Limited Distribution

TR-I-0313

Research Activities of the Speech Processing Department

January through December, 1992

ATR Interpreting Telephony Research Laboratories

March, 1993

ATR Interpreting Telephony Research Laboratories

This volume is the sixth in a series of the complete collection of technical papers from the Speech Processing Department, ATR Interpreting Telephony Research Laboratories:

volume	period	id	#papers	#pages
I	from April 1986 through December 1988	TR-I-0010	32	181
II	from November 1987 through December 1988	TR-I-0065	88	449
III	from January through October 1989	TR-I-0115	69	282
IV	from November 1989 through December 1990	TR-I-0230	113	574
V	from January through December 1991	TR-I-0261	122	633
VI	from January 1992 through December 1992	TR-I-0313	140	629
VII	from January 1993 through March 1993	TR-I-0372	27	126

The research areas of the Speech Processing Department include:

1. Large Vocabulary Continuous Speech Recognition
   (a) Hidden Markov Models
   (b) Neural Network Approaches
   (c) Feature-Based Approaches
2. Speaker Adaptation and Noise-Robust Speech Recognition
3. Language Source Modeling
4. Speech Synthesis by Rule
5. Voice Conversion
6. Speech Database Construction

For additional information, contact:

ATR Interpreting Telephony Research Laboratories
2-2, Hikari-dai, Seika-cho, Souraku-gun, Kyoto 619-02, JAPAN
Telephone: +81 7749 5 1311,
Telefax: +81 7749 5 1308

Research Activities of the Speech Processing Department, January through December, 1992

Contents

1 Introduction

At ATR Interpreting Telephony Research Laboratories, speech research is being intensively pursued to realize automatic telephone interpretation that allows speech communication between telephone users speaking different languages. Automatic telephone interpretation or *speech translation*, to use more general terminology is one of the technologies most eagerly awaited by people all over the world.

The utterance of one party is to be translated into another language, which is heard by the person on the other end. The basic constituent technologies are speech recognition, language translation, and speech synthesis, which are not only essential for the realization of speech translation, but also widely applicable in various other areas. Although this concept of automatic telephone interpretation is rather new and research is still in its early stages, it is rapidly attracting the interest of researchers and research organizations throughout the world.

2 Automatic Telephone Interpretation Project

2.1 History and General Concept

In 1983, the first experimental demonstration of on-line speech translation was given at TELECOM-83 by NEC Research Laboratories. In 1987, speech translation between English and French was conducted at British Telecom Research Laboratories. That system was based on a set of more than 400 common business phrases. At Carnegie-Mellon University (CMU), a speech translation system with spoken input was developed in 1988 in a simple doctor-patient conversation domain.

In Japan, ATR Interpreting Telephony Research Laboratories, a subsidiary of Advanced Telecommunications Research International, was established in 1986 to initiate basic research for telephone interpretation. Stimulated by these earlier activities toward speech translation, a considerable number of research organizations became interested in this research area. Some of them have started active research in this particular field. In the United States, Carnegie-Mellon University is working on English-Japanese speech translation. AT&T Bell Laboratories is making an English-Spanish speech translation experiment with a relatively small vocabulary. In Germany, a new research project named "Verbmobil" has been started aiming at language translation with speech input. Karlsruhe University has begun a speech translation project between German and English. Korea Telecom also have a 10-year research project on automatic speech interpretation; its short-term target is Korean-Japanese speech translation. Mutual cooperation and collaborations among these research groups has been already started. On January 28 of 1993, ATR Interpreting Telephony Research laboratories, Carnegie-Mellon University, and Siemens AG + Karlsruhe University successfully performed jointly the first international experiment of interpreting telephony.

The basic components of an automatic telephone interpretation ("speech translation", in more general terminology) system are speech recognition, language translation, and speech synthesis. In realistic applications, speaker adaptation for input and speaker conversion for output are also required.

A simple combination of these elements of current technology, however, does not provide a satisfactory speech translation system. What is required of these components is somewhat different from how they are used in conventional applications. The major differences are as follows:

- High performance both in speech recognition and translation is required. Unlike conventional language translation, there cannot be any "pre/post-editing", since both input and output are speech.
- Real-time operation is a strong requirement.
- Spoken language is quite different from written language. Although, in spoken language, sentences are generally shorter and their structures are not particularly complicated, spoken dialogues include elliptic and anaphoric expressions. They may also include many syntactically ill-formed expressions.

Thus, speech translation is a new area that requires significant innovations in these constituent technologies.

Although the ultimate goal of the telephone interpretation system is universal dialogue in an unlimited domain, the immediate goal should be more feasible, such as a system which is limited to specific, task-oriented areas. ATR Interpreting Telephony Research Laboratories has selected an international conference registration task as a constrained task domain where the dialogue will be goal-directed and the expected vocabulary limited to approximately 1,500 words.

2.2 ATR's Experimental Speech Translation System

Figure 1 outlines the current experimental speech translation system at ATR Interpreting Telephony Research Laboratories. The input sentence speech uttered phrase-by-phrase is recognized with speaker adaptation capability under linguistic constraints and converted into several word sequence candidates. The number of candidates is narrowed down by dependency analysis and a final choice is determined by linguistic analysis. This is followed by language translation consisting of linguistic analysis, Japanese-to-English language transfer, and English sentence generation. The final stage is to convert English sentences into speech with the original speaker's characteristics. This stage is, however, not yet integrated into the system. The other direction, English-Japanese conversion, can be considered in the same way. As it seems inefficient to split our research efforts into Japanese and English aspects, our research topics mainly cover Japanese speech recognition, Japanese-English translation, and Japanese speech synthesis. Basically, the same approach can be applied to the English-Japanese speech translation.

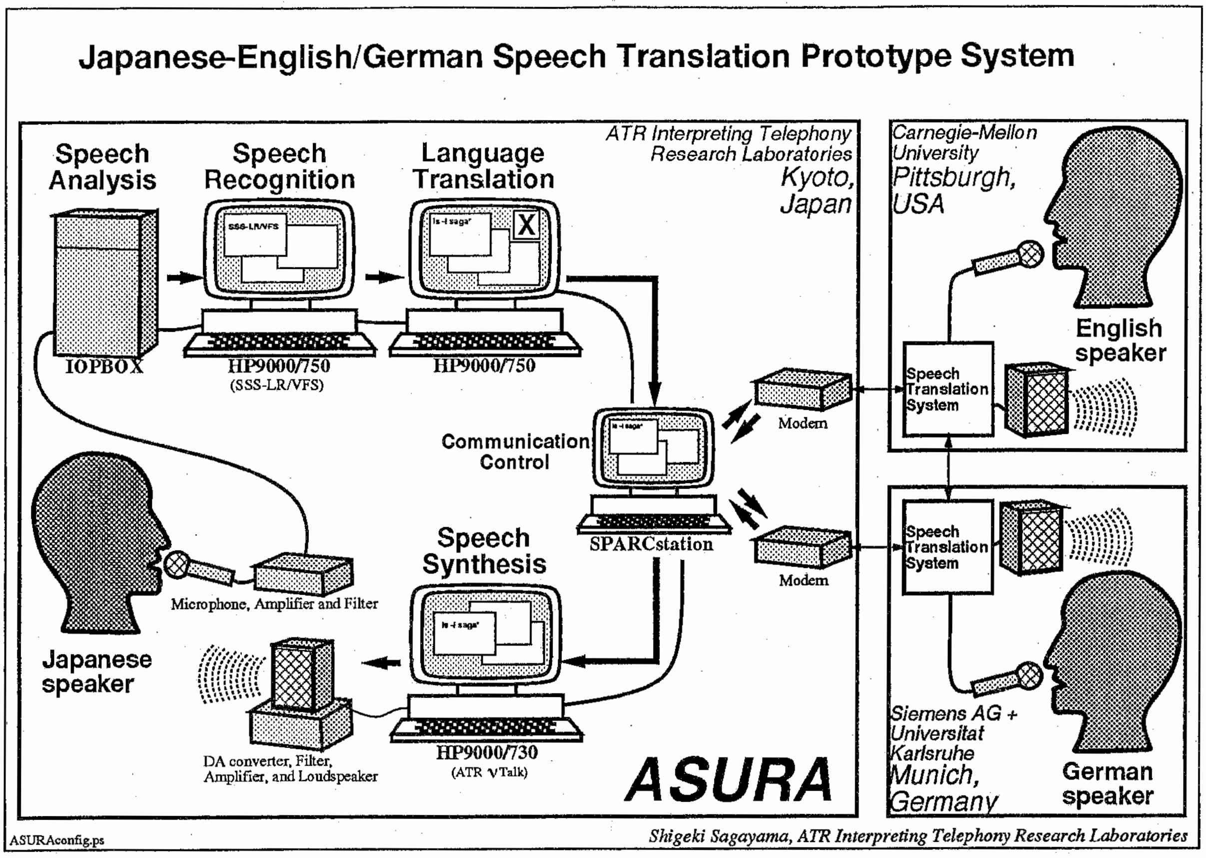


Figure 1: ASURA – ATR's experimental interpreting telephone prototype system

3 Speech Research at ATR Interpreting Telephony Research Laboratories

3.1 Research Project

ATR Interpreting Telephony Research Laboratories (Akira Kurematsu, president) consist of three departments: Natural Language Understanding Department, Knowledge and Database Department, and Speech Processing Department. The laboratory was founded in April 1986 with the support of the Japan Key Technology Center, ATR International, NTT, KDD, NHK, and other Japanese enterprises.

The main target of our institute is fundamental research into speech and language processing and the integration of speech and language processing technologies to demonstrate the feasibility of an automatic telephone interpretation system. As of 1991, the laboratory had a research budget of 2.6 billion yen.

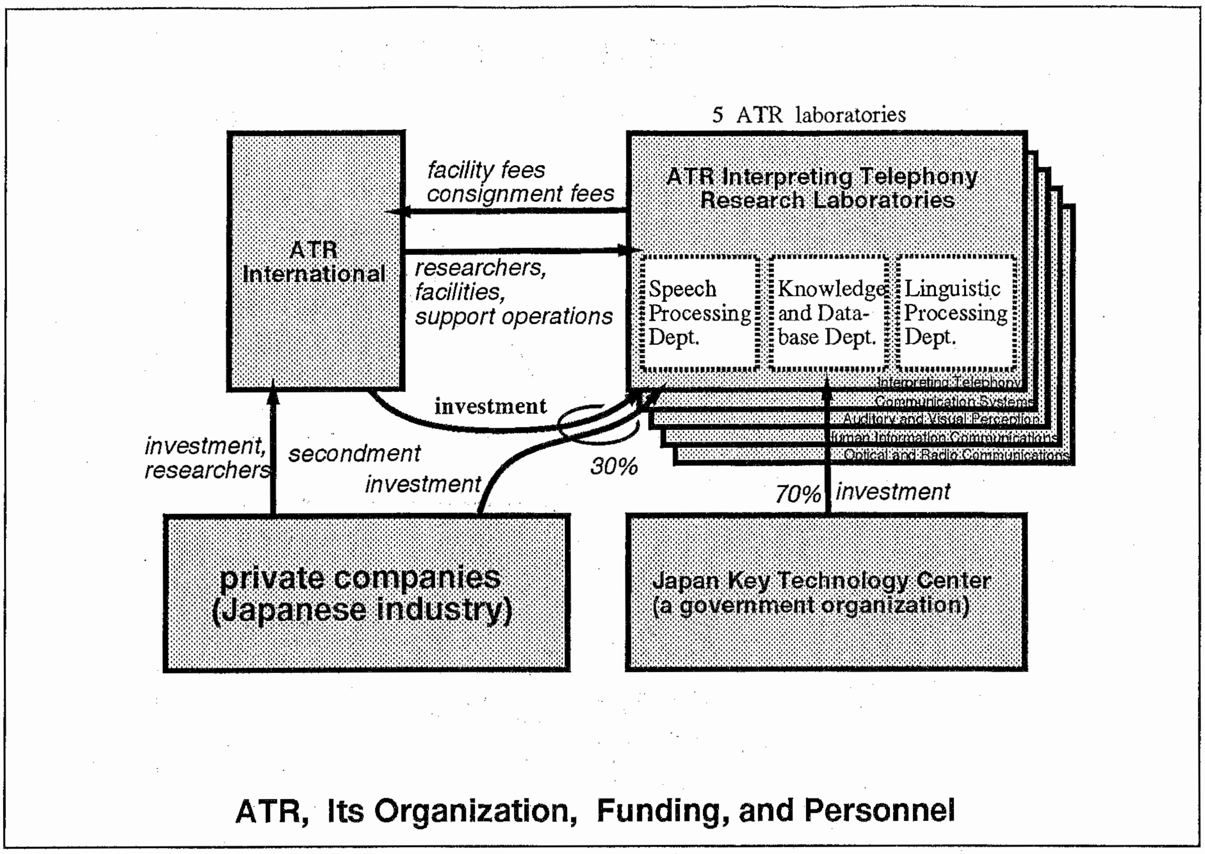


Figure 2: Funding and personnel of ATR Laboratories

3.2 Location

ATR Interpreting Telephony Research Laboratories is located in Kyoto Prefecture, although its geographical location is much closer to Nara than to Kyoto city. Nara was the capital of Japan more than 1,200 years ago. Promoted by Japanese government and industry, 12 separate areas in this district have been designated as Kansai Science and Technology Cities. They are expected to rapidly grow into Japan's new center of major scientific and technological research and education activities. ATR (including ATR International and its five subsidiary laboratories) was one of the earliest organizations to settle in this area.

ATR's transportation situation is not excellent at the moment. Figure 3 shows how to grt to ATR Interpreting Telephony Research Laboratories. The approximate time from Kyoto to Takanohara station of the Kintetsu Railway is 40 minutes by express train, which leaves Kyoto every 15 minutes. ATR shuttle buses or taxis are available at Takanohara station and take 10 minutes to reach ATR.

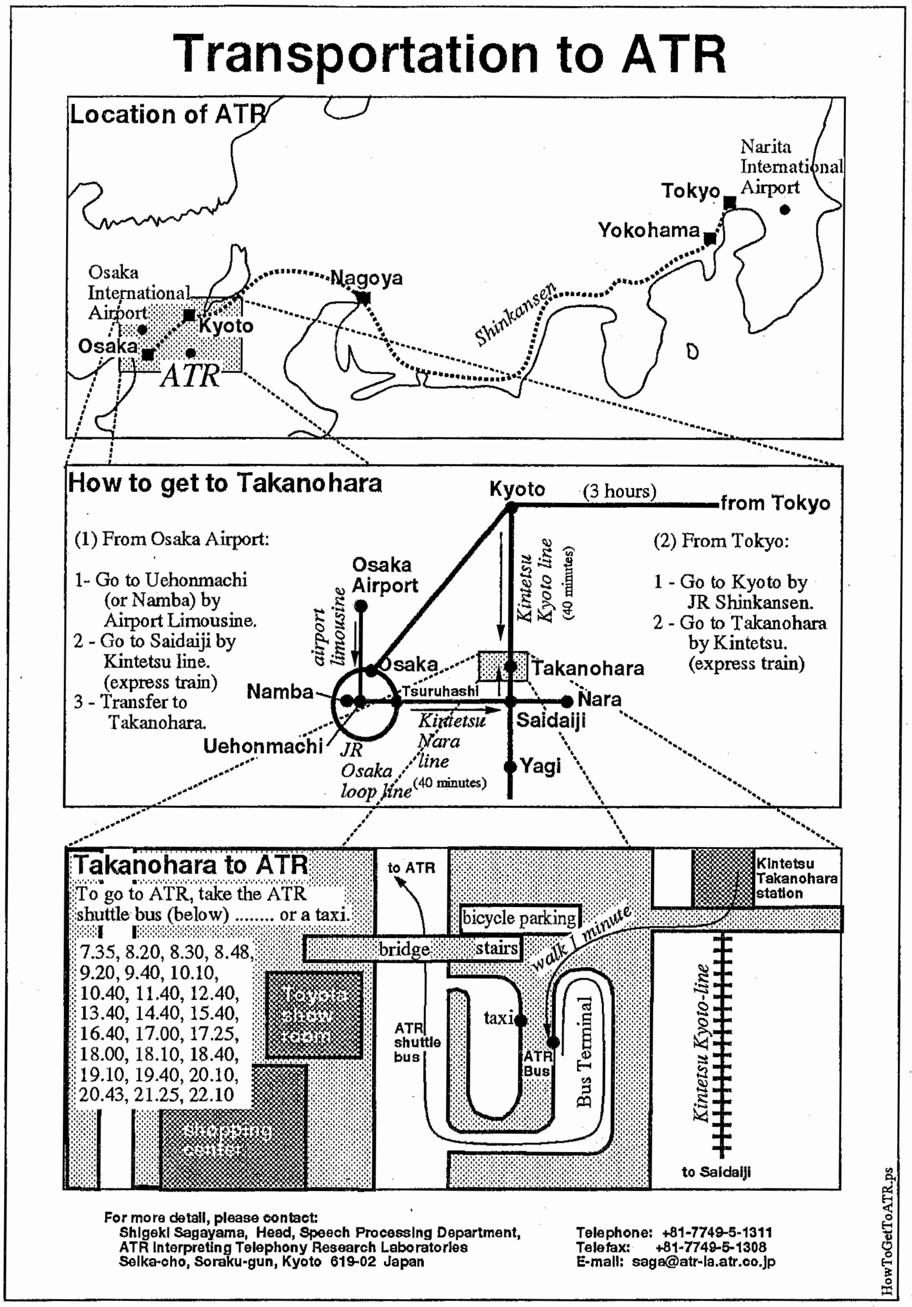
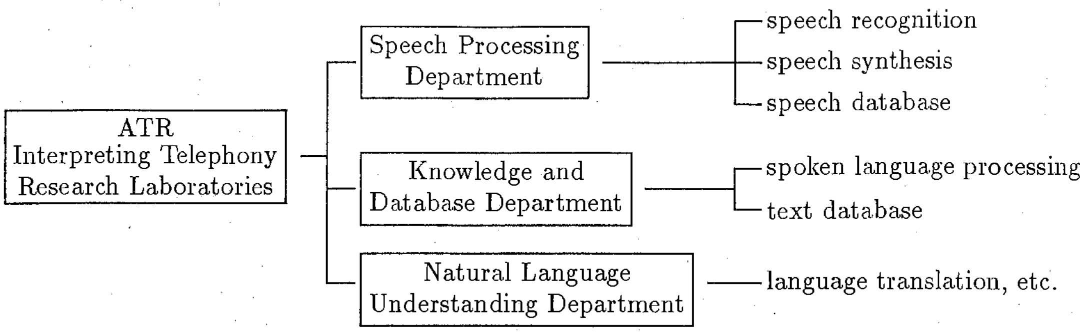


Figure 3: How to get to ATR Laboratories

3.3 Organization

ATR Interpreting Telephony Research Laboratories consist of three departments: Speech Processing Department (Shigeki Sagayama, Head), Knowledge and Database Department (Tsuyoshi Morimoto, Head), and Natural Language Understanding Department (Hitoshi Iida, Head).

An outline of the organization is shown below.



3.4 Research Staff

The research staff is mainly composed of members temporarily seconded from research institutes, laboratories, and industrial companies that support ATR, and visiting/invited researchers.

Currently (as of March, 1993), the Speech Processing Department has 23 members including a department head, two supervisors, 15 researchers, four visiting/invited researchers, and an engineer. Tables ?? and ?? shows former and current members of the research staff at the Speech Processing Department, including visiting/invited researchers. Table ?? shows the list of gradutate students who worked or are currently working as their internships at the department.

Current members can be reached through E-mail account names followed by '@atr-la.atr.co.jp'. (For example, Sagayama's E-mail address is 'saga@atr-la.atr.co.jp'.)

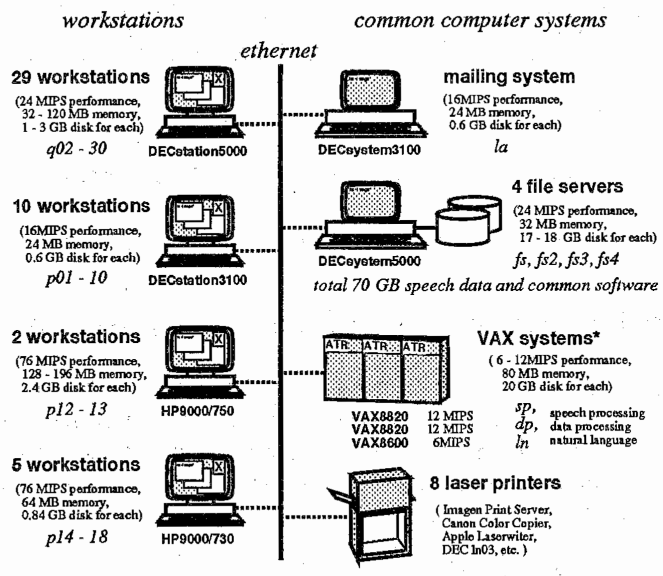
name & title	Email	position	period
Kiyohiro Shikano, Dr	-	Department Head	6/1986 – 1/1990
Shigeki Sagayama	saga	Department Head	2/1990 – 3/1993
Yoshinori Sagisaka, Dr	sagisaka	Supervisor	4/1986 – 3/1993
Hisao Kuwabara, Dr	-	Supervisor	10/1986 – 7/1989
Masahide Sugiyama, Dr	sugi	Supervisor	2/1990 – 3/1993
Tetsuo Umeda	-	Supervisor	7/1989 – 6/1990
Takeshi Kawabata, Dr	-	Senior Researcher	9/1986 – 2/1990
Shin-ichi Tamura	-	Senior Researcher	9/1986 – 2/1990
Hidefumi Sawai, Dr	-	Senior Researcher	4/1988 – 3/1991
Kazuya Takeda	-	Researcher	8/1986 – 2/1990
Satoshi Nakamura	-	Researcher	9/1986 – 8/1989
Masanori Miyatake	-	Researcher	9/1986 – 3/1989
Kaichiro Hatazaki	-	Researcher	12/1986 – 3/1989
Toshiyuki Hanazawa	-	Researcher	3/1987 –2/1990
Katsuteru Maruyama	-	Researcher	3/1987 – 2/1990
Masanobu Abe	-	Researcher	4/1987 – 2/1991
Katsuo Abe	-	Researcher	3/1987 – 2/1990
Masami Nakamura	-	Researcher	9/1987 – 8/1990
Yasuhiro Komori	-	Researcher	9/1988 – 2/1992
Hiroaki Hattori	hiroaki	Researcher	5/1989 – 4/1992
Kazumi Ohkura	ohkura	Researcher	9/1989 – 3/1993
Nobuyoshi Kaiki	kaki	Researcher	11/1989 – 10/1992
Jun-ichi Takami	jun	Researcher	11/1989 – 3/1993
Kazuki Katagishi, Dr	katagisi	Researcher	2/1990 – 3/1993
Akito Nagai	nagai	Researcher	3/1990 – 3/1993
Keiji Fukuzawa	fukuzawa	Researcher	4/1990 – 3/1993
Katsuhiko Mimura	mimura	Researcher	5/1990 – 3/1993
Shingo Fujiwara	fujiwara	Researcher	5/1990 – 3/1993
Naoto Iwahashi	iwahashi	Researcher	10/1990 – 3/1993
Jin-ichi Murakami	murakami	Researcher	3/1991 – 3/1993
Yoshinaga Kato	kato	Researcher	4/1991 – 3/1993
Kouichi Yamaguchi	yamaguti	Researcher	5/1991 – 3/1993

Yasunaga Miyazawa	miyazawa	Researcher	7/1991 – 3/1993
Tetsuo Kosaka	kosaka	Researcher	9/1991 – 3/1993
Ryosuke Isotani	isotani	Researcher	4/1992 – 3/1993
Alex Waibel, Dr	-	Invited Researcher	5/1987 – 8/1988, 6 – 9/1989
Hiroaki Saito, Dr	-	Invited Researcher	2/1988 – 7/1989
William Poser, Dr	-	Invited Researcher	9/1988 – 2/1989
Alain de Cheveigné, Dr	-	Invited Researcher	2/1989 – 2/1990
Dieter Huber, Dr	-	Invited Researcher	3 – 6/1990
David Rainton, Dr	rainton	Invited Researcher	4/1990 – 3/1993
Wilhelm N. Campbell, Dr	nick	Invited Researcher	8/1990 – 3/1993
Harald Singer	singer	Invited Researcher	3/1991 –
Helmut Lucke, Dr	lucke	Invited Researcher	4/1992 – 3/1993
Wang Wern-jun	wang	Invited Researcher	2 – 7/1991
Jacqueline Vaissiere, Dr	-	Invited Researcher	7 – 8/1992
Paul Christopher Bagshaw	-	Invited Researcher	5 – 11/1992
Kouichi Murayama	-	Engineer	9/1987 – 8/1988
Takaharu Tanaka	-	Engineer	9/1988 – 8/1989
Kouji Kitagaito	-	Engineer	9/1989 – 8/1990
Shinobu Araki	-	Engineer	9/1990 – 8/1991
Yoshinori Ono	ono	Engineer	9/1991 – 3/1993
Hubert Segot	-	Student (ENST)	4 – 9/1987
Eiichiro Kitagawa	-	Student (Waseda Univ)	8/1987
Kenji Hashimoto	-	Student (Waseda Univ)	8/1987
Takahito Yamazaki	-	Student (Shizuoka Univ)	8/1988
Furati Mulad	-	Student (Shizuoka Univ)	8/1988
Patrick G. Haffner	-	Student (ENST)	3 – 11/1988
Yasuhide Hashimoto	-	Student (Toyohashi Univ of Tech)	7 – 8/1987
Takashi Endo	-	Student (Waseda Univ)	8/1987
Rei Furukawa	-	Student (Waseda Univ)	3 – 4/1989
Jean-Claude Dang	-	Student (ENST)	3 – 11/1989
Yoshimitsu Hirata	-	Student (Toyohashi Univ of Tech)	1 – 2/1989
Mitsuru Noda	-	Student (Toyohashi Univ of Tech)	1 – 2/1989
Yasuhiro Minami	-	Student (Keio Univ.)	3–6/1989, 8/1989–2/1990, 7–10/1990
Katsunobu Ito	-	Student (Tokyo Inst of Tech)	10 – 12/1989
Yoshio Ueda	-	Student (Toyohashi Univ of Tech)	1 – 2/1990
Takeshi Hirado	-	Student (Toyohashi Univ of Tech)	1 – 2/1990
Satoru Nakamura	-	Student (Keio Univ)	7 – 9/1990, 3 – 4/1991
Toshiyuki Nomura	-	Student (Nagoya Univ)	7 – 8/1990
Mamoru Watado	-	Student (Waseda Univ)	7 – 8/1990
Hidehiro Inagaki	-	Student (Waseda Univ)	7 – 8/1990
Yasushi Maruyama	-	Student (Shinshu Univ)	3-4/1990
Atsuhiko Kai	-	Student (Toyohashi Univ of Tech)	?/1990 – ?/1991
Alain Biem	-	Student (INT)	8/1990 – 1/1991
Hidefumi Kikuchi	-	Student (Waseda Univ)	8/1991
Masafumi Tamoto	-	Student (Tokyo Inst of Tech)	8/1991
Keisuke Doi	-	Student (Ryukoku Univ)	8/1991 – 9/1992
Tetsuya Yoshida	-	Student (Keio Univ)	8 – 9/1991
Kentaro Kurinami	-	Student (Keio Univ)	8 – 9/1991
Romain Brunias	-	Student (INT)	8/1991 – 1/1992

Richard Lengagne	-	Student (INT)	8/1991 – 1/1992
Tadashi Okamoto	-	Student (Toyohashi Univ)	1 – 2/1992
Satoshi Aki	-	Student (Toyohashi Univ)	1 – 2/1992
Hideyuki Watanabe	-	Student (Hokkaido Univ)	2 – 4/1992
Hiroki Yamamoto	xyama	Student (Waseda Univ)	3 – 9/1992
Ioana Donescu	-	Student (INT)	8/1992 – 1/1993
Edward David Peter Willems	-	Student (ENST)	8 – 12/1992
Masashi Mizuno	-	Student (Waseda Univ)	7 – 9/1992
Franck Martin	-	Student (Univ de Centre Paris)	8 – 9/1992
Yasuo Iwai	-	Part-time (Univ of Kyoto)	8/1989 – 3/1990
Toshiyuki Sadanobu	-	Part-time (Univ of Kyoto)	8/1989 – 3/1990
Natsuya Yoshida	-	Part-time (Univ of Kyoto)	8/1989 – 3/1990
Miwako Kurihara	-	Part-time (Doshisha Univ)	4/1990 –
Mechtild Tronnier	-	Part-time (Kansai Univ)	9/1990 – 4/1991
Ming-Yong Zhou	zhou	Part-time (Osaka City Univ)	10/1990 –
Kazue Kinugasa	xkazue	Part-time (Kansai Univ)	2/1992 –

3.5 Research Facilities

Now, each member of the research staff is provided a DECstation5000 (speed 24MIPS) or DECstation5500 (speed 50MIPS), with 24 - 120 Mbyte memory and a 600M - 3G byte disk, which is connected to an Ethernet. We have 4 other DECsystem5000s with over 30G byte disk memory each which are used as file servers to contain the large scale speech database and are accessed from workstations through the Ethernet. Some workstations are equipped with speech input/output devices. Older computer systems, including VAX8700, and VAX8820, are also connected to the Ethernet and accessed from workstations. The department has two Hewlett-Packard HP9000 model 750s and five model 730s which run at 76 MIPS for high-speed computations and experiments of interpreting telephony. In the international experiment of interpreting telephony among Japan, USA, and Germany, held on January 28, 1993, three HP9000s were used for speech recognition, language translation, and speech synthesis.



Research Facilities at Speech Processing Department

Figure 4: Computer Facilities of the Speech Processing Department, ATR Interpreting Telephony Research Laboratories

4 Interpreting Telephony

Speech recognition and speech synthesis research results were well combined with language translation and utilized in a experimental interpreting telephone system named "ASURA" (Advanced Speech Understanding and Rendering system of ATR). This system was demonstrated on January 28, 1993, in a three-party international experiment of interpreting telephone. The success of the first international experiment was widely reported in a number of TV news programs and newspapers. The system configuration is shown in 1.

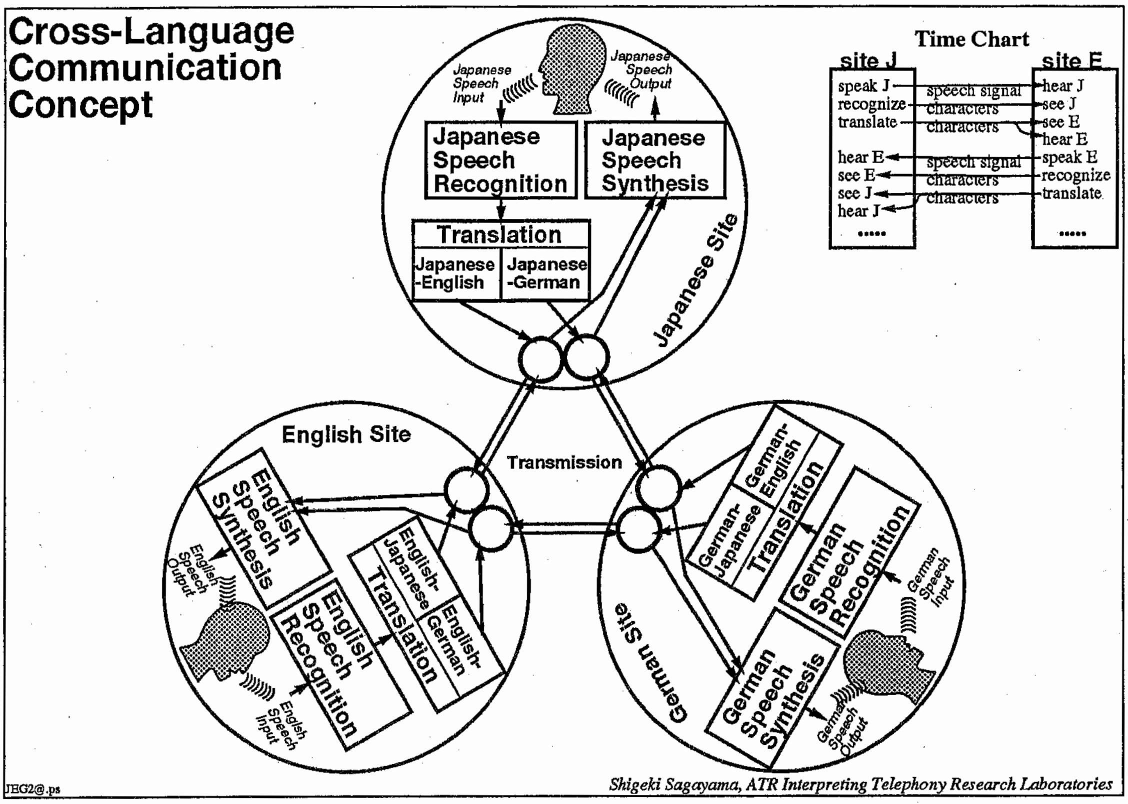


Figure 5: Conceptual diagram of interpreting telephony (Japanese, English, and German)

The task domain of the experiment was "international conference registration".

5 Technical Publications from January through December 1992

The following pages are a list of technical publications, published or coauthored by the researchers of the Speech Processing Department, ATR Interpreting Telephony Research Laboratories, published during the period from January through December 1991, including reprints of these publications. Some of these works were done in their previous affiliations and published after their joining ATR.

Abbreviations used in the list are as follows:

- ASJ: the Acoustical Society of Japan
- IEICE: the Institute of Electronics, Information and Communications Engineers (Japan)
- ICASSP: IEEE International Conference on Acoustics, Speech, and Signal Processing
- Eurospeech: Europian Conference on Speech Communications
- ICSLP: International Conference on Spoken Language Processing

List of Publications, January through December, 1992

◆

◆

◆

Yasuhiro Komori: "Minimum Error Classification Training for HMM-based Keyword Spotting," Proc. of 1992 International Conference on Spoken Language Processing, Tu.sAM.1.2, pp. 9–12 (1992.10).

◆

小坂 哲夫, 嵯峨山 茂樹: "不特定話者を対象とした混合連続分布 HMM 音声認識における混合数の検討," 日本音響学会平成 4 年度春季研究発表会講演論文集, 2-Q-20, pp. 197–198 (1992.03).
T. Kosaka and S. Sagayama: "An Investigation on the Number of Mixture Components of Continuous HMMs for Independent Speakers," ASJ Spring Meeting, 2-Q-20, pp. 197–198, (1992.03).

小坂 哲夫, 鷹見 淳一, 嵯峨山 茂樹: "話者混合 SSS による不特定話者音声認識と話者適応," 電子情報通信学会技術研究報告, SP92-52, pp. 17–24 (1992.09).
T. Kosaka, J. Takami and S. Sagayama: "Speaker-Independent Speech Recognition and Speaker Adaptation Using Speaker-Mixture SSS algorithm," IEICE Technical Report, SP92-52, pp. 17–24, (1992.09).

小坂 哲夫, 嵯峨山 茂樹: "混合連続分布 HMM 音素モデルの構造自動決定法の検討," 日本音響学会平成 4 年度秋季研究発表会講演論文集, 2-1-1, pp. 79–80 (1992.10).
T. Kosaka and S. Sagayama: "An Investigation on the Structure Determination of Continuous HMM Phone Models," ASJ Fall Meeting, 2-1-1, pp. 79–80 (1992.10).

小坂 哲夫, 鷹見 淳一, 嵯峨山 茂樹: "話者混合 SSS による不特定話者音声認識," 日本音響学会平成 4 年度秋季研究発表会講演論文集, 2-5-9, pp. 135–136 (1992.10).
T. Kosaka, J. Takami and S. Sagayama: "Speaker-Independent Speech Recognition Using Speaker-Mixture SSS algorithm," ASJ Fall Meeting, 2-5-9, pp. 135–136, (1992.10).

Tetsuo Kosaka, Shigeki Sagayama: "An Algorithm for Automatic HMM Structure Generation in Speech Recognition," Proc. of Fourth Australian International Conference on Speech Science and Technology pp. 104–109, (1992.12).

◆

K. Kurinami, M. Sugiyama: " An Optimization Technique for Speaker Mapping Neural Networks Using Minimal Classification Error Criterion," Journal Acoustic Society Japan, Vol. 13, No. 6, pp. 419–428 (1992.11).

◆

Helmut Lucke, F.Fallside: "Expanding the Vocabulary of a Connectionist Recognizer Trained on the DARPA Resource Management Corpus," Proc. of 1992 International Conference on Acoustics, Speech, and Signal Processing, Vol. 1, S1, pp. I-605–608, San Francisco, (1992.03).

Helmut Lucke: "音声認識アルゴリズムに比較検討するための統計的考察," 日本音響学会平成 4 年度秋季研究発表会講演論文集, 2-Q-15, pp. 201–202 (1992.10).
H.Lucke: "Statistical Considerations in the Comparative Evaluation of Speech Recognition Algorithms," ASJ Fall Meeting, 2-Q-15, pp. 201–202 (1992.10).

Helmut Lucke: "Bayesian Causal Trees の理論を用いる確率文脈自由文法を推定方法," 電子情報通信学会技術研究報告, SP92-113, pp. 79-86 (1992.12)
H.Lucke: "A Method of Inferring Stochastic Context-free Grammars Using the Theory of Bayesian Causal Trees," IEICE Technical Report, SP92-113, pp. 79–86 (1992.12

David Rainton, Shigeki Sagayama: "Minimum Error Classification Training of HMMs - Implementation Details and Experimental Results," 電子情報通信学会技術研究報告, SP91-107, pp. 39–46 (1992.01).
IEICE Technical Report

Rainton92ASJ03 410

David Rainton, Shigeki Sagayama: "Word Level Minimum Error Training of Phoneme HMMs," 日本音響学会平成 4 年度春季研究発表会講演論文集, 1-1-2, pp. 3–4 (1992.03).
ASJ Spring Meeting

Rainton92ISSPA08 412

David Rainton, Shigeki Sagayama: " A New Minimum Error Classification Training Technique for HMM Based Speech Recognition," Proc. of ISSPA92, pp. 279–282, Australia (1992.08)
.

Rainton92ASJ10 416

David Rainton, Shigeki Sagayama: "Sentence Level Minimum Error Training of Phoneme HMMs," 日本音響学会平成 4 年度秋季研究発表会講演論文集, 2-Q-13, pp. 197–198 (1992.10).
ASJ Fall Meeting

Rainton92ICSLP10 418

David Rainton, Shigeki Sagayama: "Appropriate Error Criterion Selection For Continuous Speech HMM Minimum Error Training," Proc. of 1992 International Conference on Spoken Language Processing, We.fAM.1.3, pp. 233–236 (1992.10).
.

Rainton92JASJ11 422

David Rainton, Shigeki Sagayama: "Minimum Error Classification Trainign of HMMs-Implementation details and experimental results," The Journal of the Acoustical Society of Japan, Vol. 13, No. 6, pp. 379-387 (1992.11).
.

◆

Sagayama92JASJ01 431

嵯峨山 茂樹: "数理統計モデルを用いた音声認識の現状と将来," 日本音響学会誌, 48 巻, 1 号, pp. 26–32, (1992.01).
S. Sagayama: "A Discussion on Statistical Approaches to Speech Recognition," The Journal of the Acoustical Society of Japan, Vol. 48, No. 1, pp. 26–32 (1992.01).

Sagayama92SpeechTech02 438

Shigeki Sagayama: "Speech Research at ATR Interpreting Telephony Research Laboratories," Speech Technology, Vol. 5, No. 4, pp. 23–27, Media Dimension Publishing Co., Ltd., (1992.02).

Sagayama92Sympo02 443

嵯峨山 茂樹: "音声認識における韻律情報の利用について," 連続音声認識シンポジウム (電子情報通信学会「マルコフモデル・ニューラルネットワークを包含する新しい音声認識手法」時限研究会主催, 於浜松舘山寺) 予稿集 (1992.02).
S. Sagayama: "On the Use of Prosodic Information," Proc. of the Symposium on Continuous Speech Recognition (Kanzanji)(1992.02).

Sagayama92kakenhi2 446

嵯峨山 茂樹: "音声認識のための確率モデル, ニューラルネットワーク, 話者適応, 韻律情報の利用等に関する研究," 文部省科研費「マルコフモデル・ニューラルネットワークを包含する新しい音声認識手法の総合的研究」報告書 (1992.02).
S. Sagayama: "Researches of Probabilistic Models, Neural Networks, Speaker Adaptation, and Prosody for Speech Recognition," *The Final Report of New Speech Recognition Paradigms Including Markov Models and Neural Networks,* Science Research Fund from the Ministry of Education and Culture (1992.02).

Sagayama92NikkeiByte06 459

嵯峨山茂樹: "音声認識," 日経バイト 6 月号 (100 号記念特集号), 日経マグロウヒル社, pp. 212–221 (1992.06).
S. Sagayama: "Speech Recognition," Proc. of Nikkei Byte, pp. 212–221 (1992.06).