RESEARCH IN PROGRESS

Artificial Intelligence Research in Australia--A Profile

Elizabeth Smith and John Whitelaw

Does the United States have a 51st state called Australia? A superficial look at the artificial intelligence (AI) research being done here could give that impression A look beneath the surface, though, indicates some fundamental differences and reveals a dynamic and rapidly expanding AI community General awareness of the Australian AI research community has been growing slowly for some time. AI was once considered a bit esoteric--the domain of an almost lunatic fringe--but the large government-backed programs overseas, as well as an appreciation of the significance of AI products and their potential impact on the community, have led to a reassessment of this image and to a concerted attempt to discover how Australia is to contribute to the world AI research effort and how the country is to benefit from it What we have seen as a result is not an incremental creep of AI awareness in Australia but a quantum leap with significantindustry and government support

The first systematic study of the Australian AI effort was undertaken by the Australian Department of Science (DOS) in 1986 The study took as its base the long-running research report Artificial Intelligence in Australia (AIIA), produced by John Debenham (1986) The picture that emerged is interesting. AI researchers are well qualified, undertaking research at the leading edge in their fields, and have significant potential to develop further The results of this study were published by DOS in the Handbook of Research and Researchers in Artificial Intelligence in Australia (Department of Science 1986). This article is based on key findings from the study and on additional information gained through meeting and talking with researchers and research groups

AI Researchers--What Do They Look Like?

The Australian research community is relatively large in number, widely dispersed, and dynamic. Also, it is not centered around any single major program, such as the Alvey program in the United Kingdom.

Australia covers an area of land a little smaller than the United States, with a population of about 16 million. AI researchers can be found in all six states and the Australian Capital Territory. Most of the AI community is concentrated in the major cities (Sydney, Melbourne, Canberra, Brisbane, Adelaide, and Perth), 16 of Australia's 20 universities, 12 other tertiary-education institutions, 12 government-based research institutions, and many private companies. The widespread nature of the community could lead to physical isolation, but it doesn't. An extensive program of conferences, seminars, and workshops is conducted as well as formal and informal networks and established research groups (discussed later).

A key element in drawing the strands together is the Australian Computer Society's National Committee on Artificial Intelligence and Expert Systems (ACS/AI&ES). Its role is similar to that of AAAI: to stimulate and promote AI in the community, bring together the differing interests in AI, support colloquia in the general field of AI, and provide a mechanism for presenting coherent views on AI to government.

Also, the AI community loses little to distance and apparent isolation from the "rest of the world " A rich collaboration exists with researchers at major AI laboratories around the world, and many of the prominent researchers in Australia have spent time at these labs. The cycle continues, and today we find many expatriate Australians at these laboratories.

Active promotion of conferences goes on in Australia, and prominent researchers from overseas can be found in the lists of keynote speakers. Australian researchers are regular participants in the well-known international conferences

All this does not mean that the geographic separation has not had an impact on the Australian research scene. Indeed, it has been a significant influence in Australia in developing the character of AI and its programs. This separation is reflected, too, in the qualifications that researchers bring to AI.

The path followed by researchers to get to their present involvement in AI varies, but a high percentage of the researchers have their first degree in the hard sciences and engineering. This condition is due in part to the fact that before the mid-1970s, computing was often taught in these disciplines rather than as a separate subject. This situation differs in the United States where psychology and the social sciences figure prominently. Few Australians have formal AI qualifications because the trend toward teaching AI as part of an undergraduate program is recent, although well under way.

Although AI research activity is on a different scale from that in the Unit-

ed States or Europe, it must be viewed in the context of a small population and a gross national product of about $A243 billion (or $175 billion U.S. - based on 9 April 1987 exchange rate). In this context, the level of activity is not disproportionate, and the quality is great.

Most research activity is centered in tertiary education (for example, universities and technology institutes), with a smaller percentage working in public-sector research institutes (such as the Commonwealth Scientific and Industrial Research Organization [CSIRO]). However, the level of activity in private industry is increasing (an encouraging response because involvement by Australian industry in research is historically very low). Once again, this situation differs from that in the United States and Europe.

AI Research Interests and Potential

This section is intended to give a flavor of Australian research, not a detailed or technical review. Full coverage of the range of projects in Australia is not possible; we touch on some research efforts as examples, and details on these efforts can be sought directly from the researchers (see "Project Contacts). (The omission of projects does not reflect on their quality but is a reflection of the constraints of the article.)

Interest and activity are primarily in four major AI areas[1]:

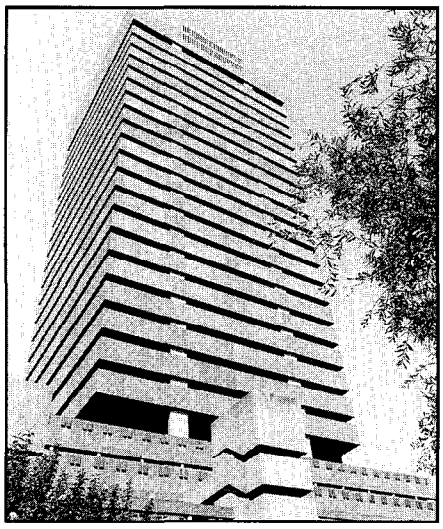
- Knowledge-Based Systems (KBS) (combining knowledge bases, knowledge acquisition and representation, expert systems, and knowledge engineering)
- Inference Systems Software (ISS) (combining computational logic, automatic theorem proving, logic-programming languages and metatheory, AI programming systems, and programming synthesis)
- Machine Perception (combining natural language comprehension, pattern recognition, image understanding, and speech recognition and understanding)
- Simulation of Behavior (combining intelligent computer-assisted instruction and cognitive modeling).

In terms of capability, numbers and immediate potential, KBS is the area of greatest activity, followed by ISS, Machine Perception and Simulation of Behavior. Most researchers are interested in more than one area at different levels of involvement.

Knowledge-Based Systems

Expert systems and KBS have been the subject of a couple of overview studies in recent years. Both showed not only the range of research in the area but also the extent to which expert systems and KBS are being incorporated into operations.

Given the potential for (relatively) short-term returns, KBS is the field in which Australian industry is most involved at this stage. This involvement usually takes one of two forms. First, some companies commission the development of an expert system to solve an in-house problem (for example, the impending retirement of key staff); only a few large companies have their own research and development (R&D) capacity in AI. However, second, KBS is one of the fields in which R&D is performed on a commercial basis by several of Australia's leading software houses, such as Scientia Computing, Computer Power, Aspect, BBJ, and Computer Sciences of Australia.



New South Wales Institute of Technology, Broadway Campus.

Researchers in tertiary education institutions and CSIRO are also active in KBS research. Applications include environmental management; process control; interpretation of regulations and legislation; and financial, construction, and medical applications. Because considerable interest has been noted from both researchers and users, we can expect to see a considerable expansion in this area in the near future.

Examples of Expert System Research in Progress

At the Australian National University (ANU) in the Department of Computer Science, Dr. Robin Stanton and a group of researchers are working on REEFPLAN. This expert system for planning and managing environmental activities in the Great Barrier Reef uses legislation-style rules, the deductive consequences of which are made visible on screen using graphics; it has required advances in rule-representation languages to cope with the kind of rules used. The system allows the detection of completeness and consistency.

At the University of Sydney in the Architectural Computing Unit, a large group under Professor John Gero is working on knowledge-based design systems. A number of related projects investigate design interpretation using expert systems to interface with commercial computer-aided design systems for design synthesis through generative knowledge, learning from existing designs, and inferring design languages from existing designs.

Ross Quinlan at the New South Wales Institute of Technology (NSWIT) has been a leading force in expert system research in Australia. His work on ID3 was a turning point in the approach to decision trees. The algorithm is in the public domain and has been used extensively in commercial packages, such as Expert-Ease. Its influence, directly and as an activity generator, is evident in much of the induction research going on today.

At the University of New South Wales (UNSW), also in Sydney, Claude Sammut's program MARVIN has been developed to learn concepts by asking questions of a human trainer. Sammut

is now extending MARVIN to provide facilities for interviewing an expert using natural language, thus building its own set of rules for the expert problem solver.

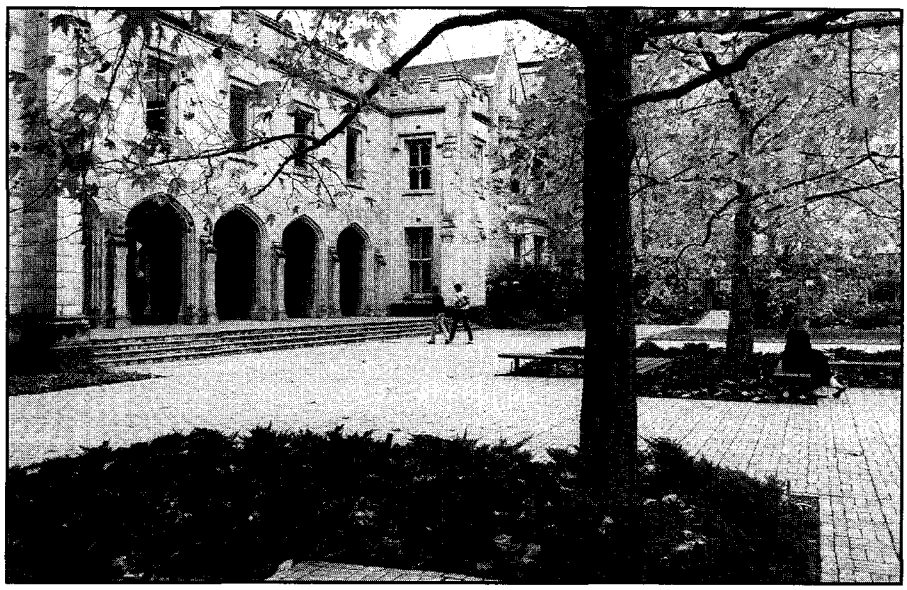
Quinlan, Debenham, and Sammut, along with other researchers from NSWIT, the three universities in Sydney, and industry, make up the Sydney Expert Systems Group. Rather than working on an application-specific expert system, the group is developing the expert systems workbench, a hybrid shell featuring a variety of plausible reasoning mechanisms and knowledge-acquisition modules that together encompass most facilities available in the better-known commercial packages. Its features will make it very attractive for application development and for teaching.

At Deakin University, Brian Garner is extending the work of Sowa in studying the scope and limitations of canonical graph models for commercial and industrial AI applications. At the CSIRO Division of Building Research in Melbourne, systems are being developed to check building designs for compliance with structural design codes and building regulations. The potential application to planning and approval mechanisms is obvious. The Australian Department of Defense is also undertaking research, mainly in KBS applications, including fault diagnosis in mechanical systems, information assessment, and resource management.

In the private sector, R&D in expert systems is expanding rapidly. BHP has developed a system for monitoring the sintering process in steel production. Lend Lease has contracted Digital to develop a KBS to capture the expertise of one of its senior-management members whose retirement is imminent, the intention being to have his expertise available at all Lend Lease sites in Australia.

Inferencing System Software

After KBS, ISS is the area most frequently identified as having an established capability. It is interesting to note that a high proportion of ISS's recognition comes from those researchers who are active outside the area.



Photograph courtesy of Norman Wodetzki, Queensberry Photography

University of Melbourne

Possibly the best-known group working in ISS is the Logic-Programming Group built around John Lloyd and Kotagiri Ramamohanarao at the University of Melbourne. One of their projects is Nu-Prolog. This language is more expressive than other Prolog languages, giving a greater opportunity to be declarative; it includes a database facility that allows storage and availability of a very large amount of data with a sophisticated indexing scheme, and it contains a coroutining facility so that in many cases the system automatically generates the coroutining information.

At UNSW, the UNSW AI Group, coordinated by Claude Sammut, is undertaking a number of projects. In the logic-programming area, the group has developed UNSW Prolog and is working on a microprogrammed Prolog machine and fast memory-access hardware.

Automatic theorem proving is the theme of a project at the Australian National University Research School of Social Sciences (RSSS). The approach is to develop a class of automated reasoning systems that are expressive and sophisticated and more accurately model reasoning than is possible with the elementary automated theorem-proving systems.

In the context of ISS, it should be noted that the trend in recent times has been away from Lisp. The emphasis is very much on the use of Prolog in different versions.

Machine Perception

Major projects in this area are in speech recognition, computer vision, and robotics. The AI research being undertaken in the Computer Vision and Robotics Laboratory with Ray Jarvis in the Department of Electrical Engineering at Monash University comes under the general title of intelligent sensory-based robotics. The research is concerned with robotic vision, range sensing, trajectory planning, and navigation for multijointed robotic manipulators and automatic guided vehicles (mobile robots). In both cases, mapping the environment using sensory data (vision and range) and planning and controlling goal-directed action within this environment are involved, with intensive computational support required throughout.

Robots of a different kind are prominent in the AI scene in Western Australia, be they shearing sheep with James Trevelyan at the University of Western Australia or deboning carcasses at the Curtin University of Technology. Both efforts have captured the public's imagination (and considerable funding).

FOPHO and Dicma are two major

projects carried by Mary O'Kane's group at the School of Information Sciences and Engineering at CCAE. The first aim is to build an automatic speech-recognition system using expertise capture techniques (in this case, the auditory and visual expertise of a phonetician transcribing in a foreign language). The second project is an attempt to build a dictating machine that will accept continuous speech input of commercial correspondence; much of the speech-recognition problem is here turned into the easier problem of word location and verification.

Simulation of Behavior

This area is less well recognized than machine perception as one of established capability. Its commercial potential is expected to be in the short term, that is within five years, rather than in the long term.

A major project in intelligent computer aided learning (ICAL) is coordinated by Tom Richards. Called EXCALIBUR, the project is collaborative and multidisciplinary. One of the aims of the project is to research the problems of designing a general-purpose ICAL authoring and engineering shell; another aim is to use ICAL delivery systems as an experimental medium for exploring cognitive modeling, especially in learning theory.

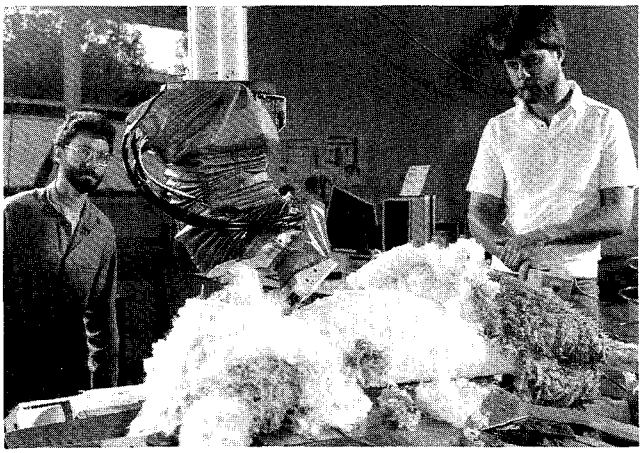
Perceived Research Needs

Many of the factors affecting the AI research community are common to other areas of science. Any research area can do with more funds; AI is no exception. However, inadequate funds for equipment and postgraduate study stand out.

Further, the boom in activity in AI has accentuated the urgent need for additional appropriately trained researchers (and funding to employ them). The problem is particularly acute in tertiary institutions that often do not have the flexibility to compete with market forces.

Communication and Linking between Researchers

We referred earlier to the geographic dispersion of Australian researchers and some of the ways it is overcome. The development of identifiable groups has been a significant factor in addition to networking and making the most of conferences.



Photograph courtesy the Australian Wool Corporation

Mr. Peter Kovesi (left) and Mr. Stewart Key research engineers with the automated sheep shearing project, watching the newly completed SM robot undergoing trials. Only the lower part of the arm is visible in this photograph. The upper part of the arm is pivoted to a carriage which slides along rails attached to the ceiling The robot wrist mechanism is hidden by the flexible covering and has been specially designed for sheep shearing. It has no kinematic singularities within its large angular workspace. This considerably simplifies the design of software and greatly extends the robot's usable workspace volume.

Although these groups are very effective, there is a cost in the time, money, and energy it takes to maintain them. It is a very different situation from wandering down the corridor in a large laboratory to discuss a problem with your colleague over a cup of coffee. The nature of the groups has been tailored to meet differing requirements: they vary in size, diversity, formality, and cohesiveness, but they all encourage the sharing of ideas and the stimulation of research. (Groups that have not been referred to in relation to specific projects are listed in the section Australian AI Groups.)

The Sydney Expert Systems Group mentioned earlier is one of the larger, more established groups and an important focus for collaboration. It includes researchers at NSWIT, the University of Sydney, UNSW, and Macquarie University, and it has a strong industry base, including members from Scientia Computing, John Lysaght Ltd., and Nucleus. It also collaborates with other groups on joint projects, for example, the Garvan Institute of Medical Research, CSIRO Division of Physics, and major commercial firms. One of its major projects is the expert system workbench referred to earlier. The successful series of conferences on the applications of expert systems is another of the group's initiatives.

In contrast, the Canberra Region Artificial Intelligence Group (CRAIG) is not only recently established but also loosely knit. Its members come from ANU, the Canberra College of Advanced Education, the Australian Defense Forces Academy, industry, and a number of government agencies (including CSIRO). Individuals within CRAIG are collaborating on research projects, but CRAIG is not the focus of their collaboration.

There are other similar regionally based groups, such as the West Australian Expert Systems Special Interest Group and the South Australian Knowledge Engineering Group. In Victoria, the Knowledge Engineers' Association has been formed, with an Australiawide membership base.

Another kind of group focuses on the research activity of a single department but reaches out to other institutions. For example, the Logic Programming Group at the University of Melbourne is based firmly in the Department of Computer Science, but it has

links to the CSIRO Divisions of Building Research and Information Technology and works closely with researchers at Monash University and the Royal Melbourne Institute of Technology. Professor Gero's group at Sydney University, although based in the Architectural Computing Unit, links into the Department of Civil and Mechanical Engineering on specific projects.

The EXCALIBUR project takes yet another approach. A group of people with related interests in five universities in three states (and, hence, widely separated physically) have defined a project in which they can bring their related interest together despite their dispersion.

Links also exist into areas that are not primarily concerned with AI, for example, computer-assisted instruction, robotics, and speech. These efforts are either conducted at the researcher level or through the respective discipline's associations.

The role of the Australian Computer Society's National Committee on AI and Expert Systems was discussed earlier, but other professional associations exist with memberships that have varying degrees of interest in AI. These groups include the Institution of Engineers, Australia, the Australian Speech Research Association, and the Australian Robot Association. Considerable collaboration goes on between these associations on a variety of issues affecting the AI community. (There are more groups active at varying levels of intensity than can be described in any useful way here. That some have not been included should not be seen as any criticism of their status and achievements.)

Computer Networking

The CSIRO Division of Information Technology has recently undertaken a review of academic and research networking in Australia (Hales and Richards 1987). The review shows that the Australian network has grown differently from those elsewhere. In the United States, the European Economic Community, and the United Kingdom, networks have developed with the aid of special grants and agencies. In Australia, the two major networks are CSIRONET and ACSnet (Australian computer science network). ACSnet is described here because it is the one principally used by AI researchers. Some smaller networks also exist.

ASCnet is a store-and-forward message-handling network. It provides multiplexing facilities across network connections, and provides facilities equivalent to Layers 4 to 7 of the OSI Reference model.

Developed primarily at Sydney University, ASCnet is not a commercial product; software is distributed at nominal cost to academic and research sites. All true ACSnet hosts run the Unix operating system, which is used in most academic institutions, CSIRO Divisions, and some private research organizations. Non-Unix machines can attach as foreign nodes. ACSnet is closely related to the UUCP network between Unix machines in the U.S., and several ACSnet nodes provide gateways into UUCP and Arpanet.

South Pacific Educational and Research Network (Spearnet) is a new network using Colored Book Protocols (developed as part of the United Kingdom academic network JANET). It is an initiative by a number of university computer centers. A variety of other private networks have also been established over wide areas.

Computer Resources

Computing facilities can vary widely between institutions. Two computer science departments are discussed here

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to describe the character of what is typical. AI laboratories are generally based on Unix. Little use has been made of Lisp machines. Sun workstations, however, have been heavily utilized.

The University of Melbourne's Department of Computer Science is mainly Unix based and operates a Vax 11/780, a Perkin Elmer 3240, Elxsi, and various minis. These machines provide computing facilities for both teaching and research. The Logic Programming Group (under Dr. John Lloyd and Dr. K. R. Rao) recently received a grant to purchase a cluster of four or five dedicated SUN III workstations. Networking within the University is based on Ethernet; external connections (primarily through the Department of Computer Science) are part of ACSnet with an Austpac connection for overseas traffic into UUCP, the EAN X.400 network, JANET, EARN, and Indonet.

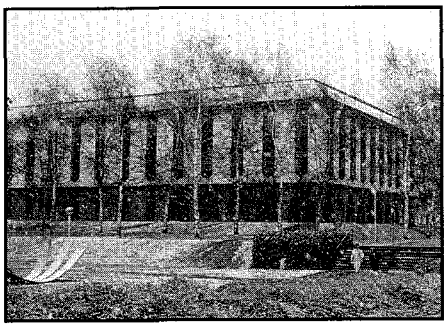
The Sydney Expert Systems Group (under Dr. Ross Quinlan) purchased a Pyramid 90X from the profits of its Applications of Expert Systems conferences. The computer is located at NSWIT and dedicated to use by the group. The group includes members from the three universities in Sydney, the institute, and private industry, all of which have Unix facilities. The group is implementing a leased-line link between the institute and the University of Sydney, and a line-of-sight laser link to UNSW.

Conferences

The number of major conferences being held in Australia and the extensive attendance at these meetings, is a good indicator of the level of activity in AI. AI has been a major stream in computing conferences, such as those held annually by the Australian Computer Society. However, conferences are now being held which focus specifically on AI and which seek to draw together researchers and users of AI.

Specialized topics are also attractive for conferences. Most prominent in the specialist conferences have been the annual conferences on the applications of expert systems, organized by the Sydney Expert Systems Group. The first meeting was held in 1985, and the third was held in May of this year. These conferences attract increasing international and local interest and bring together people from academic research environments and industry. Keynote speakers have included eminent international authorities such as Donald Michie (Turing Institute), Donald Waterman (Rand Corporation), and Patrick Winston (Massachusetts Institute of Technology).

Canberra was the venue in November 1986 for the First Australian Conference on Speech Science and Technology with keynote speakers John



Photograph courtesy of Bob Cooper

Snowing on campus, Australian National University, Canberra.

Laver and Louis Pols. The International Federation for Information Processing (IFIP) International Working Conference on Expert Systems in Computer-Aided Design was held near Sydney in February 1987, sponsored by Sydney University, cosponsored by AAAI, and coordinated by the Department of Architectural Science and Professor Gero of IFIP. Also in the specialist line were the seminars on Expert Systems in Engineering, Architecture, Business, and Government (February 1987) and the CSIRO Expert Systems Seminar in September 1986.

Conferences scheduled for 1987 include the Fourth International Conference on Logic Programming (held at the University of Melbourne in May under the auspices of its Logic-Programming Group and the Department of Computer Science), the Australian Computing Conference (ACC-87) (to be held in Melbourne in September), and the Australian Joint Artificial Intelligence Conference (AI'87) (to be held in November in Sydney).

Government Activity in AI Research

The recent growth in interest in AI is fueling, and being fueled by, the increased exchange of information in AI. Although a great deal of this interest is generated from within the AI community, government bodies have taken a role in encouraging activity in the AI area.

The Australian government has recognized the importance of AI both to Australia and in the international context, and the federal Minister for Science, Barry Jones, has been active in encouraging and promoting AI research. His department, as part of its general brief to stimulate scientific R&D in industry, government, and academic sectors, supports research projects directly and promotes communication within the research community and between it and the wider world.

The Machine Intelligence Project (MIP) and the Australian Research Grants Scheme (ARGS)--AI has been identificd as a priority area under ARGS--are the two major avenues for directing funding support. MIP supports research at the University of Melbourne, NSWIT, and Monash University. Funding has been limited especially compared with international research programs--$A550,000 ($396,000 U.S.) to date for MIP and about $A286,000 ($206,000 U.S.) provided in 1986 through ARGS; nevertheless, results have been encouraging, both in advancing research and supporting research capability.

The department's indirect role is largely a coordinating one. In this role, the department has been able to assist in bringing together divergent elements from industry and different segments of academia in forums such as ACS/AI&ES. In addition, in 1986 in order to gain a better understanding of the AI research community, the department undertook the survey of the AI research and researchers referred to earlier in the article.

A complementary role to that of DOS is carried by the Australian Department of Industry, Technology, and Commerce (DITAC). Both departments wish to see the translation of research into industrial applications

for the benefit of the Australian economy. The DOS role starts at the research end of the R&D continuum and DITAC at the development end. DOS also focuses on AI specifically rather than information technology in general. DITAC has been involved in the support of information technology for some time through its policy functions and its schemes for promoting R&D in industry. In 1985 it conducted a survey of expert system research and use in Australia.

Other specialized bodies exist, such as the Australian Telecommunications and Electronics Research Board, which provides grants for research in AI as part of its support for information technology. State governments seek to stimulate the development and applications of technology for the benefit of their own states; the Victorian Department of Industry, Technology, and Resources probably has the highest profile of such departments.

CSIRO's Division of Information Technology, although only recently formed under Tommy Thomas, is taking an active part in supporting AI research; its role is very different from most other government bodies in that it undertakes research itself. Some of this research activity was briefly referred to earlier.

Conclusion

In this article, we have not attempted to deal fully with all the activities of all the players in the AI game. The intention has been to give something of the flavor of AI activity in Australia at present and to stimulate interest in Australian AI research. An overriding impression is that the principal factor in the success of AI in Australia has been the research and the researchers themselves.

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Note

1 The aggregations are those used in the DOS study and are based on the areas used in the AIIA research report (Debenham 1986), which is widely circulated in Australian AI circles For the purpose of analysis, these areas were aggregated where appropriate As well as identifying their own area of research interest, respondents were asked to identify areas of established capability and to state whether areas had commercial potential in 5 years or in 5 to 10 years It is interesting to note that in all cases, the number of people who rated an area as having established capability is greater than the number of people who rank this area first as their own sphere of research activity It is clearly not just a question of researchers voting for their own areas.