$$

are such that no two of the birthdays are the same. Thus, the probability that in a group of n people no two have a birthday in common is

$$\frac{365 \times 364 \times \ldots \times (365 - (n-1))}{365^n}$$

Subtracting this probability from 1 gives us the probability that at least two of the people have a common birthday.

We can tabulate the results for various values of n.

Example 1: Common Birthday

Number of people	Probability of at least one common birthday
1	0
10	0.117
20	0.411
23	*0.507*
30	0.706
40	0.891
50	0.970
⋮	⋮
107	*0.99999994*

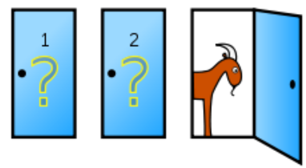
As the table shows, about half the time 23 randomly selected people are gathered together, two or more of them will share a birthday.

There are 107 students on the COGS 200 classlist for this term. There is a 99.999994% chance that at least two have a common birthday.

The Monty Hall problem is a puzzle formulated based on the American television game show "Let's Make a Deal" and named after its original host, Monty Hall.

Example 2: Monty Hall Problem

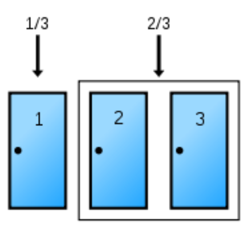
Suppose you're on a game show, and you're given the choice of three doors: Behind one door is a car; behind the others, goats. You pick a door, say No. 1, and the host, who knows what's behind the doors, opens another door, say No. 3, which has a goat. He then says to you, "Do you want to pick door No. 2?"



Question: Is it to your advantage to switch your choice?

http://en.wikipedia.org/wiki/Monty_Hall_problem

Example 2 (cont'd): Monty Hall Problem

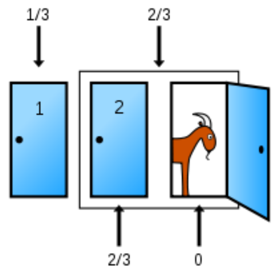


The probability that the car is behind door 1 is $\frac{1}{3}$

The probability that the car is behind one of the two other doors is $\frac{2}{3}$

http://en.wikipedia.org/wiki/Monty_Hall_problem

Example 2 (cont'd): Monty Hall Problem



The host opens door 3 revealing a goat. The probabilities for the two cases, door 1 (alone) and doors 2 and 3 (together), don't change. But, the probability that the car is behind door 3 now is 0

Therefore, the probability that the car is behind door 2 now is $\frac{2}{3}$

http://en.wikipedia.org/wiki/Monty_Hall_problem

Answer: Yes, it is to your advantage to switch. Not switching wins the car $\frac{1}{3}$ of the time. Switching wins the car $\frac{2}{3}$ of the time.

The idea that switching is beneficial is counterintuitive. In 1990, the problem (with solution) appeared in the popular press (Marilyn vos Savant's column, "Ask Marilyn," *Parade* magazine). Approximately 10,000 readers, including nearly 1,000 with PhDs, wrote to the magazine, most claiming vos Savant's solution was wrong. Even when given explanations, simulations, and formal mathematical proofs, many people still do not accept that switching is the best strategy.

Roy Meadow, a British paediatrician, first came to public attention in 1977 following an academic paper in which he described a phenomenon he called Munchausen Syndrome by Proxy (MSbP). In 1989, he published a statement that came to be known as Meadow's Law.

Example 3: Meadow's Law

> "One sudden infant death is a tragedy, two is suspicious and three is murder until proved otherwise."

Sir Roy Meadow
ABC of Child Abuse, 1989

http://en.wikipedia.org/wiki/Meadow%27s_law

Meadow's Law was used, until recently, in the investigation of cases of multiple instances of sudden infant death syndrome (SIDS), also known as crib death, within a single family.

For example, Meadow testified at the 1999 trial of lawyer Sally Clark accused of murdering two of her sons, about two years apart. Ultimately, the conviction was overturned and Clark was freed nearly four years later. But, Clark never recuperated from the loss of her babies and the miscarriage of justice. She died of alcohol poisoning in 2007.

As a result of this case, the British Attorney-General ordered a review of hundreds of other cases and two other women (at whose trials Meadow also had testified) had their convictions overturned.

Interpretations of Probability (in Statistics)

1. *Frequentist (objective):* Probability is the observed frequency of an event, based on repeated sampling of the world. It is obtained from *empirical data* (i.e., measurements) of the external world

   Example: In Vancouver, it rains 80% of the days in November

2. *Bayesian (subjective):* Probability is the degree of confidence an agent has regarding an uncertain event. It represents the *internal belief* an agent has about the external world

   Example: The patient has a 70% chance of having cancer

Both the frequentist and the Bayesian interpretations respect all standard models of probability. In statistical machine learning, the Bayesian interpretation dominates in that it allows one to update models (i.e., measures of belief) in response to observations (i.e., new evidence).

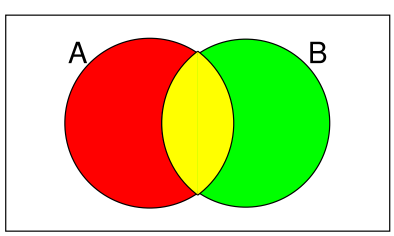
Bayes' Theorem

Machine learning has adopted the tools and techniques of computational statistics. Knowledge is represented in the form of probability distributions and inference is done by numerical computation (to combine/update these probability distributions into new probability distributions).

We provide a brief introduction to the "language" of machine learning and the central role that Bayes' theorem plays in statistical inference.

Conditional Probability

A Venn diagram shows the intersection, $A \cap B$, of two sets A and B



$A \cap B$

We can write $P(A \cap B)$ in two ways

$$\begin{aligned} P(A \cap B) &= P(A|B)P(B) \\ P(A \cap B) &= P(B|A)P(A) \end{aligned}$$

so that

$$P(A|B)P(B) = P(B|A)P(A)$$

or

$$P(A|B) = \frac{P(B|A)P(A)}{P(B)}$$

In set theory, the symbol $\cap$ denotes intersection so that $A \cap B$ is the set of points belonging to both A and B (i.e., the set coloured yellow in the Venn diagram).

In probability theory, the symbol $|$ denotes conditional probability. The term $P(A|B)$ means the probability that a point is in set A given that it is in set B.

In words, $P(A \cap B) = P(A|B)P(B)$ means "the probability that a point is in both A and B equals the probability that it is in A, given that it is in B, multiplied by the probability that it is in B." Similarly, $P(A \cap B) = P(B|A)P(A)$ means "the probability that a point is in both A and B equals the probability that it is in B, given that it is in A, multiplied by the probability that it is in A."

The equation

$$P(A|B) = \frac{P(B|A)P(A)}{P(B)}$$

is known as Bayes' theorem (or Bayes' rule). Bayes' theorem is valid in all standard interpretations of probability. See http://en.wikipedia.org/wiki/Bayes%27_theorem

Bayes' Theorem (aka Bayes' Rule)

Used (historically) to address practical problems:[1]

- assessing evidence in legal proceedings
- setting insurance rates
- decoding the German Enigma cipher during WWII (Alan Turing)
- search and rescue (e.g., recovering lost nuclear bombs, submarines, etc)
- assessing likelihood of nuclear accidents
- verifying authorship of the US Federalist Papers

The example of the US Federalist Papers is an interesting case–in–point.

[1] McGrayne, S. B. (2011). *The theory that would not die*. Yale University Press

Example 4: US Federalist Papers

> "The 1964 publication of Inference and Disputed Authorship made the cover of Time magazine and the attention of academics and the public alike for its use of statistical methodology to solve one of American history's most notorious questions: the disputed authorship of the Federalist Papers.
>
> Back in print for a new generation of readers, this classic volume applies mathematics, including the once-controversial Bayesian analysis, into the heart of a literary and historical problem by studying frequently used words in the texts. The reissue of this landmark book will be welcomed by anyone interested in the juncture of history, political science, and authorship."

Book description (for the 2008 re-issue) at amazon.com.

To understand how Bayes' theorem is used, we need to interpret it as a way to represent and update knowledge of the world. In doing this, we also define the basic terminology associated with Bayesian inference.

Bayes' Theorem (aka Bayes' Rule)

Let H be the hypothesis (i.e., belief) and let E be the evidence

$$\underbrace{P(H \mid E)}_{\text{posterior probability}} = \overbrace{P(H)}^{\text{prior probability}} \frac{\overbrace{P(E \mid H)}^{\text{likelihood}}}{\underbrace{P(E)}_{\substack{\text{unconditional probability} \\ \text{(marginal likelihood)}}}}$$

Bayesian Inference

Bayesian inference is an iterative process in which new evidence repeatedly updates an initial probability distribution

Before any evidence is taken into account, one starts with some belief about H, expressed as an initial prior probability

At each iteration step, the prior probability is taken to be the posterior probability from the previous iteration

See http://en.wikipedia.org/wiki/Bayesian_inference

“Big Data” (Wikipedia Definition)

Big data is the term for a collection of data sets so large and complex that it becomes difficult to process using on-hand database management tools or traditional data processing applications. The challenges include capture, curation, storage, search, sharing, transfer, analysis and visualization…

…The world’s technological per-capita capacity to store information has roughly doubled every 40 months since the 1980s. As of 2012, every day 2.5 exabytes (2.5×10^{18}) of data were created

http://en.wikipedia.org/wiki/Big_data

“Big Data” (Vancouver Sun)

> “Move over, firefighters and Internet magnates. The sexiest new jobs belong to statisticians.”

“Deluge of data creates advantage for tech-savvy companies”
Scott Simpson, Vancouver Sun, September 30, 2011

“Big Data” Knowledge Bases:

Approach	*Example*
Structured	Cyc
Semi-structured	Wikipedia
Unstructured	Google (the entire WWW)

COGS 200 students most likely all are users of both Google and Wikipedia.

Many will not be familiar with Cyc.

Cyc was started in 1984 by Doug Lenat.[2]

Cyc

The objective of Cyc is to codify, in a formalized representation, sufficient “pieces of knowledge” to comprise human common sense. In 1986, Lenat estimated the effort to complete Cyc would be 250,000 rules and 350 man-years of effort

[2] Lenat’s Ph.D supervisor was Ed Feigenbaum. Cyc is seen by people like Peter Norvig as an example of failing GOFAI (Good Old-Fashioned Artificial Intelligence)

In 1994, Cycorp, Inc. was founded "to further develop, commercialize, and apply the Cyc technology"

Cyc uses a *proprietary* knowledge representation language and associated inference engine based on *first-order predicate calculus (FOPC)* with some extensions

Versions of Cyc have been made available under an open source licence

Cyc Update

An article dated July 3, 2014, in Business Insider, India, titled "The Most Ambitious Artificial Intelligence Project In The World Has Been Operating In Near-Secrecy For 30 Years" quotes Doug Lenat,

> "We've been keeping a very low profile, mostly intentionally. No outside investments, no debts. We don't write very many articles or go to conferences, but for the first time, we're close to having this be applicable enough that we want to talk to you."

The article in Business Insider, India, further quotes Lenat,

> "Any time you look at any kind of real life piece of text or utterance that one human wrote or said to another human, it's filled with analogies, modal logic, belief, expectation, fear, nested modals, lots of variables and quantifiers. Everyone else is looking for a free-lunch way to finesse that. Shallow chatbots show a veneer of intelligence or statistical learning from large amounts of data. Amazon and Netflix recommend books and movies very well without understanding in any way what they're doing or why someone might like something.
>
> It's the difference between someone who understands what they're doing and someone going through the motions of performing something."

Wikipedia's knowledge base is large, compared to Cyc, but nowhere near the size of the entire internet (which is, of course, the "big data" that Google seeks to mine).

Here are some current Wikipedia statistics

(Selected) Wikipedia Statistics

Page statistics	
(English) Content pages	4,622,986
All pages (including talk pages, redirects, etc.)	34,003,182
Edit statistics	
Page edits since Wikipedia was set up	739,028,174
Average edits per page	21.73
User statistics	
Registered users	22,798,785
Active registered users (performed an action in the last 30 days)	129,522

http://en.wikipedia.org/wiki/Special:Statistics
October 14, 2014

Further, it is estimated that the English language Wikipedia currently has 6.5 million redirect pages (to accommodate synonyms, technical terms, common misspellings and variants) and 251,551 disambiguation pages (to accommodate multiple meanings). Finally, statistics (compiled January, 2010) indicate articles in the English language Wikipedia have 78.3 million internal links (to connect related Wikipedia concepts).

Currently, there are official Wikipedias in 287 different languages. See List of Wikipedias for the complete listing. Here are the major ones, based on article counts.

Wikipedia Other Languages

- More than 1,000,000 articles: Deutsch · español · français · italiano · Nederlands · polski · русский · svenska
- More than 400,000 articles: català · 日本語 · norsk bokmål · português · Tiếng Việt · українська · 中文
- More than 200,000 articles: العربية · Bahasa Indonesia · Bahasa Melayu · čeština · српски / srpski · فارسی · 한국어 · magyar · română · suomi · Türkçe
- More than 50,000 articles: български · dansk · eesti · Ελληνικά · English (simple) · Esperanto · euskara · galego · עברית · hrvatski · latviešu · lietuvių · norsk nynorsk · slovenčina · slovenščina · srpskohrvatski / српскохрватски · ไทย

There is a grand total[3] of 33,607,578 articles in the 287 Wikipedias. A total of twelve Wikipedias have more than one million articles: English (4,622,899), Swedish (1,945,221), Dutch (1,792,824), German (1,765,858), French (1,552,540), Waray-Waray (1,220,249), Cebuano (1,208,452), Russian (1,155,426), Italian (1,150,148), Spanish (1,131,289), Vietnamese (1,109,036) and Polish (1,069,896).

Wikification

Ian H. Witten in the Department of Computer Science, University of Waikato in New Zealand, defines *wikification* as the process of "automatically and judiciously augmenting a plain-text document with pertinent hyperlinks to Wikipedia articles – as though the document were itself a Wikipedia article."

David Milne, one of Ian's Ph.D graduates, created an OpenSource software toolkit called WikipediaMiner.

WikipediaMiner

Quoting from http://wdm.cs.waikato.ac.nz:8080/

"WikipediaMiner is a toolkit for tapping the rich semantics encoded within Wikipedia

It makes it easy to integrate Wikipedia's knowledge into your own applications, by:

- providing simplified, object-oriented access to Wikipedia's structure and content
- measuring how terms and concepts in Wikipedia are connected to each other
- detecting and disambiguating Wikipedia topics when they are mentioned in documents

Try the demos and services to see what we mean"

[3] Statistics at 00:00, 15 October 2014 (UTC)