The Knowledge Engineering Review

The Linköping approach to technology transfer in knowledge engineering

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Abstract

A technology transfer programme, where people from industry have been educated and trained in knowledge engineering on a project basis, has been in operation since 1984 in the Computer and Information Science Department at Linköping University. This review presents the background for the programme, its organization, examples of training projects, educational activities and plans for the future development.

1 Introduction

An important task for a university department is to disseminate knowledge into the surrounding society, public sector, trade and industry. This means that the research organization should serve as a source of competence, bringing together and distributing not only its own results but also importing and collecting state-of-the-art information from the international research community.

The main channel for effecting this task is obviously the knowledge transfer that results when people trained in undergraduate and graduate study programmes enter working positions outside the university. Less efficient but equally important is the spreading of results through written reports and oral presentations by active researchers. A third way of achieving technology transfer is through co-operative work in joint projects.

In the Department for Computer and Information Science at Linköping University we have actively pursued these strategies, e.g. by issuing a special series of reports summarizing important results in central research areas specifically directed towards industry, by arranging and participating in tutorial conferences (recent tutorials include *Artificial Intelligence*, *Software Development Environments*, *Prolog Programming Environments*, *AI and Expert Systems*) by developing continuing education programmes for industry and by direct consultations and co-operation in applied projects.

However it was felt that in many cases these methods were too slow or too restricted in order to achieve an effective technology transfer in rapidly developing areas of strategic importance for industry. Thus some years ago a discussion about this problem was initiated with industry, which led to the decision to start a special knowledge transfer programme, KTP, in 1984.

The goal of this programme is to "inject" competence derived from research into the existing industrial organization: typically, two persons, from a middle level in the organization, should come to this department for a period of one to a few years to learn new technology, and then return to their organization. The participating company pays a yearly contribution towards pay for researchers (particularly guest lecturers) and equipment.

2 Research organization in the department

The computer and information science department has presently slightly more than 100 employees, including faculty staff, graduate students, and technical and administrative staff. The research activities are organized in nine (at present) laboratories and one smaller group (for administrative

data processing). Each laboratory consists of a few graduate (PhD) researchers, five to ten (typically) graduate students, and some laboratory-specific support staff. The research programme is co-ordinated by the research committee, headed by Erik Sandewall.
The current laboratories are:

ACTLAB	(Lingas)	for complexity of algorithms
AIELAB	(Tengvald)	for artificial intelligence environments
ASLAB	(Hägglund)	for knowledge-based application systems,
CADLAB	(Kuchcinski)	for computer-aided design of digital systems,
LIBLAB	(Hjerppe)	for library and information science.
LOGPRO	(Maluszynski)	for logic programming,
NLPLAB	(Ahrenberg)	for natural language processing,
PELAB	(Lennartsson)	for programming environments
RKLLAB	(Sandewall)	for representation of knowledge in logic,

The department offers a large number of courses in undergraduate education leading to a Master's degree. A special Master's programme in AI and knowledge engineering (given in English) is planned to start in Autumn 1988. A graduate study programme is organized jointly at the department level, with PhD degrees offered in computer science, computer systems and in information science.

Computing equipment includes two DEC 2060 (one for undergraduate courses), one Vax 780, 32 Xerox AI workstations, 15 Sun/3, a large number of personal computers and MacIntoshes and some other computers (PDP-11, Gould, MicroVax, etc.).

Activities in the department are further described in research reviews issued annually (Sandewall, 1987).

3 Orientation of the knowledge transfer programme

During a number of years we have experienced a growing concern in industry about the rapid development in the information technology area and have also seen a considerable increase in the interest in what is going on at the university. For example, the following observations are made.

- Software competence is becoming an increasingly critical resource, also in areas or companies which are not primarily concerned with information technology.
- Software costs pose serious problems and it is recognized that improved hardware will by no means change this situation.
- Computerized systems are still difficult to change and maintain, while the demand for flexibility and adaptability becomes increasingly crucial.
- There is a fast international development with huge national and international research and development information technology programmes, where every country strives for a position in the markets of the future.

This development has resulted in a demand for a rapid expansion of educational programmes, a pressure on university staff from the labour market, requests for direct assistance in industry projects, and in general, in an increased volume of contacts between industry and the university.

The goal for the KTP programme is to:

- promote an effective use of the results from the STU (Swedish Board for Technical Development) programmes for knowledge development in information technology and other efforts supported by government funds;
- secure the availability of qualified competence within novel information technology areas of high importance;
- provide an environment for early experiments and evaluation of new technology as a knowledge resource for industry;
- contribute to an awareness about industry needs within the university.

A fundamental assumption is that research projects of a high international standard are carried out by the university within areas of common interest (Hägglund et al., 1985). In connection with this research the University undertakes to organize projects for medium-term visitors from industry, with an emphasis on learning, technology evaluation and other forms of knowledge transfer. The obligation for each participating company is to:

- assign one person full time or two persons half time working on the joint projects at the university, with the primary objective to learn and evaluate novel technologies and methods.
- contribute 600,000 SEK (slightly more than 50,000 GBP) a year to the KTP budget administered by the university.

The joint activities are organized in close contact with the research projects in the laboratories. Initially, two areas for the programme were established.

- AI and expert systems, including, methodology for knowledge acquisition and expert systems development, evaluation of tools, theoretical foundations and basic techniques, applications, for example in robotics, manufacturing, technical maintenance, office systems, medicine, etc.
- Software engineering and industrial information technology, with an emphasis on software development environments, especially incremental tools for languages in the Algol/Pascal/Ada family, and on the use of information technology in industrial processes and products.

Most of the activities so far have been in the first of these two areas.

Since the start in 1984, six companies have joined the programme, namely in order of their affiliation dates: S-E-Banken, Ericsson, ASEA, Alfa-Laval, Philips and Sandvik Coromant. All these are large multi-national manufacturing companies, with the exception of S-E-Banken, which is a major Swedish bank.

The programme has a budget of its own, but participating individuals are associated with one of the research laboratories in the department. Each participant is assigned to a faculty supervisor, and one graduate student, who is to work closely with the participant. Courses and other training activities are organized and co-ordinated at the department level.

4 Example of KTP training projects

The core activity for industry participants in the knowledge transfer programme is to carry out what we call *training projects*. Such projects are selected with the aim to cover some important application area from the company, with the constraint that the goals should be feasible within the allocated time, while at the same time provide an optimal learning environment for the involved people. The intention is that training projects should result in:

demonstration prototypes
experiences of knowledge acquisition and knowledge engineering
an evaluation of available tools
a basis for strategic decision making in the company.

A number of such projects have been carried out. Some of them are described below, while others are concerned with areas such as operations planning in mechanical engineering or support for decision making by operators in real-time systems. Although the intention is not to try to build full-scale systems during knowledge transfer activities, the results have been very valuable both as a basis for start-up of second-generation application projects in the companies or as an inspiration for continued research projects in the department.

4.a Economical decision making: real estate transfers

A training project carried out by S-E-Banken, was concerned with the possibility of providing knowledge-based support for legal and economical advice-giving in a bank, in particular the transfer of real estate within a family. The project resulted in a successful (rule-based)

demonstration system (LUCKY), which showed convincingly the potential for knowledge systems as a way of communicating expertise within a service business.

However the project also illuminated some of the limitations of the pure rule-based backward-chaining approach taken in LUCKY. This inspired a licentiate thesis project, where these problems were handled within a framework of non-monotonic reasoning, which also explicitly handled the strategic knowledge involved in an estate transfer consultation (Nordin, 1986). In a related Master's thesis project it was then shown how the knowledge base could be reused to provide a training environment for the bank officer.

This work is a good example of the mutual benefits of joint KTP work, where applications inspire research and research exploits new possibilities of practical interest.

4.b Sales support: spot welding robot configuration

The GARMAN project (sales support for spot-welding robot configuration) was carried out in cooperation with ASEA Robotics. The main task of the system is to support a sales engineer in the configuration of a spot-welding robot, including the welding gun and the transformer. Important aspects are to ensure that relevant and complete information is acquired from the customer, to suggest a suitable combination of equipment, and to verify that electrical and mechanical constraints are satisfied. Additional complications arise from the fact that customer preferences must be taken into account and that equipment from different vendors has to be fitted together (Rehmnert and Sandahl, 1985).

The EMYCIN system was used as the basic tool to realize the GARMAN prototype system, although significant parts of the problem were solved directly in Lisp. In later experiments the GARMAN application has been used as a test case in connection with, for example, the use of hybrid development environments.

4.c Maintenance and repair: separator systems

An important application for expert systems technology is fault diagnosis of technical equipment. For companies which deliver complicated equipment world wide with a reliability and maintenance responsibility, knowledge systems promise to offer decisive advantages over traditional approaches. In one training project, performed by Alfa-Laval, such a problem has been studied. A full scale prototype of a trouble-shooting expert system for separator-based plants has been developed, based on Epitool after initial experiments with EMYCIN and KEE. Epitool is a full-scale hybrid expert systems development environment, developed and marketed by Epitec in Linköping. Contributions to the trouble-shooting application also came from Master's thesis projects, which developed graphics facilities and coupled the system to the CAD system used at Alfa-Laval. The prototype is now further developed within Alfa-Laval, while core issues in the area of deep models for fault detection are studied in research projects in the department and in continued joint KTP activities.

4.d Customer support: performance tuning of computers

Configuration, that is, the selection and combination of components into a system which fulfils some set of requirements and constraints, is another important application area. In a project conducted by Ericsson Information Systems, the proper configuration of a customer installation of a computer system was studied. The prototype developed allows a customer to analyse system logs and readjust system parameters in order to improve the performance of his installation, without the need to summon a specialist from the computer vendor.

5 Knowledge transfer programme as a knowledge engineer training programme

The major area of interest for the companies participating in the knowledge transfer programme has been AI and expert systems. One ambition is to provide a reasonable training in knowledge engineering and expert systems development for people from industry. It is our experience that a one-year combination of a half-time course programme and half-time participation in applied work on expert systems development, provide a good basis for continued undertakings in this area.

However, it is also increasingly clear that the spectrum of applications, tools and required skills for knowledge systems activities is very broad and that different kinds of training are appropriate for different purposes. In particular we recognize the need for application-oriented knowledge engineers, who:

- are familiar with the application domain;
- build applications with shells;
- work from specifications of well understood problems;
- have limited knowledge of fundamental AI theory;
- develop "shallow reasoning" knowledge systems.

For more large-scale undertakings AI-oriented knowledge engineers are needed, who:

- build general models of domain knowledge;
- take responsibility for tool selection, adaption, integration, etc;
- are experienced in knowledge acquisition methodology and system prototyping;
- have qualified competence in AI and computer science
- develop also "deep reasoning" knowledge systems.

Our knowledge engineer training programme tries to cover both these needs. Thus it should fill the gap between commercially available tutorials including at best a course programme for a number of days or a few weeks, and the academic four-year computer science curricula in the area. We thus offer, in addition to the KTP project participation with apprenticeship in research, training projects and tool evaluation activities, a one-year half-time course programme including:

introduction to AI and expert systems
discrete mathematics
logic
AI programming systems
AI-cognitive processes
AI-knowledge representation
expert systems methodology and tools.

In addition to being part of KTP, this programme is also given either in Linköping for participants from different companies (who spend 3 days in Linköping every other week), or for a full group of 20–30 participants from a single company. In this case most of the training is given on site.

Starting in 1988, a special 1.5-year academic programme leading to a Master's degree in AI and knowledge engineering will be offered. This programme is offered within the framework of the Swedish International University, where all courses are given in English.

6 Experiences and plans for further activities

As far as we can judge the knowledge transfer programme has become a success. However, there are also aspects which have turned out to be more problematic than anticipated.

Before the programme was started, we analysed the experiences of previous efforts to work together with industry trying an effective technology transfer. It seemed that a crucial problem in many cases had been the tendency for industry participants to give a higher priority to short-term obligations than to research-related work. Often the result was that projects did not achieve a critical mass of activity and thus were felt to be a waste of time by participants from both sides.

To handle this problem we decided to concentrate our knowledge transfer activities on a small number of partners, who showed a definite commitment to the co-operation, for example, by allocating a substantial amount of financial support to the programme. However, it still seems that the problem of allocating personnel at an appropriate competence level to programme participation delays the start of activities in many cases.

Most companies have chosen to work with two KTP participants. Typically, one of them is a more experienced person with a PhD (although not in computer science) and an established position within the company. The other person is often younger, with a good background in computer science. The period of participation for a person tends to be about one year on a half-time basis, visiting Linköping 2–3 days each week. Courses and other KTP activities are concentrated to certain days during a week and thus planned to meet the needs of part-time visitors.

The length of time for active participation in Linköping varies between one and three years for participating companies. For companies that have completed the knowledge transfer programme we offer a less expensive associated membership, which does not include active project work in the department, but co-operation in various forms. Similar agreements on joint efforts have also been made with Volvo and Ericsson Telecom.

We are presently working on a further development of the kind of activities offered witin an associated membership in KTP. It is a general experience that a great effort has to be made during the initial phases of co-operation between the university and a particular company. In the successful cases such a cooperation is evolving rapidly into a situation where the infrastructure of communication and personal contacts exist, and where a mutual understanding improves the effectiveness of the joint activities. The KTP programme has served well to establish a foundation of such contacts between our department and a number of companies.

Current efforts also include the establishment of LAIC, Linköping AI Consortium, which incorporates a co-operative research programme in AI with the Defence Research Institute and participation in the AI sub-project of the Prometheus Eureka project together with the Swedish car manufacturers, Volvo and Saab. During 1988 a special competence centre in industrial information technology will also be formed at Linköping University, with the intention to improve the possibilities of utilizing advanced information technology in industrial processes and products. Researchers from different areas and departments will work together in projects within this centre. We believe that this will provide excellent opportunities to develop and integrate further knowledge engineering methodologies with front-line domain expertise in areas such as computer-aided engineering, robotics, process control and office information systems.

It should also be mentioned that the existence of a highly competent spin-off AI company, Epitec, in Linköping, has improved greatly the possibilities to provide companies with a spectrum of technology transfer services, ranging from basic training in AI to direct consultative assistance. Taken together all this contributes to strengthen Linköping's position as a leading centre in Sweden for research, education and industrial technology transfer, in computer science in general and in AI and knowledge engineering in particular.

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