PROCEEDINGS OF THE INTERNATIONAL CONFERENCE
ON FIFTH GENERATION COMPUTER SYSTEMS 1988,
edited by ICOT. © ICOT, 1988

ADVANCED INFORMATION PROCESSING IN ESPRIT - STATUS AND PLANS

Jean-Marie Cadiou

Director - ESPRIT
DG XIII (Telecommunications, Information Industries and Innovation)
Commission of the European Communities
200 rue de la Loi
B-1049 Brussels

1. INTRODUCTION

1.1 ESPRIT

The European Strategic Programme for Research and Development in Information Technology was launched (1) as a 10 year programme of precompetitive R & D in 1984 with three main objectives:

- to promote European industrial cooperation in IT;
- to provide European IT industry with the basic technologies it needs to meet the competitive requirements of the nineties;
- to contribute to the development of internationally accepted standards.

For the first five-year phase of the programme an overall effort of 1.5 billion ECUs[1] was undertaken, 50% of which was borne by the research budget of the European Community, while the participants provided the other half. The programme is implemented by means of public calls for proposals, each of which is based upon a regularly updated workprogramme (2) adopted by the Council.

The areas of research covered during the first phase of ESPRIT were Microelectronics, Software Technology, Advanced Information Processing, Office Systems and Computer Integrated Manufacturing. In these areas, a total of some 230 projects have been launched involving more than 420 different industrial, academic and research organisations. Advanced Information Processing has been the label for a broad range of projects covering Artificial Intelligence, Computer Architecture and External Interfaces.

1.2 Advanced Information Processing (AIP)

40 projects are currently supported by the ESPRIT AIP involving 193 European organisations. Because of the rapid progress being made in AIP, the requirements of research are continuously changing. To ensure that work within ESPRIT is directed into the most appropriate areas regular reassessments of the workprogramme are carried out.

Assessment of the needs of the next generation of AIP systems showed that developments are needed in the following areas:

- applicable knowledge engineering techniques;

- new computer architectures for symbolic and numeric processing and fault tolerant systems;

- advanced system interfaces.

Each of these areas has been addressed within the AIP part of the ESPRIT Programme. Below follows a survey of the work carried out as well as a discussion of plans for building upon this work during the second phase of the programme from 1988 to 1992.

2. CURRENT STATUS

2.1 The Development and Application of Knowledge Engineering

The objective of the work in this domain is to accelerate the successful introduction of knowledge-based systems to a wide variety of application domains within industry. Maximum benefit is thus gained from the use of the fast maturing knowledge engineering techniques both in end-products and in the design, manufacture and maintenance phases of the product lifecycle.

---
1 $ 1.8 billion (June 1988 exchange rate : 1.2 $/ECU)

The approach adopted has been to:

- develop the methods and techniques for knowledge acquisition and knowledge representation;
- develop domain specific systems;
- develop application independent knowledge-based system "shells", supporting languages and user interfaces;
- evaluate knowledge-based systems in the industrial environment.

The main target for recent work has been to encourage wider industrial use of the knowledge-based system shells developed within the programme. This was tackled through a number of actions aimed at evaluating the use of the systems in specific application domains. The domains chosen included disease diagnosis of agricultural crops (project 1063 - INSTIL), financial investment advice (project 316 - ESTEAM), the control and diagnosis of faults in advanced telecommunication switching systems, and the control of electrical power distribution networks (project 387 - KRITIC).

2.1.1 *Knowledge Acquisition and Knowledge Representation*

Of the two main approaches to knowledge acquisition, the more established one is based on interviews with experts. The second is to derive principles from an analysis of case studies and examples.

ESPRIT projects cover both of these approaches. A system for knowledge acquisition by interview was developed in an early ESPRIT project (304), by two industrial partners, STC (UK) and SCS (D), together with the University of Amsterdam (NL) and the University of the South Bank (UK). The system, named Knowledge Acquisition and Structuring or KADS, helps the Knowledge Based System (KBS) designer to structure the interview process, and, by using protocols of expert consultation, to elicit the requisite expertise. The results of the original KADS system have been incorporated by the partners together with a software company, Scicon (UK), into the Process Control Engineering KBS tool kit which was first demonstrated in late '87. KADS is being used within a major German funded national programme, and has supported the analysis phase of KBS development in several commercial projects undertaken by the project partners.

The second approach to knowledge acquisition develops a set of rules from an analysis of relevant examples. GEC (UK), Cognitech (F) and the University of Paris Sud, the three partners of project 1063 (INSTIL), are currently making an industrial evaluation of tools they have developed to support this process. The integrated learning system which forms the kernel of the system is being strengthened by the inclusion of methods for dealing with incomplete problem descriptors and noise. The ability to generate a knowledge base is being tested by a trial application to disease diagnosis in agriculture. The rules that are emerging are being evaluated by experts in this domain.

The target of the knowledge representation work is to bring computer representation of knowledge closer to conceptualisation and expression by systems designers.

The problem is one of representing concepts (and their defining characteristics) and the relationships between them, in a form that allows the application of reasoning processes. Semantic networks, and logic combined with an object-oriented approach, are two knowledge representation formalisms being examined as the basis of possible solutions to the problem of knowledge representation.

Several variants of semantic networks are explored in ESPRIT projects. Project 280 (EUROHELP) has developed a type of semantic network called a generic graph to represent user and information system modules; such models evolve as they adjust to growing expertise on the part of the user, reflecting the system's experience of the interaction and the current usage of the system. A prototype system to provide both instruction and help to users of the UNIX tm mail system has been demonstrated. The first prototype of a generic help system will be available in the Spring of 1988.

Another form of semantic network representation to cope with a more dynamic modification of knowledge, has been studied by Delphi (I), CGE (F) and the Free University of Brussels (B) in project 440 (MADS). This has been partially implemented in the OMEGA expert systems shell now on the market. During 1987 the Knowledge Representation System (KRS) also developed in project 440 was taken to the market by Knowledge Technologies, a small company associated with the Free University of Brussels.

The results gained by the partners CISE (I) and Framentec (F) in project 256 on the representation of qualitative or functional models of complex physical systems, such as power plants, are now the basis of an application-oriented project. This project (820) was launched to design a KBS architecture and tool kit for real-time process control applications and the original partners have been joined by Nea-Lindberg (DK), CAP (F), Ansaldo Impianti (I), and the Heriot Watt University (UK). Prototype applications are in the course of development for three areas: a thermal power plant, a cement manufacturing plant and operator support in the control room of a geostationary satellite.

2.1.2 *The Development of Domain-specific Knowledge-based Systems*

Here we are concerned with systems for specific types of application, viz. manufacturing scheduling, real-time control, and medical diagnosis. Each project combines the application of domain-specific systems with the development of new tools. Some examples are as follows :

A flexible tool package for job shop scheduling is being created by Battelle (D), Aeritalia (I), Italcad (I) and Elsag (I) in project 865. A demonstrator for this project is being used by the aircraft production planners of Aeritalia for operational scheduling of a manufacturing system.

An expert system shell with features to handle the stream of real-time input and output data that arise in the control cycle, has been built on project 857 (GRADIENT) by Computer Resources International (DK), Brown Boveri (D), and the Universities of Kassel (I), Stratchclyde (UK) and Leuven (B).

In project 599, a prototype system has been constructed to assist the consultant in electromyographical diagnosis from the analysis of bioelectrical signals from muscle and nerve tissue. It also advises on the test procedures to be performed. The novel approach adopted combines both causal and probabilistic models for diagnostic purposes, in a single network. Furthermore, it is well-integrated with the equipment and other aspects of the diagnostic system. The team of medical and software partners has successfully taken into account such aspects as user considerations and professional acceptance in the design of the knowledge-based expert system. This system was successfully demonstrated in the Autumn of 1987. One of the partners, Dansk Medico Elektronik (Judex), a computer engineering company working on real-time systems, is incorporating the design of the user interface and the knowledge-based system into its range of medical equipment.

2.1.3 *The Development of Application Independent Knowledge-based System Shells, Support Languages and User Interfaces*

The majority of knowledge-based systems consist of an inference engine, a set of rules, and a database containing domain specific information. For any particular application it is necessary to develop the set of rules and provide the domain specific data. Clearly it would significantly reduce the cost of developing a particular knowledge-based system if a kernel system was available which could be tailored to any specific application domain simply by providing the necessary rules and domain specific information. Knowledge-based system "shells" provide such a kernel, and because of their potential regarding the reduction in development costs of knowledge-based systems they have been given major emphasis within the programme. Two particular systems developed within the programme are already available. The OMEGA shell from project 440 is being marketed by Delphi (I) in Europe, the US and Japan. It is being hosted onto the currently available Portable Common Tool Environment (PCTE)[1], which will be a very useful facility for industrial users.

A second system, the Expert System Builder (ESB) developed in project 96, which provides a complete environment, compares very favourably with the current market leading shells produced in the US.

The efficient implementation of knowledge-based systems has required the development of logic-based programming languages. In Europe the Prolog language has played a prominent role, and the enhancement of Prolog and its integration into appropriate development support environments is of strategic importance to the effective development of knowledge-based systems.

Throughout 1987, steps were taken to achieve a European-wide consensus on a common definition of Prolog and, in parallel with this action, an ISO working group was officially formed.

Prolog III which extends Prolog by the addition of powerful numerical capabilities, has been fully specified in project 1106 by Prof. Colmerauer, the inventor of Prolog, and his team, and a com-

[1] PCTE : a standard set of Software Tool interfaces coming out of the ESPRIT Software Technology area.

plete implementation is available. It is being used in the development of an expert system for the diagnosis of failures in an automobile engine component by Daimler Benz and Bosch.

A further enhancement of Prolog to provide an interface to the international graphics standard, GKS, has been completed in the ACORD project (393) and the impacts of successors to GKS are being taken into account. The aim is to provide a Prolog graphics capability and natural language parsers are being implemented using the enhanced Prolog.

The development of a new logic programming environment consisting of advanced tools (e.g. a rational debugger, a language-oriented editor and a graphics interface) is being undertaken in project 973 (ALPES). Prototype versions have been demonstrated, and their integration is now in progress. Exploitation prospects are being evaluated by the prime contractor, CRIL (F).

Because of the very large amounts of data required in many industrial applications of knowledge engineering techniques it is very important that efficient interfaces are developed which will support effective interaction between the inference engines and the databases.

Within the project 311 (ADKMS), Bull, Nixdorf and Olivetti together with four universities have implemented an interface representation of two natural language parsers with a hybrid knowledge representation system called BACK. One parser is rule-based. The other is based on a linguistic theory which is being implemented in a computer system for the first time.

Techniques that combine rules and relational algebraic expressions are being developed in project 530 (EPSILON). A prototype workstation has been produced which demonstrates the feasibility of using commercially available software tools, in this case UNIX [tm] based Prolog, and a commercially available relational database. In a second work package, a prototype has been developed that connects the database management workstations into an integrated KBMS.

2.2 The Development of New Computer Architectures

The need for high performance computers capable of processing symbolic and numerical information will increase significantly over the next few years as the results of the knowledge engineering work and the advanced man-machine interfaces become embedded into a wide range of applications, eg CAD, office systems. The decision was taken at the outset of the ESPRIT programme, to concentrate on the development of highly parallel architecture machines, and the appropriate software, to achieve the performance levels required. The use of parallelism also gives the additional potential benefit of providing flexible architectures suitable for a large range of system performance. To ensure that a sound basis was provided for the development of these machines one of the first ESPRIT projects (415, PALAVDA) was launched to study the performance of the different approaches to symbolic processing on parallel architecture computers.

The results to date include :

The design of the architecture for parallel object-oriented systems has been completed, and the operating system, the POOL 2 language and its compiler are now available.

The first prototype of a logic machine, based on a Virtual Inference Machine, is now available.

An implementation of a functional parallel programming language (FP 2) is now running, and has been used as a programming language for a parallel inference machine based upon the connection method.

A wide European forum on parallel computing has been established through the organisation of an international conference on parallel architectures and languages.

A particularly important objective in the computer architecture area was to develop a low cost, high performance parallel computing capability. The partners of the Supernode project (1085), Royal Signals and Radar Establishment (UK), Thorn-Emi (UK), APSIS (F), TELMAT (F), INMOS (UK) and the Universities of Grenoble (F) and Southampton (UK), have achieved spectacular results towards this objective, making substantial progress in four key areas:

The <u>basic processing element</u>: a floating point version of the transputer - the T800-20 with 350,000 transistors, and capable of 1.5 MFLOPS - is now commercially available from INMOS.

The <u>interconnection architecture</u> and a non-blocking switch element: a highly modular architecture interconnecting nodes of 20 transputers each, has been designed. The architecture is fully reconfigurable with a project target of up to 64 nodes through the use of software controlled VLSI switches.

Input/output interface components: components are being designed capable of handling data at a rate of 100 Mbytes/sec through a number of 20MHz channels. This allows on-line, real-time handling of high resolution image information, and many other data intensive applications.

System Software: Supernode is currently programmed using OCCAM and versions of the OCCAM support system, TDS. IDRIS, a proprietary version of the emerging standard operating system, POSIX, is also supported. FORTRAN, PASCAL and C are also available. The development of a UNIX tm based operating system and a range of application software to support CAD, numerical applications, etc. is now underway.

This work has already resulted in products available on the market today. In addition to the floating point transputer already mentioned, two lines of minisupercomputer products are now available: the T.NODE series marketed by TELMAT, and the SN1000 series marketed by PARSYS, an offshoot of THORN-EMI set up for that purpose. Full user compatibility is ensured between these two product lines. That performance ranges from 25 MFLOPS to 400 MFLOPS and their prices from $ 60 000 to $ 600 000. The performance/price ratio for these machines appear to be superior to any currently available similar machine by a factor of at least 3. Further enhancements of these machines are planned, up to 1.5 GFLOPS in 1989.

In addition, the Supernode project has investigated applications in domains such as CAD and image processing. One of the partners, APSIS, has developed the Lucky Log simulator for computer aided design which is currently undergoing industrial field trials prior to general release.

A further important aspect of system architecture development is in the field of fault tolerant computing tackled in project 818 (DELTA-4). This project has developed a technique to give a distributed computer system protection against local station failures. The technique involves the addition of a plug-in module developed within the project, which can be added to any machine, whose inputs/outputs ports conform to the ISO/OSI specifications. A distributed system employing these modules can then automatically reconfigure to overcome individual node failures. A multicast communication system implemented on a LAN was demonstrated in early 1987. Demonstrators of a real time UNIX tm prototype and a Remote Service Request prototype have been developed, and work is under way on a Delta-4 system architecture and computational model.

2.3 Development of Advanced System Interfaces

The prime objective of this part of the programme is to achieve computer understanding of the environment from external sensors. The work has concentrated primarily on image processing, natural language understanding and speech processing. Furthermore, the topic of multisensor operation has been added recently to complement the ongoing work, however it is too early to report significant progress from the projects in this field.

2.3.1 *Image Processing*

The initial aim is to develop systems capable of analysing and understanding 2-dimensional and 3-dimensional scenes and sequences of pictures (four-dimensional scenes).

The analysis by computer systems of static 2-dimensional and 3-dimensional scenes and of moving scenes is already finding application in domains such as stress analysis, robotics for computer controlled manufacturing systems and security systems. In the area of 2-dimensional image processing a set of algorithms for the processing of medical X-ray images has been produced in project 26 (SIP). These algorithms are now being implemented in a prototype system which uses an explicit model of the scene (the organisation of the blood vessels) together with knowledge-based reasoning techniques to control the different processing levels. In the areas of 3-dimensional scene analysis and motion the following results are particularly interesting for industrial exploitation :

A portable interactive software environment called VIS to generate or interrogate multiple representations of images or image sequences. The VIS system is currently being evaluated prior to full exploitation.

A low-cost (using off the shelf components) prototype system for depth computation of objects in an industrial scene.

A very fast stereo image processor which is currently being extended into an integrated depth and motion analysis system.

2.3.2 *Natural Language Understanding and Speech Processing*

The most significant results achieved to date have been in the areas of natural language dialogue and the development of speech systems. The feasibility of developing an effective interface between text analysis and speech has been shown by the availability of the functional description of a system and its components providing man-machine dialogue for reference to "yellow pages" directories. This result was achieved within project 1015 (PALABRE) completed in 1987.

In the domain of natural language, two universities within the ACORD project (393), have produced parsers for the French, English and German languages. These parsers together with the deduction component produced within the project are capable of handling complex sentences, e.g. sentences which require pronoun resolution.

The availability of systems capable of understanding continuous speech in noisy environments is a requirement for many application domains. This is a longer-term goal for the programme but already significant progress has been made within restricted domains and controlled environments. Within project 26 (SIP) a stand-alone acoustic front-end is under development, an early prototype of which provides lexical access to a very large vocabulary and is capable of recognising continuous utterances under restricted conditions. Sentence recognition at a speed close to real-time is expected from the system by the end of 1988. This front-end sub-system is currently being connected to a sentence understanding sub-system which uses knowledge-based techniques. The understanding sub-system is being implemented on a parallel machine based on the transputer.

3. PLANS

3.1 Objectives

An independent assessment (3) of the first phase of the ESPRIT programme was carried out. This supported the basic ESPRIT concept of collaborative precompetitive research and suggested new areas of emphasis in information processing. In addition, the review of the workplan involving extensive consultation with industry and academia yielded new insights and recommendations. In particular, it was suggested to combine the two areas of Software Technology and Advanced Information Processing into one in order to better bring out the synergies between the two.

In April 1988 the second phase of the ESPRIT programme was adopted. The total volume of effort planned is 3.2 Billion ECU's[2] , half of which financed from the Community's budget in the years up to 1992, the other half being provided by the participants. About one third of this budget is to be directed towards Information Processing Systems work, the combination of the two previous ST and AIP areas. Such a significant effort is justified and indeed necessary in view of the importance it has to the overall ESPRIT objectives.

The programme of work defined within the Information Processing Systems (IPS) area for the second phase of ESPRIT is aimed at:

- The management and control of systems complexity.
- A reduction in system development and operational costs.
- An improvement in system quality and reliability.
- An increase in system performance.

Four key areas have been identified under which the corresponding work will be implemented :

- System Design
- Knowledge Engineering
- Advanced Systems Architectures
- Speech and Image Understanding and Multi-sensorial Systems

These four areas will now be considered in turn in greater depth to highlight the most important features.

3.2 System Design

The progress made in the first phase of ESPRIT on the development of software engineering environments (notably PCTE) and advanced design methods identified the need for greater emphasis to be given to the support of the development of systems

[2] $ 3.84 Billion at June 1988 exchange rate

incorporating hardware, software and knowledge-based components. This requirement was evident from the experience which showed that many of the problems associated with complex IT products were due to industry's inability to adequately describe the system requirements and to validate the higher levels of design. Work will now be targeted to future generations of IT products which will require levels of complexity which are far greater than those available today. This increase in complexity will be evident in the functonality of the systems, their size, performance and connectivity.

3.2.1 *System Development*

This work is expected to involve nearly all the major industrial concerns in Europe with expertise in this field. The opportunity will be taken to develop strong links between related Community and other European projects. The use of knowledge engineering (KE) techniques to support the development of complex systems will receive special consideration as will the development of an advanced system engineering environment providing the technical infrastructure for the integration of hardware, software and knowledge-based computer aided design tools.

3.2.2 *System Enhancement/Maintenance and Component Reusability*

The main objective of work under this heading is the reduction of costs associated with the post delivery phases of a product lifecycle, increase in product quality and increase in design productivity. An important and related objective of this part of the work is the capability to reuse existing, tested, system components.

3.2.3 *Evaluation and Management*

To enable fast transfer of system design and maintenance/enhancement methods and tools into product divisions of industry, results emerging from the pre-competitive projects will be fully evaluated within industrial environments. The evaluation work started in the first phase of the programme will be reinforced as the programme matures.

3.3 Knowledge Engineering

The central role that Knowledge Engineering is beginning to have in both support activities and end products puts even greater emphasis on the need for European industry to have a good command of the use of this technology. Through the first phase of ESPRIT and some national initiatives, European industry now has access to good Intelligent Knowledge-Based System (IKBS) development tools and some early results of the use of Knowledge-Based systems in the industrial environment. The technology transfer activities will now be reinforced which will require both further evaluation trials and further development of the technology for use in real-time applications and in ever more complex target systems.

Particular emphasis will be given at this stage to a number of topics which are considered in more detail below.

3.3.1 *Real-time and Cooperating Knowledge-based Systems*

Work will be carried out in Knowledge-Based techniques for real-time applications and the ability for Knowledge-Based Systems (KBS) to cooperate to solve complex problems in order to open up a broad area of application domains and to stimulate further advancement of Knowledge Engineering methods. In particular, further work will be carried out to develop techniques and tools for real-time KBS including KBS applied to signal understanding.

3.3.2 *Industrialisation of Knowledge-based Systems*

The aim of the work in this area is the development of means by which industry will be able to build large, efficient and reliable knowledge-based systems. The main topics to be covered are:

- KBS lifecycle;
- Performance evaluation of KBS;
- Man-machine interface for KBS;
- Development, maintenance and use of large knowledge bases.
- Enhancement of existing, more conventional, systems with knowledge-based components, eg. for "intelligent"access to large databases.

3.3.3 *Topics for Directed Research*

Four topics have been identified for further study to assist in the industrial development and exploitation of KBS. These areas are:

- Explanation facilities;

- Time-dependent reasoning;

- Machine learning;

- Knowledge elicitation and aquisition.

3.4 Advanced System Architectures

Given that the availability of high performance computers to European industry is a central requirement to the development of a strong IT industry in Europe, the work on advanced system architectures will be given particular emphasis in the second phase of ESPRIT.

Emphasis is given to the development of highly parallel machine architectures and exploitation of concurrency generally. Further development of the Supernode architecture and the develpoment of appropriate operating systems, PCTE-based development support environments for a range of programming languages and application software will be addressed. The exploitation of parallelism will be a central theme.

3.4.1 *High Performance Computing*

The goal is to enable the European computer industry to operate successfully in the market for supply of high-performance low cost computers.

The recognition that the next generation of machines will need to support efficiently both symbolic and numerical applications provides an opportunity for European suppliers to enter into the world market for high-performance, low-cost, computers, which in the past, has been driven by the major US computer suppliers. For these high-performance low-cost machines Europe now has the technology to forge a strong position of its own, with the intention of bringing the basic cost per MFLOPS (or equivalent) down by a factor of ten.

3.4.2 *Support for Parallel Architecture Computers*

Wide industrial acceptance and use of parallel architecture computers will be critically dependent upon the range of system and application software available to the application developers and end users. Consequently, within this area of the ESPRIT programme, the techniques and tools will be developed to fully exploit the hardware architecture to achieve the highest possible performance and reliability for a range of diverse application domains. The workprogramme has been defined so as to identify the developments in the operating systems to efficiently manage the resources of the highly parallel machines, the development of the design support methods and tools and appropriate environments, and, where necessary, the further development of high level languages.

3.4.3 *Fault Tolerant Architectures*

The capability of computing systems to operate correctly in the presence of errors and faults is a pre-requisite in many safety critical and other domains. The work on advanced system architectures for current and future generation computing systems will therefore take fully into account the fault tolerance requirements. To achieve these requirements work will be carried out on the target machine architectures themselves as well as the appropriate techniques and tools to be used during the system design phase.

3.4.4 *Neural Computing*

Interest in this new field of computing is rising strongly and a pilot programme of work is being considered to:

- Assess the maturity of neural computing for industrial applicatons;

- Develop the technical foundations for a more strategic action in the future.

3.5 Speech and Image Understanding and Multi-sensorial Systems

The main aim of the work in this domain is the development of the concept and design tools for use in meeting the substantial industrial demand for complex signal processing and control systems.

In the longer term the requirement will be for more generic speech and image processing and multi-sensorial techniques which are not constrained by particular application domain factors. However, in the shorter-term work will be focused on the design and development of signal analysis systems for speech, vision and muti-sensor signals which can operate effectively in the fields of robotics, manufacturing, process control, medecine, etc. These current signal analysis systems are primarily application specific and of low complexity compared to the needs of the next generation systems. The longer term work will proceed via the integration of a number of technologies to provide powerful numerical computation capabilities, symbolic processing and reasoning capabilities.

This part of the Information Processing Systems sector of the ESPRIT programme provides the opportunity to pull-through much of the technology work underway in the rest of the sector. Speech, vision, and multi-sensorial systems require not just the development of a single technology, but also the effective integration of all of the technologies covered by the programme.

3.5.1 *Speech*

The main objectives of this part of the workprogramme are the development of continuous speech understanding systems, speaker indepenNdent recognition of a medium size vocabulary and the development of dialogue workstations for industrial use.

3.5.2 *Image Understanding*

The emphasis in the second phase of ESPRIT will be placed on the development of versatile, flexible, vision systems; versatility in regard to the interpretation of fast changing image scenes and flexibility to ensure that the user is able to adapt the system to a range of different tasks. Also the movement from low and medium level vision processing to a high level image understanding in two and three dimensions will be specifically addressed.

In the shorter term the objective of utilising the already available algorithms and processing technology to realise complete vision systems will be addressed. In the longer term techniques for handling moving senes in real-time will be developed, and the necessary projects to provide methods and tools to develop systems capable of operating in real-time will be launched in time for use in later phases of the programme.

3.5.3 *Multi-sensorial Systems*

The main goal of the work in muti-sensorial systems is the develpoment of the approNpriate methodology and support tools for the design of a wide range of application independent muti-sensorial signal processing systems. In particular the work will cover:

- The development of methods, tools and archigtectures;

- The development of tools for the fusion of information flow from numerous heterogeneous signal channels;

- The definition of models for information extraction;

- The development of a methodology for knowledge base generation.

4. CONCLUSION

The first phase of ESPRIT has demonstrated the feasibility and importance of industrial cooperation across borders in the European context. Such a cooperation in precompetitive R&D, augmented by a substantial element of academic participation, is having a profound effect on how the Information Technology Community in Europe is viewing its future. These cooperations are already providing building blocks in several areas, notably expert systems and paralNlel architectures.

In the years that lie ahead, the European IT industry will need to build on these foundations and integrate the results already obtained in order to meet the competitive requirements of the 1990's.

5. REFERENCES

(1) Official Journal of the European Communities L69 9.3 1984, page 54.

(2) ESPRIT Workprogramme, CEC, 22 July 1987.

(3) The Mid-Term Review of ESPRIT, CEC, 15 October 1985.

(4) ESPRIT; the First Phase: Progress and Results; EUR 10940; CEC 1987.

(5) ESPRIT Annual Report 87.

(6) Proceedings of the 3rd Annual ESPRIT Conference 1986 - Results and Achievements, North Holland, 1987

(7) Proceedings of the 4th Annual ESPRIT Conference 1987 - Achievements and Impact, North Holland, 1987