Speech Processing

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Course Contents

- Both the theoretical and practical issues for spoken language processing will be considered
- Technology for **Automatic Speech Recognition** (ASR) will be further emphasized
- Topics to be covered
  - Statistical Modeling Paradigms
    - Spoken Language Structure
    - Hidden Markov Models
    - Speech Signal Analysis and Feature Extraction
    - Acoustic and Language Modeling
    - Search/Decoding Algorithms
  - Systems and Applications
    - Keyword Spotting, Dictation, Speaker Recognition, Spoken Dialogue, Speech-based Information Retrieval, etc.

Textbook and References (1/3)

- References books
  - X. Huang, A. Acero, H. Hon. Spoken Language Processing, Prentice Hall, 2001
  - Jacob Benesty (ed.), M. Mohan Sondhi (ed.), Yiteng Huang (ed.), Springer Handbook of Speech Processing, Springer, 2007
  - M.J.F. Gales and S.J. Young. The Application of Hidden Markov Models in Speech Recognition. Foundations and Trends in Signal Processing, 2008
  - C. Manning and H. Schutze. Foundations of Statistical Natural Language Processing. MIT Press, 1999
  - T. F. Quatieri. Discrete-Time Speech Signal Processing - Principles and Practice. Prentice Hall, 2002
  - J. R. Deller, J. H. L. Hansen, J. G. Proakis. Discrete-Time Processing of Speech Signals. IEEE Press, 2000
  - F. Jelinek. Statistical Methods for Speech Recognition. MIT Press, 1999
  - S. Young et al.. The HTK Book. Version 3.0, 2000 "http://htk.eng.cam.ac.uk"
  - L. Rabiner, B.H. Juang. Fundamentals of Speech Recognition. Prentice Hall, 1993
  - 王小川教授， 語音訊號處理， 全華圖書 2004

Textbook and References (2/3)

- Reference papers
  - L. Rabiner, “A Tutorial on Hidden Markov Models and Selected Applications in Speech Recognition,” Proceedings of the IEEE, vol. 77, No. 2, February 1989
  - A. Dempster, N. Laird, and D. Rubin, "*Maximum likelihood from incomplete data via the EM algorithm*," J. Royal Star. Soc., Series B, vol. 39, pp. 1-38, 1977
  - Jeff A. Bilmes "A Gentle Tutorial of the EM Algorithm and its Application to Parameter Estimation for Gaussian Mixture and Hidden Markov Models," U.C. Berkeley TR-97-021
  - J. W. Picone, “Signal modeling techniques in speech recognition,” proceedings of the IEEE, September 1993, pp. 1215-1247
  - R. Rosenfeld, ”Two Decades of Statistical Language Modeling: Where Do We Go from Here?,” Proceedings of IEEE, August, 2000
  - H. Ney, “Progress in Dynamic Programming Search for LVCSR,” Proceedings of the IEEE, August 2000
  - H. Hermansky, "Should Recognizers Have Ears?", Speech Communication, 25(1-3), 1998

Textbook and References (3/3)

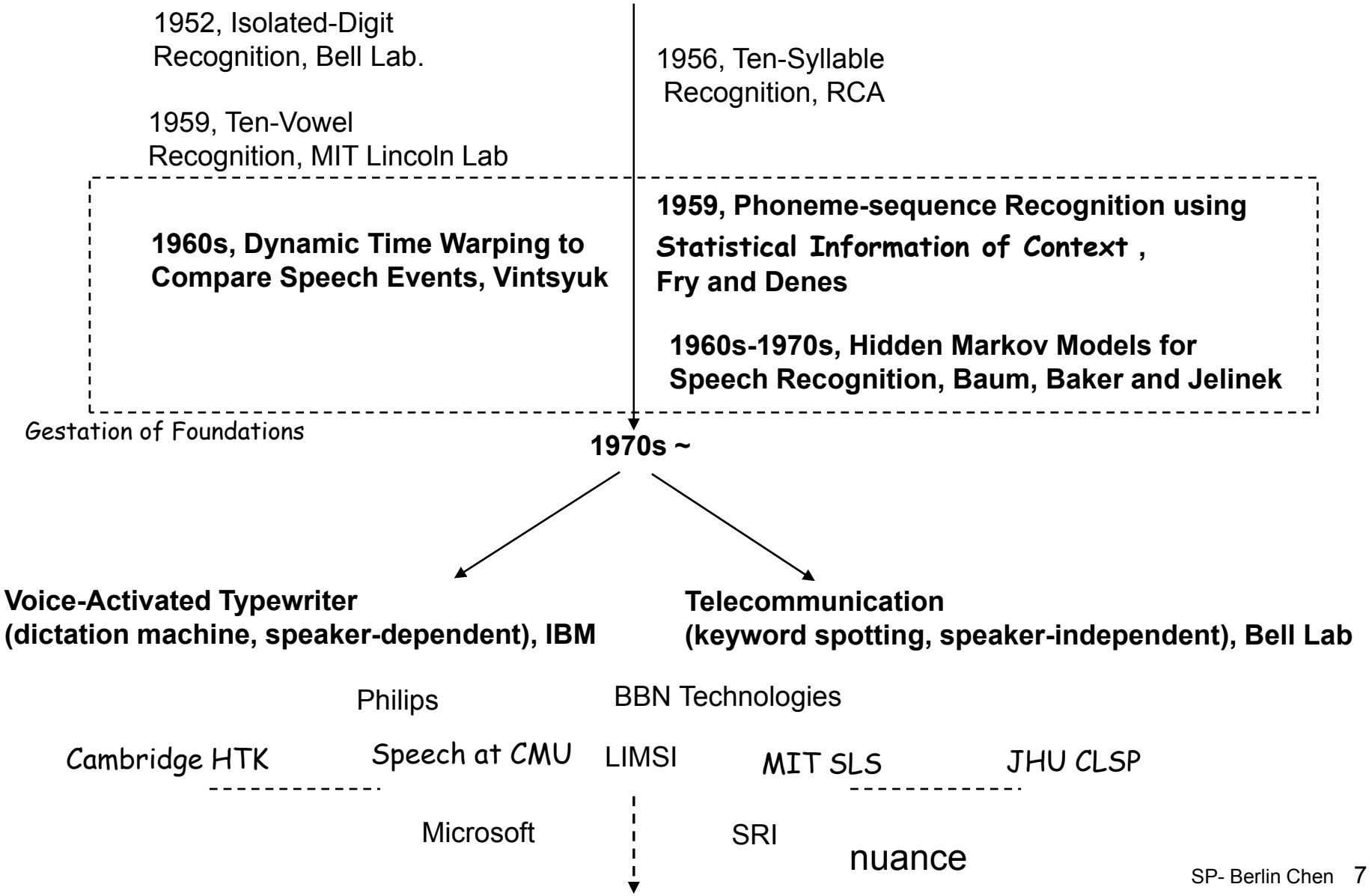
- L.S. Lee and B. Chen, “Spoken document understanding and organization,” *IEEE Signal Processing Magazine*, vol. 22, no. 5, pp. 42-60, Sept. 2005
- M. Gilbert and J. Feng, “Speech and Language Processing over the Web,” *IEEE Signal Processing Magazine* 25 (3), May 2008
- C. Chelba, T.J. Hazen, and M. Saraclar. Retrieval and Browsing of Spoken Content. *IEEE Signal Processing Magazine* 25 (3), May 2008

Introduction

References:

1. B. H. Juang and S. Furui, "Automatic Recognition and Understanding of Spoken Language - A First Step Toward Natural Human-Machine Communication," Proceedings of IEEE, August, 2000
2. I. Marsic, Member, A. Medl, And J. Flanagan, "Natural Communication with Information Systems," Proceedings of IEEE, August, 2000

Historical Review



Areas for Speech Processing

- Production, Perception, and Modeling of Speech
- Signal Processing for Speech
- Speech Coding
- Speech Synthesis (Text-to-Speech)
- Speech Recognition (Speech-to-Text) and Understanding
- Speaker Recognition
- Language Recognition
- Speech Enhancement
- Multichannel Speech Processing

C.f. Jacob Benesty (ed.), M. Mohan Sondhi (ed.), Yiteng Huang (ed.), Springer Handbook of Speech Processing, Springer, 2007

Progress of Technology (1/6)

- US. National Institute of Standards and Technology (NIST)

Speech Group

Mission

The Speech Group contributes to the advancement of the state-of-the art of spoken language processing (speech recognition and understanding) so that spoken language can reliably serve as an alternative modality for the human-computer interface.

This objective is served by:

- developing measurement methods
- providing reference materials
- coordinating community-wide benchmark tests within the research and development community
- building prototype systems.

Current Activities

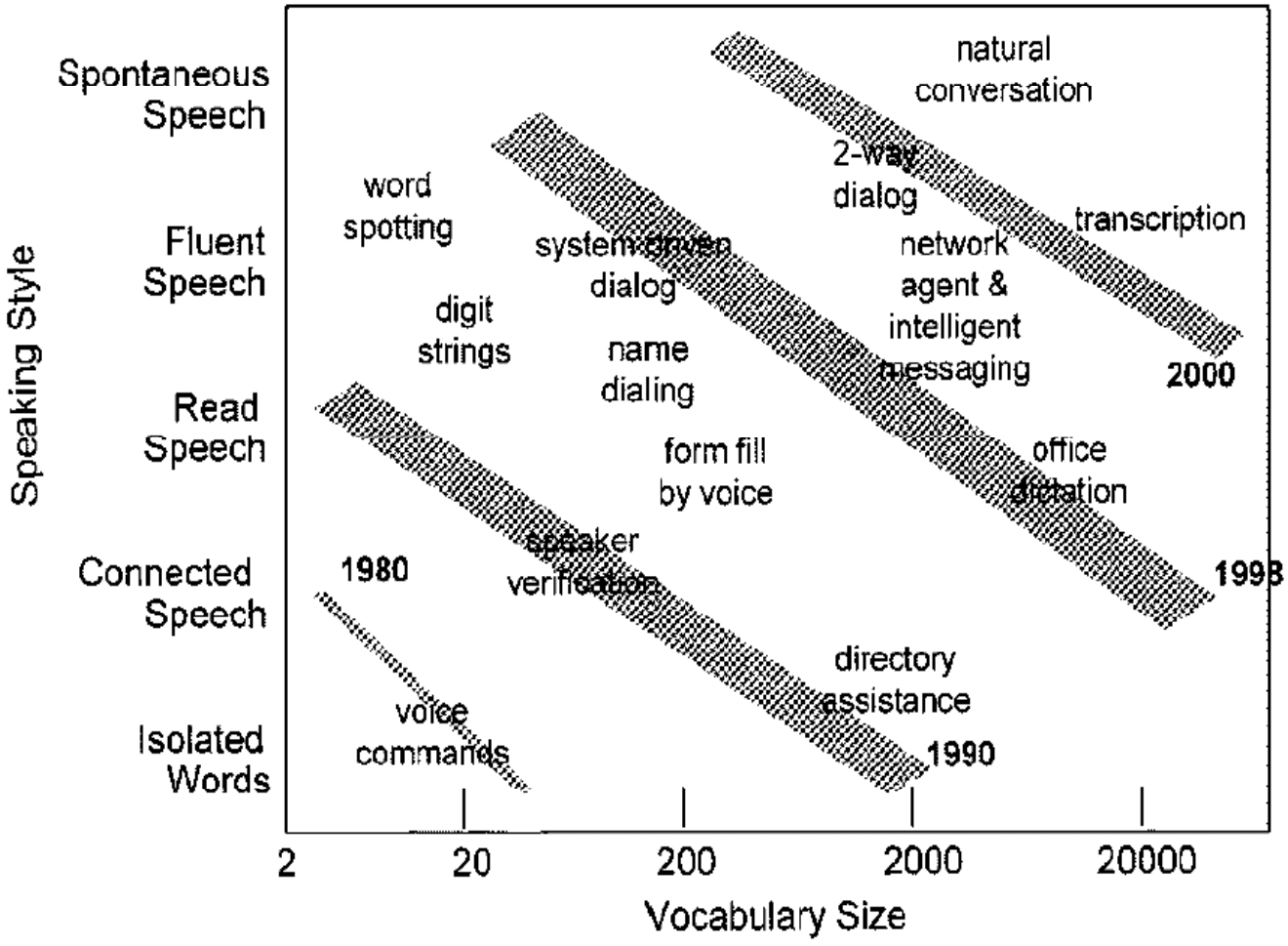
Evaluation	Evaluation Period	Workshop
ACE-06 - Automatic Content Extraction	11/06-20/06	12/14-15/06
CLEAR-06 - Classification of Locales, Events, Activities, and Relationships	(tbd)	(tbd)
GALE-06S - GALE Translation	Jun 22 - Jul 13, 2006	Sept. 2006 (TBD)
LRE-05 - Language Recognition	Oct 24 - Nov 7, 2005	Dec 6-7, 2005
MT-06 - Machine Translation	July 24 - July 28, 2006	September '06 (tbd)
RT-06S - Rich Transcription Spring Meeting Recognition	April 2006	May 2006
SRE-06 - Speaker Recognition	April 24 - May 13, 2006	June 25 - 27, 2006
Spoken Term Detection	November, 2006	December, 2006

Speech Group

http://www.nist.gov/speech/

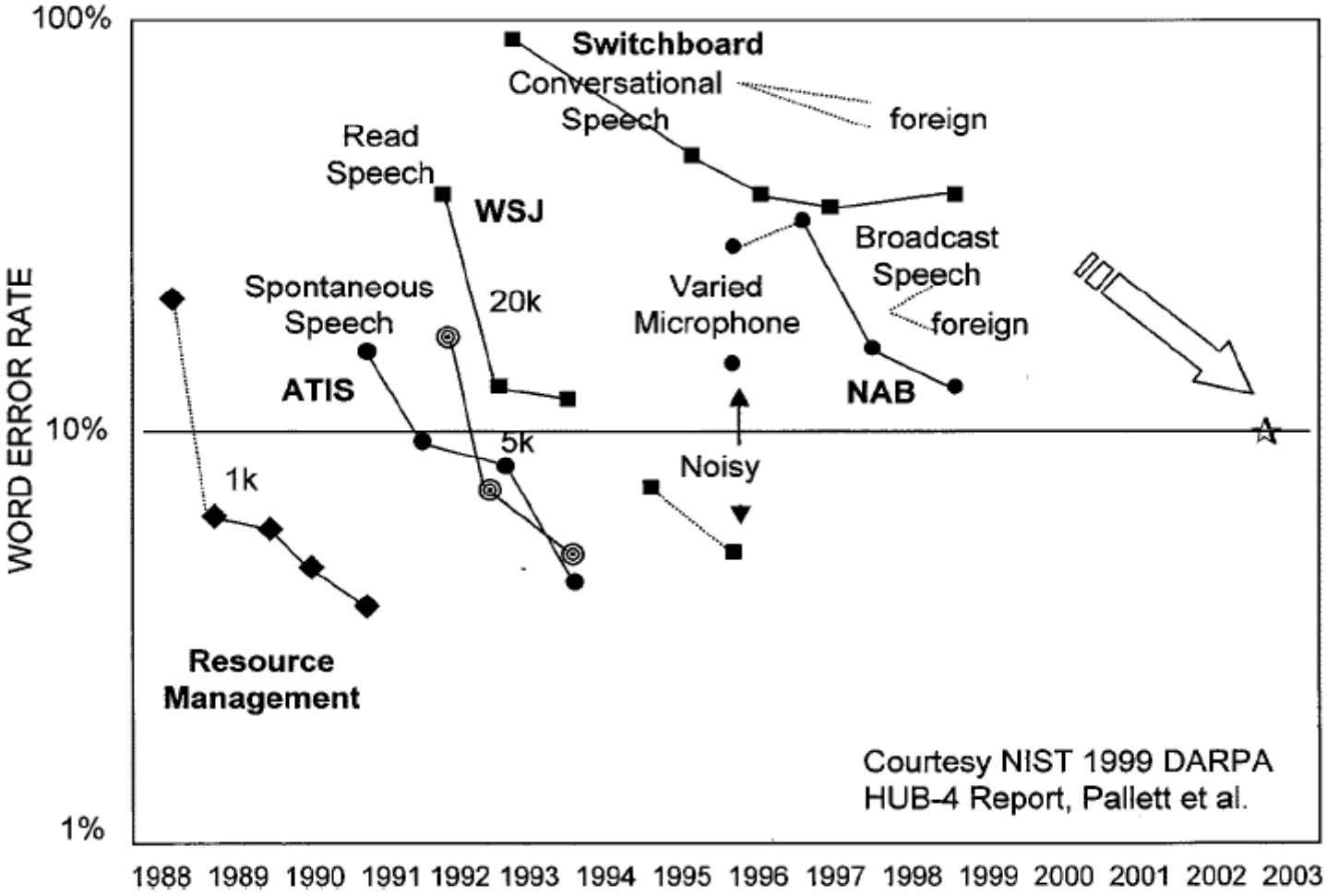
Progress of Technology (2/6)

- Generic Application Areas (vocabulary vs. speaking style)



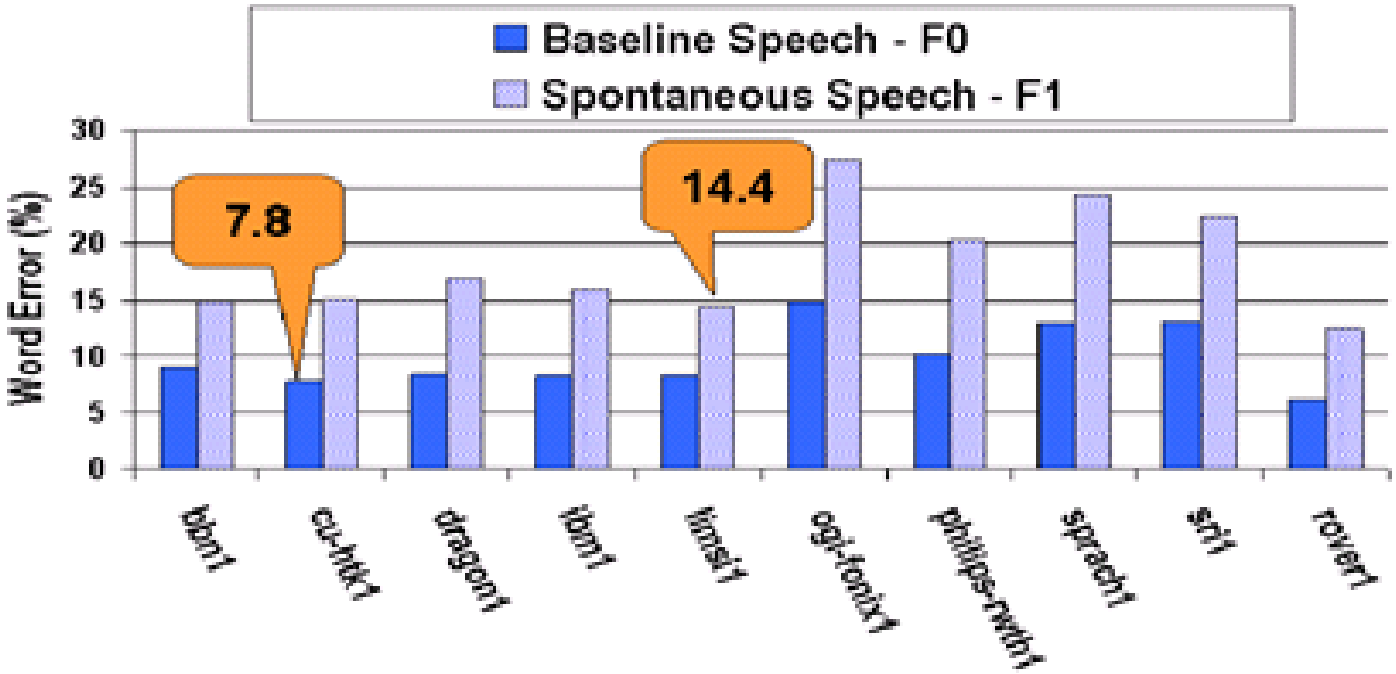
Progress of Technology (3/6)

- Benchmarks of ASR performance: Overview



Progress of Technology (4/6)

- Benchmarks of ASR performance: Broadcast News Speech



Progress of Technology (5/6)

- Benchmarks of ASR performance: Conversational Speech

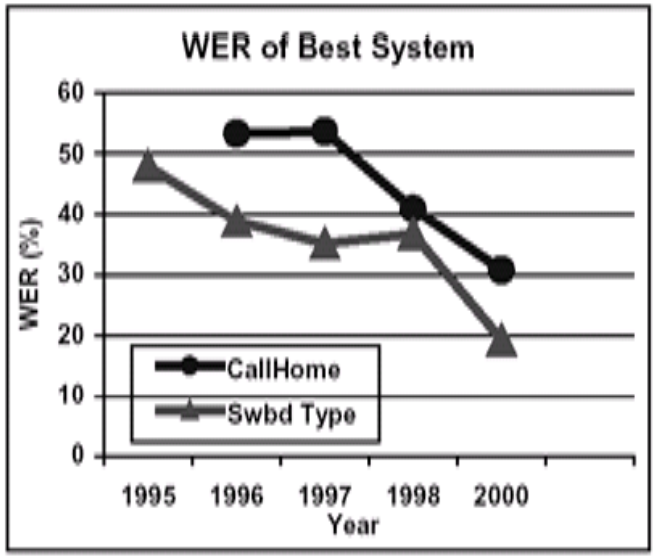


Figure 4 History of lowest word error rates (WER) obtained in NIST conversational speech evaluations on Switchboad and CallHome type conversations in English [26].

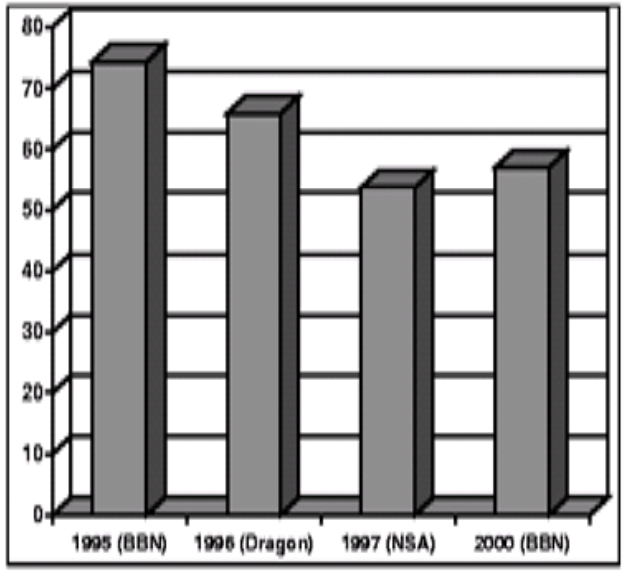


Figure 5 Chinese Character error rates of the best performing evaluation system in NIST Mandarin conversational speech evaluations 1995-2000 [26].

Progress of Technology (6/6)

- Mandarin Conversational Speech (2003 Evaluation)
  - Acoustic/Training Test Data:
    - training data: 34.9 hours, 379 sides, from LDC CallHome (22.4hrs) and CallFriend (12.5hrs), 451K Words (+7K English word), 628K Characters
    - development data: dev02 1.94 hours from CallFriend

		CER (%)	
		dev02	eval03
P1	trans for VTLN	55.1	54.7
P2	trans for MLLR	50.8	51.3
P3	lat gen (bg)	49.3	50.5
	tgintcat rescore	48.9	49.8
P4	lat MLLR	48.6	49.5
CN	P4	47.9	48.6

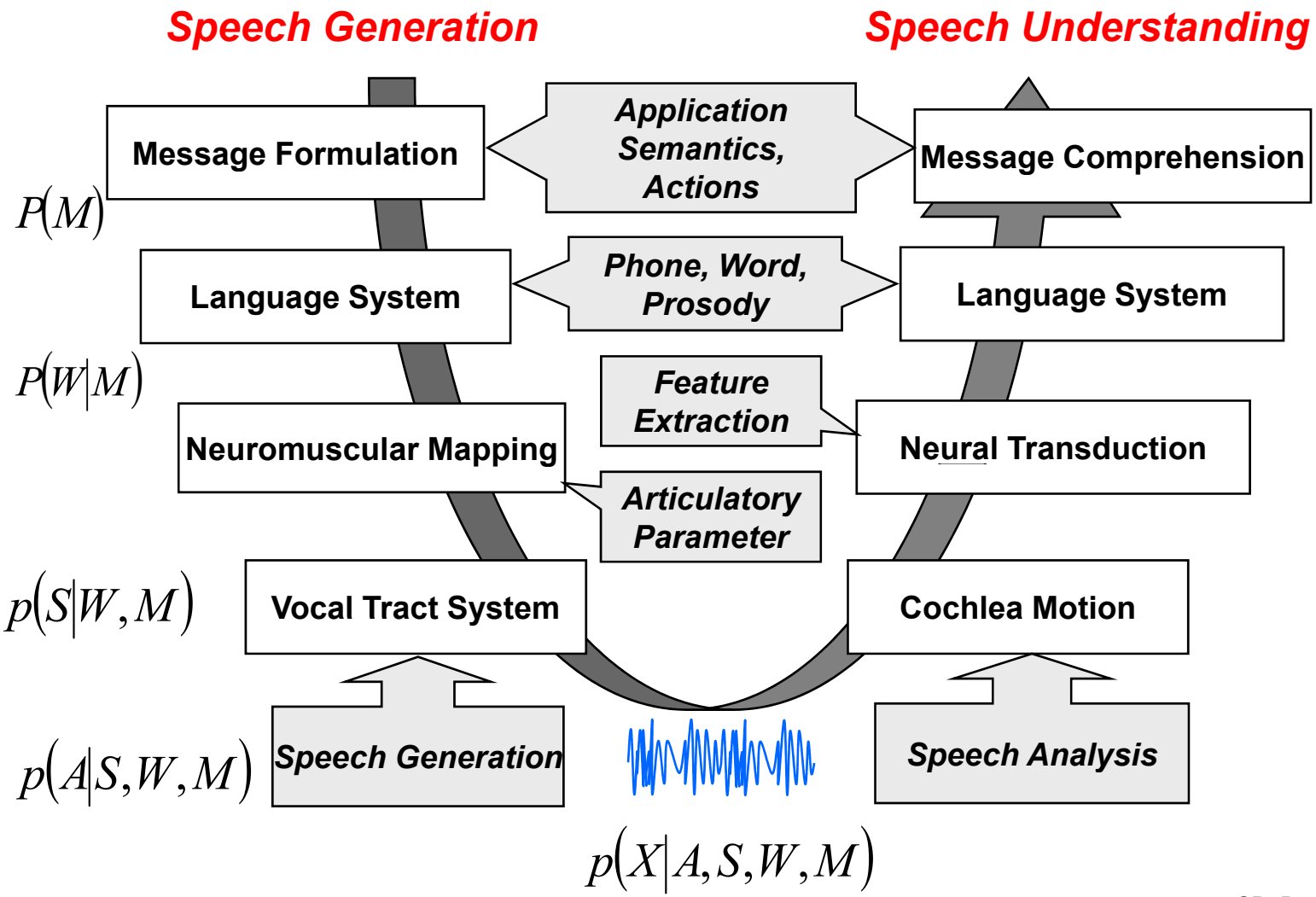
%CER on dev02 and eval03 for all stages of 2003 system

    - Adopted from

Cambridge University
Engineering Department

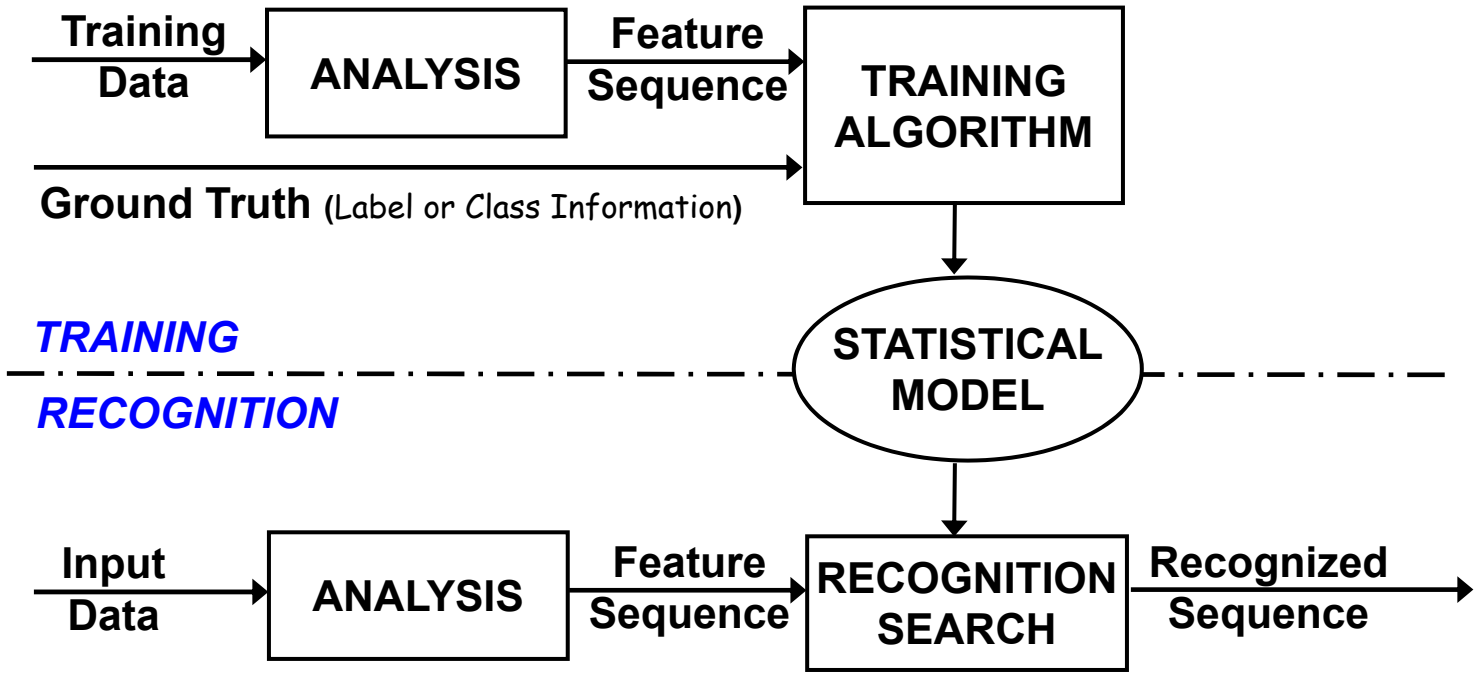
Rich Transcription Workshop 2003

Determinants of Speech Communication



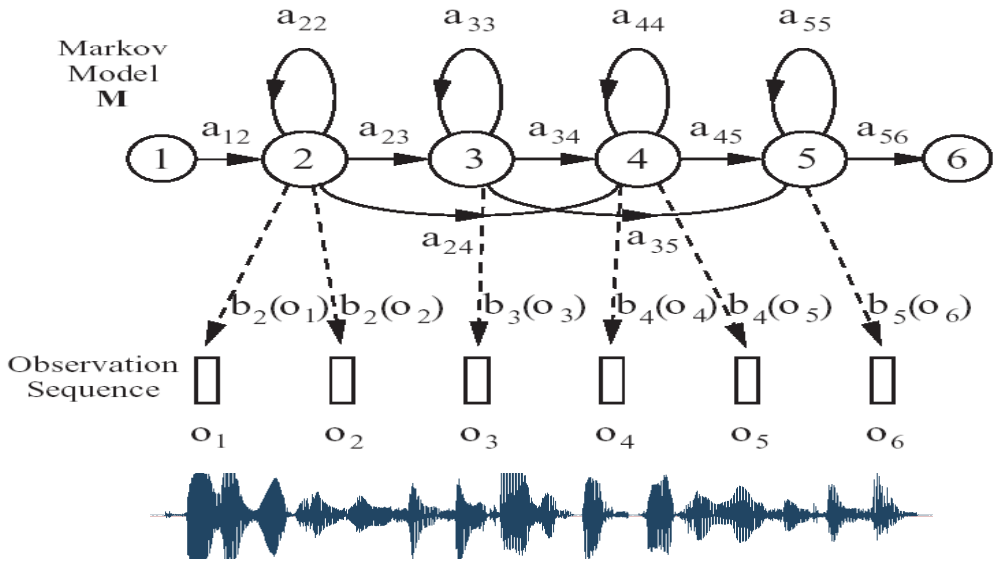
Statistical Modeling Paradigm (1/2)

- The statistical modeling paradigm used in speech and language processing

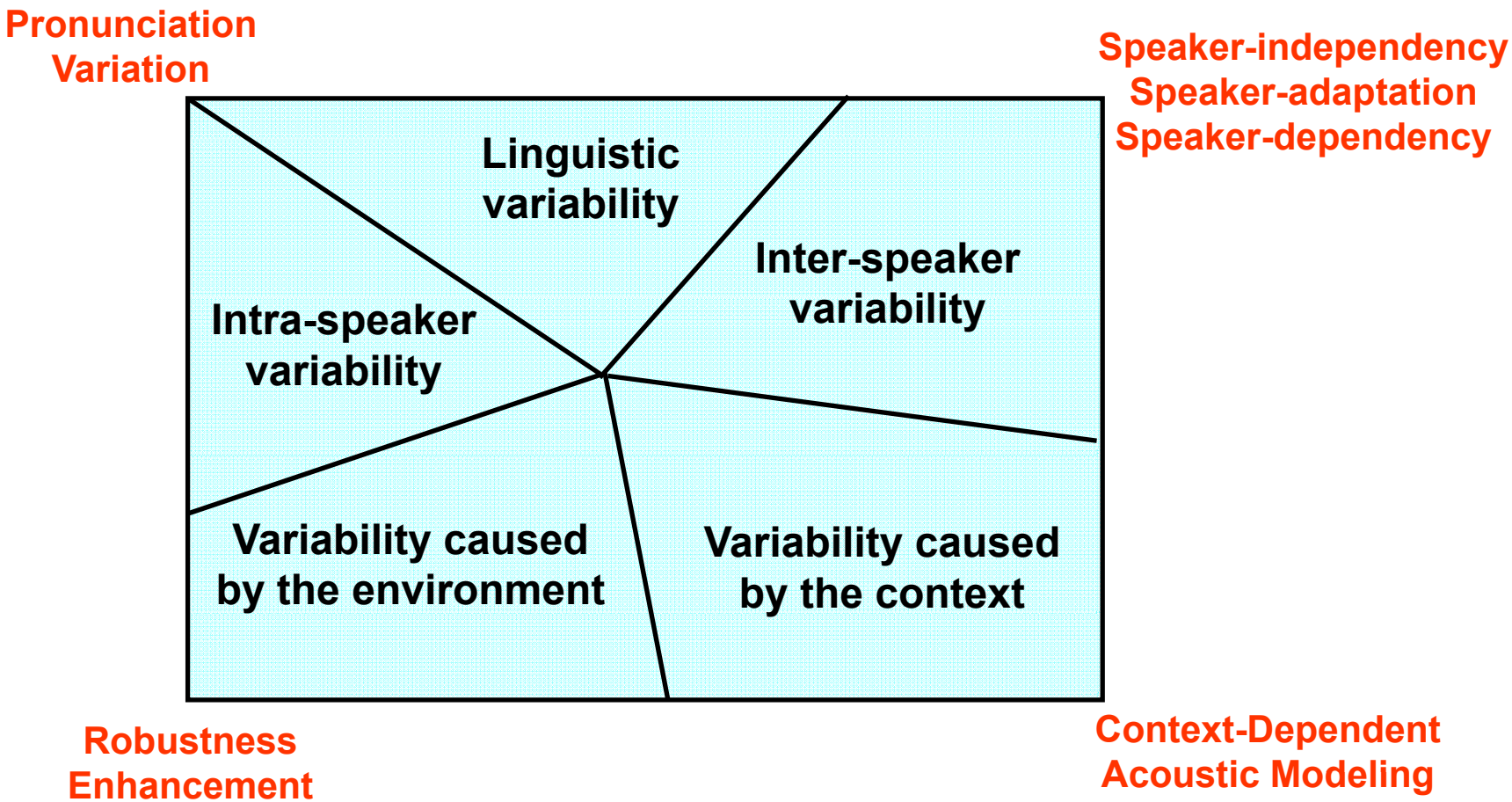


Statistical Modeling Paradigm (2/2)

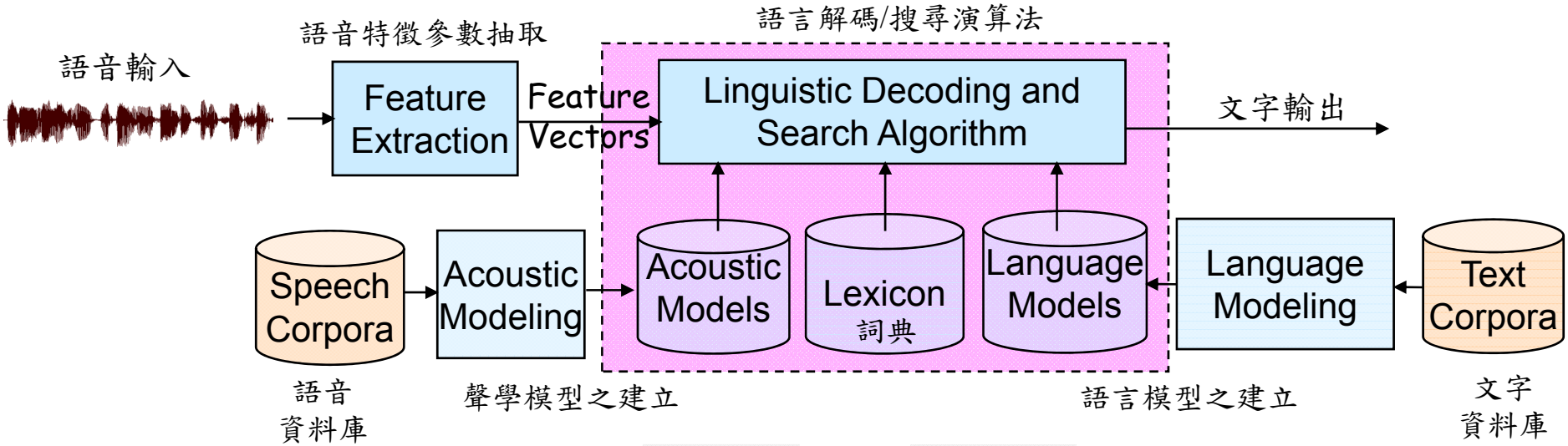
- Approaches based on Hidden Markov Models (HMMs) dominate the area of speech recognition
  - HMMs are based on rigorous mathematical theory built on several decades of mathematical results developed in other fields
  - HMMs are generated by the process of training on a large corpus of real speech data



Difficulties: Speech Variability



Large Vocabulary Continuous Speech Recognition (LVCSR) (1/3)



可能詞句　　語音輸入

$$\hat{\mathbf{W}} = \arg\max_{\mathbf{W}} P(\mathbf{W}|\mathbf{X})$$

貝氏定理

$$= \arg\max_{\mathbf{W}} \frac{p(\mathbf{X}|\mathbf{W})P(\mathbf{W})}{P(\mathbf{X})}$$

詞彙網路搜尋

$$= \arg\max_{\mathbf{W}} p(\mathbf{X}|\mathbf{W})P(\mathbf{W})$$

聲學模型機率　　語言模型機率

Large Vocabulary Continuous Speech Recognition (cont.) (2/3)

- Transcription of Broadcast News Speech

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 0 SIL 71695 -1 35 1280.422 1.00000 1.00000
 1 行政院 55302 35 80 720.973 1.00000 0.75715
 2 秘書長 50877 80 118 459.867 0.56604 0.18618
 3 劉 2406 118 137 371.101 0.26549 0.50987
 4 世 6603 137 157 610.122 1.00000 1.00000
 5 芳 1111 157 177 545.281 0.22222 1.00000
 6 和 3407 177 196 374.724 0.15385 0.00000
 7 蒙藏 66970 196 237 844.522 1.00000 0.53602
 8 委員會 58282 237 281 776.631 1.00000 1.00000
 9 委員長 58283 281 332 955.699 1.00000 0.83401
10 徐 5422 332 356 561.555 0.36598 0.54206
11 志 5919 356 372 420.553 0.40000 0.54860
12 修 5075 372 416 988.773 0.31579 0.84565
13 上午 40289 416 449 681.523 1.00000 0.75001
14 到 1302 449 463 337.270 0.33333 1.00000
15 立法院 52750 463 509 1077.581 1.00000 0.85865
16 報告 9234 509 550 1061.472 1.00000 1.00000
17 預算 49933 550 587 738.046 1.00000 0.82290
18 編列 9691 587 616 576.571 1.00000 0.60458
19 情況 31054 616 666 1020.239 0.75000 0.81394
20 SIL 71695 666 703 1341.544 1.00000 1.00000
21 好幾 24960 703 729 326.342 0.00760 0.73112
22 位 8111 729 741 273.841 0.18748 1.00000
23 在野 42491 741 767 605.460 0.99551 1.00000
24 立委 21015 767 792 518.366 0.98152 0.75214
25 認為 41950 792 842 957.432 0.96371 0.57802
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31 外蒙 47896 1043 1084 786.448 1.00000 1.00000
32 為 8063 1084 1100 316.677 0.30057 1.00000
33 我國 47848 1100 1135 804.705 1.00000 1.00000
34 領土 20696 1135 1186 778.006 0.76186 0.96218
35 主張 36487 1186 1237 1003.320 0.07122 1.00000
36 全數 31649 1237 1304 1427.742 0.06937 1.00000
37 刪除 39728 1304 1349 818.702 1.00000 0.65401
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39 委員會 58282 1392 1432 870.207 1.00000 1.00000
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44 過 3023 1566 1580 279.248 0.07692 1.00000
45 院長 49392 1580 1613 632.123 0.10656 0.80456
46 許 3809 1613 1634 526.977 0.08333 1.00000
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50 該 2847 1706 1721 403.345 0.18182 1.00000
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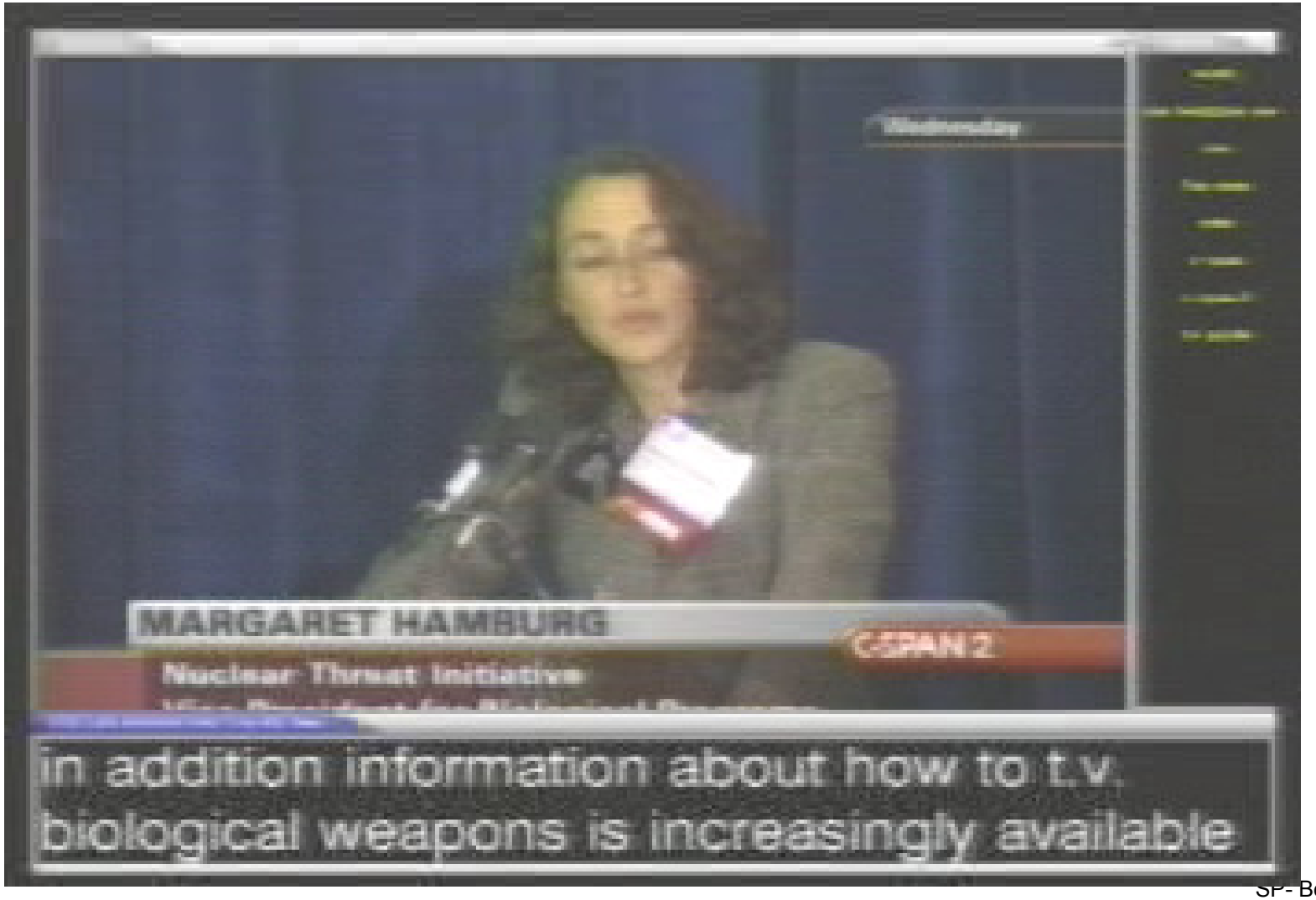
Large Vocabulary Continuous Speech Recognition (cont.) (3/3)

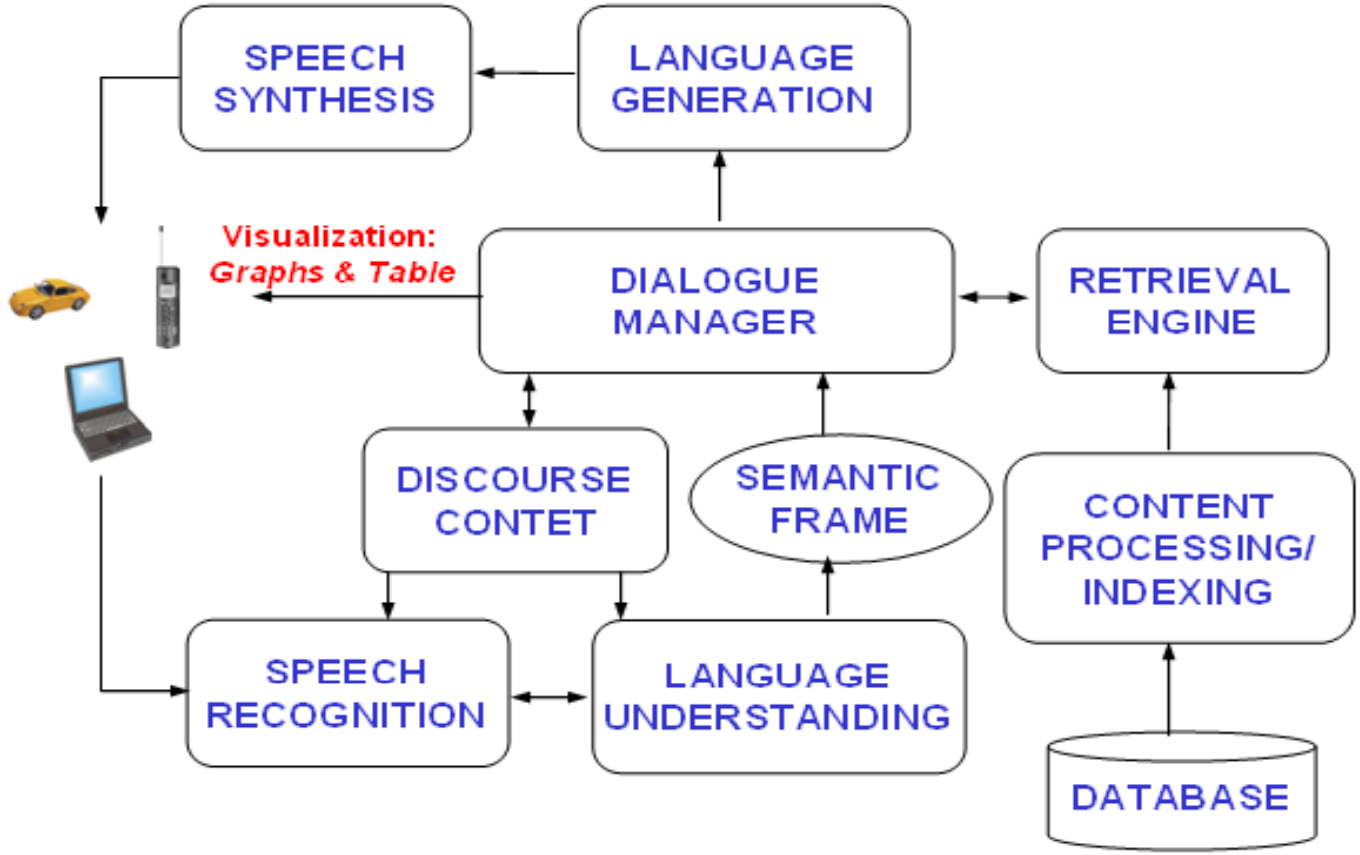


Spoken Dialogue (1/5)

- Spoken language is attractive because it is the most natural, convenient and inexpensive means of exchanging information for humans
- In mobilizing situations, using keystrokes and mouse clicks could be impractical for rapid information access through small handheld devices like PDAs, cellular phones, etc.

Spoken Dialogue (2/5)

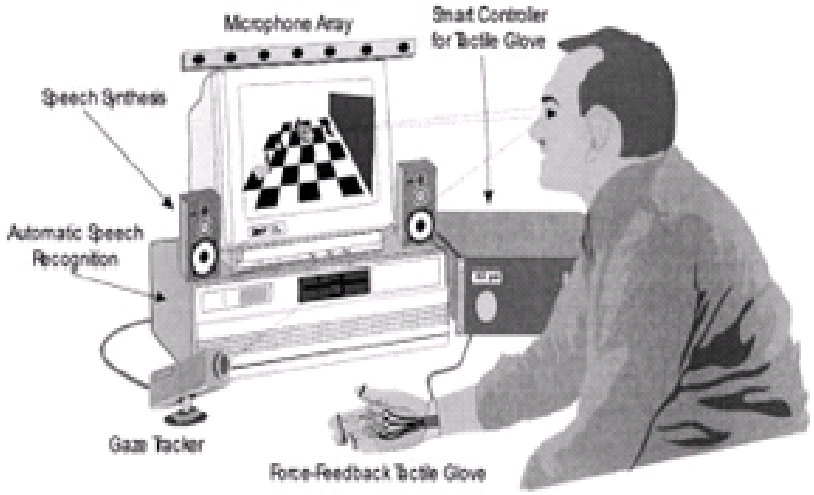
- Flowchart



C.f. V. Zue, J.R. Glass, Conversational Interfaces: Advances and Challenges. Proceedings of the IEEE, Vol. 88, No. 8, August 2000

Spoken Dialogue (3/5)

- Multimodality of Input and Output



Experimental client workstation incorporating sight, sound, and touch modalities for human/machine communication. The eye tracker provides a gaze-controlled cursor for indicating objects in the display. The tactile force-feedback glove allows displayed objects to be grasped, "felt," and moved. Hands-free speech recognition and synthesis provides natural conversational interaction [7].

C.f. I. Marsic, A. Medl, And J. Flanagan, Natural Communication with Information Systems. Proceedings of the IEEE, Vol. 88, No. 8, August 2000

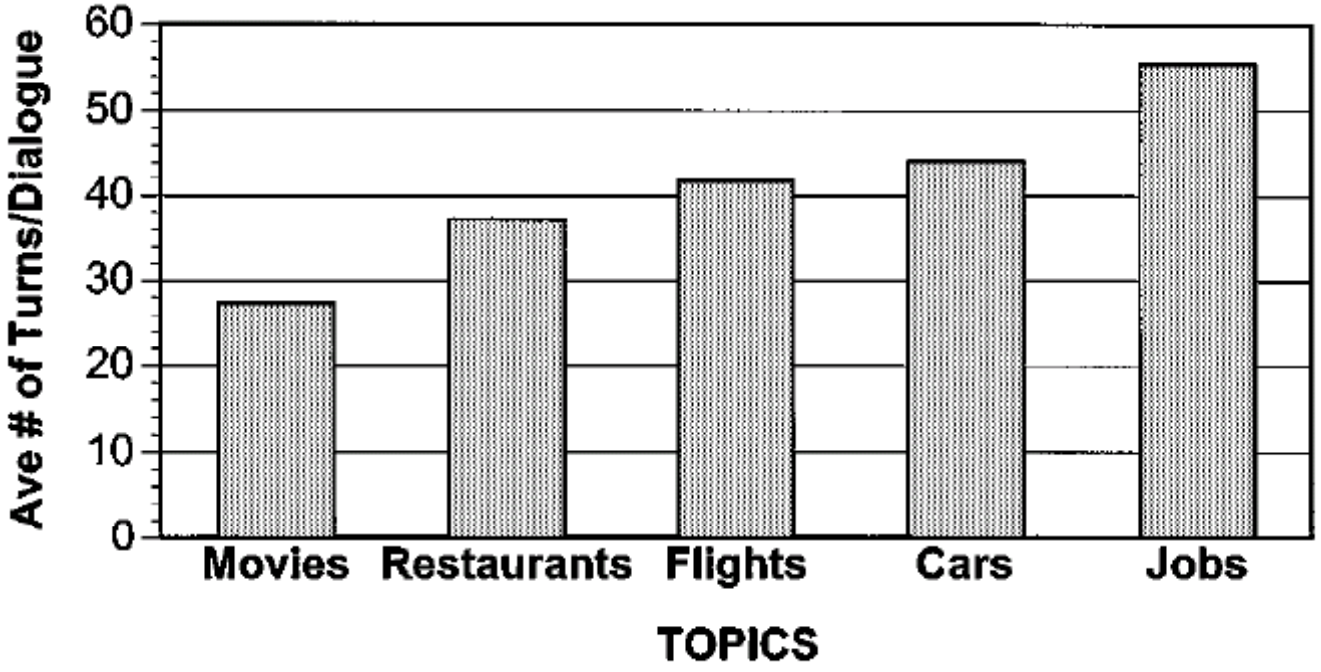
Spoken Dialogue (4/5)

- Deployed Dialogue Systems

Domain	Language	Vocabulary Size	Average Words/Utt	Average Utts/Dialogue
CSELT Train Timetable Info	Italian	760	1.6	6.6
SpeechWorks Air Travel Reservation	English	1000	1.9	10.6
Philips Train Timetable Info	German	1850	2.7	7.0
CMU Movie Information	English	757	3.5	9.2
CMU Air Travel Reservation	English	2851	3.6	12.0
LIMSI Train Timetable Info	French	1800	4.4	14.6
MIT Weather Information	English	1963	5.2	5.6
MIT Air Travel Reservation	English	1100	5.3	14.1
AT&T Operator Assistance	English	4000	7.0	3.0
Air Travel Reservations (human)	English	?	8.0	27.5

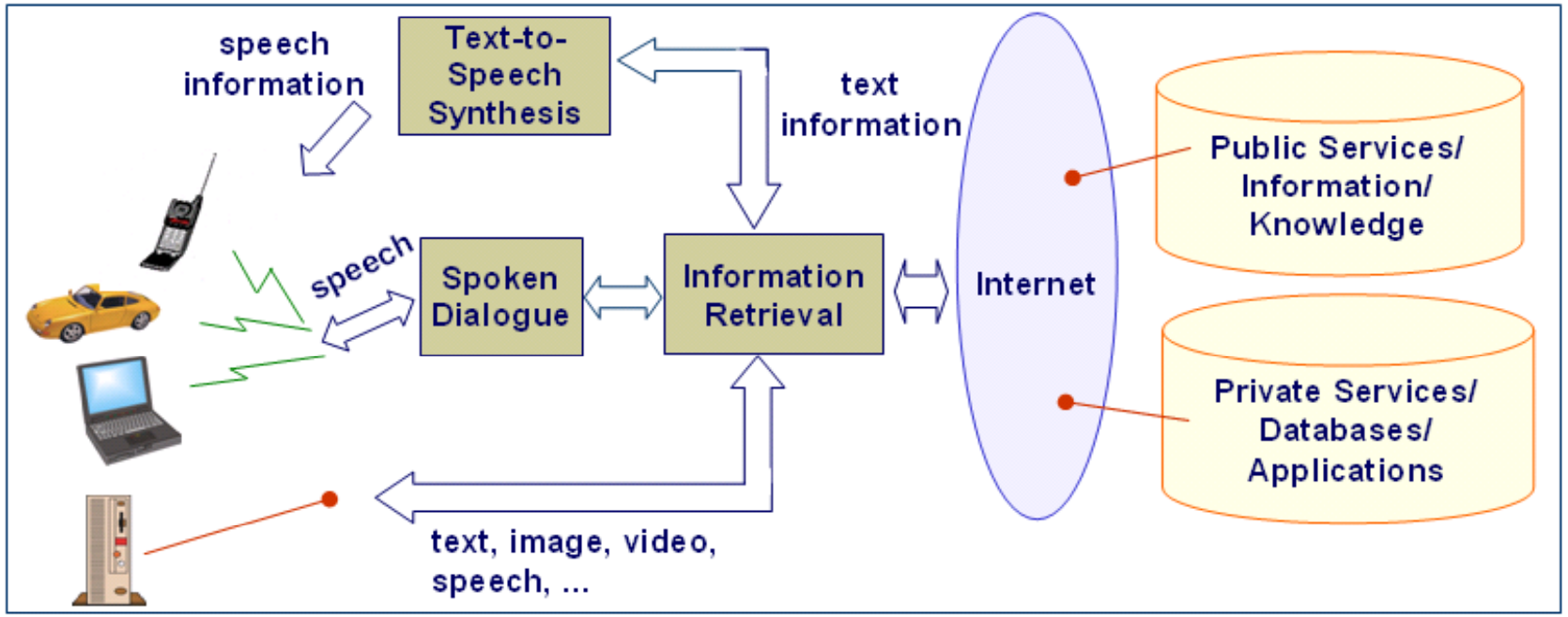
Spoken Dialogue (5/5)

- Topics vs. Dialogue Terms

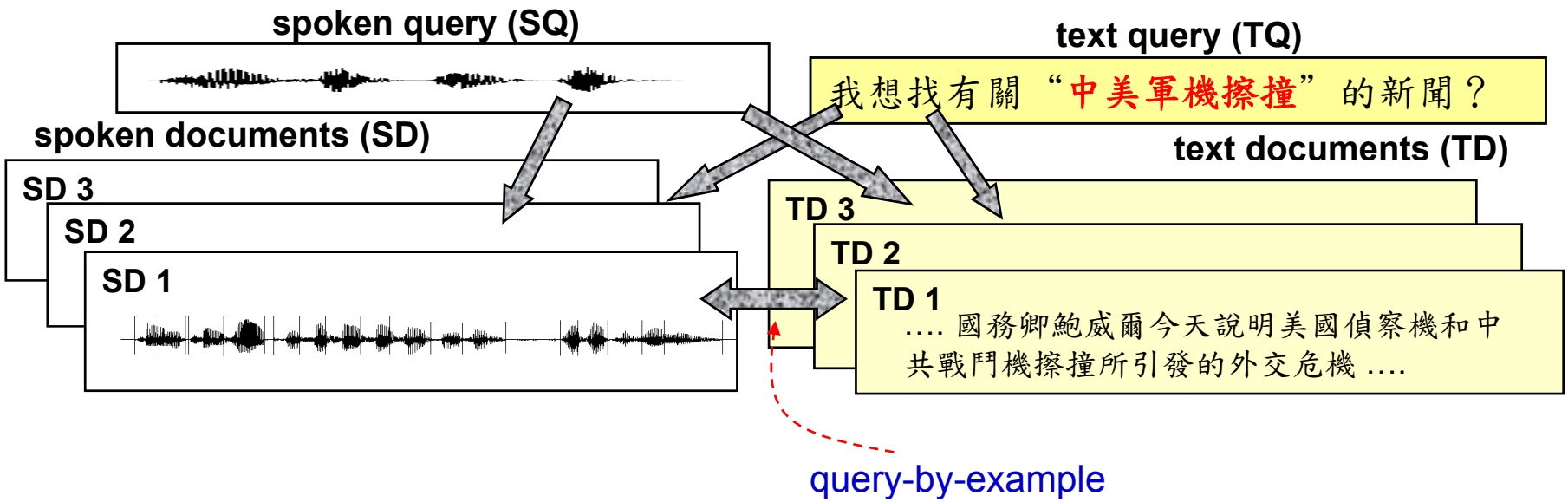


Speech-based Information Retrieval (1/6)

- Task :
  - Automatically indexing a collection of spoken documents with speech recognition techniques
  - Retrieving relevant documents in response to a text/speech query



Speech-based Information Retrieval (2/6)



- SQ/SD is the most difficult
- TQ/SD is studied most of the time

Speech-based Information Retrieval (3/6)

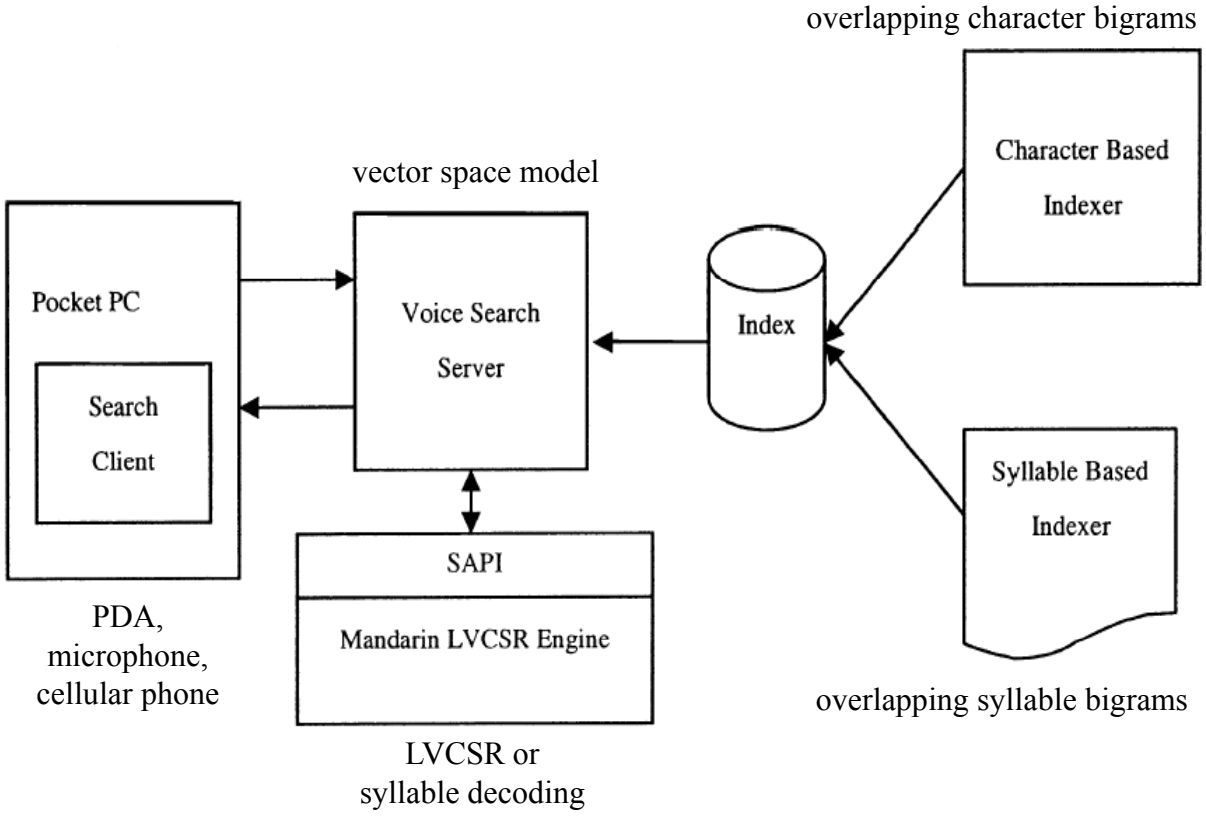
輸入聲音問句："請幫我查總統府升旗典禮"

中文語音資訊檢索雛形展示系統。

C.f. B. Chen, H.M. Wang, Lin-shan Lee, "Discriminating capabilities of syllable-based features and approaches of utilizing them for voice retrieval of speech information in Mandarin Chinese", IEEE Transactions on Speech and Audio Processing , Vol. 10, No. 5, pp. 303-314, July 2002.

Speech-based Information Retrieval (4/6)

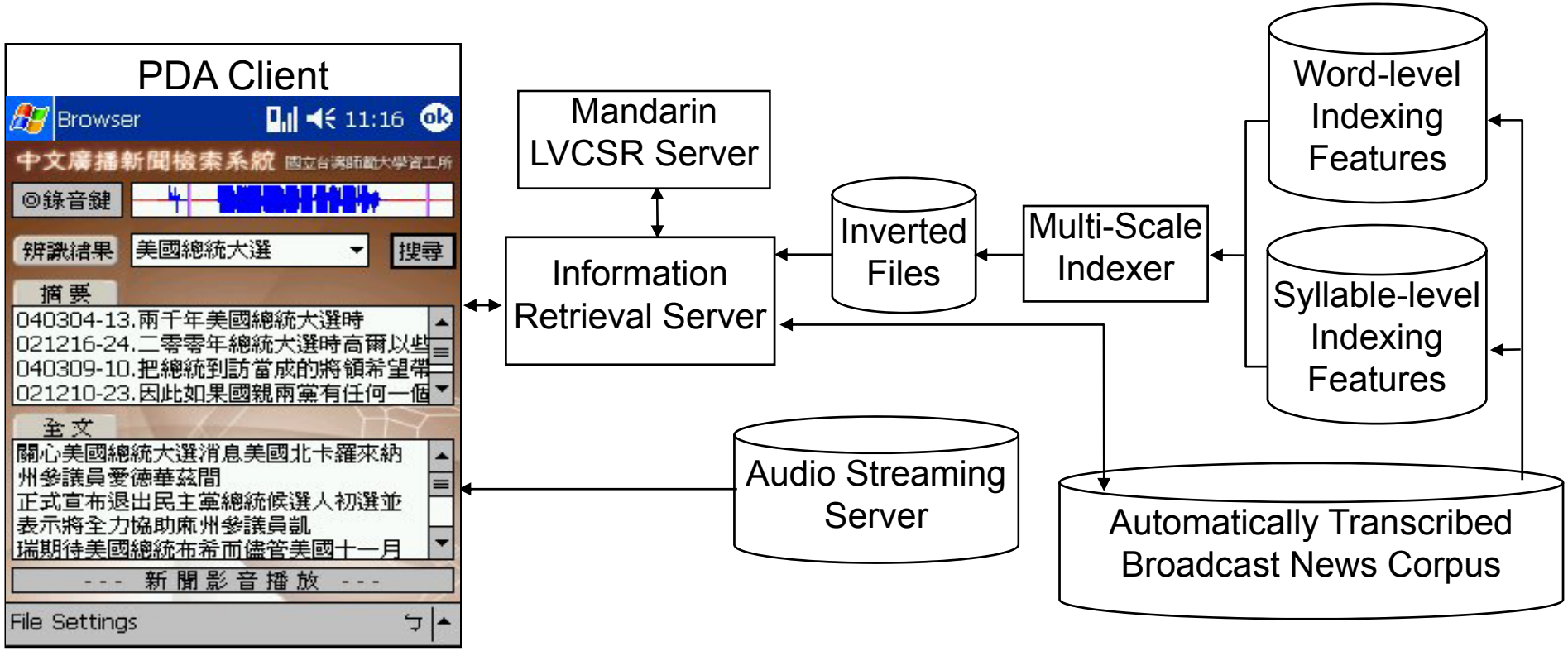
- Spoken queries retrieving text news documents via mobile devices



C.f. Chang, E., Seide, F., Meng, H., Chen, Z., Shi, Y., And Li, Y. C. 2002. A system for spoken query information retrieval on mobile devices. IEEE Trans. on Speech and Audio Processing 10, 8 (2002), 531-541.

Speech-based Information Retrieval (5/6)

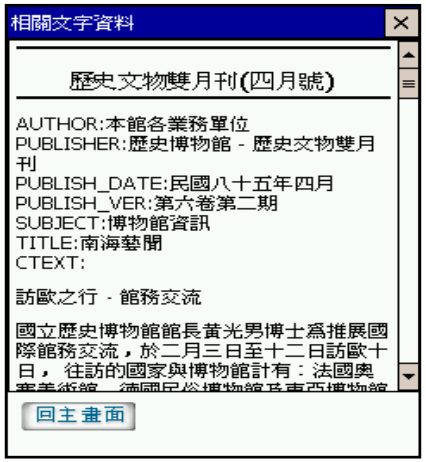
- Spoken queries retrieving text news documents via mobile devices

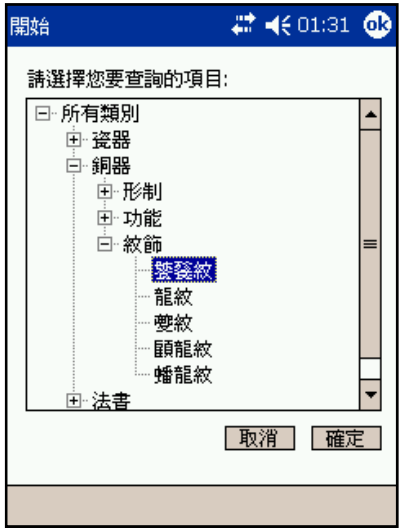


C.f. B. Chen, Y..T. Chen, C.H. Chang, H.B. Chen, "Speech Retrieval of Mandarin Broadcast News via Mobile Devices," Interspeech2005

Speech-based Information Retrieval (6/6)

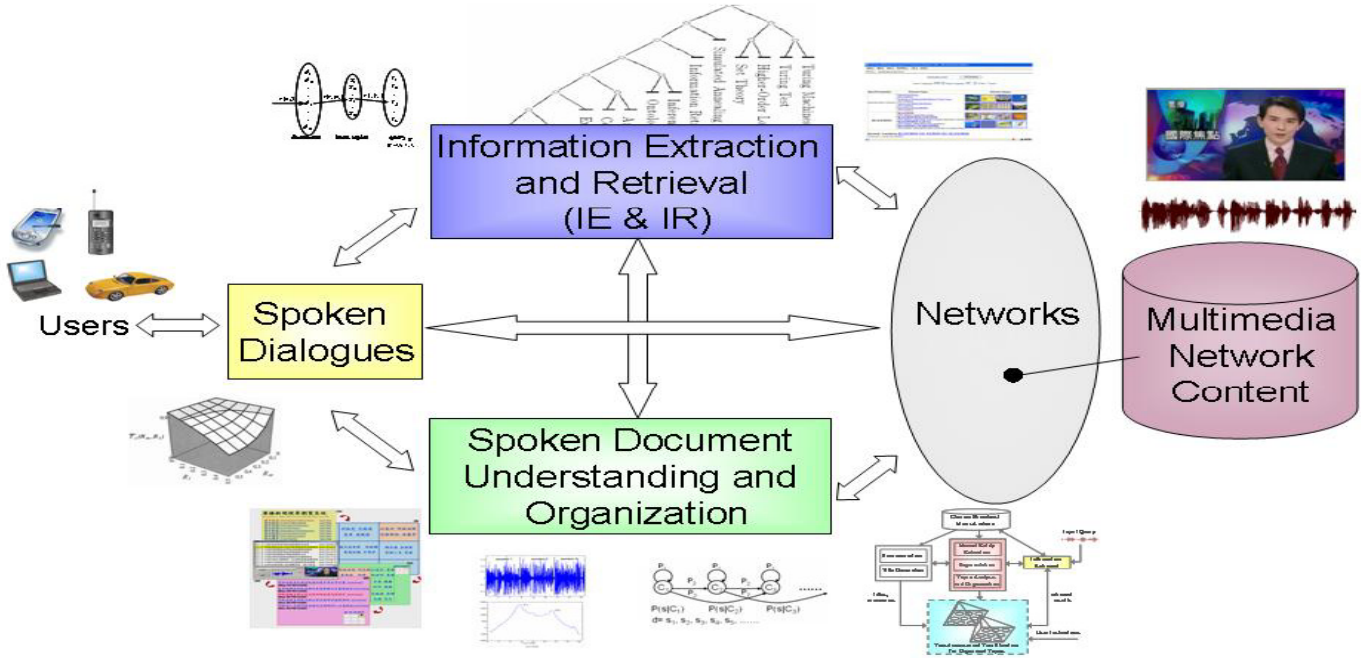
- PDA-based IR system for digital archives
  - Current deployed at National Museum of History, Taipei





Spoken Document Organization and Understanding (1/2)

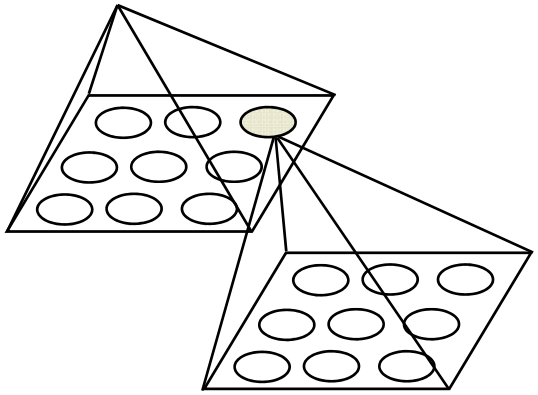
- Problems
  - The content of multimedia documents very often described by the associated speech information
  - Unlike text documents with paragraphs/titles easy to look through at a glance, multimedia/spoken documents are unstructured and difficult to retrieve/browse



C.f. L.S. Lee and B. Chen, "Spoken document understanding and organization," IEEE Signal Processing Magazine, vol. 22, no. 5, pp. 42-60, Sept. 2005

Spoken Document Organization and Understanding (2/2)

- For example, spoken documents can be clustered by the latent topics and organized in a two-dimensional tree structure, or a two-layer map



Two-dimensional
Tree Structure
for Organized Topics

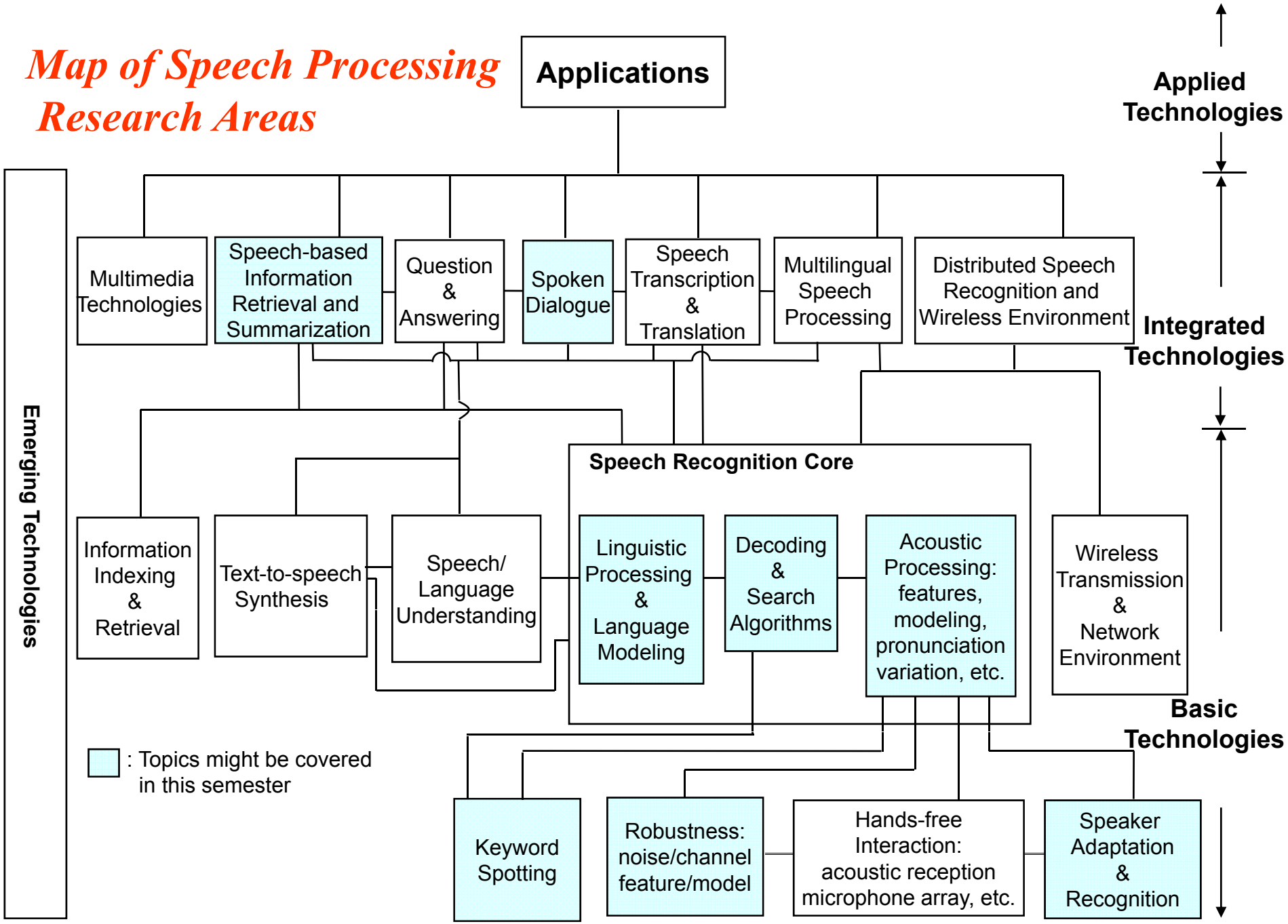
Speech-to-Speech Translation

- Multilingual interactive speech translation
  - Aims at the achievement of a communication system for precise recognition and translation of spoken utterances for several conversational topics and environments by using human language knowledge synthetically (adopted form ATR-SLT)

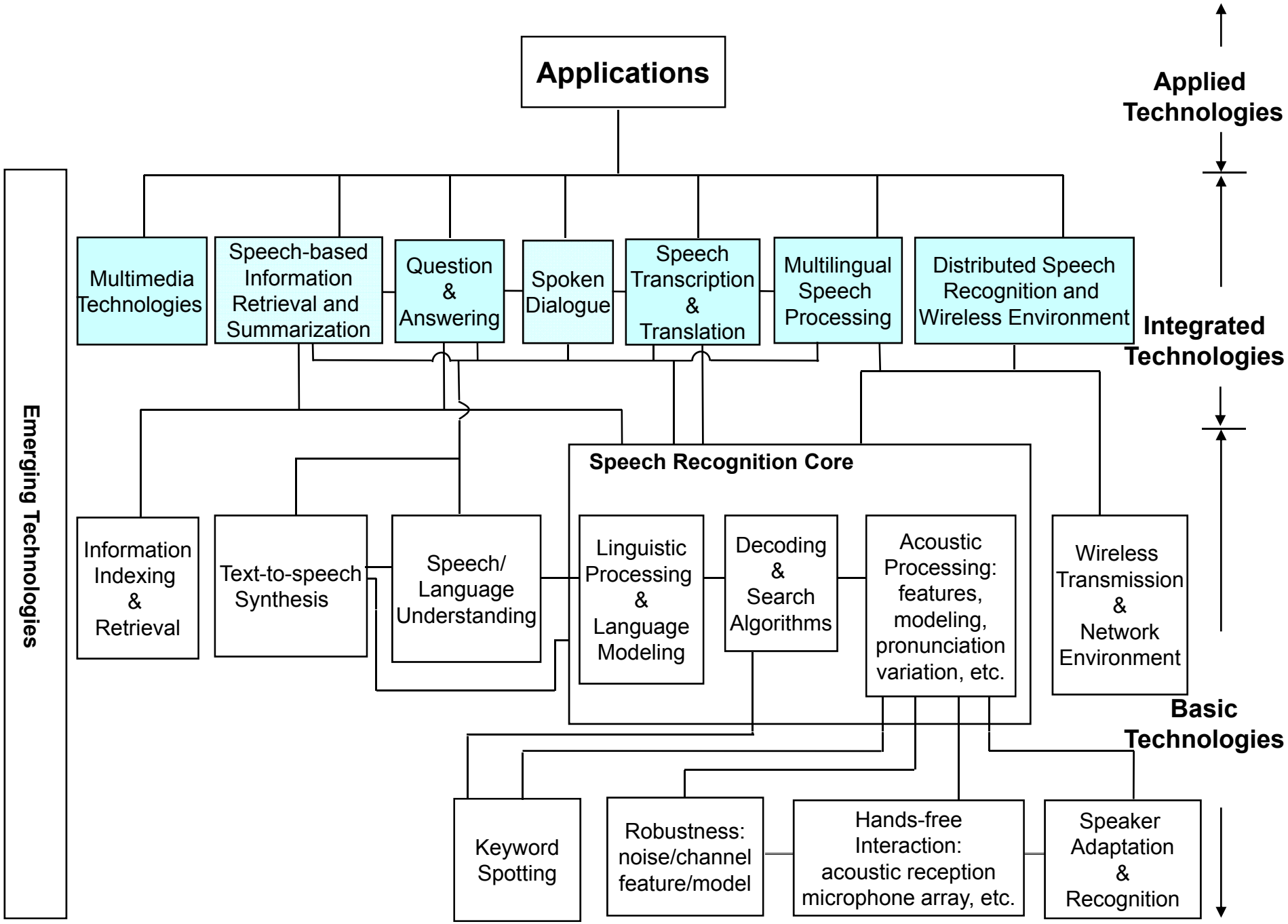
ATR-SLT

IBM Mastor Project

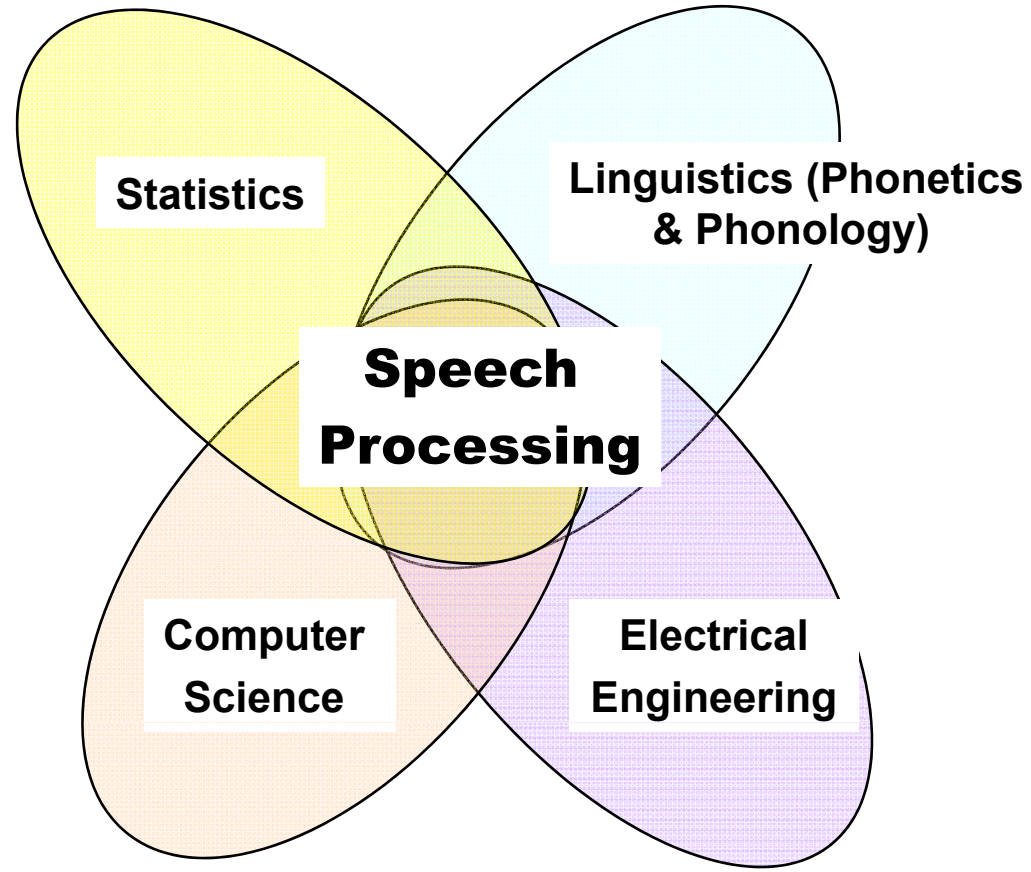
Map of Speech Processing Research Areas



Adapted from Prof. Lin-shan Lee


Applications
Applied Technologies
Integrated Technologies
Basic Technologies
Emerging Technologies
Multimedia Technologies
Speech-based Information Retrieval and Summarization
Question & Answering
Spoken Dialogue
Speech Transcription & Translation
Multilingual Speech Processing
Distributed Speech Recognition and Wireless Environment
Speech Recognition Core
Information Indexing & Retrieval
Text-to-speech Synthesis
Speech/ Language Understanding
Linguistic Processing & Language Modeling
Decoding & Search Algorithms
Acoustic Processing: features, modeling, pronunciation variation, etc.
Wireless Transmission & Network Environment
Keyword Spotting
Robustness: noise/channel feature/model
Hands-free Interaction: acoustic reception microphone array, etc.
Speaker Adaptation & Recognition

Different Academic Disciplines

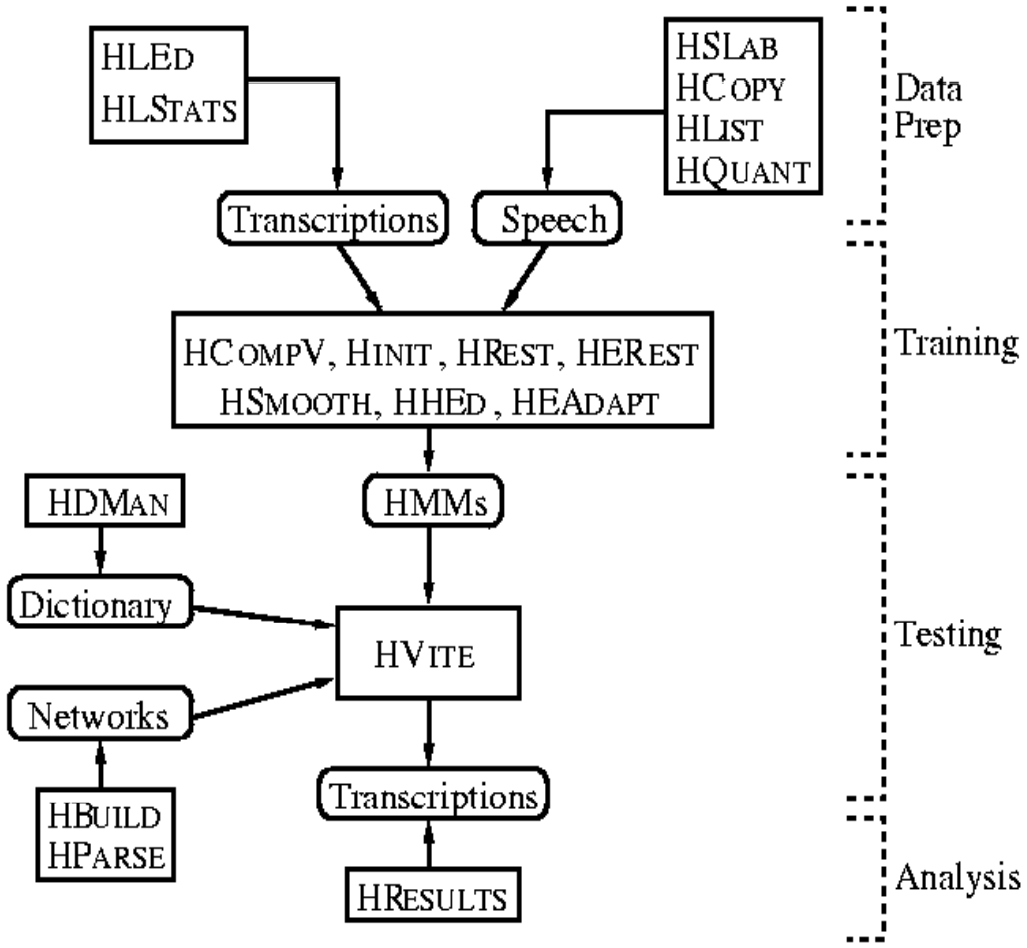


Speech Processing Toolkit (1/2)

- HTK (**H**idden Markov Model **T**ool**K**it)
  - A toolkit for building Hidden Markov Models (HMMs)
  - The HMM can be used to model any time series and the core of HTK is similarly general-purpose
  - In particular, for the acoustic feature extraction, HMM-based acoustic model training and HMM network decoding

Speech Processing Toolkit (2/2)

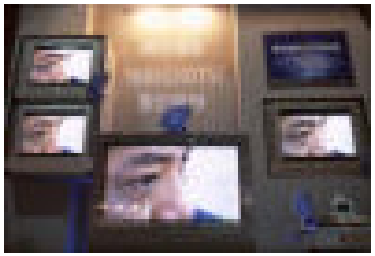
- HTK (**H**idden Markov Model **T**ool**K**it)



Speech Industry (1/3)

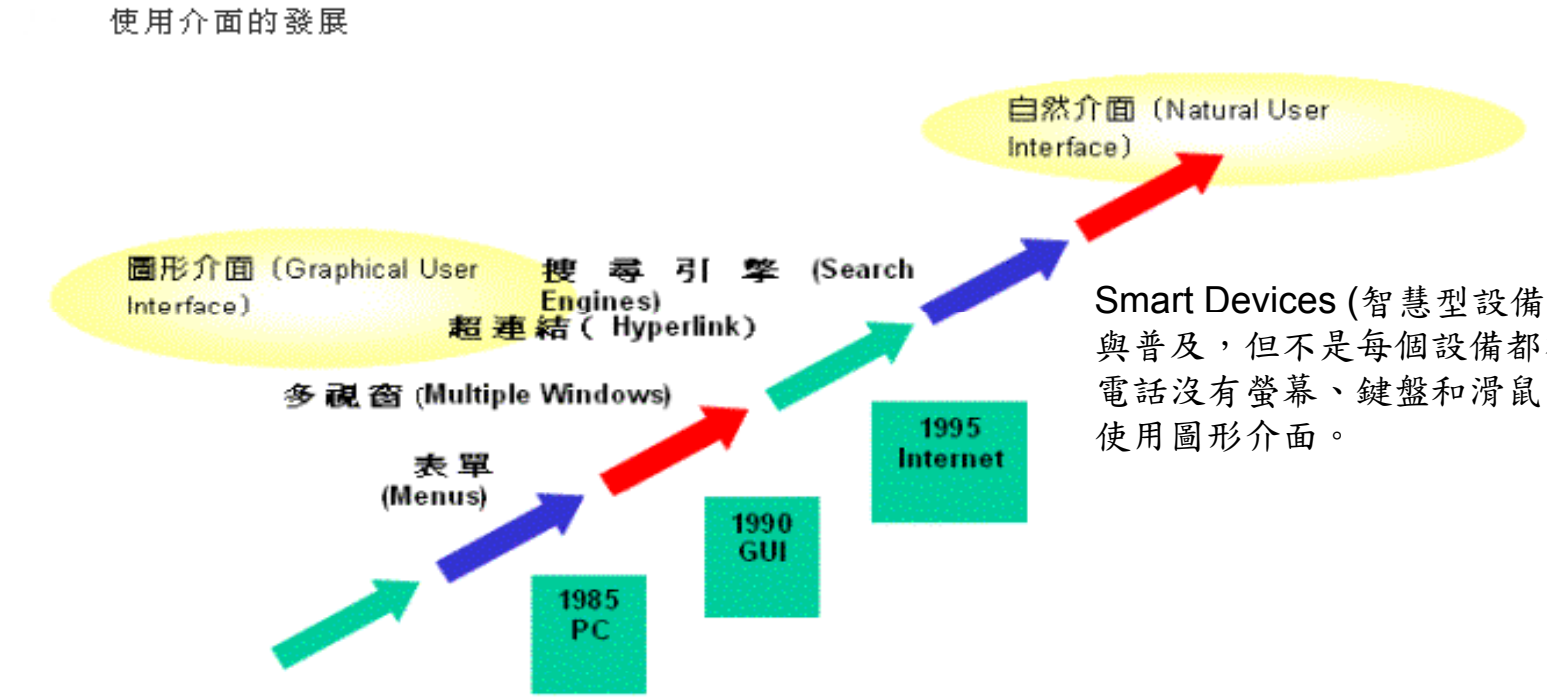
- Telecommunication
- Information Appliance
- Interactive Voice Response
- Voice Portal
- Multimedia Database
- Education
- …..



Speech Industry (2/3)

- Microsoft: Smart Device/Natural UI



Source：微軟自然互動服務產品部門 (NISD)副總裁李開複博士講稿， 2003/04

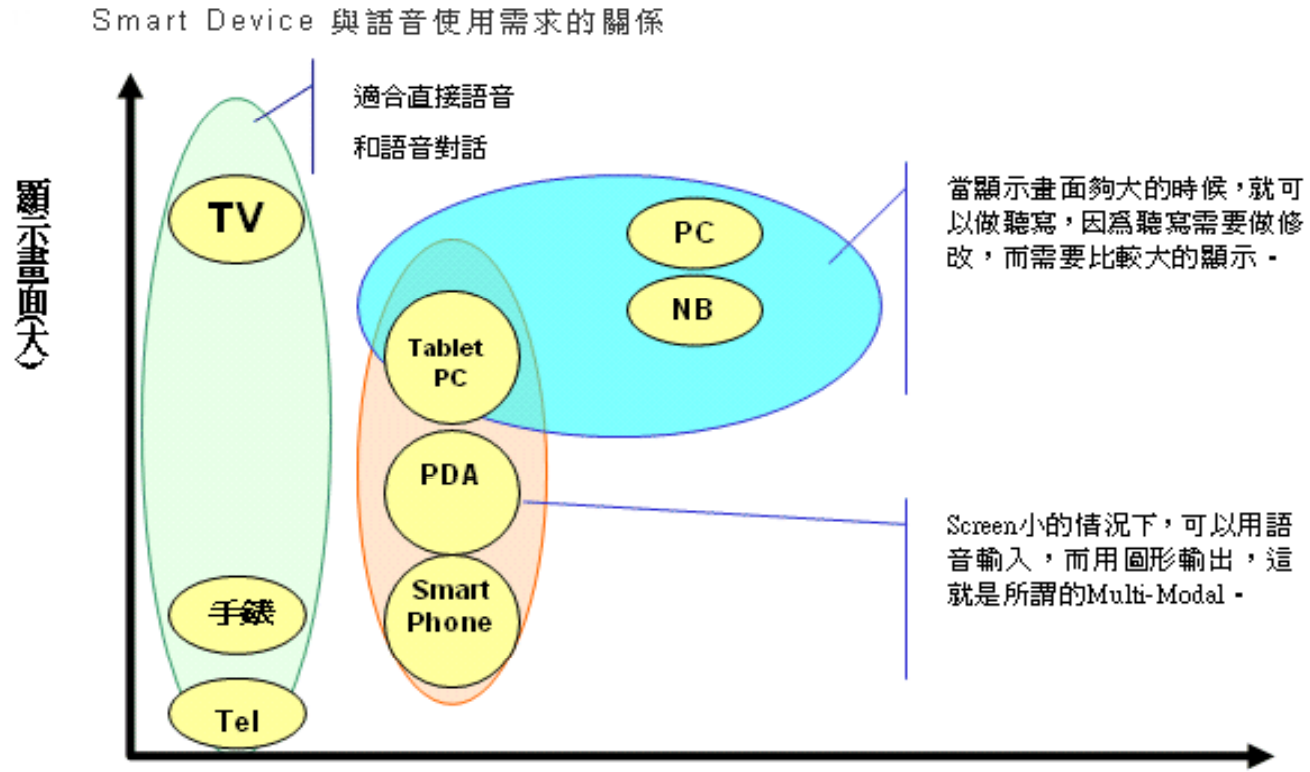
Smart Devices (智慧型設備)日益繁多與普及，但不是每個設備都有螢幕，例如：電話沒有螢幕、鍵盤和滑鼠，就無法使用圖形介面。

.NET 的最初構想，以符合人類需求的自然介面，其包括 –

- 語音合成
- 語音辨識技術
- 結合XML為基礎的網路服務

Speech Industry (3/3)

- Microsoft: Smart Device/Natural UI



手寫	X	O	O
滑鼠	X	X	O
鍵盤	X	X	O

Journals & Conferences

- Journals
  - IEEE Transactions on Audio, Speech and Language Processing
  - Computer Speech & Language
  - Speech Communication
  - Proceedings of the IEEE
  - IEEE Signal Processing Magazine
  - ACM Transactions on Speech and Language Processing
  - ACM Transactions on Asian Language Information Processing
  - …
- Conferences
  - IEEE Int. Conf. Acoustics, Speech, Signal processing (ICASSP)
  - Annual Conference of the International Speech Communication Association (Interspeech)
  - IEEE Workshop on Automatic Speech Recognition and Understanding (ASRU)
  - International Symposium on Chinese Spoken Language Processing (ISCSLP)
  - ROCLING Conference on Computational Linguistics and Speech Processing
  - …

Tentative Schedule

Date	Topic List
03/27	Overview & Introduction
	Hidden Markov Models
	Spoken Language Structure
	Acoustic Modeling & HTK Toolkit
	Statistical Language Modeling & SRI LM Toolkit
	Midterm
	Speech Signal Representations
	Digit Recognition, Word Recognition and Keyword Spotting
	Large Vocabulary Continuous Speech Recognition
	Speech Enhancement and Robustness
	Model Training and Adaptation Techniques
	Utterance Verification and Confidence Measures
	FINAL/Project