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Dissertation

Corporate Technological Positioning in Automatic Speech Recognition and Natural Language Processing

by

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“How can computers understand people, since very often people do not understand each other?”.

R. Schwartz, Plenary Session, ICASSP 98

ABSTRACT

Quantitative and qualitative data have been exploited to study corporate technological positioning in Automatic Speech Recognition (ASR) and Natural Language Processing (NLP). We conducted also a survey with executives and researchers, adding feedback on our findings from patents and publications. The analysis showed:

– Two clusters of firms exist: *first:* large firms (particularly originating from telecommunications & electronics, operating systems & applications, and non IT sectors), *second* small firms specialising in speech technologies.

– The emergence of small specialised firms depends heavily on the strength of universities and public research institutes in the particular sciences, and less on large firms found in the same region. The role of initial funding from the ARPA programme (US Dept. of Defence) has been very influential for the development and diffusion of this science.

– Integration of ASR and NLP at the organisational level is extremely weak. For the time being, these two research communities have been functioning more or less independently, with the former progressing more rapid than the latter.

This study also argues that large firms, having built technological capabilities in ASR and NLP with a small proportion of their corporate technological resources, have two options, depending on the rate of progress in these technologies (especially NLP) in future.

i) if it is high, substantial investments (including those in complementary technologies) could open up massive market opportunities.

ii) if it is low, modest investments will allow the exploitation of small niche markets.

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List of Acronyms

ANN Artificial Neural Network

ACM Association for Computing Machinery

AI Artificial Intelligence

API Application User Interface

ARPA Advanced Research Project Agency

ASR Automatic Speech Recognition

BIDS Bath Information & Data Services

CGI Common Gateway Interface

EU European Union

HMM Hidden Markov Model

ICASSP International Conference on Acoustics, Speech and Signal Processing

ICSLP International Conference on Speech and Language Processing

IEEE Institute of Electrical and Electronics Engineers

ISI Institute for Scientific Information

IT Information Technology

IVR Interactive Voice Response

JAIR Journal of Artificial Intelligence Research

JASA Journal of the Acoustical Society of America

NLP Natural Language Processing

NTBF New Technology Based Firm

OECD Organisation for Economic Co-operation and Development

PDA Personal Digital Assistant

PTO Public Telephone Operator

ROI Return On Investment

RTA Revealed Technology Advantage

SBU Strategic Business Units

SME Small Medium Enterprise

TTS Text-To-Speech (i.e. speech synthesis)

UK United Kingdom

US United States of America

WWW World Wide Web

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K. Koumpis

Brighton, August 1998

Dedicated to my father's memory, who taught me hard work and to the pioneers of speech processing technology, whose visions and efforts, have given keys to communication and independence to all of us.

CHAPTER 1

RATIONALE

1.1 Introduction

Companies are continually seeking to gain advantage from technological progress. Building a computer that is able to ‘hear’ and ‘understand’ human voice has been of major significance because this supports direct communication between humans and machines through a communication mode which humans commonly use among themselves and they are highly skilled in. This task falls in the area that is known as *speech understanding*. Research in this area is subdivided into two categories that correspond to the two main components of such a system. Automatic Speech Recognition (ASR) deals with the decoding of the speech signal to a discrete symbol string, such as words, phonemes or other language units and Natural Language Processing (NLP) deals with the interpretation of this symbol string for meaning extraction.

Since the 1960s, scientists have invented powerful systems some of which are commercially available and can recognise what humans say with more than 95% accuracy. The ability of computers to perceive and communicate has also evolved dramatically over the past decade as a result of research in artificial intelligence (AI) and related disciplines that address issues of human and machine perception. These innovations, which are increasingly depending upon interactions between technologies, have seen a tremendous growth and they also offer great economic opportunities. Communication with computers using spoken language may have a lasting impact upon several markets and the environment people live and work in.

1.2 Aim of Study

Scientists are particularly interested in this area of research because humans use speech and language to ‘communicate ideas’ while corporate practitioners are looking to deploy critical applications that rely on spoken language interfaces. The choice of studying corporate technological positioning in ASR and NLP was based mainly on the following considerations:

A. ASR and NLP are a set of techniques to perform new functions which had been beyond the scope of conventional computer or telephony interfaces. This enables us to study how firms create and assimilate a radical new technology.

B. It is a field, through which it is possible to see a clear pattern of innovation, from laboratory discovery in the 1960s, to two decades of uncertainty in the 1970s and 1980s, leading to a successful commercialisation and rapid diffusion in the late 1990s.

C. It offers the possibility of understanding the interdependencies between software and hardware systems, key components in IT both in industry and academia.

D. It is a strategically important set of core or background technologies, which must be mastered by firms in a variety of sectors in order to remain competitive.

E. It is a field dominated by US firms[1], although language diversity creates new opportunities for non-English applications worldwide.

1.3 Research Methodology

In this dissertation, in order to identify technological positioning within a sector we analysed two types of output data, namely US patent and scientific publications data. This methodology has already been applied successfully in other sectors as is described in paragraph 3.6 about similar research approaches. Our conceptual framework to analyse the competencies of top performing companies is mainly based on the research of Mitchell & Hamilton (1988), Teece & Pisano (1994) and Granstrand, Patel & Pavitt (1997). The above data have been complemented with the opinions of corporate practitioners by putting a specially designed questionnaire on the Internet. Other sources of information, such as case studies found in newsletters[2], websites and scientific papers have also been exploited in order to find out what specific market experience discloses.

1.4 Limitations of the Study

The author is aware of the fact that applications of ASR and NLP are extremely wide and therefore the research has been focused on those providing natural interactivity and accessibility of digital services through multimodal dialogues, understanding of messages and communicative acts, unconstrained language input and keyboard–less operation.

[1] The American Council on Competitiveness gave to speech recognition in computers an A grade when examining the US technological position. In the same class there were: database systems, biotechnology, jet propulsion, magnetic information storage, pollution reduction, software, vision in computers and computers generally (Source Stewart, 1991).

[2] Three major newsletters for ASR exist, describing the latest developments in speech recognition applications, new products, R&D, marketing and investments in this emerging industry. All are published monthly and more information can be found:

Developments in speech technology such as speech synthesis, coding, speaker verification/identification or language identification are very important and often overlapping, but because of space limitations they could not be included here.

An important point is the difficulty in data gathering. Since the area of research touches on the most delicate issues concerning competitiveness of firms, some persons have been more cooperative than others in answering the questions listed in the survey. In these cases, data collection is based on alternative sources.

Another point to note is that this work is not about National Systems of Innovation. Although we shall examine several companies worldwide, it is not our main goal to make international comparisons in style of management, financial issues or research facilities availability. Only if we notice some national trends, may we be able to draw some additional meaningful conclusions.

Finally, the author is aware of the fact that in order to obtain complete results of the overall innovation process, R&D expenditure figures should be used in addition to the patent and bibliometric indicators. However, such figures were impossible to be obtained in a common basis in order to perform comparisons.

1.5 Structure of the Dissertation

The structure of the dissertation is as follows. *Chapter 1* has served an introduction to the area and scope of research, methodology and limitations. *Chapter 2* recounts the evolution of ASR and NLP and their techno-economic features. *Chapter 3* provides the conceptual framework of empirical analysis for identifying the important components of corporate innovation strategy and sets the analytical questions of the study. Then it presents the three types of data analysed to perform technological positioning. Strengths and weaknesses of the collection methodology employed are discussed. We devote the three next chapters to answer each of the analytical questions. *Chapter 4* examines the evolution and technological trajectories in ASR and NLP before the recent market penetration. *Chapter 5* deals with the degree of which language constraints constitute barriers for Asian and European companies in this field. *Chapter 6* examines the market orientation of firms involved in ASR and NLP by identifying whether these technologies are coped as sources of core or background competencies. Afterwards we classify the firms into four groups. For further understanding the profile of one company from each group is illustrated. Finally, *Chapter 7* draws the main conclusions and discusses implications and possible avenues for these technologies.

ASRNews, by Voice Information Associates (VIA), **Speech Recognition Update**, by TMA Associates **VoiceNews**, by Stoneridge Technical Services.

CHAPTER 2

DEFINITIONS AND ASPECTS OF AUTOMATIC SPEECH RECOGNITION AND NATURAL LANGUAGE PROCESSING

2.1 Introduction

In the first part of this chapter we give the definitions of ASR and NLP and illustrate the importance of voice processing technology by describing a variety of products and services based on them. Our aim is to offer as wide as broad understanding as possible avoiding using stilted terminology. In the second part, we address the interdependencies of ASR and NLP and explain the reasons why they are treated by firms as 'key technologies' in order to achieve market innovation.

2.2 Definition and Description of Automatic Speech Recognition

ASR is the process by which a computer maps an *acoustic speech signal* to *text* and has gained a significant amount of commercial success due to its demonstrable increase in productivity by greatly assisting human operators or replacing the human element altogether. A speech interface, in a user's own language, is ideal because it is the most natural, flexible, efficient, and economical form of human communication. Several major areas of commercial application of ASR are dictation, personal computer interfaces, automated telephone services, and special purpose industrial applications.

2.2.1 The Role of ARPA in Development of ASR Technology

Speech recognition began in the 1960s when computer scientists at five prestigious groups (at Carnegie Mellon University, MIT Lincoln Labs, Stanford Research Institute, Bolt Beranek & Newman and Systems Development Corporation) began to research the field after receiving finance from the US Defense Department's Advanced Research Projects Agency (ARPA), which also created the original Internet. When the programme started 'the majority of informed technical opinion put general speech recognition by computers as not possible in the foreseeable future and perhaps not possible at all'. The conclusion of after five years of research were that 'cost effective speech input ot computers is an attainable goal' (Anon, 1978). Consequently in this case, US government's pursuit of a critical new mission provided the necessary initial impetus to expand this technology.

ARPA through its Spoken Language Technology programme has concentrated on two domains, continuous ASR (based on *Wall Street Journal* text) and the Air Travel Information Service (ATIS) task. This program features also an annual competitive evaluation of systems on a common test corpus, which has proven to be highly useful in prompting rapid improvements in algorithms, attracting international participation as well.

2.2.2 Industrial Research Outside ARPA

As Rudnicky *et al.* (1994) report industrial research outside of the ARPA community has concentrated on different problems. For example Lucent Technologies Bell Labs continue to work on telephony bandwidth recognition, while IBM continues to do work on large vocabulary systems.

Despite the optimism of researchers and prototypes built in the 1980s, commercial applications remained elusive. It was not until the early 1990s that companies ranging from giants like IBM to start-ups like Dragon Systems began offering the first commercial systems. These systems, designed for personal computers, initially recognized only individual words and forced users to speak slowly and unnaturally. The commercial turning point came up in 1992, when AT&T introduced a five-term speech recognition technology into its nationwide long-distance network.

ASR makes substantial strides so it drops in price every year. But this is not the whole story. If system's dialogue ambiguities confuse the users - or if the system does not recover gracefully from errors - the whole application can be a failure even if the recognition is satisfactory.

2.3 Definition and Description of Natural Language Processing

Natural Language Processing (also called language technology, linguistic engineering, computational linguistics etc.) aims to study and develop methods by which *natural*[1] languages such as English or Greek can be processed effectively by computers. In other

[1] Computers can deal with formal (structured) entities, so a computational treatment of language must be about constructing and manipulating formal entities. Consequently, the relation is computational $\subseteq$ formal $\subseteq$ natural. (Source: Ramsay, 1998).

words the field of language processing is about constructing and manipulating formal entities, which embody the 'meaning' of what has been said. NLP is a discipline between linguistics and computer science which is concerned with the computational aspects of the human language faculty. It belongs to the cognitive sciences and overlaps with the field of AI. Natural language capabilities allow users to speak in a conversational pattern, using whole sentences and a normal cadence.

A growing number of groups are discovering the potential of large scale linguistic resources such as computer readable dictionaries, tagged recorded speech and bilingual texts. The existence of these resources has allowed the development of NLP system components such as part-of-speech taggers and machine tractable lexicons. Internationally supported projects have recently appeared with the specific objective of creating and disseminating standards for the representation of linguistic formalisms and data.

Developers of this technology bring sophisticated knowledge to deal with complex cognitive tasks such as extracting information from discourse and dynamically updating their knowledge states on the basis of heavily context-dependent utterances. Example key areas include information retrieval, machine assisted translation, grammatical and stylistic analysis, natural language interfaces for databases, automatic localisation of software and its documentation, and so on. As multi-technology products embed multi-knowledge, the development of those systems requires a great effort. A number of skills such as programming, user interface design and integration with the audio hardware are essential. The special attraction of computational linguistics lies in the combination of methods and strategies from the humanities, natural sciences, and engineering. The problem of dialogue modeling still remains a very difficult area of research. Current applications simulate a natural dialogue largely by careful expert programming of explicit grammars and dialogue flow. This helps reducing the search space and resolve the acoustic ambiguity.

The design of task-independent systems is the major challenge of time being. We have to see whether it is possible to extend these systems introducing flexible dialogs or more automated methods. Also, as a general problem, the actual use of prosody[2] in spoken language understanding is an open issue.

2.4 Applications of ASR and NLP Technologies

The first real-life speech recognition systems, in the early 1980's, had small vocabularies, required speaker training, and demanded unnatural pauses between words. Those systems were based on pattern matching using dynamic programming techniques. Several improvements were made possible among each of the 3 axes (from isolated to continuous

[2] Prosody covers acoustic phenomena of speech like intonation, indicators for phrase boundaries, and accentuation. This information can support the intelligibility of speech or even sometimes resolves ambiguities of the meaning.

speech, from speaker-dependent to speaker-independent and on the increase in the size of the vocabulary), with a similar approach. But the use of statistical models, such as Hidden Markov Models (HMMs) allowed for a large improvement on the 3 axes simultaneously, while also increasing the robustness of systems. New techniques allowed better recognition either in noisy conditions or using different microphones. Those progresses result now in the availability of systems which can be used on specific tasks in several domains. The general metaphor used is shown in the following figure, illustrating the relation between ASR and NLP.

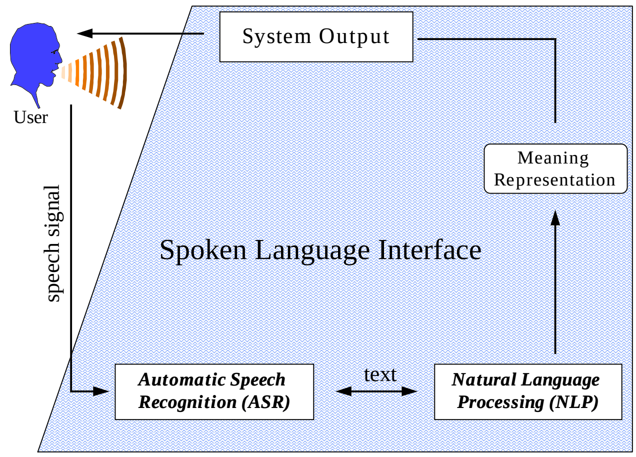


Figure 2-1 ASR and NLP as Major Components of a typical Conversational System.

Understanding of these techniques is far from complete, and progress will require sustained interdisciplinary research, drawing on computer science and AI, electronics engineering, linguistics and cognitive psychology. Nevertheless, rule-based, statistical and connectionist methodologies have all contributed to the development of viable techniques over the last decade. As a result, a wide range of computational applications now incorporate language technology. The following diagram illustrates the progress in this field during the last twenty years.

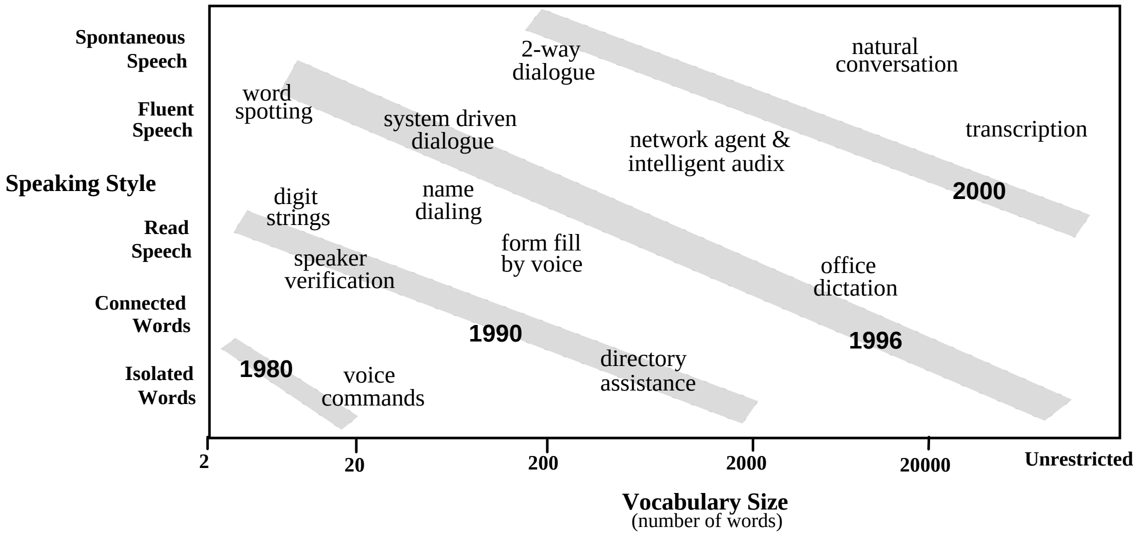


Figure 2-2 Progess in ASR and NLP Technologies. Source: Nikil Jayant, Plenary Session, ICASSP 98

Communication systems using speech technologies can be classified (Kamm *et al.,* 1997) in *Human-computer communication* and *computer-mediated human-human communication* applications. Many of the first category applications are already available. These include personal calendars and files, stock market quotes, business inventory information, product catalogues, weather reports, restaurant information, movie schedules and reviews, and train or airline schedules. Applications in the second category are based on functionality for accessing and using the network to communicate with other humans. These include spoken language interfaces for voice calling, for retrieving and sending e-mail and voice mail, for paging and faxing, and for translating what a user says in one language into a language that the other user understands. In addition to supporting remote access that is both hands and eyes-free, language interfaces for these applications can also provide functionality that is difficult or impossible to provide with touch-tone inputs or other modalities.

We can also classify these systems in *computer applications* and *embedded systems*. The following list refers to some key applications being deployed, piloted or developed by companies either well-known or recently established and research centres as well.

Computer Applications

- dictation
- education (e.g. language training)
- government
- insurance, banking, finance, accounting
- personal telephony (e.g. telecommunication assistant, data access)
- games

Embedded Systems

- voice dialing cellular or home phones
- voice controlled answering machines
- personal assistants, organisers
- control and home entertainment
- translation and foreign language issues
- toys and learning aids

2.5 ASR and NLP as Key and Interdependent Technologies

ASR and NLP in mimicking the most basic means of human communication are fundamental technologies. And when a fundamental technology reaches price and performance levels that encourage practical products, new entrepreneurial opportunities are created. Key technologies are defined by OECD (1989) as follows:

While a key technology may sometimes be a high technology, it is likely that it will more often be a best practice, established technology that is a yet only partly diffused throughout the industry in question.

As the world of speech recognition becomes accessible and affordable, more and more businesses are turning to these technologies and their applications. Indeed ASR and NLP seem to be able to play a part in the *getting ahead* notion of Hamel & Prahalad (1994) instead of catching up, by fundamentally reinvent existing competitive space or invent entirely new competitive space in ways that amaze customers and dismay competitors. The range of industries that use speech recognition is growing everyday. These include software systems development, network integrators, communication carriers, retail, banking, finance, real estate, legal, marketing, advertising, entertainment, government, military, medical and many others. Decision-makers responsible for assessing new technologies in vertical and other key players in the speech industry have already shown interest for ASR and NLP.

The diversified interest in speech technologies can be seen by examining the origin of people participating in major international conferences and exhibitions. In the following figure, coming from the web site of an international trade show organiser, we can see the origin of the participants and outline the direct signal of corporate intentions.

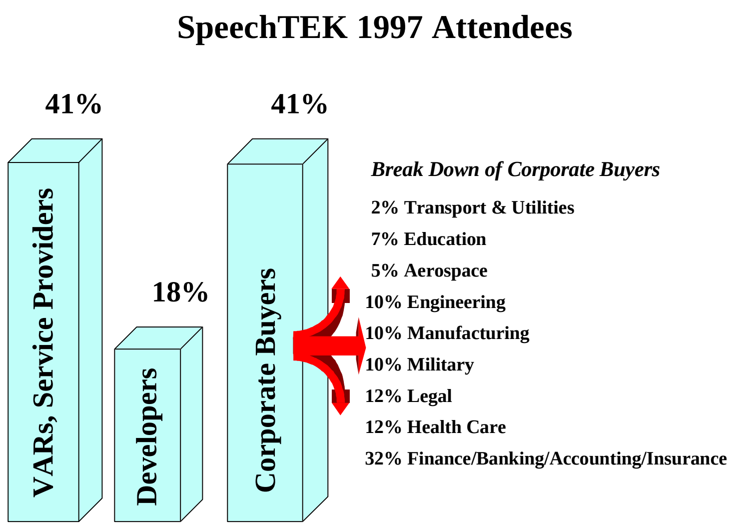


Figure 2-3 Source: http://www.speechtek.com/stfacts.htm

It is very interesting that Value Added Resellers (VARs), Service Providers and Corporate Buyers were represented by 82% of the participants. Apart from the suppliers, the potential customers of these technologies try to find ways of how to take advantage of the progress in ASR and NLP in order to become more competitive in their original markets. Currently, three vertical markets - finance, travel and telecommunications - provide the best opportunity for reseller and vendor sales of voice-based phone systems. Financial sectors seem to be particularly interested in these technologies, because they regarded as a mean to reduce cost and extend the variety of provided services for market differentiation.

While the market demand has started to be outlined, the future of applied ASR and NLP will be determined by the growing need for user-friendly software. Even though the successful simulation of human language competence is not to be expected in the near future, engineers and computational linguists have numerous immediate research goals involving the design, realization and maintenance of systems which could make everyday life easier.

In order to have accurate recognition is not only necessary to recognise sound units (phonemes, syllables, or words) but also to have an optimised language modeling, which means that the fields of ASR and NLP are gradually converging. In the rest of the document for convenience we shall refer to these technologies as *ASR&NLP*.

2.5.1 Speech Processing: Emerging Technologies for Market Innovation

Market innovation includes the identification of market trends and opportunities, the translation of these parameters into specifications of new products and services and the promotion and diffusion of these products and services.

According to TMA Associates, a California based consulting company, the market for speech-recognition software will grow by a factor of ten each year. Great revenues from advanced speech recognition products and services are expected especially in telephony market, according to the same source.

Forecast of ASR Telephony Market

	1996	1997	1998	1999	2000	2001	2002	2003
ASR Sales ($ US million)	235	408	970	2,093	4,899	11,623	21,496	36,822

Table 2-1 Source: The Telephony Voice User Interface, TMA Associates in Speech Technology Magazine

Tidd *et al.* (1997) suggest that in general high rates of market growth are associated with high R&D costs, marketing costs, investment in capacity and high product margins. Using the simple two-by-two matrix model they have proposed, with technological maturity as one dimension and market maturity the other, we can see a shifting of ASR&NLP products from the *technological* to the *complex* quadrant. Products and services in the technological quadrant compete on the basis of performance, rather than price or quality. For this reason early adopters of speech products for dictation were high profit professionals such as surgeons, radiologists, engineers or lawyers. More users can take advantage of newly affordable[3] speech to text software since market and technology started becoming more matured. Complex quadrant seems to be the next stage as specific commercially viable applications are under development across many market sectors such as telecommunications, finance, government, intelligence, security, education, healthcare, etc. and there is no clearly defined use of the new technology. Developers in co-operation with lead users will create the specifications of new products and services in this case.

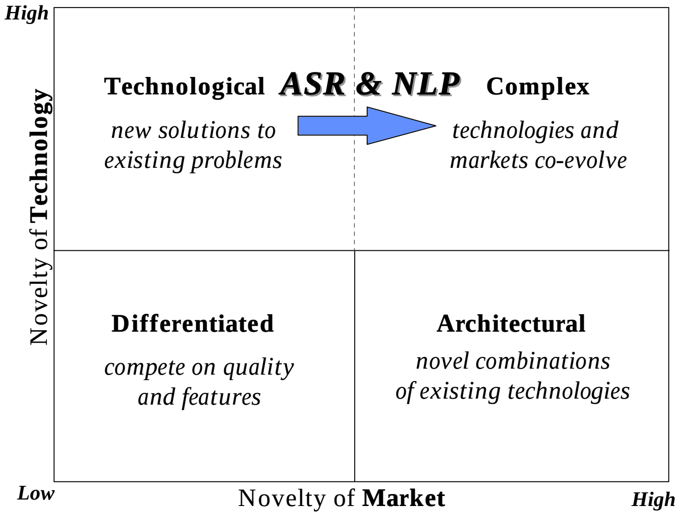


Figure 2-4 Technological and Market Maturity in ASR and NLP

Further details about the reasons that companies invest heavily in this field and their main strategies are described in Chapter 6.

[3] Several companies offer their own desktop dictation products for less than $100. In addition, inexpensive dictation products are proliferating in the market as memory and CPU speeds rise in the average PC.

CHAPTER 3

CONCEPTUAL FRAMEWORK AND FIELDWORK METHODOLOGY

3.1 Introduction

At the initial stage of a high technology industry the borders of research and market arena are constantly changing. New players, competencies or resources appear, evolve and change quickly. Since it is not possible to analyse all driving-forces, in this study the focus has been on identifying key technologies and strategies to gain competitive advantage. The selection of a technology position is based on the strategic direction and the likely future business environment in which the firm will be operating. In the next paragraphs, we briefly review the existing literature in technological positioning, especially for emerging technologies. The research approach in positioning is based on a conceptual framework, which is established later on, in order to answer the three major analytical questions of this study.

3.2 Theoretical Background in Technological Positioning

During the last decades the concepts position and positioning have emerged as an important field of research. In the literature of technology and corporate strategy, firm depends critically on the technological and related skills to achieve its objectives, mainly:

- to sustain and develop the existing businesses
- to identify and exploit new business opportunities
- to cope with major and unexpected opportunities and threats

Since speech based technologies are passing from the invention phase (conceiving the idea) to the innovation phase (successful exploitation of the idea) investment in these areas can produce two types of benefits for the firm (Pavitt, 1998a):

- extra profits from:
  - increased sales and / or higher prices for superior products
  - lower costs and / or increased sales from superior production processes
- accumulated firm specific knowledge, that may be useful for the development of future innovation

Porter (1980) introduced a partly new positioning concept that focused more on the selection of specific strategies rather than the structure.

The goal of competitive strategy ... is to find a position in an industry where company can best defend itself against these competitive forces or can favour them in its favour.

Positioning still remained a controlled, conscious process where the strategies were to be made explicit before being formally implemented and the process focused on tangible strategic positions.

Apart from Porter and his followers, a more relationship-oriented approach on positioning was developed for competitive strategy. This relationship-oriented approach, often called the *network approach*, used qualitative case-studies of buyer-seller relationships instead of quantitative, cross-sectional data. Within this network approach the concept position is used as a measure of the network-structure. The relationships define the position of each player in the network.

Mitchell & Hamilton (1988) suggested that return on investment (ROI) often fails to deal explicitly with the implications of *not* pursuing a corporate research program. They have proposed an overall framework for R&D after realising that (p. 15):

The research director is often aware that failure to position the corporation in key technical areas may have the effect of foreclosing numerous downstream options which could turn out to be very important to the corporation in the future.

In their framework, which is shown in figure 3-1, there are three overlapping categories of R&D that large firms must finance with different objectives and criteria of selection. The important point is to recognise that expenditures are not so much directed towards an investment as they are towards the creation of an *option*. This *strategic position* for R&D programs is located close to neither axis.

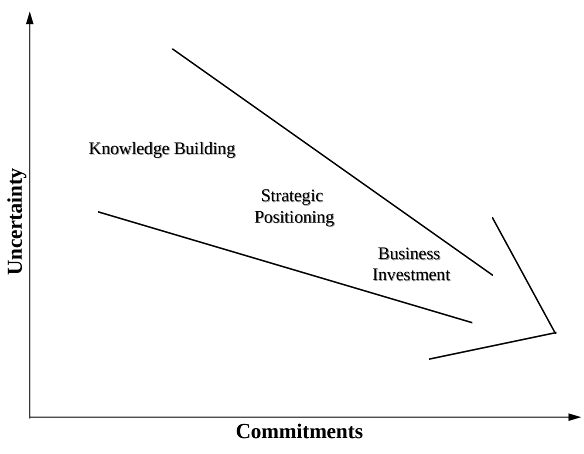


Figure 3-1 R&D as a Strategic Option

Among the broad range of skills needed to strategically manage technology effectively, Dodgson (1990, p. 6) emphasises into *technology assessment*:

Firms should be aware of their technical strengths and those of their competitors. They need to understand how future technological developments may affect their competitive position. This may involve dealing with universities and public research laboratories on the one hand, and keeping a very close watch on competitors (What are they patenting? Who are they recruiting?) on the other.

Since early 1990s, there has been a shift in management fashion from short-term operational efficiency and flexibility to longer term capacities for change and survival. The most influential analysts have been Hamel & Prahalad (1990, 1994) by spreading the notion of firm-specific *core competencies*. Core competencies[1] focus on the contribution of technological related skills to management that empower business quickly to changing opportunities. However, to some extent we find this approach less suitable for the analysis of ASR&NLP technologies because of a major limitation (Pavitt, 1998a). This limitation has to do with the fact that large firms do not concentrate only on fields with core or *distinctive competencies* but they also have:

- *background competencies:* in order to co-ordinate technical change
- *emerging competencies* in a growing range of fields in order to remain competitive as products become more multi-technological.

Teece & Pisano (1994) have also proposed a framework for understanding and evaluating the role of technology in corporate strategy. They also introduced the *dynamic capabilities* of firms, which give central importance to the accumulation and exploitation of firm specific capabilities, stressed on three dimensions (*positions*, *paths*, and *processes*) which for science based technologies are achieved as follows:

- *positions:* develop tech-related products
- *paths:* exploit basic science
- *processes:* obtain complementary asset and redefine divisional boundaries

Granstrand *et al.* (1997) introduced the importance of *distributed competencies*, by showing that large firms have significant competencies outside their intuitively obvious distinctive capabilities. This approach is different from what Hamel & Prahalad (1994) had proposed about the importance of *core competencies*, as shown from the following quotation (p. 22):

The challenge for the management is to give more attention to the distribution of corporate technological competencies beyond the core, the enhancement and integration of new competencies, and the potential for related product market.

[1] A practical example of what competence is, can be found in Miyazaki (1993), pp. 18-19.

In the next section we summarise the main analytical approaches which we have chosen as applicable to our research.

3.3 Outline of Conceptual Framework

It is necessary to have a comprehensive framework for understanding the myriad ways in which technology affects both strategy and the day-to-day functioning of the business. The literature reviewed above consists of several points of analysis to evaluate the technological position of companies' strategy under the light both their own and competitors intentions, and competencies and the characteristics of innovations.

We use the approach of Mitchell & Hamilton (1988) to explain the level of adoption of these new technologies from firms. According to them reducing technical uncertainties and building a strong technical background can turn technical strength into a profitable investment. We also apply the framework of Teece & Pisano (1994) to analyse the data from scientific publications. This is directly applicable to ASR&NLP because first they are science-based technologies and secondly the main sources of innovation are R&D and basic research. The basis of analysis of the patent data collected for this thesis comes from the article of Granstrand *et al.* (1997), which is shown in fugure 3-2. The results are used to classify firms capabilities in *distinctive*, *background*, *marginal*, or *niche* categories, each one with its own different perspectives and implementations. Our framework is outlined by the following diagram:

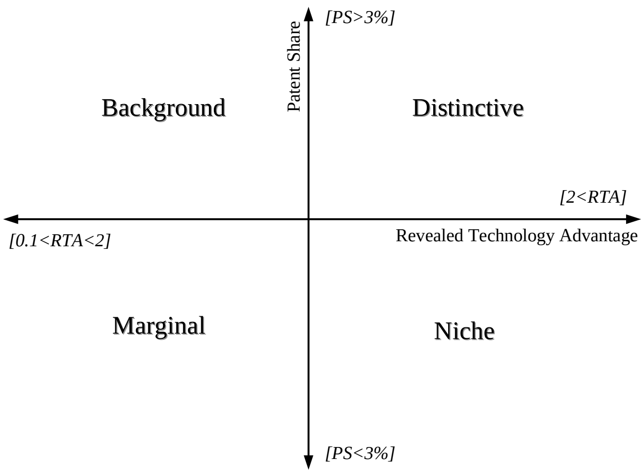


Figure 3-2 Classification Based on Distributed Competencies

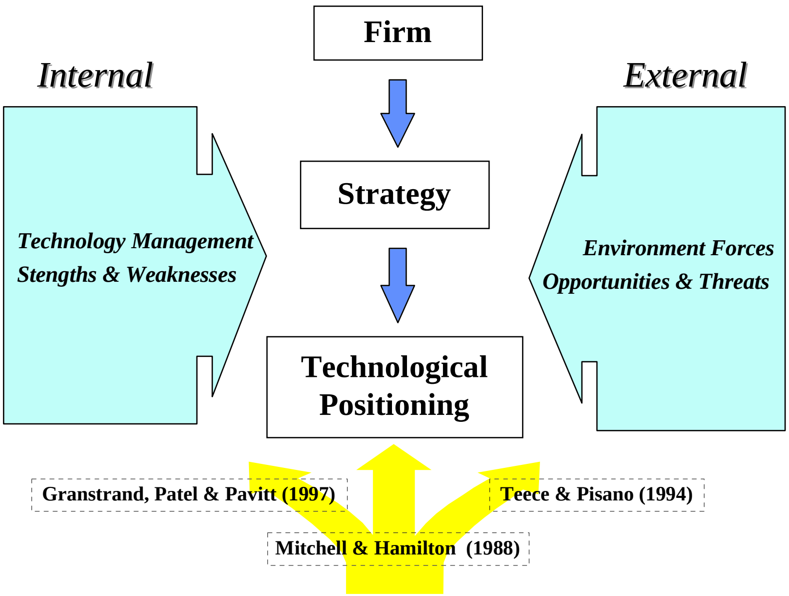


Figure 3-3 Outline of the Conceptual Framework for Technological Positioning in ASR&NLP.

3.4 Research Analytical Questions

Taking into consideration the fact that firms are on the whole becoming more technologically diversified over the time as opportunities emerge from general advances in science and technology (Granstrand *et al.*, 1997), using implications from the previously established conceptual framework it is possible to answer specific questions related to positioning ASR&NLP technologies. Our study is focused on three overall research questions (with respect to a new industry) for ASR&NLP that will occupy us in the next phase of this study.

1. Long process of evolution or revolution in research advances and market adoption. Effectiveness of the collaboration between scientists from different disciplines with respect of multi-technology dimension of ASR&NLP.

2. To what extent are language constraints barriers to entry for Asian countries with tradition in IT (e.g. Japan) and what is the situation in Europe.

3. Identification of key players. Core or background competencies building. Adopting new technologies and accessing the market. Key areas of future research.

In the process of this analysis several new aspects will come out, which we are to explain. Apart from the technological dimension there would be particularly interest in some socio-economic issues about the users' response in adopting products/services based on spoken language interfaces. These are addressed in the last chapter for future research.

3.5 Fieldwork Methodology

In this section, we describe the methodology of collecting data in order to measure technological activity within firms by analysing two types of output data of the learning process, namely US patent data and scientific publications data. These data may overlap since industrial researchers patent more and publish less than academics (Rappa & Debackere, 1992), but may reveal different patterns, depending on where the firm strength lies either in research or development. These data are to be complemented by the responses of the firms' researchers and R&D managers. We discuss the strengths and weaknesses of the methodology employed.

In our analysis we use the following symbols in order to refer to the source of the data we use.

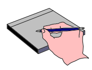
Source of Data	**Symbol**
US Patent Office	
Scientific Publications	
Internet Survey	

Table 3-1 Symbols indicating the Sources of Data used in our Analysis

3.5.1 Data from Patents

During the last decades, in the literature of industrial innovation, patents are frequently used as measure of technological change and evaluation of the major players. Freeman (1982, p. 54*)* comments that:

Patents are a measure of inventive output rather than innovative success, and therefore should be used together with some measure of innovation. But provided their limitations are kept in mind, they are probably more useful than is commonly believed in industry.

A problem with patenting data arises immediately, because until recently patents did not cover software inventions, and firms sometimes used other methods (Tang, 1997) to protect their technological lead. Very often advances are not patentable while is extremely difficult to define what constitutes novelty during the patent evaluation procedure. But, in addition to other science and technology indicators patents provide a uniquely source of information because they are legal documents. More details about the advantages and disadvantages of studying patenting data for industrial innovation can be found in OECD Patent Manual (1993).

3.5.1.1 Sources and Criteria of Collecting Patenting Data

The requirement of novelty for the granting patents means that they are an indicator particularly appropriate for large firms. The data were collected using the Patent Bibliographic Database[2], which is freely searchable and contains all US patents issued from 1/1/1976 onwards. Especially for the ASR we have counted separately the patents prior and after 1988, since HMMs and ANNs[3] were established as leading technologies after this year.

Illustration 3-1
Patent Data Collection Method

The classification of patents may be a source of problems[4] especially in a fast-evolving and multi-technology field, so the procedure to find out which companies patent in ASR&NLP started by making the following set of queries on the Patent Advanced Search Page of US Patent Office:

- abst/"speech recognition" OR "voice recognition"
- abst/"language processing" OR "language understanding" ANDNOT ("speech recognition" OR "voice recognition")

By this technique we managed to find all assignees even if they have granted only one patent. Please refer to Appendix A for the full list of results.

In order to count the total number of patents of each firm the query is:

- ISD/1/1/76->12/31/97 AND AN/"Company Name"

Although every attempt to solve incompatibilities with assignees' names has been made, might be some slight differences in the total number of patents of each company.

3.5.2 Data from Corporate and Academic Scientific Publications

Academia often helps companies with specific technical problems and they also provide knowledge of scientific research future technologies may emerge from. This collaboration can be highlighted by a cross examination of the patenting and publication activities. Patents granted to researchers and/or scientific papers published by corporate

[2] Provided by the US Patent and trademark Office on the WWW. [http://patents.uspto.gov/]

[3] The ANNs appeared in Applied Science and Technology Index for the first time in 1987 (Howard, 1987) while in the theory and applications of HMMs in ASR are described in Rabiner's (1989) classic paper.

[4] Most of the patents in ASR&NLP were included in the **CLASS 704** (*Data Processing: Speech Signal Processing, Linguistics, language Translation and Audio Compression/Decompression*) but patents can also found in **CLASS 381**, (*Electrical Audio Signal Processing Systems and Devices*), **CLASS 340** (*Communications: Electrical*) **CLASS 455** (*Telecommunications*), **CLASS 379** (*Telephonic Communications*) **CLASS 707** (*Data Processing: Database and File Management, Data Structures, or Document Processing*) **CLASS 364** (*Electrical Computers and Data Processing Systems*) **CLASS 706** (*Data Processing: Artificial Intelligence*) etc.

practitioners are often the outcome of joint research by a firm and a university laboratory. Corporate research results are often released in conference presentations and journals[5], becoming a part of permanent public knowledge. Hicks (1995) argues that is often difficult to make a distinction between science and technology. Therefore, academic and industrial researchers construct the distinction between public and private knowledge in such a way to provide themselves with maximum advantage (pp. 401-402).

Firms are able to publish precisely because they can choose which information to make public. ... Firms want to participate in barter exchange networks to further aim their of accessing technical opportunities produced in the science base.

Nelson (1959, p. 96) had given a less market oriented explanation for the same phenomenon:

Often new knowledge is of greatest value as a key input of other research projects which, in turn, may yield results of practical and patentable value. For this reason scientists have long argued for free communication of research results...

Some other explanations why the companies publish can be found at Rosenberg's (1990) work about the investment of firms in long term research. These are the following:

- to improve image in the academic and scientific community
- to help in recruiting high grade technical people

Both two aspects of firms strategy are important. Unless the researchers with the requisite skills are in place, the technology will never successfully be generated or acquired externally. Especially for software, where the important knowledge is tacit, it is very common to present long-term research results without giving critical information or the algorithmic implementations. In this case publications are of little importance to competitors apart from offering clues about research directions and the opportunity to search and estimate tacit knowledge output. However, firms' policy to publish selectively has been used in this dissertation in order to evaluate the level of activity in this field, as well as the level of collaboration with other research centres or universities.

In case of ASR&NLP there are many journals where research achievements can be published worldwide. University and industry speech specialists, linguists, computational linguists, AI investigators, cognitive scientists, and philosophers can get information about computational aspects of research on speech, linguistics, and the psychology of language processing and performance.

[5] Conference talks serve are given soon after the research is completed, in contrast to journal publications. The advantages of journal articles lie partly in quality, since they are refereed more strictly (Source Hicks, 1995)

3.5.2.1 Collecting Scientific Publications Data: Sources and Criteria

Only a few of those journals can claim to be devoted exclusively to the design and analysis of ASR&NLP systems. In order to identify the most important references for science progress in these fields two experts[6] have been conducted. Taking into consideration their opinions the focus was based on the following:

For ASR:

- **IEEE Transactions on Speech and Audio Processing**
- **Speech Communication**[7]
- **Journal of the Acoustical Society of America** (JASA)

For NLP:

- **Computational Linguistics**
- **Communications of the ACM**
- **Journal of Artificial Intelligence Research** (JAIR)[8]

But in order to maintain presence and facilitate co-operation, particularly between companies and researchers, conferences are held to bring together software developers, representatives of government agencies and researchers to exchange views on speech technologies and to discuss ways of collaborating in future. The most important of these are:

- **ICASSP** IEEE International Conference on Acoustics, Speech and Signal Processing
- **Eurospeech** European Conference on Speech Communication and Technology
- **ICSLP** International Conference on Speech and Language Processing

The ICASSP is held annually whereas the other two conferences are held bi-annually. In fact, some groups and the majority of corporate researchers publish only in ICASSP.

Illustration 3-2
Publications Data Collection Method

The data were collected using the BIDS ISI Service, which provides access to three multi-disciplinary citation indexes and an index of conference proceedings. The data are supplied and owned by the Institute for Scientific Information Inc.

In our research, in order to find authors' corporate affiliation or address, the Science Citation Index (SCI) was used by making the following queries:

- speech & recognition , voice & recognition (in the title or abstract)
- language & processing , language & understanding (in the title or abstract)

Whenever two or more authors either had a joint paper or they were from different companies / universities the publication entry was “shared” among all authors.

---

[6] Dr. Phil Green, Head of Speech and Hearing Research, Department of Computer Science, University of Sheffield.

Dr. John Carroll, School of Cognitive and Computing Sciences (COGS), University of Sussex.

[7] Instead of BIDS, data have been collected from the site of ELSEVIER’s Speech Communication Online, for the period 1994-97 [http://www.elsevier.nl/locate/specom]

[8] Instead of BIDS, data have been collected from the site of Journal of Artificial Intelligence Research for the period 1993-97 [http://www.jair.org/].

Please notice that:

! Collaborative papers within the same organisation are not counted separately.

! For multinationals only one country or state is mentioned.

! For the Conference Proceedings search only in titles is available, and first authors only mentioned. This limitation of search engine may restrict the number of results.

! Data for years 1984, 1985, 1989, 1995 are not available by BIDS.

3.5.3 Data from the World Wide Internet Based Survey

In order to complete and validate the analysis of patenting and publications data, we designed a Speech Technologies Survey for corporate practitioners (Appendix C).

3.5.3.1 Description of the Survey

Instead of sending the questionnaire by mail (which is not always affordable and environmentally friendly), the survey was put on the WWW and we only had to inform the industry experts by sending an introductory note about the scope of research and the confidentiality issues. The WWW address was also mentioned, so that the survey could be accessed via internet browsers. This allowed respondents to fill the questionnaire, click ‘submit’, and have the info delivered to us by email. The most advantageous characteristic of a survey on the WWW is the easy processing responses because these are stored hierarchically and the CGI[9] mechanism we used was sending only the filled questions / answers.

A motive to participate was given by offering access to the results of the research to all participants. All major companies were informed about the survey via email, while several contacts were also made directly by the author during conferences and other scientific meetings[10] in order to increase the number of responses. Over a three months time the survey repeatedly announced in the most related electronic newsgroups[11]. This type of data collection reflects the opinions of only those Internet users who have chosen to participate. Although the results cannot be assumed to represent the opinions of speech industry as a whole they tend to offer very interesting indications which accoomplish the previous findings.

[9] Common Gateway Interface, standard for interfacing external applications with information servers, such as HTTP or WWW servers.

[10] ICASSP 98, Seattle, USA and ELSNET Summer School in Language and Speech, Barcelona Spain.

[11] These newsgroups are: **comp.speech** and **comp.dsp** (Speech & Digital Signal Processing), **comp.ai.nat-lang** and **sci.lang** (Artificial Intellingence / Natural Language).

3.5.3.2 Survey Participants

There were 56 participants in the survey. The distribution of their position is shown on the next figure. The high percentage of researchers and developers should not be assumed as a drawback for strategic planning analysis. As Hamel & Prahalad (1994) suggest 'In our work and research we have found the ferment of intellectual revolution more often in the middle of organisations than at the top'. Nonaka & Takeuchi (1995) also point out that middle managers are the knowledge engineers of the *knowledge-creating* company, converting tacit images and perspectives into explicit concepts.

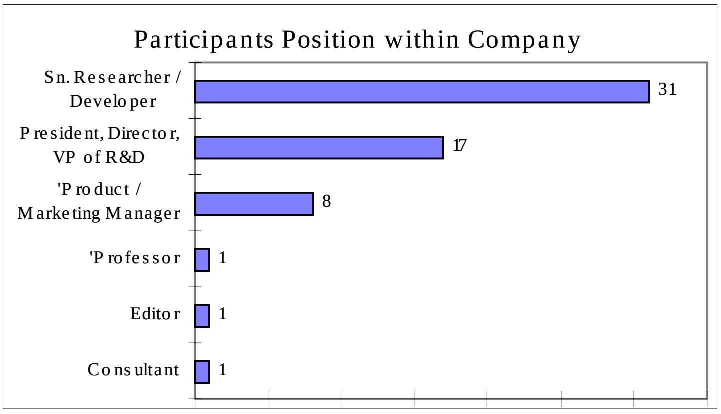


Figure 3-4 Participants Positions

We must also notice that three of the participants did not answer any of the questions. They just gave their own and their companys' names. Two of them though sent brochures about their firms activities by mail. Although the objective of the survey was to approach people from the industry, one independent consultant, one magazine editor and one professor, all related to the ASR&NLP participated and gave their opinions, after having found the survey announcement in a newsgroup. Several people also replied after author's introductory note and explained because of either time or confidentiality constraints they were unable to fill out the questionnaire. Nevertheless, they would be interested to see the results. Finally, two companies were represented by two participants each. Consequently, **our data fully reflect the activities of 51 different companies in ASR&NLP**.

The question about area of products or/and services was answered by 51 respondents gives further information about the activities of companies in the sample. A wide spectrum of answers, was given which is summarised in the figure 3-6.

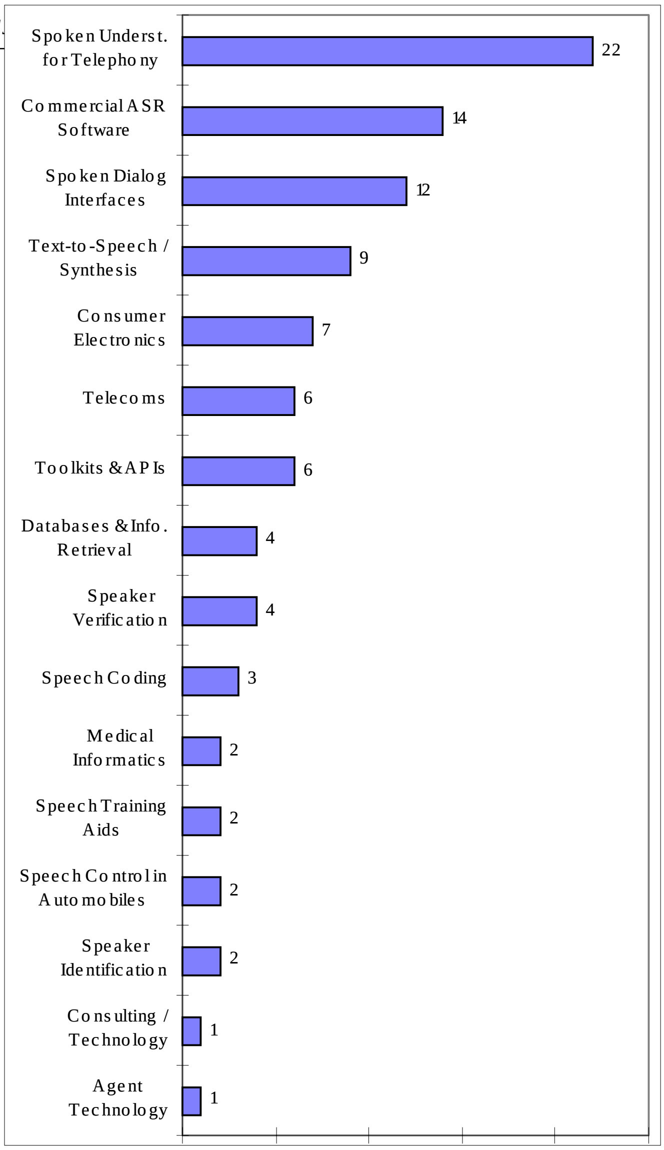


Figure 3-5 Major Areas of Products and Services

In the last two questions we had also asked whether the participants would like to receive a copy of the results via email, and everybody answered 'yes'. Finally, some of the participants in the last question about any further comments, apart from reminding confidentiality issues gave some useful points. One of them had to do with the limitation of the survey, by saying: 'greatly depends on the environment who fills it out: academic, small or large company' and some others about the 'boundaries of European countries markets'. Another participant suggested that apart from those categories of professionals mentioned in one of the questions, they also hired a ‘general AI person’ for computational linguistics analysis.

3.6 Similar Research Approaches

Various types of output indicators such as patent, bibliometric, technometric (technology specification measures) have been used to measure innovation trends as well as strengths in a firm, selected technological field or country level (Soete & Wyatt, 1983), Pavitt (1984), Narin & Davidson (1988), Schmoch & Grupp (1989), Miyazaki (1993) and Granstrand *et al.* (1997). Also Mahdi (1996) using information compiled from the internet and publications data showed that the emergence of firms based on new science depends heavily on the strength of universities and public research institutes in the underlying sciences. A specific work for evaluation of academic research and collaboration with industry has been done by Hicks & Katz (1997).

In the field of speech technologies there have been some attempts mainly by consultants to forecast and analyse the market. These include *Automatic Speech Recognition: A Study* *of the World-Wide Market*, first published in 1991 (revised in 1995) with an overview of technology, products, markets, and research efforts in the speech recognition market by Voice Information Associates. In the same field can be found *The Telephony Voice User Interface, Speech Recognition, Text-to-Speech, and Speaker Verification Over the Telephone* by TMA Associates. Finally, the *Report on Voice and Speech Processing* by Wohl Associates is in progress, examining various aspects of the speech marketplace, interviewing vendors and users, and forming opinions as to the status of the market and its future directions. It is worth to mention that the author did not have access to these reports (as many others I suspect), since single copies cost from $1250 to $3450.

CHAPTER 4

EVOLUTION OR REVOLUTION IN RESEARCH AND MARKET

4.1 Introduction

The interdependent nature of ASR&NLP lead us to understand the importance of examining the evolution of a cluster of technologies during competence building. In this chapter we use statistic results from our data in order to answer the first analytical question and examine the factors of growth in ASR&NLP. As technical expertise is a commutative process, we will examine how knowledge is accumulated over time. In order to understand the evolution of the speech industry it is important to analyse both the internal and external context. Internal and external driving-forces are therefore important parts for the analysis in new industries, where these driving-forces are changing quickly.

4.2 Internal Driving Forces

The internal driving-forces deal with the action and learning of the organisation, not on the individual level. We are aware of the fact that people in an organisation seldom share the same values and meanings. The dimensions of the internal driving-forces focus on the informal organisation structure and on the evolution of the organisational competence in order to adapt the rapidly changing environment. The collaboration between researchers from different disciplines (mathematicians, linguists and engineers) was not very effective in the case of ASR&NLP, although there have been some research milestones over the last forty years.

The adoption of HMMs and ANNs perhaps gave the most important impetus in these technologies. Especially for the HMMs, which is currently the most successful technique in pattern-matching for large vocabulary, speaker independent and continuous speech recognisers, widespread understanding and application of their theory occurred after some decades after their initial investigation[1]. There are several reasons why this fact happened.

[1] Neither the theory of HMMs not their applications to ASR are new. Markov defined the basic structure in 1913 to describe the stochastic process. The basic theory was published in a series of classic papers by L. E. Baum and his colleagues in the late 1960s and early 1970s and was implemented by J.K. Baker at Carnegie Mellon University (CMU) and F. Jeniken and his

First, the basic theory of HMMs was published in mathematical journals, which were not generally read by engineers. The second reason was that the original applications of the theory of speech processing did not provide sufficient tutorial material for the most readers to understand the theory and to be able to apply it to their own research (Rabiner, 1989).

Internal driving forces are very related to the origin of the department or the whole company if it is a start-up. This question was answered by 42 participants and the results are summarised in the next figure. It is clear that apart from the corporate decision to be involved in that area of research, which is explained in Chapter 6, 14% of the companies began their lives as university spin-offs and 20% began as specialised in ASR&NLP firms.

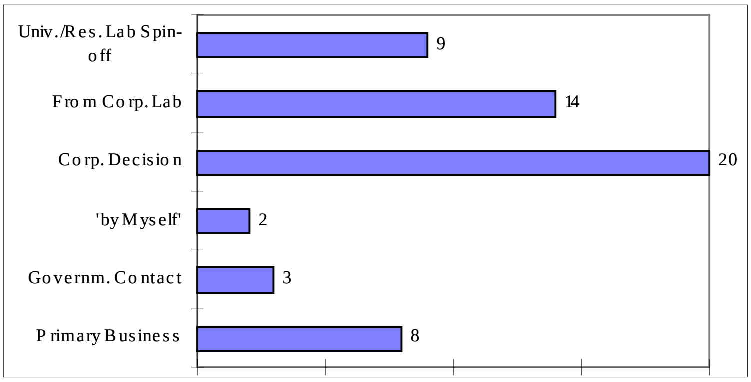


Figure 4-1 Origin of Speech Technologies Dept.

The allocation of resources from a company is reflected on the size of the R&D group. The responses of 47 survey participants are summarised into the figure 4-2 and show that many companies have hired large number of scientists to implement full scale product development. Although 40% of the responses indicate very small companies or exploratory activity by large companies speech departments with over ten researchers allow them to develop real life applications.

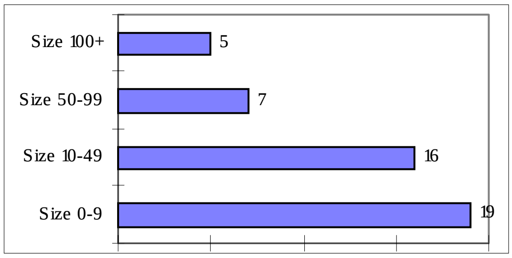


Figure 4-2 Size of Speech Tech. Dept.

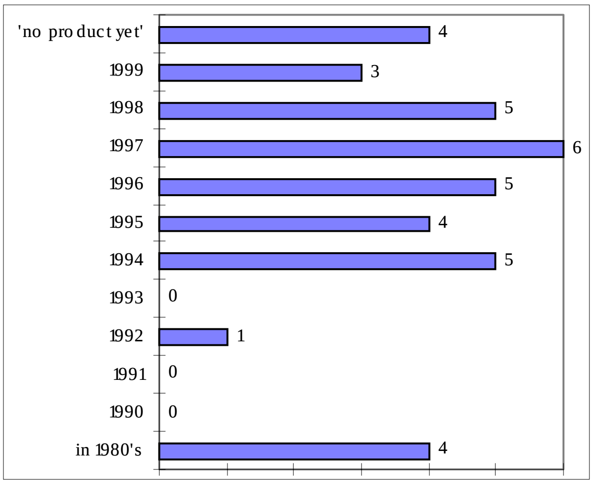


Figure 4-3 Year of First Product into Market

Interestingly our survey showed (figure 4-3) that 67% of 35 companies managed to have their first complete product to market during the last five years (1994-98), while 18% of them are currently conducting research without having any product yet. The fact that most of the answers referred to the last

colleagues at IBM in the 1970s. After several years of research the very first English speech dictation product Sphinx was developed at CMU. Now several of the members of that research group and the developer of Sphinx have move to Microsoft.

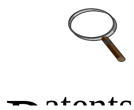
five years is logical, as we have to do with an emerging area of technology. Several respondents said that they expect a product to be ready in the near future, while others could not even estimate when their effort will be ready to reach the market.

In the question about how many qualified scientists and engineers were employed, 37 respondented (table 4-1) and most of them said that they basically hire computer scientists and sometimes none of the two other disciplines. A speech technologies department or a small specialised firms hosts the following number of scientists.

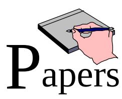
Computer Engineers	27
Linguistics Scientists	6
Psychologists / Cognitive Scientists	2

Table 4-1 Distribution of Researchers within Speech Tech. Departments

Only one company had more linguistics scientists than computer engineers, while in another company psychologists were more than linguists.



Our data in patenting (Appendix A) and scientific publications (Appendix B) indicate a very weak integration of ASR&NLP technologies in the same organisation[2]. Schwartz[3] claimed that only 70% accuracy can be based on recognisers themselves, the rest comes from language processing. So even if the rate of improvement in recognition technology slow down, much more research must be undertaken in language understanding. In NLP there was also very much diversification in publications. No specific organisations seem to be strong enough in the field. Countries such as Israel seem to have comparatively strong competencies in that field. The explicit focus of companies and universities either on ASR or on NLP clearly indicates weak recognition of how interdependent both technologies are. Consequently, a very interesting question is raised: Can system providers who are not experts in language processing and semantics, integrate this technology or will they lose their market share to speech understanding technology providers? That suggests that companies may have to change the synthesis of their R&D groups, giving more emphasis to language modeling in the next few years.



4.3 External Driving Forces

The external driving-forces reduce the degrees of freedom of the company and are subjective interpretations of the external environment. Changes in the actions of other companies will probably influence both the interpretations of the external environment and the activities in the positioning act.

[2] As exceptions in patenting one could refer to Hitachi and IBM, while AT&T/Lucent have published satisfactorily in NLP too.

All survey participants were acutely aware of their companies' and their competitors' technical strengths. They normally recognised 4-5 different companies each to be their competitors in the same market. That shows that market diversity has already started. From the 46 answers the most highly recognised as competitors and of course 'key players' are[4]: IBM (14), L&H (11), Dragon (10), AT&T/Lucent (8), Philips (8), ALTech (7), Nuance (7), VCS (5), Purespeech (4), Microsoft (3), Sony (3), Apple (2), NEC(2)... and over 15 other firms referred only once in the answers. This set of companies is quite consistent with the data from patents and publications (tables 4-2, 4-4, 6-1) apart from the recently established ALTech and Nuance who take advantage of the parent organisation research (MIT and SRI respectively). Japanese companies are not recognised by survey participants as major competitors in the field.

Indeed, one of the most important external driving forces for the improvement of spoken language interfaces was the reduce in cost of computing power and random access memory (RAM), during the 1990s. The size of an effective vocabulary in an ASR&NLP application is directly related to the RAM capacity of the computer it is installed in. Also processing power is critical, because it affects the speed the computer can search the RAM for pattern matching.

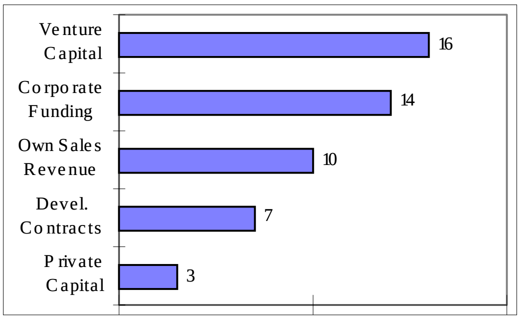


Figure 4-4 Major Sources of Finance

As mentioned above, founders of the small companies employed a variety of means and sources to start them. They commonly began with an individual or small group of people convinced of the potential of a new business based on this particular technologies. The management at this initial stage is mainly concerned with the process of convincing others - primarily financiers - of this business opportunity (Dodgson & Rothwell, 1989). The responses of 40 participants in this question (figure 4-4) show the importance of availability of formal venture capital to transfer into market good ideas or results from academic research. This is consistent with the fact that several small companies in this field have gone public successfully. But venture capital was not the only source of finance in none of the companies.

---

[3] Schwartz R. M. (1998) *Speech Recognition: Are We Having Fun Yet?*, Plenary Session ICASSP '98.

[4] In parentheses the frequency in answers.

4.4 Paths in Technological Progress

There is a distinction between systems based on software and hardware up to the late 1980s. Hardware approaches have been significantly preferred by the Japanese microelectronics giants. As Tannenbaum (1984) mentions, the decision to put certain functions into hardware is based on such factors as cost, speed, reliability and frequency of expected changes. However, software solutions on a relatively cheap hardware infrastructure for ASR&NLP has lead companies to organise their system components from silicon to software in order to secure the largest market share possible.

Neural network technology evolving from neuro-biological insights, has also been used effectively for ASR by giving a computer system an amazing capacity to learn from input data. Artificial neural networks have provided solutions to problems normally requiring human observation and thought processes. Neural networks perform computation in a very different way than conventional computers, where a single central processing unit sequentially dictates every piece of the action. Neural networks are built from a large number of neural cells. The power of neural computation comes from the massive interconnection among the cells which share the load of the overall processing task, and also from the adaptive nature of the parameters. Hybrid systems based on both HMMs and ANNs have been proposed as well, trying to take advantage of the above both technologies.

In the following diagram we show the patenting patterns in both technologies per year[5]. Patenting data are available since 1976, but it took assignees almost two decades to increase from four patents in 1976 to eighty patents in 1997. Patenting in ASR is by far higher than NLP. Patents in NLP mentioned in figure 4-5 are mutually exclusive with those in ASR.

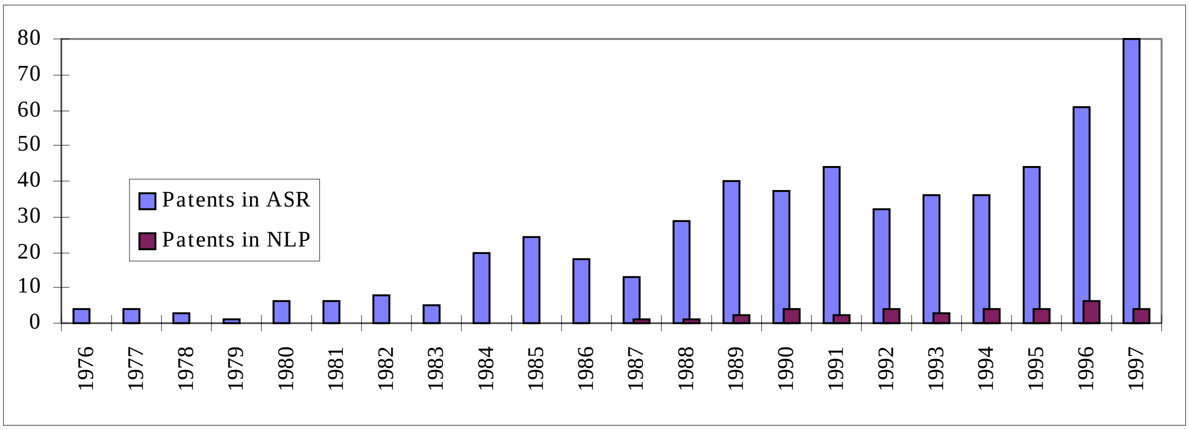


Figure 4-5 Patents in ASR and NLP per year

[5] Patents are not published directly at the date of legal application, but in most countries 18 months after, hence they always lag behind. They are, however, generally applied distinctly before the introduction of respective products into marketplace (Source: OECD, 1993).

Technological entrants into the field have been numerous, with individually owned patents (in fact, mainly very small firms) accounting for 8% of the total patenting. One of the most notable feature of the data is the increasing share of small firms. It has been proved that small firms are more reliant than large ones on national and even regional systems of innovation in which they are embedded. Consequently, in the next chapter we shall perform regional analysis of the data.

It is interesting to see whether companies patent or prefer other methods to protect innovation since firms normally deploy more than one of the protection methods in order to maintain an innovative lead. In this question which was answered by 43 persons the results (figure 4-6) 65% of them said their companies patent, validating our focus on patenting data as an indicator for studying positioning[6].

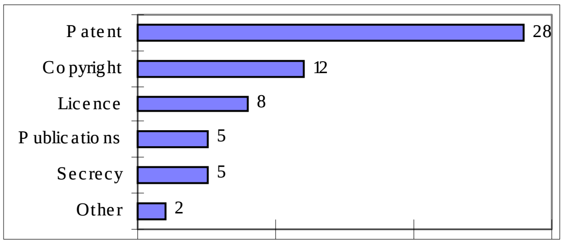
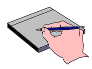


Figure 4-6 Methods of Protecting Innovation

Particularly for the ICASSP annual conference, which is preferred by the corporate researchers to publish their research achievements, figure 4-7 shows the amount of papers in ASR during the period 1982-97.



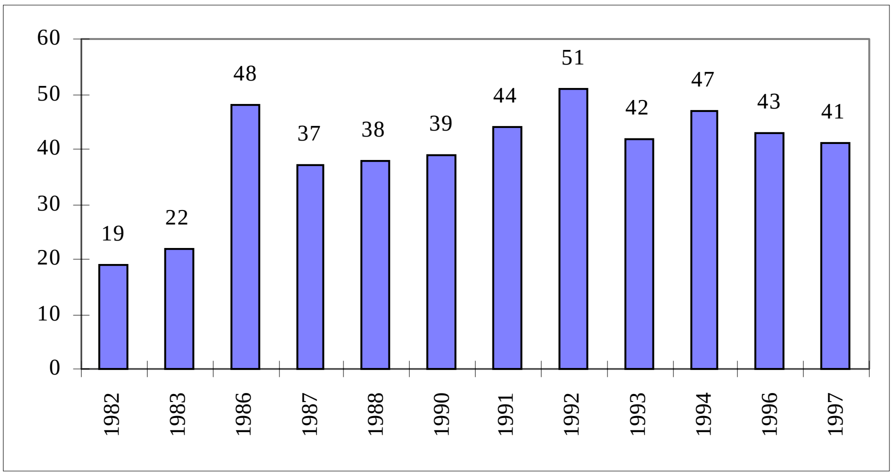


Figure 4-7 ICASSP Papers in ASR per year

Comparing the above with the figure 4-5 it is obvious that ASR was among the interest of researchers earlier than it appeared in patenting data.

We assume companies are competent in the given technical field when they are granted five or more patents between 1976 and 1997. Often many patents are granted under the names of subsidiaries and divisions that are different from those of their parent companies. So these patents are listed separately. Consolidating patenting under the names of parent

6 Not all participants' companies who suggested patenting as a method of protecting innovation method are listed in the patenting data in Appendix A. This suggests that some of the participants are not fully aware about their company's policy in patenting or they were talking about patent applications in progress. For example from 1/1/1998 to 31/7/1998 (7 month period) 106 patents for ASR and 11 for NLP had been granted by US Patent Office.

companies has been done manually and shown with the thicker borders in the table follows.

Table 4-2 Top US Patent Recipients in ASR and NLP 1976-1997

Company Name	ASR 1976-87	ASR 1988-97	NLP 1987-97	Total Firms Patents in ASR&NLP	Total Patents of Firm (all sectors)		% Firm's Share in all ASR & NLP patents[7]		% Share of ASR & NLP in Total Firm's Patents[8]		Country / US State
Apple Computer, Inc.		10		10	842		1.58		1.19		CA
AT&T Bell Laboratories	5	12		17	4088	9157	2.7	6.03	0.42	0.41	NJ
AT&T Corp.		5		5	1205		0.79		0.41		NJ
Lucent Technologies Inc.		13		13	1118		2.06		1.16		NJ
Bell Telephone Laboratories, Inc	3			3	2746		0.48		0.11		NJ
British Telecommunications		5	1	6	600		0.95		1.00		UK
Canon Kabushiki Kaisha	2	4	1	7	1537		1.11		0.05		JAPAN
Casio Computer Co., Ltd.	2	3		5	1346		0.79		0.37		JAPAN
Dragon Systems, Inc.		*15*		*15*	*15*		*2.38*		*100*		*MA*
Exxon Corporation	3			3	3	1248	0.48		100	0.64	NY
Exxon Res. and Eng. Company	2	3		5	1245		0.79	1.27	0.40		NJ
Fujitsu Limited		7	2	9	6883		1.43		0.13		JAPAN
Hitachi, Ltd.	7	8	8	23	18880		3.65		0.12		JAPAN
International Business Machines	1	39	4	44	16351		6.98		0.27		NY
ITT Corporation	1	5		6	847	878	0.95		0.70	0.91	NY
ITT Defense Communications		2		2	31		0.32	1.27	6.45		NJ
Kabushiki Kaisha Toshiba		22		22	11847	14763	3.49	4.44	0.19	0.19	JAPAN
Tokyo Shibaura Denki K. K.	6			6	2916		0.95		0.20		JAPAN
Kurzweil Applied Intelligence[9]		*15*		*15*	*15*		*2.38*		*78.95*		*MA*
Matsushita Electric Industrial	8	14	1	23	10406	10475	3.65	3.97	0.22	0.24	JAPAN
Panasonic Technologies, Inc.		2		2	69		0.32		2.90		NJ
Mitsubishi Denki Kab.Kaisha	2	4		6	11328	11348		0.95	0.05	0.07	JAPAN
Mitsubishi Elect. Res. Labs, Inc.		2		2	20			0.32	10		MA
Motorola		16		16	10597		2.54		0.15		IL
NEC Corporation	1	16	2	19	7589	7760		3.0	0.25	0.37	JAPAN
Nippon Electric Company, Ltd	10			10	171			1.59	5.84		JAPAN
Nissan Motor Company, Ltd	11			11	2596		1.75		0.42		JAPAN
Ricoh Company, Ltd.		15		15	4042		2.38		0.37		JAPAN
Sharp Kabushiki Kaisha	3	5	2	10	5217		1.59		0.19		JAPAN
Sony Corporation		7	1	8	8165		1.27		0.09		JAPAN
Texas Instruments Inc		11	1	12	6409		1.90		0.19		TX
Threshold Technology, Inc	*5*			*5*	*9*		*0.79*		*55.55*		*NJ*
U.S. Philips Corporation	2	4		6	12337		0.95		0.05		NY
Voice Control Systems, Inc.		*11*		*11*	*13*		*1.75*		*8.61*		*TX*

It is clear that ASR&NLP business environment becomes a combination of large traditional companies and a host of smaller companies and start-ups (written in italics). From the relatively low patent shares of large firms in ASR&NLP, is shown that these technologies constitute background ones. Companies seem to have realised that this field may have a long-term strategic significance, so they try to built up a competence or undertake exploratory research in order to provide strategic flexibility to respond quickly when opportunities arise. Unlike large firms, small ones are very specialised rather than diversified in their research portfolio. Interestingly, among the technological leaders we can find automobile and consumer electronics companies. This reflects the recently acquired and rapidly technological competencies in non IT-sectors, which may give them a competitive advantage in both improved operations and products. Exceptionally Nissan

[7] Total number of patents of all firms in ASR and NLP is 630, which is constituted from 145 patents in ASR for the period 1976-87, 450 patents in ASR during the period 1988-97 and 35 patents in NLP during the period 1976-97.

[8] Final figures estimated on a parent company basis.

[9] Kurzweil Applied Intelligence was rocked by an accounting fraud in 1994 and then bought by Lernout & Hauspie.

have pulled out from ASR research, after having received 11 patents prior to 1998 and none afterwards.

The table 4-2 entries are interestingly correlated with them in table 4-3, which shows the top ten patent recipients in the period 1990-95. Eight out of ten companies appearing in table 4-3 (apart from Eastman Kodak and General Electric) were are also top ranked in ASR&NLP fields.

Table 4-3 Top Ten US Patent Recipients (1990-95)

Company	Total Patents
Canon	6041
Toshiba	5977
Mitsubishi	5716
Hitachi	5697
IBM	5649
General Electric	5218
Eastman Kodak	5031
Motorola	4254
NEC	3859
Matsushita	3790

So far, the scope of the technological research activities of large firms has been very broad and not very much focused on applications for problem-solving. However, the comparison between the firms in tables 4-2 and 4-3 clearly shows the importance of ASR technology for the research portfolio. However, several large firms may apply for patents in fields which have not been explored yet, just to be able to block their competitors in case of a critical application with market success in the future.

Comparing with the frequency that small firms appear in table 4-2 (written in italics) and the special newsletters, we find that not all small innovating companies patent at least very often. However, it is important for small firms to strike a balance between the risk of paying high patent fees for an invention that may ultimately be of low value and the risk of foregoing protection for innovations that may turn to be critical for market success. Also, the securing of intellectual property rights on major international markets, while an expensive exercise, is seen by the venture capital investors as a necessary protection of the key intellectual assets of the new technology enterprises.

The table 4-4 contains the top publishing firms and institutions in ASR during the period 1982-97. It is shown that small firms or spin-offs of listed universities are generally the same often mentioned in newsletters and financial newspapers. Several large firms in the

Table 4-4 Top Publishers of ICASSP Papers in ASR 1982-97

Company , University or Research Lab Name	1982-97	% Papers Share	Country/ State
ATR RESEARCH LABS	26	5.64	JAPAN
AT&T BELL LABS	45	9.76	NJ
BBN LABS	16	3.47	MA
BROWN UNIV	5	1.08	RI
CARNEGIE MELLON UNIV	38	8.24	PA
CTR STUDI & LAB TELECOMUN	5	1.08	ITALY
DRAGON SYSTEMS	5	1.08	MA
GEORGIA INST TECHNOLOGY	5	1.08	GA
IBM CORP	27	5.85	NY
INST NATL RECH INFORMAT & AUTOMAT	5	1.08	FRANCE
INT COMP SCI INST	7	1.52	CA
MASSACHUSETTS INST TECH (MIT)	12	2.60	MA
NIPPON ELECT CO (NEC) LTD	7	1.52	JAPAN
NIPPON TELEGRAPH & TEL (NTT)	12	2.60	JAPAN
PANASONIC TECHNOL INC	7	1.52	CA
PHILIPS RES LAB	9	1.95	GERMANY
ROYAL SIGNALS & RADAR	6	1.30	UK
RUTGERS STATE UNIV	5	1.08	NJ
SRI INTERNATIONAL	8	1.74	CA
UNIV CAMBRIDGE	12	2.60	UK
UNIV EDINBURGH	5	1.08	UK
UNIV KARLSRUHE	5	1.08	GERMANY
TOTAL	461		

table 4-4 are also listed in the top patenting positions in table 4-2 (e.g. AT&T, IBM, Philips...). Therefore, there is a consistency in data from patents and publications for the large firms. However, small firms such as Dragon and universities such as Carnegie Mellon, MIT, Cambridge etc. are found in scientific publications top ranking (tables 4-4 and 6-1).

4.5 Conclusion

In the early stage ASR&NLP technologies were approached with extensive exploring and experimenting, probing and learning rather than targeting and developing. It has taken many years to generate sufficient technology push and begin commercialisation of related products and services. In the previous section we showed that there has been a long process of evolution instead of a revolution concerning that speech recognition applications are multi-technology products.

Adapting the analysis of Mitchell & Hamilton (1998) in ASR&NLP case we find that a number of topics are potentially relevant to profitable investments and could be included in a firm's exploratory knowledge-building effort. However, significantly higher levels of effort must be devoted to any topic if it is ever to be developed to the stage where it may have commercial payoff.

Area of Technology	***Knowledge Building*** ***(Exploratory Topics)***	***Strategic Positioning*** ***(Research Focus)***	***Business Investment*** ***(Potential Applications)***
ASR	acoustic modeling noise cancellation front-end design adaptation rejection	APIs / tools to develop apps support of several languages support of several platforms detecting and recovering errors portability	operating system enhancements telecommunications applications hands-free terminals car applications medical applications
	task/speaker variability evaluating performance		
NLP	language modeling corpus desing and collection dictionary building dialogue building		

Table 4-5 Options positioning in ASR & NLP. Source: Author's Elaboration

The evolutionary period in technological progress has resulted in a market revolution. Overall ASR has created a very strong technology push. The industry will no longer be new when the product development shifts from radical to evolutionary. This is related to the development of a dominant design within the industry (perhaps not in technological basis but in interface, such as Windows in PC market). The dominant design reduces the level of uncertainty and heightens price competition, while increasing the emphasis on process innovations (Abernathy & Utterback, 1978). Future strategic values and resources will then be partly predictable.

CHAPTER 5

ENTRY BARRIERS FOR ASIAN AND EUROPEAN FIRMS

5.1 Introduction

Language interface systems are under development in research labs in North America, Europe and Asia. These projects have focused on a small set of common languages including English, Chinese, Spanish, Japanese, German and French as well as on their respective regional dialects. The linguistic fragmentation of the world software market represents an opportunity for country specific solutions, since a large part of development and marketing costs depend on the number of language versions of a product, while the size of language market addressed first constitutes an important competitive advantage. It is very interesting to find out the level that language constrains and diversification have operated as barriers for firms with a proved record in microelectronics, information and communication systems.

5.2 Language Priorities and Firms' National Environment

In the question about the major human languages that companies were, are or plan to develop applications for, apart from two participants who answered generally 'in all major languages' and one who said that their technology is language independent, the rest gave answers which are shown on the figure 5-1. Interestingly, English is not the dominant language for developing applications. Although two thirds of

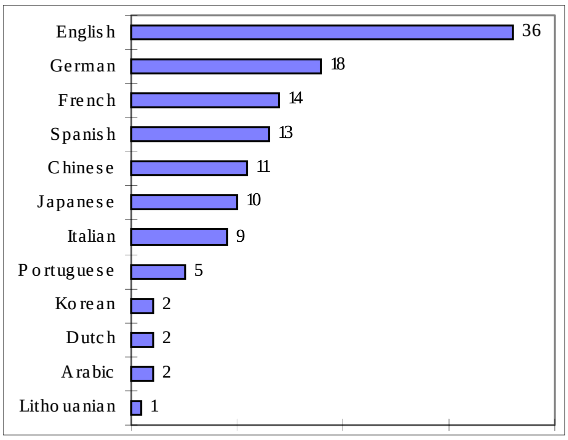


Figure 5-1 Major Human Languages for Development

companies work in English-based[1] systems, they have started transferring their applications in other languages seeking for new markets, where competition would be weaker. Crucially, reaching global markets will require companies to customise applications for many languages.

In the question about the favourability of national environment for corporate activities, the majority of the participants (26 out of 35) recognised their national environment as particularly favourable. Some others (mainly from Japan) said that is favourable for researchers availability, while facing problems dealing with the language structure and representation. Finally, some participants from France, UK, Portugal and Italy said something similar to 'not as in the US, but better than most places in the world'. Finally, a participant from a country with a less spoken language said 'No, but somebody must do that', which shows the opportunities arising for small local companies.

5.3 *National and Regional Patterns in ASR & NLP*

Analysing the data from patenting in ASR&NLP from a regional perspective we clearly confirm the US dominance in the field with 43% of all patents granted. Japanese firms have the 34% of patents, while the third country (UK) has only 2%.

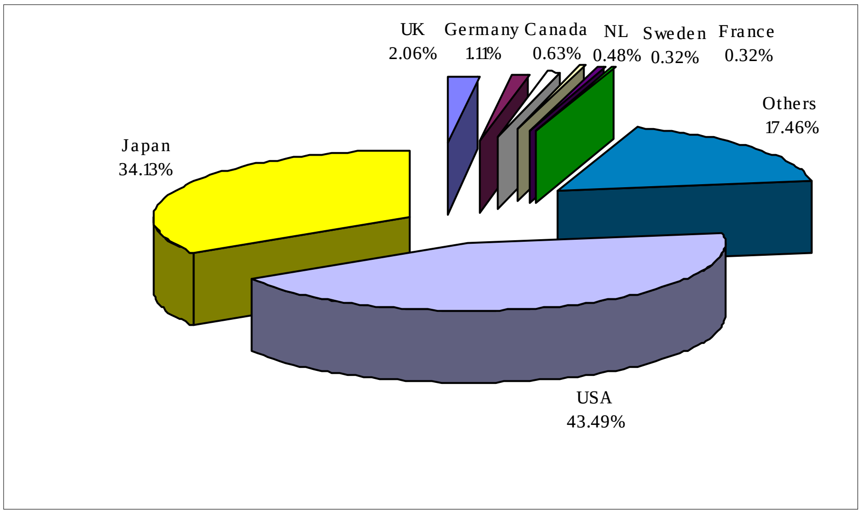


Figure 5-2 National Patterns in ASR&NLP Patenting Worldwide

Especially for the US, data analysis in a state level indicate New York, New Jersey, California, Massachusetts and Texas as the regions with the highest patenting rates in ASR&NLP. The high performance of the above states (with the exception of California and Massachusetts) is explained by the existence of the largest American IT giants, such as IBM,

[1] English language in ASR&NLP covers mainly US English, but also British, Canadian, Australian or Irish English.

AT&T, or TI (see figure 4-3). Particularly, 65% of ASR&NLP patents in New York state belong to IBM, 73% in New Jersey to AT&T, 50% in Texas to Texas Instruments, 100% in Illinois to Motorola and 25% in California belong to Apple.

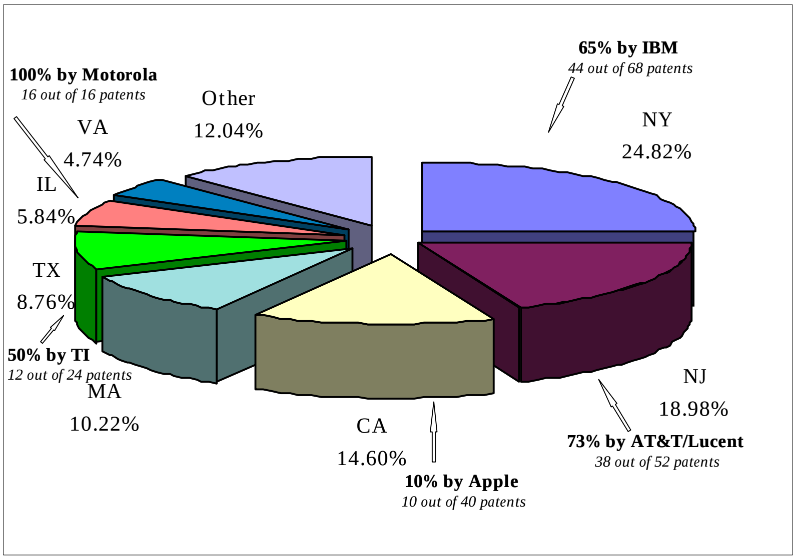


Figure 5-3 Regional ASR&NLP Patenting Patterns within the US and the respective Contribution of Large Firms

The cases of Silicon Valley (CA) and Route 128 (MA) have been examined by many analysts, but especially for ASR&NLP the ARPA funding gave a boost in academic and enterprising activity in these two areas. Most of the top ranking small firms in ASR&NLP patenting are established there (CA: Dialogue Systems and Emerson & Stem, MA: Dragon and Kurzweil). Consequently, the emergence of successful specialised firms depends heavily on the strength of universities and public research institutes in the particular sciences and less on large firms found in the same region.

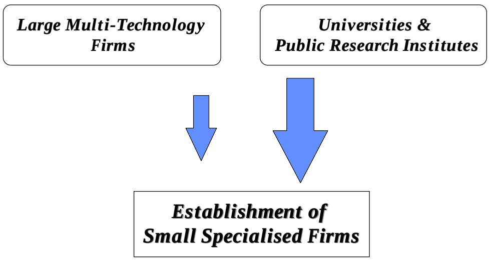


Figure 5-4 The Origin of Small Specialised Firms

Although the performance of Japanese giants (Hitachi, Toshiba, NEC, etc.) in patenting is very high, market penetration is has not recognised either from survey participants or the industry newsletters. In the next paragraph we attempt to explain this phenomenon.

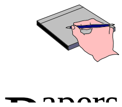
5.4 The Case of Asian Firms

The Japanese and Chinese markets are especially alluring because complicated writing schemes in those countries make keyboard use problematic. Chinese uses between

4,000 and 6,000 characters, while Japanese uses 2,000 but also relies on three other alphabets in parallel. Both languages are also riddled with homonyms (words that sound the same but have different meanings). Moreover, words are strung together without gaps, making parsing even harder. Moffet (1998, p. 56) reports as follows about that:

What West takes for granted - the ability to put language in to digital form - is a vexing problem for cultures whose writing is based on thousand of ideograms, the symbols used in Chinese, Japanese and other Asian languages.

The author found it very difficult to contact companies in Asia, while it is hard to get information from alternative sources. In the NIKKEI Weekly[2] web site - the Japan's only English language business newspaper - information is updated daily without offering the facility of searching previous issues. Only a very limited number of experts from Japan responded to the survey and our main source of data was personal contacts with people at the ICASSP 98. One person claimed that small companies in Asia seem to face lack of venture capital which is a major source of funding in the field, as the survey has shown. Some of the interviewees also claimed that lack of investment comes from lack of vision, while several directors, because of the recent financial crisis, are forced to cut some research departments.



From the publications data we find that in Japan there is certainly a growing focus on cognitive science research and an appreciation of its importance for human-computer interaction, while it is not as strong as in the US. Cognitive science activities are particularly strong at some universities, the University of Tokyo for example, and at several industrial research labs, especially ATR and NTT.

There have been few commercial ASR telecommunications applications in Japan since ANSER system was introduced for public use (Nitta 1994, Sugamara *et al.* 1994). Kitai *et al.* (1997) reviewed ASR applications in Japan during the last years and reported that some PC manufactures (NEC, IBM-Japan, Toshiba, etc.) have developed their own ASR software to run on their own platforms. Non PC manufactures (NTT, NTT-DATA, etc.) have also developed their own ASR to run on PCs. Especially NTT have developed a software-based interactive system with speech recognition and synthesis functions which enables the easy and rapid development of applications prototypes by visual basic programming. IBM-Japan started to sell its Japanese dictation software for PCs in Nov. 1996. Users could input Japanese sentences by speaking with pauses between phrases, but this program has been improved with ViaVoice 98[3] version. NEC has a similar product that lets users dictate and manage email by voice. Interested readers in Japanese ASR products can refer to a comprehensive description made by JASJ (1996) and IEICE (1996).

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[2] THE NIKKEI WEEKLY is the English version of the Nihon Keizai Shimbun and can be found in electronic form at http://www.japanone.com/

[3] At the IBM's Japan site http://www.ibm.co.jp/ only a few entries were also in English in order to extract info.

One of the most important programs covering most state-of-the-art issues in ASR&NLP has been dated back in 1993 at the ATR[4] Interpreting Telecommunications Research Laboratories using massively parallel machines for speech processing and speech/language databases. They have also developed a Japanese/English translation system (Reaves *et al.* 1998) for spontaneous speech recognition and synthetic output.

The long-term research of several non computing companies (SONY, Nippondenso, etc.) have given products such as car navigation systems. Several microprocessor companies develop hardware based ASR&NLP. For instance Sharp and OKI have recently announced voice control software with microcontroler chip and multilingual TTS chip respectively (Speech Recognition Update, 1998).

In parallel, the market of quality speech recognition products in the Asia Pacific region is targeted by non Asian firms. Motorola, Lexicus division, for instance, recently announced an agreement to license its Chinese speech technology to L&H, while most of the American and European companies in the survey claimed to develop applications for Japanese and Chinese.

5.5 The Case of European Firms

The language diversification in Europe is also targeted by US firms[5] as the survey it is shown by the survey. However, opportunities are excellent for several continental companies involved in these technologies. In Belgium, the Flanders Language Valley[6] is a huge investment in infrastructure and people focused on developing software that can bridge the gap between humans and machines. In the UK, multinationals and university departments have led to several spin-off companies. Especially in Cambridge and Surrey they get very good results by undertaking a range of research and development projects. Europe’s leadership in digital telephony through large R&D expenditures and continuous innovation in component and interface technologies (Davies, 1997) provides a platform for countless applications in computer-telephony integration.

The EU has realised that new technology combined with knowledge of language will enable people to retain national and cultural identities and appreciate the differences of others and will give new potential to local companies. With the exception of Philips, most

[4] ATR was founded in 1986 with support from industry, academia, and government, to serve as a major center of basic and creative telecommunications R&D. The government provides 70% of the annual budget; and over 150 companies provide the remaining 30%. Government funding comes from dividends on its shares in the partially privatized Nippon Telephone and Telegraph (NTT).

[5] For instance, the IBM’s European Speech Research Teams are situated in Winchester (UK), Paris (France), Heidelberg (Germany), Seville (Spain), Rome (Italy) and Cairo (Egypt), working on six languages: UK-English, French, German, Spanish, Italian and Arabic.

[6] See also Microsoft Case Study Chapter 6.

non telecommunications European companies involved in ASR&NLP are small ones and small firms have become an important strategic target of the EU policy. The following model[7] describes the policy to strengthen European position at the forefront of language-enabled digital services.

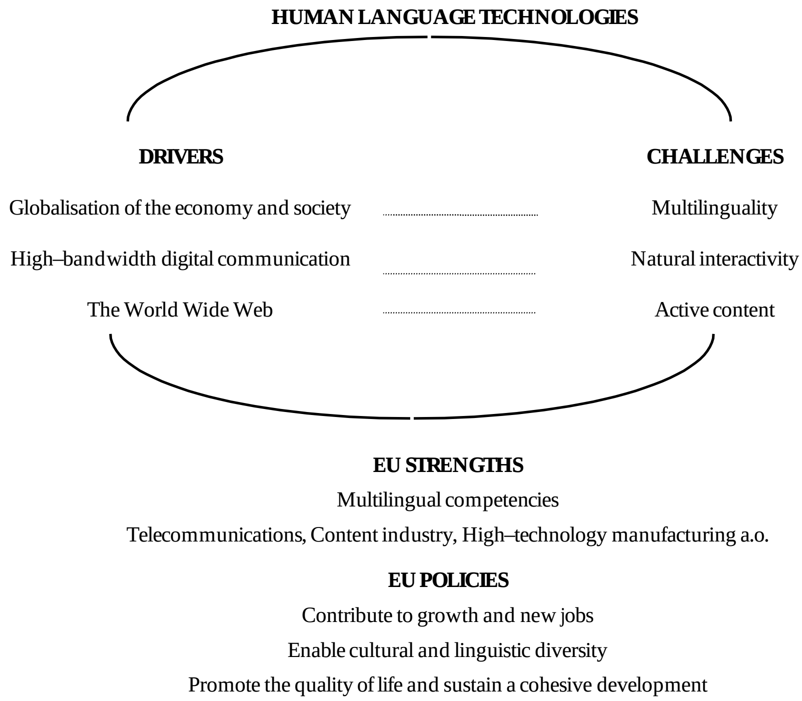

Figure 5-5 European Union's Model for Exploiting Human Language Technologies

Several Framework Programmes in the R&D area have been launched, which lasted 4-5 years: FP1 (1984-87), FP2 (1987-91), FP3 (1990-94), FP4 (1994-98), and the next programme FP5 (1998-2002) is now being prepared. The activities in spoken language processing and more generally in multimodal communication, took essentially place in two programs: ESPRIT/IT program, and TELEMATICS, with a specific action line on language engineering. Mariani (1997) has identified 31 spoken language EU projects in various areas, since 1983, in different topics related to speech processing. One of these projects, namely SQALE[8], on multilingual large vocabulary ASR concluded that the same general approach to system design is applicable to all its language studies. Typically there are some language specific problems to solve, however the basic approach appeared to be straight forward to port across languages.

European PTOs have also realised that a single company in each country cannot achieve the required uniformity of speech understanding services. Therefore, they had to establish EURESCOM[9] having as objective to explore how general multilingual services could be

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[7] *Human Language technology, Living and Working Together in the Information Society*, Discussion Document, Luxembourg, July 1997, http://www2.echo.lu/langeng/en/fp5/lt.html

[8] The aim of SQALE (Speech Quality Assesment for Linguistic Engineering) was to adapt the ARPA evaluation paradigm to the European multilingual environment. For further details refer to Young *et al.* (1997).

[9] EURESCOM is a private company totally founded by 23 European telecommunication operators.

provided in all participating countries. Details about the progress of this project in France, UK, Italy, Germany, Spain and Portugal can be found in Johnston *et al.* (1997).

5.6 Conclusion

Asian and European companies are active in this field and they have also implemented complete systems and attempts have been made to develop toolboxes for prototyping. Nevertheless, the dominance of US companies in operating systems perhaps will not allow them to establish standards. Undoubtedly the former is explained by the difficult interface problem which the Asian languages cause to interface designers, especially in a world market in which Roman alphabet interfaces are so dominant. For this reason, alliances with US giants may be proved to be very important for market success.

Especially in Japan research activities are investing more in hardware than in empirical investigations or software development environments. The activity of firms in applications involving specific consumer electronics and devices is expected to increase significantly, because of the strong competence in the field. Similar opportunities may arise for European firms by taking advantage of their leadership in mobile communication systems.

CHAPTER 6

KEY PLAYERS: CORE OR BACKGROUND COMPETENCIES

6.1 Introduction

In an environment where the uncertainty about future strategic values and resources are not reducible, companies struggle to build a base of competence and resources for the forthcoming business. Commercial opportunities emerging from major scientific and technological advances are not always clear at the same time. Product features valued by users are not obvious as well. Once identified, they can be quite easily imitated by competitors (Pavitt, 1998a). In this chapter we shall examine the market orientation of firms involved in ASR&NLP by identifying whether these technologies are coped as sources of core or background competencies. Later we classify the firms into four groups. For further understanding the profile of one company from each group is illustrated.

6.2 Accessing External Knowledge and Resources

The need to acquire external technologies increases as the number of component technologies increases. In such cases, the policy is to acquire specific pieces of basic technology from other firms or universities, who can provide better technology at less cost, than that which could have been obtained from in-house research activities. One of the most important factors affecting the balance between in-house generated and externally acquired technology is the degree to which company strategy dictated that it should pursue a policy of technological leadership or differentiation (Tidd *et al.*, 1997).

To identify the importance of linkages for technology transfer and market success, we asked whether companies develop speech applications independently or in collaboration with others (figure 6-1). Apart from 7 participants who answered with something similar to ‘we have several partners, the more the better’, and 15 who said that their companies develop applications basically independently, the rest 28 indicated external partnerships. Universities and research labs seem to be preferable in this exploratory phase of development than approaching other companies. Most companies are reliant largely on internally generated knowledge, claiming that their in-house activities are the major source of technical know-how. Nevertheless, they all enjoy a variety of often strong external technological links with universities, research institutes and other industrial companies.

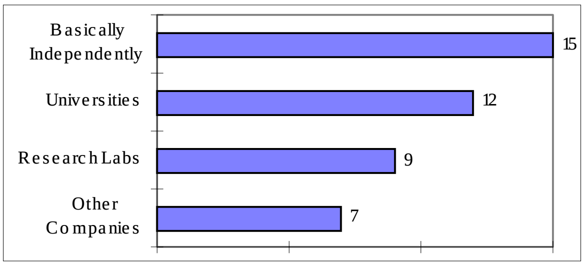

Figure 6-1 Partners for Applications Development

The majority of participants also referred to joint projects as a general notion[1] (figure 6-2), which shows that the complexity of problems faced in these technologies need inter-firm co-operation, and also that only few companies have the ability to cope with complicated projects on their own. The factor of exchanging researchers shows the importance of multidisciplinary and *tacit* (person-embodied) knowledge in ASR&NLP. Therefore many techniques can be effectively transferred by experience and face-to-face interactions. Some of the respondents also mentioned that they have performed data collection in collaboration with other companies in order to reduce the cost. Rothwell & Dodgson (1993) suggested that NTBFs are likely to have diverse and extensive linkages with a variety of external sources of innovation, but the management and exploitation of these linkages can be difficult and consume the limited technical and managerial resources of a small firm.

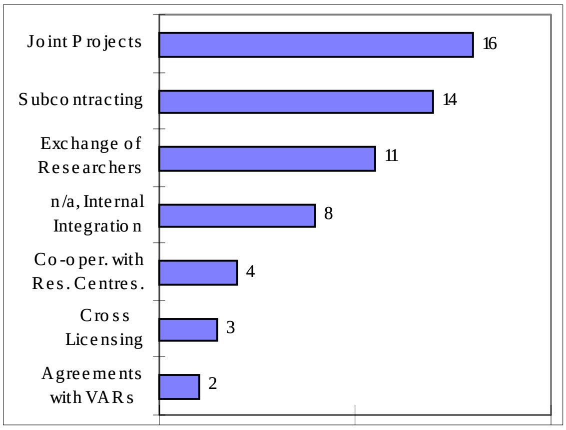

Figure 6-2 Models of Collaboration

The strategic options that a firm may adopt in order to establish its technology as a standard include licensing, entering into strategic alliances, adopting an appropriate positioning strategy, and diversifying in the production of complementary products. There are benefits, costs and risks in each of these options (Hill, 1997). In the question about links for establishing standards[2] in the market participants did not give any

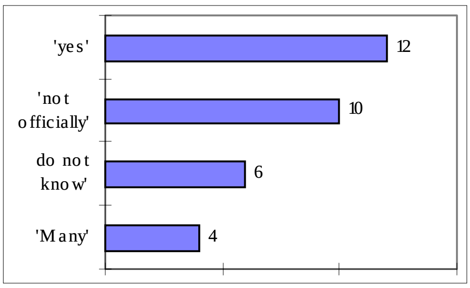

Figure 6-3 Links for Standards Establishment

[1] There are two basic types of formal joint venture: a new company formed by two or more separate organisations, which typically allocate ownership based on shares of stock controlled; or a more simple contractual basis for collaboration. The critical distinction between the two types of joint venture is that an equity arrangement requires the formation of a separate legal entity (Source: Tidd *et al.*, 1997, p. 208-209).

[2] For the purposes of this study a standard is a tool for defining the technical terms of entry to markets.

clear indication since the 32 answers were very brief (figure 6-3). However the results are reasonable for a not well-defined market.

In the following table the listed firms and universities have published more than five papers in ASR&NLP combined during the examined period. For the full list of publishing data, reader should refer to Appendix B.

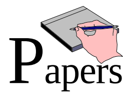

Table 6-1 Top Journal Papers Publishers in ASR and NLP 1982-97

	ASR in JASA[3] / IEEE Transactions on Speech and Signal Proc[4] / Computer Speech and Language / Speech Communication				NLP in Computational Linguistics / Communications of the ACM / Journal of Artificial Intelligence Research (JAIR)				
Company, University or Research Lab Name	1982-97	Collab.	Total	%	1982-97	Collab.	Total	%	Country or US State
ARIZONA STATE UNIV	1	5	6	1.30	-	-	-	-	AZ
ATR RESEARCH LABS	6	9	15	3.24	-	-	-	-	JAPAN
AT&T BELL LABS - LUCENT TECH.	24	9	33	7.14	6	2	8	5.19	NJ
CNRS, LIMSI	5	2	7	1.52	1	-	1	0.65	FRANCE
CUNY, CTR RES SPEECH & HEARING SCI	2	3	5	1.08	-	1	1	0.65	NY
DUKE UNI	8	1	9	1.95	1	-	1	0.65	NC
INDIANA UNIV	7	4	11	2.38	-	-	-	-	IN
INRIA LORRAINE	3	2	5	1.08	-	1	1	0.65	FRANCE
KOREA ADV INST SCI & TECHNOL	5	1	6	1.30	-	-	-	-	S. KOREA
MED UNIV S CAROLINA	3	3	6	1.30	-	-	-	-	SC
MASSACHUSETTS INST TECH (MIT)	9	6	15	3.25	1	1	2	1.30	MA
NIPPON TELEGRAPH & TEL (NTT)	4	5	9	1.95	1	-	1	0.65	JAPAN
PHILIPS RES LAB	5	3	8	1.73	-	-	-	-	NETHERL.
TECHNION ISRAEL INST TECHNOL	-	-	-	-	3	3	6	3.90	ISRAEL
TEL AVIV UNIV	1	-	1	0.21	2	2	4	2.60	ISRAEL
UNIV CALIF BERKELEY	-	2	2	0.43	1	4	5	3.25	CA
UNIV CALIF LOS ANGELES	6	3	9	1.95	-	-	-	-	CA
UNIV CAMBRIDGE	8	1	9	1.95	-	2	2	1.30	UK
UNIV IOWA	2	3	5	1.08	-	-	-	-	IA
UNIV MINNESOTA	5	2	7	1.52	1	-	1	0.65	MN
UNIV TEXAS	4	1	5	1.08	1	-	1	0.65	TX
UNIV WATERLOO	6	4	10	2.16	-	-	-	-	CANADA
INDIVIDUAL	1	1	2	0.43	8	-	8	5.19	
TOTAL (in Appendix B)	270 (58.44%)	192 (41.56%)	462		88 (57.14%)	66 (42.86%)	154		

Interestingly, nearly half of the published papers in the above table (over 40%) are collaborative. Several initiatives have shown that small high-tech businesses thrive where they are able to access academic based resources and research facilities, with relative ease.

6.2.1 Mergers, Alliances and Acquisitions in Speech Industry

As Dodgson (1990) suggests 'few firms possess all the skills required to create a new technology'. Decisions on acquisition and collaboration as a means of dealing with technological opportunities and threats are an important component in firms' strategy. In June/July 1998 Speech Technology Magazine[5] there is an article about the most important mergers, alliances and acquisitions in speech industry. Some of the most significant deals are included in the following table:

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[3] Years: 1982-97

[4] Years: 1995-97

[5] Speech Technology Magazine is published quarterly by CI Publishing [http://www.speechtechmag.com]

Table 6-2 Mergers, Alliances and Acquisitions in Speech Industry, Source: Author's elaboration

Mergers, Alliances and Acquisitions	Main Objective of Action
Microsoft acquired 18% of L&H, which had earlier acquired Kurzweil	spoken language interfaces for operating systems
Microsoft and Intel invested in Wild fire Communications	telecom assistant developing
Microsoft invested in General Magic	virtual assistant development
Motorola and Intel invested in Nuance Communications	ASR for self-service transactions and network applications
Nuance Communications signed alliance with Omron	ASR and automation systems
L&H acquired Applicationns Technology (AppTek)	specialised linguistic software (Arabic, Korean)
Intel invested in ALTech	speech-activated telephony solutions
IBM announced an alliance with ALTech	speech-activated telephony solutions
VCS announced strategic alliance with IBM	speech-driven telephony
Dragon Systems Inc. and Corel Corp. announced alliance to integrate NaturallySpeaking across the Corel product line.	spoken language interfaces for desktop applications
VCS announced an agreement to acquire Pure-Speech	speech-driven telephony
Aspect Telecommunications announced entry into an agreement to acquire Voicetek Corporation	IVR systems
Telex Communications and EV International announced a merger	manufacturing of audio communications equipment
Andrea Electronics announced aggrement to acquire Lamar Signal Processing,	digital signal processing (DSP) noise cancellation microphone voice-driven interfaces
General Magic has acquired NetPhonic Communications	virtual assistants / voice enabled WWW browsers
Fonix Corp. announced acquisition of AcuVoice	speech-activated telephony solutions
Fonix Corp. announced acquisition of Articulate Systems	ASR for medical transcription
Fonix Corp. announced acquisition of 3D Planet	intelligent agent technology
Entropic has merged its US and UK operations	spoken recognition and synthesis software tools and components

Three main patterns exist in table 6-2. *First*, firms with a record in ASR&NLP (e.g. IBM) try to extend their research portfolio in more specific areas with selected partnerships. *Second*, new entrants (e.g. Microsoft) try to build a background through massive investments in several specialised companies. Interestingly, large firms also invest simultaneously in different small firms, which compete each other in niche markets and have similar types of competencies and resources. For example, the seed money Intel invested in Nuance and ALTech gives the opportunity to influence these specialised companies to develop applications compatible to Intel's own platforms[6]. *Third*, small companies often agree to share their resources and know-how in order to survive the competition.

6.2.2. Conclusion on External Knowledge and Resources

Speech industry has seen new partnerships, mergers and acquisitions which promise to shape the market for the years to come. Recent investments, buy-outs, and merges show that large firms try to adopt these new technologies as fast as possible rather than develop them in-house. Several companies in the same time have agreed to share technologies and expect to co-operate on future research initiatives. This trend seems to be fully consistent with the Freeman's (1991) point who identified the rapid development and diffusion of new technologies, especially in IT, as the main reason for growth of strategic alliances.

[6] Most of Nuance's server software, currently runs on hardware from Sun Microsystems, but Intel assists Nuance in developing software for its processors. ALTech's software runs only on Intel servers. The company will also port its products to new

Successful innovators even in the same ASR&NLP market do not come from the same industry or have the same size and competencies. A value innovator targets on the mass of buyers by focusing on the key commonalties in what customers value. The most known case is that of Dragon Systems and IBM who are among those companies both of which are battling for market leadership in dictation systems for PCs. This early marketing involvement may reduce design cost, because customer requirements are not necessarily consistent with developing principles.

It is very interesting to see in figure 6-4 what skills or capabilities believe that companies have today. In this question we got a wide variety of answers which show to what extend management of ASR&NLP companies is context dependent. Corporate culture, personalities, experience and informal networks important factors. But the key strategic issue is that of the personnel. The success of these companies, as explained by their executives and researchers, is based mainly on the quality and commitment of their employees.

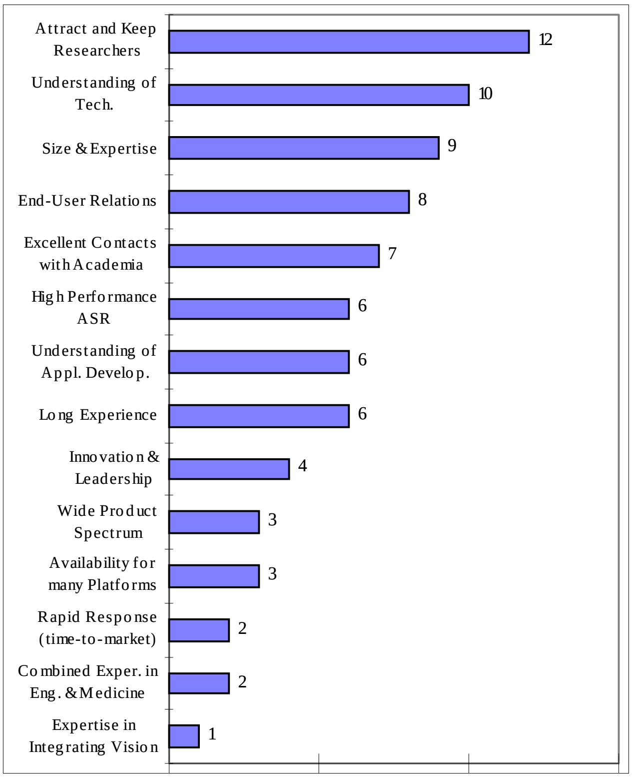

Figure 6-4 Unique Company Skills & Capabilities

In the following paragraphs we attempt a classification of the firms involved in ASR&NLP, identifying their common perspectives and their different competencies.

6.3 The Coexistence of Very Large and Small Firms

Granstrand *et al.* (1997) have proposed a classification method based on two dimensions of large firms' technological competencies (figure 6-5). Along the Y-axis is the percentage share of ASR&NLP in the total patenting of the firm (Patent Share), reflecting the relatively importance of each field in the firm's technological portfolio. Along the X-axis is an index of the firm's revealed technology advantage (RTA) in ASR&NLP. The RTA index for a given firm in the given field is defined as the firms share in ASR&NLP, devided by the firm's share of total patenting in all fields: in other words, the relative importance of the firm in each field of technological competence, after normalising for the firm's size. Applying the

processors, which will have a new set of multimedia instructions, some of which will be aimed at improving speech-recognition processing.

above method while keeping the original values on axes to distinguish high or low performance in such a new industry will result to the pattern shown in the next figure.

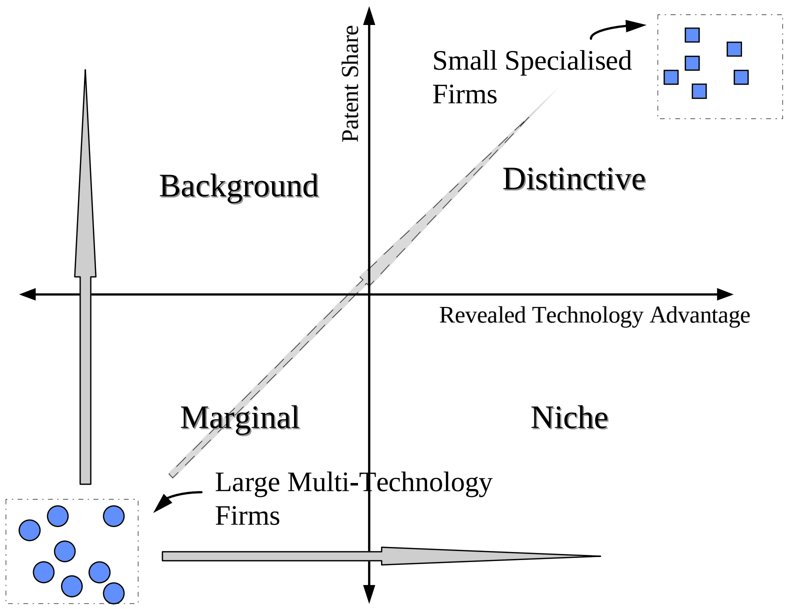

Figure 6-5 Technological Profiles of Large and Small Firms in ASR&NLP

It is obvious that two clusters of firms exist. For large firms in *marginal* quadrant ASR&NLP fields (at least at present) take only a small proportion of corporate technological resources, without offering a strong competitive position. However, for some of these firms ASR&NLP may emerge as a major opportunity for the future. This is a very important overall issue for their corporate strategy, as they have to decide whether will move to either to *background* or *niche* quadrants. Companies found in background quadrant are enabled to co-ordinate and benefit from the technical change. In the next few years some of these large firms are expected to take advantage of their enormous R&D budget and excellent internal training and provide successful products/services. Firms in the niche quadrant can obtain a competitive position with relatively small share of corporate technological resources. It is almost impossible for large firms to move from their technological diversity to the *distinctive* quadrant for ASR&NLP. Consequently, large firms, have two options, depending on the rate of progress in these technologies (especially NLP) in future: i) if it is high, substantial investments (including those in complementary technologies) could open up massive market opportunities and ii) if it is low, modest investments will allow them to exploit small niche markets.

In our analysis, companies such as Dragon Systems, L&H (Kurzweil), Threshold Technology, VCS Systems, Dialogue Systems and Emerson & Stem are classified in the distinctive quadrant. All above companies have a high percentage (from 56% to 100%) of ASR&NLP patents in their research portfolio.

The two clusters of firms can also be recognised in the figure 6-6 (please notice the different scaling in the horizontal axis), where they have been classified according to their contribution in ASR&NLP and the importance of these technologies for the firm. Interestingly, all firms are found in a very narrow band (up to 7%), since none of them have managed to build a strong competitive advantage and dominate the field. All necessary parameters for the classification of top patenting companies have been estimated in the table 4-2.

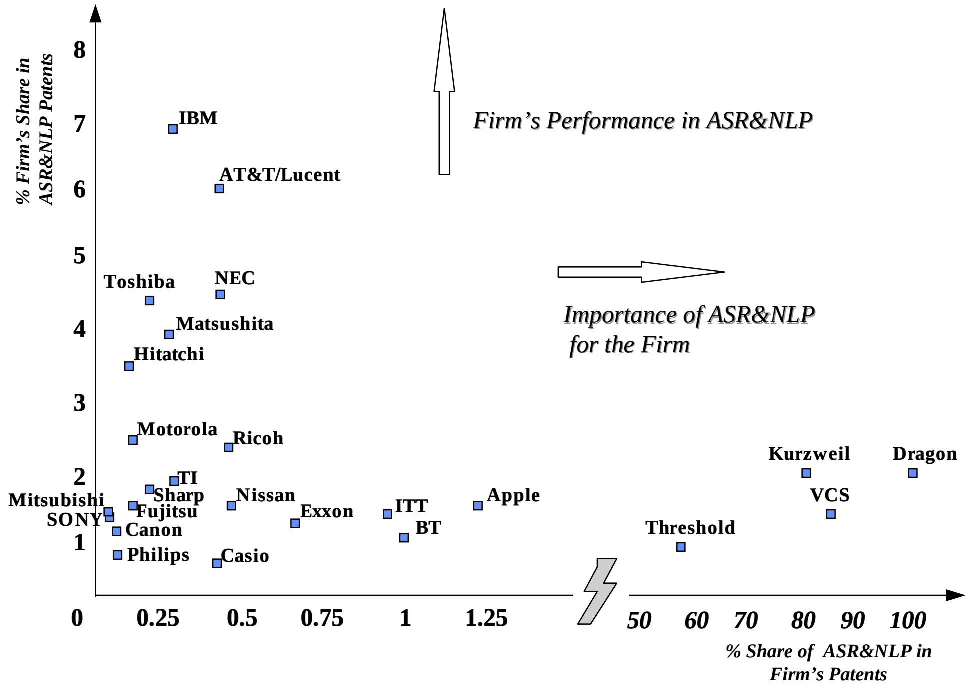

Figure 6-6 *The Coexistence of Very Large and Small Firms in ASR&NLP*

If we also consider the framework of Mitchel & Hamilton (1988) described in par. 3.2, we conclude that many large corporations are currently committing relatively modest R&D in ASR&NLP expenditures to provide an opportunity to make a profitable investment. Many companies have moved from the *knowledge building* stage, which represents the early-stage and relatively inexpensive research for developing and maintaining expertise in fields of potential future advantage, to the *strategic position* one. Fewer companies have established an important linkage of applied R&D and feasibility demonstration, concerned with reducing technical uncertainties, identifying potential markets and building in-house competencies. Finally, much fewer companies have managed to be in the stage of *business investment*, being able to develop and distribute new and better products and have revenues from their R&D expenditures. It is not possible to give figures for this model because of the lack of R&D expenditures data, as it has been stated in the limitations paragraph.

6.4 Classification of Corporate Profiles

Using quantitative and qualitative data we are able classify the corporate profiles in ASR&NLP according to the major business of large firms. While much can be learnt from successes or mistakes of companies studies we did not want to critic on them the validity and reliability problem of studying in-depth only a small number of companies.

6.4.1 Group A. Telecommunications & Electronics Driven Firms

For many years, telecommunications service providers traditionally focused on voice traffic, primarily providing a voice connection from one location to another. This perception has changed in recent years as markets have become increasingly liberalised, deregulated and competitive. In this new environment service providers have begun to offer sophisticated products and services to differentiate themselves. With all its current and potential applications, speech technology is rapidly becoming an essential component of how organizations operate. Management is realising that the integration of speech technology is the key to increase productivity, enhance customer service and cut costs.

As a result, telecommunications systems are moving from their former voice-only emphasis to an emphasis on voice and data. For example, AT&T, Nortel, Bell Atlantic, BT and GTE have developed their own speech technology, refine it in their own labs and use it in their products/services. In Europe for instance, some of the big PTOs activities are[7]:

Illustration 6-1

Italian and French PTOs in Speech Technologies

Telecom Italia implemented its voice-based directory inquiries and customer service applications as it wished to reduce the number of staff used to handle telephone inquiries and to redeploy these staff for more value-added tasks such as selling products and doing more value-added work. Implementation of its voice-based services has allowed it to do this.

France Telecom is using language engineering to improve the general public's access to information and services and to increase the attractiveness of its, advertising-funded, Yellow Page service to advertisers. The price of advertising is directly proportional to the number of callers to the service. The service has available throughout France since 1993, has 11 million callers per months and has grown by 30% since its inception in 1993.

Several microelectronics firms have investigated and demonstrated voice processing chips. Annual demand for voice recognition and synthesis chips could reach tens of millions of units within four years[8]. Using voice chips for control applications will add value and reduce costs in dozens of products, from high-end computers and security systems to toys. In the next illustration we present the case of Matsushita[9], one of the world's leading manufacturers of electronic products.

Illustration 6-2

Speech Technologies in Matsushita

[7] Source: Language Engineering sector of the Telematics Applications Programme within the EU Fourth Framework. Priority Language Engineering Market. http://www2.echo.lu/langeng/en/reps/priority/telecoms.html

[8] Source: John Wiley & Sons, Inc. Technical Insights, [http://www.wiley.com/technical_insights/]

[9] Sources [http://www.panasonic.com/] [http://www.mei.co.jp/] ITRI Loyola College [http://itri.loyola.edu/]

Matsushita was founded in 1918 and currently supports development of products under many trade names such as Panasonic, National, Technics and Quasar. Matsushita's product lines are in audio, video, home appliances, information, communication, housing, building, and industrial products. In March 1996 the company had 254,000 employees and annual sales of $64 billion. R&D expenditures were $3.71 billion, or 5.8% of sales. ⇒

There are 250 researchers in the Central Lab in Kyoto, which interacts with both the product development and the sales divisions. Human interface is one of eight departments in this lab. Matsushita operates Speech Technology Laboratory (STL) in Santa Barbara, CA, and nine other offices or labs in the US. STL was founded in 1981, and has a diverse staff of engineers, computer scientists and linguists who are engaged in applying speech processing technology to the needs of the consumer market, including speech synthesis, speech recognition and speech training. On of the major products Panasonic announced is CyberTalk, an English Speech Synthesis System. This technology is available to be licenced by software developers and hardware manufacturers. Also offered a number-reading system with a high quality female voice for use in proofreading or other financial applications.

The above cases show that large firms have identified the importance of spoken language interfaces for their traditional markets. R&D is normally conducted through a combination of specialized laboratories as well as corporate divisions that operate flexibly and independently. Additional R&D efforts are conducted through partnerships with universities and other companies.

6.4.2 Group B. Operating Systems and Applications Driven Firms

In this category, firms' the major business is computer operating systems and desktop applications. Penetration of speech as an interface will hinge upon how quickly applications and operating systems embrace it. Moreover, it will be critical to re-invent applications and operating system controls around speech-rather than simply voice-enabling pull-down menus.

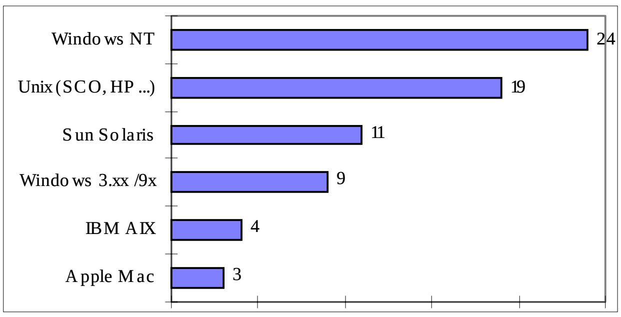

Figure 6-7 Main Platforms for Appl. Development

Several from the 44 respondents to the question about operating system platforms answered that are working on PC ones, without giving further details. From the rest we have the next figure. Apart from the operating systems some participants mentioned the supported IVR platforms or the telephony boards they use, but these responses were not many in order to have indications about the most widely accepted hardware standards. It is worth noticing that although Microsoft dominates the PC operating

systems market, very few respondents consider Microsoft as a competitor (in technological terms at least). To explain this attitude a case study follows[10].

Illustration 6-3

Microsoft in Speech Technologies

Microsoft founded in 1975, is the major developer of a wide range of software for business and professional use, including operating systems, languages and applications programs, as well as hardware and CD-ROMs for the microcomputer marketplace with annual sales over $500 million.

The Microsoft Speech Technology Group engages in R&D of speech technologies for use by a broad audience of computer users and in a wide range of applications. Their focus is on how to voice-enable the whole computer system, and not just a portion of it. The main projects pursued to reach this vision of a fully voice enabled computer are: i) Whisper (ASR), ii) Whistler (Speech Synthesis and Text-to-Speech) and SAPI (Speech Application Programming Interface).

In January 1998 Microsoft was claiming to spend this year working to add voice recognition to its operating systems, having just invested heavily in the Belgian company L&H as one effort to accelerate next-generation products. This technology was likely to appear first in Windows CE, the operating system used in palmtop computers. Six months later Microsoft officials said that voice recognition was not ready for incorporation into mainstream office suites (Rooney, 1998). In the same time new suites announced by Corel and Lotus including voice-recognition capability. Corel WordPerfect Suite 8 incorporates Dragon Systems' technology and Lotus' SmartSuite Millennium Edition incorporates IBM's technology. Microsoft has not yet voice-enabled its operating systems or its Web browser Internet Explorer, though development is ongoing. In contrast, IBM incorporated speech recognition in its OS/2 Warp OS and has developed software that lets users of Netscape's Navigator browser surf the Internet using voice commands.

"There's a big gap between people's expectations and what we can deliver," a Microsoft top researcher said. He argued that speech recognition is a lot more than what other players in the market sell today. "Dictation is not the goal of our research," he said. "Our goal is really to voice-enable the whole computer."

Unlike many other companies including IBM and Dragon, Microsoft has yet to turn its speech recognition software into a product. Technology is still largely under development, though some of its pieces are available in shipping Microsoft software. From the above it is obvious that Microsoft with its investment in L&H try to rush a first generation program to market to have something to put up against competitors, who have just released their next generation programs. However, we should not underestimate the power of Microsoft. The strong links with Carnegie Mellon University, which is undoubtedly a leader in academic ASR research, may offer the necessary know-how to build soon competitive products which could be easily promoted by taking advantage of the large installed base of company's operating systems.

[10] Sources: Microsoft Research [http://www.research.microsoft.com/], TechInvestor [http://www.techweb.com/investor/], ASRNews, 1998a and Computer Retail Week [http://www.crw.com].

6.4.3. Group C. Speech Technology Specialised Firms

Firms in this category are entirely focused on speech technologies. This enables them to often build better tools, applications and services, than large multi-technology companies that treat this market as peripheral to their main business. Normally, they have a flexible enough organisation to respond adequately to the numerous fast changing niche markets which are evolving (i.e. telephone speech, security systems...). The number of these firms is quite high, although many of these companies do not appear in the patenting or publications data, because they have been recently established or have a secrecy policy The culture of laboratory is heavily oriented to those companies and it is likely to be the discipline of the R&D director and many senior managers. Two particular aspects of several Group C firms were striking to the author - the exceptional skills and experience sets of the researchers and the combination of technical and non-technical personnel in the management teams. If the large companies are not too cautious, these energetic firms may capture a large share of the market and become *superstars*[11].

Very often these companies are university spin-offs such as ALTech (MIT), Nuance Communications (SRI), Entropic (Cambridge). Spin-offs tend to cluster around their respective incubator organisations, public or private forming regional networks of expertise. In our case, patenting data show that new companies have not been established close to the giants such as AT&T or IBM in New Jersey or New York, but in California or Massachusetts, where the ARPA speech technologies project took place. This indicates that academic researchers decide to start high tech companies more than those already work in industry, taking into account the importance of their established links and the availability of capital. Especially for the US, the role of defense industry investment, liberal tax regimes and venture capital explains that trend. In the same regions the performance of individuals patenting is also very high. Consequently, our data tend to confirm the pattern that small firms are even more reliant than large ones on national and even regional systems of innovation in which they are embedded. In the next illustration we present the case of Nuance Communications[12], a spin-off company specialised in ASR&NLP.

Illustration 6-4

Nuance Communications in Speech Technologies

Nuance Communications was founded in 1994 as a spin-off of SRI, a California based leader in the development of ASR&NLP technology. Nuance has now 90 employees and targets four business segments: financial services, transportation, package tracking, and telecommunications centers. For the time being, however, the majority of its clients are in financial services, including Charles Schwab, Chase Manhattan, Fidelity, Lloyds, and Merrill Lynch.

[11] Superstars are large firms that have emerged from small beginnings, through high rates of growth based on the exploitation of a major invention or high technological trajectories. Some well-known examples from the electronics/IT sector are: DEC, TI, Intel, Xerox, Microsoft, Sony and Casio.

[12] Sources: Nuance Communications [http://www.nuance.com], The New York Times [http://www.nytimes.com], CNN [http://www.cnn.com], Red Herring Magazine [http://www.redherring.com/], Computer World [http://www.computerworld.com] and Information Week [http://www.techweb.com].

Exploiting the academic research achievements products came early into market including: i) Nuance6.2, a software product that combines ASR&NLP for telephony applications, ii) Nuance Developer's Toolkit for development, prototyping, and deployment of ASR applications with NLP and iii) Nuance Verifier, a speaker verification product that creates a voiceprint based on a caller's voice, providing security.

In September 1995, Nuance received its first round of venture funding from U.S. Venture Partners and Mayfield Fund. In January 1997, company had a second round of funding, raising over $7 million. New investors included Morganthaler Fund and Asset Management, Motorola and Intel. Intel's Architecture Labs assistance and name recognition, company has the opportunity to branch into new areas.

Red Herring Magazine has chosen Nuance as one its Top 50 Private Companies for 1998 in its annual Herring 100 list appearing in the September issue. Nuance was the only ASR&NLP vendor given this honor. The achievement is the second such honor this year, as Nuance was also named as one of Upside Magazine's Hot 100 Private Companies in its May issue.

6.4.4 Group D. Non IT Firms

Kodama (1992) points out that high-tech companies are now having to face *invisible competitors*, not knowing which sector these competitors come from. Although, it is really difficult to say if any of the non IT companies (e.g. Ford, Nissan, Ricoh...) have get involved in speech processing technologies their presence should not be underestimated. They develop their own speech technology in order to adapt it in their own products. In addition, the technology will be improved to allow for natural language in automobiles and other eyes-busy environments. Ricoh, for example, has recently announced a voice activated camera, while more cars are expected to have Global Positioning Systems (GPS) that will help drivers reach their destinations by conversing with the system about possible routes. In the next illustration we present the involvement of Mercedes Benz[13] in ASR.

Illustration 6-5

Mercedes Benz in Speech Technologies

For the past 20 years Daimler-Benz Aerospace AG (DASA), and the Daimler-Benz research institute, have been working on ASR. In 1987, a speaker independent speech recognition module was developed on the basis of telephone information systems for the input of digits and instructions. At that time it was tested by German Telekom and achieved an accuracy for this special application of 96%. At the moment it supports German and English, while Italian, French and Spanish are in development.

Engineers also developed an ASR system that renders a large number of controls in cars, after a German federal road traffic agency had confirmed the accident risked posed by driver inattention or distraction urging the industry to develop voice rather than push-button systems. The system has to be able to understand everybody - owner, partner, family and friends. It also has to be suitable for rental cars whose drivers can change daily. It must also understand commands when conditions are not ideal, such as when the air-conditioner is operating, the engine is accelerating and the windows are down.

The hardware is no larger than a man's hand. A printed circuit board with a processor and a few microchips serving as main memory are the most conspicuous elements. The small size also naturally suggests other applications for the system, for instance in running personal computers, video recorders and all those technical systems whose operation by means of push-buttons alone would be too difficult or time-consuming.

[13] Sources: Daimler Benz Aerospace [http://www.dasa.com], Mercedes Benz [http://www.mercedes.com], The SPRACH Project SPeech Recognition Algorithms for Connectionist Hybrids ESPRIT Ref. 20077, and *The West Australian* (August 17, 1996).

6.5 Conclusion

Applications of ASR&NLP were vigorously attempted by many companies. Large firms make long term investments to build technological capabilities by capitalising economies of scope, enabling them to explore and experiment with these technologies for possible deployment. Some of the firms may have been early starters, but may have failed to sustain their competencies. Others may have been late comers, but they may catch up, through various organisational routines, such as alliances, merges or buy-outs. Technological competencies and advantage were to be obtained either through internal R&D, joint venturing, subcontracting, exchange of researchers, and most commonly by employing a combination of these.

There have been some stochastic phenomena in this industry - key players come and go or priorities change. However, as Granstrand *et al.* (1997) underline, failure to exploit radically new technologies in large firms has more to do with failure in product development, marketing and organisational adaptation rather than with failure in technological competencies. Competence building is a long process, involving trial and error (not necessary for academic spin-offs who take advantage of academic research). In none of the large firms ASR seems to be a core technology, while the figures for NLP are much lower.

Twiss (1995) suggests that 'the knowledge base required by a company is expanding rapidly in both depth and breadth' and categorised company's technology base in *Core, Complementary, Peripheral* and *Emerging technologies*. For companies in Groups A and D, ASR&NLP are *peripheral* technologies, which are defined as not necessarily incorporated in the products or services but contribute to the effectiveness of the whole business. For companies in Group B, both technologies are *complementary*, knowledge of which is essential in product design, especially for additional product features. Finally, for companies specialised in ASR&NLP constitute *core* technologies, dominating the corporate thinking. Since the characteristics of ASR&NLP are included in Mahdi's (1996) definition of *new science*, interest readers can refer to this work about the factors in the emerge of '*new science*'-based firms[14].

[14] The term *'new science'*-based firms emphasises more in the newness of science that firm make business in, rather than in entrepreneurship of the founders of the firms that most of the authors use in the term of NTBFs.

CHAPTER 7

CONCLUSIONS: REALISING OPPORTUNITIES, BOTTLENECKS AND UNKNOWNS

7.1 Conclusion

Technological positioning has a key bridging role in both overriding corporate goals and changes in the business environment of the firm. Equally, it is important to understand the strategies being adopted by firm's competitors. The main conclusions of our research in ASR&NLP industry are summarised in the Abstract at the beginning of this paper.

7.2 Evaluation of the Research Methodology

Quantitative and qualitative data have been exploited to explore corporate technological positioning in ASR&NLP. Taking advantage of several Internet tools we managed to access with relative ease a large variety of information sources related to our study in a reasonable time. The research procedure allowed us to achieve a balance among company-specific, industry-specific and country/regional-specific perspectives. To get more precise information, we conducted a special survey with executives and researchers, adding feedback on the validity and accuracy of previous findings. Company profiles and press releases were obtained from firms own and independent sites as well. We attempted to focus on statistically significant results wherever such statistical tests have been reported. A framework was used to establish the extent of competence building in ASR&NLP within firms. There is a consistency in data from patents and publications for the large firms. However, small firms and universities are usually found in scientific publications top ranking.

7.3 Computer Science: The Keystone for ASR&NLP Progress

The past two decades have seen the emergence of new branches of science, such as geographic information systems (GIS), remote sensing, computational fluid dynamics or biotechnology, thriving on the technological advances in computer science. ASR&NLP is another case that IT breakthroughs (algorithmic, hardware and networking advances) have created new sciences, technologies and markets. A pattern appears as researchers attempt to scale up in capability and capacity without limit: every old bottleneck broken reveals another. Understanding the bottlenecks, the corresponding solutions and potential upper bounds to growth permits the development of effective spoken language interfaces. When researchers overcome current bottlenecks, ‘effective language understanding’ will simply mean "applications."

The view that ‘everything gets better, faster and cheaper’ seems to be compatible with the progress in ASR&NLP. Companies now regard the Internet as an efficient way to provide centralised information to customers through a home page. Companies may also develop *voice interface home pages* accessible using speech recognition over the telephone. The telephone is considerably more available than the Internet access for most people, since they will need access to information stored anywhere no matter where and when people are. Finally, as portable computers shrink in size but our fingers do not, we can confidently expect to see ASR&NLP playing an important role in the interaction with personal digital assistants (PDAs).

7.4 ASR&NLP: Opportunities, Bottlenecks and Unknowns

There is considerable interest in both business and higher educational institutions for ASR&NLP applications. Enormous gains are to be made by collaborating on R&D projects, and sharing information, resources and tools. By working together more closely and by linking up users, product developers and researchers a knowledge basis can be created, allowing firms to compete even more effectively within this industry and offering to users/consumers better and cheaper products/services. ASR&NLP advances offer opportunities especially for users with disabilities, non computer literate people and speakers of languages with restrictions in phonetic alphabet, such as Chinese or Japanese.

7.4.1 Opportunities - Key Areas of Future Research

In the question about the key areas of research activity and companies’ time horizon for meeting these challenges, 33 participants of the survey suggested a wide spectrum of research areas as critical for successful product development. Two of them were unwilling to disclosure their future research plans and one explained: 'since we are entering at a highly competitive time and area'. The majority suggested the *spontaneous recognition and understanding* as the most challenging problem, while some of the participants gave a horizon of 5-10 years to achieve this goal. The second highly challenging problem were *dialogue and interface design tools*, with a horizon of 2-3 years. The third area - which should deserve more interest as all bibliometric data have shown - is that of *natural language analysis and understanding* which some of the participants referred to as 'human factors'. The other areas of research include: *speaker and language adaptation*, *text-to-speech* (1 year horizon), *audio information retrieval, embedded systems, wireless coding, usability of speech medical applications etc.*

7.4.2 Bottlenecks in ASR&NLP Technological Progress

The first analytical research question has shown that the progress in ASR has been spectacular, while in the contrary NLP possess very difficult problems for researchers. In other words, NLP is still considered as being good for research, but not yet ready for real life applications. The main reason is undoubtedly due to the fact that the task is profound in terms of semantic understanding, and that contextual dependencies are difficult to integrate. To date, the major bottleneck inhibiting the creation of robust and accurate NLP systems is the problem of linguistic knowledge acquisition, in particular how a machine can obtain the linguistic sophistication necessary for accurate processing of language. Such knowledge has typically to be hand-coded by language engineers, a time-consuming process which rarely results in accurate, robust systems.

The entire cognition process and other fundamental problems can not be solved by supplying higher volumes of resources (e.g. as computing power in ASR). Over the past few years, there has been a shift from trying to manually derivelinguistic information to extracting this information automatically from on-line resources such as corpora[1], dictionaries and encyclopedias. In addition, a number of text corpora have been carefully annotated with linguistic information. Programs employing machine learning techniques to automatically learn linguistic information are becoming more reliable all the time, as more sophisticated techniques are being developed and larger training corpora are made available.

7.4.3 Unknowns - The Users' Response to ASR & NLP Applications

User acceptance of this technology has been optimistically forecast by several vendors. Interactive innovation process requires that industry react more in tune with customer requirements. For researchers who have concentrated almost exclusively on improving the recognition accuracy or the syntactic rules, it may come as surprise to see that real users are sometimes more concerned about the comfort of the microphone headband, for instance,

[1] large files containing linguistic material.

than the actual performance itself. In a survey, IBM discovered four motivations for users buying speech recognition software: finding a convenient alternative to the computer keyboard, increasing productivity, ease of use and just plain fun.

Creation of human-serving technologies requires both a deep understanding of the particular technology, as well as an understanding of how people work, learn and interact with each other. True innovation occurs at the fringes of a discipline rather that at the centre. At the fringes, concepts and ideas rub and spark against each other to create new approaches and new solutions. The above probably means that the proper use of speech technology in everyday applications will require the development of new user interface paradigms.

REFERENCES

Abernathy, W.J. and Utterback, J.M. (1978) *Innovation and the evolution of technology in the firm*.

Harvard University Graduate School of Business Administration.

Anonymous, (1978) *Speech Understanding Systems: A Report,* Artificial Intelligence Vol. 9, pp. 307-316.

ASRNews, (1998a) January Newsletter, Voice Information Associates, Inc. Lexington, USA

ASRNews, (1998b) March Newsletter, Voice Information Associates, Inc. Lexington, USA

Cole R.A., Mariani J., Uszkoreit H. Zaenen A. and Zue V. (1995) *Survey of the State of the Art in Human Language Technology*, Postscript version (November 21, 1995) of a study sponsored by the US National Science Foundation, Directorate XIII-E of the Commission of the European Communities, and the Center for Spoken Language Understanding, Oregon Graduate Institute.

Davies A. (1997) *Competitive Complex Product Systems: The Case of Mobile Communications*, IPTS Report, No 19, Seville.

Dodgson M. (1990) *Technology Strategy,* MBA Review, pp. 4-6

Freeman C. (1982) *The economics of Industrial Innovation*, 2nd Edition London, Frances Pinter.

Freeman C. (1991) *Networks of Innovators: a Synthesis of Research Issues,* Research Policy, Vol. 20, pp. 499-514.

Granstrand O. Patel P. and Pavitt K.L.R. (1997) *Multi-technology corporations: Why they have "distributed" rather than "distinctive core" competencies,* California Management Review, Vol.39, No.4, p.8.

Gross N., Judge P.C., and Wildstorm S.H. (1998) *Let's Talk*, Business Week, Feb. 23, pp. 45-53.

Grupp H. (1989) *Technology Indicators in Corporate Forecasting*. Paper presented at the colloquium on Use of the Technology Indicators in Strategic Planning, Brussels Jan. 23-24.

Hamel, G. and Prahalad, C.K. (1994) *Competing for the Future,* Harvard Business School Press, Boston.

Howard, J. M. (1987) *Applied Science and Technology Index,* New York, The H.W. Wilson Company.

Hicks D. (1995) *Published Papers, Tacit Competencies and Corporate Management of the Public Private Character of Knowledge* Industrial and Corporate Change, Vol. 4, No. 2, pp. 401-424.

Hicks D. and Katz J.S., (1997) *The Changing Shape of the British Industrial Research*, STEEP Special Report, No. 6, SPRU, University of Sussex.

Hill C.W.L (1997) *Establishing a Standard: Competitive Strategy and Technological Standards in Winner-take-all Industries,* Academy of Management Executive, Vol 11, No. 2, pp. 7-25.

Hirschman, L. and Pao, C., (1993) *The Cost of Errors in a Spoken Language System* Proceedings of the Third European Conference on Speech Communication and Technology, pp. 1419-1422.

International Data Corporation, (1996) *Home Media Consumer Survey, Residential Telecommunications*, New York

IEICE (1996), Proc. Inf. and Systems Society Conf. of IEICE. pp. 213-215. (in Japanese, or english summary in Kitai et al.)

JASJ (1996), Proc. JASJ, Mar.-Sept. 1996, (in Japanese, or english summary in Kitai et al.)

Johnston, D., Sorin, C., Gagnoulet, C., Charpentier F., Canavesio, F., Lochschmidt, B., Alvarez, J., Cortazar, I., Tapias, D., Crespo, C., Azevedo, J., and Chaves, R., (1997) *Current Experiment Applications of Speech Technologies for Telecom Services in Europe* Speech Communication Vol. 23, pp. 5-16.

Kamm, C., Walker, M., and Rabiner, L., (1997) *The Role of Speech Processing in Human-Computer Intelligent Communication*, NSF Workshop on Human-Centered Systems Information, Interactivity and Intelligence.

Kaufmann, M., (1992) *ARPA* in the Procedings of the Speech and Natural Language Workshop, San Diego California.

Kitai M., Hakoda K., Sagayama S., Yamada T., Tsukada H. Takahashi S., Noda Y., Takahashi J., Yoshida Y., Arai K., Imoto T, and Hirokawa T. (1997) *ASR and TTS Telecommunications Applications in Japan*, Speech Communication Vol. 23, pp. 17-30.

Kodama F. (1992) *Technology Fusion and the R&D*, Harvard Business Review, Jul.-Aug., pp. 70-88.

Ledingham B. (1998) *Understanding Speech Technology* CTI Magazine, Feb. Issue

Mariani J.J. (1997) *Spoken Language Processing and Multimodal Communication : A View from Europe*. NSF Workshop on Human-Centered Systems: Information, Interactivity and Intelligence.

Mahdi S. (1996) *Key National Factors in the Emergence on 'New Science'-Based Firms: a Case Study on Computational Chemistry Firms*, M.Sc. Dissertation SPRU, University of Sussex.

Meissel W.S. (1998) *Speech Recognition Upadate*, TMA Associates, Tarzana, California, May 1998

Mitchell G.R. and Hamilton W.F. (1988) *Managing R&D as a Strategic Option*, Research Technology Management, Vol. 31, No. 3, May-Jun. Pp. 15-22.

Miyazaki K. (1993) *The Dynamics of Competence Building in European and Japanese Firms: The Case of Optoelectronics, D.Phil. Thesis*, SPRU, University of Sussex.

Moffet S. (1998) *Kissing Kanjui Goodbye?* Business Week, Special Report, Feb. 23. pp. 56.

Narin F. and Davidson (1988) *The Growth of Japanese Science and Technology: Science and Technology Indicators show a dramatic Strengthening*, CHI Research, Washington, George Washington University.

Nelson R. (1959) *The Shape Economics of Basic Scientific Research*, Journal of Political Economy, pp. 297-306.

Nitta T. (1994) *Speech Recognition Applications in Japan* in Proc. ICSLP '94, Vol. 2, pp. 671-674.

Nonaka I. and Takeuchi H. (1995), *The Knowledge-creating Company*, Oxford University Press.

OECD (1989) *Science and Technology Policy Outlook*, Paris, p. 110.

OECD (1993) *The Measurement of Scientific and Technological Activities Using Patent Data as Science and Technology Indicators*, Patent Manual, Paris.

Pavitt K.L.R. (1984) *Sectoral Patterns of Technology Change Towards a Taxonomy and a Theory*, Research Policy 13, 9 pp 343-373.

Pavitt K.L.R. (1998a) *Lecture Notes of Technology and Corporate Technology and Corporate Strategy Course*, mimeo, SPRU, University of Sussex, Brighton.

Pavitt K.L.R. (1998b) *Personal Communications*

Porter M. (1980) *Competitive Strategy*, Free Press, New York.

Prahalad C.K. and Hamel, G. (1990),*The core competence of the corporation*. Harvard-Business-Review, Vol. 68, No. 3, May-June pp. 79-91.

Price P. (1996), *A Decade of Speech Recognition; The Past as Springboard to the Future*, Proceedings ARPA 1996 Speech Recognition Workshop, Morgan Kaufmann publishers.

Rabiner L. (1989) *A Tutorial on Hidden Markov Models and Selected Application in Speech Recognition*, Proceedings of the IEEE, Vol. 7, No. 2, pp. 257-286

Rabiner L. (1995) *The impact of voice processing on modern telecommunications*, Speech Communication Vol 17(3-4) pp. 217-226.

Ramsay A. (1998) *Practical Computational Semantics*, Plenary Session, ELSNET's 6th European Summer School on Language and Speech Communication, Barcelona.

Reaves B., Nishino A. and Takezawa T. (1998) *ATR-Matrix: Implementation of a Speech Translation System*, ATR Interpeting Telecommunications Research Laboratory, Kyoto.

Rothwell R. and Dodgson M. (1993) *SMEs: Their Role in Industrial and Economic Change*, International Journal of Technology Management, Special Issue, pp. 8-22.

Rooney P. (1998) *MicrosofT Says Voice Recognition is Not Ready*, Computer Retail Week, 17 June.

Schmoch U. And Grupp H (1989) *Patents between Corporate Strategy and Technology Output: An Approach to the Synoptic Evaluation of US, European and German Patent Data* in Roan A.F.G., Nederhof A.J. and Moed H.F. (eds) *Science Indicators: Their Use in Science Policy and their Role in Science Studies*, DWSO Press, Leiden pp 49-67.

Sjöström R. (1996) *Positioning Under Strategic Uncertainty Positioning in New Industries*, Dissertation English Summary, Linköpings University, Sweden.

Soete L. and Wyatt S.M.E. (1983) *The Use of Foreign Patenting as an Internationally Comparable Science and Technology Output Indicator*, Scientometrics Vol. 5, pp 311-354.

Stewart T.A. (1991) *Where We Stand, in The New American Century*, Fortune, Special Issue, p. 17.

Sugamura N., Hirokawa T., Sagayama S., and Furui S., (1994) *Speech Processing Technologies and Telecommunications Applications at NTT*, in Proc. IVTTA '94 pp. 37-42.

Tannenbaum A.S. (1984) *Structured Computer Organisation*, Englewood Cliffs, NJ Prentice Hall.

Tang P. (1997) *How electronic publishers are protecting against piracy: doubts about technical systems of protection*. Submitted to The-Information-Society, Feb. '97.

Teece D. and Pisano G. (1994) *The Dynamic Capabilities of Firms: An Introduction, Industrial and Corporate Change*, Vol. 3, No. 3, pp. 337-556.

Twiss, B. (1995) *Managing Technological Innovation*, Fourth Edition, Pitman, London.

Walker, M.A., Litman, D., Kamm, C. and Abella, A., (1997), *A Framework for Evaluating Spoken Dialog Agents*, Annual Meeting of the Association of Computational Linguistics/European Association of Computational Linguistics, Madrid, Spain.

Young S.J., Adda-Dekker M., Aubert X., Dugast C., Gauvain J.L., Kershaw D.J., Lamel L., Leeuwen D.A., Pye D., Robinson A.J., Steeneken H.J.M., Woodland P.C., (1997) *Multilingual Large Vocabulary Speech recognition: The European SQALE Project*, Computer Speech and Language, Vol. 11, pp. 73-89.

The following table shows the patenting collected data for the technological positioning in ASR&NLP with the procedure described in Chapter 3.

US Patent Recipients in ASR and NLP 1976-97

Name of Company, University of Research Institute	ASR 1976-87	ASR 1988-97	NLP 1987-97	Total Patents in ASR & NLP	% Share in all ASR & NLP patents	Total Patents of Firm	% Share in Total Firm's Patents	Country or US Stare
Acuson Corporation	-	1	-	1	0.16	58	1.72	CA
Adaptive Solutions	-	1	-	1	0.16	5	20	OR
Advanced Products and Technologies, Inc.	-	1	-	1	0.16	3	33.33	WA
Alcatel USA Corp.	-	1	-	1	0.16	20	5	NY
Alcatel, N.V.	-	3	-	3	0.48	540	0.55	NL
Apple Computer, Inc.	-	10	-	10	1.58	842	1.19	CA
ATR Laboratories	-	2	-	2	0.32	35	5.71	JAPAN
Arbor International, Inc.	-	1	-	1	0.16	3	33.33	VA
Articulate Systems, Inc.	-	1	-	1	0.16	1	100	MA
Asulab S.A.	2	-	-	2	0.32	108	1.85	CH
AT&T Bell Laboratories	5	12	-	17	2.7	4088	0.42	NJ
AT&T Corp.	-	5	-	5	0.79	1205	0.41	NJ
Audio-Technica U.S., Inc.	-	1	-	1	0.16	3	33.33	OH
Bayerische Motoren Werke A.G.	-	1	-	1	0.16	50	2	GERMANY
BBN Corporation	-	1	-	1	0.16	5	20	MA
Bell Atlantic	-	7	-	7	1.11	129	5.42	VA
Bell Canada	-	1	-	1	0.16	12	8.33	CANADA
Bell Telephone Laboratories, Incorporated	3	-	-	3	0.48	2746	0.11	NJ
Bendix Corporation	1	-	-	1	0.16	1171	0.09	MI
Blaupunkt-Werke GmbH	1	-	-	1	0.16	112	0.90	GERMANY
Boston Technology, Inc.	-	2	-	2	0.32	14	14.28	MA
Boston University	-	1	-	1	0.16	184	0.54	MA
British Telecommunications	-	5	1	6	0.95	600	1	UK
Canon Kabushiki Kaisha	2	4	1	7	1.11	15372	0.05	JAPAN
Casio Computer Co., Ltd.	2	3	-	5	0.79	1346	0.37	JAPAN
Clemson University	-	1	-	1	0.16	79	1.26	SC
Creative Technology Limited	-	1	-	1	0.16	1	100	SINGAP.
CSELT- S.p.A.	-	1	-	1	0.16	278	0.36	ITALY
Commonwealth of Australia	1	-	-	1	0.16	143	0.70	AUSTRAL.
Computer Basic Technology Research Assoc.	-	2	-	2	0.32	3	66.6	JAPAN
Custom Command Systems	-	1	-	1	0.16	1	100	MD
Daimler-Benz AG	-	1	-	1	0.16	1696	0.06	GERMANY
Dana Corporation	-	2	-	2	0.32	761	0.26	OH
Dialog Systems, Inc.	4	-	-	4	0.64	5	80	MA
Digital Acoustics, Inc.	-	1	-	1	0.16	1	100	MA
Digital Equipment Corporation	-	2	-	2	0.32	1915	0.10	MA
Dragon Systems, Inc.	-	15	-	15	2.38	15	100	MA
Eastman Kodak Company	-	2	-	2	0.32	10736	0.019	NY
Electric Power Research Institute	-	2	-	2	0.32	728	0.027	CA
Emerson & Stern Associates, Inc.	-	2	1	3	0.48	5	60	CA
Emhart Industries, Inc.	-		1	1	0.16	597	0.17	IN
Envirotest Systems Corp.	-	1	-	1	0.16	5	20	AZ
Ericsson Messaging Systems Inc.	-	1	-	1	0.16	1	100	NY
Excel, Inc.	-	1	-	1	0.16	9	11.10	MA
Exxon Corporation	3		-	3	0.48	3	100	NY
Exxon Research and Engineering Company	2	3	-	5	0.79	1245	0.40	NJ
Faxts-Now, Inc.	-	1	-	1	0.16	1	100	CA
Figgie International, Inc.	-	1	-	1	0.16	33	3.03	VA
First Opinion Corporation	-	2	-	2	0.32	2	100	CA
Florida Probe Corporation	-	1	-	1	0.16	1	100	FL
Fonix Corporation	-	1	-	1	0.16	1	100	UT
Ford Motor Company	-	1	-	1	0.16	4108	0.02	MI
Fuji Xerox Co., Ltd.	2	-	-	2	0.32	1525	0.13	JAPAN
Fujitsu Limited	-	7	2	9	1.43	6883	0.13	JAPAN
General Electric Company	2	-	-	2	0.32	17596	0.01	VA
General Telephone Inc.	1	-	-	1	0.16	1	100	NY

Gold Star Electron Co., Ltd.	-	1	-	1	0.16	37	2.70	S. KOREA
Grumman Aerospace Corporation	-	1	-	1	0.16	699	0.14	NY
GTE Laboratories Incorporated	-	1	-	1	0.16	902	0.11	MA
HAL Trust, L.L.C.	-	1	-	1	0.16	1	100	PA
Hitachi, Ltd.	7	8	8	23	3.65	18880	0.12	JAPAN
Intel Corporation	-	2	-	2	0.32	1888	0.11	CA
Intelligent Business Systems	-	-	1	1	0.16	1	0.16	CT
International Business Machines Corporation	1	39	4	44	6.98	16531	0.27	NY
Interstate Electronics Corp.	2	-	-	2	0.32	11	1.75	CA
Academia Sinica	-	1	-	1	0.16	9	11.10	CHINA
ITT Corporation	1	5	-	6	0.95	847	0.70	NY
ITT Defense Communications	-	2	-	2	0.32	31	0.70	NJ
Kabushiki Kaisha Carrylab	-	1	-	1	0.16	1	6.45	JAPAN
Kabushiki Kaisha Meidensha	-	1	1	2	0.32	204	100	JAPAN
Kabushiki Kaisha Toshiba	-	22	-	22	3.49	11847	0.19	JAPAN
Konica Corp.	-	2	-	2	0.32	1565	0.13	JAPAN
Kor Team International, Inc.	-	1	-	1	0.32	1	100	CA
Kurzweil Applied Intelligence, Inc. ->L&H	-	15	-	15	2.38	19	78.95	MA
Lear Siegler	-	1	-	1	0.16	212	0.47	CA
Loma Linda University Medical Center	-	1	-	1	0.16	24	4.16	CA
LoJack Corporation	-	1	-	1	0.16	1	100	MA
Lucent Technologies Inc.	-	13	-	13	2.06	1118	1.16	NJ
Matsushita Electric Industrial Co	8	14	1	23	3.65	10406	4.34	JAPAN
Medical Research Council	-	2	-	2	0.32	31	0.65	UK
Microsoft Corporation	-	2	-	2	0.32	424	0.47	WA
Milton Bradley Company	1	-	-	1	0.16	4	25	MA
Mitel Corporation	1	-	-	1	0.16	168	0.60	CA
Mitsubishi Denki Kabushiki Kaisha	2	4	-	6	0.95	11328	0.05	JAPAN
Mitsubishi Electric Research Laboratories, Inc.	-	2	-	2	0.32	20	10	MA
Miyagi National College of Technology	-	1	-	1	0.16	2	50	JAPAN
Motorola	-	16	-	16	2.54	10597	0.15	IL
Nartron Corporation	-	1	-	1	0.16	86	1.16	MI
National Aeronautics and Space Administration (NASA)	1	-	-	1	0.16	96	1.05	CA
National Research Council of Canada	-	1	-	1	0.16	29	3.44	CANADA
National Research Development Corporation	-	3	-	3	0.48	1115	0.27	UK
National Semiconductor Corporation	1	-	-	1	0.16	1540	0.07	CA
NCR Corporation	1	-	-	1	0.16	1590	0.06	OH
NEC Corporation	1	16	2	19	3.0	7589	0.25	JAPAN
New York Institute of Technology	-	1	-	1	0.16	52	1.92	NY
Nippon Electric Company, Ltd.	10	-	-	10	1.59	171	5.85	JAPAN
Nippon Hoso Kyokai	-	1	-	1	0.16	220	0.45	JAPAN
Nippon Telegraph & Telephone Public Corporation	1	-	-	1	0.16	419	0.24	JAPAN
Nippondenso Co., Ltd.	-	1	-	1	0.16	2701	0.04	JAPAN
Nissan Motor Company, Limited	11	-	-	11		2596	0.42	JAPAN
Nokia Mobile Phones Ltd.	-	1	-	1	0.16	226	0.44	FINLAND
Northern Telecom Limited	-	2	-	2	0.32	1678	0.12	CANADA
Oki Electric Industry Co., Ltd.	2	7	-	9		1282	0.70	JAPAN
Olivetti	-	1	-	1	0.16	482	0.20	ITALY
Palantir Corporation	-	-	1	1	0.16	10	20	CA
Panasonic Technologies, Inc.	-	2	-	2	0.32	69	2.90	NJ
PhoneMate, Inc.	-	1	-	1	0.16	22	4.55	CA
Philosophers' Stone LLC	-	1	-	1	0.16	2	50	WY
Pioneer Electronic Corporation	-	3	-	3	0.48	2166	0.14	JAPAN
Pitney Bowes Inc.	1	-	-	1	0.16	1234	0.08	PT
Presidenza Dei Consiglio Dei Ministri Del Ministro Per Il Coordinamento Delle Iniziative Per La Ricerca Scientifica E Tecnologica	-	1	-	1	0.16	1	100	ITALY
PSC, Inc.	-	2	-	2		35	5.71	NY
Position Orientation Systems, Inc.	-	1	-	1	0.16	2	50	VT
Purdue Research Foundation	1	-	-	1	0.16	271	0.37	IN
Regie Nationale des Usines Renault	-	1	-	1	0.16	446	0.22	FRANCE
Ricoh Company, Ltd.	-	15	-	15		4042	0.37	JAPAN
Sanyo Electric Co., Ltd.	-	3	-	3	0.48	1755	0.17	JAPAN
Secretary of the Navy US	-	1	-	1	0.16	7011	0.01	DC
Secretary of the Air Force US	-	2	-	2	0.32	3025	0.06	DC
Secretary of State for Industry UK	1	-	-	1	0.16	46	2.17	UK

Scott Instruments Company	1	-	-	1	0.16	4	25	TX
Seiko Epson Corporation	-	1	-	1	0.16	1513	0.07	JAPAN
Semantic Compaction Systems	-	-	1	1	0.16	4	25	PA
Sensory Circuits, Inc.	-	1	-	1	0.16	1	100	CA
Sharp Kabushiki Kaisha	3	5	2	10	1.59	5217	0.19	JAPAN
Sierra Matrix, Inc.	-	1	-	1	0.16	1	100	CA
Siemens Aktiengesellschaft	1	2	-	3	0.48	11607	0.03	GERMANY
Smiths Industries Public Limited Company	-	1	-	1	0.16	174	0.57	UK
Software AG	-		1	1	0.16	3	33.33	GERMANY
Sony Corporation	-	7	1	8	1.27	8165	0.09	JAPAN
Speech Systems, Inc.	-	2	-	2	0.16	3	66.66	CA
SRI International	-	4	-	4	0.63	320	1.25	CA
Societe pour l'Etude et la Fabrication de Circuits Integres Speciaux-EFCIS	1	-	-	1	0.16	2	50	FRANCE
Symbol Technologies, Inc.	-	1	-	1	0.16	281	0.35	NY
Symbolics Inc	-	-	2	2	0.32	7	28.5	MA
Systems Research & Applications Corporation	-	-	2	2	0.32	2	100	VA
Sun Microsystems, Inc.	-	1	-	1	0.16	600	0.16	CA
Sunquest Information Systems, Inc.	-	1	-	1	0.16	2	50	AZ
Technology International Incorporated	-	1	-	1	0.16	10	0.2	LA
Telia AB	-	2	-	2	0.32	16	12.5	SWEDEN
Teradyne, Inc.	-	1	-	1	0.16	110	0.90	MA
Texas Instruments Inc	-	11	1	12	1.90	6409	0.19	TX
Tele Guia Talking Yellow Pages, Inc.	-	2	-	2	0.32	2	100	PR
Threshold Technology, Inc	5	-	-	5	0.79	9	55.5	NJ
Telephonics Corporation	-	1	-	1	0.16	4	25	NY
Tokyo Shibaura Denki Kabushiki Kaisha	6	-	-	6	0.95	2916	0.20	JAPAN
Toyota Jidosha Kogyo Kabushiki Kaisha	1	-	-	1	0.16	1817	0.05	JAPAN
University of Pennsylvania	-	1	-	1	0.16	305	0.32	PA
U.S. Philips Corporation	2	4	-	6	0.95	12337	0.05	NY
Voice Powered Technology International, Inc.	-	2	-	2	0.16	2	100	CA
VCS Industries, Inc. (Voice Control Systems, Inc.)	-	11	-	11	1.75	13	84.61	TX
Voice Processing Corp.	-	1	-	1	0.16	1	100	DC
Worthington Data Solutions	-	1	-	1	0.16	3	33..33	CA
Xerox Corporation	1		-	1	0.16	8148	0.01	CT
Patents granted to private individuals	1	1	-	2	0.32			SWITZERL.
	1	1	-	2	0.32			FL
	3	5	1	9	1.43			WA
	1	9	1	11	1.75			CA
	-	1	-	1	0.16			NH
	-	1	-	1	0.16			GERMANY
	-	2	-	2	0.32			NY
	-	5	-	5	0.79			UK
	-	1	-	1	0.16			CT
	-	2	-	2	0.32			MD
	-	1	-	1	0.16			KS
	-	1	-	1	0.16			MA
	-	1	-	1	0.16			MI
	-	1	-	1	0.16			SPAIN
	-	1	-	1	0.16			FRANCE
	-	1	-	1	0.16			SC
	-	2	-	2	0.32			DC
	-	1	-	1	0.16			IL
	-	1	-	1	0.16			AR
	-	1	-	1	0.16			TX
	-	1	-	1	0.16			NV
	-	1	-	1	0.16			NJ
Total	**145**	**450**	**35**			**266913**		

Notes:
Total number of patents of all firms in ASR&NLP is 630, which is constituted from 145 patents in ASR for the period 1976-87, 450 patents in ASR during the period 1988-97 and 35 patents in NLP during the period 1976-97. From them 49 patents have been granted to private individuals.
Total number of patenting performance of all firms (all sectors) in Appendix A is 266,913.

The following table shows the scientific publications data collected in six major journals for the technological positioning in ASR&NLP with the procedure described in Chapter 3.

Journal Publications in ASR & NLP 1982-97

	ASR in JASA[1] / IEEE Transactions on Speech and Signal Processing[2] / Computer Speech and Language / Speech Communication[3]				NLP in Computational Linguistics, Communications of the ACM, Journal of Artificial Intelligence Research (JAIR)[4]				
	1982-97	Collab.	Total	%	1982-97	Collab.	Total	%	Country or US State
21ST CENTURY TECHNOL INC					1		1		VA
AALBORG UNIV	1		1						DENMARK
ADV MUS NOTAT SYST					1		1		MA
AMALGAMATED SOFTWARE INC					1		1		CA
ANDERSEN CONSULTING					1		1		IL
APPLE COMPUTER					1		1		CA
ARIZONA STATE UNIV	1	5	6						AZ
ATR RESEARCH LABS	6	9	15	3.24					JAPAN
AT&T BELL LABS - LUCENT TECHNOLOGIES	24	9	33	7.14	6	2	8	5.19	NJ
AUBURN UNIV						1	1		AL
AUDIOLOGIC		1	1						CO
BBN LABS					1		1		MA
BELL-NORTHERN RESEARCH	1		1						CANADA
BENTLEY COLL	1		1						MA
BILKENT UNIV					1		1		TURKEY
BOSTON UNIV	2	2	4	0.87					MA
BOYS TOWN NATL RES HOSP	1	1	2						NE
BRIGHAM YOUNG UNIV					1	1	2	1.30	UT
BROOKE ARMY MED CTR		1	1						TX
BROWN UNIV		1	1		1		1		RI
CANON INC	1		1						JAPAN
CARLETON UNIV					1		1		CANADA
CARNEGIE MELLON UNIV	2		2		3	1	4	2.60	PA
CENT INST DEAF	1		1						MO
CLAREMONT UNIV						1	1		CANADA
CLEMSON UNIV					1		1		SC
CNET FRANCE TELECOM	3		3						FRANCE
CNRS,LIMSI	5	2	7	1.52	1		1		FRANCE
COCHLEAR PROPRIETARY LTD		1	1						AUSTRALIA
COMM US ASSOC COMP MACHINERY					1		1		NY
COMMUNICATIONS RESEARCH CENTRE	1		1						CANADA
CORNELL UNIVERSITY					1	1	2	1.30	NY
CTR STUDI & LAB TELECOMUN (CSELT)	2		2						ITALY
CREARE RES & DEV INC		1	1						NH
CUNY, CTR RES SPEECH & HEARING SCI	2	3	5	1.08		1	1		NY
DEAKIN UNIV					2		2	1.30	AUSTRALIA
DEPT VET AFFAIRS MED CTR	1		1						CA
DERA	1	1	2						UK
DIGITAL EQUIPMENT CORP					1	2	3	1.95	CA
DRAGON SYST	1		1						MA
DSP COMMUN	1		1						ISRAEL
DUKE UNI	8	1	9	1.95	1		1		NC
SCI COGNIT & PSYCHOLINGUIST LAB,CNRS	1	1	2						FRANCE
ELTA ELECTR IND LTD						1	1		ISRAEL
ENTROPIC SPEECH INC		1	1						CA
EXPTL DIVING UNIT		1	1						FL
FLORIDA ATLANTIC UNIV					1		1		FL
FRANCE TELECOM	1		1						FRANCE
FREE UNIV AMSTERDAM HOSP	4		4	0.87					NETHERL.
GALLAUDET UNIV	1	1	2						DC
GERMAN RESEARCH CENTRE FOR IA (DFKI)						1	1		GERMANY
GEORGIA INST TECHNOL					1		1		GA
GTE LABS	1		1						MA
HARVARD UNIV		4	4	0.87					MA
HASKINS LABS INC	2	1	3						CT
HELSINKI UNIV TECHNOL		2	2						FINLAND

[1] Years 1982-97
[2] Years 1995-97
[3] Instead of BIDS, ELSEVIER's Speech Communication Online site Elsevier Science http://www.elsevier.nl/locate/specom 1994-1997
[4] Instead of BIDS, Journal of Artificial Intelligence Research http://www.jair.org/home.html site. 1993-1997

HITACHI LTD	1		1						JAPAN
HONG KONG POLYTECH		1	1						CHINA
HOP CANTONAL UNIV GENEVA		1	1						SWITZERLAND
HOUSE EAR RES INST	3		3						CA
HUMAN FACTORS RES INST		1	1						NETHERL.
IBM CORP	3		3		1	3	4	2.60	NY
IDIAP		1	1						SWITZERL.
IND TECHNOL RES INST	1		1						TAIWAN
INDIAN INST SCI	1		1						INDIA
INDIANA UNIV	7	4	11	2.38					IN
INSO CORP					1		1		MA
INST NATL RECH INFORMAT & AUTOMAT		1	1						FRANCE
INST NEW GENERAT COMP TECHNOL						1	1		JAPAN
INST FOR PERCEPTION RESEARCH (IPO)	1	1	2						NETHERL.
INRIA LORRAINE	3	2	5	1.08		1	1		FRANCE
INRS TELECOMMUN	2	1	3						CANADA
INST NATL TELECOMMUN		1	1						EGYPT
IRST	1		1						ITALY
ITT CORP									CA
JOHNS HOPKINS UNIV		1	1		1		1		MD
KPN RES		1	1						NETHERL.
KOBE UNIV		1	1						JAPAN
KOREA ADV INST SCI & TECHNOL	5	1	6	1.30					S. KOREA
KUM-OH NATIONAL INSTITUTE OF TECHNOLOGY		1	1						S. KOREA
LINKOPING UNIV HOSP	1		1						SWEDEN
LOUGHBOROUGH UNIV	2	1	3						UK
LOUISIANA STATE UNIV	1	1	2						LA
LERNOUT & HAUSPIE		2	2						BELGIUM
LOS ALAMOS NATL LAB		1	1						MN
LOYOLA MARYMOUNT UNIV					1		1		CA
MANHATTAN EYE EAR & THROAT HOSP		1	1						NY
MASSACHUSETTS EYE & EAR INFIRM		2	2						MA
MASSACHUSETTS GEN HOSP	1		1						MA
MAX PLANCK INST PSYCHOLINGUIST		1	1						NETHERL.
MCGILL UNIV	1	3	4	0.87					CANADA
MED CTR AUGUSTA		1	1						GA
MED UNIV S CAROLINA	3	3	6	1.30					SC
MEMPHIS STATE UNIV	1	1	2						TN
MICHIGAN STATE UNIV	1		1						MI
MICROELECTR & COMP TECHNOL CORP						2	2	1.30	TX
MICROSOFT CORP	1		1			1	1		WA
MINISTRY COMMUNICATIONS	1	2	3						TAIWAN
MINIST POSTS & TELECOMMUN					1		1		JAPAN
MASSACHUSETTS INSTITUTE OF TECH (MIT)	9	6	15	3.25	1	1	2	1.30	MA
MITRE CORP						2	2	1.30	MA
MITSUBISHI ELECTR CORP					1		1		JAPAN
MORGAN STANLEY & CO					1				NY
MOTOROLA INC	1		1						CA
MRC INST HEARING RES	1		1						UK
NANJING UNIV	1		1						CHINA
NASA					3		3	1.95	CA
NATL CENT UNIV	1		1						TAIWAN
NATL TAIWAN UNIV	2	1	3						TAIWAN
NATL TSING HUA UNIV	1	1	2		1		1		TAIWAN
NATL CHIAO TUNG UNIV	1		1						TAIWAN
NATL UNIV SINGAPORE	1		1			1	1		SINGAPORE
NIPPON ELECT CO (NEC) LTD	1		1						JAPAN
NIPPON TELEGRAPH & TEL (NTT)	4	5	9	1.95	1		1		JAPAN
NORTHEASTERN UNIV	3	1	4						MA
NOVA UNIV					1		1		FL
NYNEX SCI & TECHNOL INC	2		2						NY
OHIO STATE UNIV		3	3		1	2	3	1.95	OH
OLD DOMINION UNIV	2	1	3						VA
OPEN UNIV					1		1		UK
OREGON GRAD INST SCI & TECHNOL	2	1	3						OR
OREGON STATE UNIV						1	1		OR
PANASONIC TECHNOL INC	2		2						CA
PHILIPS RES LAB	5	3	8	1.73					NETHERL.
PRICE WATERHOUSE TECHNOLOGY CENTRE					1		1		CA
POHANG UNIVERSITY	1		1						S. KOREA
PURDUE UNIV		1	1		1		1		IN
QUEENS UNIV		1	1		1		1		CANADA
QUEENS UNIV BELFAST	3		3						N. IRELAND
RENAISSANCE TECHNOL						1	1		NY

RIT RES CORP		1	1						NY
RND NETWORKS LTD	1		1						ISRAEL
ROYAL INST TECHNOL (KTH)	1		1						SWEDWEN
RUTGERS STATE UNIV	1		1			1	1		NJ
SALK INST,COMPUTAT NEUROBIOL LAB	1		1						OH
SAMSUNG ADV INST TECHNOL	2		2						KOREA
SIEMENS					1		1		GERMANY
SIMON FRASER UNIV	1		1		1		1		CANADA
SINAI SAMARITAN MED CTR		1	1						WI
STATE UNIV GHENT	1		1						BELGIUM
SO METHODIST UNIV						1	1		TX
SRI INTERNATIONAL	1	3	4			2	2	1.30	CA
STANFORD UNIV		1	1			1	1		CA
SUMMER INST LINGUIST						1	1		CA
SUNY UNIV		1	1			2	2	1.30	NY
SYST RES & APPLICAT CORP					1		1		VA
SYRACUSE UNIV	1	3	4						NY
TAKENAKA TECH RES LAB		1	1						JAPAN
TATA INST	1	1	2						INDIA
TATUNG INST TECHNOL	1		1						TAIWAN
TECH UNIV CRETE	1	1	2						GREECE
TECH UNIV MUNICH	2	1	3						GERMANY
TECHNION ISRAEL INST TECHNOL					3	3	6	3.90	ISRAEL
TEL AVIV UNIV	1		1		2	2	4	2.60	ISRAEL
TELECOM AUSTRALIA									AUSTRALIA
TELECOM PARIS	2		2						FRANCE
TEXAS A&M UNIV	1		1		1	1	2	1.30	TX
TEXAS INSTRUMENTS INC	1	1	2						TX
TNO,INST PERCEPT	2		2						NETHERL.
TOKYO INST TECHNOL		1	1						JAPAN
TOSHIBA CO LTD	1		1						JAPAN
TU WIEN					1		1		AUSTRIA
UNIV ALABAMA		2	2						AL
UNIV ALBERTA	3		3						CANADA
UNIV AMSTERDAM	1	1	2						NETHERL.
UNIVERSITY ANTWERP		1	1						BELGIUM
UNIV ARKANSAS	1	3	4						AR
UNIVERSITY BIRMINGHAM		1	1						UK
UNIV BOLOGNA		1	1						ITALY
UNIV BORDEAUX		1	1						FRANCE
UNIV BRITISH COLUMBIA	1	2	3			1	1		CANADA
UNIV BRISTOL		1	1			1	1		UK
UNIV CALIF BERKELEY		2	2		1	4	5	3.25	CA
UNIV CALIF LOS ANGELES	6	3	9	1.95					CA
UNIV CAMBRIDGE	8	1	9	1.95		2	2	1.30	UK
UNIV CHICAGO	1		1						IL
UNIV CINCINNATI					1		1		CI
UNIV COLOGNE					1		1		GERMANY
UNIV DELAWARE					1		1		DE
UNIV DUNDEE	1		1						UK
UNIV E ANGLIA	1		1						UK
UNIV EDINBOURG					1		1		UK
UNIV ERLANGEN		1	1						GERMANY
UNIV FIRENZE						1	1		ITALY
UNIV FREIBURG	1		1						GERMANY
UNIV S FLORIDA	1	1	2		1		1		FL
UNIV GENEVA						1	1		SWITZERL.
UNIV GOTTINGEN		1	1						GERMANY
UNIV GRANADA	3		3						SPAIN
UNIV HAMBURG					1		1		GERMANY
UNIV HELSINKI		1	1		1		1		FINLAND
UNIV HONG KONG	1	2	3			1	1		CHINA
UNIV ILLINOIS	1		1		2		2	1.30	IL
UNIV IOWA	2	3	5						IA
UNIV KANSAS		1	1						KS
UNIV KEELE	1		1						UK
UNIV LIVERPOOL		1	1						UK
UNIV MARIBOR	1		1						SLOVENIA
UNIV MASSACHUSETTS	3		3	1					MA
UNIV MARYLAND		1	1		1		1		MD
UNIV MALAGA					1		1		SPAIN
UNIV MELBOURNE	3	1	4	0.87					AUSTRALIA
UNIV MICHIGAN	1	1	2		1		1		MI
UNIV MISSISSIPPI		1	1						TN
UNIV MINNESOTA	5	2	7	1.52	1		1		MN

UNIV MONTANA						1	1		MT
UNIV MONTREAL						1	1		CANADA
UNIV N CAROLINA	4		4	0.87					NC
UNIV NEBRASKA		2	2						NE
UNIV NOTTINGHAM	2		2						UK
UNIV QUEENSLAND	1	1	2						AUSTRALIA
UNIV OLDENBURG	1	1	2						GERMANY
UNIV PADOVA	1		1						ITALY
UNIV PATRAS	1		1						GREECE
UNIV PARIS	1		1						FRANCE
UNIV POLITECN CATALUNYA	2	1	3						SPAIN
UNIV PROVENCE		1	1						FRANCE
UNIV READING	1		1						UK
UNIV ROCHESTER		1	1			1	1		NY
UNIV ROME					1	2	3	1.95	ITALY
UNIV SOUTHAMPTON	1		1						UK
UNIV SHEFFIELD	2	1	3						UK
UNIV SYDNEY	1	1	2		1		1		AUSTRALIA
UNIV SUSSEX	1		1						UK
UNIV TENNESSEE	1		1						TN
UNIV TEXAS	4	1	5	1.08	1		1		TX
UNIV TOKYO	1	1	2		1		1		JAPAN
UNIV TORONTO		1	1			2	2		CANADA
UNIV UTAH		2	2						UT
UNIV UTRECHT	4		4	0.87					NETHERL.
UNIV WAIKATO					1		1		N. ZEALAND
UNIV WASHINGTON		1	1			1	1		WA
UNIV WATERLOO	6	4	10	2.16					CANADA
UNIV WISCONSIN		1	1			3	3	1.95	WI
UNIV WOLLONGONG		1	1						AUSTRALIA
UNIV W. ONTARIO					1		1		CANADA
USAF,INST TECHNOL	1	1	2						OH
VANDERBILT UNIV					1	1	2	1.30	TN
VET ADM MED CTR		1	1						MN
WALTER REED ARMY MED CTR	2	1	3						DC
WASHINGTON UNIV	2	1	3						MO
WAYNE STATE UNIV		1	1						MI
WESTERN MICHIGAN UNIV		1	1						MI
XEROX CORP					1	1	2	1.30	CA
YESHIVA UNIV		1	1						NY
PRIVATE INDIVIDUAL AUTHORS	1	1	2		8		8	5.19	
TOTAL	270 (58.44%)	192 (41.56%)	462		88 (57.14%)	66 (42.86%)	154		

NOTE: Collaborative papers within the same organisation are not counted separetaly.
For multinationals only one country or state is mentioned.
Source BIDS-ISI, ELSEVIER

The following table shows the scientific publications in ICASSP Conferences collected for the technological positioning in ASR&NLP with the procedure described in Chapter 3.

ICASSP PAPERS IN ASR 1982-97

	1982	1983	1986	1987	1988	1990	1991	1992	1993	1994	1996	1997	1982-97	%	Country/ State
AALBORG UNIV								1					1		DENMARK
ALCATEL			1										1		FRANCE
APPLE COMPUTER						1				1			2		CA
ATR RESEARCH LABS					1	2	6	4	5	3	4	1	26	5.64	JAPAN
AT&T BELL LABS			3	9	6	4	3	3		3	2	6	39	8.46	NJ
BBN LABS			3	3	2	2	1	2		2	1		16	3.47	MA
BELL TEL LABS INC		4	1			1							6	1.3	NJ
BOSCH TELECOM											1		1		GERMANY
BOSTON UNIV							1					1	2		MA
BROWN UNIV		1			1		1			1	1		5		RI
CHINESE ACAD SCI						1	1	1			1		4		CHINA
CANON INC												1	1		JAPAN
CARNEGIE MELLON UNIV	2	1	3	2	1	3	8	5	5	3	3	2	38	8.24	PA
CHENGDU INST RADIO ENGN					1								1		CHINA
CNET LANNION A TSS RCP								1					1		FRANCE
CNRS,LIMSI			1							1	1		3		FRANCE
CONCORDIA UNIV			1										1		CANADA
CTR NATL ETUD TELECOMMUN	3						1						4	0.86	FRANCE

CTR RECH INFORMAT MONTREAL							1						1		CANADA
CTR STUDI & LAB TELECOMUN	1		1	1	2								5	1.08	ITALY
DAIMLER BENZ AG						1		1					2		GERMANY
DRA										1	1		2		UK
DRAGON SYST		1	1						2		1		5	1.08	MA
DSP GRP INC							1						1		CA
DUKE UNI									1	1	1		3		NC
ECOLE NATL SUPER TELECOMMUN		1											1		FRANCE
ELECTROTECH LAB								1					1		JAPAN
ELSAG SPA,ELETTRON SAN GIORGIO	2												2		ITALY
ESCUELA TECN			1										1		SPAIN
FAC SCI LUMINY,INTELLIGENCE ARTIFICIELLE GRP	1												1		FRANCE
FAC POLYTECH MONS											1		1		BELGIUM
FRAUNHOFER INST						1							1		GERMANY
FUJITSU LABS LTD							1						1		JAPAN
GEORGIA INST TECHNOL			1		1		2	1					5	1.08	GA
GTE LABS		1	2					1					4		MA
HELSINKI UNIV TECHNOL	1						1	1					3		FINLAND
HEWLETT PACKARD LABS			1										1		CA
HITACHI LTD	1		1								1		3		JAPAN
IBM CORP		1	3	7	5	2		2	2	1	3	1	27	5.85	NY
INDIAN INST SCI										1			1		INDIA
INDIANA UNIV				1									1		IN
INST NATL RECH INFORMAT & AUTOMAT						2	2	1					5	1.08	FRANCE
INRIA LORRAINE										1			1		FRANCE
INRS TELECOMMUN								1					1		CANADA
INST NAT RECH SCI TELECOMMUN						1							1		CANADA
INTEL CORP		1											1		CA
INT COMP SCI INST						1	1	1	2	1	1		7	1.52	CA
INST DEF ANAL,CRD	1												1		NJ
IRISA									1				1		FRANCE
ITT CORP			1		2		1						4		CA
KATHOLIEKE UNIV LEUVEN									1	1	1		3		BELGIUM
KEIO UNIV		1											1		JAPAN
KOREA ADV INST SCI & TECHNOL							1				1	1	3		KOREA
L&H SPEECH PROD								1					1		BELGIUM
LOGICA LTD	1												1		UK
MATRA COMMUN								1		1			3		FRANCE
MARCONI SPEECH & INFORMAT SYST								2					2		UK
MATSUSHITA ELECT IND CO LTD			1	1				1					3		JAPAN
MINISTRY COMMUNICATIONS					1		1	1					3		TAIWAN
MINIST POSTS & TELECOMMUN										1			1		JAPAN
MIT		1	2	1	3	1	1	2		1			12	2.60	MA
MITSUBISHI ELECTR CORP											1		1		JAPAN
MOTOROLA INC											1		1		CA
NAGOYA UNIV				1		1				1		1	4		JAPAN
NATL INST STAND & TECHNOL						1							1		MD
NATL TAIWAN UNIV						1					1		2		TAIWAN
NATL TSING HUA UNIV							1		1				2		TAIWAN
NATL CHIAO TUNG UNIV										1	1		2		TAIWAN
NATL RES COUNCIL CANADA			1	1	2								4		CANADA
NATL UNIV SINGAPORE									1				1		SINGAPORE
NBS			1										1		MD
NIPPON ELECT CO (NEC) LTD		1	3				2		1				7	1.52	JAPAN
NIPPON HOSO KYOKAI			1										1		JAPAN
NIPPON TELEGRAPH & TEL (NTT)			2	2	1			2	1	1		3	12	2.60	JAPAN
NOKIA RES CTR											1	1	2		FINLAND
NORTHEASTERN UNIV				1		1	1						3		MA
NYNEX SCI & TECHNOL INC									2			1	3		NY
OLIVETTI & C SPA			1										1		ITALY
OROS SA					1								1		FRANCE
OSAKA UNIV			1										1		JAPAN
PA TECHNOL			1										1		UK
PANASONIC TECHNOL INC			1	1		2	2		1				7	1.52	CA
PHILIPS RES LAB				1		2	1	2	1	1		1	9	1.95	GERMANY
PURDUE UNIV					1								1		IN
ROYAL INST TECHNOL (KTH)	1		2										3		SWEDWEN
ROYAL SIGNALS & RADAR	1	1			2	1	1						6		UK
RSRE,SPEECH RES UNIT				1									1		UK
RUTGERS STATE UNIV								1	2		2		5		NJ
SCHLUMBERGER PALO ALTO RES				1									1		CA
SHANDONG ENGN INST				1									1		CHINA
SOUTHEAST UNIV									1				1		CHINA

SPEECH SYST INC							1						1		CA
SRI INTERNATIONAL					1	3	1		2	1			8	1.74	CA
STANFORD UNIV	1												1		CA
TATA INST					1								1		INDIA
TECH UNIV MUNICH	1										1		2		GERMANY
TECHNION ISRAEL INST TECHNOL							1						1		ISRAEL
TELECOM AUSTRALIA										1			1		AUSTRALIA
TELECOM PARIS							2	1				1	4		FRANCE
TELEFON INVEST & DESARROLLO											1	1	2		SPAIN
TEXAS INSTRUMENTS INC		1	1							1	1		4		TX
TOHOKU UNIV			1					1	1				3		JAPAN
TOKYO INST TECHNOL								2				1	3		JAPAN
TOYOHASHI UNIV TECHNOL									1				1		JAPAN
TOSHIBA CO LTD							1	1					2		JAPAN
TSING HUA UNIV				1						1			2		CHINA
UNIV BRISTOL								1					1		UK
UNIV CALIF DAVIS					1		1						2		CA
UNIV CALIF LOS ANGELES											1		1		CA
UNIV CAMBRIDGE					1	1	1	1	1	2	3	2	12	2.60	UK
UNIV COLL SWANSEA									1				1		UK
UNIV COLORADO								1					1		CO
UNIV DUBLIN						1							1		IRELAND
UNIV DUISBURG										1			1		GERMANY
UNIV EDINBURGH				1	1	1	1	1					5		UK
UNIV E ANGLIA									1	2			3		UK
UNIV S FLORIDA										1			1		FL
UNIV GRANADA										1			1		SPAIN
UNIV HONG KONG								1		1			2		CHINA
UNIV KARLSRUHE									1	1		3	5		GERMANY
UNIV LJUBLJANA									1				1		SLOVENIA
UNIV QUEBEC								1	2	1			4		QUEBEC
UNIV PARIS							1		1				2		FRANCE
UNIV POLITECN CATALUNYA							1			1		1	3		SPAIN
UNIV POLITECN MADRID						1							1		SPAIN
UNIV ROCHESTER											1		1		NY
UNIV SHEFFIELD			1								1	1	3		UK
UNIV SYDNEY										1			1		AUSTRALIA
UNIV TOKYO			1									1	2		JAPAN
UNIV ULM											1		1		GERMANY
UNIV WATERLOO							1				1		2		CANADA
UNIV WESTERN AUSTRALIA										1			1		AUSTRALIA
UNIV WISCONSIN							1						1		WI
US DEPT DEF		2											2		MD
USN,RES LAB	1												1		DC
VERBEX CORP		3											3		MA
WASEDA UNIV	1	1	1							1			4		JAPAN
XEROX CORP										1			1		CA
YAMANASHI UNIV			1										1		JAPAN
TOTAL	19	22	48	37	38	39	44	51	42	47	43	31	461		

Note: First Authors only mentioned. Data for years 1984, 1985, 1989, 1995 are not available by BIDS.

Briefing sent via email to speech industry technical directors, R&D managers and senior researchers in order to announce the Speech Technological Positioning Survey.

Dear Dr. / Mr./ Mrs. ,

I am a masters student at SPRU - Science & Technology Policy Research. I am undertaking research to examine Corporate Technological Positioning in Automatic Speech Recognition and Natural Language Processing, under the supervision of Prof. Keith Pavitt. The study aims to identify key technologies which will influence the speech products and services market success, with a particular focus on the achievements and the potential of the major players.

In addition to data on patenting and scientific publications the analysis will be based on the opinions of speech technology experts. A worldwide Internet-based survey has been launched for this purpose and I shall be grateful if you will take a few minutes to fill out the questionnaire. This is accessible at:

>> http://www.sussex.ac.uk/Users/prpk6/quest.htm

The details of the responses will remain confidential and will only be used for scientific purposes. No companies or individual names will be mentioned from the answers that will be received.

The aggregate results of the survey will be published and sent to each participant via e-mail (if specified) as soon as my dissertation is finished.

Comments and suggestions are more than welcome. The survey is public, so I would appreciate if you could forward this e-mail to your colleagues or friends in the same or similar organisations.

T H A N K Y O U I N A D V A N C E !

Kindnest Regards,

K. Koumpis

Speech Technologies Survey

For my M.Sc. dissertation at the Science Policy Research Unit (SPRU), under the supervision of Prof. Keith Pavitt, I am studying Corporate Technological Positioning in Automatic Speech Recognition and Natural Language processing. In addition to data on patenting and scientific publications the analysis will be based on the opinions of speech technology experts.

I shall be very grateful if you will take a few minutes to fill out this questionnaire, which was designed to explore the achievement and potential of the major players in these applications.

Please note:

- *The details of the responses will remain **confidential** and will only be used for scientific purposes. No individual or company names will be mentioned from the answers that will be received.*
- *The aggregate results of the survey will be published and sent to each participant via e-mail (if specified) as soon as my dissertation is finished.*

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1. About You

- Name
- Your job title
- Your e-mail address [Only for sender identification and to send back results upon request]

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2. Company Profile

- Company's name
- How the speech technologies department was established?
- Speech technology department size ○ 0-9 ○ 10-49 ○ 50-99 ○ 100+
- How many qualified scientists and engineers are working for speech related projects?
  - Computer Engineers
  - Linguistics Scientists
  - Psychologists / Cognitive Scientists

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3. Products and Services

- Area of products or / and services?

  When your first complete product was launched or expected to be launched?
- Main platforms?
- Which are the major human languages that you are developing or plan to develop applications for?
- Do you see the national environment as favourable (e.g. availability of researchers, language constraints etc.) for your company's activities?

4. Company Linkages and IPR Issues

- Does your company develop speech applications independently or in collaboration with others (e.g. universities, other companies etc.)?
- What skills or capabilities make your company unique today?
- Which methods of collaboration do you use (e.g. joint projects, exchange of researchers, subcontracting etc.)? Were these schemes efficient?
- Which companies compete in the same market as your company?
- Has your company links with other software or hardware companies in order to establish standards in the market?
- Does your company patent or prefer other methods to protect innovation?
- Which are the major sources of finance for your company's research purposes (e.g. venture capital, government schemes etc.)?

5. Personal Opinions

- Which do you identify as key areas of research activity and what is your company's time horizon for meeting these challenges?
- Do you want a copy of my results to be sent to you via e-mail? ○ Yes ○ No
- Any further comments ?

Submit *Reset*

Your contribution is greatly appreciated.
Comments and suggestions are still more than welcome, please send e-mail to k.koumpis@sussex.ac.uk

K. Koumpis @ SPRU