Natural Language Processing
CS224N/Ling284

Christopher Manning
Spring 2010
Lecture 1

Course logistics in brief

- Instructor: Christopher Manning
- TAs: Mengqiu Wang, Val Spitkovsky
- Time: MW 11:00-12:15.
  - Section: Fri 11:00-11:50 Skilling 191
- Programming language: Java 1.5+
- Other information: see the webpage.
  - http://cs224n.stanford.edu/
- Handouts:

vs.

?

This class

- Assumes you come with some skills…
  - Some basic linear algebra, probability, and statistics; decent programming skills
  - But not everyone has the same skills
    - Assumes some ability to learn missing knowledge
- Teaches key theory and methods for statistical NLP: MT, information extraction, parsing, semantics, etc.
  - Learn techniques which can be used in practical, robust systems that can (partly) understand human language
- But it's something like an "AI Systems" class:
  - A lot of it is hands-on, problem-based learning
  - Often practical issues are as important as theoretical niceties
  - We often combine a bunch of ideas

Natural language: the earliest UI

Dave Bowman: Open the pod bay doors, HAL.
HAL: I'm sorry Dave. I'm afraid I can't do that.

(cf. also false Maria in Metropolis – 1926)

Goals of the field of NLP

- Computers would be a lot more useful if they could handle our email, do our library research, chat to us …
- But they are fazed by natural human languages.
  - Or at least their programmers are … most people just avoid the problem and get into XML, or menus and drop boxes, or …
- But someone has to work on the hard problems!
  - How can we tell computers about language?
  - Or help them learn it as kids do?
- In this course we seek to identify many of the open research problems in natural language

What/where is NLP?

- Goals can be very far reaching …
  - True text understanding
  - Reasoning about texts
  - Real-time participation in spoken dialogs
- Or very down-to-earth …
  - Finding the price of products on the web
  - Analyzing reading level or authorship statistically
  - Sentiment detection about products or stocks
  - Extracting facts or relations from documents
- These days, the latter predominate (as NLP becomes increasingly practical, it is increasingly engineering-oriented – also related to changes in approach in AI/NLP)

Commercial world

the problem session for your course, CS224n in Gates B03 from 1:15-2:05
Skilling Aud
Create New iCal Event...
Show This Date in iCal...

ski resort

Sugar Bowl Ski Lodging
Escape to our Snowbound Village. Fresh tracks steps from your room.
www.sugarbowl.com

Their are many approaches, out

The hidden structure of language

- We're going beneath the surface…
  - Not just string processing
  - Not just keyword matching in a search engine
    - Search Google on "tennis racquet" and "tennis racquets" or "laptop" and "notebook" and the results are quite different … though these days Google does lots of subtle stuff beyond keyword matching itself
    - Not just converting a sound stream to a string of words
      - Like Nuance/IBM/Dragon/Philips speech recognition
- We want to recover and manipulate at least *some* aspects of structure and meaning

Is the problem just cycles?

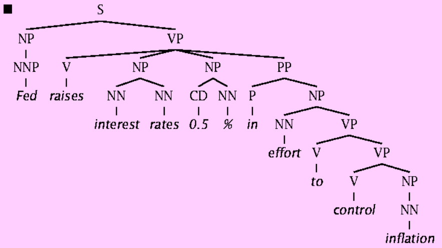
- Bill Gates, Remarks to Gartner Symposium, October 6, 1997:
  - Applications always become more demanding. Until the computer can speak to you in perfect English and understand everything you say to it and learn in the same way that an assistant would learn -- until it has the power to do that -- we need all the cycles. We need to be optimized to do the best we can. Right now linguistics are right on the edge of what the processor can do. As we get another factor of two, then speech will start to be on the edge of what it can do.

The early history: 1950s

- Ear
les
- Fo
lan
- Fir
- MT
wo
- Lit
ser
- Pro

Why is NLU difficult? The hidden structure of language is hugely ambiguous

- Structures for: *Fed raises interest rates 0.5% in effort to control inflation* (*NYT* headline 17 May 2000)
-



Where are the ambiguities?

Part of speech ambiguities

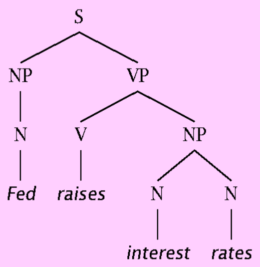
Syntactic attachment ambiguities

		VB					
	VBZ	VBP	VBZ				
NNP	NNS	NN	NNS	CD	NN		
Fed	*raises*	*interest*	*rates*	*0.5*	*%*	*in*	*effort*
						to	*control*
							inflation

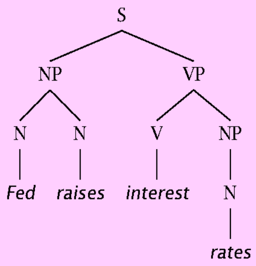
Word sense ambiguities: Fed → *"federal agent"*
interest → *a feeling of wanting to know or learn more*

Semantic interpretation ambiguities above the word level

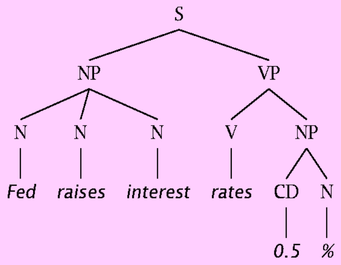
The bad effects of V/N ambiguities (1)



The bad effects of V/N ambiguities (2)

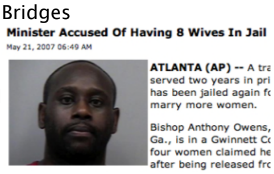


The bad effects of V/N ambiguities (3)



Why NLP is difficult: Newspaper headlines

- Minister Accused Of Having 8 Wives In Jail
- Juvenile Court to Try Shooting Defendant
- Teacher Strikes Idle Kids
- China to Orbit Human on Oct. 15
- Local High School Dropouts Cut in Half
- Red Tape Holds Up New Bridges
- Clinton Wins on Budget,
- Hospitals Are Sued by 7
- Police: Crack Found in M


Minister Accused Of Having 8 Wives In Jail

May 21, 2007 06:49 AM

ATLANTA (AP) -- A tra
served two years in pri
has been jailed again fo
marry more women.

Bishop Anthony Owens,
Ga., is in a Gwinnett Co
four women claimed he
after being released fro

Reference Resolution

U: Where is A Bug's Life playing in Mountain View?
S: A Bug's Life is playing at the Century 16 theater.
U: When is it playing there?
S: It's playing at 2pm, 5pm, and 8pm.
U: I'd like 1 adult and 2 children for the first show.
How much would that cost?

- Knowledge sources:
  - Domain knowledge
  - Discourse knowledge
  - World knowledge

Why is natural language computing hard?

- Natural language is:
  - highly ambiguous at all levels
  - complex and subtle use of context to convey meaning
  - fuzzy, probabilistic
  - involves reasoning about the world
  - a key part of people interacting with other people (a social system):
    - persuading, insulting and amusing them
- But NLP can also be surprisingly easy sometimes:
  - rough text features can often do half the job

Making progress on this problem…

- The task is difficult! What tools do we need?
  - Knowledge about language
  - Knowledge about the world
  - A way to combine knowledge sources
- The answer that's been getting traction:
  - probabilistic models built from language data
    - P("maison" → "house") high
    - P("L'avocat général" → "the general avocado") low
- Some computer scientists think this is a new "A.I." idea
  - But really it's an old idea that was stolen from the electrical engineers….

Where do we head?

Look at subproblems, approaches, and applications at different levels

- Statistical machine translation
- Statistical NLP: classification and sequence models (part-of-speech tagging, named entity recognition, information extraction)
- Syntactic (probabilistic) parsing
- Building semantic representations from text. QA.

- *(Unfortunately left out: natural language generation, phonology/ morphology, speech dialogue systems, more on natural language understanding, …. There are other classes for some!)*

Daily Question!

- What is the ambiguity in this (authentic!) newspaper headline?

Ban on Nude Dancing
on Governor's Desk

Machine Translation

美国关岛国际机场及其办公室均接获一名自称沙地阿拉伯富商拉登等发出的电子邮件，威胁将会向机场等公众地方发动生化袭击後，关岛经保持高度戒备。 ➡ The U.S. island of Guam is maintaining a high state of alert after the Guam airport and its offices both received an e-mail from someone calling himself the Saudi Arabian Osama bin Laden and threatening a biological/chemical attack against public places such as the airport .

The classic acid test for natural language processing.

Requires capabilities in both interpretation and generation.

About $10 billion spent annually on human translation.

Scott Klemmer: I learned a surprising fact at our research group lunch today. Google Sketchup releases a version every 18 months, and the primary difficulty of releasing more often is not the difficulty of producing software, but the cost of internationalizing the user manuals!

Mainly slides from Kevin Knight (at ISI)

Translation (human and machine)

对外经济贸易合作部今天提供的数据表明，今年至十一月中国实际利用外资四百六十九点五九亿美元，其中包括外商直接投资四百点零七亿美元。

Ref: According to the data provided today by the Ministry of Foreign Trade and Economic Cooperation, as of November this year, China has actually utilized 46.959 billion US dollars of foreign capital, including 40.007 billion US dollars of direct investment from foreign businessmen.

IBM4:
the Ministry of Foreign Trade and Economic Cooperation, including foreign direct investment 40.007 billion US dollars today provide data include that year to November china actually using foreign 46.959 billion US dollars and

Yamada/Knight:
today's available data of the Ministry of Foreign Trade and Economic Cooperation shows that china's actual utilization of November this year will include 40.007 billion US dollars for the foreign direct investment among 46.959 billion US dollars in foreign capital

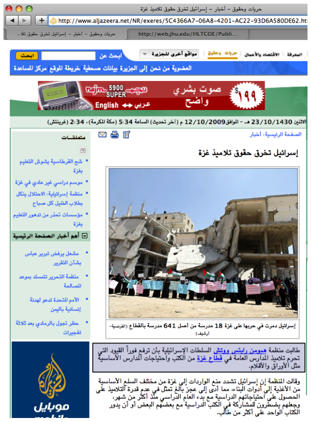
Machine Translation History

- 1950s: Intensive research activity in MT
- 1960s: Direct word-for-word replacement
- 1966 (ALPAC): NRC Report on MT
  - Conclusion: MT no longer worthy of serious scientific investigation.
- 1966-1975: 'Recovery period'
- 1975-1985: Resurgence (Europe, Japan)
  - Domain specific rule-based systems
- 1985-1995: Gradual Resurgence (US)
- 1995-2010: Statistical MT surges ahead

http://ourworld.compuserve.com/homepages/WJHutchins/MTS-93.htm

What happened between ALPAC and Now?

- Need for MT and other NLP applications confirmed
- Change in expectations
- Computers have become faster, more powerful
- WWW
- Political state of the world
- Maturation of Linguistics
- Hugely increased availability of data
- Development of statistical and hybrid statistical/symbolic approaches



حريات وحقوق – أخبار – إسرائيل تخرق حقوق تلاميذ غزة

http://www.aljazeera.net/NR/exeres/5C4366A7-06A8-4201-AC22-93D6A580DE62.htm

حريات وحقوق – أخبار – إسرائيل تخرق حقوق تلا...
http://web.jhu.edu/HLTCOE/Publi...
المعرفة
الاقتصاد والأعمال
حريات وحقوق
مواقع أخرى للجزيرة
ابحث عن
ابحث
العضوية من نحن إلى الجزيرة بيانات صحفية خريطة الموقع مركز المساعدة
najm 5900 SUPER نجم
English ↔ عربي
صوت بشري واضح
$ ١٩٩

الاثنين 23/10/1430 هـ - الموافق12/10/2009 م (آخر تحديث) الساعة 5:34 (مكة المكرمة)، 2:34 (غرينتش)

الصفحة الرئيسية: أخبار

إسرائيل تخرق حقوق تلاميذ غزة

إسرائيل دمرت في حربها على غزة 18 مدرسة من أصل 641 مدرسة بالقطاع (الفرنسية-أرشيف)

طالبت منظمة هيومن رايتس ووتش السلطات الإسرائيلية بأن ترفع فوراً القيود التي تحرم تلاميذ المدارس العامة في قطاع غزة من الكتب واحتياجات المدارس الأساسية مثل الأوراق والأقلام.

وقالت المنظمة إن إسرائيل تشدد منع الواردات إلى غزة من مختلف السلع الأساسية من الأغذية إلى أدوات البناء، مما أدى إلى عجز بالغ تمثل في عدم قدرة التلاميذ على الحصول على احتياجاتهم الدراسية مع بدء العام الدراسي منذ أكثر من شهر، وجعلهم يضطرون للمشاركة في الكتب الدراسية مع بعضهم البعض أو أن يدور الكتاب الواحد على أكثر من طالب.

متعلقـــات

- شح القرطاسية يشوش التعليم بغزة
- موسم دراسي غير عادي في غزة
- منظمة إسرائيلية: الاحتلال ينكل بطلاب الخليل كل صباح
- مؤسسات تحذر من تدهور التعليم بغزة

أهم أخبار الصفحة الرئيسية

- مشعل يرفض تبرير عباس بشأن التقرير
- منظمة التحرير تتمسك بموعد المصالحة
- الأمم المتحدة تدعو لهدنة إنسانية باليمن
- حظر تجول بالرمادي بعد ثلاثة تفجيرات

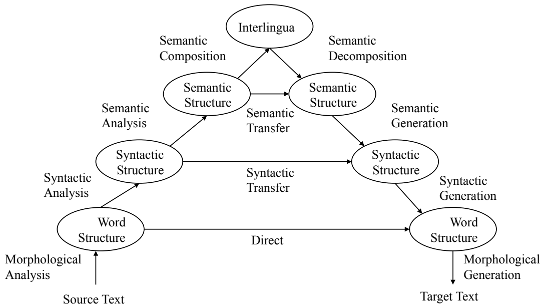
طالبت منظمة هيومن رايتس ووتش السلطات الإسرائيلية بأن ترفع فوراً القيود
التي تحرم تلاميذ المدارس العامة في قطاع غزة من الكتب واحتياجات المدارس
الأساسية مثل الأوراق والأقلام.

Called on organization Human Rights Watch the Israeli authorities to immediately lifl restrictions that deny public school students in the Gaza Strip books

Google translate

Called Human Rights Watch, the Israeli authorities to immediately lift restrictions that prohibit public school students in the Gaza Strip of books and basic school needs such as paper and pens.

Three MT Approaches: Direct, Transfer, Interlingual (Vauquois triangle)



Statistical Solution

- Parallel Texts
  - Rosetta Stone

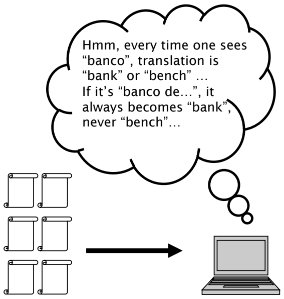
Hieroglyphs

Demotic

Greek

Statistical Solution

- Parallel Texts
  - Instruction Manuals
  - Hong Kong Legislation
  - Macao Legislation
  - Canadian Parliament Hansards
  - United Nations Reports
  - Official Journal of the European Communities



Hmm, every time one sees "banco", translation is "bank" or "bench" …
If it's "banco de…", it always becomes "bank", never "bench"…

Warren Weaver

- “Also knowing nothing official about, but having guessed and inferred considerable about, the powerful new mechanized methods in cryptography—methods which I believe succeed even when one does not know what language has been coded—one naturally wonders if the problem of translation could conceivably be treated as a problem in cryptography. 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.’ ”
  - – Warren Weaver (1955:18, quoting a letter he wrote in 1947)

“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.’ ” – Warren Weaver, March 1947

“… as to the problem of mechanical translation, I frankly am afraid that the [semantic] boundaries of words in different languages are too vague … to make any quasi-mechanical translation scheme very hopeful.”
– Norbert Wiener, April 1947

Centauri/Arcturan [Knight, 1997]

Your assignment, translate this to Arcturan: farok crrrok hihok yorok clok kantok ok-yurp

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2a. ok-drubel ok-voon anok plok sprok . 2b. at-drubel at-voon pippat rrat dat .	8a. lalok brok anok plok nok . 8b. iat lat pippat rrat nnat .
3a. erok sprok izok hihok ghirok . 3b. totat dat arrat vat hilat .	9a. wiwok nok izok kantok ok-yurp . 9b. totat nnat quat oloat at-yurp .
4a. ok-voon anok drok brok jok . 4b. at-voon krat pippat sat lat .	10a. lalok mok nok yorok ghirok clok . 10b. wat nnat gat mat bat hilat .
5a. wiwok farok izok stok . 5b. totat jjat quat cat .	11a. lalok nok crrrok hihok yorok zanzanok . 11b. wat nnat arrat mat zanzanat .
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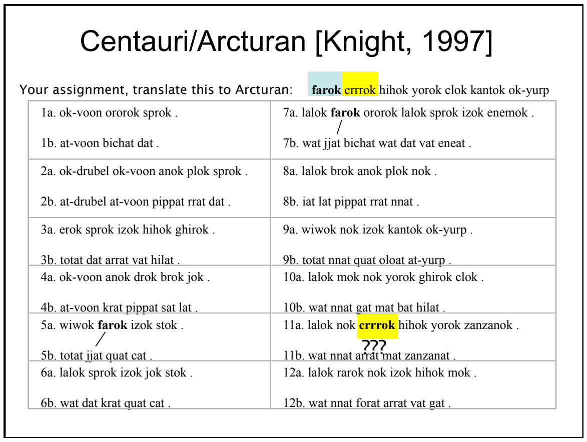

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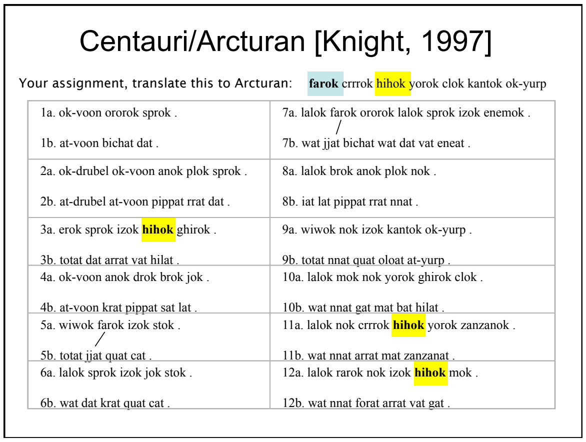

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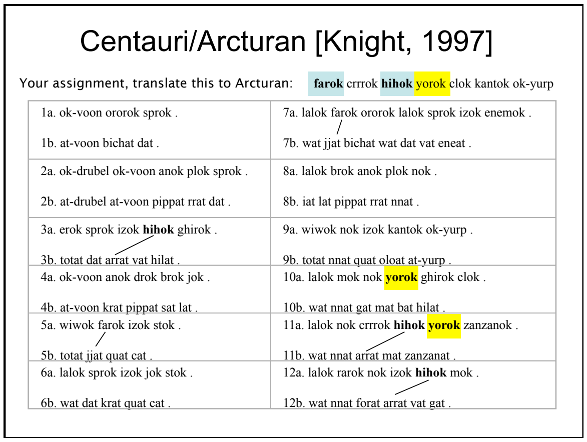

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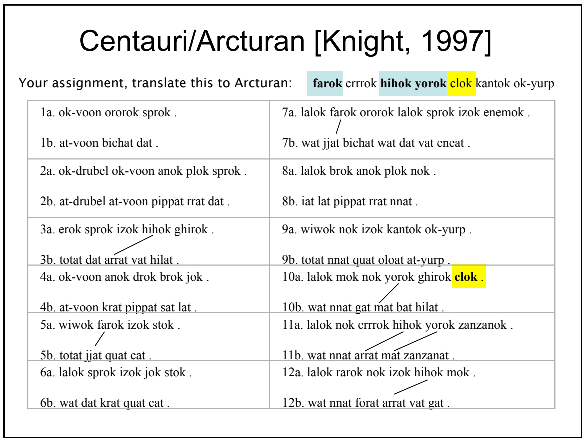
4a. ok-voon anok drok brok jok . 4b. at-voon krat pippat sat lat .	10a. lalok mok nok **yorok** ghirok clok . 10b. wat nnat gat mat bat hilat .
5a. wiwok farok izok stok . 5b. totat jjat quat cat .	11a. lalok nok crrrok **hihok** **yorok** zanzanok . 11b. wat nnat arrat mat zanzanat .
6a. lalok sprok izok jok stok . 6b. wat dat krat quat cat .	12a. lalok rarok nok izok **hihok** mok . 12b. wat nnat forat arrat vat gat .



Centauri/Arcturan [Knight, 1997]

Your assignment, translate this to Arcturan: **farok** crrrok **hihok yorok** clok kantok ok-yurp

1a. ok-voon ororok sprok . 1b. at-voon bichat dat .	7a. lalok farok ororok lalok sprok izok enemok . 7b. wat jjat bichat wat dat vat eneat .
2a. ok-drubel ok-voon anok plok sprok . 2b. at-drubel at-voon pippat rrat dat .	8a. lalok brok anok plok nok . 8b. iat lat pippat rrat nnat .
3a. erok sprok izok hihok ghirok . 3b. totat dat arrat vat hilat .	9a. wiwok nok izok kantok ok-yurp . 9b. totat nnat quat oloat at-yurp .
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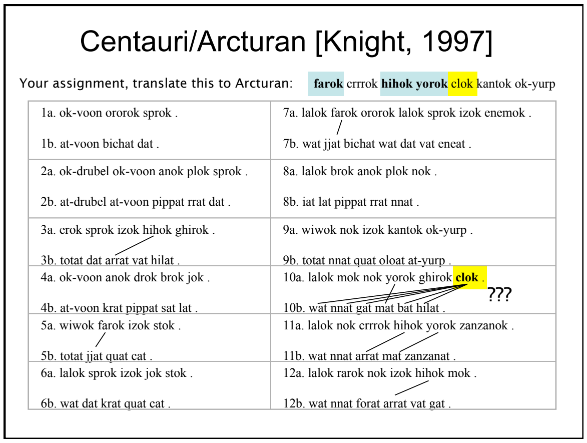

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2a. ok-drubel ok-voon anok plok sprok . 2b. at-drubel at-voon pippat rrat dat .	8a. lalok brok anok plok nok . 8b. iat lat pippat rrat nnat .
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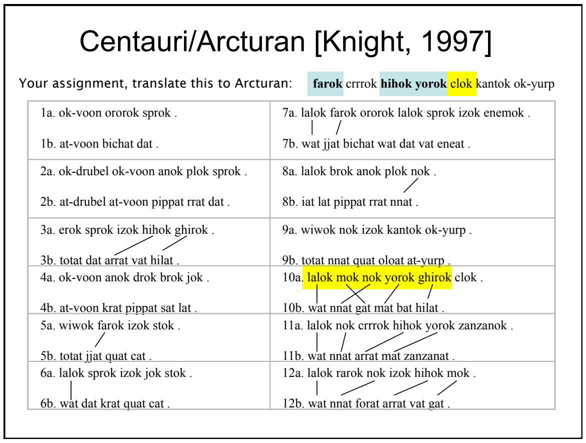

Centauri/Arcturan [Knight, 1997]

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Centauri/Arcturan [Knight, 1997]

Your assignment, translate this to Arcturan: **farok** crrrok **hihok yorok clok** kantok ok-yurp

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process of elimination

Centauri/Arcturan [Knight, 1997]

Your assignment, translate this to Arcturan: **farok** crrrok **hihok yorok clok** kantok ok-yurp

1a. ok-voon ororok sprok . 1b. at-voon bichat dat .	7a. lalok farok ororok lalok sprok izok enemok . 7b. wat jjat bichat wat dat vat eneat .
2a. ok-drubel ok-voon anok plok sprok . 2b. at-drubel at-voon pippat rrat dat .	8a. lalok brok anok plok nok . 8b. iat lat pippat rrat nnat .
3a. erok sprok izok hihok ghirok . 3b. totat dat arrat vat hilat .	9a. wiwok nok izok kantok ok-yurp . 9b. totat nnat quat oloat at-yurp .
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cognate?

Centauri/Arcturan [Knight, 1997]

Your assignment, put these words in order: **{ jjat, arrat, mat, bat, oloat, at-yurp }**

1a. ok-voon ororok sprok . 1b. at-voon bichat dat .	7a. lalok farok ororok lalok sprok izok enemok . 7b. wat jjat bichat wat dat vat eneat .
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zero fertility

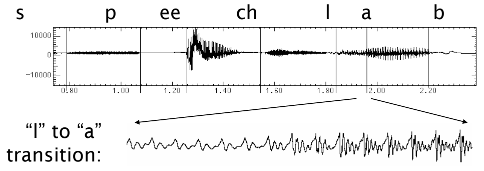
It’s Really Spanish/English

Clients do not sell pharmaceuticals in Europe => **Clientes no venden medicinas en Europa**

1a. Garcia and associates . 1b. Garcia y asociados .	7a. the clients and the associates are enemies . 7b. los clients y los asociados son enemigos .
2a. Carlos Garcia has three associates . 2b. Carlos Garcia tiene tres asociados .	8a. the company has three groups . 8b. la empresa tiene tres grupos .
3a. his associates are not strong . 3b. sus asociados no son fuertes .	9a. its groups are in Europe . 9b. sus grupos estan en Europa .
4a. Garcia has a company also . 4b. Garcia tambien tiene una empresa .	10a. the modern groups sell strong pharmaceuticals . 10b. los grupos modernos venden medicinas fuertes .
5a. its clients are angry . 5b. sus clientes estan enfadados .	11a. the groups do not sell zenzanine . 11b. los grupos no venden zanzanina .
6a. the associates are also angry . 6b. los asociados tambien estan enfadados .	12a. the small groups are not modern . 12b. los grupos pequenos no son modernos .

Speech Recognition: Acoustic Waves

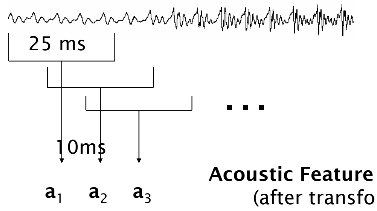
- Human speech generates a wave
  - like a loudspeaker moving
- A wave for the words “speech lab” looks like:



Graphs from Simon Arnfield’s web tutorial on speech, Sheffield:
http://www.psyc.leeds.ac.uk/research/cogn/speech/tutorial/

Acoustic Sampling

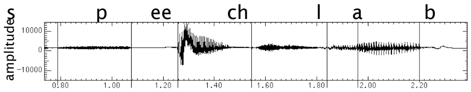
- 10 ms frame (ms = millisecond = 1/1000 second)
- ~25 ms window around frame [wide band] to allow/smooth signal processing – it let’s you see formants



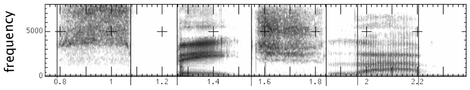
Result:
Acoustic Feature Vectors
(after transformation,
numbers in roughly **R**^{14})

Spectral Analysis

- Frequency gives pitch; amplitude gives volume
  - sampling at ~8 kHz phone, ~16 kHz mic (kHz=1000 cycles/sec)



- Fourier transform of wave displayed as a spectrogram
  - darkness indicates energy at each frequency
  - hundreds to thousands of frequency samples



The Speech Recognition Problem

- The **Recognition Problem: Noisy channel model**
  - We started out with English words, they were encoded as an audio signal, and we now wish to decode.
  - Find most likely sequence **w** of "words" given the sequence of acoustic observation vectors **a**
  - Use Bayes' rule to create a **generative model** and then decode
  - ArgMax$_{\mathbf{w}}$ $P(\mathbf{w}|\mathbf{a})$ = ArgMax$_{\mathbf{w}}$ $P(\mathbf{a}|\mathbf{w})\, P(\mathbf{w}) / P(\mathbf{a})$
    = ArgMax$_{\mathbf{w}}$ $P(\mathbf{a}|\mathbf{w})\, P(\mathbf{w})$
- **Acoustic Model:** $P(\mathbf{a}|\mathbf{w})$
- **Language Model:** $P(\mathbf{w})$ ⬅ A probabilistic theory of a language

Probabilistic Language Models

- Assign probability $P(\mathbf{w})$ to word sequence $\mathbf{w} = w_1, w_2, \ldots, w_k$
- Can't directly compute probability of long sequence – one needs to decompose it
- Chain rule provides a **history-based** model:

$$P(w_1, w_2, \ldots, w_k) = P(w_1)\, P(w_2|w_1)\, P(w_3|w_1,w_2) \cdots P(w_k|w_1,\ldots,w_{k-1})$$

- **Cluster** histories to reduce number of parameters
- E.g., just based on the last word (1st order Markov model):

$$P(w_1, w_2, \ldots, w_k) = P(w_1|\text{<s>})\, P(w_2|w_1)\, P(w_3|w_2) \cdots P(w_k|w_{k-1})$$

- How do we estimate these probabilities?
  - We count word sequences in corpora
  - We "smooth" probabilities so as to allow unseen sequences