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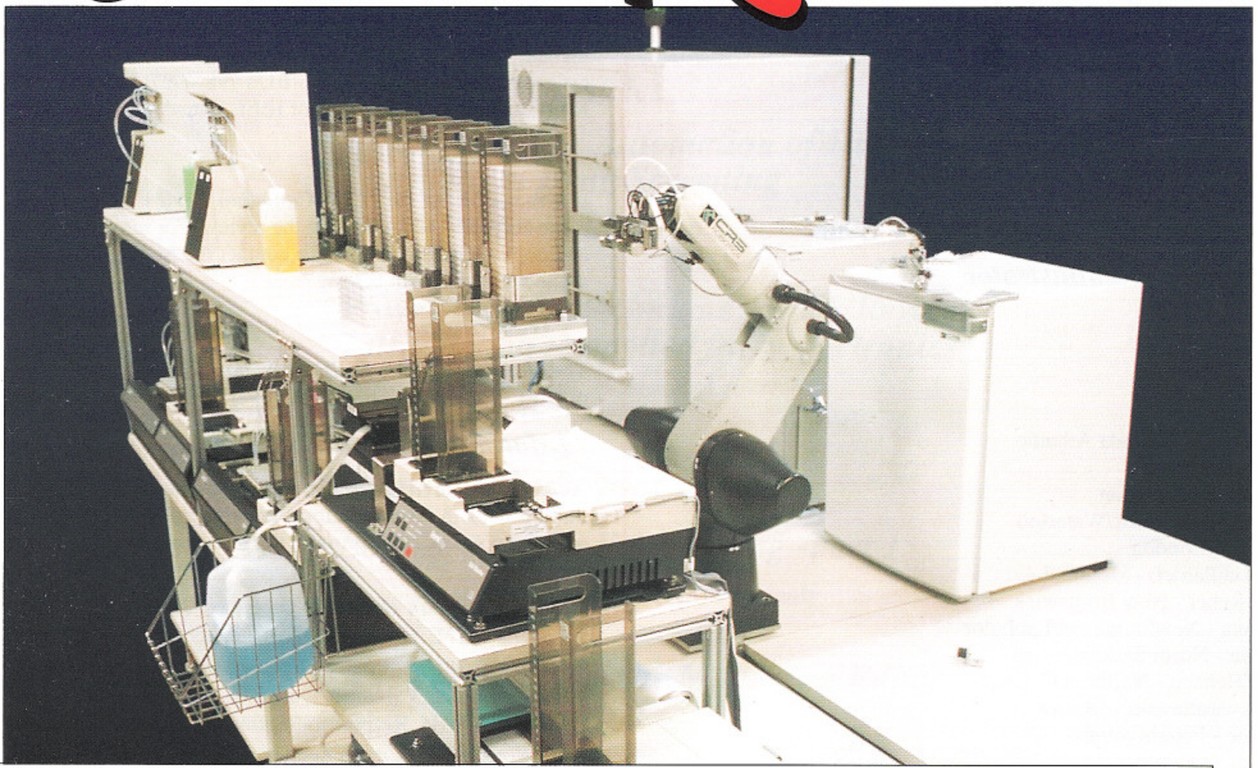
IEEE Canadian Review



- *Advances in the Automation of High Throughput Drug Screening*
- *Introduction to Applied Fuzzy Electronics*
- *Software Patent Engineering - Part 1*
- *L'École de technologie supérieure de Montréal lance un nouveau programme de doctorat en génie*
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Cover picture

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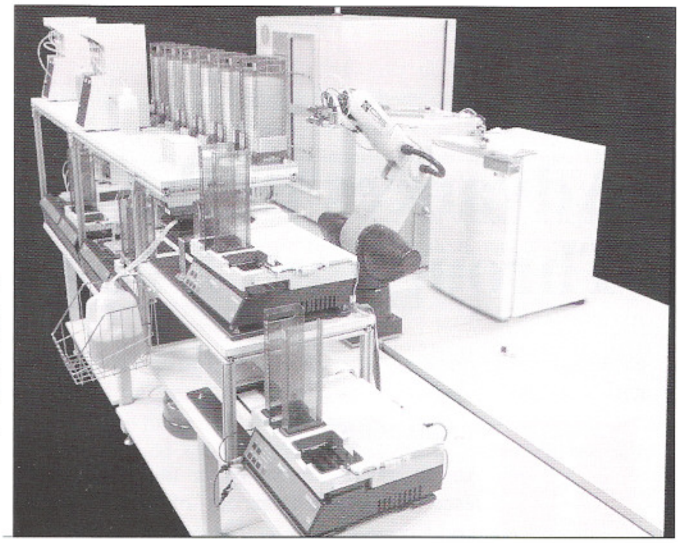
The photograph shows an installed high throughput drug screening system using "mini-batching" for increased throughput. This system uses a modular software and hardware architecture and can process 19,000 samples in 12 hours.



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Advances in the Automation of High Throughput Drug Screening

by Denis Delorme, CRS Robotics

The automation of High Throughput drug Screening (HTS) has progressed remarkably over the last decade, but improvements in key areas of technology are necessary to bring about increased levels of productivity in the marketplace. This article describes the basics of HTS and the automation of HTS. Finally, a comprehensive software and hardware architecture developed by CRS Robotics is presented, which provides for modularity and extensibility by end users.

La technologie de l'automatisation d'acquisition de donnees a haut debi en laboratoire pharmaceutique (en anglais, "High Throughput drug Screening) a grandement evolue depuis dix ans. Toutefois, des ameliorations s'imposent dans le but de repondre aux exigences accrues du marche. Dans cet article, nous allons passer en revue les elements de base de cette technologie et par la suite, presenter l'architecture logicielle/materielle de la societe CRS Robotics permettant aux utilisateurs d'apporter un certain niveau de personalisation.

Introduction

An analytical laboratory is the place where the research and development of the pharmaceutical world is performed, and is subject to the constantly changing research directions (inputs, outputs and processes) of an R&D department: in an ongoing quest for new products. This highly dynamic environment is not at all suited to traditional automation techniques. New ones need to be developed.

In Canada, there are many companies including multi-nationals such as Merck-Frosst (Kirkland, Quebec), and smaller players such as Allelix (Mississauga, Ontario), investigating and investing in some level of laboratory automation. These companies are part of a $60 million per year - and growing - global market.

CRS Robotics (Burlington, Ontario) has long been a leader in designing and manufacturing human scale robots for industrial automation devoting significant resources towards the development of software and hardware products specifically for laboratory automation. This article describes the automation of the analytical laboratory and specifically the automation of High Throughput Screening, or HTS, with some real world examples from CRS Robotics for illustration.

The Drug Discovery Process

When a synthetic or natural (biochemical) compound is discovered, its properties are not known. It may have been developed to combat a particular disease or to promote growth of a particular cell type but in no case is the full set of potential uses known and other uses are not obvious. The only way to determine the range of uses for a compound is to test it for a variety of potential uses. Large pharmaceutical companies have libraries containing thousands of compounds developed over the years. To manually test each against the thousands of potential uses would take a considerable amount of time and money and is not generally feasible in an industry where time to market is so critical.

One of the main classes of processes used for this screening is known collectively as Enzyme Linked Immuno-Sorbent Assays, or ELISA. These assays involve mixing a compound with a known cell type, incubating for a period of time, possibly adding a chemical tag and then measuring any reaction. The chemical tags are extra reagents that highlight the reaction e.g. radio-isotopes, fluorescing compounds or simple pH indicators. When processed by an appropriate detector, these tags are detected or read, and an image of the reaction can be formed. Incubation steps simply allow time for the reaction to take place. Incubations are often performed under controlled environmental conditions including temperature, relative humidity, and the concentration of trace gases, notably CO_2. Of course the whole process is more complex than this, but this complexity is why traditional automation is inadequate. The exact sequence of steps that a sample goes through is at the discretion of the biochemist in charge. Compound and sample volumes to use, volume and type of extra reagents, tag types, incubation times, and temperatures are all variables determined by the biochemist. The number of combinations and permutations, combined with the number of compounds and potential test samples would overwhelm any biochemist or traditionally automated system attempting to perform an exhaustive screening.

Fortunately, shortcuts can be taken. Pharmaceutical companies want a quick «go» or «no go» decision for a particular combination of compound and cell type. High Throughput Screening, or HTS, can be viewed as a coarse filter. For example, 1000 compounds at 5 different concentrations screened against 100 different cell types generates one-half million data points. If there are 100 hits or sample/compound combinations exhibiting interesting behavior, then only those 100 combinations need to be investigated further.

Basics of HTS Automation

Ten to fifteen years ago, all screening was done by hand. All of the sample preparation, compound preparation, sample/compound mixing, tag addition and data generation was a manual process. Individual test tubes were used for the reactions. These required large amounts of space for storage and millilitre volumes of reagents and cells.

Key to the introduction of automation was the development of miniaturized transport vessels and most screening today is performed using 96-well micro-titer plates. These plates, available from a variety of manufacturers, have a range of features but share a standard footprint, about the size of a 3 inch x 5 inch index card. They have a 8 x 12 regular grid of wells, each being a miniature test tube with a volume range of 50 - 300 microlitres. Deep well/high volume versions are available as well. A variety of accessories are available from lids and seals to specialized filters, all designed to work together. The result is a single, small, stackable, sealable liquid transport vessel which can hold 96 different cell types, compounds or reagents.

Micro-titer plates provide some improvements over individual test tubes. Instead of moving one sample at a time, 96 samples move at once. Whether the manipulation is automated or manual, handling one small plate is much easier than 96 test tubes. Smaller volumes of reagents can be used (microlitres instead of millilitres) which results in a cost reduction for the screening. Since each well on a plate is treated identically as its neighbours, and there are many wells on a plate, it is common to use a subset of wells to contain standard compounds or controls. These wells go through the same treatments as the others and can be used to validate or invalidate the results for a plate. The controls can identify problems in the procedure or with specific instruments, or they can indicate that there were no problems with the processing of the plate. This builds in a level of quality control at the lowest level that is not possible with test tubes or other single sample transports.

There are a number of instrument manufacturers making a variety of different instruments designed to work with these standard plates, including incubators, shakers and complex liquid handlers. All have two things in common: they need to be «fed» one plate at a time and they need to be told what to do. A simple device like an incubator needs a plate placed inside and the temperature set correctly. A more complex device, such as a liquid handler, can execute arbitrarily complex sequences of instructions, being an automation tool itself.

In the simplest of systems, small batches of five to ten plates are prepared and moved from station to station by a technician. In incubators or shakers, it is up to the technician to keep track of a sample's time in the device. At liquid handlers, each of potentially multiple plates needs to be placed at a specific location within the unit, which is then instructed which program to execute. Optional parameters such as volumes must also be set. At the reader, which generates the data, correct file names must be provided and parameters set. It is also critical that the technician maintain the correct ordering of the plates being worked with, especially if the plates are not labelled in any obvious fashion. Clearly, additional automation is desirable.

Current Automation: Making Things Happen

Currently, most of the automation for HTS centres on plate-based systems. Integrated systems use a mechanical manipulator, typically a robot, to move single micro-titer plates to and from the various instruments in a pre-determined fashion.

An example of such a system is a CRS plate-based system installed at Ligand Pharmaceuticals (San Diego, California); see Figure 1. It has a capacity of 120 plates and can run 45 to 60 plates through a typical screening overnight (say 12 hours). The added throughput represents a 50% increase in productivity (20,000 compounds per week [1]) without additional staff.

Such integrated laboratory automation systems have a range of costs depending on what is provided and what is expected. On average, a moderately complex system costs in the order of $200k-300k in North America, not including instrumentation which can add an additional $100k-300k. A workstation costs in the order of $150-$200k including instrumentation. Prices can be significantly higher in Europe. Of this cost, the robot sub-system itself is a relatively small part. Costing between $25k and $80k, depending on model and options, it represents about 10-15% of the cost of a large integrated system, and about 30% of the cost of a workstation. These typical prices are accepted by customers since these systems can pay for themselves in as little as one year.

But as with any automated system, there are some problems. In particular, the standard for micro-titer plates is incomplete in some key areas making automation more difficult. It is then up to the system integrator to develop hardware and software that provides for robust, reliable plate handling.

Most automated laboratory systems today feature software that takes care of scheduling samples through the system. The biochemist sets up the scientific method to be executed by specifying a series of Lab Unit Operations, or LUOs, and providing a set of parameters specific to each LUO. This sequence denotes the exact steps or method that are to be performed on a single sample. A technician then executes a scheduling algorithm on a particular number of samples which determines the sample step interleaving - the master sequence of operations. The scheduler must balance the load, prevent deadlocks and enforce resource use and availability. It can be viewed as a multi-user, multi-resource scheduler with tight time tolerances, no backtracking and a need for a level of consistency between samples.

Note the difference in roles here between the biochemist and the technician. Prior to automation, the biochemist established what work had to be done, and the technician did it. Now, the biochemist does the same thing, but the automated system does the work. The focus of the technician is shifting away from the detailed work and towards feeding and maintaining the automated system.

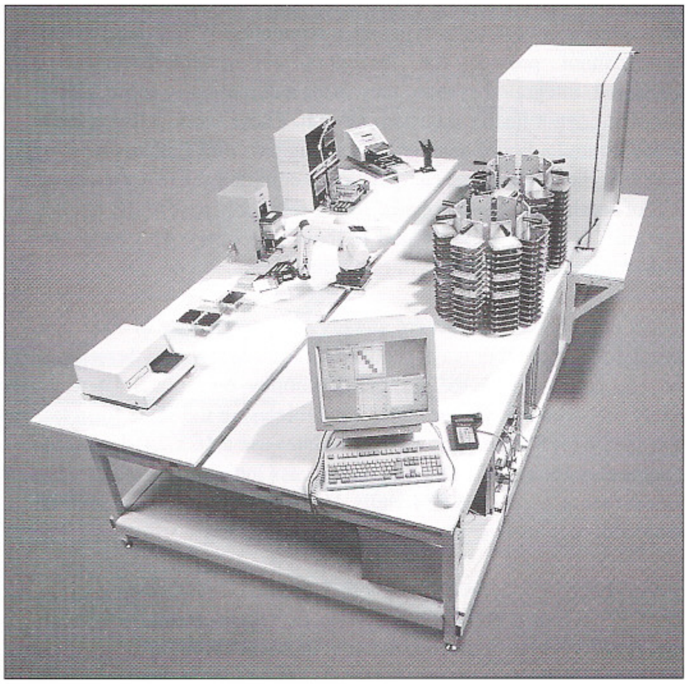


Figure 1: Overview of Ligand's Plate-Based HTS System

Once the sequence of LUOs is established, it is up to the lower level software to translate these high-level requests into the actual robot motions and instrument communication required to perform the task. This is done at a lower level than most technicians are trained for, requiring a knowledge of robotics, automation and a basic understanding of the underlying chemical methods. This is when direct access to the robot comes into play. Most software that a technician uses hides the fact that a robot is in the system. The technician simply enters the LUOs for a single sample and then tells the system to run a specific number of samples. The system software is responsible for integrating the robot into the system without guidance from the user (biochemist, technician). The robot in these systems is tending to the instruments. Older systems were «robot-centric» in that the focus used to concentrate on, or revolve around, the robot - the other instruments were slaves of the robot and its controller. In newer systems, the focus is on a central control computer (typically a PC) with all of the other instruments, including the robot, being slaves of this computer.

The next set of building blocks are the interfaces to the various instruments. These range in complexity from very simple racks to highly complex liquid handlers and analyzers. The more complex instruments typically have an RS-232 serial interface through which commands can be sent and data received. All have different protocols and quirks which must be dealt with to use the devices effectively. Instrument device driver software development currently represents a large portion of the engineering time for a new system.

Ongoing Developments

Customers want to increase throughput, reduce the use of consumables such as compounds and plates, increase reliability and reduce complexity. There are several technologies that are being explored in an effort to improve these systems. Indeed, as advances in automation continue, the amount of automation obtainable for a given amount of money is continually increasing.

For example, there are several instrument manufacturers who are currently offering «work cell» types of instruments. While these instruments cannot provide the throughput or completeness of a customized, integrated system, they offer automation to those laboratories that cannot justify a custom system. These work cells typically revolve around a liquid handler and can include racks, incubators and readers. Some instruments can perform a complete ELISA on a small batch of samples and compounds. Being relatively new to the market, these units are somewhat limited in their ease of use and what they can do for the user but they will only improve.

Current plate-based systems are already running at close to maximum throughput and so other ways need to be found to increase throughput. One way is to increase the number of samples on a plate. There are already 384-well micro-titer plates available using the same form factor as the 96-well plates (the 384-well plates use a 16 x 24, 4 millimetre square, regular grid). Devices that access individual wells need to be modified to access the 384 wells. Devices that do not access individual wells can use the plates without modification.

A «mini-batching» approach is another option currently being examined. CRS recently delivered a system to Wyeth-Ayerst (Princeton, New Jersey) which will significantly increase throughput for their HTS group, as well as provide a simpler, more comprehensive single point interface for their technicians. The system uses a mini-batching scheme made possible through developments by Titertek Instruments (Huntsville, Alabama). This development is a magazine containing a stack of 20 standard micro-titer plates and a series of instruments that can deal with the magazine. The robot need only move a single payload - the magazine - to transport 20 plates through the system. The theoretical throughput increase is 20 times since the robot motion for a magazine is not much different from that of a single plate, although the actual throughput is somewhat less due to other overheads. There are currently a limited number of instruments available which have the stacking mechanism integrated, but continuing development addresses future requirements and the availability of the stacker as a separate product provides an immediate work-around.

The system as installed at Wyeth-Ayerst can hold ten magazines of twenty plates for a total of 200 plates; see Figure 2. For a comparison of performance between a plate and stack based system, a particular process scheduled for the plate-based Ligand system (see Figure 1) above would take 9.2 hours to process 60 plates, or 84 plates in 12 hours. The identical process using the stack-based Wyeth-Ayerst system would take 6.25 hours to process 60 plates, or 200 plates in 12 hours. The robot in the Wyeth-Ayerst system is only active about 10% of the time, leaving room for the addition of new instruments or multiple instances of the same instruments. In this way, the robot working time can be increased, along with processing throughput.

This new system uses CRS's recently developed POLARA (PrOgramming architecture for LAboratory Automation) laboratory automation architecture and software. This provides a very modular architecture at its lower level wrapped by a single point GUI that is used for all of the human-machine interfacing. The modular architecture allows the client to install new instruments very efficiently, and provides for client development of new, or modification of existing, instrument drivers. This addresses the need of system integrators and the desire of end-users for a less complex system. Almost anything that needs to be done to the sys-

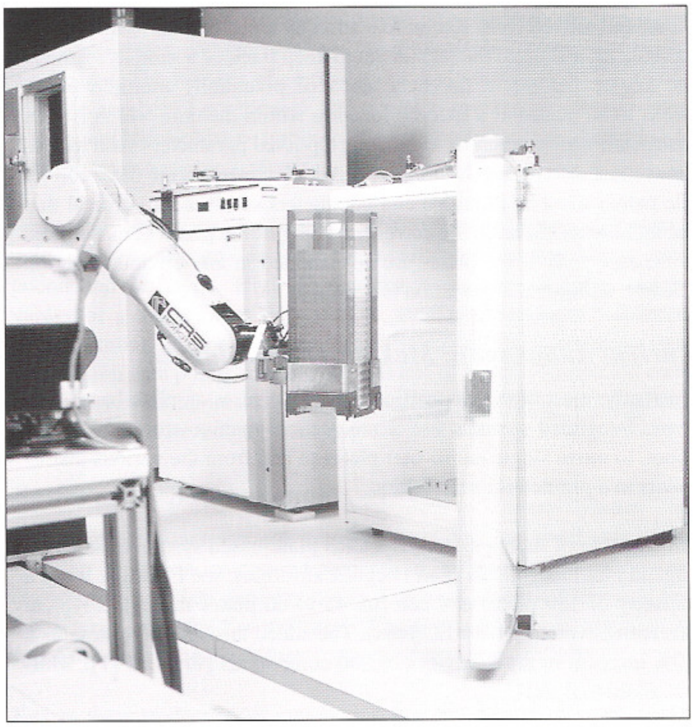


Figure 2: Close-up stack handling in Wyeth-Ayerst mini-batching system.

tem at the user (technician) level can be done through this interface. Reliability is increased since each instrument has its own thread of execution that is used to monitor and report any significant events to a central logging and error recovery process. Each instrument thread also takes care of its own error correction in those instances where it is possible. Having separate threads also means that even if one instrument is having difficulties, the others continue processing normally.

The POLARA architecture has at its heart CRS's RAPL-3 language (Robot Automation Programming Language). This is a newly developed language which is platform independent. It defines the interfaces to support true multi-tasking, several mechanisms for inter-process communication and synchronization, and mechanisms for communicating with non-RAPL-3 programs as supported by the underlying operating system. This operating system, CROS (CRS Robot Operating System), can execute on the Intel-based CRS C500 controller (CROS-500), Windows NT (CROSnt) and UNIX. Approximately 80% of the CROS code is common, with hardware specific code accounting for most of the differences. The RAPL-3 language is a structured programming language with many features and ideas taken from BASIC, Pascal, and C. It is at once simple enough to be used by naive users and powerful enough for complex applications.

The POLARA architecture relies on the multi-tasking abilities of CROS and RAPL-3. It uses a client-server model to distribute intelligence to where it is needed. Each instrument in the system (robot included) has a server to which the other processes can connect and request services. Each of these servers is an independent thread of execution responsible for all housekeeping and providing access to all of the instrument's services. There is also a central server for time, logging and error handling services. This Run Time Manager, or RTM, process also provides the link between the Graphical User Interface (GUI) front end (a separate Windows NT application) and the RAPL-3 processes running under CROSnt.

The ability to run CROS under Windows NT provides the flexibility and power to handle the many tasks and database considerations required by today's laboratory systems. No longer are applications restricted by the limited hardware and other resources available on the robot controllers. Instead, applications have the full set of resources and flexibility of a PC, and in reality on several networked PCs. The single point GUI is a separate NT process and is the only part of the system that the technician needs to deal with. It can be customized to some extent to meet a customer's specific needs. This interface presents information to the technician in the language that he/she is familiar with, which increases the intuitiveness of the interface and leads to shorter and flatter learning curves.

The POLARA architecture is distributed in that the PC performs most of the communication, data processing, and provides general system control while the C500 motion controller provides the hard real time platform for the low level control of the robot. The controller worries about the 1 millisecond closed loop servoing, whereas CROSnt processes typically execute with time granularities on the order of 1 second. The two communicate using the same socket protocol used in the client-server architecture of POLARA, through a dedicated RS-232 link between the PC and C500. This link can just as easily be between two CROSnt processes over a network line and is transparent to the processes. In fact, they do not even know they are on different machines.

The modularity of laboratory software such as POLARA must be accompanied by a modular hardware design philosophy that accommodates fast, efficient system redesign, ease of service and efficiency of operation. To meet these requirements, a tiered approach to peripheral interfacing is adopted to account for the different communication requirements of discrete sensors and actuators, laboratory instruments, robotic motion devices, and a central database; see Figure 3. First, the need to interface to simple digital I/O devices through an industry standard interface bus, such as Interbus-S, permits efficient physical connection to essentially «dumb» devices such as simple sensors and

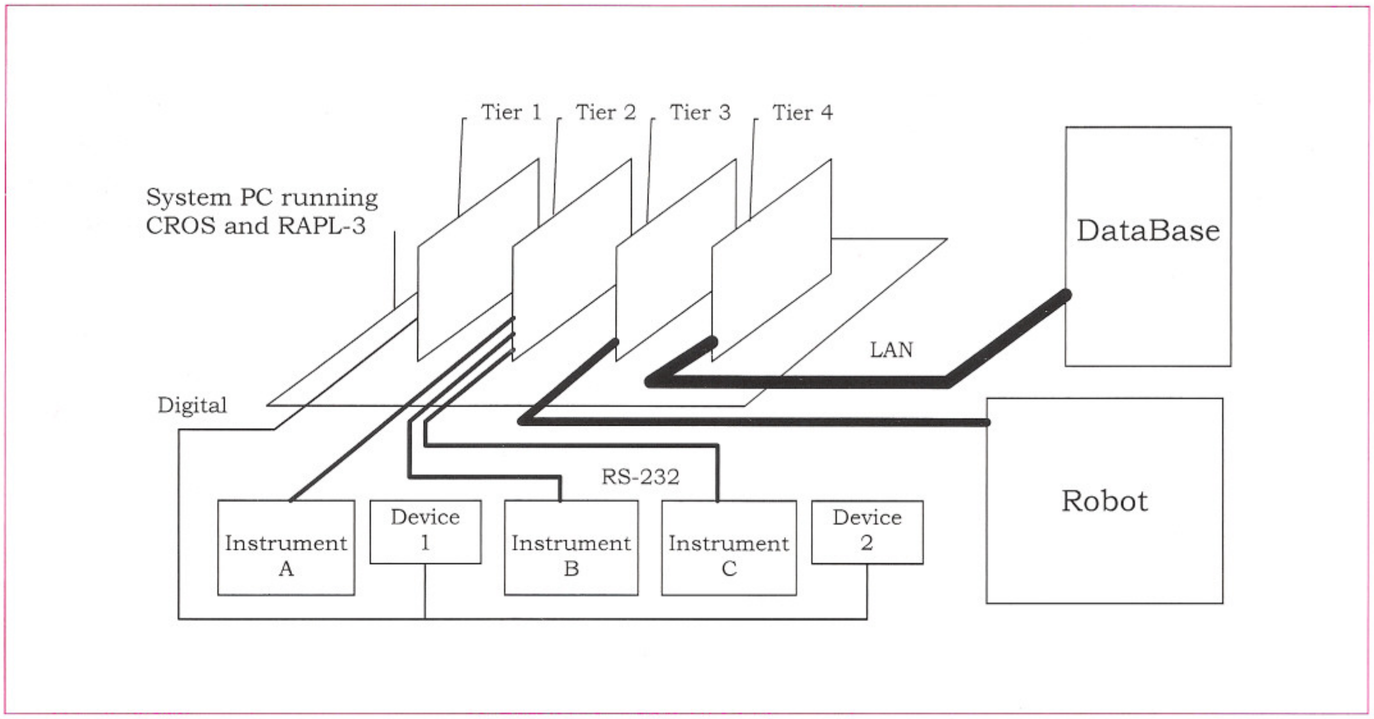


Figure 3: POLARA's interfacing for laboratory automation

actuators. Peripherals such as this can be classified as having low bandwidth and simple communication requirements. The driving need in this area is the reduction of installation costs within the system by reducing the need for wiring. Interfacing to the main computer is realized by a multi-drop cable to a Programmable Logic Controller (PLC) for very complex systems or to a built-in PLC board in the main computer. Multi-tasking RAPL-3 software can then control this digital network.

Secondly, a serial communication bus capable of interfacing to complex, stand-alone peripherals such as analytical equipment is required. Bandwidths of 19.2 kbps can be handled easily by RS-232, RS-422 or RS-485 technology. Multi-port serial drivers for workstations can be used effectively to asynchronously and concurrently service these peripherals. Interconnection is a single cable to the main computer.

Thirdly, a communication network capable of Mbps bandwidth is required to tightly couple discrete motion control devices so that motion control is handled efficiently. In large systems, it is important to optimize «robotic» time since it is typically a limiting factor in large systems. Also, many applications require prompt «on-time» access to motion in order to maintain the integrity of the chemical process. Such a motion control network administers the action of high speed robotics devices used in distributed but coordinated tasks. Interfacing at this level requires coupling to a time-critical real time operating system that can manage the high speed requirements of robotic control associated with kinematics processing, servo control, fault detection and safety circuits. Dedicated hardware and software resources beyond the NT domain are required to maintain the integrity of this level in order to detect and react to failures in a timely way.

Still, the structure of the RAPL-3 environment permits ease of programming and interfacing on the system level while relying on the lower level self-sufficient intelligence of a separate motion engine.

Finally, interfacing the automation system to a central database is essential, since the sole purpose of a high throughput screening system is to generate data - and lots of it! Typical LAN technologies are sufficient to accommodate the data rates that are required. Remote hook-up technologies available in commercially available software provide distributed access to data.

Standardized software interfacing at the system level is more the issue, with the need to access databases using an open database concept. The volatility of the database can be expected as new requirements are generated, and the need to re-program the database requirements at the data source is essential.

CRS - The Company

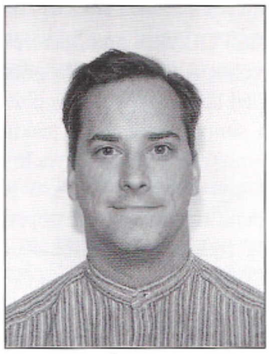
CRS started as a group of three McMaster University engineering graduates, and a graduate of Mohawk College's Electronics Engineering Technology program in 1981. The first robot, the 5 Degree of Freedom (DOF) articulated M1, made its debut in 1986. In October of 1995, CRS and its 70 employees made a successful Initial Public Offering (Toronto Stock Exchange) and completed the acquisition of ISRA of Darmstadt, Germany. ISRA's strengths in machine vision and laboratory automation prompted more investment in laboratory systems. In March of 1996, the CRS Burlington, Ontario facility achieved ISO 9001 quality certification and later that year acquired XIRIS, a Burlington, Ontario based machine vision company.

The CRS web page at «http://www.crsrobotics.com» provides more detail about the corporation and available products.

References

[1] Laboratory Automation News, Vol. 1, No. 3 (July 1996), pp. 6-9, Association for Laboratory Automation (ALA).

About the author



Denis Delorme holds HB.Sc and MSc. degrees in Computer Science (1992 and 1994 respectively) from the University of Western Ontario (London, Ontario). After a brief stint in the interactive entertainment industry, he joined CRS Robotics full time at the end of 1994 as a senior programmer bringing with him almost three years of summer and internship experience at CRS. Since that time, he has worked on several analytical laboratory systems for CRS doing software architecture design and implementation, and instrument driver development. He is now Laboratory Automation Project Manager responsible for both the management of customer systems and the development of new products. He can be reached via e-mail at «ddelorme@crsrobotics.com».

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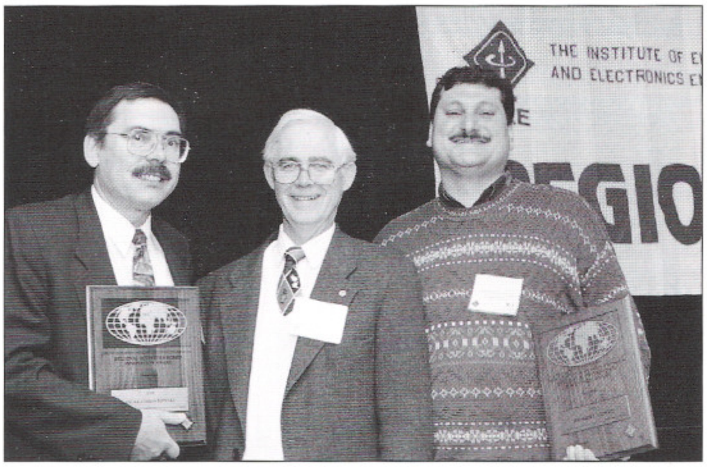

Photo: (from left to right),
J. Chrostowski, R. Findlay and I. Gedeon

At the recent IEEE Sections' Congress 1996 in Denver, two members of IEEE Canada were honored for their contributions to Region 7 activities. In the photo above, receiving their awards from Dr. Ray Findlay (Vice-President, Regional Activities Board) are Jacek Chrostowski and Ibrahim Gedeon.

Jacek received his award for "Leadership in developing new electronic services for IEEE Canada". Ibrahim received his award for "Outstanding contributions in promoting IEEE/Industry relations". We offer our congratulations to both winners.

Introduction to applied fuzzy electronics,

by Ahmad M. Ibrahim, McMaster University

This book starts with a no-frills introduction to the fundamental concepts of Fuzzy Logic. The book deals also with the principles of Fuzzy Control Systems and electronic Neural Networks. The book is suitable for both graduate and under-graduate levels.

The recent hype of Fuzzy Logic (FL) follows a typical generic pattern common to many conceptual constructs introduced and explored in the last few decades. The evolution of such powerful paradigmatic offerings as the Catastrophe Theory, Deterministic Chaos, Fractals and Neural Networks shows many similarities with the FL saga.

All these areas, FL included, experienced their ups and downs. Usually there was a period of cooling after the initial honeymoon enthusiasm. The "so what?" scepticism is a rather typical feature for almost all truly innovative additions to the arsenal of science and technology. According to the philosopher of science Thomas Kuhn ("The Structure of Scientific Revolution") the conservatism usually rests with those who have vested interests in maintaining the leverage and the power of control of the previous paradigm. In the case of Fuzzy Logic, it was probabilistic analysis and stochastic theories. At the extremes, FL, similarly to most other above-mentioned directions, was labelled as a pseudo-science or was dismissed with a typical "we knew it all along" triviality argument.

And yet, the final acid test is provided by the practical applications and the overall engineering usefulness of a new paradigm. All the above mentioned theories have a clear evidence of being useful tools of technological innovation. The track record of FL was mostly established during the last decade. It quickly developed a network of productive connections to various areas of science, technology and engineering design. Furthermore, FL (along with Neural Networks and Chaos) is gradually finding its way into the engineering curriculum. The monograph by Dr. Ibrahim, Professor of Electrical and Computer Engineering at the DeVry Institute of Technology (Toronto), is an excellent asset in assisting such a development.

"Introduction to Applied Fuzzy Electronics" avoids typical extremes of many monographs covering new areas. They are either too descriptive and popular or, on fall into the opposite extreme of being far too technical, overloaded with numerous minor details and hence, for all practical purposes, were unreadable outside a relatively narrow segment of experts.

Despite their occasional use as textbooks (for the lack of better alternatives), both these categories are not well suited for an easy and active mastering of the subject in the educational environment; the former because of the lack of the tutorial parts, the latter because of the formidable amount of effort it takes "to get through".

Ibrahim's monograph successfully combines the best features of the professionalism, entertaining and reader-friendly style, and a pro-active approach in stimulating the reader's mind through the easy-to-follow examples and open-ended questions. It starts with a no-frills introduction to the fundamental concepts of FL (Sets, Boolean operations, etc.). This part is written almost in the style of some of "... for Dummies" books, yet without the undue profanity often found in such texts. The central concept, partial membership in the set, is illustrated on many examples like the known the "glass-is-half-empty-or-half-full" dilemma.

The monograph culminates in the introduction of the principles of fuzzy control systems and electronic neural networks implementing fuzzy learning algorithms. As such, it can also be used as a short cut to expose the reader to the major principles of neural networks - no prior knowledge of this area is assumed.

Despite the concise format, Dr. Ibrahim succeeds in providing an extended bibliography, glossary and a few pages of insightful quotations. Instead of the accompanying diskette, the book has a listing of some Internet nodes from which a reader can start independent search and download some FL software. This section, inevitably incomplete and almost certainly to be quickly outdated, nonetheless, appears to be a sign of the time.

Within the next few years, we will witness the appearance of various hybrid forms of paper-bound and Internet bound means of publishing and education. It will open up some tough problems to be resolved, as it affects such areas as copyright, authorship, marketing strategies, etc. Some new forms of those are almost certainly bound to appear. Coincidentally, the very essence of the philosophical basis of FL may be one of the most relevant tools in addressing these issues. I can foresee that such concepts as "fuzzy publication" and "fuzzy authorship" will gain some legitimacy. There are already proposals about the "Fuzzy Democracy" when the voters will be allowed to cast, say, a "25% conservative, 35% liberal and 40% NDP" ballots if they have mixed political preferences.

The convenient format and relatively compact size of the book (192 pages) makes it an attractive textbook for a 1 or 2 semester introductory course on the principles of fuzzy control and neural networks. It also gives a profound exposure to the general flavour of fuzzy thinking. The latter emphasises the possibility of the simultaneous taking into account of opposite statements. Dr. Ibrahim makes several references on the Heisenberg Uncertainty Principle in this regard.

On a practical side, Dr. Ibrahim's book provides a valuable offering for both the graduate and undergraduate level. The required background does not go beyond the standard calculus and introductory electrical circuits. As such, the book is also suitable for self-directed studies by the practitioners interested in using or assembling fuzzy control systems.

Book review prepared by Dr. Alexander A. Berezin

Alexander A. Berezin is Professor of Engineering Physics at McMaster University.

The book is published by Prentice Hall.

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Message from the Conference Chair

Please accept this invitation to attend **CCECE '97**, the 10th annual Canadian Conference on Electrical and Computer Engineering, to be held **May 25-28, 1997, in St. John's, Newfoundland**. Our conference theme, **Engineering Innovation: Voyage of Discovery**, serves as a reminder that 1997 marks the 500th anniversary of the discovery of Newfoundland by John Cabot. We can think of no better way of marking this momentous occasion than by celebrating the diversity of engineering innovation in Canada; please take this opportunity to join us as we embark on our own voyage of discovery in the ever changing world of electrotechnology.

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I encourage you to plan now to attend **CCECE '97**. Take this opportunity to embark on your own voyage of discovery, and experience the unique culture and beauty of Newfoundland.

Sincerely,

T. David Collett
Chair - **CCECE '97**

Un message du Président

Veuillez accepter cette invitation à vous joindre à nous à l'occasion du **CCGEI '97**, 10ième Congrès Canadien annuel en Génie Électrique et Informatique, qui se tiendra du 25 au 28 mai 1997 à Saint-Jean de Terre-Neuve. Le thème du Congrès, **Innovation en Génie: le voyage de la découverte**, nous rappelle que 1997 marque le 500ième anniversaire de la découverte de Terre-Neuve par John Cabot. Quelle meilleure façon pour nous de commémorer cet évènement que de célébrer la diversité de l'innovation au Canada, alors que nous nous embarquons pour notre propre voyage d'exploration dans le monde toujours changeant de l'électrotechnologie?

CCGEI '97 comprendra des sessions techniques, des sessions plénières et une exposition technologique, et couvrira une grande variété de sujets touchant au génie électrique et informatique. Nous pensons que le programme du Congrès présentera un intérêt pour tous les ingénieurs de la communauté canadienne.

Faites vos plans pour venir au **CCGEI '97**. Profitez de l'occasion pour vous embarquer pour votre propre voyage de la découverte et faites l'expérience de la culture et de la beauté de Terre-Neuve, qui restent uniques.

Sincèrement

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English on reverse

Software Patent Engineering - Part I

by *James Anglehart, Swabey Ogilvy Renault*

This is the first in a series of three papers on patent protection for software. These papers are based on a lecture on software patents given during the IEEE Montréal/Patent and Trademark Institute of Canada's two-day seminar on patents held in Montreal last October (and to be repeated next October in French and in February 1998 in English). This first paper explores what forms of "intellectual property" are available for protecting software, and introduces the recent changes in the US which have placed software on a level playing field with other technologies when it comes to patent protection. Subsequent papers will give some practical examples of how a description of a software invention is prepared for a patent application, and how a patent legally protects a software invention.

Cet article sur la brevetabilité d'un logiciel est le premier d'une série de trois basée sur une conférence prononcée lors du cours offert à Montréal en octobre dernier par la section de Montréal de IEEE et l'Institut canadien de brevets et marques. Ce cours de deux jours sera offert de nouveau en français en octobre prochain et en anglais au mois de février 1998. Ce premier article expose la propriété intéllectuelle en matière de logiciel, et explique les développements récents aux États-Unis favorables envers la protection des inventions informatiques par brevet. Les autres articles dans la série exposeront la rédaction d'une description d'un logiciel pour une demande de brevet, ainsi que la protection légale d'un logiciel conférée par le brevet.

Introduction

In 1994, Stac Electronics, owner of two US patents on data compression algorithms used for increasing hard disk space, had sued Microsoft for patent infringement and settled for US $43 million in cash and US$39.9 million in stock investments [1]. While there are an exhaustive number of examples of companies successfully enforcing patent rights to protect their interests and investments involved in developing new and innovative technology, Stac Electronics was the first to enforce a US software patent and win against an industry giant such as Microsoft. While patent lawsuits can make the headlines, patents are only involved in lawsuits when the commercial interest is great, as it certainly was in the case of MS-DOS. On the other hand, patents are much more frequently involved in behind-the-scenes technology license negotiations, or they are active, unbeknownst to the patentee, in discouraging competitors from using the patented technology. Patents have always been the number one means to protect new and innovative technology. Now, it is accepted policy in the US and Canada to grant patents on new and innovative software.

For many high-tech companies, the most significant asset they have is know-how and other intangibles, collectively referred to as "intellectual property" (IP) (Table 1). IP includes patents, trademarks, designs and copyrights, which are either created or reinforced by registering a document with a government agency (e.g. the Patent Office), and IP includes other non- registrable property such as trade secrets. Without IP protection for software, a competitor may freely and legally take any idea, concept, design, method, structure, function or algorithm from the software. Whereas software can benefit from the protection of all forms of IP, no single form of IP protection will completely protect software. Therefore the best protection of IP relating to software is a hybrid or combined approach.

Software patents have been granted in the US and in Canada almost since the beginning of computer software, but Patent Office policies never officially accepted a new and inventive algorithm or computer program as patentable subject matter. In the past two years, we have seen the US and Canadian Patent Offices change their software patent policies, removing the hesitation to seek patent protection for new software inventions.

Copyright protection for software

Copyright laws were originally created to give a creator or author the right to exclude others from producing and reproducing an original artistic work, such as a literary work. The copyright laws in Canada and the United States were changed to protect a computer program just like a literary work, with source code and object code being considered as different forms or "translations" of the same computer program. Copyright applies only to original works, and the object of copyright is to protect the author's expression of an idea, not to protect the idea itself.

When it comes to protecting how software works or what features, functions and menu options are provided by the software, copyright has not been useful in giving software producers good IP protection [2] since the style or expression involved in coding is usually not nearly as important as its function. If a competitor wants to copy a function or feature from software created by another, and does so without copying code and without direct or indirect inspiration of the expression found in the original computer program code, copyright does not provide protection. On the other hand, software copying or pirating, in which computer program code is reproduced either in whole or in substantial part, is still a damaging activity done both by end users and by competitor developers. Copyright does make such copying of software illegal, and for this purpose it is a very useful tool.

Copyright is not difficult to obtain, in fact it exists automatically from the time an original work is created. It lasts for fifty years after the death of the author, and so the term for software copyright is more than adequate. A work does not need to be published to benefit from copyright protection. Registration of copyright is not required, but it is a good idea to register the copyright of all computer programs created within your organization to maintain a clear record of ownership. A patent agent or lawyer will handle a registration of a copyright for about $300. For more information on copyright, see the Canadian Intellectual Property Office (CIPO) and US Copyright Office web sites [3].

Trade Secrets

A trade secret is any knowledge concerning a process, material or a product which is not known to competitors and is of commercial value. The strength of a trade secret is the difficulty others will face in obtaining the secret information, e.g. by reverse engineering, espionage, or research and development. A trade secret is not registered with a government office, but rather its owner creates and maintains the secret by undertaking the necessary contractual and managerial steps to prevent a leak of the secret by those authorized to know the secret. A trade secret can last forever, i.e. as long as the information is maintained secret.

In the case of software, there are many circumstances in which a particularly valuable algorithm can be used to process data or produce a particular result, without giving any indication as to what the algorithm is or how it works. Analysing the inputs and outputs of a device may prove ineffective in telling what processing is taking place. If the public is prevented from gaining access to the program code, and if the algorithm is initially a secret, then it may be kept a secret. Software which is sold to a customer can be kept secret either physically by storing the program in a device from which the customer will never be able to obtain a listing of the program, and/or contractually by including in the contract of sale, lease or license a requirement that the software must be kept secret. With respect to employees, employee contracts and internal documentation need to be in order to ensure that trade secrets are properly handled and respected to maintain secrecy.

If software is well protected from access by the public, trade secret protection for the algorithm may be better than patent protection. However, if a competitor is able to discover independently the secret, the value of the trade secret is lost, and if the software is innovative, the competitor could obtain a valid patent and prevent continued use of the trade secret.

Software Patent Protection

A patent is an officially granted title under the Patent Act. A patent is a document that describes an invention in sufficient detail so as to allow the public to make the invention, in exchange for which the public (government) grants the inventor the right to exclude others from making, using or selling the invention as claimed in the patent for a limited period of up to 20 years in the country where the patent is granted [4]. A patent includes a series of claims that define the scope of the exclusive rights. A patent results from a patent application which is filed at the Patent Office. Canadian patent applications are published automatically 18 months after the date of filing. US patent applications are not published until the date of patent grant. A US patent application is automatically examined, and it takes between two to three years on average for a US Patent (in software) to be examined and granted.

There are over 5.6 million US patents granted. The US Patent Classification System has about 60,000 sub-classes. A patent search often gives a very good idea of what has been done before in an area of technology, and it is therefore a very good idea to have a patent search done before proceeding with a patent application [5]. However, in many areas of computer software, inventors never filed for patents, either believing that software was not patentable or that the lifespan of the software invention was too short to make patenting worthwhile. As a result, the collection of US patents in some areas of computer-related technology is very incomplete, and a patent search may not always be worthwhile for software inventions.

The total cost for having a registered patent agent prepare, file and obtain a US and Canadian Patent for a software feature or function, like any electronic invention, is about $9,000 to $17,000 (typically around $11,000) [6]. A patentable invention can be any machine, process, material or manufacture, and software may be considered either as an item which creates a different machine once loaded and running in a general purpose computer, or as a method or process when loaded and running, either of which can be considered patentable.

Prior to 1994, US Patent Office policy did not fully accept software patents, and patent applications were sometimes rejected merely because the invention related to software. In July 1994, the US Court of Appeals rendered a favourable decision on the patentability of a software invention [7]. Subsequently, in 1995-96 the US Patent and Trademark Office set out guidelines on the examination of software patents8 which allow patents to be granted for software inventions. Even recording media, such as CD-ROMs, containing patented software can now be protected as a patentable article of manufacture in the USA.

In Canada, Patent Office policy allows patents to be granted for new machines, circuits and processes involving or created by new software [9], although recording media containing new software are not patentable. The Canadian Patent Act was revised in 1993, and even as recently as this, the legislators decided not to explicitly include software in the defined list of types of patentable inventions. The only Canadian court decision on whether software can be a patentable invention decided that a new and inventive computer program is not a patentable invention [10], so a Canadian Patent for software could still be declared invalid in the Courts, even if the present Patent Office policy supports granting patents for software inventions.

Recognizing Patentable Functions and Features in Software - Some Examples

Before discussing software inventions, it is helpful to understand what a patentable invention is. Here's an exercise: Imagine that (a) is a complete summary of the state of the art before the invention (b) is made. Then (c) is the essential feature or characteristic which makes (b) a patentable invention, i.e. that which distinguishes it as new and non-obvious. The patent claims are based on (c).

A simple mechanical example is: a) carts having two or more wheels; b) the wheelbarrow; and c) the use of handles on a container supported by a single wheel which is balanced and steered by hand.

Another example is: a) knifes; b) a pair of scissor or shears; c) a pivot joint connecting two complementary knives together so that the cutting edges make contact as the handles are closed.

A simple electrical example is: a) an interior car light controlled by a dashboard switch; b) a car interior light activated by a car door switch; c) a mounting for the switch in the vehicle door frame such that opening of the door allows the switch to conduct, while closing the door cuts off current to the light.

Take a few moments to think carefully about these examples. If (a) is the sole state of prior knowledge, the technical advance involved in (b) is certainly new, and it is also inventive because there would be no suggestion from (a) to provide the new and innovative patentable feature set out in (c). In these examples, (a) is the only prior state of the art. In the electrical example, (c) would not, of course, be an invention if (a) included door mounted switches for refrigerators, since the structure in (c) would be known, except for an obvious change in environment from refrigerator doors to car doors. Not all changes in environment or application are, however, considered to be obvious, and sometimes it is an invention to apply known technology to a new environment or application.

Following the a-b-c formula, let's consider a few software inventions:

A first example is: a) general help menus called by pressing F1; b) context sensitive help; and c) a program module responsive to the help request (e.g. pressing F1) which checks program variables to find the location or context in the program and selects a best help page for the context.

Another example is: a) drawing programs in which the user sets exact line or object position coordinates when creating or moving lines and other objects; b) the "snap to" function making line or object coordinates selected jump to any other point, line or object near to the user set coordinate; c) a program module which is activated after a user sets a line or object coordinate to determine if the set coordinate is near to an existing point, line or object, and if so, to substitute the user set coordinate with the actual coordinate of the nearby point, line or object.

A further example is: a) secret key encryption; b) data encryption using public/secret key pairs; and c) the use of an algorithm which combines a recipient's public key with a sender's secret key to create an encryption key which can be readily determined by the recipient having knowledge of the sender's public key, but not by others [11].

In the case of the last example, as in all others, the patent must describe the inventor's preferred way to carry out the invention (b), i.e. a specific working configuration or algorithm must be given. However, the patent may claim the invention in a more general broad manner, along the general lines of the characterizing feature in (c).

In the above examples of software inventions, a new function in (b) was created using software. The new function is a patentable invention over the prior state of the art of (a). The new function may only be a small part of what the whole new software does, and thus the patent may only protect this small part of the whole. Therefore, a patent typically protects a single innovative function of a computer program, and not all innovative or original features. This is in contrast to copyright which will protect copying of any and all original program modules, and in contrast to trade secret protection which will protect any and all secret algorithms or processing features. However, a patent for a software function or algorithm should stop competitors from providing the same function in their software or hardware system, whether it is done with the same code or independently generated code. Of course, when the patented function is the core function of the software, then good protection is provided. Twenty years of patent protection for software is a significant period of time, which should be long enough to recover the investment in developing the software and obtaining the patent.

The next article will present how a software invention is described in a patent.

References

1- For more details, see Irah Donner's column "Computer Law" in the IEEE Computer Society's Computer, p.91, Vol. 27, Number 11, November 1994.

2 - The First Circuit US Federal Court restricted the scope of copyright protection for the expressive aspects of a computer program in Lotus Development Corp. v. Borland Intern., Inc., June 7, 1995

3 - The US Copyright office web page is at "http://lcweb.loc.gov/copyright". The Canadian Copyright Guide and Patent Guide can be browsed at "http://info.ic.gc.ca/ic-data/marketplace/cipo/contact/cont_e.html".

4 - See the author's overview article on patents, IEEE Canadian Review, No. 22, Spring/Summer 1995.

Table 1: Intellectual Property (IP) Protection for Software in USA/Canada

Type of IP	Object Protected	Means	Effect
Patent	Any new and non-obvious method of data processing or functional structure of a computer system, or a related improvement.	A patent application is filed as per the Patent Law at the Patent Office. The application is examined and must be granted.	The patentee has the legal right to exclude others from making, using or selling the patented invention in the country for a period of typically up to 20years.
Copyright	Any original expression found in: new program code; or text, images, sound recordings,and video appearing on screen during execution or in a user's manual.	Copyright Laws protect original works. Copyright can be registered with the Copyright Office.	Copyright gives the right to exclude others from copying, transmitting and adapting the copyrighted work for a duration exceeding 50 years.
Trademark	Words, phrases and designs used in identifying a product or services sold. The trademark must not have beeen previously used by others for the same type of products or services.	A trademark can be registered under Trademark Laws and must be used in commerce as registered.	A registered trademark grants its owner the right to use the mark and exclude othersfrom using the same or similar marks for the same products or services. A registered trademark can be renewed indefinitely.
Canadian Industrial Design Registration and US Design Patent	A new distinctive appearance, design or ornamentation of a product. In the US, a screen icon can be protected.	An application under the industrial designs or design patent law is filed with the designs office. The application is examined before being granted.	A registered design gives its owner the right to exclude others from making,using or selling the same or a similar design for up to 10 years in Canada and 14 years in the USA.
Trade Secret	Information and knowhow, such as proprietary algorithms, compilers, circuitry, etc., which is not known by others.	A trade secret is protected by contracts with all those who have access to the secret information. In some cases, data encryption, tamper-proof "black boxes" or IC's may be used to prevent access.	Trade secret information may remain proprietary for as long as it is kept secret.

5 - A patent search of US patents along with a patent agent's opinion on the patentability of a software invention typically costs about $1,000 to $1,500 Canadian when the search is done by keyword and by classification.

6 - Quoted in Canadian dollars (January 1997). The Patent Office fees are typically a total of $2,200 and are included in the cost. A little more than half of this total cost is spent on preparing and filing the patent applications, and the remainder is usually spent one to two years thereafter. More complex inventions result in the higher fees.

7 - See In re: Alappat, US Court of Appeals (Case No. 92- 1381, July 29, 1994)

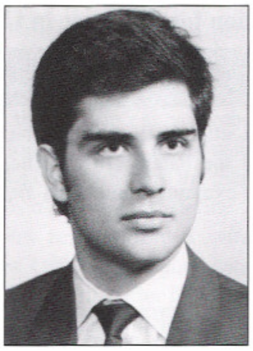
8 - See the following USPTO web site page and select the guidelines from the "USPTO" menu: "http://www.uspto.gov/web/menu/menu5".

9 - See Patent Office Record, p. 10, vol. 123, No. 7, February 14, 1995, Industry Canada.

10 - See Schlumberger Canada Ltd. v. Commissioner of Patents, Federal Court of Appeal, June 15, 1981.

11 -The public-key cryptosystem was developed by Diffie and Hellman. A famous improvement is described in US Patent 4,405,829 (Sept. 1983). See also "http://www.rsa.com/"

About the author



James Anglehart is a registered Canadian and US patent agent working with the firm of Swabey Ogilvy Renault, Patent and Trade Mark Agents, in Montreal (email:"j.anglehart@ieee.ca") in the area of electronic and computer-related inventions.

He received his B.A. degree in Physics (Co-op) and French from the University of Victoria in 1987.

He is chairman of the Public Awareness Committee of the Patent and Trademark Institute of Canada (PTIC) and is a member of Sigma Xi. He is director of the IEEE/PTIC two-day patent course, held in Montreal for the first time last October.

In Memoriam: A. Roger Kaye

A. Roger Kaye, a senior member of IEEE and well known internationally for his contributions to the field of high speed networks and network protocols, passed away on February 11, 1997 after a sudden illness. He was a Professor and the holder of the Mitel/Systemhouse Chair of Office Automation in the Department of Systems and Computer Engineering at Carleton University, Ottawa, Canada. Professor Kaye founded a major research laboratory in computer communications and high speed network protocols at Carleton University. He was the leader of a multi university research theme project on Enterprise Networks sponsored by TRIO (Telecommunications Research Institute of Ontario). A memorial fund at Carleton University has been established in his memory, to provide scholarships for students in the field of telecommunications. [For photo and web site see http://www.sce.carleton.ca/faculty/kaye/kayememorial.htlm]

A few words from the Managing Editor

By Vijay K. Sood, Editor

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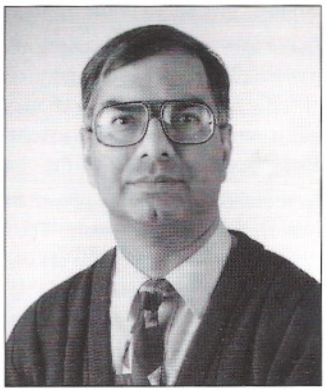

It is with pleasure I present to you the Winter 1997 issue of the Review. I welcome the addition of a new member, Mr. Geoffrey Wong, to the editorial staff and I look forward to his input. Members from Ontario now have their own local representative. Note that I am still on the lookout for another Associate Editor from Western Canada.

Getting articles for the Review is a non-trivial task, requiring considerable patience and some innovative persistence. Two corporations/authors for promised articles pulled out at the very last minute and this is extremely disheartening. The Review is mailed to some 12000 members in Canada, besides corporate sponsors and libraries. The direct and indirect readership of the Review is both substantial and learned. The benefits to Canadian companies of feature articles are therefore quite significant and offer authors a wide readership.

I am pleased to initiate some new features in this edition. Firstly, reviews of two books (one in English and one in French) by Canadian authors are presented. I hope that this will become a regular feature. If you have recently published a book on Electrical/Computer Engineering and would like to have your book reviewed, do contact me.

Secondly, higher education in Canada is under-going some re-thinking and new programs are being considered by many University engineering departments. I encourage department chairmen to let the IEEE readership know about these new programs. Dans cette édition du Revue, un description d'un nouveau programme de doctorat en génie électrique résolument orienté vers les applications industrielles est présenter.

Thirdly, a series of three articles on Software Protection is being launched. This is a topic of considerable interest in view of the explosive growth of software industries within Canada and elsewhere. These articles are a result of an IEEE sponsored course recently given in Montreal and is to be repeated elsewhere. Details are available in this edition of the Review (see page 20).

L'École de Technologie supérieure de Montréal lance un nouveau programme de doctorat en génie.

par Vijay K. Sood, Editeur

L'École de technologie supérieure de Montréal lançait en janvier 1997 un nouveau programme de doctorat en génie résolument orienté vers les applications industrielles.

In January 1997, the École de technologie supérieure of Montreal has launched a new Ph.D. program in engineering which is highly oriented towards industrial applications.

Poursuivant son développement, l'ÉTS vient d'ouvrir un programme de doctorat en génie (Ph.D.), lequel est supporté par les quatre départements de l'ÉTS qui en offrent chacun un volet particulier: génie électrique, génie mécanique, génie de la production automatisée et génie de la construction. Ce programme vise à former les chercheurs dont l'industrie a besoin. Ses objectifs sont de permettre à l'étudiant de contribuer à l'avancement des connaissances dans le domaine de l'ingénierie et de lui faire acquérir des qualités supérieures de synthèse, d'innovation, d'objectivité technique, de sensibilisation sociale et économique et de leadership. Il comporte 90 crédits répartis dans les activités pédagogiques suivantes : thèse de doctorat (60 crédits), examen de synthèse (9 crédits), problématique de recherche (3 crédits) et activités de cours (18 crédits). En plus des laboratoires munis d'équipements et de matériel intégrant les plus récentes innovations technologiques, l'École met à la disposition des étudiants du programme de doctorat un laboratoire de calcul avancé équipé d'un réseau de dix postes de travail, d'un serveur rapide et d'un serveur central avec 16 CPU. Dans le cadre de leurs études de doctorat à l'ÉTS, plusieurs étudiants peuvent bénéficier d'un soutien financier. Chaque année, l'ÉTS ainsi que plusieurs sociétés publiques ou privées offrent des bourses d'excellence. D'autres bourses importantes, pouvant atteindre annuellement plus de 17 000 $, sont offertes par différents organismes comme le Fonds FCAR (Fonds pour la formation de chercheurs et l'aide à la recherche) et le CRSNG (Conseil de recherches en sciences naturelles et en génie du Canada). On peut obtenir de plus amples informations sur le programme de doctorat en génie de l'ÉTS en communiquant avec le Décanat des études avancées et de la recherche au (514) 396-8829.

Fig. 1 Le nouvel édifice de l'ÉTS

Un nouveau campus pour l'ÉTS

En début d'année, l'ÉTS a emménagé dans un nouveau campus, le 1100 rue Notre-Dame Ouest. L'édifice original, une ancienne brasserie construite dans les années 40, a été complètement réaménagé afin de créer un environnement propice à la recherche et à l'enseignement de haut niveau, tout en assurant une vie étudiante des plus stimulantes. Quelque 2 200 étudiants de premier, deuxième et troisième cycles universitaires fréquentent présentement l'ÉTS; grâce à sa relocalisation, l'institution pourra en accueillir éventuellement 2 800. Le nouveau campus de l'ÉTS, un "bâtiment intelligent" de 500 000 pieds carrés, a nécessité un investissement de 42 millions de dollars. Parmi les plus modernes au monde dans son genre, il est doté d'une infrastructure réseautique qui permet l'intégration des télécommunications et des technologies du bâtiment. Ce système a été développé grâce à la collaboration de Bell Canada, Johnson Controls et Nordx. Parmi les innovations, notons aussi un amphithéâtre de 340 places, pouvant se subdiviser en trois salles distinctes, ainsi qu'une salle de vidéoconférence qui permettra l'enseignement à distance et la tenue de conférences scientifiques internationales par le biais de satellites de communication. L'ÉTS entend profiter de sa relocalisation pour intensifier son rôle de chef de file dans l'utilisation et le développement des nouvelles technologies et poursuivre sa croissance. L'édifice servira également de laboratoire expérimental à l'implantation des technologies de l'information et de communication dans les immeubles.

Le Groupe de recherche en électronique de puissance et commande industrielle (GRÉPCI)

L'ÉTS offre un milieu de recherche très stimulant pour les étudiants gradués grâce à de nombreux laboratoires et groupes de recherche. L'un d'entre eux est le GRÉPCI composé de sept professeurs et d'une vingtaine d'étudiants gradués et de stagiaires post-doctoraux. Le groupe mène des projets dans les trois domaines suivants:

Commande intelligente des entraînements électriques et des robots Ce volet comprend la conception, la simulation et l'implantation en temps réel de commandes intelligentes appliquées aux entraînements électriques et aux robots à membrures rigides ou flexibles. Les commandes intelligentes possèdent des capacités d'adaptation et d'apprentissage qui leur permettent de pallier les variations et incertitudes paramétriques du processus. Pour ce faire, les commandes intelligentes font appel aux principes de la commande adaptative, de la linéarisation par retour d'état, de l'apprentissage par réseaux de neurones, etc. L'implantation en temps réel de ces commandes intelligentes requiert l'utilisation de processeurs de signal en version microcontrôleur dans les cas simples ou d'architectures parallèles dans les cas plus complexes. Ce volet comprend également la commande des réseaux de production d'énergie électrique. Professeurs responsables: Ouassima Akhrif, Ph.D., Louis-A. Dessaint, Ph.D., et Maarouf Saad, Ph.D.

Simulation en temps réel des systèmes de puissance La simulation en temps réel des systèmes de puissance, en particulier des réseaux électriques de transport d'énergie et des FACTS (Flexible AC Transmission Systems) offre plusieurs avantages par rapport à la simulation en temps différé. Elle permet d'abord de réaliser un grand nombre d'essais en peu de temps en utilisant des algorithmes de commande et des stratégies de contrôle différents. De plus, un simulateur en temps réel permet l'interface directe avec les commandes industrielles. Enfin, sur le plan didactique, la simulation en temps réel présente de nombreux attraits pour l'étude des systèmes. Développer des modèles mathématiques du thyristor et du GTO (Gate Turn Off) adaptés à la simulation en temps réel et étudier différentes topologies de commande constituent les points saillants de ce volet. Le Groupe cherche également à solutionner en temps réel et sur des ordinateurs parallèles les équations dynamiques de grands réseaux. Les méthodes et modèles développés serviront tant à la simulation en temps réel qu'à l'implantation de systèmes de commande évolués à des fréquences d'échantillonnage élevées. Professeurs responsables: Ambrish Chandra, Ph.D., Pierre-Jean Lagacé, Ph.D. et Michel Lavoie, M.Ing.

Fig. 2 Les professeurs membres du GRÉPCI

1re rangée: Ouassima Akhrif, Louis-A. Dessaint, Ambrish Chandra
2e rangée: Kamal Al-Haddad, Maarouf Saad, Michel Lavoie
(Pierre-Jean Lagacé n'apparaît pas sur la photo)

Électronique de puissance Dans le domaine de l'électronique de puissance, la recherche est centrée principalement sur les convertisseurs statiques d'énergie électrique utilisant des semi-conducteurs de puissance. L'accent est mis essentiellement sur la recherche de nouvelles structures utilisant le principe de la commutation sans perte et du fonctionnement à fréquence inaudible, le but étant d'augmenter le rendement et la puissance massique. Par ailleurs, les nouveaux composants semi-conducteurs (IGBT, MCT, etc.) sont à l'étude afin de les intégrer à de nouvelles applications industrielles. Enfin, la modélisation et la simulation sont largement utilisées pour aider à la conception de convertisseurs complexes et à la détermination de leurs caractéristiques statiques et dynamiques en vue d'élaborer de nouvelles lois de commande pour différentes applications industrielles couvrant la gamme des alimentations de faible et moyenne puissances. Professeur responsable: Kamal Al-Haddad, D.G.E.

Si vous désirez plus de renseignements sur les activités du GRÉPCI, veuillez communiquer avec le directeur du Groupe, Louis-A. Dessaint, Ph.D., ing. Tél.: (514) 396-8872 Fax : (514) 396-8684 email: dessaint@ele.etsmtl.ca

Impressions du Sections' Congress 1996 (Denver) - par Mark Provencher, Section St-Maurice

Général
Ce congrès nous a permis de mieux connaître les rouages et les services de l'IEEE. Nous sommes plus en mesure de trouver les informations requises pour aider nos propres membres lorsque ceux-ci veulent des services spécifiques. Les conférences concernant les " récents gradués ", le " développement des membres" et surtout le " futur de IEEE " nous permettent de connaître les orientations de la société.

Spécifique à la section St-Maurice
La section St-Maurice étant une petite section nous nous sommes principalement attardés aux conférences et présentations nous permettant de trouver des solutions et des moyens de communications avec nos membres. Ainsi, les conférences " The Recent Graduate ", " Electronic Communications ", "Membership Development/Retention " et naturellement " Section Management Large and Small ".

Cérémonie d'ouverture et soirée
Ayant personnellement un intérêt marqué pour l'astronautique, la cérémonie d'ouverture avec l'astronaute Ron SEGA nous a fasciné.

Rencontres de confrères
Un élément à ce type de congrès est la rencontre avec les membres des diverses sections dans le reste du monde. Nous sommes toujours surpris de constater que des membres ou des sections dans le monde peuvent connaître des problèmes similaires aux nôtres. C'est d'ailleurs une rencontre avec un président de la petite section de Croatie qui confirme que les petites sections ont des problèmes similaires dans le monde.

Visite touristique
Il faut mentionner que l'organisation du congrès nous a laissé quelques heures pour une visite dans la ville de Denver. Le paysage magnifique des montagnes aux alentours, vue du centre-ville et du non moins célèbre " mile-high ".

Circuits et machines électriques et électrotechnique

par: Réal-Paul Bouchard et Guy Olivier
professeurs, École Polytechnique de Montréal

This is a book review of two recent textbooks written in French, entitled (translated) **Circuits and Electric Machines** and **Electric Power**. These books evolved from course notes written at Montreal's École Polytechnique over the last twenty years. Although intended as a support for university teaching, these books can be of considerable interest to practicing engineers. They cover a wide range of material, from the rudiments of electric circuits, to the description of power apparati and their behavior in networks. Specialized topics include an extensive look at the various transformer connections and their uses, symmetrical components theory and short circuit calculations and, possibly for the first time in a general purpose textbook on power, harmonic analysis.

Ces deux livres complémentaires, parus récemment chez les éditions de l'École Polytechnique de Montréal, font la synthèse des notes de cours préparées depuis près de vingt ans par les professeurs et chargés de cours de cette institution en électrotechnique. Bien qu'ils s'adressent à prime abord à une clientèle universitaire - d'un niveau plus avancé que le livre bien connu de Théodore Wildi, sans pour autant s'adresser aux spécialistes - ces livres sont d'un intérêt certain pour un grand nombre d'ingénieurs oeuvrant en électrotechnique. On y retrouve dans un ordre croissant de complexité un recueil des rudiments de l'électrotechnique, les descriptions des appareils électriques et leur fonctionnement en réseau, des sujets plus avancés comme l'analyse des circuits triphasés par la méthode des composantes symétriques et les nombreuses connections des transformateurs, et un sujet de pointe, l'analyse des harmoniques. A travers ces sujets et de nombreux exemples, les auteurs adressent plusieurs préoccupations courantes dans l'apprentissage de l'électrotechnique industrielle. On y dresse une bonne vue d'ensemble, avec beaucoup d'éléments pratiques ajoutés à l'analyse quantitative habituelle. A mon avis, l'approche pédagogique très structurée et bien détaillée adoptée par les auteurs constitue le principale atout de ces livres.

Les livres couvrent un grand éventail de sujets dans de courts chapitres bien délimités, commençant par les rudiments et progressant vers le fonctionnement des appareils de puissance dans un réseau. On y définit d'abord dans **Circuits et machines électriques** les paramètres et variables d'un circuit électrique, la modélisation des éléments d'un circuit réel par des composantes idéalisés (source, résistance, inductance, capacitance, etc.), la mise en équation d'une description de réseau par les lois de Kirchoff, et les tensions, courants et puissances en régime permanent dans un réseau soumis à de nombreuses excitations. On y introduit alors la notion de phaseur pour représenter les formes d'ondes sinusoïdales. Suite à une courte description des phénomènes transitoires dans les circuits, on aborde l'électrotechnique comme tel avec des chapitres sur les circuits magnétiques, les réseaux triphasés et les appareils électriques à courant alternatif. Dans les premiers chapitres d'**Électrotechnique**, on reprend quelque peu les notions de circuits électriques et magnétiques, mais avec une vision axée sur l'appareillage électrique. Ensuite on y présente en détail les éléments d'un réseau électrique de grande puissance: circuits triphasés équilibrés et déséquilibrés (par le biais des composantes symétriques), fonctionnement des transformateurs monophasés, biphasés et triphasés, transformateurs de mesure, et fonctionnement des moteurs asynchrones monophasés et triphasés. Ce deuxième volume traite aussi de quelques fonctions d'analyse de réseau réservés habituellement pour des livres plus spécialisés: calcul des valeurs de base (ou per unit), analyse des harmoniques et analyse des défauts.

On décrit les concepts de base aussi simplement que possible, quelque fois avec des analogies, et avec beaucoup d'exemples, d'exercices, de figures et de graphiques. Les exemples servent souvent à présenter des problèmes courants en électrotechnique, comme par exemple la compensation réactive, la compensation de séquence homopolaire, les techniques de mesure et la facturation de l'énergie. De même dans la présentation des sujets d'électrotechnique, les exemples et illustrations facilitent la compréhension.

La présentation des transformateurs et des moteurs asynchrones dans **Électrotechnique** est riche en détails. De façon générale, des tableaux et graphiques présentent plusieurs renseignements pratiques: classes d'équipements et leurs usages, schémas de construction, paramètres typiques, phénomènes transitoires particuliers à la mise sous tension et les palliatifs pour y remédier. L'analyse quantitative est souvent accompagnée de tableaux de synthèse, et les procédures de calcul sont bien décortiquées. Je note comme contenu particulièrement bien présenté dans ce livre les séquences suivantes: (1) la description sur une centaine de pages des nombreuses configurations de transformateurs triphasés standards (Y-Delta, YY, V et à trois enroulements) et spécialisés (zig-zag, mise à la terre, connexion Scott), leur modèles en séquences directes et homopolaires, et l'utilisation de certains modèles comme compensateurs de séquence homopolaire; (2) la présentation du moteur asynchrone triphasé couvrant plusieurs aspects; et (3) l'analyse de la distorsion d'ondes électriques par l'approche récente des harmoniques, avec de nombreux exemples courants. A ma connaissance, ceci est le premier livre didactique d'électrotechnique général de langue française à traiter ce sujet.

Signalons aussi quelques autres atouts. Plusieurs textes, dispersées dans les deux livres, décrivent les appareils de mesure et les techniques de mesures courantes, et les essais où des séries de mesures servant à déterminer les paramètres des appareils. On saura apprécier dans ces livres la terminologie courante de l'électrotechnique en langue française. Notons finalement que ces deux livres à reliures souples se vendent à prix forts raisonnables.

Critique préparée par Maurice Huneault.

Maurice Huneault est diplômé en génie électrique de l'Université Laval (B.Sc.A. et M.Sc.A.), et de l'Université McGill (Ph.D.) où il a enseigné brièvement. A l'emploi de la compagnie CYME International depuis 1989, il est spécialisé dans l'analyse des grands réseaux électriques.

Les livres sont publiés par École Polytechnique de Montréal.

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This course will also be offered in English in February 1998.