ALBERTA INFORMATICS CIRCLE OF RESEARCH EXCELLENCE

2005 Research Report

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APRIL 2004 - MARCH 2005

This document is an excerpt from the 2005 iCORE Annual Research Report. For information or copies, please contact iCORE.

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ADVANCED TECHNOLOGY INFORMATION PROCESSING SYSTEMS

ATIPS has built a team of international-class researchers with complementary knowledge and expertise, the effective combination of which leads to the creation of unique and highly imaginative solutions for a variety of applications.

GRAHAM JULLIEN

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The Advanced Technology Information Processing Systems Laboratory at the University of Calgary (ATIPS) leverages highly advanced and emerging computing technologies to conduct research into the development and implementation of a variety of information processing systems, including: high performance digital signal processors, machine vision systems, information security systems, streaming video processors, bio-engineering devices, arithmetic intensive processors, wireless networking components, opto-electronic sensors and processors. ATIPS' research effort is principally concerned with the exploitation of microstructure techniques, including micro-electronics, System-on-Chip (SoC), micro-electro mechanical systems, microfluidics, and sensors, to the benefit of Canadian industry, Canadian health, high technology diversification in Alberta, and the training of highly qualified personnel.

EXECUTIVE SUMMARY

Our fourth year of operation has continued to build on the exciting successes of 2003 as the group begins to reap the benefits of longer-term investment. This year has also seen the groundwork laid for the major thrust of ATIPS 'second term' as we have expanded our research into biomedical applications through new collaborations with international-class researchers in medical science and bioengineering.

In 2004-2005 we achieved the following milestones and successes:

- Successful demonstration of (wireless) transcutaneous power and data transfer
- Successful fabrication of the microneedle array for drug-delivery/blood-sampling - with Micralyne Inc.
- Successful demonstration of a SoC implementation of secure key establishment - with Non-Elephant Encryption Systems Inc. (NE2), and the Centre for Information Security and Control (CISaC – University of Calgary)
- Development of a suite of defect detection algorithms for TDI in-camera processing systems - with DALSA Corp, led by fellow iCORE Chair Hugh Williams
- New implementation and simulation results for an improved hearing instrument architecture using our novel multi-dimensional logarithmic number system - with Gennum Corp.
- New 2D algebraic integer mappings for error-free image and video transforms
- Design and successful demonstration of a novel ultra-low noise Cellular Neural Network (CNN) analog array for signed digit and DBNS arithmetic
- Downloads of QCADesigner have exceeded 3000. Konrad Walus wins the "Research Leaders of Tomorrow" award at the 2004 Alberta Science and Technology Gala in Edmonton
- Lexel™ Array poster wins the Micralyne Award at the 2004 CMC Texpo

Major new multidisciplinary research projects and programs have been initiated in the following areas:

- A $506K NSERC Strategic Grant in collaboration with CISaC and supported by NE2, and General Dynamics Canada
- A ground-breaking new initiative in neuron-silicon interfacing in collaboration with Dr N. Syed of the Faculty of Medicine. This work has great potential for treating neuronal damage and enabling biological neural networks.
- New initiatives in nerve-regeneration, bio-cell ion-channel activation, and wireless patient monitoring with colleagues Dr D. Zochodne (Medicine), Dr V. Birss (Chemistry), and the "Ward of the 21st Century", multidisciplinary project with Dr J.W. Haslett (iCORE Chair, ECE)

New collaborative ties with key academic and industry groups including:

- A new collaboration with the Microelectronics Institute at Tsinghua University, Beijing
- An IP sharing agreement with Semiconductor Manufacturing International Corporation, Shanghai
- Research exchange agreements with GETA (Helsinki), LIRMM (Montpellier), and LIP (Lyon)

Continued collaborative ties with:

- DALSA Corp. (Waterloo, ON): machine vision and imaging systems
- Gennum Corp (Burlington, ON): video processors and hearing instruments
- RCIM, University of Windsor: integrated circuit design
- CMC Microsystems: SoC Research Network (interaction with 26 other universities)
- LIRMM, Montpellier University, France: number theoretic and crypto systems

Infrastructure advancements:

- A technologist has been hired for the Class 100 Integration Facility
- The University of Calgary has provided funding to support the building of a Class 1000 facility adjacent to the Class 100
- ATIPS has secured all funding to support the CFI grant to establish an Integrated Sensor Lab (ISL) and has identified a technician for that facility

Our research has resulted in the creation of a substantial amount of intellectual capital

- 78 publications in journals conferences and books
- 21 contributions to international standards
- One patent awarded, a further six applications filed; Registered a key invention

ATIPS team members have also graduated seven students, with three more defending their theses shortly, and attracted some of the best graduate students interested in our research, to the ATIPS environment. Last year saw the beginnings of the ATIPS team's work on cryptographic implementation systems. This work has grown faster than might have been anticipated and is becoming a major element of ATIPS' research work. The award of a NSERC Strategic Research Grant (in collaboration with industry) will support our continued drive into information assurance and security whilst also making a valuable contribution to ATIPS' growing SoC capability. As awareness of the potential of microsystems design grows, ATIPS' reputation and expertise has supported the development of new collaborations with medicine and bioengineering. This effort has led to a number of proposals and initiatives, including ATIPS' first shared post-doctoral fellow (PDF) with the Faculty of Medicine.

Together with ATIPS' existing expertise in information processing and circuit design, microconvergence and information security will form the core of ATIPS' thrust into new and exciting application areas. By embracing these opportunities, ATIPS strives to maintain its position on the leading edge of advanced technology research.

RESEARCH PROGRAM OVERVIEW

Our research goal is to build and apply our knowledge and expertise to innovate at all steps in the design process.

To support this, ATIPS has built a team of international-class researchers with complementary knowledge and expertise, the effective combination of which leads to the creation of unique and highly imaginative solutions for a variety of applications. These self-directed researchers can be effectively pooled in various combinations to create larger research teams on 'higher-level' system problems.

In our fourth year, we have expanded upon our previous successes and collaborations, starting a number of new biomedical research efforts with members of the Faculty of Medicine. Notable amongst these are two new collaborations with Dr Naweed Syed that are the first projects related to the building of microchips for the manipulation of, and communication with, neurons using electric fields and charge transfer techniques. This work shows great potential for repairing nerve damage.

Some of our specific successes this year include:

- New initiatives in bio-cell research technologies and wireless patient monitoring
- New collaborations with the Microelectronics Institute at Tsinghua University, Beijing, and Semiconductor Manufacturing International Corporation, Shanghai
- Successful demonstration of wireless power and data transfer to an implanted device
- Successful fabrication of a microneedle array for drug-delivery/blood-sampling

- Successful production of a hardware prototype of a secure key establishment system in less than six months; over 20 contributions to international standards
- 78 publications in journals conferences and books
- The first external publications using ATIPS' QCADesigner tool for an emerging nano-technology with application to future circuit design
- Three new research exchange agreements with establishments in Europe

WIRELESS NETWORKS

Digital Signal Processors for Wireless Base-Stations

The goal is to produce single-chip high performance solutions for the very high data rate signal processing required for next generation Gbps wireless networks. In 2004-2005 we completed the design for an advanced single chip DSP using ATIPS' fault tolerant special number representations. The chip is scheduled for a fabrication run later in 2005, using the services of CMC Microsystems, and testing and integration into a board level system will begin once the fabricated chips are received.

System-on-Chip for Low-Power Wireless Platforms

The research goals are to develop low-power platforms for a variety of applications, including secure communications, remote bio-analysis, and multi-media compression systems. Our work this year has successfully demonstrated a prototype hardware implementation of NE2's key establishment algorithm for secure transmission over wireless, wired, and fibre networks. This year we also began a major strategic push to investigate novel cryptographic implementations on custom hardware. This is a three-year collaborative project with Dr H. William's CISaC group and is supported by NE2 Inc.

2004-2005 also saw our first demonstration of (wireless) transcutaneous power and data transfer, initially for the re-creation of gastrointestinal motility. This technology should enable a number of biomedical innovations and one that has already been referenced in a new grant proposal. One application that could benefit directly from this work is a recently initiated project to develop an implantable blood glucose monitor that has the potential to be used in an insulin delivery system for diabetics. The sensor does not require oxygen for its operation, unlike most of previously reported sensors, resulting in improved accuracy and longer-term stability. This latter work is a collaboration between Dr V. Birss of the Department of Chemistry, and Dr Jullien.

Future wireless SoC developments include a new project investigating in-situ real-time patient vital sign monitoring. This is an extension of our long-term ad hoc sensor network project with RFIC iCORE/NSERC Industrial chair Dr J. Haslett and Canada Research Chair Dr M. Okoniewski (Department of Electrical and Computer Engineering, University of Calgary).

Graham Jullien with some of his ATIPS research team members

EMBEDDED SYSTEMS/FAULT TOLERANT SYSTEMS

These systems are broadly defined as those that contain full-custom, field-programmable or processor-based integrated circuits.

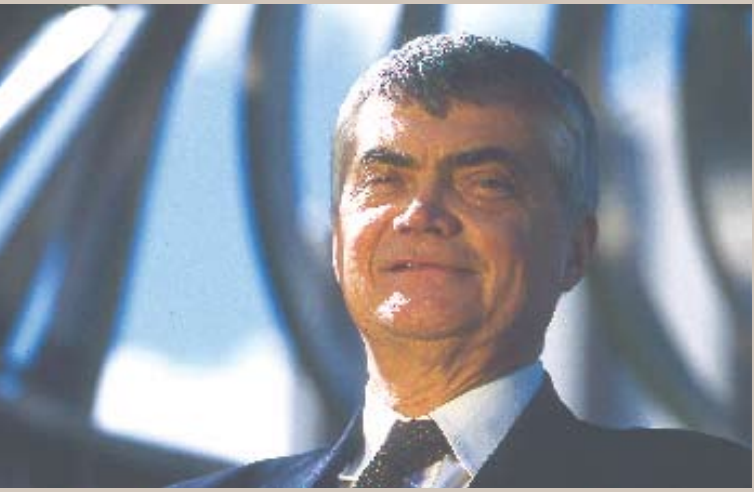
Machine Vision

Our goals and objectives for machine vision are to develop new algorithms and implementation techniques for in-camera processing of moving images obtained from targeted industrial inspection processes. In 2004-2005 we completed a suite of defect detection algorithms and developed FPGA code for their implementation onto camera systems manufactured by DALSA Corp. In addition, we have filed a full patent application on our TDI self-synch algorithm. This year we also demonstrated the potential of plenoptic camera systems.

We have developed two new approaches to the tracking of multiple moving objects and will carry out detailed performance assessments in the coming year.

Hearing Instruments

Our medium-term research goal is to develop next generation embedded systems for completely-in-the-canal (CIC) hearing instruments. This research is being conducted with one of our industrial sponsors (Gennum Corp). In 2004-2005 we refined our MDLNS approach for low-power hearing instrument architectures and successfully demonstrated the performance advantage. We are currently testing a very-low power adiabatic logic chip to further enhance our low-power design capability. Over the next year we will complete testing of this device and continue to investigate the use of adiabatically-powered look-up tables in enhancing the low-power performance of MDLNS implementations.



Graham Jullien

Application-Optimized Arithmetic

Our research goals are to develop application-specific special number representations and arithmetic "custom-fits" to both the algorithms to be implemented and the advanced and emerging fabrication processes used in device construction, such that system performance is optimized. The range of applications for this research encompasses many of our other projects including work on the implementation of arithmetic for cryptography applications and the digital hearing aid processor project.

A number of advances have been made in the employment of our new number systems and some new techniques have been added to our repertoire. We have demonstrated the use of complex MDLNS in performing Fast Fourier Transforms and developed efficient algorithms for performing key cryptographic functions. In the coming year we will take this work and perform in-depth assessment of the performance advantage of these techniques. This work has benefited greatly from our collaboration with LIRMM (Montpellier) and continues to make rapid progress.

Video Processors

The goals and objectives of this research are to increase the efficiency of implementing the compression standards determined by international standards committees, and to take part in the process of defining new standards. We continue to publish a substantial body of work on video processing architectures and error-free encoding algorithms for the MPEG-4 and H.264 standards. This year ATIPS researchers made 21 separate contributions to the definition of these standards. The coming year should see the completion of the ITU-T/ISO/IEC review of our block motion estimation architecture for inclusion in the H.264 standard. Also in development is a generic SoC multimedia platform suitable for handheld devices.

Circuit techniques

Often our investigations into architectures and arithmetic lead us to examine special circuit (transistor-level) techniques and their implementation. Our research objectives are to explore such implementations in order to improve overall system performance. This year saw the completion of the design, fabrication, and testing of the first CNN chip: a successful "proof of concept". The prototype chip performs so

well that we are now designing a new test-jig in order to measure the very low switching noise inherent in the design. Our CNN architectural explorations in 2004-2005 have also produced the first 3-state CNN signed-digit redundant adder and the first logic-free CNN DBNS adder and representation formatter. This latter design has significant promise for crypto hardware that is resilient to power analysis, and other types of side-attacks.

Fault-Tolerant Systems

Our research goals are to produce low-overhead fault tolerant computational systems that take advantage of special number representation properties. In 2004-2005 this technique was used as the key technology in the design of the ATIPS adaptive filter chip for the TRLabs 1.2Gbps wireless LAN project. This chip is currently being readied for submission to CMC Microsystems for fabrication.

ADVANCED TECHNOLOGIES AND COMPUTING WITH NANOTECHNOLOGY

Advanced CMOS System-on-Chip Platforms

Our objectives here are to bring the advantages of SoC design to research projects that require advanced system-level implementation techniques. Our goal is to develop several basic chip architectures, or platforms that can be custom modified to target different facets of our research. These include low-power bio-platforms and high-throughput signal processing platforms. In 2004-2005 we designed a second-generation Lexel™ array chip: the Lexel™ array provides the ability to manipulate, characterize and separate microscopic particles using non-uniform electric fields. We are developing a generic Lab-on-a-Chip platform based on the Lexel™ design. Mr Jeff. Keilman, an ATIPS Masters student, received the CMC Texpo Micralyne Award for his work on the Lexel™ array.

Advanced Image Sensors

Our goal is to develop imagers with enhanced functionality customized for different applications, such as very high-contrast or low-light scenes. By capitalizing on our knowledge of imager physics, circuit design, and custom architectures we aim to find solutions that best meet the needs of the biomedical research community. In parallel, we will continue to develop our portfolio of expertise in Integrated Sensors. This year we demonstrated the capability to apply an invisible "watermark" to digital images in the image sensor chip itself and published work on expanding the dynamic range of imaging sensors.

Microconvergence

Microconvergence refers to the integration of advanced microstructure technologies such as micro-electronics, micro-electro-mechanical systems (MEMS), micro-fluidics, RF-wireless, opto-electronics and photonics. Microconvergence is an integral part of the ATIPS modus operandi and some microconvergent designs are addressed under other headings. Our principal research objectives lie in the integration of these technologies for applications to biotechnology and the health sciences.

The microneedle array for drug delivery and blood sampling – designed in collaboration with Micralyne Inc. – has now been built and early tests show that it will work well. A new initiative begun in 2004 with the Department of Chemistry is the development of a prototype wireless biosensor for continuous monitoring of glucose levels: a possible automatic warning system for diabetics. The sensor could also be used as the front-end of an insulin release system. When complete, the prototype will be used for Phase I Clinical trials.

The Class 100 Microsystems Integration Facility and included equipment, is now being commissioned and a Class 1000 Laboratory will be constructed adjacent to it shortly. The Integration Laboratory is a shared facility among a number of groups with a presence in the University of Calgary's Calgary Centre for Innovative Technology (CCIT) building.

Nanotechnologies

Our research goal is to explore the potential of emerging nanotechnologies that have the most potential for a smooth transition from existing microelectronics design techniques. Quantum-dot Cellular Automata (QCA) can be used to represent the classical deterministic states of '0' and '1' and thus to build computing systems with familiar architectures. As engineers we are interested in exploring the potential of this technology even though commercial fabrication techniques have not yet been established. To do this we have defined a new research paradigm by developing a Computer Aided Design (CAD) tool for a technology that is not yet proven in terms of fabrication. This concept has been well received by the international research community with papers using the tool for analysis already appearing. Both CAD tool downloads and major publications have resulted from this work and the tool will reach its second major release this year. We are currently working on parallelizing the code to take advantage of the enhanced speed offered by multi-processor and grid-computing concepts.

RESEARCH PROJECTS

WIRELESS NETWORKS AND COMMUNICATIONS

Digital Signal Processors for Wireless Base Stations

The TRLabs 1.2Gbps WLAN (wireless local area network) project has continued during this term. ATIPS researchers have designed a single-chip Tbps throughput Digital Signal Processor (DSP) to facilitate the very high data rate processing required. This adaptive filter chip is a low-overhead fault tolerant design that takes advantage of application-optimized number representations developed by ATIPS. As mentioned before, the design is being finalized for fabrication submission through CMC Microsystems, and testing and integration will begin once the fabricated chips are returned. The earlier work on a fault tolerant processor scheme has been published and is being implemented in the design.

System-on-Chip for Low-Power Wireless Platforms

Over the past year, a team from the ATIPS Laboratory has been working with Non-Elephant Encryption Systems (NE2) to apply SoC design techniques to NE2's patented key establishment technique for secure communications. The team has also been developing efficient symmetric encryption algorithms based on the Advanced Encryption Standard. This work is in collaboration with iCORE Chair Prof. H. Williams' Centre for Information Security and Cryptography (CISaC). Rapid-prototyping of the design has progressed much faster than expected with a hardware platform now completed that includes the first architecture for the NE2 algorithm along with a simulator for demonstrating and verifying the design.

The success of this work has supported the joint ATIPS/CISaC award of an NSERC Strategic Grant to investigate "Novel Implementation of cryptographic algorithms on custom hardware platforms", worth $506,000 over three years. This project aims to develop faster hardware/software implementations of commercially used cryptographic algorithms using novel hardware architectures. These protocols will help protect private and confidential transmissions over a variety of media including wireless, fibre-optic, and conventional wired networks. Other SoC crypto work has included the development of a polynomial residue system multiplication technique over GF(pk) and a Montgomery multiplication algorithm over GF(2k).

An exciting development for 2004 was the demonstration of our transcutaneous power and data transfer designs using Radio Frequency (RF) wireless techniques. The initial application targeted for the technology was for the sequenced electrical stimulation of nerves for the re-creation of impaired gastrointestinal motility, for which the electrical power requirements are substantial. To address the problem of providing electrical power inside the human body, ATIPS researchers developed a model to describe the RF transfer of power between an external transmitter and an implanted receiver. This model formed the basis for the design of two transcutaneous inductive links that were successfully used to transfer both power and data, demonstrating the viability of the design and verifying the predictions of the model. This work brings significant technology to the ATIPS laboratory and could enable a number of biomedical devices, such as the implantable blood glucose monitor being designed at ATIPS. A collaborative team from Bioengineering and Medicine have already referenced this work in a grant proposal for measuring bone and tissue forces at the microscopic level.

A new implantable wireless glucose monitor is also being developed, which will be described in the section on microconvergence.

EMBEDDED SYSTEMS / FAULT TOLERANT SYSTEMS

Machine Vision

A suite of defect detection algorithms has been developed. Many of them have been included in a set of FPGA code that can be downloaded into a DALSA Eclipse™ camera. Simulations have also been developed that demonstrate more complex algorithms that can be used in more recent camera models that have an FPGA with a larger number of logic blocks than the model we have used for our experiments. We have published a journal paper on our novel TDI Self-Synchronization algorithm and we have converted the provisional patent (No. 60/481,806) into a full disclosure for patent protection. This work has been recently presented at a meeting with representatives of engineering groups at DALSA.

We have investigated the construction of a 1-D plenoptic camera system for simultaneous capture of stereo pairs on a single sensor. Plenoptic systems offer the potential to passively measure depth with a single sensor. We have had some issues with the mounting of a suitable lenticular array in front of a commercial digital camera sensor, and are currently resolving these in discussion with DALSA engineers.

We have conducted research into the automated tracking of multiple moving objects. As humans we perform this highly complex function routinely when walking down a busy street or driving on the highway.

Machine vision systems currently lag some distance behind this capability. Research at ATIPS aims to change that and this year we have successfully mated merged probabilistic data association (MPDA) with a smoothing particle filter (SPF). The combination of these techniques results in a robust tracking system that effectively tracks targets in a noisy environment. This research is currently being developed for a system that can be used on high manoeuvrable targets such as speed skaters.

We have also developed a new Fuzzy Particle Filter that is more efficient at tracking highly manoeuvrable objects even against a densely cluttered scene. Over the coming year we will conduct a more detailed performance comparison of this novel approach against existing equivalent techniques.

Hearing Instruments

Improvements were made to our MDLNS approach for low-power hearing instrument architectures and the first journal paper was published on difficult operations in the closed MDLNS system using Range-Addressable Look-Up Tables (LUTs) for conversion between binary and MDLNS. New implementation and simulation results for improved architectures have also been accepted for publication. A very-low-power test chip using "Adiabatic Logic" for high fan-in gates has been designed and successfully manufactured. The device is currently under test and the results look promising.

Application-Optimized Arithmetic

One of ATIPS' core strengths has been the ability to 'redesign' arithmetic operations in order to reduce computational complexity, increase accuracy, reduce design times, decrease the silicon 'real-estate' necessary, or improve the fault-tolerance of a design. This 'optimization' of the calculation process is application specific and has yielded considerable benefits and some very novel ways of addressing issues of performance and cost.

MDLNS is an example of one of these optimization schemes that is being considered for Digital Signal Processing (DSP) applications as a means of accelerating the calculations. One application for the MDLNS approach is the Hearing Instrument research highlighted above. In addition, this year we have been able to demonstrate that Complex MDLNS-based arithmetic can perform Fast Fourier Transforms with the necessary floating-point accuracy. Work is now underway to design the necessary chip architecture to exploit the potential performance gains.

A small test chip was fabricated and successfully tested to allow the evaluation of our DRAM programmable base 2DLNS FIR filter architecture. This work capitalizes on the low transistor count of DRAMs but removes the circuitry associated with the refresh problem.

Efficient arithmetic algorithms have been developed for finite fields used in cryptographic applications (mainly Elliptic curve cryptography), including several variants of a modified Montgomery's multiplication algorithm for binary fields GF(2m) and extension fields GF(pk) of small and medium prime characteristic. These algorithms have been published and are currently undergoing in-depth performance assessment in collaboration with colleagues in the Department of Mathematics and Statistics at the University of Calgary.

Continuing the development of ATIPS' double-base number system (DBNS), we have investigated approaches for converting integers to their DBNS representation. DBNS arithmetic requires fewer operations than conventional arithmetic for point and scalar multiplication – offering a distinct advantage in elliptic curve cryptography. The use of continued fraction expansions offers some promise in accelerating the conversion from integer to DBNS and its performance will also be assessed in more depth through the coming year.

In collaboration with LIRMM and ST Microelectronics (France), ATIPS is investigating leak resistant arithmetic as a protective measure against so-called 'side-channel' attacks on secure communications. Also in this collaboration, we have proposed two new number representation schemes (Adapted Modular Number System, Polynomial Modular Number Systems) and efficient algorithms for improving the arithmetic in the ring of integers Z/nZ. A full Residue Number System (RNS) implementation of the widely used RSA public-key cryptography scheme has also been published.

Video Processors and Processing

Video processor work has progressed strongly in the last year, principally focused on architecture contributions to the H.264/MPEG-4 Standards. H.264 offers superb scalability and high quality video compression and processing, and has been adopted as the standard for next generation DVD movie compression.

ATIPS' work on these advanced video codecs has yielded a substantial volume of publishable work on IP blocks for hardware implementations and over 20 contributions to international standards. Published work includes research on two architectures for block motion estimation - the most computationally intensive task in the encoding process. The combined ITU-T/ISO/IEC committee that is defining the H.264 standard is currently reviewing these and a second architecture is in design. The goal of this work is to

alleviate the block motion "bottleneck" obstructing real-time encoding performance. We are developing an FPGA platform suitable for handheld devices.

Additional work has been published on lifted biorthogonal Discrete Wavelet Transform (DWT) architectures, MPEG-4 architectures, a VLSI prototype for adaptive variable length coding, and prototyping for the H.264 transform.

Our work has continued on the use of algebraic integer coding for error-free representation of irrational coefficients used in many video and image processing transforms. This includes the implementation of Daubechie's wavelets, error-free 4x4 DCT encoding, 2D algebraic integers for 8X8 DCT architectures, and a low-power DCT core.

Circuit Techniques

Work on ultra-low noise digital arithmetic circuit design has focussed on a class of analog cellular arrays known as recursive CNNs. These designs will be particularly useful in a mixed signal environment, where digital noise must be kept to a minimum: for example, in the processing of signals from sensitive biosensors.

The prototype chip proposed last year has now been designed, fabricated and tested, verifying the viability of our proposed technique. An on-chip noise measuring circuit block has been developed to isolate the measurement from off-chip noise interference and a special test jig is being designed. This design will be refined as part of the ongoing research.

In 2004-2005, ATIPS published the first papers on the 3-state signed digit CNN , a switching-free DBNS CNN architecture, and an invited paper that highlights our various CNN arithmetic techniques.

In another approach to asynchronous design, a test chip based on digital asynchronous design and test techniques, developed by one of Dr Jullien's students at the University of Windsor, has been fabricated and is currently under test in the ATIPS Laboratory.

Fault Tolerant Systems

Fault tolerance will become increasingly important as technological advances take us into the nanometer realm. Our particular approach to fault tolerance addresses the use of appropriate number representations for computational fault tolerance, which is acknowledged as being more difficult to build into integrated circuits than data communication and storage fault tolerance. In 2004-2005 we used these techniques to design our high throughput adaptive filter for the TRLabs Gigabit LAN project. Upon completion of the manufacture of the chip we will be able to assess and refine our fault tolerant design approach.

ADVANCED TECHNOLOGIES AND COMPUTING WITH NANOTECHNOLOGY

Advanced CMOS System-on-Chip Platform

The ability to manipulate, characterize and separate microscopic particles is tremendously useful in clinical diagnosis, biomedical research, and environmental analysis. While these functions can be performed using mechanical, chemical, and biological techniques, the use of dielectrophoresis (DEP) is seen as a more effective method of achieving these objectives based solely on the frequency dependent dielectric properties of the micro-particles.

ATIPS' work in the field combines dielectrophoresis, electric field sensors, and the associated digital processing circuitry to great effect in the micromanipulation of bio-cells. A poster on the Lexel™ array by Mr Jeff Keilman, an ATIPS Masters student, won the CMC Texpo Micralyne award in 2004 and the latest results from tests on our Lexel™ I array chip were presented at BioCAS 2004. Our second generation Lexel™ II array has been designed and built.

Experimental results obtained on model microscopic particles have verified the ability of the Lexel™ I array to implement interdigitated dielectrophoretic, quadrupole levitation, and travelling wave dielectrophoretic field configurations.

The Lexel™ I array forms the base structure of a bio-analysis Lab-on-a-Chip platform currently under development. A new project on a low-power wireless platform for biosensors was started in 2004 with our first paper on a new DC-DC CMOS charge pump accepted in.

Advanced Image Sensors

ATIPS advanced image sensor work shows considerable promise for applications ranging from biomedical analysis to security to large structure inspection systems. During 2004, ATIPS began the process of combining imaging technology into a number of micro-convergent systems as well as making advances in the technologies required to improve imaging system performance.

Important developments made by ATIPS researchers include enhanced functionalities such as on-chip individual pixel dynamic range control to suppress image 'hot spots' and reveal more detail in high-contrast conditions. ATIPS has also developed an algorithm and chip design that permits the automatic (invisible) watermarking of digital images as they are

captured by the camera. The "first-of-its-kind" prototype device has been fabricated through CMC and the final package is currently being assembled. This type of watermarking can be used to prove ownership and also to provide evidence of tampering with the image file. Enhancements to the algorithm are being investigated and this work may be the subject of a future patent application.

This year we began to investigate enhancing the low-light level performance of CMOS imagers, focusing initially on low-noise analog read-out circuitry. This technology will be very useful for cell-detection in Lab-On-A-Chip systems.

Microconvergence

As has been stated previously, microconvergence is a common feature of many of ATIPS innovations and is now an integral part of our thinking and design planning. As such, some microconvergent innovations will have already been described under other headings.

This year, work began on developing a small wireless camera microsystem, principally for gastro-intestinal inspection, although such a device has a range of potential applications. Current research is focusing on reducing the image data rate required to transmit video from the device and on possibilities for integrating the camera and radio transceiver onto a single substrate.

We are also involved in the technologies associated with MEMS and microfluidics. A recent example of that work is the successful implementation of a novel microneedle array that contains several hundred microneedles on a silicon die just over 1mm on a side. The array uses channels through the die for fluid transport, allowing bio-analysis and other devices to be mounted on the reverse side of the array.

Under development, in collaboration with Dr V. Birss from the Department of Chemistry at University of Calgary, are a new glucose sensor and signal conditioning and processing circuitry designed in the ATIPS Lab. This sensor will provide continuous automatic monitoring of glucose levels for diabetics to replace the current self-test procedures. ATIPS will help to optimize the sensor's performance and design a prototype for Phase I Clinical trials.

Silicon – Neuron Interfacing

We have recently initiated a contact with Prof. Naweed Syed of the Departments of Anatomy and Physiology in the Faculty of Medicine at the University of Calgary. Prof. Syed has created quite a stir in the media with the disclosure that he and a team led by Prof. Dr Peter Fromherz of the Max Planck Institute in Germany, have closed the loop between live neurons and a silicon chip. This work has very important ramifications for future therapies for a variety of diseases and traumas associated with neuronal damage and further possibilities of information processing using biological neural networks.

The ATIPS Laboratory will be continuing the work of the team at the Max Planck Institute by producing large arrays of neuron stimulators and sensors along with information processing systems on single wafers on which networks of neurons may be grown.

Nanotechnologies

ATIPS has continued to focus on Quantum-dot Cellular Automata (QCA) as a promising emerging technology for future integrated circuit design. Significant progress has been made in advancing the art of QCA simulation and design with the release of QCADesigner 1.4, our unique CAD tool for QCA architectures and presently the most advanced tool available for this purpose. Konrad Walus received the "Research Leaders of Tomorrow" award at the 2004 Alberta Science and Technology Gala in Edmonton for this work. The QCA architecture work on the use of majority logic has been published, as has our work on performance comparisons.

Using this tool we have been able to design the first simple processor in this future technology. This processor is the culmination of work conducted over the past year on circuit optimization including the development of a majority reduction scheme targeted at QCA applications. We have determined that one of the original building blocks of QCA, the coplanar crossover will most likely not work in complex circuits and so we have proposed a multilayer QCA design scheme whereby interconnects are crossed over on separate layers of QCA cells.

We are presently incorporating multilayer QCA principles and simulation capabilities into QCADesigner 2.0, which will be released mid-2005. Recent investigations into the device concept called "Split Current QCA" have led us to believe that such a device concept will not work and we are presently investigating other device geometries for implementing semiconductor QCA-like circuits that will be able to operate at current fabrication densities and at room temperatures.

Additional work this year has addressed the design of adder and multiplier structures using QCA elements and will continue this year with new work already begun on interfacing with QCA structures and the continuation of the parallelization program for QCADesigner. This latter development should allow us to efficiently simulate large circuits created with the tool.

2004 is also noteworthy as the year that other institutions began publishing research that used QCADesigner as a key research tool.

RESEARCH TEAM MEMBERS

PARTNERSHIPS AND COLLABORATIONS

Portions of the ATIPS research program are conducted by students at our collaborative institutions: the University of Windsor and the University of Western Ontario. These students are funded by Micronet and NSERC grants and this expanded base allows the ATIPS team to leverage additional resources to add further value to the work of the ATIPS Laboratory. The following represents the most important events and highlights over the past year in terms of research team members and contributions:

Infrastructure And Grants

- The modular Class 100 Integration Room has been installed and populated with equipment. The installation, including the connection of utilities, has been supported by a $250K grant from the University of Calgary's CCIT Building Fund. A technologist has been hired to oversee safety and to commission and maintain the equipment.
- ATIPS' System-on-Chip Laboratory has successfully produced a hardware prototype of a secure key establishment system in less than 6 months – this is a demonstration of the power of modern integrated circuit design tools and appropriate design flows and an outcome of our interaction with the CMC Microsystems' System-on-Chip Research Network (SOCRN).
- A major strategic push to investigate novel implementations of cryptographic algorithms has begun in collaboration with CISaC and is supported by NE2 Inc., and SGI Canada.
- $288K in Micronet R&D awards and matching funds for ATIPS Collaborative projects with Academia and Industry.
- $506K NSERC Strategic Grant for "Novel Implementation of cryptographic algorithms on custom hardware platforms" in partnership with CISaC and supported by NE2 Inc.
- $154.5K NSERC Discovery grants for four ATIPS team members in 2004
- $200K in equipment and operating grants with collaborating researchers
- $60K in silicon allocation (integrated circuit fabrication) from CMC
- QCADesigner, our emerging technologies CAD tool, had over 3000 international downloads in 2004-2005 and work has begun on parallelizing the code for faster processing.

People Successes

- Dr Ivars Finvers has accepted a joint position between the ATIPS Laboratories and the RFIC Research Group (Dr J.W. Haslett, Director), as a Research Associate.
- Dr Chris O'Neill has taken up a part-time position as Strategic Research Manager in the ATIPS Laboratory. This is a new position with the mandate to manage the cluster that has grown around ATIPS and is jointly funded by ATIPS and RFIC.
- Dr Rudolf Potucek has taken up a position as Postdoctoral Fellow in the ATIPS Laboratories.
- Dr Potucek is jointly funded by ATIPS and the Faculty of Medicine.
- Dr Laurent Imbert (France) has had his leave from CNRS (France) extended for a further 12 months.
- Dr Zhun Huang, from the Microelectronics Institute at Tsinghua University, Beijing, has accepted a position in the ATIPS Laboratories.
- Dr Roberto Muscedere, Postdoctoral Fellow supervised by Dr G. Jullien, has accepted a faculty position at the University of Windsor, as an Assistant Professor.
- Mr Minyi Fu, a PhD student co-supervised by Dr G. Jullien, has accepted a position at Gennum Corporation, Burlington, Ontario.
- Mr Venkata Ramanan joined the ATIPS Laboratory for two months as an intern student from IIT, Guwahati in India working on the Lexel™ II Array biosensor project.
- Mr Vadim Milirud transferred to the Masters program at the University of Calgary from Ben-Gurion University in Israel.
- Mr Konrad Walus has accepted an Assistant Professorship at the University of British Columbia.
- Mr Rumi Zhang has accepted a position as a PhD graduate student in the ATIPS Laboratory.

Partnerships And Collaborations

- Key partnerships with academic and industry groups including Gennum Corp, DALSA Corp., and Micralyne Inc. These partnerships have resulted in substantial funding, productive research initiatives, and IP.
- Our partnership with NE2 Inc. has helped us to gain the aforementioned Strategic Grant.

- New partnerships have been agreed with Tsinghua University and Semiconductor Manufacturing International Corporation, in China.
- Partnership with Micralyne Inc. has resulted in the successful fabrication of a novel design for microneedle arrays.
- Four new collaborations have been initiated with members of the faculty of medicine as part of a major new thrust promoting the biomedical potential of ATIPS' microsystems engineering expertise.
- Exchange agreements have been signed with research groups from GETA (Helsinki), LIRMM (Montpellier), and LIP (Lyon).

Team Leader and ATIPS Faculty

NAME AND ROLE	RESEARCH INTERESTS OR TOPIC	OTHER INFORMATION
G. A. Jullien: ATIPS Lab. Director and Team Leader	Integrated Circuits System-on-Chip Computer Arithmetic Signal and Video Processing Machine Vision Neural Networks MEMS, QCA Fault Tolerance	Fellow of the IEEE Director of the Centre for Microsystems Engineering Member of 8 national and international awards and reviews committees Member of the Board of Directors of CMC Microsystems, Micronet R&D and DALSA Corp Invited to edit a special issue of IEEE Proceedings on System-on-Chip 2004-2005 Co-author of Micralyne Award at Texpo 2004
V.S. Dimitrov: iCORE Research Associate	Number Representations Cryptography Digital Signal Processing Large-scale Optimization Parallel Algorithms	PI on a $506K NSERC Strategic Grant Member of the Signal and Image Processing Program Committee for IASTED 2004 Member of the Centre for Information Security and Cryptography (CISaC) Management Board
W. Badawy: iCORE Research Associate	VLSI Architectures System-on-Chip Video Processing Image Recognition Low-power Design VLSI prototyping	IEEE award for notable service and contributions towards the advancement of IEEE and the engineering professions Man of the Year (2004), the American Biographical Institute, NC, USA Program Co-Chair of the 2004 IEEE "International Workshop on System on Chip for Real-time Applications" Technical Co-Chair of the 2004 "International Conference on MEMS, NANO and Smart Systems"
O. Yadid-Pecht: iCORE Research Associate	CMOS Image Sensors Integrated Sensors Smart Sensors Image Processing algorithms & Hardware implementation Micro-systems	IEEE International Conference on Electronics, Circuits and Systems General Conference Chair Deputy Editor-in-Chief of the IEEE Trans. on Circuits and Systems IEEE Circuits and Systems Society - Distinguished Lecturer IEEE Circuits and Systems Society - Achievement Award

Research Associates

NAME AND ROLE	RESEARCH INTERESTS OR TOPIC	OTHER INFORMATION
I. Finvers	Wireless Monitors & Analog Instrumentation for Health Sciences	Joint position with RFIC Research group
J. Yeboah	CNN Analog Arrays for Low-Noise Digital Adder Design: cellular neural networks, transistor circuit design, computer arithmetic, and integrated circuit design	
H. Zhun	Integrated circuit designs for security applications	Partially funded under NSERC Strategic Grant

Postdoctoral Fellows

NAME AND ROLE	RESEARCH INTERESTS OR TOPIC	OTHER INFORMATION
S. Amer	MEMS Modeling and its manufacturability	Fully funded from the MTC
M. El Zewidi	Secure Data Mining	Fully funded from the MTC
A. Fahmy	Security protocols for streaming data	Fully funded from the MTC
L. Imbert	Computer arithmetic, data security and cryptography, application-optimised arithmetic, efficient implementation of cryptographic systems, high speed computing, fault-tolerant algorithms	Visiting CNRS scholar from Laboratoire d'Informatique Robotique et Microélectronique de Montpellier (LIRMM), France.
R. Muscedere	Difficult Operations in Double-Base Number Systems: multi-dimensional logarithms, conversion and arithmetic algorithms, and integrated circuit implementation	Now an Assistant Professor at the University of Windsor
R. Potucek	Neuron-silicon interfacing Dr Potucek is the first joint PDF between ATIPS and the Faculty of Medicine	Joint initiative with Professor Naweed Syed's Neuroscience Research Laboratory
P. Zhang (MEMS)	Bio MEMS, Optical MEMS, MEMS Processes, Integration Facility procedures	$30K Micralyne fabrication grant
W. Zhang (SoC)	Data Stream SoC Architectures, VLSI Design, Integrated Circuit Test, Neural Networks	

PhD Students

NAME AND ROLE	RESEARCH INTERESTS OR TOPIC	OTHER INFORMATION
M. Ahmadi	Plexel Arrays for bio-sensors	eMPOWR (NSERC) Scholarship
I. Amer	New standards for high performance streaming video processor architectures (H.264)	iCORE Graduate Student Scholarship AIF Studentship Nominated for "Best Student Paper" at IEEE Conference on Acoustics, Speech, and Signal Processing, Philadelphia, Pennsylvania, USA, March 2005

NAME AND ROLE	RESEARCH INTERESTS OR TOPIC	OTHER INFORMATION
I.C. Baykal	Defect detection using in-Camera Video Stream Processing: Self-Synchronized TDI, Machine Vision, Line-scan CCD, FPGAs, and Video Processing	Applied for provisional patent for a novel TDI self-synchronization technique for CCD cameras Successfully defended thesis January 2005
J. Cai	Video Streaming platform for multi-stream management	
R. Choudhury	Ridgelet Transforms for image compression	eMPOWR (NSERC) Scholarship
A. Entershari	Flexible on chip DEP Arrays for bio-sensors	eMPOWR (NSERC) Scholarship
J. Eskritt, (Part-time)	Applications of MDLNS with complex bases for quadrature signal processing: computer arithmetic, logarithmic number systems, digital signal processing, integrated circuit design	Also ATIPS Lab Manager
M. Fu	Applications of Algebraic Integers in New Architectures for Video Codecs: multi-dimensional algebraic integers, DCT, VLSI design	Research Centre for Integrated Microsystems: University of Windsor
Y. Ghallab	Sensors for electrical fields in micro-channels	Successfully defended in April 2005. Has accepted a postdoctoral position with the joint ATIPS neuron-silicon interfacing group
S. Hammouda	Analog IP migration	
Y. Ibrahim	Very low-noise Arithmetic Processing Unit using Non-Linear Analog Arrays: CNNs, computer arithmetic, analog circuit design	Research Centre for Integrated Microsystems: University of Windsor Defending in June 2005
T. Mohamed	Streaming video compression standards and algorithms (MPEG-4), Architecture for motion tracking	iCORE Scholarship AIF Studentship
B. Prasad	Lab-on-a-Chip analysis platform, Cell tracking algorithms for bio-sensors	
C. Rahman	Motion Estimation Architectures for H.264 / MPEG-4 Part 10 Advanced Video Coding	eMPOWR (NSERC) Scholarship
A. Razavi	Hybrid CMOS Imagers, plenoptic camera systems	EMPOWR (NSERC) Scholarship
M. Sayed	Embedded memory solutions for video applications	iCORE International Scholarship Strategic Microelectronics Council Industrial Collaboration Award at CMC MR&DCAN (co-authored)
Khan Arif Wahid	Compression transforms, algebraic integers, VLSI architectures	Uof C Graduate Faculty Council Scholarship April, 2003 eMPOWR (NSERC) Scholarship
K. Walus	Quantum Cellular Automata: modeling and simulation of quantum dot arrays, design tool development, split-current QCA	NSERC Postgraduate scholarship eMPOWR (NSERC) Scholarship ASTECH "Research Leader of Tomorrow" award Defends his thesis in August 2005

NAME AND ROLE	RESEARCH INTERESTS OR TOPIC	OTHER INFORMATION
K. Wooding	Cryptography and Network Security, Computational Number Theory, Computer Engineering	Co-supervised with Dr H. Williams, CISaC Partially funded by NSERC & Micronet
J. Wu	Asynchronous Multi-Dimensional Logarithmic Number System (MDLNS)	Transferred from RCIM, University of Windsor

MSc Students

NAME AND ROLE	RESEARCH INTERESTS OR TOPIC	OTHER INFORMATION
A. Chan	FPGA implementations and ECC encryption protocols	Co-supervised by Dr M. Jacobson, Department. Of Computer Science Partially funded by NSERC
I. Chervensky	The use of wavelet transforms in biomedical imaging	Co-supervised by collaborator, Dr Mintchev, Director Bio-Instrumentation Lab Partially funded by NSERC
I. Choi	Bio-Cell analysis system for diagnosis purposes	
J. Doherty	Transcutaneous Powering of an Implantable Stimulator for Re-creation of Impaired Gastrointestinal Motility: transcutaneous power transfer, circuit modeling, data coding, integrated circuit design	AIF Scholarship and travel award. Co-supervised by Dr K.I.V.S. Kaler, Director of the Biosystems Research and Applications Group
L. Fleshel	CMOS wide dynamic range sensors	Transferred from Ben-Gurion University
R. Glabb	Low-power System-on-Chip Platforms: IP blocks, design reuse, wrappers, System-on-Chip & embedded design, Cryptography	SoC Lab Manager, Principal Contact for NE2 Collaboration, Major contributor to Strategic Grant application with NE1, SGI and CISaC Successfully defended thesis in April 2005
S. Hamami	Active Pixel Sensor with Pipeline ADC	Writing-up Will be progressing to the PhD program
J. Hogan	Gastrointestinal Pressure Sensors	
P. Horbal (Part-time)	Adiabatic logic for ROM-Based Architectures: adiabatic circuits, minimized dual-rail switching trees, applications to DBNS and MRRNS processors	ATIPS Webmaster and publicity director
N. Karanwal	Software simulation of Fast Fourier Transforms	Partially funded by NSERC & Micronet
J. Keilman	Lexel™ Arrays for Cell Manipulation using Dielectrophoresis: non-uniform electric field generation, microfluidics, integrated processors	NSERC Postgraduate Scholarship Micralyne Award Winner (Texpo 2004) Defending thesis in June

NAME AND ROLE	RESEARCH INTERESTS OR TOPIC	OTHER INFORMATION
M. Mazur	Interfacing with Quantum Cellular Automata, computer communication, Digital logic design/FPGA programming, Embedded systems/firmware development	
V. Milirud	Wireless CMOS imagers	Transferred from Ben Gurion University (Israel)
G. Nelson	CMOS Imager watermarking	NSERC Postgraduate Scholarship
Y. Qiu	An H.264 compatible hardware/software platform for digital video streaming	
G. Schulhoff	Modelling Quantum Dots on a Computer Cluster: quantum dots, quantum mechanics, QCA, simulation tools, computer clusters	
A. Shaohui	Digital Video Processing	Graduated M.Eng. this year
P. Sheridan	Galois field arithmetic and efficient algorithms for matrix inversion over finite fields and rings	Co-supervised with Dr H. Williams, I Partially funded by NSERC
T. Tam	CMOS Imagers: Analog Noise Reduction, Optimising analogue chain to increase sensitivity	Awarded NSERC PGS M scholarship
R. Zhang	Logic design for Quantum Cellular Automata	Defended successfully in March at the University of Western Ontario. Currently with ATIPS on an AIF scholarship

Other Team Members

NAME	ROLE	OTHER INFORMATION
J. Eskritt	ATIPS Lab. Manager & Administrator for the CCIT SoC Secure Laboratory	Also PhD Candidate
P. Horbal	Technical writer and other publicity functions	Also MSc candidate
J. Nakaska	ATIPS Lab Assistant, Webmaster	Also PhD candidate in the RFIC Group
C. O'Neill	Strategic Research Manager	Part-time

COLLABORATIONS

Over the past year we have developed and maintained numerous important collaborations. Some represent current work and some represent an investment that will enable our research growth and technology transfer activities in the coming years. Of the collaborations listed, some have provided financial support (and/or access to IP) to ATIPS while the remaining will or have enabled access to otherwise confidential IP and knowledge.

UNIVERSITIES AND INSTITUTES

PROVINCIAL	
COLLABORATOR	PIS INVOLVED
Centre for Information Security and Cryptography (CISaC) (U of C) **Department of Mathematics (U of C)** Prof. Hugh Williams, iCORE Chair in Cryptography, established CISaC in 2003 to bring together a multidisciplinary group with a shared interest in cryptography and quantum computing. Drs. Dimitrov and Jullien are members of this centre and Dr Dimitrov also sits on the board of CISaC as the Engineering Representative. A joint project between CISaC and the ATIPS Lab. was started in 2003 with NE2, Calgary, and a major Strategic grant was awarded to CISaC and ATIPS this year, supported by NE2 and SGI Canada.	H. Williams R. Scheidler V.S. Dimitrov G.A. Jullien
Institute for Quantum Informations Science (IQIS, U of C) Growing out of our collaboration with CISaC and NE2, we are currently in discussions that also include Dr Barry Sanders' IQIS group, and General Dynamics Canada. This collaboration is investigating the potential of a major initiative in the field of Information Assurance and Security (IAS) that could form the basis for significant growth in the field of IAS within Alberta.	B. Sanders H. Williams G.A. Jullien J.W. Haslett
Centre for Biomedical Research Engineering (U of C) Collaborations have been initiated with members of this group interested in the use of Microsystems for bio-engineering applications. A joint CSA-CIHR grant application has been submitted.	Jullien Shrive
Department of Chemistry (U of C) We are jointly investigating instrumentation techniques for nano-biosensors and their integration with our low-power SoC bio-platform. A key part of this collaboration is our work on implantable glucose monitors.	Jullien Birss
Departments of Anatomy and Physiology (U of C) We have begun a collaboration with Prof. Naweed Syed of the Departments of Anatomy and Physiology. Prof. Syed has created quite a stir in the media with the disclosure that he and a team led by Prof. Dr Peter Fromherz of the Max Planck Institute in Germany, have closed the loop between live neurons and a silicon chip. This work has vast ramifications for future therapies for a variety of conditions associated with neuronal damage. It may also lead to advancements in information processing using biological neural networks. The ATIPS Laboratory will be continuing the work begun by the Max Planck institute, producing large arrays of neuron stimulators and sensors complete with information processing systems on single wafers on which networks of neurons may be grown.	Syed Jullien
Faculty of Medicine (U of C) A collaboration has begun with Dr Douglas Zochodne of the Faculty of Medicine to look at Microsystems for nerve regeneration. A joint CIHR grant has been submitted.	Zochodne Syed Jullien
Faculty of Medicine (U of C) Dr Jullien has formed an alliance with Dr Henry Duff's research group to explore the potential of microsystems in bio-cell ion-channel activation applications.	Duff Jullien

COLLABORATOR	PIS INVOLVED
Faculty of Medicine, Radio Frequency Integrated Circuits Group (U of C) Dr Jullien has joined a team, led by Dr Bob Sheldon of the Faculty of Medicine, to explore the development of wireless monitoring devices for in-situ real-time cardiovascular measurements. This collaboration will also involve the RFIC group, directed by Dr J.W. Haslett, iCORE Chair, and has close links with the "Ward of the 21st Century" project, for which J.W. Haslett is a principal investigator.	Sheldon Duff Roach Haslett Jullien
Centre for Microsystems Engineering - U of C Faculty of Engineering Researchers The CME was established to support research initiatives in the area of micro- & nano-systems and their integration into novel devices. A series of seminars and workshops were presented over the past year.	Jullien, Spiewak and more than 25 other members from the Faculty of Engineering
University of Alberta Drs Badawy and Moussa continue their collaboration on the development of new designs for micro-pumps for drug delivery. The new micro-pumps will be used to further their work on the iPill, for which they received international recognition in 2003.	W. Badawy W. Moussa
City of Calgary Dr Badawy has been applying his novel work on vision systems to the development of an Active Camera Tracking System for Traffic Analysis. The City of Calgary is contributing $90K/year and also allowing special access to traffic lights and infrastructure.	W. Badawy
NATIONAL	
COLLABORATOR	PIS INVOLVED
CMC Microsystems CMC provides microsystem design tools, and fabrication and information services to 44 Canadian Universities, and Colleges. Dr Jullien has been a member of CMC since 1985. He was on the Board of Directors from 1989-93 (vice-chairman of the Board in 1993) and rejoined the Board in 2001. He is one of 10 principal researchers in the System-on-Chip Research network, funded by a $40M CFI grant. Drs. Badawy and Jullien are lead clients for the IP blocks that were purchased from the CFI funds, and the IP-block authoring suite being developed by a sub-committee of the Technical Advisory Committee. A secure laboratory has been set up in the CCIT building to handle commercial IP blocks in the development of SoC platforMs ATIPS researchers and other users of the ATIPS Laboratory provided over 50% of the posters at the 2004 Texpo, a national CMC workshop showcasing Microsystems research form all Canadian University members. Several CMC members from École Polytechnique and the University of Toronto attended as guests at the ATIPS Lab. retreat, during the iCORE 2004 Banff Summit.	ATIPS Laboratory members Other Canadian university participants in the SOCRN
Micronet R&D (NCE) Dr Jullien was one of the founding members of Micronet, one of the first 14 Networks of Centres of Excellence, and one of only 5 to be funded through the full 14 year life-span of networks in the NCE program. Dr Jullien sits on the Board of Directors, the Steering Committee, and the Coordinating Committee of Micronet. Dr Jullien leads a project between the Universities of Calgary and Windsor that was funded at one of the highest levels in 2003, and the largest funded project in 2004. In addition, Dr Jullien is a co-applicant for a second project at the University of Windsor.	ATIPS W. Badawy V.S. Dimitrov G.A. Jullien, W.C. Miller M. Ahmadi (RCIM U Windsor) Other Micronet participants
RCIM Laboratory faculty, University of Windsor We have a formal association with the Research Centre for Integrated Microsystems and are co-applicants on 2 Micronet grants. G. Jullien currently supervises or co-supervises 2 graduate students. Our area of research is in hearing instruments, MEMS, and signal processors. Dr Jullien is an Adjunct Professor at Windsor.	G. Jullien V.S. Dimitrov W.C. Miller M. Ahmadi
ECE Department University of Western Ontario Collaboration on QCA arithmetic structures, and quantum cellular automata arithmetic and logic structures. G. Jullien was awarded an Adjunct Professorship at Western in order to enhance this collaboration. A co-supervised Masters student successfully defended his thesis in March 2005.	Jullien Wang

INTERNATIONAL	
COLLABORATOR	PIS INVOLVED
Laboratoire d'Informatique, de Robotique et de Microélectronique de Montpellier, France G.A. Jullien and V.S. Dimitrov, have a strong research association with Dr L. Imbert (CNRS Researcher) and Dr J-C. Bajard (Director of the Department of Fundamental and Applied Informatics). This research focuses on computer arithmetic, cryptography, and fault tolerance. Dr Imbert has received a renewal of his leave from CRNS, France, to spend another year at the University of Calgary. Dr Bajard visited the ATIPS laboratory from March to April 2004, to discuss joint research. Prof. Valerie Berthé, also with LIRMM, visited Calgary for two weeks in 2004 to discuss joint research on the Double-Base Number System and associated Multidimensional Logarithms, discoveries by members of the ATIPS Laboratory. In total, this collaboration has resulted in the submission of five research papers in the past year. A research exchange agreement has also been signed between ATIPS and LIRMM, on the same basis as that described below with LIP in Lyon	G. Jullien V.S. Dimitrov L. Imbert J. C. Bajard V. Berthé M. Robert
Laboratoire de l'Informatique du Parallelisme (ENS) Lyon A research exchange agreement has been signed with LIP to promote collaboration in graduate student training and research. Both parties will offer short-term research internships for graduate internship and exchange students. The training will consist of collaborative research projects between laboratories and supervisors at the two institutions.	J. M. Muller G. Jullien
Ben-Gurion University, Isreal Dr Yadid-Pecht was head of the VLSI Systems Center at Ben-Gurion University (Israel) and is still collaborating on research with the staff there.	O. Yadid-Pecht
Graduate School in Electronics, Telecommunication and Automation (GETA) Helsinki University of Technology Dr V.S. Dimitrov has strong ties with GETA, and was a consultant there from 1997-2000. He has taught short courses at GETA from 1998 to the present. G. Jullien also took part in a short course given in September 2004. The areas of research are DSP, number theoretic techniques and cryptography. An agreement was signed in 2004 for a student exchange program between the two laboratories. This will also facilitate research collaboration between the ATIPS Laboratory and various universities in Finland who are indirectly party to this agreement. The student exchange will allow graduate students to visit each other's research laboratories for a period of about 3 months, and will include taking graduate courses as part of their degree program.	V.S. Dimitrov G.A. Jullien I. Hartimo
Microelectronics Institute Tsinghua University, Beijing Research collaboration with the Microelectronics Institute was initiated by a visit, in August, to Prof. H. Chen, Academic Director of the Institute, and some of his colleagues. We have agreed to work on some areas of security systems that lend themselves to integrated circuit implementations. A recent Ph.D graduate, Zhun Huang, has accepted a position in the ATIPS Laboratory to work on the NSERC Strategic Grant.	Chen Jullien
John Hopkins University, USA Dr R. Etienne-Cummings (Johns Hopkins), specializing in Neuromorphic Engineering, and Dr Yadid-Pecht have co-written a guest editorial for a special issue on Smart Sensors in the Analog Integrated Circuits journal, published in June 2004. They have also co-edited a book on CMOS Imagers for Kluwer Press.	O. Yadid-Pecht R. Etienne-Cummings
University of Texas, Austin Dr Earl Swartzlander, of the Department of Electrical and Computer Engineering, has had strong ties with Dr Jullien's research group over the past 18 years. Dr Swartzlander and Dr Jullien have been involved in the organization of several conferences in the area of array processing and computer arithmetic, and Dr Swartzlander was a plenary speaker at the SPIE Conference in August 2004, co-chaired by Dr Jullien.	G. Jullien E. Swartzlander
University of Louisiana at Lafayette Professor M. Bayoumi, Director of the Centre for Advanced Computer Studies and Head of the Computer Science Department at the University of Louisiana at Lafayette, visited the ATIPS Laboratory and presented a seminar, "Integration: Challenges and Opportunities", on April 16th, 2004. Prof Bayoumi also returned on June 5th to attend the iCORE Banff Summit and to take part in the ATIPS Laboratory panel discussion and to provide feedback to students in the ATIPS Laboratory Retreat. G. Jullien and M. Bayoumi have also been invited as guest editors for a special issue on "System on Chip" in the IEEE Proceedings. This is the flagship technical journal for The Institute of Electrical and Electronic Engineers (IEEE).	G. Jullien M. Bayoumi

For brevity we list other academic collaborations together with contacts and research areas in the following table.

GROUP	CONTACT(S)	FIELD OF STUDY
Centre for Microsystems Engineering (CME)	Dr K. Kaler, Dr A. Budiman, Dr M. Okoniewski, and others	Micro/Nano-systems design & integration
Ben Gurion University	Dr M. Katz	VLSI (Very Large Scale Integration)
University of Maryland	Dr Cohen, Dr Abshire	CMOS Sensors
Qinetiq, Malvern, UK	Dr I. Proudler	Emerging Technologies
UCLA	Prof. M. Ercogovac	Computer Arithmetic
University of Florida, Gainesville	Dr F. Taylor	Real-Time Architectures
Eshraghian Laboratories Pty Ltd, Perth, Australia	Dr K. Eshraghian	VLSI Design, Processor Architectures, emerging technologies
Universita' degli Studi di Trento	Dr Andreas Caranti	Number Representations, Crypto
Notre Dame University, Indiana	Dr Craig Lent	Quantum Cellular Automata
The University of Wisconsin, Madison	Dr M. Schulte	Computer Arithmetic

INDUSTRIAL COLLABORATIONS

COLLABORATOR	PIS INVOLVED
DALSA Corp., (Ontario – head office) Dr Jullien has had a long-term research interaction with DALSA Inc. Dr Jullien helped pioneer the concept of in-camera defect detection in 1990 with J. Roberts of DALSA. This idea, patented in 1995 has resulted in sales exceeding $20M over the past decade. Related research has been supported by Micronet with industrial funding from DALSA (approximately $500K over the past decade with matching funds).	G. Jullien J. Roberts G. Ingram C. Flood M. Miethig
Non Elephant Encryption Systems (NE2) (Alberta) This interaction, started in June 2003, has led to the development of custom hardware, simulators, and rapid-prototyping emulators for a patented NE2 key establishment algorithm that promises to revolutionize secure network transmission. The research team is a collaboration between the ATIPS secure SoC laboratory, CISaC, and a team from NE2. On the back of this success, and with support from NE2 and SGI Canada, ATIPS and CISaC have been awarded a Strategic Grant to continue and expand the scope of the work. In a related sphere this collaboration is also expected to evolve to include one of NE2's partners: General Dynamics – a multi-national corporation interested in security products and services.	G. Jullien V.S. Dimitrov H. Williams R. Scheidler L. Imbert M. Tims B. Mackie
TRLabs, Calgary (Alberta) TRLabs has provided sponsorship to the ATIPS Laboratory since its inception. An intern student was partially supported from TRLabs funding working on signal processing components for an experimental 1.2Gbps wireless LAN during 2004.	G. Jullien, G. McGibney
SGI, Alberta and international We are establishing a close working relationship, investigating software and hardware based cryptography initiatives, through their participation in our Strategic Grant.	G. Jullien V.S. Dimitrov H. Williams R. Scheidler L. Imbert B. Kondruck
Gennum Corporation (Ontario – head office) Dr Jullien has been working with Gennum Corp. since 1994. The initial work, which is still on-going, was in the area of video signal processing (for broadcast quality TV signal processing). Since 1998 our group has worked with Gennum on hearing instrument processors. Since 1994, Gennum has contributed over $700K (including matching funds) to our research.	G, Jullien V.S. Dimitrov D. Salvador D. Lynch D. Simmons X. Liu

COLLABORATOR	PIS INVOLVED
Micralyne Inc., Alberta Micralyne is a fabricator of MEMS and speciality integrated circuits in Edmonton. We have been communicating with the company since the ATIPS Laboratory was established. In 2005 we received the first prototypes of the micro-needle blood-sampling / drug delivery system jointly developed between ATIPS and Micralyne and supported by Micralyne funds. A poster describing our recent research on the Lexel™ Array won the Micralyne Award at the 2004 CMC Texpo.	G. Jullien P. Zhang C. Lumb Y. Loke T. Zhou
SMIC, Shanghai IP sharing with the Semiconductor Manufacturing International Corporation (SMIC), in Shanghai. In August 2004, G. Jullien visited a former research associate, who leads one of the design groups at SMIC, and discussed the possibility of obtaining integrated circuit fabrication in one of their advanced processes. Discussions are currently in progress, and a pilot chip design in a selected SMIC process will be started in 2005.	G. Jullien W. Luo
Other industrial contacts We have several other industrial contacts as follows: Qinetiq, UK, (formerly the Royal Signals and Radar Establishment). We have had strong interactions with Dr J. McWhirter, FRS, Dr I. Proudler, and Dr R. Walke in the area of array processors for DSP in the past. Dr Jullien will be visiting Dr Proudler in May 2005 to discuss QCA and QCADesigner. Dr Dimitrov has served on the advisory board of iPROS, a Toronto based start-up in the area of high performance arithmetic for communication systems.	ATIPS Laboratory personnel, and other industrial teams

INTELLECTUAL PROPERTY

TYPE OF IP AND ATIPS MEMBER	TITLE/NAME	STATUS
PATENTS		
Yadid-Pecht	"Optical image using a method for adaptive real-time expanding of the dynamic range"	Approved December 14, 2004 US Patent No. 6,831,689
Badawy	"Mesh Based Frame Processing And Applications"	Filed May 4, 2004 Canadian Patent Application, No.: 2466247
Badawy	"Mesh Based Frame Processing And Applications"	Filed May 7, 2004 United States Patent Application, No. 10/840,433
Ghallab & Badawy	"Imaging System"	Filed July 23, 2004 United States Patent Application, No. 10/896,867
Badawy	"Video Based Monitoring System"	Filed July 29, 2004 United States Patent Application, No. 10/898,952
Mintchev, Kaler, Yadid-Pecht	"Integrated Esophageal Pressure, pH and Bolus Transit Sensor"	Submitted 2004 United States Provisional Patent (Sandhill Scientific – UTI)
Dimitrov & Jullien	"Efficient technique for Elliptic Curve Cryptography computations using a special form of the Double Base Numbering System"	Filed December, 2004 United States Patent Application, No. 60/481,806
INVENTIONS		
Baykal & Jullien	"Synchronization of Time Display and Integration Cameras"	Filed April 21, 2004 Full patent submission filed April, 2005 United States Provisional 60/521,414

FUNDING

This year Graham Jullien and his team received funding from NSERC (~$591K), and the University of Calgary ($577K) to support his lab's exciting new research in biomedical engineering. In addition, government consortiums (CMC and Micronet) have contributed ~$274K, with another ~$258K coming from several industrial sources such as GCE Market, DALSA, Gennum, Micralyne, Sandhill Scientific, and Intellisense.

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