ANNUAL REPORT

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2002 – 2003

RÉSEAU QERRAnet

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Quebec Network for
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For the period:

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Réseau QERRAnet
Quebec Network for Research in Artificial Reality
Rapport Annuel 2002-2003 Annual Report

MISSION STATEMENT

To investigate the use of distributed information systems to create shared environments across different physical locations.

Études sur l'utilisation des systèmes d'information répartis pour la creation d'environnements partagés sur des sites répartis.

OBJECTIVES

- To develop an infrastructure for distributed co-operative research in augmented reality that fosters integration, cooperation and collaboration.
- To contribute to the academic missions of both McGill University and Université Laval by providing our graduate students in science and engineering with the opportunity to study with world-class researchers.
- To positively impact society through the results of our research by developing new tools and methodologies for use in the educational, industrial and health-care sectors.

- Développer une infrastructure pour la poursuite de recherches en réalité augmentée coopérative distribuée favorisant l'intégration des activités de même que la coopération et la collaboration entre les chercheurs.
- Contribuer à l'atteinte des objectifs de formation académique de l'Université McGill et de l'Université Laval en offrant aux étudiants aux cycles supérieurs l'opportunité de travailler dans des équipes formées de chercheurs de calibre international.
- De valoriser l'impact des résultats de la recherche sur la société par le développement de nouveaux outils et de nouvelles methodologies ayant un fort potentiel d'application dans les domaines de l'éducation, de l'industrie, de même que dans le secteur des soins de santé.

Executive Summary

The primary objective of QERRAnet (formerly known as Réseau Québécois de recherche en réalité artificielle distribuée) is to create a network comprised of Quebec's leading scientists in the areas of artificial intelligence, computer vision and robotics – collectively known as intelligent systems – for the purpose of developing a new research program in virtualized and shared reality (VSR).

The key players behind the creation of QERRAnet include researchers from both the Computer Vision and Systems Laboratory (CVSL) of Université Laval and a subset of researchers from the Centre for Intelligent Machines (CIM) of McGill University. These individuals share a common passion and interest in the study of fundamental science underlying VSR and its application in the areas of medicine, manufacturing and natural resources. Many of these researchers had already worked together for several years on collaborative initiatives under various NSERC and NCE IRIS programs before forming QERRAnet.

Today, the network is comprised of 21 members from three institutions – 12 full members from McGill University, 8 full members from Université Laval and one associate member from École Polytechnique.

The full members of QERRAnet are listed below:

L'objectif principal du réseau QERRAnet (connu auparavant sous le nom de Réseau Québécois de recherche en réalité artificielle distribuée) est de créer un réseau composé des scientifiques québécois de pointe dans les domaines de l'intelligence artificielle, de la vision numérique et de la robotique – domaines souvent regroupés sous le vocable de « systèmes intelligents» – afin de développer un nouveau programme de recherche en réalité virtualisée et partagée (RVP).

Les principaux chercheurs à l'origine de la création de QERRAnet sont issus en partie du Centre for Intelligent Machines de l'Université McGill et du Laboratoire de Vision et Systèmes Numériques de l'Université Laval. Ces chercheurs partagent la même passion et le même intérêt pour l'étude des sciences fondamentales supportant la RVP et ses applications dans les domaines de la médecine, des ressources naturelles et des procédés de fabrication. La plupart des chercheurs de QERRAnet ont déjà collaboré étroitement pendant plusieurs années sur des projets subventionnés par divers programmes du CRSNG et du Réseau de centres d'excellence canadiens IRIS avant de former le réseau QERRAnet.

Aujourd'hui, le réseau est formé d'une vingtaine de membres provenant de trois universités – 12 membres réguliers de l'Université McGill, 8 membres réguliers de l'Université Laval et un membre associé de l'École Polytechnique.

La liste des membres réguliers de QERRAnet se trouve ci-dessous:

Jorge Angeles	**Tal Arbel**
Robert Bergevin	**Benoit Boulet**
Martin Buehler	**Peter Caines**
James Clark	**Jeremy Cooperstock**
Gregory Dudek	**Frank Ferrie**
Clément Gosselin	**Vincent Hayward**
Patrick Hébert	**Michael Langer**
Denis Laurendeau	**Xavier Maldague**
Marc Parizeau	**Denis Poussart**
Kaleem Siddiqi	**André Zaccarin**

The process of forming the network began in early 2001, when originating members Robert Bergevin, Denis Poussart, Frank Ferrie and Vincent Hayward held a series of formal and informal meetings. The purpose of these meetings was to effectively develop a network that would capitalize on the complementary infrastructures of both universities, with the goal of establishing a virtual laboratory of world-class status. In a meeting held at McGill University in the spring of 2001, the *Réseau Québécois de recherche en réalité artificielle* was officially formed, and Frank Ferrie was voted as interim Director. In early 2002, members Denis Laurendeau and André Zaccarin joined the network.

The scientific research program of the Network was adopted at a meeting held at Université Laval in February 2002. The main research themes within the Network are:

- wideband communications and human-computer interaction;
- data acquisition from real-world themes;
- integration of human inhabitants in virtual worlds.

In addition, detailed plans were formulated with respect to i) the composition of the membership, ii) proposed activities of the student membership, iii) management structure iv) budget and financial reporting requirements and v) the creation of various committees to represent both the student community as well as participants from industry. Further into 2002 and early 2003, a more formal organizational structure was put in place. This includes an Advisory Board that oversees the functions of the network according to the regulations set down by the university. It is comprised of senior officials from both universities and industry, and is expected to meet once a year, likely at the Annual General Meeting of the Network.

Our research program provides excellent training opportunities for graduate students and postdoctoral fellows. In 2002-2003, the student population of QERRAnet consisted of 69 Master's students, 47 PhD students and 3 Postdocs. Scientific contributions by members comprised of 33 articles in refereed journals, 81 articles appearing in refereed conference proceedings and three patent applications. Additionally, the network held approximately 40 seminars on related topics.

Le processus de mise sur pied du réseau a débuté en 2001 quand les fondateurs, les Dr Robert Bergevin, Denis Poussart, Frank Ferrie et Vincent Hayward, ont tenu une série de réunions formelles et informelles dont l'objectif principal était de développer un réseau sachant tirer profit des infrastructures complémentaires des deux universités, avec le but ultime d'établir la synergie nécessaire à la création d'un laboratoire virtuel de calibre international. Lors d'une réunion tenue à l'Université McGill au printemps 2001, le *Réseau Québécois de recherche en réalité artificielle* a été officiellement formé, et le Dr Frank Ferrie a été élu directeur intérimaire. Au début de l'an 2002, les membres Denis Laurendeau et André Zaccarin se sont greffés au réseau.

Le programme de recherche scientifique du Réseau a été adopté lors d'une réunion tenue à l'Université Laval en février 2002. Les thèmes de recherches incluent:

- les techniques de communication à large bande et la communication personne-machine;
- l'acquisition de données de scènes réelles;
- l'intégration des personnes dans les environnements virtuels.

De plus, les procédures détaillées ont été formulées en ce qui a trait i) à l'adhésion au réseau et au divers types de membres, ii) aux activités proposées pour les étudiants membres, iii) aux mécanismes de gestion, iv) à la structure administrative pour la gestion du budget et des finances, et v) à la création de divers comités représentant la communauté étudiante et les participants du secteur industriel. Plus tard en 2002 et au début de l'an 2003, une structure organisationnelle plus formelle a été mise en place. Cette structure inclut un comité conseil qui supervise le bon fonctionnement du réseau selon les règles établies par l'Université. Ce comité conseil, composé de représentants venant des deux principales universités de même que du secteur industriel, se rencontre une fois par année lors de la réunion générale annuelle du Réseau.

Notre programme de recherche représente un milieu fertile et dynamique pour la formation d'étudiants aux cycles supérieurs et de stagiaires postdoctoraux. En 2002-2003, le nombre d'étudiants membres de QERRAnet s'élevait à 69 étudiants à la maîtrise, 47 étudiants au doctorat et 3 stagiaires postdoctoraux. Les contributions scientifiques des membres comptent 33 publications dans les revues scientifiques, 81 publications dans des comptes-rendus de conférences et 3 dépôts de demandes de brevet. De plus, le réseau a tenu 40 séminaires sur des

Over the years, members of QERRAnet have enjoyed considerable success in attracting funding for core research and infrastructure support. As a new entity, the Network was approved funding under the FQRNT/NATEQ regroupement stratégique program for the period January 1, 2002 to December 31, 2005. This funding is matched internally through McGill's Office of the Vice Principal (Research), and Un. Laval's Office of the Vice-Recteur (Research). The average funding from all sources for 2002-2003 is approximately $4.6M/year. This funding is broken down into $2.5M/year in grants from Federal agencies, $.7M/year from Provincial agencies and $1.3M/year from contract research.

A key milestone of the Network is the design and implementation of the QERRAnet Shared Presentation Facility (QPSF), a virtual seminar room enabling participants from Laval and McGill to come together "at a distance". Beginning with an initial series of networking experiments between the two principal nodes in 2002, a preliminary design for the QSPF was completed in early 2003, with initial implementation scheduled for summer 2003. Built on the foundations of the RISQ network, the infrastructure permits high quality, real-time audio and video streaming. The virtual seminar room is created by linking together wall-sized displays and camera systems that permit the participants at each location to view their counterparts, remote presenters, and audio/video data in real-time. Over the duration of this project, part of our research will be directed at the scientific and technical questions of how the create the illusion that all participants share a common space – with significant impact on important applications such as tele-medicine, distance education, and distribution of cultural content to remote regions.

sujets pertinents à sa programmation de recherche.

Les membres de QERRAnet ont bénéficié d'un succès retentissant au niveau du financement de la recherche et du support à l'infrastructure. Le Réseau QERRAnet est financé par le programme de regroupement stratégique du FQRNT/NATEQ pour la période de janvier 2002 à décembre 2005. Ce financement est généreusement complété par les bureaux respectifs des Vice-Principaux à la Recherche des institutions participantes. En moyenne, le financement provenant de toutes les sources pour l'année 2002-2003 était d'environ $4.6M/an. Ce financement comprend $2.5M/an en subventions de recherche provenant des agences fédérales, $.7M/an provenant des agences provinciales et $1.3M/an provenant des contrats de recherche.

Une étape décisive dans l'échéancier du Réseau QERRAnet est la conception et l'implantation de la salle de réunion virtuelle partagée (SRVP), une salle de séminaire virtuelle permettant aux participants de l'Université McGill et de l'Université Laval de se réunir "à distance". Via une série d'expériences de test des infrastructures du réseau entre les deux noeuds principaux en 2002, un design préliminaire de la SRVP a été complété au début de 2003, et une première implantation technique est prévue pour l'été 2003. Tirant profit au maximum des ressources offertes par le RISQ, cette implantation permet la transmission en continu de données audio et vidéo de très haute qualité en temps réel. La salle de réunion virtuelle partagée exploite un ensemble de caméras et des écrans géants pour permettre aux participants localisés à chaque noeud de visualiser les participants et présentateurs des autres noeuds, de même que d'autres données audio/vidéo en temps réel. Au cours de ce projet, une partie des recherches portera sur l'étude des questions scientifiques et techniques pertinentes à la création de l'illusion que tous les participants de la SRVP occupent le même espace – étude qui aura un impact majeur sur des applications importantes relatives à la télé-médecine, à la formation à distance, et la diffusion de contenu culturel aux régions éloignées.

Management Structure

The objective of the organizational structure of QERRAnet is to be light, but extremely responsive. This is in large part due to the fact that the nature of the research to be carried out by the network is dynamic and must remain open to outside influence. QERRAnet's management structure is designed not only to reflect the realities of university-based research, but also to respond to the challenges introduced by the geographical distribution of our membership.

La structure organisationnelle de QERRAnet se veut légère et capable de réagir rapidement. Ceci se justifie en grande partie par la nature de la recherche menée par le réseau qui est très dynamique et qui doit rester ouverte aux influences de l'extérieur. Les mécanismes de gestion de QERRAnet sont conçus afin de refléter les réalités de la recherche universitaire tout en relevant le défi associé à la distribution géographique des membres du réseau.

To meet this objective, a lateral management structure was formed.

Afin de rencontrer cet objectif de légèreté et d'efficacité, une structure de gestion horizontale a été retenue.

On the McGill side, overall scientific leadership of the network is provided by the Director. The primary role of the Director is to oversee the scientific research program of the network in terms of its definition, support, promotion and finance. Working with the membership at large, the Director is assisted by an Associate Director, located at Université Laval, and an Advisory Board, comprised of leaders in the scientific, academic and business community. The Director, and ultimately the network, report to the Dean of Engineering in the Faculty of Engineering of McGill University.

Du côté de McGill, le leadership scientifique du réseau est la responsabilité du Directeur dont le principal rôle est de veiller à la bonne marche du programme de recherche scientifique du réseau quant à sa définition, à son support, à sa promotion, et à la gestion financière. En collaboration étroite avec tous les membres, le Directeur est assisté par un Directeur Associé, à l'Université Laval, et d'un comité conseil formé de leaders provenant des communautés scientifique et académique de même que du secteur des affaires. Le Directeur, et le réseau lui-même, dépendent du Doyen de la Faculté de Génie à l'Université de McGill.

Direction et Secretariat: There are three administrative positions under this budgetary category – manager, assistant (1) and assistant (2). The manager and assistant (2) positions are located at McGill. The manager's key responsibility is to oversee the day-to-day operations of the network as they relate to budgetary issues, report preparation, dissemination of information and organization of network events. The assistant (2) position provides administrative support to the manager and is also located at McGill.

Direction et Secretariat: Trois postes administratifs occupent ce poste budgétaire – gestionnaire, assistant (1) et assistant (2). Les postes du gestionnaire et de l'assistant (2) sont occupés par du personnel localisé à l'Université McGill. Les responsabilités du gestionnaire sont d'assurer le bon fonctionnement des activités quotidiennes du réseau en ce qui concerne les questions budgétaires, la préparation des rapports, la diffusion de l'information et l'organisation des événements du réseau. L'assistant (2) fournit un support administratif au gestionnaire et est aussi occupé par un membre localisé à l'Université McGill.

Professionels et Techniciens: This budgetary category consists of four positions: a network systems manager, two network specialists and one research engineer. At McGill, the network systems manager oversees the systems operations of the network and the complex technical infrastructures of the two universities. This position is supported by one of the network specialist positions indicated in the budget. Both of these technical positions are

Professionnels et Techniciens: Ces items budgétaires portent sur quatre postes : un chef de réseau, deux experts de réseau et un ingénieur de recherche. À l'Université McGill, le chef de réseau gère les opérations des systèmes et infrastructures techniques complexes des deux universités. Ce chef de réseau est assisté par l'un des experts de réseau dont il est fait mention dans le budget. Ces deux postes techniques sont occupés par du

located at McGill and report to the Director of QERRAnet.

On the Laval side, the Associate Director oversees the research program of his unit. This is to ensure that each unit retains a high degree of autonomy while still contributing the overall objectives and operations – both administratively and technically – of the network. In addition, to ensure continuity, should the Director be unavailable for any extended period of time, the Associate Director will assume the Director's responsibilities. This position reports to the Dean of Science and Engineering at Université Laval and the Director of QERRAnet. The Associate Director is assisted by the second network specialist position outlined in the budget as well as the assistant (1) position.

The position of research engineer is divided equally between the two universities to support one part-time position at each unit.

This lateral management structure is designed to emphasize interaction, integration and collaboration. There is a high degree of fluidity in communication between the two universities, thus resulting in the rapid transfer of knowledge across many levels while building on a framework of resource sharing.

personnel localisé à l'Université McGill et dépendent du Directeur de QERRAnet.

Du côté de l'Université Laval, le Directeur Associé dirige le programme de recherche de son unité. Ceci permet à chaque unité de maintenir un degré élevé d'autonomie tout en contribuant aux objectifs et aux activités communes – tant administratives que techniques – du réseau. De plus, si le Directeur doit s'absenter pour une période prolongée, le Directeur Associé est en mesure d'assumer les responsabilités du Directeur. Le Directeur associé dépend du Doyen de la Faculté des Sciences et Génie de l'Université Laval et du Directeur de QERRAnet. Il est assisté par le deuxième expert de réseau mentionné dans le budget et par l'assistant (1).

Le poste d'ingénieur de recherche est partagé à parts égales entre les deux universités et couvre le salaire d'un poste à temps partiel dans chaque unité.

Ces mécaniques de gestion horizontale sont conçus pour favoriser au maximum le niveau d'interaction entre les membres, l'intégration des ressources et la collaboration entre les principaux nœuds du réseau. La communication entre les deux universités est fluide et harmonieuse, ce qui permet un transfert rapide des connaissances à tous les niveaux, tout en tablant sur la mise en commun d'une infrastructure pour le partage des ressources.

Central Administration

Director:	Frank P. Ferrie	Directeur Associé:	Denis Laurendeau
Manager:	Marlene Gray	Coordonnatrice de Recherche:	Annette Schwerdtfeger
Network System Manager:	Jan Binder	Professionnel de Recherche:	Denis Ouellet
Systems Specialist:	Daniel Chouinard	Faculty Members:	8
Administrator	Cynthia Davidson		
Faculty Members:	12		

1. Research Excellence

- Articles appearing in top-ranked international venues, a key indicator of world class standing. Includes high impact peer-reviewed journals and conference proceedings. The latter are particularly important in information sciences where they serve as the principal dissemination venues and are highly selective (< 15% acceptance rates).

- Awards and distinctions for scientific achievement, quality of contributions (best-paper awards, etc.), senior fellowships, editorships of prestigious journals, etc. (indicators of international leadership).

- Impact of research on respective scientific fields as evidenced by seminal articles (widely cited), pioneering research directions, notable "firsts" and breakthroughs.

- Research funding, notably the ranking of individuals within peer-reviewed granting programs (e.g. NSERC), and funding by highly selective programs associated (e.g. DARPA, NSF).

- Other distinctions such as NSERC research chairs, University endowed chairs, CRC chairs, etc.

2. Excellence of Training (HQP)

- Production of first class Ph.D, Masters, and Postdoctoral students as evidenced by the number of students enrolled and the number of degrees awarded.

- Subsequent impact of graduates in their respective scientific fields and academic careers

1. Excellence de la recherche

- Les articles publiés dans des revues internationales, qui, de tout temps, sont reconnus comme étant un indicateur objectif de la qualité des contributions. Ceci comprend des revues et des comptes-rendus de conférences avec comité de lecture de stature internationale. Les comptes-rendus de conférences sont particulièrement importants dans le domaine des sciences de l'information où, de par leur grande sélectivité (< 15% de taux d'acceptation), ils servent de principal moyen de dissémination des résultats de la recherche.

- Les prix et les honneurs pour les réalisations scientifiques de premier plan, la qualité des contributions (prix du meilleur article, etc.), la participation à des associations professionnelles à titre de membre senior, la participation au comité éditorial de revues scientifiques prestigieuses, etc. (qui sont également des indicateurs du leadership international des membres).

- L'impact de la recherche sur les domaines pertinents comme la publication d'articles à large diffusion, la poursuite de travaux de recherche précurseurs, les premières à caractère scientifique et technique et les percées significatives.

- Le financement de la recherche, comme, notamment, la performance des membres dans les concours de programmes de subventions (e.g. CRSNG), et le financement octroyé par des programmes hautement compétitifs (e.g. DARPA, NSF).

- Les autres honneurs et réalisations comme la détention de chaires de recherche du CRSNG, de chaires universitaires, ou de chaires du CRC, etc.

2. Excellence de la formation de personnel hautement qualifié

- Formation de premier plan d'étudiants au doctorat, à la maîtrise et de stagiaires postdoctoraux démontrée par le nombre d'étudiants inscrits et le nombre de diplômes octroyés.

- L'impact ultérieur de ces diplômés dans leur domaines scientifique et carrière académique

(e.g. students who have gone on to become leaders in their fields, started new companies, etc.)

3. Impact on Society

- Intellectual property leading to creation of new methods, processes or products. Evidenced through the granting or patents, licenses, and copyrights.

- Creation of new enterprises (spin-off companies), graduates working in Québec and Canada in the private and public sectors.

- Collaborations with industry in the form of research partnerships and contracts, etc.

4. Value Added by Regroupement

- Ability to attract new researchers, graduate students and postdoctoral fellows.

- Ability to attract new research funding (local, national, international research programs, private industry, etc.)

- New collaborations flowing from the regroupement (all sectors).

- Enrichment of the research program and environment (seminars, colloquiums, invited talks, etc.).

- New intellectual property flowing from the research program of the regroupement.

respectifs (i.e. les étudiants qui se hissent au rang de leaders dans leur domaines, qui ont fondé des nouvelles compagnies, etc.)

3. Impact sur la société

- La propriété intellectuelle menant à la création de nouvelles méthodes, procédés et produits et se mesurant par l'octroi de brevets, de licences et de droits d'auteurs.

- La création de nouvelles entreprises, la contribution des diplômés travaillant au Québec et au Canada dans les secteurs privé et public.

- Les collaborations avec l'industrie, notamment les partenariats de recherche et les contrats, etc.

4. Valeur ajoutée par le regroupement

- La capacité d'attirer de nouveaux chercheurs des étudiants aux cycles supérieurs et des stagiaires postdoctoraux.

- La capacité d'attirer du nouveau financement de la recherche (des programmes de recherche locaux, nationaux, et internationaux; de l'industrie privée, etc.)

- Les nouvelles collaborations provenant du regroupement (tous les secteurs).

- L'enrichissement du programme de recherche et de l'environnement (séminaires, colloques, présentations spéciales, etc.).

- La nouvelle propriété intellectuelle issue du programme de recherche du regroupement.

Summary

Faculty Members	21	PhD Students	47
Technical Staff	3	M.Eng. and M.Sc. Students	69
Administrative Staff	3	Research Associates / Engineers	16
Postdoctoral Fellows	3	Visiting Research Students	2
Visiting Scientists	1	Undergraduate Project Students	31

ARTICLES		**INTELLECTUAL PROPERTY**	
Refereed Journals	33	Patents	3
Refereed Conferences	81	Spin-off Companies	2
Book Chapters	2		

Funding Sources

(per annum)

NSERC			FQRNT		
Research	712,550		Research	408,565	
Strategic / Multi	667,500		Equipment	2,000	**410,565**
Chair	200,000	**1,580,050**			
NCE/IRIS	862,515		VRQ	242,000	
NCE-Other	84,800	**947,315**	Provincial-Other	46,000	**288,000**
CFI	30,000	**30,000**			
Total Federal		**2,557,365**			
Total Provincial		**698,565**			
Total Industry		**1,323,000**			
GRAND TOTAL		**4,578,930**			

Angeles, Jorge 514-398-6313 angeles@cim.mcgill.ca

Analysis, synthesis, and optimization of mechanical systems
- CAD/CAM integration
- Geometric modeling
- Multibody dynamics
- Robot design and control
- Theory of kinematic chains

Arbel, Tal 514-398-8204 arbel@cim.mcgill.ca

Computer Vision
- Probabilistic Inference
- Object Recognition
- Feature Identification/Matching
- Active Vision

Medical Imaging
- Image Registration
- Image-Guided Neurosurgery

Bergevin, Robert 418-656-2131, ext. 5173 bergevin@gel.ulaval.ca

- 2D and 3D generic object detection, description, and recognition
- Contour and junction extraction, segmentation and approximation
- Perceptual organization, shape analysis, database indexing and matching

Boulet, Benoit 514-398-1478 boulet@cim.mcgill.ca

Robust control systems
- Industrial process control
- Tunable multivariable control
- Model validation
- Robotics and space structures

H-infinity control
- Fuzzy logic control
- Manufacturing execution systems

Buehler, Martin | 514-398-8985 | buehler@cim.mcgill.ca

Robust locomotion
- Dynamically stable legged locomotion
- Design and control of walking, climbing and running robots
- Teleoperation and autonomous operation of remote systems
- Control of direct drive motors and robots

Caines, Peter | 514-398-7129 | peterc@cim.mcgill.ca

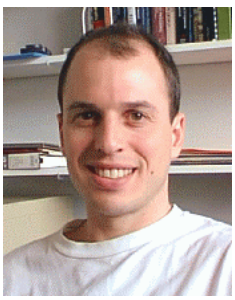
Systems and control theory
- Hybrid and nonlinear systems
- Hierarchical control and large scale systems
- Logic control systems
- Adaptive control
- Stochastic filtering, identification and control
- Application to robotics, air traffic control
- Industrial processes, manufacturing, communication networks

Clark, James | 514-398-2654 | clark@cim.mcgill.ca

Analog VLSI smart sensors, active vision
- Visual-motor systems
- View-based recognition, attention
- Mobile robot collaboration

Computer vision
- Robotics
- Analog VLSI
- Cognitive neuroscience
- Signal processing

Cooperstock, Jeremy | 514-398-5992 | jer@cim.mcgill.ca



Intelligent environments
- Ubiquitous computing
- Multimodal interfaces
- Adaptive and learning systems
- Media spaces
- Videoconference technology

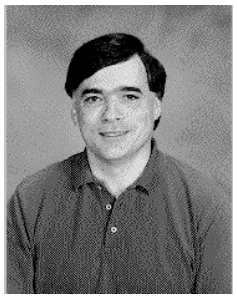
Human-computer interaction
- Artificial intelligence
- Multi-agent systems

Dudek, Gregory | 514-398-4325 | dudek@cim.mcgill.ca

Navigation
- Shape recognition
- Mobile robotics, telerobotics, teleoperation
- Vision and visualization, graphics, artificial intelligence

Robot mapping
- Map making, localization, pose estimation, landmark learning
- Virtual environment creation
- Object recognition
- Scene modeling

Ferrie, Frank | 514-398-6042 | ferrie@cim.mcgill.ca



Computer vision and artificial perception
- Active vision
- Sensors
- Environment modeling
- Shape representation
- Visual reconstruction, recognition and visualization
- Robotics
- Artificial intelligence

Gosselin, Clément | 418-656-3474 | gosselin@gmc.ulaval.ca

- Kinematics and dynamics of parallel mechanisms and manipulators
- Mechanics of grasping and gripper design
- Trajectory planning of robotic manipulators
- Modeling and control of complex robotic systems

Hayward, Vincent | 514-398-5006 | hayward@cim.mcgill.ca

Haptic interfaces
- Device design and control
- Rendering and simulation computational techniques
- Applications to medicine, rehabilitation and music

Physics based simulation
Touch perception

Hébert, Patrick	418-656-2131, ext. 4479	hebert@gel.ulaval.ca

3D imaging

- Hand-held range sensors
- Positioning systems
- Geometric calibration
- Sensor fusion

3D modeling

- Theory-representation-measurement quality
- Geometry and image based approaches
- Deformable objects and learning

Rendering and augmented reality

Langer, Michael	514-398-3740	langer@cim.mcgill.ca

Computer Vision and Graphics

- Signal processing
- Physics-based appearance modelling
- Rendering and vision algorithms

Human Vision

- Psychophysics
- Computational modeling

Laurendeau, Denis	418-656-2131, ext.2979	laurend@gel.ulaval.ca

- Artificial 2D/3D vision applied to fixed and mobile robotics
- Telerobotics
- Artificial vision applied to biomedical engineering

Maldague, Xavier	418-656-2962	maldagx@gel.ulaval.ca

- Infrared Thermography for NonDestructive Evaluation
- Industrial Inspection using Computer Vision
- Advanced learning concepts

Parizeau, Marc | 418-656-2131, ext. 7912 | parizeau@gel.ulaval.ca

- Pattern recognition
- Evolutionary computations
- Neural networks
- 2D and 3D computer vision

Poussart, Denis | 418-656-3554 | poussart@gel.ulaval.ca

- Computer vision, especially related to 3D sensing and modeling
- Advanced processing architectures, including focal plane VLSI sensing
- Distributed virtual environments, with emphasis on hard real time aspects linked to critical applications in industry and medicine

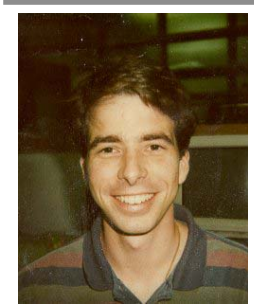
Siddiqi, Kaleem | 514-398-3371 | siddiqi@cim.mcgill.ca

Computer vision
- Shape representation and recognition
- Efficient indexing and matching

Computer graphics and image processing
- Shape segmentation
- Image smoothing and enhancement

Psychophysics
- Shape perception
- Visual search

Zaccarin, André | 418-656-3594 | zaccarin@gel.ulaval.ca



- Study and development of advanced coding algorithms for still images and video sequences
- Dense motion field estimation, model-based coding, 3D motion models, segmentation-based coding, fast coding algorithms
- Image segmentation, analysis and modeling, medical imaging and motion estimation for computer vision

Scientific Output

The Network is comprised of 21 researchers, 20 of whom reside in the universities of McGill and Laval. The composition of the membership combines the productivity, leadership and international reputation of experienced members with the enthusiasm of young and innovative scientists. The QERRAnet faculty regularly serve on the program committees of leading international meetings, on editorial boards of leading journals and as external reviewers for national and international programs. In the period 2002-2003, scientific contributions by QERRAnet members amounted to 33 articles in refereed journals and 81 articles in refereed conference proceedings and 2 book chapters.

Contribution to Training (HQP)

The depth of experience within the QERRAnet academic ranks is largely responsible for its ability to maintain a high standard of excellence in research and training. Students affiliated with QERRAnet, along with faculty members, have an established influence in prominent conferences worldwide, complemented by a high degree of student co-authorship of papers. The training aspect of this participation is key in the teaching of graduate students, who are encouraged to face a community of international scholars early in their academic development. Both universities conduct active seminar programs – over 40 seminars were held on related topics during the past year.

In 2002-2003, the student population of QERRAnet consisted of 69 Master's, 47 PhD's and 3 Postdoctoral Fellows, as well as 1 Visiting Scientist and 16 Research Associates/Assistants.

In addition, about 31 undergraduate students were provided with the opportunity to conduct their project thesis work in various labs supported by Network members, and approximately 40 undergraduate courses in the engineering and science disciplines were taught by QERRAnet members.

Funding

The average annual funding to the members from all sources in 2002-2003 was approximately $4.6 million. This includes an infrastructure grant awarded to QERRAnet from NATEQ/FQRNT under the Regroupement stratégique program. The allocation of FQRNT funding is $233,250 out of a total project cost of over $476,000 per annum.

The funding breakdown is outlined below:

- FEDERAL AGENCIES: $1.6M/year from various NSERC research grants: $.9M/year from National Centres of Excellence program; and $30K/year from CFI and other Canadian sources.

- PROVINCIAL AGENCIES: $.4M/year from FQRNT, and $.3M/year from VRQ and other provincial sources.

- Industry: $1.3M/year from various sources, such as DARPA, DRES and PRECARN.

The emphasis on collaboration has been of historical importance to the members, and significantly predates the creation of QERRAnet. This is best reflected in the National Centres of Excellence Program, where Professors Frank Ferrie, Denis Poussart, Denis Laurendeau and Vincent Hayward began collaborations some 15 years ago. Today, the NCE/IRIS program continues to play a major role in inter-university research programs within QERRAnet.

IRIS/Precarn projects involve Profs. James Clark and Jeremy Cooperstock: "Parallel Distributed Camera Arrays" and "Visual Information for Surveillance and Teleconferencing Applications" (with James Elder); Prof. Vincent Hayward: "Foundations of Haptic Interfaces for Virtual Environments and Communications". "Reality-Based Modeling and Simulation of Physical Systems in Virtual Environments" and "Intelligent Tools for Diagnosis and Intervention"; and Profs. Denis Poussart and Denis Laurendeau in "Vertex: Virtual Environments from 3D Representations to Task Planning and Execution".

QERRAnet members are also involved in the MITACS, GEOIDE and AUTO 21 of the NCE.

Profs. Denis Laurendeau and Denis Poussart continue their research under the NSERC Strategic Program with the project "SKALPEL-ICT Simulation Kernel Applied to the Planning and Evaluation of Image-Guided Cryo-Therapy". SKALPEL-ICT aims at developing a simulation environment for the treatment of liver cancer using cryotherapy. The project team has developed models for simulating (1) the growth of the iceball in the tumor and (2) the non-linear visco-elastic behavior of the tumor when inserting the cryoprobe. The team is also developing a Magnetic Resonance Image processing algorithm for building the 3D model of the tumor, as well as an approach for distributing the computations on a cluster. The ultimate goal of this project is to develop a cooperative distributed environment for both surgery planning and for the training of surgeons.

This past year, six QERRAnet members were receiving CFI (Canadian Foundation for Innovation) funding; three members were participating in multi-collaborative CFI projects; and three members were involved in major VRQ projects.

Intellectual Property

In partnership with CAE, Profs. Frank Ferrie and Gregory Dudek are in the final year of an NSERC Strategic Grant entitled "From Sensors to Virtual Reality". Two key technologies emerged from this research – 1) the development of new methods for acquiring models of real-world environments and 2) the development of methods for on-line updating of 3D model databases. The latter was directly responsible for the creation of a new spin-off company, headed by Philippe Simard, PhD student with Prof. Frank Ferrie.

QERRAnet member Vincent Hayward received a patent this year entitled "Electro-Mechanical transducer suitable for tactile display and article conveyance" (US6,445,284).

Another member, André Zaccarin, applied for two patents as a result of his collaborations with colleagues at Intel Corporation:

- André Zaccarin, P. Austin and V. Balasubrawmanian, "Method for using objective measurement of video quality in video encoder", Patent application in preparation to be filed with the U.S. Patent & Trademark Office, 2003;
- André Zaccarin, "Methods and apparatuses for selecting encoding options based on decoding energy requirements", Patent application filed with the U.S. Patent & Trademark Office, April, 2002.

Initiatives

The past year saw two significant and successful initiatives undertaken by the QERRAnet—Laval group in conference and workshop hosting and preparation.

International Conference on Pattern Recognition: ICPR 2002 (August 11-15, 2002 - Palais des congrès de Québec)

The QERRAnet Laval members were heavily involved in the organization of the ICPR 2002 conference which was held at the Québec City Convention Center on August 11-15, 2002. The theme of the conference was "Pattern Recognition for Humankind and the Environment".

From the over 1200 papers submitted, 250 papers were accepted for oral presentations and 555 papers were accepted for poster presentations. Over 900 people from around the world attended the conference. The conference also included 8 tutorials which were attended by a total of 150 people, 7 invited talks and a panel session, all of which covered applications related to the conference theme.

WORKSHOP on Fundamental Issues and Future Research Directions for Parallel Mechanisms and Manipulators (October 2 to 4, 2002, Université Laval)

The *Fundamental Issues and Future Research Directions for Parallel Mechanisms and Manipulators Workshop* dealt with the geometry, the kinematics and the dynamics of parallel mechanisms or manipulators. Technological applications in robotics and flight simulation were also addressed. After having spent two decades of studying research on parallel mechanisms, this workshop enabled the most renowned researchers in the field to meet and to present their progress, and identify areas of future development. The unique format of the workshop allowed for ample discussions on a wide range of relevant topics. Just over 100 people attended the workshop, including 35 participants from Québec, an additional 25 from North America, 30 from Europe, 13 from Asia and 1 from Africa. The workshop included 28 oral presentations and 10 poster presentations.

Innovation

Prof. Jeremy Cooperstock and his research team have achieved several breakthroughs in real-time networked media. In October 2002, Prof. Cooperstock, in collaboration with musicians from McGill University (CIRMMT) and Stanford University of California (CCRMA) joined in a highly successful evening of cross-continental jazz, playing together in surround sound and full-screen video, over the Internet, using ultraconferencing systems designed by Prof. Cooperstock and collaborators. Despite the fact that performers were at opposite sides of the continent, the system maintained a delay below 50 milliseconds, which feels to the musicians almost like being on the same stage. In June 2002, musicians from McGill and Stanford again jammed together, using Prof. Cooperstock's low-latency ultra-videoconferencing system. The event featured full-screen, bi-directional video and multi-channel audio, in what was heralded as the first demonstration of its kind. This event was considered a major success in demonstrating the feasibility of highly interactive events over the Internet.

Prof. Denis Laurendeau is partnered with the "Institut de réadaptation physique de Québec" in a project that will have applications in rehabilitation engineering. This project aims at developing virtual reality tools for rehabilitation experiments using mental imagery on people possessing permanent or temporary physical disabilities. Dr. Laurendeau is also participating in a research project that involves the use of virtual reality for planning military urban operations.

Spin-Off Companies

The diversity of research carried out within the Network environment has led to the creation of a number of companies, largely through our students, in the exploitation of technologies. Examples of these companies includes – Skygazer Technologies Inc.; Deus ex Machina Inc., Espace Courbe Inc., Haptic Technologies Inc., VisionSphere Tech. Inc., AutoVu Technologies Inc., Innovmetric Software Inc., Viagenix Inc., and Teneon Software, out of a total of about 20 over the past decade.

During the past year, Network members were involved, either as founders, owners, or consultants in the following companies: ART Advanced Research Technologies Inc., Immersion and Coronado Systems Inc.

Professor Vincent Hayward, former graduate student Dr. Mahvash and others at McGill founded a company called Real-Contact Inc., which is involved in surgical simulators for training.

As mentioned, two graduate students supervised by Prof. Frank Ferrie have started their own company as a direct result of their studies at McGill.

"Philippe et Louis Simard, deux anciens étudiants du Centre for Intelligent Machines de l'Université McGill, ont conjointement fondé en 2003 SimActive Inc., une entreprise oeuvrant en vision artificielle. Les recherches respectives des frères Simard au CIM les ont menés au développement d'une technologie qui a rapidement suscité un grand intérêt auprès de plusieurs organisations internationales. Située au cœur du centre-ville de Montréal, SimActive s'est donc donné pour mission le développement de logiciels innovateurs destinés à la modélisation 3D."

AWARDS TO FACULTY MEMBERS

Jorge Angeles	James McGill Professor	McGill University
	Design Engineering Chair	NSERC
Tal Arbel	University Faculty Award	NSERC
Benoit Boulet	Nomination-Faculty's Outstanding Teaching Award	McGill University
	Nomination- Principal's Prize for Excellence in Teaching	McGill University
Martin Buehler	William Dawson Scholar	McGill University
Peter Caines	Fellow	Royal Society of Canada
Gregory Dudek	William Dawson Scholar	McGill University
Clément Gosselin	Canada Research Chair in Robotics and Mechatronics	NSERC
Vincent Hayward	E.(Ben) & Mary Hochhausen Fund for Research in Adaptive Technology for Blind and Visually Impaired Persons	Canadian Institute for the Blind
Denis Laurendeau	Chair, Local Arrangements	ICPR Conference
Xavier Maldague	President: 2002-2004	IEEE: Quebec Section
	Conference Chair	ThermoSense XXV (of SPIE)
Kaleem Siddiqi	Nomination – Principal's Prize for Excellence in Teaching	McGill University

AWARDS TO STUDENTS

Marc Bédard	Scholarship	Shell Canada Ltd.
	Scholarship	NSERC
François Bernier	Scholarship	NSERC
	Scholarship	FQRNT
Guillaume-Alexandre Bilodeau	Scholarship	NSERC
	Scholarship	FQRNT
Gianni Campione	Scholar	Precarn
Maxime Descoteaux	Fellowship	FCAR
Hanifa Dostmohamed	Scholar	Precarn
Stéphane Drouin	Scholarship	NSERC
	Scholarship	FQRNT
Tina Ehtiati	Best Student Poster Award	Precarn/IRIS Conference
Christian Gagné	Scholarship	FQRNT
	Scholarship	NSERC
	Best-paper award	Genetic and Evolutionary Computation Conference
Christina Georgiades	Scholarship	Hellenic Foundation
	Scholar	Precarn
Melita Hadzagic	Scholarship	NSERC/Lockheed Martin Canada Ltd.
Ziad Hafed	Postdoctoral Fellowship	NSERC
	Scholar	Precarn
	Major Fellowship	McGill University

Vincent Lévesque	Scholar	Precarn
	Best Demonstration of IRIS technology Miniature Tactile Display	IRIS/Precarn Conference
	Scholarship	NSERC
	Fellowship	FQRNT-FCAR
Muhua Li	J. W. McConnell Award	McGill University
Neil Neville	Scholarship	Governor General Award
Svetlana Ostrovskaya	Dean's Honour List	McGill University
Jerome Pasquero	Scholar	Precarn
	Best Demonstration of IRIS technology Miniature Tactile Display	IRIS/Precarn Conference
Ioannis Poulakakis	Scholarship	Tomlinson Award
Alessio Salerno	Fellowship	Hydro-Quebec
	Major Fellowship	McGill University
Clovis Simo	Scholarship	ACDI
Qi Wang	Scholar	Precarn

1. **Wideband Communications and Human Factors**

   a. **Fundamental Research**
      i. exploration of perceptual phenomena
      ii. acceptance thresholds and discrimination

   b. **State Determined HMIs**
      i. pose estimation
      ii. person identification
      iii. gesture recognition
      iv. speech recognition

   c. **Multi-Modal Interfaces (including haptic devices in simulation)**

2. **Data Acquisition from Real-world Scenes: Texture Analysis for Scene Rendering**

3. **Integration of Human Inhabitants in Virtual Worlds**

Theme 1
Wideband Communications and Human Factors

ON THE PERFORMANCE OF MILITARY DISTRIBUTED INFORMATION SYSTEMS

Éric Dorion, Denis Laurendeau

The goal of this thesis is to force the reflection on the problem of ensuring performance in military distributed applications. From the general problem 4 sub-problems will be identified, explained and as many solutions to address these will be proposed. The sub-problems are: Military command and control measure of merit for system instrumentation, quality of service (QoS) and related concepts for guaranteeing performance, CORBA (Common Object Request Broker Architecture) architecture in support to performance and a UML (Unified Modeling Language) based methodology to encompass performance modeling efforts.

LA QUALITÉ DE SERVICE RÉSEAU POUR APPLICATIONS DISTRIBUÉES ANALYSIS OF QOS (QUALITY OF SERVICE) IN A DISTRIBUTED SIMULATION ENVIRONMENT

Mario Couture, Denis Laurendeau

Le développement d'Internet des 10 dernières années a donné naissance à une grande variété d'applications de type client-serveur dont les exigences réseaux sont de plus en plus élevées. Le besoin de priorisation au niveau des transferts réseaux a provoqué l'émergence de nouvelles technologies communément identifiées par le vocable "qualité de service" (QoS, Quality of Service). Les applications distribuées de type client-serveur peuvent dorénavant utiliser ces standards afin de fournir différents niveaux de qualité de service et rendre plus déterministes les transferts de données entre différentes plates-formes réparties sur différentes réseaux.

Le problématique de ce projet de maîtrise consiste à évaluer certains standards de QoS et à étudier leur implémentation dans une application distribuée (GQoS_9). Nous utilisons cette application dans différentes contextes physiques et logiciels afin de mesurer la pertinence de l'utilisation de la QoS. Nous déduisons de nos tests les différentes paramètres et facteurs qui peuvent servir de guide aux concepteurs et aux développeurs d'applications distribuées.

CONTRIBUTION À LA RECONNAISSANCE DES STRUCTURES DES DOCUMENTS ÉCRITS: APPROCHE PROBABILISTE

Souad Souafi-Bensafi, Marc Parizeau, Hubert Emptoz

Le travail de cette thèse se situe dans le cadre de la rétroconversion des documents papier qui consiste à traduire leur contenu sous une forme électronique réutilisable selon les besoins de l'application considérée. Nous nous intéressons en particulier à des documents dits à "typographie riche et récurrente" et dont nous devons extraire la structuration logique en se basant sur des marquages typographiques qui les caractérisent et qu'il faut identifier à partir des images de ces documents.

Le problème de reconnaissance considéré, bien qu'il porte sur le niveau de structuration logique, est basé sur des données devant être fournies par une analyse du document à un niveau physique. Or, les documents considérés présentent de nombreuses difficultés à cause de leur complexité et leur variabilité. Notre objectif était de concevoir un système abordant ce problème de reconnaissance de la structure logique en s'adaptant à ces difficultés. Dans cette optique, nous avons décomposé le problème posé en plusieurs parties et nous avons adopté des méthodes probabilistes appropriées à chaque partie.

Nous avons développé une approche générique pour une modélisation hybride (structurelle et statistique) de la structure logique. Sa généricité est garantie par le fait que le modèle est construit par apprentissage automatique supervisé. Nous avons combiné l'utilisation de plusieurs modèles, à savoir, un réseau bayésien classifieur et un automate fini probabiliste, que nous avons intégrés dans une représentation arborescente hiérarchique de la structure logique. Outre l'originalité de notre approche, nous avons apporté une contribution particulière dans l'apprentissage des réseaux bayésiens en développant une nouvelle méthode basée sur la programmation génétique.
Nous avons appliqué notre approche à une base de documents composées de tables de matières de périodiques de structures très variables. Nous avons établi des mesures d'évaluation à chaque niveau de reconnaissance. Les résultats obtenus sont satisfaisants et encourageants et ouvrent diverses perspectives notamment pour développer davantage l'interactivité entre les différentes composantes du système de reconnaissance conçu en tentant d'identifier et de corriger les erreurs issus plus particulièrement du traitement au niveau physique de nos documents.

EVOLUTIONARY RE-ENGINEERING: APPLICATION TO PATTERN RECOGNITION AND LENS SYSTEM DESIGN

Christian Gagné, Marc Parizeau

Problem: To develop infrastructures and expertise to solve hard problems with Evolutionary Algorithms (EA) in the area of pattern recognition and optical design.

Motivation: The development of intelligent systems for pattern recognition and computer vision involves solving numerous hard problems. EA are a generic problem-solving method that could greatly contribute to the advancement of these areas.

Approach: The project has three main aspects: development of software tools, application to hard problems, and evolutionary re-engineering.

Development of software tools:
- Develop a C++ EA framework that is versatile, easy to use and robust.
- Develop tools to efficiently distribute evolutions on several CPU.
- Develop graphical tools to visualize and analyze evolution results.

Application to hard problems:
- Demonstrate applicability of EA, particularly genetic programming, to the solving of hard problems.
- Using EA to solve hard problems of pattern recognition.
- Using EA to solve hard problems of optical design.

Evolutionary re-engineering:
- Develop generic methods of re-engineering with EA.
- Understand and analyze the generic methods developed for re-engineering.
- Apply re-engineering methods to hard problems.

Expected results:
- Generic, robust, and distributed software infrastructure of EA, used in the scientific community.
- Solving hard problems of pattern recognition and optical design with EA.
- Development of generic methods allowing an efficient evolutionary re-engineering of existing solutions.

ENGINEERING AND QUANTIFICATION OF A PARALLEL AND DISTRIBUTED SYSTEM OF MASTER/SLAVE FOR EVOLUTIONARY COMPUTATION

Marc Dubreuil, Marc Parizeau

Problem: Evolutionary algorithms require an enormous computing power to solve problems. Fortunately, problems can easily be divided into several parts and calculated in parallel. It is now possible to purchase low cost computer ensembles which are solely used to distribute computations. Thus the problem involves designing a parallel and distributed system which can respond to the needs of evolutionary algorithms on a computer cluster. This system must perform well, be tolerant to errors, persistent with data, independent of different types of evolutionary algorithms, as well as enable a minimum waiting time. This system must also be quantified in order to determine its optimal performance.

Motivation: This project is part of the research on evolutionary algorithms carried out in the Computer Vision and Systems Laboratory and is specifically linked to the Open BEAGLE project, an evolutionary algorithm software environment. These algorithms have recently received increasing attention from those who are searching for a means to apply them to complex problems. The solving of these problems often requires days on sequential computers. With the advent of affordable computer clusters, it is possible to solve these complex problems in a parallel and distributed fashion. The ultimate goal of this project is thus to diminish the computing time required to solve complex problems involving evolutionary algorithms.

Approach: The project is divided into two main steps: the creation of tools (servers, units for clients, monitors) and the quantification of the system. The server is optimized to be robust to errors so that if it breaks down, it will resume its work where it left off with a minimum of data loss. Furthermore, a Load Balancing function will be implanted so that each client finishes his computations at the same time, irrespective of their different speeds.

The second tool, client unit, must be simple to use and transparent: a user must not manage the communications between the server and the client. Moreover, to reduce dead time where clients wait to receive data to be computed, the tool must be multi-thread. One thread is present to carry out the computation and the other thread communicates with the server from time to time to give or receive data. The latter thread comes into play when the quantity of information to be calculated for the client is almost completed. Thus, the client never ceases to compute until all data has been treated.

The monitor is the third tool which must be able to recognize the state of the problem solving and be able to search for the best data. This tool is therefore indispensable when the problem solving requires days to complete since it will provide a means of monitoring the computation.

All of these tools must be quantified so as to determine the number of clients with whom the server can communicate data before sequential computation becomes more advantageous. Thus, one can determine the number of clients which render the system optimal.

Challenges: There are already several systems which enable the distribution of evolutionary algorithm data. However, no such system is available or optimized for a cluster of computers and the quantification of such a system has received very little attention. Since our system is optimized for clusters and is in the area of open source, users will know exactly how many clients should be involved to optimize the problem solving process.

Applications: The applications for this system cannot be determined since this system is the basis for the distribution of evolutionary algorithm applications. Two projects will soon be tested: an application for the recognition of handwriting and the design for a system of lenses.

DETERMINING OPTIMAL MODELS FOR PROBABILISTIC IMAGE CORRESPONDENCE

Tal Arbel, Matthew Toews

Problem: Determining optimal models for probabilistic image correspondence.

Motivation: Automatic pose estimation, as well as object and person tracking and identification, often requires computing the correspondences between features in one image to features in a second image, where some change has occurred in the scene between image acquisitions. Since there are often ambiguities in the possible feature matches, it would be instructive to be able to assign a degree of confidence to various competing hypotheses. Although other probabilistic image correspondence methods are found in the literature, the choice of features is often based on task-specific intuition. We would like to be able, instead, to automatically select optimal features that: (a) minimize the chances of false matches, and (b) lead to convergence to a solution in optimal time.

Approach: Recently, we have developed a probabilistic image correspondence model that uses information theory to automatically select optimal image feature points for correspondence, both in terms of the quality of the correspondences and the processing speed. Different feature points are selected based on the current choice of image similarity metric and on the current image set. We envision extending this result to the problem of determining optimal similarity metrics for matching, and defining automatic criteria for determining whether meaningful correspondence is, in fact, possible.

Challenges: Image correspondence is one of the main problems in the field of computer vision. Its main challenge lies in that it is fundamentally ill-posed, in that more than one solution is plausible. As such, validation of the quality of the solution is difficult for general images where ground-truth is not available.

Applications: This approach can improve the speed and quality of the image correspondence task within the context of pose estimation, object and person tracking and identification. Furthermore, we are currently in the process of applying the approach to difficult problems within the domain of medical imaging, in particular, to matching brain structures from an atlas MRI to patient MRI. Finally, we are exploring the possibilities of applying the strategy to the problem of finding signal correspondences in other domains such as sound and speech processing.

IMAGE-GUIDED NEUROSURGERY

Tal Arbel, Catherine Laporte, Rupert Brooks, D.L. Collins

Problem: Image-Guided Neurosurgery - where to best acquire images?

Motivation: Neurosurgeons often rely upon pre-operative images, such as patient MRI, in order to identify and locate tissues of interest during neurosurgical procedures. However, movements of brain tissue during craniotomies (i.e. open brain operations) reduce the effectiveness of using pre-operation images for intra-operative guidance. For this reason, surgeons often make use of intra-operative images (e.g. ultrasound images) in order to estimate the degree and direction of the current brain deformation. However, it is essential that intra-operative images be acquired as quickly as possible, particularly in cases where ultrasound images are acquired on the surface of cortex (as this could lead to irreparable tissue damage in the worst case). For this reason, it would be instructive to be able to provide the surgeon with real-time, computer-based visual feedback describing where to best acquire the next set of intra-operative images. This feedback is completely task-dependent and could be useful to address a wide variety of tasks beyond deformation estimation, e.g. where to look next in order to identify particular brain structures or pathologies.

Approach: Recently, we have developed an active vision strategy where we have shown how information-theoretic notions of entropy can be useful in guiding an active observer (e.g. a robot) along an optimal trajectory by which the identity and pose of objects in the world can be inferred

with confidence, while minimizing the amount of data that must be gathered. We wish to extend the approach to applications within the domain of neurosurgery by building predictive maps off-line depicting the degree of information content in different viewpoints about the brain structures of interest. These maps can then be used as guidance for the surgeon during neurosurgical procedures.

Challenges: Medical imaging is a challenging domain in which to develop computer vision algorithms primarily because the images are 3D and noisy. Intra-operative images, usually ultrasound or intra-operative MRI, are particularly noisy, with artifacts that are not well-understood. Furthermore, image acquisition during surgery poses many practical challenges, including reduced access to tissues due to the size of the skull opening. Finally, providing visual feedback to the surgeon in order for the surgeon to accurately reproduce an acquisition trajectory is a non-trivial task.

Applications: The primary application that we are currently investigating is the problem of matching intra-operative ultrasound images to pre-operative MRI in order to correct for non-linear brain deformations during neurosurgery. The described approach could be used to provide guidance as to where to acquire images in order to reduce the uncertainties associated with the resulting image registration. In addition, the approach can be applied to the problem of locating structures of interest in the brain, such as tumor boundaries and critical locations for human function.

TRANSDUCTION AND DISPLAY OF TACTILE SENSATIONS

Jerome Pasquero, Vincent Lévesque, Qi Wang, Vincent Hayward

Problem: Systems capable of recreating computer controlled tactile sensations resembling those resulting from direct contact of the skin with objects are still not available although this idea was mentioned many decades ago. The lack of progress can be attributed to several reasons among which we include: lack of knowledge of what information resulting from skin deformation the CNS processes to provide conscious experience of touch and technological difficulties associated with the integration of high density actuator arrays a the required resolution.

Motivation: Practical displays, if they were available, would certainly be useful in many situations.

Approach: The approach is three-pronged. In effort we seek to understand how skin deforms when contact is made between a finger and an object. Part of this involves building instruments to measure deformation directly. Another part involves the development of models capable of predictions which are at least qualitatively correct. In another effort we build devices with provide only subsets of all possible cases of deformation because we feel that they are feasible and useful. A more recent collaborative effort is dedicated at relating these deformations with neuro-anatomical neuro-physiological knowledge.

Challenges: Construction of miniature electromechanical devices. Complex and unusual distributed partial differential equations. Uncertain neuro-anatomical neuro-physiological knowledge.

Applications: Braille displays, Virtual Environments, Computer-Human Interaction devices, Neuroscience experimental devices.

DESIGN OF UNCONVENTIONAL AND EFFECTIVE HAPTIC DISPLAYS

Hanifa Dostmohamed, Hsin Yun Yao, Diana Garroway, Vincent Hayward

Problem: The creation of the ideal general-purpose haptic display is very unlikely for many years to come.

Motivation: We focus on the design of special purpose devices which are very effective for certain tasks. An example is the current development is a device dedicated to the display of the shape of objects. We observed that certain extraordinarily impoverished tactile signals were capable of eliciting very strong sensation of shape. Another example is the development of a device capable of magnifying sensations associated with the manipulation of tissues for medical purposes.

Approach: These devices are constructed from simple components which are easily manufactured or purchased. When appropriate, their development is associated with human performance studies.

Challenges: The discovery of such specific purpose effects and devices which are practically relevant.

Applications: Presently focused on medically oriented tasks including intra-operative activities.

DESIGN OF UNCONVENTIONAL AND EFFECTIVE HAPTIC DISPLAYS

Gianni Campion, Moshen Mahvash, Vincent Hayward

Problem: Simulation techniques for surgical training are still primitive because systems typically are fraught with artifacts and imperfections which destroy realism. It is needed to develop simulation techniques which are truly physics based in the sense that they share key properties with the physical world including for the haptic case: conservation of energy, continuity, precise reconstruction and absence of signal aliasing.

Motivation: Train people on high quality virtual systems.

Approach: Energy based approaches and synthesis though function interpolation methods from pre-computed or pre-recorded responses. These ideas are presently being extended to the graphic simulation domain.

Challenges: Models which can be synthesized in real time and yet which guarantee conservation, continuity, precise reconstruction, and absence of signal aliasing for the case of multidimensional nonlinear and non homogeneous objects.

Applications: Surgical training simulators, CAD systems.

Theme 2
Data Acquisition from Real-world Scenes: Texture Analysis for Scene Rendering

ACTIVE STEREO PAIR SYSTEM CALIBRATION

Éric Samson, Denis Laurendeau, Marc Parizeau

Problem: The goal of stereo vision is to extract depth information of a scene using two different points of view. Generally this is achieved using two cameras placed side by side. Research on stereo vision has mainly focused on the processing of images taken by this kind of sensor. A lot of work has been done on the matching problem, reconstruction and high-level understanding, for example. Few studies, however, have focused on the basis of a stereo system : the stereo sensor.

In this context, a new versatile stereo pair called the agile stereo pair (ASP) has been developed by the Computer Vision and Systems Laboratory (CVSL) with the collaboration of the Robotics Laboratory of the Mechanical Engineering Department of Laval University. This new sensor is able to dynamically orient its two cameras in a quick and accurate fashion as well as continuously change its baseline. Moreover, the ASP has a compact design.

The depth information extraction with a stereo pair requires the knowledge of the position of the two cameras relative to each other. This is referred to as the extrinsic parameters. With a standard stereo pair, these parameters are estimated by a unique calibration procedure. Due to the mobility of the cameras of the ASP, the extrinsic parameters are ever changing. The classical approach thus cannot be applied to the new sensor. A new procedure allowing the determination of the extrinsic parameters at any given time must therefore be developed in order to use the ASP for depth information extraction.

Approach: The estimation of extrinsic parameters at any given time is performed using a model of the mechanical camera orienting system. The current camera position is thus calculated from a reading of the position encoder of the motors, the model of the mechanical orienting system and the parameters of that model. The latter are estimated by a unique calibration procedure. Due to the accuracy of the mechanical orienting system, it is expected that the extrinsic parameters obtained using this method will be good enough to obtain high quality 3D measurements with the ASP.

Challenges: Developing a calibration procedure enabling an accurate estimation of the parameters of the mechanical camera orienting system. The quality of the 3D measurements made by the ASP is directly related to the accuracy of these parameters.

Applications: Mobile robotics, Security, Target tracking, 3D modeling, Motion capture, Human-machine interactions.

Expected results: 3D measurements with accuracy comparable to those of standard stereo pairs.

A SELF-REFERENCING HAND-HELD 3D SENSOR

Richard Khoury, Patrick Hébert

Problem: The CVSL is developing a hand-held range sensor designed to digitize 3D real objects. In order to integrate range measurements in a global coordinate system without human intervention, this sensor must be able to calculate its own position in space. The principle of self-

referencing algorithms, which are presently being used, is based on the observation and tracking of fixed laser reference points projected on the object to be digitized. However, these algorithms often lack robustness or impose a very limited number of reference points for real time treatment.

Motivation: A sensor which can move freely in space enables the rapid construction of a 3D model of the surface for a real object even if not all of the facets are visible from the same viewpoint or if some facets may be difficult to access. In order to integrate all of the measurements obtained with this sensor, it is however necessary to estimate the movement of the sensor between each image, and consequently provide the position of the sensor in a global coordinate system. A sensor which uses observations to self-reference itself becomes attractive since it limits the dependence on an external positioning device which is precise but costly. Moreover, this should lead to an increase in freedom of movement in the workspace and consequently lead to a greater reduction in modeling time.

Approach: At the present time, the sensor uses two different algorithms: the first algorithm tracks the reference points in a continuous sequence while the second algorithm fuses two sequences, which is essential when an interruption occurs. The latter leads to a recognition problem, which is addressed by using the stability of the Delaunay tetrahedrisation, built using each set of reference points. In order to avoid failure during tracking and improve computing performance, the tracking and recognition aspects will be integrated into a hybrid algorithm. Finally, the possibility of extending the system to enable the detection of passive points and to eliminate the need of projecting laser points in all situations will be evaluated.

Challenges: The self-referencing algorithms which are presently being used impose a limit on the number of reference points (less than 50) for tracking and require one viewpoint in which most points must be visible. These two constraints must be eliminated. However, eliminating the constraint involving the number of points will probably lead to an increase in the complexity of the matching, which is problematic in a real-time system. And to eliminate the second constraint on visibility, one must construct, maintain and continually validate a model of reference points.

Applications: A sensor equipped with a robust and precise self-referencing system will be very useful for interactive modeling, by reducing the acquisition and modeling time. Furthermore, in several areas where it is not possible to move an object which is to be modeled (measurements in the field, in archaeology, in areas of forensics or engineering expertise), the flexibility of such a system will be an asset, if not a necessity.

POSITIONING OF A HAND-HELD RANGE SENSOR

Ying Wang, Patrick Hébert

Problem: To capture the geometry of an object, it is often necessary to mount the object and/or the range sensor on a translation or rotation stage. Multiple images must be captured from different views to get a complete object scan, especially when top and bottom views are required. Thus a 3D digitizing system based on a laser range sensor should be more flexible, portable and easy to use. This has led to the birth of the hand-held sensor. Such a sensor combines a range sensor with a positioning device allowing the sensor to be moved around the object and the measurements automatically integrated in a common global coordinate system. Estimating a precise position of the sensor in real-time becomes the key problem.

Motivation: Positioning devices include mechanical, electromagnetic, optical and inertial systems. All of these systems have their limitations, such as freedom of motion (mechanical devices), precision and accuracy (electromagnetic devices), visibility (optical devices), and time integration error (inertial devices). Furthermore, one must pay special attention to synchronization and calibration of these devices with the range sensor. In order to remove these limitations and improve the freedom of motion, the desire of reducing the dependency on the position device arises naturally, i.e. the sensor could be self-referenced from observations. This is the aim of this project.

Approach: In order to position the sensor in a global coordinate system, a set of reference points are projected in the scene using a fixed and independent projector. The imaging sensor then captures both the laser pattern - for surface measurements - and reference points simultaneously. One advantage of this is that no physical target has to be placed on the object, the other is the possibility to project a set of points on one or several selected areas. The main steps are: (1) Tracking in a sequence while the sensor is continuously moving; (2) Registration of two independent sequences; (3) Integration (moving all of the individual frames in a global coordinate system).

Challenges: The challenge of this project lies in correspondence, i.e. 2D and 3D correspondence. For 2D correspondence between a stereo pair, the epipolar constraint is exploited. For 3D correspondence between two sets of 3D reference points, the rigidity constraint is used. The result of the 2D correspondence influences the 3D correspondence directly. Thus, 2D correspondence is of primary concern.

Applications: There are many applications for robustly and accurately computing the camera motion, such as 3D model building, object tracking and augmented reality.

IMAGING AND 3D MODELING USING A LASER RANGE SENSOR: APPLICATION IN THE WOOD INDUSTRY

Michel Robert, Patrick Hébert

Problem: In the wood industry, numerous efforts have been invested in optimizing the profitability of sawmills. The general objective involves maximizing the value of the products for each tree which is processed. At the present time sawmills have sophisticated equipment to ensure an optimal transformation of the trees. The optimization systems use laser triangulation sensors for the rapid acquisition of the 3D shape of logs in continuous motion. These sensors enable the control of the positioning of the logs and the opening of the saws in real time. The results of the analyses allow us to determine that the geometric model obtained can be improved.

Motivation: Studies which have been carried out using a sawmill wood transformation process simulator can potentially improve the geometric model produced by a laser range sensor. The results of our simulations confirm these conclusions and show that an error in the geometric model at the primary breakdown step has a considerable impact on the yield of the sawmill.

Approach: The method used consists in a re-engineering of the existing system in order to improve the quality of the 3D modeling chain of the sensor. The configuration of the sensor is composed of six synchronized cameras and four co-planar laser projectors. From this system, an analysis of the sources of error is carried out for the laser trace detection steps in the images, the calibration of the sensor and the reconstruction of the 3D model. The processing algorithms are then revised according to the importance of the errors to create a more precise model and eventually proposals are made for the calibration and/or acquisition of images. The results obtained are then validated with the help of reference geometric models. Finally, an evaluation of the impact and the improvement of the 3D model on the yield of the sawmill plant is carried out.

Challenges: The existing system produces a geometric model whose precision is insufficient and does not allow the yield objectives of the sawmill to be obtained. Furthermore, this system uses an explicit calibration which requires extrinsic parameters of the cameras and laser planes. Thus, the challenge of this project involves the revising of the calibration model used and the proposal of a more precise implicit calibration method. A detailed study of the system must permit the sources of measurement errors to be identified and allow the necessary corrections to be made in order to optimize the yield potential. Finally, the challenge also consists in developing a procedure for the evaluation of the quality of the sensor.

Applications: Modern sawmills consist of automated machines and optimization systems for the performance of the wood transformation operations in real time. Since triangulation sensors are widely used in existing optimization systems, an

improvement of the 3D model would have a considerable impact on the yield of the sawmills for Canada's wood industry.

MODULE DE POSITIONNEMENT INERTIEL POUR AMÉLIORER LA ROBUSTESSE DU SUIVI DE POINTS DE RÉFÉRENCE DANS UNE SÉQUENCE D'IMAGES

Martin Labrie, Patrick Hébert

Problème: La mise en correspondance de points de référence observés dans différentes images est un problème qui touche plusieurs domaines de la vision numérique. Notamment, la reconstruction 3D de scènes ou d'objets en est un de ceux-là. Les principaux problèmes sont les faux appariements ainsi que le décrochage lors du suivi. Le but de ce projet est de créer un module matériel et logiciel de positionnement 3D inertiel afin d'automatiser et améliorer cette mise en correspondance. Celui-ci doit être compact et portable sur différents types d'appareils.

Motivation: Ce projet s'inspire principalement d'un problème d'appariement relié au capteur télémétrique maniable développé au laboratoire de vision et systèmes numériques (LVSN). Ce capteur doit suivre différents points de référence dans les images afin de déterminer son déplacement relatif dans l'espace. Une autre utilité de ce module serait d'estimer la position dans l'espace d'une caméra tout usage afin d'apparier des points à travers les clichés et ainsi faciliter la reconstruction d'un modèle 3D de la scène ou de l'objet photographié. C'est donc un projet de convergence entre la vision numérique et la photogrammétrie. Avec la disponibilité de nouvelles composantes électroniques à bas coût, nous voulons non seulement revoir le design des positionneurs inertiels mais nous voulons intégrer ceux-ci avec un logiciel qui permettrait d'améliorer l'appariement automatique des points de référence en reconstruction 3D.

Approche: L'approche préconisée pour le capteur du LVSN est simple. Le nuage de points 3D de référence est constamment mis à jour dans le référentiel global. Si la nouvelle position du capteur est estimée à l'aide du module, alors il est possible de prévoir la position d'un certain nombre de points de référence dans une image. Pour une caméra unique, il est aussi possible de déduire le déplacement d'un point dans l'image par l'approximation du déplacement 3D que fournit le module.

Défis: Le capteur du LVSN permet un appariement de points grâce à un suivi entre les images. Il faut donc permettre à celui-ci de retrouver rapidement et efficacement les différents points de références afin qu'il réévalue sa position courante dans l'espace. Pour ce qui est des algorithmes d'appariement déjà existants, ceux-ci sont exigeants en temps de calcul et requièrent parfois une intervention humaine. Il faut donc accélérer et automatiser ce processus à l'aide du module de positionnement. Le plus grand défi demeure l'intégration du système pour la reconstruction 3D d'une scène ou d'un objet à partir de photographies.

Applications: Les applications d'un tel projet sont très nombreuses. La modélisation d'objets, de scènes, de bâtiments ou même de rue est très en demande. Comme exemple, la reconstruction 3D d'un lieu à partir d'images pourrait être réalisée et utilisée afin de le communiquer. Nos collègues chercheurs du domaine militaire s'intéressent aussi beaucoup à ce type de technologie afin de modéliser des environnements urbains pour simuler des interventions.

QUALITY, EFFICIENCY AND RELIABILITY OF 3D IMAGE SURFACE RECONSTRUCTION

Dragan Tubic, Patrick Hébert

Problem: Traditionally, 3D modeling, which consists in creating a virtual 3D model from surface measurements and real objects, is composed of the following three steps which are applied sequentially: acquisition, registration and integration of multiple views. Due to the complexity of existing

computation methods, the application of these three steps does not allow the creation of interactive systems where the reconstructed model is available during acquisition. The objective of this project is to unify all three modeling steps and to allow the reconstruction of models irrespective of the type of range data. This project is specifically aimed at hand-held sensors and real time interactive acquisition systems.

Motivation: The acquisition of range data and the reconstruction of models are usually conducted separately, sometimes even in different locations. Without interactive modeling, it is difficult to ensure that the acquired data are sufficient for a complete reconstruction, which in the case of error, significantly increases the cost and time required for modeling. Moreover, hand-held sensors are often designed using laser curves projected on the surface of an object. Nevertheless, methods for model reconstruction and pose refinement from range curves are nonexistent or too complex.

Approach: Our hypothesis consists in suggesting that the solution to 3D modeling problems does not solely depend on new methods, but rather on an adequate representation of shapes in 3D space. The representation that we have selected is an implicit representation in the form of a vector field. This enables the incremental integration of multiple views and contains all of the necessary information for an efficient registration whose complexity is linear with respect to the number of points measured on the surface. Vector fields can be efficiently compressed and displayed, which enables the performance of all of the modeling steps with a single representation of the surface.

Challenges: The main challenge of this project is the development of algorithms for all of the modeling steps: registration, reconstruction, compression and surface rendering using an implicit representation, i.e. vector fields. In particular, all of these algorithms must be incremental and of linear complexity to enable an interactive modeling. The algorithms must also enable the reconstruction of models from all types of range data: point clouds, curves measured on the surface and range images. They must also allow the combination of different types of data so as to build a model.

Applications: Even if this is a relatively new research area, 3D modeling has several applications such as virtual reality, reverse-engineering, industrial inspection, biometry, forensics and archaeology.

SIMULATION VISUELLE RÉALISTE D'UN ENVIRONNEMENT: RECONSTRUCTION PROJECTIVE ET EXTRACTION DE PROPRIÉTÉS DE TEXTURES À PARTIR D'UN NOMBRE RESTREINT DE PHOTOGRAPHIES.

Marc Bédard, Patrick Hébert

Problème: Des logiciels de photogrammétrie permettent de reconstruire des objets ou des environnements 3D à partir d'un ensemble de photographies. Ces logiciels permettent également d'appliquer des textures extraites des photographies. Comme l'ensemble des photographies peut contenir plusieurs points de vue d'une même texture, c'est la texture dans l'image dont le point de vue correspond le mieux au point d'observation du modèle reconstruit qui est appliquée lors du rendu [Debevec]. Toutefois, varier l'illumination du modèle texturé selon cette approche ne donne pas un rendu réaliste. Pour accroître le réalisme, il faut réussir à caractériser les textures et extraire leurs propriétés.

Motivation: Une méthode a été développée pour extraire une carte de radiance d'un environnement à partir de photographies [Debevec et Malik]. Cette méthode a été utilisée pour caractériser les textures du modèle reconstruit par une pseudo-BRDF [Yu et Malik]. Il est donc désormais possible de simuler des changements d'éclairage et d'obtenir un rendu réaliste. Cependant, bien qu'intéressante, l'approche de Yu et Malik nécessite plusieurs interventions humaines à diverses étapes de l'extraction des caractéristiques des textures, notamment pour délimiter les zones d'ombrage dans les photographies. Le but du projet est d'automatiser le processus de reconstruction 3D et d'extraction des caractéristiques des textures afin de faciliter l'utilisation des techniques de modélisation et de rendre accessible à tous une technologie très en demande.

Approche: Reprendre l'approche de Yu et Malik et automatiser les interventions manuelles. La première automatisation à réaliser consiste à choisir les régions de faible variance de la radiance. Cette sélection permet de considérer la radiance

constante, ce qui minimise le flou induit par le système optique, et réduit ainsi la complexité de calcul. Une autre intervention à automatiser est celle de la sélection des zones caractéristiques du ciel pour procéder à l'ajustement du modèle révisé du ciel. Finalement on tentera de limiter l'intervention humaine lors de l'extraction des zones ombragées.

Défis: Assurer la robustesse du processus, tel est le véritable défi de l'automatisation.

Applications: Les applications sont multiples, et un tel outil est très en demande dans les domaines du cinéma, de la réalité virtuelle ou de la réalité augmentée, du jeu vidéo, de l'architecture, etc. car il permet de reproduire rapidement, facilement et de manière réaliste, des environnements 3D de grande envergure.

QUANTITATIVE SUBSURFACE DEFECT CHARACTERIZATION IN THE PRESENCE OF COMPLEX SHAPE SURFACES BY TNDT

Clemente Ibarra, Xavier Maldague

Problem: Thermography for Nondestructive Testing (TNDT) is a non-invasive and fast inspection technique with the capability to perform remote inspections on large surfaces. These features give thermography an interesting advantage with respect to other NDT approaches. However, TNDT faces several problems that can be classified in three categories: (1) emissivity problems; (2) non-even heat distribution; and (3) surface shape. This study deals with the quantitative inspection of objects with complex geometry.

Motivation: TNDT techniques are usually used under the assumption that the part being inspected has a planar surface. However, when complex shape objects are examined, the surface shape produces a signal distortion that may lead to faulty defect detection. Heat emission (as well as heat absorption) is at its maximum when the normal to the surface is parallel to the direction of the flow of energy. Therefore, the emitted (or absorbed) signal is weaker when there is an angle between the normal on the surface and the direction of flow. This intensity reduction is caused exclusively by the surface geometrical variations but it can lead to incorrect subsurface defect detection if corrective measures are not adopted. Moreover, the points furthest away from the source (or sensor) will absorb (or will emit) less energy compared to the closer ones. Without shape information on the object, defects located under the surface will be difficult to detect by TNDT.

Approach: Shape-from-Heating (SfH), stands out among other shape correction TNDT techniques because, besides the traditional TNDT material, no additional equipment is needed. Furthermore, calibration steps are not mandatory. Shape extraction by (SfH) is made from the Early Recorded Thermogram (ERT), i.e. the first thermal image of the sequence in which defect contrasts have not yet developed, intensity variations are therefore exclusively related to surface geometry and not to the presence of a flaw.

Challenges: SfH performance is reduced due to non-even heating problems and frequency noise. Moreover, no quantitative shape correction model has been proposed yet that allows defect characterization (size and depth), in the presence of complex shape surfaces. Therefore, quantitative approaches like Pulsed Phase Thermography (TPP) combined with Neural Networks (NN); Wavelet Transform (WT); or Contrast Methods (maximum-Cmax, Differentiated Absolute Contrast-DAC) should be used once the shape correction is made. The challenge is thus to recover the inspected surface geometry and to correct the thermal images so that the detection and the characterization of defects are completed in a suitable way.

Applications: Aircraft industry is a good example of an application. Aircraft fuselage and wings are never completely flat. The inspection of aeronautical structures is carried out visually 90% of the time. The remaining 10 % of the time eddy currents are mostly used. Occasionally ultrasounds or other techniques are employed. However, these techniques are slow and they are prone to subjective interpretation and human errors. TNDT allows the examination of surface portions up to 4 m^2, thus greatly reducing the inspection time making the technique especially interesting for the examination of aeronautical parts. Boiler tube corrosion characterization is another example of an application.

ÉVALUATION NON-DESTRUCTIVE (ÉND) PAR ULTRASONS

François Mainguy, Xavier Maldague

Dans ce projet, on s'intéresse à la caractérisation (quantification et détection) en employant les ultrasons. L'accent est mis sur la stimulation ultrasonore au moyens de sondes piezo-électriques. Quant aux algorithmes de traitement du signal, ils seront incorporés directement dans des circuits VLSI programmables. Ce projet est réalisé en collaboration avec la Compagnie HARFANG Microtechniques inc.

ALGORITHMES DE QUANTIFICATION DE DÉFAUTS AUX FORMES COMPLEXES

Lilia Najjar, Xavier Maldague

Dans ce projet, on s'intéresse à de nouveaux algorithmes de traitement des signaux basés sur la transformée de Fourier à trois dimensions. Il s'agit d'une extension de la technique de thermographie de phase pulsée. La troisième dimension devrait permettre de conserver la connaissance de temps nécessaire à l'inversion du signal.

INTELLIGENT FUSION OF A HYBRID (INFRARED AND VISIBLE) SENSOR IN THE CONTEXT OF PEDESTRIAN DETECTION AND SURVEILLANCE.

Hélène Torresan, Xavier Maldague, Patrick Hébert

Problem: The detection of the movement of people has become more and more important over the past few years. Numerous applications in the area of security and surveillance are emerging. The goal of this project is to develop a prototype combining an infrared and visible sensor to enable the detection and surveillance of pedestrians over a period of time. More specifically, the project will be carried out in an environment where one to three pedestrians are moving in a range of 9 to 21 meters within an area affected by various lighting and atmospheric conditions involving wind, snow, night and day.

Motivation: The addition of an infrared sensor will provide information which complements the images obtained in the visible range. Visible images offer a rich content where the detection of people can however be limited by a change in lighting conditions. Infrared images generally allow a better contrast to be obtained between a person and the environment, but these images are not as robust to changes in temperature and wind conditions. An intelligent fusion of the information provided by both sensors could reduce false alarms and the advent of non detected pedestrians, thereby increasing the performance of a pedestrian detection and surveillance system.

Approach: The detection of pedestrians is a process involving several interdependent steps. The quality of the steps involving data acquisition, locating zones of movement, classification and monitoring over time is crucial for a more robust detection. Data acquisition requires the constitution of a database which combines sequences of visible and infrared images obtained under different climatic and lighting conditions. The sequence of images must be synchronized, corrected and calibrated both geometrically and with temperature. The extraction and monitoring over time of each region of interest makes use of movement and is carried out independently for each sequence. A matching of the regions of interest is developed using the epipolar constraints. Finally, for the step involving the classification, critical parameters indicating the presence of people are determined on the basis of characteristics such as temperature, geometry and ratios compared to the rest of the environment.

Challenges: The detection and monitoring of people in interior and exterior environments involves numerous challenges. Algorithms treating the detection of people already exist in the Computer Vision and Systems Laboratory and perform well for visible images (extraction of regions of interest, geometric calibration). One of the challenges is to adapt these algorithms for the treatment of infrared images. Then, the respective limitations of the two sensors must be clearly identified so as to extract the complementary information. The greatest challenge involves the development and proposal of a method of intelligent fusion which will enable the robustness of human detection to be improved while reducing false alarms and the advent of non detected pedestrians.

Applications: The applications of a visible sensor for pedestrian detection and monitoring are already numerous and can be applied to many public environments (parking lots, airports, etc.). With the addition of an infrared sensor, these systems will become more robust and will be able to function under varying lighting and climatic conditions, both day and night, in summer as well as in winter.

ROBUST CONTROL OF AIRCRAFT

Nabil Aouf, Benoit Boulet

Problem: The integrated control of modern aircraft using engine vectored thrust and control surfaces is a challenging problem, but often necessary for proper operation. For large aircraft with flexibilities, vibrations must also be controlled.

Motivation: The well-known British Harrier VSTOL aircraft can take-off and land vertically like a helicopter, and fly at Mach 1 like regular jet fighter aircraft. To accomplish this feat, the engine thrust vector is controlled using nozzles, and this must be carefully coordinated with engine thrust and control surfaces in a typical maneuver from hover to full-speed horizontal flight.

Approach: A gain scheduling approach was developed for the integrated control of the Harrier in which solutions to Riccati equations are interpolated between design points to obtain a smooth control behavior.

Challenges: It is very difficult to prove the stability of gain scheduling schemes, especially when it is used on a complicated nonlinear aircraft model. We have shown through extensive simulations that our gain scheduling scheme was stable and met performance specifications on the full nonlinear model of the Harrier.

Applications: Military aircraft and commercial airliners can benefit from improved control systems for performance, passenger comfort and reduced airframe fatigue.

CONTROL OF STRUCTURE-INDUCED NOISE IN AUTOMOBILES

Jean-Gabriel Roumy, Dany Dionne, Benoit Boulet, Hannah Michalska

Problem: Automobile manufacturers operate in a very competitive environment and constantly try to win market shares. The noise level inside a car is an important issue that can sometimes become a major selling point for particular car models.

Motivation: This research is part of the AUTO21 Network of Centers of Excellence. Two noise reduction problems are being looked at by a team of researchers from McGill University, the University of Windsor, the University of Victoria, and led by the Université de Sherbrooke. The first problem is to reduce the road-induced structural vibrations causing low-frequency noise inside the cabin via adaptive feedforward and feedback

control. The second is to reduce the noise caused by fans of the HVAC system.

Approach: The McGill team is investigating the robust control of structural vibrations for noise reduction. We have been working on the system identification of an experimental one-quarter suspension system (one wheel) to obtain a state-space model. Then, uncertainty models will be derived and robust control strategies will be developed.

Challenges: We are modeling a nonlinear mechanical suspension system with a linear time-invariant model, and this is likely to result in robustness issues. Moreover, uncertainty in the modal parameters is always difficult to deal with in a closed-loop system. There is no systematic way for identification of such systems, and so we had to develop a heuristic approach.

Applications: This research is applicable to active car suspension control for cabin noise reduction.

CLOSED-LOOP MIMO CONTROL OF AN INDUSTRIAL MIXING PROCESS

Suet Yan Deng, Benoit Boulet

Problem: The dynamics of industrial mixing processes are typically nonlinear, highly coupled, and uncertain, so that robust nonlinear decoupling control may be required for satisfactory operation. Yet it is often necessary to control very accurately things like concentrations and moisture content of the pulp at the output of the tank so that downstream processes can operate within specifications.

Motivation: One such blending process in operation at the Falconbridge nickel smelter in Ontario has coupled nonlinear multivariable dynamics, and its model parameters vary with the quality of the ore concentrates at its input.

Approach: A thorough analysis of the dynamics of the Falconbridge process was undertaken. It was found that a redesign of the process from a single-tank to a cascaded three-tank process would provide better control, although this would prove to be a very expensive alternative. Thus, we investigated multivariable control for the existing Falconbridge process using exact feedback linearization, switching control, and linear state feedback.

Challenges: One of the challenges is that the state of the process consisting of the masses of water and of each type of ore in the mixing tank is not directly measurable. Furthermore the densities are not accurately known. However, it was found to be possible to reconstruct the state from the measurements, and therefore to use state feedback linearization.

Applications: Mixing processes are ubiquitous in some industries such as minerals and metals, food and beverages, and chemicals. Our work on a fairly generic blending process could be applied to these other industries as well.

IN-CYCLE CONTROL OF THE THERMOFORMING PROCESS

Ben Moore, Benoit Boulet, Nabil Aouf

Problem: Thermoforming is a process in which useful tub-shaped plastic parts are manufactured from a flat sheet of plastic material. The goal of the research is to develop a control strategy that is capable of tracking desired sheet temperature profiles throughout the reheat cycle.

Motivation: The basic motivation is improved part quality. Higher quality parts can be achieved through better control of material distribution before the actual forming of the sheet via accurate control of sheet temperature distribution. Close temperature control and disturbance rejection will also result in a reduction in the number of rejected parts for a given production cycle. As a result,

production efficiency will increase and material costs can significantly decrease.

Approach: We developed a deterministic low-order process model of the sheet reheat phase. The first principles approach was chosen as the modeling technique, mostly to gain insight into the dynamics of sheet reheat. Then the model was linearized and a five-zone multivariable H-infinity controller was designed.

Challenges: The highly nonlinear nature of the radiation heaters made it difficult to use a linear control strategy, even though it displayed some robustness in simulation. A nonlinear model predictive controller was designed and proved better in some conditions than the linear H-infinity controller.

Applications: Thermoforming has never benefited from advances in control theory. It has relied instead on human operators who develop an expertise in open-loop control after years of practice. Our work is among the first in the world to apply feedback control to the thermoforming process.

ROBUST TUNABLE CONTROL

Yingxuan Duan, Benoit Boulet, Ammar Haurani, Hannah Michalska

Problem: Process dynamics have a tendency to change over time, so that controller robustness and tunability are typically necessary for satisfactory long-term operation.

Motivation: Industrial processes are typically characterized by highly-uncertain, coupled multivariable dynamics that often include transport delays. In a very competitive international commodity market, their accurate control is key to a profitable operation.

Approach: Different approaches that are investigated include robust tunable control (RTC) using H-infinity control theory, and robust model predictive control. Typical H-infinity controllers are robust but not tunable, while model predictive controllers are tunable, but generally not robust.

Challenges: Robust tunable control presents challenging theoretical problems. The entire H-infinity theory was built towards providing a fixed controller without any tuning possible. We have revisited the single-input single-output theory of robust closed-loop performance via an internal model controller parametrization and mu-analysis to arrive at a characterization of robust performance in terms of a simple frequency domain tradeoff of performance versus robustness. This result allows us to devise on-line tuning strategies via a finite-impulse response controller redesign strategy using the fast solution of a set of linear matrix inequalities. The alternate approach of robust model predictive control for RTC is also progressing well. We have achieved significant results for uncertain retarded system models.

Applications: The theory of robust tunable control is applicable in a wide variety of applications where on-line tunability is important to keep the plant running despite slow variations in its dynamics.

STATE ESTIMATION OF HIDDEN JUMP PROCESSES

Hannah Michalska

Special contribution from CIM member

Motivation: This project emerged in collaboration with researchers in the Aerospace Faculty of Technion University, Haifa, that came into effect through a doctoral stage of a graduate student.

Problem: The project initially involved the analysis of optimal pursuit-evasion game-type guidance laws in missile interception scenarios. It was readily noticed that any further reduction in the miss

distance was only achievable through better state estimation of the evader. As the evader's maneuvering strategy can be viewed as a random jump process, this called for the development of state estimating filters which would partly act as fast maneuver detectors. Since the jump process itself is "visible" only indirectly, through the system dynamics, the filter cannot be designed in terms of a finite recursive procedure.

Approach: Approximate methods are considered which are based on adequate truncations of associated estimation Lie algebras.

MULTI-SENSOR MULTI-TARGET TRACKING

Hannah Michalska

Special contribution from CIM member

Motivations: This project was initialized through collaboration with Lockheed Martin Canada Ltd. and currently involves two doctoral students.

Approach: The objective is to design improved algorithms for statistically reliable tracking of multiple, "dim" targets in clutter by correct association of data generated by a given bank of sensors. The projects calls for the development of improved data-association algorithms allowing for correct probabilistic correlation of noisy measurements with "identified" target tracks, as well as the development of a new generation of trackers in the form of interactive multiple model filters with in-built multiple hypothesis testing mechanisms enabling rapid and reliable maneuver detection. Bearing only tracking is also a topic of interest in this theme.

Applications: Applications include: airborne or underwater surveillance systems, traffic surveillance and control.

MODELING THE RECONNECTION OF VORTEX FILAMENTS

Abeer G. Ghuneim, Kaleem Siddiqi, Luca Cortelezzi

Problem: This project concerns itself with the modeling of vortex filaments in three-dimensional (3D), inviscid and incompressible flows.

Motivation: Vortices arise in nature and in numerous industrial settings, e.g., they are commonly produced behind the wing-tips of aircraft and behind the blades of helicopter rotors and machine propellers. Their behaviour in 3-D is complex and may involve changes in their topology. The modeling of vortices is crucial towards understanding this behaviour, and can help in the designing of devices with improved efficiency.

Approach: We represent vortex filaments as thin tubes on a 3D-grid and use a vortex filament method to describe their motion within a level-set framework. Our hybrid method incorporates the accuracy of vortex methods in modeling filament motion and the benefits of working on a fixed grid within the level-set framework. These benefits include a general grid characterization of the reconnections that may occur and natural filtering of high-frequency perturbations. We have validated the consistency of our hybrid method reproducing the motion of well studied configurations of vortex filaments. More importantly, we have demonstrated the capability of this hybrid method to simulate the reconnection of vortex filaments for a number of examples, including the reconnection subsequent to the head-on collision of two sinusoidally perturbed circular filaments.

Challenges: The key challenge is to extend this approach to domains where the vorticity field is distributed not along filaments but along more

complex geometric structures, such as vortex sheets (surfaces in 3D).

Applications: To our knowledge, these are the first results illustrating the use of a hybrid level-set Lagrangian framework to model and simulate the reconnection of vortex filaments in an inviscid fluid. Our results have applications in numerous industrial settings and as well may help to better understand natural phenomena.

OBJECT RECOGNITION USING SHOCK GRAPHS

D. Macrini, A. Shokoufandeh, S. J. Dickinson, K. Siddiqi, S. W. Zucker

Problem: We extend our previous work in both shock graph matching and hierarchical structure indexing to propose the first unified framework for view-based 3D object recognition using shock graphs.

Motivation: Although a number of approaches have been proposed for shock graph matching, these approaches do not address the equally important indexing problem. Furthermore, most of the research has focused thus far on sets of 2D views but not on the full 3D object recognition problem.

Approach: The heart of the framework is an improved spectral characterization of shock graph structure that not only drives a powerful indexing mechanism (to retrieve similar candidates from a large database), but also drives a matching algorithm that can accommodate noise and occlusion. We describe the components of our system and evaluate its performance using both unoccluded and occluded queries. The large set of recognition trials (over 25,000) from a large database (over 1400 views) represents one of the most ambitious shock graph-based recognition experiments conducted to date.

Challenges: A key future challenge is to extend this framework to include other aspects of an object's appearance than that provided by its silhouette, e.g, surface shading and texture.

Applications: This research has applications in any setting where the recognition and classification of objects from images is of interest.

WHITE MATTER FIBRE TRACT RECONSTRUCTION

Jennifer Campbell, G. Bruce Pike, Kaleem Siddiqi

Problem: This project concerns itself with the analysis of MR diffusion images, with the goal of reconstructing white matter fibre tracts from them.

Motivation: Many algorithms have been proposed for tracking white matter fibres using the principle eigenvector of the diffusion tensor. However, these approaches can fail when fibres cross or branch at a subvoxel scale.

Approach: We present a modification of existing tracking schemes that provides more accurate tracking and robustness to noise by using the RMS diffusion distance. The algorithm produces putative tracts as well as a scale measure of the likelihood that a tract exists between any two points. We have also investigated the use of a flux maximizing geometric flow for fiber tract reconstruction.

Challenges: Among the key challenges are the extension of this framework to the case of high angular diffusion data, and as well, the evaluation of its performance in the reconstruction of distinct fibers which cross one another and single fibers which branch. In order to address these challenges we have begun to apply our algorithms to phantoms with known fiber tract structure.

Applications: With a surge of recent interest in MR diffusion imaging, the development of algorithms which can automatically or semi-automatically extract white matter fibre tracts is of tremendous importance. Such algorithms can allow researchers to reason about cortical connectivity and ultimately its association with brain function.

BLOOD VESSEL SEGMENTATION

Alexander Vasilevskiy, Kaleem Siddiqi

Problem: This project concerns itself with the segmentation of blood vessels and arteries obtained from MR angiography images.

M**otivation**: Whereas several algorithms have been proposed for the automatic segmentation of blood vessels viewed in such images, most fail when the blood vessels are very narrow or when contrast in the intensity signal is low.

Approach: To address this problem we derive the gradient flows which maximize the rate of increase of flux of an appropriate vector field through a curve (in 2D) or a surface (in 3D). The key idea is to exploit the direction of the vector field along with its magnitude. The calculations lead to a simple and elegant interpretation which is essentially parameter free and has the same form in both dimensions. We illustrate its advantages with several level-set based segmentations of 2D and 3D angiography images of blood vessels.

Challenges: The key challenge now is to validate the framework on a variety of angiography data sets. This is the subject of the current Master's thesis research of Siddiqi's student Maxime Descoteaux.

Applications: These results are of importance to image-guided neurosurgery where maps of vasculature, obtained non-invasively through the processing of angiography images, can both guide a surgeon towards important landmarks and also help avoid the pitfalls of puncturing vessels and causing internal bleeding.

HAMILTON-JACOBI SKELETONS

Sylvain Bouix, Kaleem Siddiqi, Lei Zhu, Steve Haker, Allen Tannenbaum, Steven W. Zucker

Problem: This project concerns itself with the development of robust algorithms for computing medial representations (skeletons) of 2D and 3D objects.

Motivation: Whereas medial representations have been popular for representing objects in computer vision, medical image analysis, computational geometry and computer-aided design, few algorithms exist for volumetric data, which are robust, efficient and accurate.

Approach: Our approach is based on a measure of the average outward flux of the gradient vector field of the Euclidean distance function to the boundary of an object. This measure has very different limiting behaviors depending upon whether the region over which it is computed shrinks to a singular point or a non-singular one. Hence, it is an effective way to distinguish between these two cases. We combine the flux measurement with a homotopy preserving thinning process applied in a discrete lattice. This leads to a robust and accurate algorithm for computing skeletons in 2D as well as 3D, which has low computational complexity. We illustrate the approach with several computational examples. We have also applied our skeletonization algorithms to blood vessel visualization.

Challenges: A key challenge now is to use our framework to carry out a statistical analysis of 3D shape, based on properties of the underlying medial representations of a population of objects.

Applications: These results are of importance to computer vision, computer aided design and also medical image analysis.

INTRA-SURGICAL BRAIN DEFORMATIONS IN IMAGE-GUIDED SURGERY

Michel Audette, Kaleem Siddiqi, Terry M. Peters

Problem: This project concerns itself with developing an integrated framework for the range image sensing, segmentation and registration of intra-surgical brain deformations in image-guided surgery.

Motivation: Image-guided surgery is a technique for localizing anatomical structures on the basis of volumetric image data and for determining the optimal surgical path to reach these structures, by the means of a localization device, or probe, whose position is tracked over time. The usefulness of this technology hinges on the accuracy of the transformation between image volume and the space occupied by the patient anatomy and spanned by the probe. Unfortunately, in neurosurgery this transformation is often degraded by intra-surgical brain shift, and hence this must be accounted for and modeled.

Approach: Our approach is to integrate the steps of: 1) a model-based segmentation of the pre-operative brain surface in MR data, 2) range sensing of the cortex in the operating room, 3) range to MR rigid transformation computation and 4) range-based non-rigid brain motion estimation.

Challenges: A key challenge now is to use optimize the framework such that it is computationally efficient and can be applied in realistic settings without extensive pre-processing.

Applications: These results are of importance to image-guided surgery applications.

TOWARDS DIRECT MOTION AND SHAPE PARAMETER RECOVERY FROM IMAGE SEQUENCES

Stephen Benoit, Frank P. Ferrie

Problem: A novel procedure is required to construct image-domain filters (receptive fields) that directly recover local motion and shape parameters. These receptive fields are derived from training on image deformations that best discriminate between different shape and motion parameters.

Motivation: Both the structure from motion problem and the study of receptive fields have received considerable attention in computer vision, but to date, only incremental achievements have been accomplished. Structure from motion is an ill-posed problem, optical flow is noisy, underconstrained and less informative than advertised, and the generation of receptive fields are still a hit-or-miss art.

Approach: Filter pairs (receptive fields) can be synthesized to perform or detect specific image deformations. At the heart of the method is the use of a matrix to represent image deformation correspondence between individual pixels of two views of a surface. The image correspondence matrix can be decomposed using Singular Value Decomposition to yield a pair of corresponding receptive fields that detect image changes due to the deformation of interest.

Challenges: Training to learn the appearance changes of all possible textures undergoing all possible motions is infeasible. A new science was needed to map the geometry of image change into a filter bank of detectors.

Applications: The research findings detail the construction of 1-D receptive fields that detect local surface shape and motion parameters within cross sections. As an example of the application of the theory, we show how the recovered shape and motion model parameters are sufficient to produce local estimates of time to collision.

A LEARNING-BASED METHOD FOR SUPER-RESOLUTION AND INTEGRATION OF IMAGES

Isabelle Bégin, Frank P. Ferrie

Problem: Super-resolution addresses the problem of enhancing the resolution of a low-resolution image. This technique can benefit applications concerned with image zooming and feature identification. Since super-resolution involves the estimation of information, it is indeed an ill-posed problem. In this research, a learning-based algorithm for super-resolution and image integration is proposed.

Motivation: Over the last two decades, many approaches were studied to deal with single-frame or sequence-based super-resolution. Most of them are based on regularization, Bayesian inference, convex sets, back-projection or sampling theory. More recently, learning methods started to be used. For applications where substantial amounts of data are available, it is believed that taking advantage of the information contained in the data could lead to better results. This aspect is naturally included in learning-based methods by using this previously gathered high-resolution data to train the system. The learned relationships between low/high-resolution training images will allow enhancing the resolution of a newly acquired low-resolution image. As for a Bayesian approach, the advantage is that it can easily include prior information about images. Furthermore, a Bayesian framework can deal with multiple images. Thus, a learning method based on a MAP estimator seems to be a logical way to integrate and super-resolve multiple images.

Approach: The proposed approach is a Bayesian learning method. It consists of modeling the relationship between an image/scene training pair (low-resolution/high-resolution pair) with a Markov network. Bayesian belief propagation is used to obtain the posterior probability of the scene, given a low-resolution input image. Integrating images in such an approach is still under investigation. In order assess its efficiency, many aspects of the method need to be addressed. The sensitivity of the method both to noise as well as to blurring discrepancies between the test low-resolution image and the training set needs to be evaluated. Feasibility and confidence measures must also be developed in order to compare the proposed approach to other methods.

Challenges: The main challenge of the research is to handle image integration in a learning-based approach. This aspect of the research is still being investigated. Also, some aspects of the method must be formalized. For instance, the generation of the training set (including pre-processing steps) should be adapted to a realistic situation where blurring and decimation processes of both the training set and the low-resolution image are unknown and/or different. Finally, a notorious problem of learning-based is that the training set must be complete enough so as to contain as much image variations as possible. As a consequence, huge storage capacities are needed and the algorithms are usually time-consuming. Efforts will be made in order to reduce this drawback.

Applications: Resolution is very important for nearly all applications involving the use of images. Target recognition, surveillance and feature identification in medical imaging and remote-sensing are examples of applications with a crucial need for high-resolution data. As such, research in resolution enhancement techniques is fundamental. In this research, super-resolution will be tested on mosaicing applications with synthetic images and sequence of images acquired by a gantry robot. The algorithm will also be tested on remote-sensing images.

ONLINE UPDATING OF SYNTHETIC VISION DATABASES

Philippe Simard, Frank P. Ferrie

Problem: It is well-known that complex visual tasks can sometimes be mitigated in the presence of strong prior knowledge. This is the basis of so-called model-based vision, which has been quite successful in controlled environments. In this research, we consider the application of these concepts to the domain of natural scenes. Specifically, we consider how a model-based approach can be used to detect where a natural scene has undergone change, and how this change

can be quantified for the purpose of updating the model using only image measurements as input.

Motivation: The inference of 3D measurements based on 2D imaging data is usually referred to as the shape-from-motion problem. It is of great interest in the vision literature and consists, in its classic form, of determining the structure of the scene given two (or more) images. Mainly because the measurement process implies a loss of dimension, the problem is ill-posed. In other words, many solutions may explain the imaging data.

Work related to this research includes research on recursive surface reconstruction using multiple images. Current algorithms actually consider scene reconstruction as an iterative problem i.e. the three-dimensional model is incrementally refined as new data is gathered. At each iteration, a completely new model is constructed and then merged with the prior version. Although such algorithms can be applied for model updating, they do not fully take advantage of the prior information as they require the reconstruction of the entire scene at each iteration.

Other techniques actually optimize the updating process by using the model to reduce the amount of processing required. Unfortunately, using such approaches requires simple parametric shapes to minimize complexity. Even though this allows the problem to be made more tractable, they do not generalize very well for surfaces having more complex shapes.

Approach: The proposed approach requires a single imaging device (of any type), as long as its projective geometry can be determined. It is differential and as such, requires motion of the sensor which is assumed to be known. It uses the geometric information of the model to predict the warping of sensor imagery. Given that a motion is induced, image predictions can be generated. If the predictions are different from the observations, the model is assumed to be inconsistent with reality and geometric errors can be localized. The model geometry is then corrected using an optimization procedure in which the difference between predictions and observations is minimized. The prior model serves to reduce the dimensionality of the minimization space as well as to provide boundary conditions, significantly reducing problem complexity.

Challenges: A great challenge in using a predictive approach is being able to estimate, prior to the updating process, the effects of uncertainties on the predictions and therefore on the results. Existing algorithms usually estimate the confidence in their outputs only after their generation. From an application point of view, having the ability to predict in advance the relative importance of uncertainties in the system and the expected quality of the results is crucial As our approach proposes the adjustment of the model to explain observations, the capability to handle uncertainty is also required to avoid the danger of overfitting the data.

Applications: The technique is useful for real-time applications and/or where large scale models are necessary. A growing number of applications actually require models having highly accurate geometry. Synthetic vision systems in aviation are a good example as they require a precise model for rendering artificial views of the world. Their goal is to support navigation and situational awareness in low visibility conditions. Because the model reflects at best a nominal state of the environment, it needs to be periodically updated to ensure its consistency with reality.

ACTIVE SURFACE RECONSTRUCTION FROM OPTICAL FLOW

Marcel Mitran, Frank P. Ferrie

Problem: This research describes the design and implementation of an active surface reconstruction algorithm for two-frame image sequences. The objective is to build a system that uses a passive sensor and an active viewer to accumulate information for disambiguating the depth sampling process involved in surface reconstruction. The viewer is considered to be restricted to a short baseline.

Motivation: The field of computer vision continues to play an important role in the development of autonomous robotic agents. Autonomous navigating robots should ideally be

able to move through an unknown environment unaided. This involves path planning, obstacle detection, and scene recognition/interpretation. Such tasks are all dependent on the robot's ability to quickly build sufficiently complete models of its environment. Thus, surface reconstruction remains an important motivator in the field of computer-vision.

Approach: The human visual system provides consistent proof that 2-D image sensing is sufficient for interacting with a 3-D world. Evolution has provided biological vision systems with a large set of tools for interacting with a 3-D world. Stereoscopic vision provides detailed representation for nearer objects (one meter away in humans). In most cases however, when moving through the world, objects are outside the stereoscopic range. Human experience in every day life demonstrates that, even under such conditions, it is possible to successfully perform many everyday tasks such as trajectory planning, obstacle detection and figure/ground separation. A similar task in computer vision involves recovering 3-D structure from a set of 2-D images. This problem requires the temporal accumulation of information through a monocular observer. The relationship between subsequent still images in a video stream provides a wealth of information in the form of spatio-temporal change. The temporal integration of such velocity fields is essential for solving shape-from-motion, time-of-collision, object tracking, object-recognition, and figure/ground separation problems.

Challenges: At first glance the problem of 3-D reconstruction from motion images seems trivial as it is intuitively sound to suggest that changes in intensity on an image plane are somewhat coupled with the projection of the apparent motion of the 3-D space surrounding the plane. It is however incorrect to say that such projections are unique and complete. The loss of a dimension, quantization of intensity, discrete sampling of infinitesimal spatial data and sensor noise make the problem of recovering 3-D structure from a set of 2-D intensity images ill-posed (impossible). This begs the question, how does the 2-D human visual system successfully interact with the 3-D world with such consistency? Many suggest that the answer lies in considering the human observer not as a passive viewer, but rather as an active observer. By interacting with the environment, a human can quickly and robustly achieve sufficiently stable representations of the world for navigation. Although the human observer is active, it is wrong to assume complete freedom of motion exists in all six degrees of freedom under most conditions.

This research examines weakly active surface reconstruction in the case of an autonomous monocular viewer. The term weakly active implies a severely constrained configuration space for the viewer. Most active vision algorithms assume full motion control is available to a viewer. This is not often the case for a holonomically constrained autonomous explorer, which must first see its world before moving through it. Thus a more realistic active motion model is considered, which constrains the viewer to small displacements between observations.

Applications: Active computer vision systems for autonomous explorers (robotics, remote sensing, 3-D modeling).

HIERARCHICAL POSE ESTIMATION FROM RANGE DATA FOR SPACE APPLICATIONS

Louis Simard, Frank P. Ferrie

Problem: Estimate the pose of an object in space from sparse range data.

Motivation: With the advent of fast, reliable 3-D imaging systems capable of acquiring scenes at video rates, the application of range imagery to space robotics has become a viable technology, particularly in satellite servicing. The principal task of a vision system in the latter context is tracking the 6 degree-of-freedom (d.o.f.) pose of an object at rates sufficient for robotic control, generally on the order of 10 Hz or greater. Modern tracking algorithms generally have little difficulty, per se, in achieving such rates as frame-to-frame coherency limits the computational complexity of determining correspondence. However, the situation can become difficult when the coherence assumption is violated, e.g., occlusions by other objects in the scene, acquisition failures by the sensor system, or sudden accelerations beyond the sampling rate of

the system. Furthermore, initial correspondence needs to be established in the first place, which often requires the intervention of a human operator. All of these are typical of space environments and must be dealt within an operational system.

Approach: The problem is partitioned into two halves, one dealing with estimation of the translation and the other with the orientation. This greatly reduces the complexity of the overall problem without compromising the accuracy of the solution. Figure/ground separation via template matching is used to retrieve the translation component. A novel hierarchical view-based method is used to determine the orientation.

Challenges: The method must handle very sparse range data, be computationally efficient, robust to noise, and handle virtually any type of range data.

Applications: Satellite servicing and space robotics.

SURFACE RECOVERY FROM THREE DIMENSIONAL POINT DATA

Peter Savadjiev, Frank P. Ferrie, Kaleem Siddiqi

Problem: The focus of this research is the reconstruction of 3D surface models from incomplete data. In particular, the research presented here considers the problem of finding a surface S that approximates a physical surface P by using a set of point coordinates sampled from the surface P. It examines how existing methods for surface reconstruction can be combined to obtain improved results, in terms of discontinuity preservation in 3D, robustness to noise, and ability to reconstruct objects with arbitrary topologies.

Motivation: The reconstruction of three dimensional surface models lies at the core of the process of inferring geometrical and physical scene descriptions from image data, which represents the goal of computer vision. Once a three dimensional model of an object or a scene is reconvered, it can be used by higher level processes that interpret the visual information and perform "intelligent" tasks, such as object recognition, navigation in the environment, manipulation of objects, etc.

Approach: The approach to surface reconstruction presented here combines two different philosophies, namely that of parametric reconstruction, and that of a geometric flow reconstruction approach. Many algorithms for surface recovery are based on either one of the two types of approaches, but few have attempted to bring the two together in order to combine their advantages. A novel hybrid algorithm for surface reconstruction is introduced in this work. This algorithm is a combination of a curvature consistency algorithm, which is a parametric surface modeling approach, and the flux maximizing flow algorithm, which is a geometric flow algorithm implemented through the level-set method. Combining these two methods is equivalent to augmenting a geometric flow algorithm with information obtained from local parameterizations of the data. It thus becomes possible to study and compare the behaviour of such a hybrid algorithm with that of a purely geometric flow algorithm, and to verify that a hybrid algorithm yields better qualitative and quantitative results than either a parametric reconstruction, or a purely geometric flow-based approach alone.

Challenges: The main challenge faced in this work is the creation of a global surface model using only local sources of information. Other challenges include filtering unwanted noise from the data while preserving important features, such as discontinuities, and imposing minimal limitations on the topology of the reconstructed surface model. The approach presented in this work has been tested experimentally with a variety of data sets. The results show that the method can overcome, to most extent, the challenges described above.

Applications: This research can be applied to any domain that requires the manipulation of 3D computer models of objects. Such domains include reverse engineering, the creation of CAD models of mechanical parts, tracking and pose estimation of satellites in space, biomedical engineering, prosthesis design, art conservation, virtual reality, and so on.

SPATIOTEMPORAL INDICATORS, MOTION SCALE SPACE, AND PSYCHOPHYSICAL CORRELATES FOR CONTENT BASED VIDEO INDEXING AND RETRIEVAL

Prasun Lala, Frank P. Ferrie

Problem: When searching through video archives for particular scenes of interest, the amount of data is too overwhelming for a human operator to be usefully parsed. The general field of content based video indexing aims to make this task manageable by automatically categorizing and indexing video content. An algorithm to detect and categorize scenes using psychophysically correlated motion metrics would enhance the state of the art for this field.

Motivation: The aim of a Content Based Video Indexing and Retrieval (CBVIR) system is to assist a user in retrieving a video sequence from a possibly enormous database. The user could have a specific sequence in mind and know that it is contained in the database; the user could have a sequence in mind but be unsure of whether it is contained in the database; or the user could just be browsing for a video without a definite sequence in mind. The progressively diminishing cost of acquiring digital video data and the consequent accumulation of media stores add to the mentality that working with video should be as simple as working with text. CBVIR is a fast maturing field addressing the growing needs for rapid multimedia archiving and access. The same element that helps to extend the indexing capabilities of video compared to still images also complicates the process: temporal information across frames. Within the many proposed algorithms for video content classification using spatio-temporal cues, global and local estimates of motion are used for scene analysis, object tracking, as well as sequence segmentation into semantically coherent parts.

What is the semantic relevance of the chosen segmentation and characterization algorithms used for indexing a particular video sequence in a CBVIR system? Indexing of an object/feature in a video sequence is dependent on the domain of interest, the user, and the type of shot amongst many other variables. Characterizing the types of motion (or lack thereof) within a video sequence is a promising first step for finding indices with perceptual relevance for a user trying to parse through an immense amount of video data.

Approach: Phase Correlation is a particular image processing algorithm that has been used previously for image registration and optical flow estimation for video compression amongst other imaging tasks. It characterizes the relationship between two images by capitalizing on a fundamental phenomenon of the discrete Fourier transform: a positional shift in the spatial domain appears as a phase shift in the frequency domain. This method holds promise for motion-related content indexing of video, possibly with correlates to perceptual estimates of motion. Issues of scale space as it applies to motion characterization will be investigated as well with an emphasis on cues from the biological/psychophysical model of visual motion perception. Other spatio-temporal indicators with a potential for visual motion categorization will be researched and investigated.

Challenges: The range of potential classifications for "types" of visual motion in a semantically relevant manner is huge, possibly without limit. Of course, application specificity helps to narrow the relevant scope of investigation. A challenging task is narrowing the scope of investigation while maintaining cross-application relevance. While it is not that hard to produce psychophysical experiments that quantify the success rate of an already given algorithm (when compared to humans) for categorizing visual motion, creating relevant psychophysical experiments that expose a new path to investigate for spatio-temporal indicators is a much more difficult task.

Applications: Potential users come from the domains of news broadcasting, advertising, music video, distant learning, video archiving, and medicine amongst many others. Applications such as live broadcast, video-on-demand, and digital libraries motivate the research on parsing and indexing of this data for its effective retrieval.

3D TRACKING OF NON-RIGID, ARTICULATED OBJECTS

Haigo Djambazian, Frank P. Ferrie

Problem: To determine the pose of a rigid, articulated object (such as a human hand), given sequential observations from two or more monocular cameras at distinct vantage points.

Motivation: Tracking of non-rigid objects, such as human limbs and hands, is an essential task in the design advanced Human Computer Interfaces (HCI). The traditional approach generally uses a bottom-up approach that first attempts to identify the 3D locations of surface elements from which articulations can be identified and the kinematic state of the structure determined. In contrast, the idea behind this research is to investigate whether machine learning approaches can be exploited to infer the relation between 3D state (e.g. articulation) and 2D observations (television images) at several different vantage points. With respect to applications in HCI, the goal is to develop new methods for tracking gestures in real-time using data acquired with relatively inexpensive video cameras.

Approach: The learning phase of the method results in populations of models (local) that describe the appearance of small regions of the object for small regions in the state space. To effectively train off-line, it is necessary to model the appearance of the object as a function of the state. The local models use principal components analysis (PCA) on windowed regions of the object. Manifolds in PCA space represent the appearance of the small local regions as they undergo deformations. The tracking algorithm recursively matches the link appearances while searching in the state space of the articulated object. To match the object appearance to the model, a coarse search finds the models that are active. The error of the projected object image is then minimized (at the new unknown state) in model subspace by fine-tuning the state.

Challenges: To work in practice, the tracking algorithm must be robust to variations in illumination and appearance with respect to the training data. It must also function in real-time, which essentially translates into sampling rates at television rates (30 Hz). A particular challenge is the design of appropriate appearance models which can account for the expected range of inputs (different hand sizes, skin tones, etc.).

Applications: To date the theory has been successfully applied to a single finger model with excellent results for a two camera system. Even at this early stage, the resulting system can provide a basis for a simple gesture recognition system for HCI.

VISION IN CLUTTERED 3D SCENES

Linqiao Zhang, Yousef Farasat, Michael Langer

Problem: When a camera moves through a 3-D scene, it records images from different vantage points and different directions. The image sequence can be used to compute the 3-D structure of the points in the scene. In computer vision, this problem is known as "structure from motion" (SFM). Typical SFM methods identify common points in different images, for example, by visually tracking points from image frame to frame. Many SFM techniques have been developed and work well for scenes whose salient points are easily identified. Traditional SFM methods do not work well in cluttered 3-D scenes, however. The reason is that, in such scenes, points are occluded in some image frames and not in others, making them difficult to track.

Motivation: Cluttered 3-D scenes are quite common in the real world. For example, indoor man-made scenes such as restaurants or shopping malls are cluttered with people, tables, poles, and other objects. The problem of recovering the camera motion and scene geometry is more difficult in cluttered scenes than in uncluttered scenes. However, despite the difficulty, we believe that certain components of the problem can be solved, namely recovering the motion parameters of the camera and crude statistics about the distribution of objects. Our motivation here comes from biological vision systems. Animals such as cats, birds and monkeys that inhabit cluttered 3-D scenes like forests and grasslands use image motion to guide navigation. For such animals, cluttered 3-

D scenes are the rule, not the exception. We regard these biological systems as an existence proof for the problem we are addressing. Our goal is not to achieve the same remarkable performance of such biological systems in navigating cluttered 3-D scenes, but merely to develop computer vision solutions that perform as well as possible, given today's technology.

Approach: We have recently introduced computational methods for recovering statistical properties of motion recorded by a camera moving in a 3-D cluttered scene. The methods are based on Fourier transforms and extend classical image motion estimation methods that assume non-cluttered scenes. Although the methods we have developed are designed for cluttered 3-D scenes, the methods thus far are restricted to the sideways camera motions - that is, there is no forward component in the motion. This project will extend the methods to allow more general camera motions, and will address the SFM problem in this context.

Challenges: When the camera motion has a forward and sideways component, there is greater complexity in the image motion and the relationship to scene structure is also more complex. The challenge is to model this complexity at the appropriate level. We have preliminary theoretical results that suggest the problem of recovering camera motion from the image sequences is solvable. These need to be verified with real world data. A further challenge is to recover structure properties of the scene geometry. Because of the complexity of 3-D cluttered scenes, we will seek to recover statistical properties. Choosing an appropriate representation for this statistical structure is an open problem, which we need to address.

Applications: The general application of the project is to the problem of visual reconstruction of complex scenes. Recovering 3-D models of scenes can be used in computer graphics rendering applications, for example simulation of what an observer sees moving through a cluttered scene.Commericial applications are varied and range from entertainment, to architectural visualization and urban planning, to scientific visualization of arbitrary 3-D cluttered data sets.

ÉTUDE DES MAINS ROBOTIQUES SOUS-ACTIONNÉES

Lionel Birglen, Clément Gosselin

Motivation: Les mains robotiques sous-actionnées, dont les prototypes Mars et Sarah créés par le Laboratoire de Robotique de l'Université Laval, tirent profit des techniques de sous-actionnement qui représentent une solution intermédiaire entre les mains robotiques pour la manipulation et les préhenseurs simples. Dans une main sous-actionnée, le nombre d'actionneurs (moteurs) est plus petit que le nombre de degrés de liberté et différents mécanismes permettent l'adaptation mécanique du doigt à la forme de l'objet.

Problématique: Bien que connue depuis longtemps, les mains robotiques sous-actionnées n'ont jamais été étudiées rigoureusement. Or de nombreuses problématiques inhérentes à leur nature restent à élucider: quelles sont les limites de la capacité d'adaptation de ces doigts, la prise de l'objet est-elle toujours stable, comment concevoir et contrôler au mieux ces mains? Répondre à ces questions est fondamental pour assurer la fiabilité des prototypes ou applications industrielles et suggère l'étude approfondie des propriétés de ces systèmes en lieu et place d'un design intuitif, aussi bon soit-il.

Travaux: De nombreux résultats ont été mis à jour pendant la réalisation de ces travaux. Il a notamment été découvert comment caractériser et optimiser la capacité d'un doigt sous-actionné à deux phalanges de créer une prise stable tout en conservant sa capacité d'adaptation. De plus, de nouveaux outils et critères de performances ont été introduits qui permettent l'étude des capacités en force des doigts sous-actionnés, quel que soit le mécanisme employé et quel que soit le nombre de phalanges, menant à la notion de design optimal. Des prototypes ont été réalisés afin de vérifier dans la pratique les propriétés théoriques et confirment les hypothèses avancées. Les travaux en cours consistent en l'étude approfondie des doigts à trois phalanges (type le plus courant) et la commande de ces mains.

Theme 3
Integration of Human Inhabitants in Virtual World

DETECTING HUMANS IN A CLUTTERED SCENE

Jérôme Vignola, Robert Bergevin

Problem: Tracking people is a very active problem in computer vision. The goal of this project is to create a system to robustly detect humans in a cluttered scene and create a 2D skeleton of the detected persons. Detection is made on the basis of a single colour image.

Motivation: This project is part of a project called COGNOIS, which aims at localizing humans in a cluttered scene to eventually track them and understand their actions. This project is one of the first steps in COGNOIS. Information gathered during this research will be used, in a further step, to create a 3D representation of skeleton type using stereoscopy.

Approach: The approach used in the project is general, in the sense that no hypothesis on identity or appearance of the person is made a priori. Detection is made using a simplified model of human morphology and possibly colour as well as some heuristics. Basic knowledge is given to the system, such as perceptual grouping laws, and the system must establish links between the elements to perform human detection and recognition of their parts. All of this is done without any specific model, to make the system as generic as possible.

Challenges: Many human detection systems already exist. However, they often have many constraints and strong hypotheses, such as wearing tight clothes, walking parallel to the camera, staying upright, having a fixed background, etc. In addition, the majority of these systems track people without localizing their parts, which is insufficient for our needs. Our greatest challenge will be to create a robust system without a priori hypotheses on the person's clothes or position, etc. This is to ensure that the envisioned real world applications world are feasible.

Applications: Applications of such a project are numerous. For instance, usage in parking lots, airports and other public areas; surveillance, perceptual man-computer interfaces, learning of sport movements, assisted car driving, etc.

IMAGE DATABASE QUERY BY OBJECT RECOGNITION ALGORITHMS

Guillaume-Alexandre Bilodeau, Robert Bergevin

Problem: With the popularity of the WWW and information technologies, very large databases of images and video sequences must be processed automatically. This is the case for image database query and video surveillance. Currently used systems are limited in their use because objects in images are not modeled adequately. Textures, colours and 2D shapes of objects do not characterize them sufficiently well. Models are sensitive to viewpoint, and textures and colours are given much more importance than they receive in reality.

Approach: The approach used to reach our objectives is inspired by two theories in cognitive psychology. The first theory stated by Biederman has been developed using experiments with human subjects. These experiments have shown that humans perceive objects as a hierarchy of grouped primitives. The second theory demonstrates that if straight line segments randomly oriented are shown to humans asked to group them in pairs, humans group them naturally by length, proximity, orientation, and level of overlap. These are the laws of perceptual grouping. The theoretical representation model used in this project is based

on the first theory, whereas, the algorithms used to build the model reflects the second theory. Hence, the theoretical representation model is an attributed graph where the nodes are simple volumetric primitives and the arcs reflects the spatial arrangements of the volumetric primitives. The second theory is used in the algorithms for building the model. The volumetric primitives projections can be viewed as straight line segments and circular arcs that perceptually form groups. Hence, the algorithms for creating models are grouping lines in accordance with the laws of perceptual grouping.

Challenges: Comparing and querying images require a software with abilities similar to a human operator. The use of colours, textures, and interest points in the images are not enough, because two chairs might be, for example, of different colours, dimensions and proportions. Query of images and video sequences must be done at the basic semantic level of identity of objects (e.g. chair, lamp, table, human, etc.), while taking into account the context in which the object is found. To this day, no software or algorithms have this functionality. The incapacity of designing such algorithms comes from the difficulty of dividing an image into its constitutive objects, from the difficulty of modeling shapes generically and from the difficulty of abstracting reflections, textures, shadows and distortions caused by the image capture process.

Applications: Query of databases of manufactured object images, video surveillance, robotic vision systems.

Expected results: The expected results of this project are the proposal and design of a theoretical representation model usable in practice to describe manufactured objects, the design of algorithms for comparing the described object, the testing of the implemented algorithms, and an evaluation of the results obtained to grasp the difficulties specific to our approach.

DESCRIPTION OF A MOVING PERSON OBSERVED BY A MULTI-CAMERA SYSTEM

Stéphane Drouin, Marc Parizeau, Patrick Hébert

Problem: The description of a person and of his actions must be available in order to model and to recognize his behaviour. The goal of this project is to produce a stable description in three-dimensional space (3D) from a sequence of images acquired by a calibrated and synchronized multi-camera system.

Motivation: This project is presented in the context of COGNOIS, for which one of the objectives is to acquire, to describe and recognize the behaviours of people. All available information at the time of acquisition, e.g. the calibration and synchronization parameters of the cameras, is used in order to produce the 3D temporal description of a person, for a multi-camera sequence. The results could be used as ground truth to evaluate other methods not using all of this information. This description will serve for a later stage of movement analysis.

Approach: First, networked cameras are calibrated with a moving pattern and synchronized with a specialized electronic circuit. We suppose that the calibration parameters do not change for the acquisition period. Second, the parameters of a skeletal representation – the model – of a person are estimated in 3D space. Feedback from the model in each image allows a simple segmentation to isolate feature points on the subject. The invariant elements of the description – the limb lengths – are filtered to produce the final result. An approach based on the extended Kalman filter is used for this purpose. For the segmentation, we suppose that distinctive feature points are present on the subject. We also suppose that only one person is present in the scene.

Challenges: The calibration of a wide area vision system poses significant practical challenges. The suggested solutions usually use cumbersome calibration patterns and ignore the synchronization. The main challenge is to develop a precise and efficient calibration procedure that will adapt to a broad range of camera configurations. The 3D description of a person is generally made by fitting a model specific to each individual. The challenge here is to propose a method using a generic model of a person whose invariant elements are estimated by observation. To ensure the robustness of the segmentation to occlusions is also a challenge.

Applications: Description and tracking of people is useful in many applications, such as the monitoring of a swimming pool, the analysis of a sport movement like a golf swing, or of video games where the player physically takes part in the action.

REGION MATCHING OF IMAGES TAKEN AT DIFFERENT TIMES AND LOCATIONS

Michel Lantagne, Robert Bergevin, Marc Parizeau

Problem: With the recent availability of low cost yet powerful computer hardware, one can now envision the emergence of sophisticated and intelligent surveillance systems integrating a network of loosely-coupled computation nodes, each connected to a camera. These systems attempt to track a person from non overlapping fields of view in order to determine whether each camera is observing the same person. The problem consists in measuring the similarity between two human silhouettes.

Motivation: This project is a part of COGNOIS: Communication and Observation toward a Generic Natural Ontogeny for Intelligent Systems. The goal of COGNOIS is the development of a general intelligent architecture with skills for observation and communication for many applications in the real world. One application of COGNOIS is the construction of a system able to detect and track one or many persons in a scene with a sparse network of cameras. Thus, this system requires a module for information integration of images taken at different times and viewpoints.

Approach: Human silhouette comparison can be addressed by characterizing a person's appearance. The project takes in entries of a human silhouette segmented image which may include labelled body parts. The approach uses different methods of region matching. The project is divided into several parts. First, many colour and texture descriptors are studied and tested so as to enable the characterization and segmentation of human body parts. Second, a region matching scheme is used to compare the regions within two human silhouettes. Then, a similarity measure is defined to facilitate person matching. Finally, spatio-temporal coherence is used to improve the matching and tracking.

Challenges: Many systems have been developed recently for the detection and tracking of people, but in the majority of cases they impose many constraints. For example, several systems assume that there is only one person in the scene at a time, the person must stay within the scene and face the camera, the background must remain static or simple, etc. When these assumptions are not respected, the system's robustness degrades rapidly. The main challenge is to develop a system where the number of starting assumptions is reduced while preserving a good robustness.

Applications: Description and tracking of people is useful in several situations. Here are some examples: intelligent monitoring and surveillance systems in airports, parking lots and old age homes for detection of problematic situations (and to start an alarm), user interfaces allowing actions to be defined by simple movements of the user, participation and interaction in a virtual reality, translation of sign language, supervision and interventions in medical operations, etc.

OIDF (ONUS, INTERFACE, DATA, FONCTION), UN ENVIRONNEMENT DYNAMIQUE ADAPTÉ POUR LE SUPPORT D'APIA (ACTOR, PROPERTY, INTERACTION ARCHITECTURE)

Martin Simoneau-Drolet, Denis Poussart

Problème: APIA est une architecture de simulation numérique, distribuée, générique, capable de respecter des contraintes temps réel, développée dans le cadre du projet VERTEX. Le choix d'un support logiciel adéquat pour établir une telle architecture est crucial. Les premiers éléments

APIA (architecture, acteur, propriété, interaction) ont été réalisés à l'aide d'objet C++ , dans une première version, puis à l'aide de composantes CORBA dans une seconde version. Bien que ces versions aient permis de montrer l'efficacité du principe APIA, il demeure certains inconvénients majeurs reliés au manque de flexibilité de ces supports. Parmi ceux-ci, il importe de mentionner les difficultés de déploiement, les contraintes sur la réutilisabilité et l'extensibilité ainsi qu'une difficulté d'intégration avec d'autres éléments informatiques environnants.

Approche: Dans le but d'améliorer les possibilités d'APIA, une architecture par composante flexible, OIDF (onus, interface, data, fonction), parfaitement adapté pour soutenir APIA, a été conçu. Ce framework, à l'instar d'APIA, est basé sur la composition implicite d'objet, une caractéristique favorisant une grande flexibilité et permettant d'envisager des applications plus complexes. Le modèle OIDF est parfaitement générique et il peut supporter des applications autres que les simulateurs (afficheur, lecteur de scripts, traitement de texte, fureteur...). En donnant aux programmes interagissant avec APIA un niveau de flexibilité équivalent, OIDF favorise l'intégration d'APIA avec d'autres applications.

AMÉLIORATION DE LA RÉUTILISATION, DE LA COMPOSITION, DE L'EXTENSION ET DE LA MODIFICATION DES ENVIRONNEMENTS VIRTUELS EN COURS D'EXÉCUTION

François Bernier, Denis Poussart

Problème: Les environnements virtuels actuels se concentrent principalement sur l'amélioration sur les technologies de la réalité virtuelle comme l'affichage graphique et la répartition réseau. Par conséquent, la gestion du réalisme (la conformité entre ce qui est décrit dans le scénario et ce qui est vécu par l'usager) ne peut être prise en charge par un framework. De plus, ces approches limitent la liberté d'action des usagers ainsi que la réutilisation, la composition, la modification et l'extension des scénarios et des environnements virtuels en cours d'exécution.

Motivation: S'il était possible d'écrire des scénarios qui possèdent les caractéristiques mentionnées précédemment, il en résulterait de nombreux bénéfices : - Expérience virtuelle accrue, moins limitative et plus près du monde réel. - Économie de temps et d'argent pour concevoir des environnements virtuels - Création d'un marché de parties de scénario pouvant être vendues ou achetées et s'intégrant aux scénarios déjà existants.

Approche: L'approche consiste à produire un méta-scénario qui guidera, structurera et contrôlera l'écriture des scénarios. De plus, il faudra construire un mécanisme d'ordonnancement pour supporter le niveau de dynamisme recherché. Le tout sera réunit dans un framework qui servira à concevoir des environnements virtuels pour les applications de jeux, des mondes virtuels réparties sur internet et, surtout, pour effectuer des simulations d'opérations de nature critique comme l'inspection de barrages et la cryochirurgie.

Applications: Le framework servira principalement à implémenter une simulation pour la planification, l'entraînement et l'assistance d'interventions de nature critique tel que l'inspection de barrages et la cryochirurgie. Ces applications se feront en collaboration avec l'Hôpital Saint-François d'Assise à Québec et avec le centre de recherche d'Hydro-Québec (IREQ) à Varennes.

Résultats attendus: Il devrait être possible d'utiliser le même framework d'environnement virtuel pour les deux applications. De plus, le passage d'un mode d'intervention à un autre (planification, entraînement et assistance) devrait requérir des modifications mineures dans le scénario et le framework. Finalement, le métalangage devrait augmenter les caractéristiques présentées précédemment.

GESTION DE LA CONFORMITÉ TEMPORELLE D'UN ENVIRONNEMENT VIRTUEL DYNAMIQUE

Éric Boivin, Denis Poussart, Denis Laurendeau

Problème: La mise à jour du scénario d'un environnement virtuel (EV) en cours d'exécution est une caractéristique très recherchée. Celle-ci vise à éviter l'interruption de l'expérience virtuelle suite à l'application d'une modification au sein du scénario de l'EV. Grâce à diverses stratégies logicielles, comme le chargement dynamique de composantes, la modification d'un scénario est devenue une opération aisément réalisable. Cependant, les modifications apportées doivent être largement encadrées pour assurer le maintien de la conformité avec la virtualité définie.

Motivation: Les avancements en matière de dynamisme sont à la base de plusieurs défis reliés aux EVs. Outre la réutilisation de modèles, une forme de dynamisme quelconque peut avoir des effets positifs sur la scénarisation dynamique, la consolidation des EVs persitants, l'amélioration de l'accessibilité et l'émergence d'un modèle d'affaires profitable.

Approche: Le développement des EVs traîne un lourd passé motivé par la distribution. Les motivations initiales ont concentré leurs actions autour de considérations technologiques, qui aujourd'hui, ont beaucoup changé. Les travaux suggérés s'orienteront sur une approche plus conceptuelle où les influences associées à la technologie et à la distribution seront plus discrètes.

Défis: La classification des diverses formes de dynamisme, l'éclaircissement du phénomène de dépendance entre les modèles d'un EV, le maintien de la conformité avec la virtualité définie et l'automatisation graduelle de la planification de la séquence d'exécution sont tous des objectifs nécessaires à l'obtention d'un EV dynamique. Pour ce, la compréhension de divers sous-concepts associés au dynamisme, telles que la granularité, l'extensibilité, l'interopérabilité et la composabilité des modèles virtuels, constitue des préalables incontournables.

Résultats attendus: Afin de restreindre le champ de recherche, les aspects reliés à la distribution telle que la parallélisation, la répartition de charges, l'ajout de ressources et d'usagers distants ne seront pas abordés. Également, l'atteinte d'une solution dite temps-réel ne constitue pas une priorité.

INTERFACE LOGICIELLE POUR LE TRAVAIL COOPÉRATIF À DISTANCE DANS UN CONTEXTE DE RÉALITÉ AUGMENTÉE

François Dinel, Denis Laurendeau

Problème: Le travail coopératif à distance implique que plusieurs utilisateurs situés dans des lieux physiques différents interagissent simultanément dans le même environnement de réalité augmentée. Le présent projet vise à développer une plate-forme logicielle permettant à deux utilisateurs situés dans des lieux physiques différents de manipuler des objets simples appartenant à un environnement virtuel dont le modèle réside sur un serveur. La première partie du projet s'intéresse à la mise au point d'une interface logicielle portable facilitant l'utilisation d'un gant de réalité virtuelle (CyberGlove) dans le contexte de la manipulation d'objets. La seconde partie du projet vise la mise au point d'une plate-forme logicielle permettant à deux utilisateurs de visualiser l'environnement virtuel sur deux affichages 3D différents (et reliés au serveur contenant la description de l'environnement virtuel via un lien Ethernet haute vitesse) et de manipuler les objets situés dans cet environnement en utilisant le gant mentionné ci-dessus.

Motivation: Le travail coopératif à distance en contexte de réalité augmentée permet de réaliser des tâches nécessitant de la coopération entre intervenant en des lieux différents. De nombreuses raisons peuvent nuire à ce que plusieurs intervenants soient en même temps au même endroit. Ce projet vise à rendre réalisable ces tâches malgré la barrière de distance.

Approche: La méthodologie de recherche consistera à effectuer une revue de la littérature sur les systèmes comparables. Par la suite, nous procéderons à une analyse des besoins relatifs à l'application et définirons l'architecture logicielle

répondant à ces besoins. L'implantation de cette architecture sera effectuée en langage C++ et le prototype sera testé sur la plate-forme de réalité virtuelle du Laboratoire de Vision et de Systèmes Numériques de l'Université Laval.

Défis: Le principal défi de ce projet consiste à réaliser la plate-forme logicielle en tenant compte des contraintes inhérentes à l'utilisation d'un réseau et en exploitant les ressources de qualité de service offertes par les différents liens de communication.

Applications: Le travail coopératif dans un contexte de réalité augmentée est un domaine de pointe permettant d'interagir avec d'autres personnes et/ou objets dans des simulations très poussées dans plusieurs domaines tels que, par exemple, la défense nationale, les opérations urbaines et la médecine. D'ailleurs, ce projet est réalisé en coopération avec le RDDC Valcartier (R&D pour la Défense Canadienne de Valcartier).

Résultats attendus: Est attendu que l'interface logicielle pour le gant sera complété, de même que l'interface logicielle de travail à distance. Le tout devra être réalisé en utilisant les méthodologies proposées par le domaine du génie logiciel.

SIMULATEUR DE CRYOCHIRURGIE : PRÉDICTION DE LA DISTRIBUTION DE TEMPÉRATURE

Nathalie Harrison, Denis Poussart, Denis Laurendeau

Ce mémoire de maîtrise a pour but de simuler le comportement physique de transfert thermique associé à la cryochirurgie et de l'intégrer dans un environnement virtuel destiné à la planification, l'entraînement et l'exécution de tâches critiques.

L'étude du transfert thermique est d'abord réalisée expérimentalement in vitro dans un appareil d'imagerie par résonance magnétique. Des données de température et des images sont recueillies afin d'initialiser les variables du problème et de valider les résultats de la simulation. Par la suite, une analyse numérique par la méthode des différences finies permet d'estimer la distribution de température dans la boule de glace et d'identifier la position de l'isotherme de destruction cellulaire.

L'algorithme de simulation est ensuite intégré à un environnement virtuel qui gère l'exécution de la simulation et l'interaction avec l'usager. L'information de température ajoutée à l'imagerie augmente la réalité perçue par le chirurgien et améliore sa compréhension du problème en vue d'une meilleure prise de décision.

FAST COMPUTATION OF NON-LINEAR AND VISCO-ELASTIC MECHANICAL FORCES AND DEFORMATIONS FOR SURGERY SIMULATION

Jean-Marc Schwartz, Denis Laurendeau

Problem: Surgery simulation is a rapidly expanding field, that aims at providing physicians with tools allowing extensive training and precise planning of given surgical interventions. The design of such simulation systems requires accurate geometrical and mechanical models of the organs of the human body, as well as fast computation algorithms suitable for real-time conditions. Most existing simulation systems use very simple mechanical models, based on the laws of linear elasticity. Numerous biomechanical results, however, indicate that biological tissues exhibit much more complex behaviour, including important non-linear and visco-elastic effects.

Approach: We have developed a method allowing the fast computation of mechanical deformations and forces including non-linear and visco-elastic effects. This method uses finite element theory and has been constructed as an extension of the so-

called tensor-mass algorithm for linear elasticity. It consists in pre-computing a set of tensors depending on the geometrical and mechanical properties of each finite element, which are later combined in the simulation part itself. Our non-linear model does not assume any particular form of mechanical law, so that the proposed method is generic enough to be applied to a wide variety of behaviours and objects.

3D RECONSTRUCTION OF HEPATIC TUMOURS FROM INTERVENTIONAL MAGNETIC RESONANCE IMAGES

Alexandra Branzan-Albu, Denis Laurendeau

Problem: Our research work is focussed on the geometric modeling of hepatic tumours and consists in developing segmentation and 3D reconstruction techniques which are adapted for MR liver images.

Approach:

1.Segmentation

Using a database consisting of sequences of 2D images corresponding to parallel and equidistant anatomical slices, a large difference is noted between the horizontal intra-slice resolution (ca. 1.56 mm) and the vertical inter-slice resolution (ca. 10 mm). This difference cannot be minimized during the acquisition process, due to the respiratory motion artefact and to technical limitations. Therefore, 3D segmentation approaches are not reliable in our case and we must consider 2D segmentation techniques. We concentrate on two particular features of abdominal MRI data. The first one is the inhomogeneous texture of the liver tumours at a certain stage of their evolution. For instance, large-sized liver tumours develop a lobular appearance. The second feature is the non-uniform sharpness of the tumour boundary which may contain sharp segments alternating with "blurred" segments. Due to infiltration into surrounding tissues, malignant liver lesions often present contours that do not reveal a clear-cut transition.

To detect the region of interest, we create an isolabel tumour contour map using a multi-threshold technique and a similarity measure for the contours. In order to extract the isolabel contour map of the tumour, we need a minimum amount of information about its location in the liver. The radiologist is asked to select one single reference pixel located inside the tumour. The tumours characterized by "blurred" contours of variable sharpness are detected with a pixel aggregation algorithm based on local texture information.

2. 3D Reconstruction

The results of the 2D segmentation of liver tumours are further used in the 3D reconstruction of the tumour. We have developed a 3D reconstruction approach using shape-based interpolation and contour-based extrapolation. While interpolation generates intermediate slices between every pair of adjacent input slices, extrapolation performs a smooth closing of the external surface of the model. Surface rendering is accomplished through the generation of a triangular mesh using a parametric representation of 2-D intermediate slice contours.

Expected results: The semi-automatic 2D segmentation method for hepatic tumours and the technique for the 3D reconstruction of geometric models have been successfully tested and validated on a large database provided by the iMRI Interventional Unit at St-François d'Assise Hospital in Québec City. At the present time, we are developing an entirely automatic method for liver and liver tumour segmentation. Research involving the synthesis of the 3D geometric model of a tumour and the corresponding biomechanical viscoelastic model is also ongoing in the laboratory.

TRACKING OF THE VISUAL ATTENTION OF HUMAN INHABITANTS IN A VIRTUAL WORLD

James Clark

Problem: Tracking of the visual attention of human inhabitants in a virtual world.

Motivation: For efficient and rapid display of task-crucial information, or for unobtrusive or distracting display of irrelevant details, it is desirable to know the allocation of a viewer's spatial attention.

Approach: Tracking of eye movements, or overt visual attention, is a known, proven technology, but there still remains many unexplored avenues of applications to virtual worlds. We want to augment eye movement tracking with tracking of covert attention (attention shifts without eye movements). Recent work in our lab has shown that microsaccadic eye movements are correlated with covert attention shifts. We propose to combine the microsaccade measurements with image based saliency models of covert attention in a statistical recursive filter (Kalman filter or particle filter) to track the locus of spatial attention.

Challenges: Covert attention tracking is an enormously challenging problem that no one has done before. We feel that we have made inroads on this problem. Perhaps a greater challenge or opportunity lies in making effective use of attention tracking in virtual and augmented reality applications.

Applications: Intelligent user interfaces, that can guess where a viewer is attending. This will permit information to be assimilated more quickly and unconsciously. Using change-blindness techniques, knowing where people are attending will allow us to present information in a way which is not noticeable to the viewer.

A DISTRIBUTED SHARED VISUALIZATION ENVIRONMENT

Jeremy Cooperstock, Benoît Ozell

Objectives: The goal of this project is to create an environment that simultaneously supports distributed computer-mediated human-human interaction through audio, video, and possibly haptic communication, as well as shared visualization and manipulation of synthetic objects. The Distributed Shared Visualization Environment is a project that aims to explore the challenging research problems associated with distributed computer-mediated human-human interaction. The project brings together researchers with a wide range of backgrounds in digital image processing, audio processing, music, haptics, human computer interaction, communications, teleoperation, telepresence and engineering. The focus is not on a single problem domain (e.g. office environments), but rather, seeks to create a general-purpose environment for collaboration and shared visualization.

Problem:*:* In the camera-monitor mediated world of videoconferencing, the limitations of communications bandwidth and equipment capability tend to place a severe handicap on the senses of sight and sound and eliminate the sense of touch. As a result, even in state of the art videoconference rooms using the highest quality equipment, the sense of co-presence enjoyed by individuals in the same room is never fully achieved. Gaze awareness, recognition of facial gestures, social cues through peripheral or background awareness, and sound spatialization through binaural audio, all important characteristics of multi-party interaction, are often lost in a videoconference. While many of these issues can be addressed in part by improved display technology and increased bandwidth, we believe that the result will still be inadequate.

Challenges: To overcome these limitations, we believe that the computer must play a more active role as an intermediary in the communications. Furthermore, it is necessary to move from the restricted videoconference environments of television monitors and stereo speakers to immersive spaces in which video fills the

participant's visual field and is reinforced by spatialized audio cues. Haptic feedback should be introduced to help bridge the physical separation of remote individuals. This feedback could range from reproducing the floor vibrations in response to a user walking about to the tactile response of a surgeon's instrument as it moves through different tissue.

Collaborative Framework in Engineering: In the field of computational based design and high performance computing, engineers and designers in remote locations need to collaborate using videoconferencing, but also need to exchange virtual (synthetic) models and analyze simulation results. Simple simulation, visualization and analysis tasks are usually fulfilled at the same place, on the same computer or on computers connected together by a local area network. But as projects grow and become more complex, high-performance computers are needed to solve problems and high-performance visualization environments are needed to analyze solutions. These facilities are often not available at the same location.

In order for participants to maximize the effectiveness of their discussion and analysis of simulation results, synthetic objects need to be created in 3D as if they were part of the videoconference scene. The participants should be able to manipulate them as if real, to point out certain parts of an object to others, and to identify different views on these objects for others to see. These objects could be displayed on walls or on a table in 3D. Depending on the application, gesture and speech recognition may also be integrated so that the virtual environment responds to various commands.

Approach: The planned testbed consists of three small audio-insulated rooms, two based at McGill University and a third at Ecole Polytechnique or CERCA, each equipped with high resolution video projectors, cameras, microphones, and multi-channel audio, interconnected by a high speed network backbone. The video will be rear-projected to cover three walls of each room, thereby encompassing the users' visual field and creating the illusion of a larger shared space. Multi-channel audio will be used to produce effective spatialization of sound sources, enhancing the sense of co-presence. Powerful computer hardware will be exploited to perform advanced, real-time graphics rendering, supporting three-dimensional visualization through stereoscopic shuttered glasses.

Application: This project will facilitate and enhance the human interaction in multi-disciplinary design and analysis in engineering and scientific application. It will encourage international collaborations using advanced high-speed networks, enabling researchers to work together, whether their colleagues live across the country or across the ocean, and to access geographically-distributed computing, storage, and display resources.

The usefulness of this type of environment will be greatly enhanced through its manipulative capabilities and functional links to current CAD and CAE packages. Teams scattered around a country or around the world could work together on the same project using the integrated collaborative framework that is proposed. Using the infrastructure of videoconferencing, several persons can work together locally or use global communication networks such as broadband ISDN. This type of collaborative framework for distributed and distance problem solving and analysis finds applications in other fields of science, medicine, architecture, education, etc.

PARALLEL DISTRIBUTED CAMERA ARRAYS

Jeremy Cooperstock, Jim Clark, Sidney Fels, Roel Vertegaal

Problem: Intelligent Environments are spaces in which machine perception and reasoning capabilities are used to enhance human activity through background computation. Perhaps the most challenging technical problem facing researchers in this area is the need for reliable, high-resolution, and unobtrusive vision systems that can track objects and people as they move about such a space. This capability is required in order to recognize user actions and gestures and to perform synthetic reconstruction of a (visual) scene in the environment. Current applications typically rely on

a small number of (often expensive) video cameras or laser rangefinders for this purpose, which tend to restrict both the visual coverage and the total resolution available. This usually imposes undesirable restrictions, for example, in the case of eye-tracking, the need for the user to remain stationary in front of a camera. Such restrictions limit that technology's potential for application in Collaborative Virtual Environments (Vertegaal, 1999a).

When using computer vision for object tracking, two cameras will provide absolute depth information through stereopsis, which can be used to aid in the recognition of the object. The use of more than two cameras does not significantly improve the accuracy of depth information, but can provide a greater coverage of the object viewed. This increased coverage can be expected to yield improved object recognition performance or view reconstruction capabilities. However, techniques for integration of arbitrary multiple views are computationally expensive (Vedula, 1999) and are unlikely to scale well.

This project will consider the use of a large, parallel, distributed array of low-cost cameras with embedded image processing capabilities for use in object tracking and scene reconstruction for Intelligent Environments. The use of large camera arrays is rapidly becoming feasible as the cost of image sensors has been greatly reduced in the last few years (e.g., the cost of a CMOS camera is currently less than $25). However, integration of image data from a multitude of cameras is a major challenge that currently inhibits the creation of camera arrays that are sufficiently large.

The solution involves a number of smaller technical challenges. For example, to simplify integration of views of moving objects, we must be able to synchronize the image acquisition between a large number of cameras. To cope with large amounts of image data, we must (1) develop more efficient image compression techniques (e.g., knowledge-based); (2) design detection algorithms capable of dealing with low resolution image data; (3) develop parallel, distributed software and hardware for the processing of large images; and (4) develop communication infrastructures between cameras that can handle potentially high data rates with low latency.

Objectives: To provide more robust and efficient object tracking for Intelligent Environments, we aim to create a set of networked low-cost camera arrays that collectively provide high resolution and large field-of-view image processing capabilities. Our approach involves the development of a number of novel technologies, such as:

- Smart cameras with on-board reconfigurable image processing and network communication capabilities.
- Techniques for cooperative parallel distributed image processing that are suitable for multi-camera image data.
- Techniques for reconstruction of arbitrary viewpoints from a network of video cameras viewing a scene.

At the same time, we plan to apply these technologies to current problems in the area, including:

- Person and gaze tracking
- Background removal in complex, dynamic environments
- Focus-of-user attention recognition

Approach: Current work on the development of multi-camera arrays tends to be based either on physically clustered cameras, as in the USC panoramic vision system (Neumann et al, 2000) or on small arrays of expensive, high-resolution cameras connected to workstations where video processing is performed (Kanade, 1997). Neither of these approaches satisfies our objectives, for reasons of cost, viewing area coverage, and parallel processing capabilities.

Our first milestone requires the development of a scalable, integrated camera with on-board image processing hardware. We will draw upon our experience in developing the Local Positioning System (LPS) (Fels, 2001), which uses a CMOS camera connected to a field programmable gate array (FPGA) and digital signal processing (DSP) chip to track active infrared tags in large rooms in real-time. This initial platform will be scaled to the production of multiple camera modules that provide inter-camera synchronization, efficient inter-camera networking and high speed data communication to a host machine. We believe that reconfigurable FPGA hardware would provide a suitable alternative to standard programmable microprocessor or DSP chip implementations for this application, with the advantages of greater speed and more efficient usage of circuitry, leading to power consumption reduction. The benefits of this approach are especially important for embedded systems applications.

One of the difficulties in working with reconfigurable FPGA architectures has been the

lack of high-level design tools. This is changing, however, and we plan to work with the Handel-C design tools from Celoxica Corp., which permit hardware descriptions (in VHDL or EDIF netlists) to be generated from C language programs. Celoxica, in cooperation with Xilinx will make available their RC1000-PP development board, which contains a Xilinx Spartan-II 200K gate device, flash RAM, and assorted peripherals, including an NTSC video digitizer. We propose to use these boards to develop our embedded system smart camera prototypes, the design of which can then be transferred to compact special-purpose camera units for the full network demonstration phase of the project.

There are a number of advantages to tightly interconnecting the processing circuitry of multiple smart cameras. A mechanism akin to the attentional process in the human brain can be employed to actively direct various image processing activities to different cameras as task requirements and environmental conditions warrant (Vertegaal, 2002). For example, in a person-tracking task, some cameras may be able to see the person's eyes, and could therefore engage in gaze tracking activities, while other cameras could track the person's body orientation, or be engaged in peripheral alerting tasks.

In addition, each smart camera unit can be thought of as a single node in a coarse-grained MIMD parallel computer. Such a distributed computer can effectively approach a computationally intensive problem by breaking it into a number of subtasks that are worked on cooperatively by each processor. The programming of such MIMD systems is challenging, but biological metaphors can be used to some benefit (Clark and Hewes, 1994; Clark, submitted). In such approaches, separate processors collaborate and share the work efficiently through the application of heuristic load balancing strategies, mimicking some of the ways in which biological cells or colonies of insects distribute their tasks (Bonabeau, Dorigo and Theraulaz, 1999). Our proposal is to consider similar techniques for parallel distribution of various image processing tasks in our network of smart cameras. The interconnection of both image data and control signals between the cameras in the network will permit the implementation of such decentralized load balancing strategies.

As part of our research, we plan to investigate architectural issues associated with the implementation of the distributed parallel processing approaches, above. Among the considerations will be the development of adaptive processing architectures that can easily and quickly change their process in accordance with task requirements, as well as communication structures that will facilitate collaboration between separate smart camera units. Reconfigurable FPGA architectures are well suited to this sort of on-line rearrangement of process activity, and the development of adaptive mechanisms for these devices will form a portion of the proposed research.

Value added to our ongoing work

The development of our large camera array will serve as an important testbed for the Local Positioning System (LPS) developed by Prof. Fels. Building on the work of IBM Research Labs (Morimoto et al, 1998), which uses intermittent on- and off-camera axis illumination of the eyes with an infrared light source to obtain an isolated image of the user's pupils (the bright-dark pupil technique), we will experiment with the potential of a smart camera array used for low-cost, non-intrusive long-range eye-tracking.

The capability to track the user's eye gaze behavior is particularly important in Intelligent Environments that are shared between users at different locations (see Vertegaal et al., 2001). Communication of user eye gaze has been demonstrated to be crucial in the efficient management of group conversation (Vertegaal et al., 2000). Systems that use eye-tracking for this purpose tend to have a limited range of operation and are prohibitively expensive (Vertegaal, 1999a). Furthermore, they often restrict the user's head movement and position (e.g. the user must be sitting at a fixed distance in front of PC monitor). Systems that do allow free head movement typically require the user to wear head mounted optics and provide no easy way of reporting point of gaze in absolute scene coordinates. The tracking of the eyes of multiple users at great distance is a challenging task given the small size of the image processing target, the eyes of a user. As such it will provide a crucial benchmark for the performance of the proposed multi-camera tracking technology. One of the great values of ubiquitous eye tracking technology is that it may greatly improve the functionality of speech recognition in Intelligent Environments. The proposed sensing technology will be applied to disambiguate the target of voice commands between multiple appliances without the need for verbal labeling (Vertegaal, 2002).

The large camera array will also be used to further our user studies on the tracking of laser pointers (both infrared and visible red) within large projection displays [Fels et. al. in press]. We have initial data suggesting that the resolution of laser tracking significantly impacts task performance in these large projection systems. The large camera array will allow us to have sub-pixel resolution for tracking laser pointers on such displays, which is useful for collaborative work environments, virtual reality environments and teleconferencing applications (Vertegaal 1999a).

Application: One of the major application benefits of the camera array is the potential for high quality view synthesis, i.e. the generation of a reconstructed view of an individual in the "scene" from an arbitrary viewing angle, with the background removed, as is required for the Shared Reality Environment (Cote et al, 2001). As the computational demands for this task are very high, current state-of-the-art approaches (Kanade, 1997) cannot operate in real-time, even on powerful machines. By distributing the processing task over a collection of smart camera nodes, which dynamically configure communication paths to appropriate neighbouring nodes, we intend to study the feasibility of real-time view synthesis using such an array. However, unlike other tasks in which the communication bandwidth is fairly low, view synthesis requires high bandwidth transfer of regions of computed pixels, from the processing elements to a host PC with low latency. This will require serious architectural consideration, in particular, regarding the structure of "taps" into the array so that reconstructed high resolution video can be extracted from any particular region.

PROJECTING CHANGE MAP INFORMATION ONTO A SYNTHETIC TERRAIN MODEL IN A USEFUL AND USEABLE MANNER

Prasun Lala, Frank P. Ferrie

Problem: Data such as range points for a three dimensional terrain model may also have associated metrics such as confidence in accuracy. A concurrent method to display such metrics is needed when rendering these data as images.

Motivation: The Enhanced and Synthetic Vision System (ESVS) is a Canadian Forces Search and Rescue (CF SAR) Technology Demonstrator project to help SAR helicopter crews see in poor visibility conditions. Pilots see rendered synthetic images of a stored terrain model on a head-mounted display. A given terrain model may be inaccurate and consequently provide the pilot with erroneous information. The Artificial Perception Laboratory has developed an image-based algorithm for online updating of erroneous terrain models. This algorithm also generates a confidence metric for each point in the terrain model. A method to convey this confidence metric to the pilot is needed. The method should not add unnecessary interference or clutter to the pilot's tasks at hand.

Methods for displaying error or other information about terrain model data exist in the fields of cartography and meteorology, but these methods mostly use symbols to label data points with additional information (e.g. confidence). The viewer must consciously interpret/intellectualize the information. Pilots' requirements in this regard are different as they need an immediate "real-time" perceptual interpretation of a given scene. Intellectualization or excessive training to interpret data will impede a pilot's normal function. Furthermore, their goal directed motor tasks depend on these interpretations; that is, there are basic reflexes based on visual feedback from the rendered images. Thus a chosen confidence visualization method cannot confound the interpretation of the underlying terrain data. To further differentiate the needs for the ESVS, the confidence metric data generated from the image based model updating algorithm are time (motion) dependent, not static.

Approach: The proposed approach is to represent the population of confidence metric data as a transparent "anomaly" surface around (above) the rendered terrain model. This general anomaly surface accumulates the visible portion of enclosing "confidence" volumes around individual terrain range data points. The normalized diameter of the enclosing volume for each range data point is based on its confidence value from 0-1 (0 equaling maximum confidence). Thus less accurate range

data will have a more distant anomaly surface above it. The original data remains visible to the pilot and there is an intuitive metric for confidence in that data. The suitability of such a system for both basic orientation and feature detection is being investigated. Presumably, dynamically changing a transparent anomaly surface as confidence measures are updated will not create the disorientation effects that would be associated with dynamically changing the actual terrain data.

Challenges: The mapping of a confidence metric to an anomaly surface is not trivial. The goal is to choose an algorithm that relates confidence in a data point to the distance of the anomaly surface above it in a psychophysically intuitive manner, while retaining computational efficiency. Methods being investigated include taking the convex hull of sampled points on the "confidence cloud" around the data as well as relating the anomaly surface distance to the density of this cloud.

Of course, a truly transparent surface is also not visible. The challenge is to render the anomaly surface in such a way that its shape and depth are immediately apparent while not impeding discernment of the terrain below. The first series of methods being investigated focus on opaque, striped markings on the transparent surface whose position, length, and orientation are determined by the surface curvature. Thus these markings are independent of the pilot's point of view. These methods are based on visualization research on radiation doses applied to tumours. An opaque marking method that does depend on the pilot's point of view is using grids based on intersecting planes. While the first method appears to be more psychophysically intuitive for determining surface shape and depth, it is also more computationally expensive, depending on methods such as line integral convolution. In the case of the ESVS, the computational load will depend on the frequency with which the anomaly surface is to be updated. When using opaque markings, a psychophysical challenge that arises is to reduce the phenomenon of *vection*, the (erroneous) perception of self motion induced by moving visual (optokinetic) stimuli. Such a phenomenon might occur when surface markings are "moving" because of a changing anomaly surface shape. Potentially, the impact of such an illusion to a pilot's vehicular control could be severe. Further psychophysical experiments will investigate a subject's ability to estimate confidence in data, as well as the interference of the confidence visualization with interpretation of the underlying data.

Applications: Beyond the ESVS, a transparent surface based data confidence visualization method is relevant wherever 3D data is rendered for display; for example, it could be used in disaster management applications where a known 3D model is being compared to an updated post traumatic model.

ÉTUDE DES PERFORMANCES, ANALYSE ET OPTIMISATION D'UN MÉCANISME PARALLÈLE SPATIAL À 6 DEGRÉS DE LIBERTÉ ACTIONNÉ PAR CÂBLES

Benoît Cantin, Clément Gosselin

Objectif: L'objectif de ce projet est d'évaluer les performances ainsi que les limitations du mécanisme et de son contrôleur dans le but d'y apporter les améliorations possibles. Ces améliorations augmenteront l'agilité du mécanisme en plus de lui permettre d'effectuer des trajectoires sortant de l'espace atteignable statique.

Méthodologie: La méthodologie peut être résumée comme suit:

- Dans un premier temps, une étude sur les limitations des performances causées par le matériel utilisé sera menée. Des modifications au niveau matériel ainsi que le remplacement des composantes en cause seront ensuite effectués.
- Ensuite, une estimation de la contribution de chacun des éléments sur la dynamique du système sera calculée. Cette estimation permettra de déterminer les facteurs qui limitent les accélérations maximales du mécanisme. Des objectifs de performance seront fixés.
- Des modèles dynamiques seront ensuite développés. L'implantation de ces modèles permettra la modification du contrôleur actuel dans le but de rencontrer les objectifs fixés précédemment.
- Finalement, en se basant sur les modèles dynamiques développés précédemment, des contrôleurs permettant au mécanisme d'effectuer

des trajectoires sortant de son espace atteignable statique seront développés.

- Les résultats obtenus lors des étapes précédentes seront assemblés et le mémoire ainsi que des articles scientifiques seront rédigés.

Support informatique et technique: Les travaux seront réalisés sur les ordinateurs du laboratoire de robotique à l'aide des logiciels disponibles soit: MATLAB, Maple, ProEngineer, ADAMS et des logiciels maison. Le mécanisme à câbles ainsi que le contrôleur sont disponibles au laboratoire.

Échéancier:
Hiver 2003: Cours et étude sur les limitations matérielles.
Été 2003: Développement des modèles dynamiques et modification du contrôleur.
Automne 2003: Développement du contrôleur permettant les trajectoires hors de l'espace atteignable statique.
Hiver 2004: Cours et rédaction du mémoire et des articles.

Université Laval

Student	Program	Supervisor & Co-Supervisor	Topic/Thesis
Bédard, Marc	M.Sc.	Hébert	Simulation visuelle réaliste d'un environnement: reconstruction projective et extraction de propriétés de textures à partir d'un nombre restreint de photographies
Cantin, Benoît	M.Sc.	Gosselin	Étude des performances, analyse et optimisation d'un mécanisme parallèle spatial à 6 degrés de liberté actionné par câbles
Couture, Mario	M.Sc.	Laurendeau	La qualité de service réseau pour applications distribuées
Dinel, François	M.Sc.	Laurendeau	Interface logicielle pour le travail coopératif à distance dans un contexte de réalité augmentée
Dorion, Éric	M.Sc.	Laurendeau	On the performance of military distributed information systems
Drouin, Richard	M.Sc.	Laurendeau	Intelligent protocol for exchanging visual information
Dubreuil, Marc	M.Sc.	Parizeau	Engineering and quantification of a parallel and distributed system of Master/Slave for evolutionary computation
Fortin, Pierre-Alexandre	M.Sc.	Hébert	Telecollaboration in the context of augmented reality: Application to theatrical production
Giasson, David	M.Sc.	Laurendeau	3D Segmentation algorithms for modeling of dental roots
Harrison, Nathalie	M.Sc.	Poussart / Laurendeau	Simulateur de cryochirurgie: Prédiction de la distribution de température
Jobin, Jean-Philippe	M.Sc.	Gosselin	Conception d'une scène à géométrie variable
Khoury, Richard	M.Sc.	Hébert	A self-referencing hand-held 3D sensor
Labrie, Martin	M.Sc.	Hébert	Module de positionnement inertiel pour améliorer la robustesse du suivi de points de référence dans une séquence d'images
Lantagne, Michel	M.Sc.	Parizeau / Bergevin	Region matching from images at different times and locations
Mainguy, François	M.Sc.	Maldague	Évaluation Non-Destructive (ÉND) par ultrasons

Student	Program	Supervisor & Co-Supervisor	Topic/Thesis
Martel-Brisson, Nicolas	M.Sc.	Zaccarin	Détection et poursuite de régions en mouvement à partir de séquences vidéos
Najjar, Lilia	M.Sc.	Maldague	Algorithmes de quantification de défauts aux formes complexes
Petitclerc, Mario	M.Sc.	Zaccarin	TBD
Robert, Michel	M.Sc.	Hébert	Imaging and 3D modeling using a laser range sensor: application in the wood industry
Simo, Clovis	M.Sc.	Laurendeau	Distributed architecture for finite element modeling of visco-elastic tissues
Torresan, Hélène	M.Sc.	Maldague / Hébert	Intelligent fusion of a hybrid (infrared and visible) sensor in the context of pedestrian detection and surveillance
Vignola, Jérôme	M.Sc.	Bergevin	Detecting humans in a cluttered scene
Wang, Ying	M.Sc.	Hébert	Positioning of a hand held range sensor
Bernier, François	Ph.D.	Poussart	Amélioration de la réutilisation, de la composition, de l'extention et de la modification des environnements virtuels en cours d'exécution
Bilodeau, Guillaume-Alexandre	Ph.D.	Bergevin	Image database query by object recognition algorithms
Birglen, Lionel	Ph.D.	Gosselin	Étude des mains robotiques sous-actionnées
Boivin, Éric	Ph.D.	Laurendeau / Poussart	Gestion de la conformité temporelle d'un environnement virtuel dynamique
Drouin, Stéphane	Ph.D.	Parizeau / Hébert	Description of a moving person observed by a multi-camera system
Gagné, Christian	Ph.D.	Parizeau	Evolutionary re-engineering: application to pattern recognition and lens system design
Ibarra Castadeno, Clemente	Ph.D.	Maldague	Quantitative subsurface defect characterization in the presence of complex shape surfaces by TNDT
Samson, Éric	Ph.D.	Laurendeau / Parizeau	Active stereo pair system calibration
Schwartz, Jean-Marc	Ph.D.	Laurendeau	Fast computation of non-linear and visco-elastic mechanical forces and deformations for surgery simulation

Student	Program	Supervisor & Co-Supervisor	Topic/Thesis
Simoneau-Drolet, Martin	Ph.D.	Poussart	OIDF (onus, interface, data, fonction), un environnement dynamique adapté pour le support d'APIA (actor, property, interaction architecture)
Souafi-Bensafi, Souad	Ph.D.	Parizeau	Contribution à la reconnaissance des structures des documents écrits: approche probabiliste
Tubic, Dragan	Ph.D.	Laurendeau / Hébert	Quality, efficiency and reliability of 3D image surface reconstruction

McGill University

Student	Program	Supervisor & Co-Supervisor	Topic/Thesis
Ajersch, Mark	M.Eng	Boulet	Control in Thermoforming
Boussemart, Yves	M.Eng	Cooperstock	Gestural Interfaces in Immersive Environment
Boyer, Alexandre	M.Eng	Boulet	SISO Robust Tunable Control Design
Campbell, Don	M.Eng	Buehler	Bounding in the Hexapod Rhex
Campion, Gianni	M.Eng	Hayward	High Fidelity Computer Graphics for Surgical Simulation
Castrillon, Manuel	M.Eng	Clark	Partial Reconfiguration
Deschenes, Francois	M.Eng	Buehler/ Nahon	Control Enhancements to the LAR System
Dostmohamed, Hanifa	M.Eng	Hayward	Haptic Display of Shape without Force Feedback
Farasat, Yousef	M.Eng	Langer	TBD
Garroway, Diana	M.Eng	Cooperstock/ Hayward	Haptic Interaction for 3D Animation
Geng, Lei	M.Eng	Angeles	TBD
Georgiades, Christina	M.Eng	Buehler/ Nahon	Simulation and Control of a Six-legged Robot in a 3D Environment
Ghuneim, Tariq George	M.Eng	Angeles	Design of a Spherical Epicyclic Transmission Based on Cams
Gipsman, Daria	M.Eng	Langer	TBD
Haccoun, Laurent	M.Eng	Boulet/ Michalska	Three-dimensional Position Control of a Magnetically Levitated Object
Hadjimichael, Basil	M.Eng	Boulet	Manufacturing Planning and Control
Hilario, Maria Nadia	M.Eng	Cooperstock	Object Detection and Recognition using Infrared Sensors

Student	Program	Supervisor & Co-Supervisor	Topic/Thesis
Khan, Waseem Ahamad	M.Eng	Angeles	Distributed Dynamics of Systems with Closed Kinematic Chains
Kiriy, Evgeni	M.Eng	Buehler	A Localization System for Autonomous Golf Course Mowers
Lalli, Gino	M.Eng	Boulet	Control in Extrusion Blow Molding
Laporte, Catherine	M.Eng	Arbel	Entropy-Based Aspect Graphs for Active Object Recognition
Laprise, Pierre-Olivier	M.Eng	Clark	Computer Vision Using Parallel Distributed Processing and Reconfigurable Computing
Lévesque, Vincent	M.Eng	Hayward	Measurement of Skin Deformation Using Fingerprint Feature Tracking
Liu, Jinbo	M.Eng	Boulet/ Michalska	Design of a Magnetic Levitation System
Liu, Shuo	M.Eng	Boulet/ Michalska	Temperature Control Using a Heat Exchanger
Liu, Yu	M.Eng	Angeles	The Robust Kineostatic Design of a Parallel Shoenflies-Motion Generator
Ma, Zhongjing	M.Eng	Caines	Rate Control
McCallum, Jacqueline	M.Eng	Buehler	Stair Descent with a Hexapod Robot
Nair, Vinod	M.Eng	Clark	Distributed Video
Ndrialisoa, Raserijuonia	M.Eng	Angeles	The Design of a Parallel Shoenflies-Motion Generator
Neville, Neil	M.Eng	Buehler	Dynamic Behaviours for the RHex Hexapod Robot
Pasquero, Jerome	M.Eng	Hayward	A Tactile Display using Lateral Skin Stretch
Perez, Michael	M.Eng	Cooperstock	TBD
Roumy, Jean-Gabriel	M.Eng	Boulet	Active Control of Vibrations of a Car Chassis
Sato, Akihiro	M.Eng	Buehler	Development and Control of a Bipedal Robot using Electric Motors
Savadjiev, Peter	M.Eng	Ferrie/Siddiqi	Surface Recovery from 3D Point Data

Student	Program	Supervisor & Co-Supervisor	Topic/Thesis
Steeves, Charles	M.Eng	Buehler	Design and Behavioural Control of a Dynamic Quadruped with Active Wheels
Sud, Daniel	M.Eng	Cooperstock	Hand Tracking for Gesture Recognition
Sugiharto, Rainer	M.Eng	Angeles	Path Planning of a Wheeled Mobile Robot
Tang, Fan	M.Eng	Angeles	Kinematics and Design of a Wheeled Mobile Robot
Toews, Matthew	M.Eng	Arbel	Optimal Feature Points for Image Correspondence
Yao, Hsin-Yun	M.Eng	Hayward/ Ellis	Tactile Amplifying Diagnostic Probe for Orthopaedic Applications
Zhang, Weimin	M.Eng	Angeles	Application of Speed-o-Cam in Dual Epicyclic Transmission
Zhang, Xiang	M.Eng	Angeles	The Innovative Design of Planetary Cam-Roller Trains
Descoteaux, Maxime	M.Sc.	Siddiqi	Blood Vessel Segmentation
Dimitov, Pavel	M.Sc.	Siddiqi	Shapes, Parts and Recognition
Garden, Matthew	M.Sc.	Dudek	Learning-based Recommender Systems
Phillips, Carlos	M.Sc.	Siddiqi	View-based Object Representations
Rao, Malvika	M.Sc.	Dudek/ Whitesides	A Randomized Algorithm for Robot Localization in a Self-similar Environment
Pelletier, Stéphane	M.Sc.	Cooperstock	High-Resolution Video Synthesis from Mixed-Resolution Video Based on the Estimate-and-Correct Method
Zhang, Linqiao	M.Sc.	Langer	Rendering Falling Snow Using an Inverse Fournier Transform
Al-Widyan, Khalid	Ph.D.	Angeles	Robust Design of Robotic Mechanical Systems
Arseneau, Shawn	Ph.D.	Cooperstock	Occlusion Detection In the Spatiotemporal Domain
Bégin, Isabelle	Ph.D.	Ferrie	Learning-based Methods for Integration and Super-resolution of Images
Benoit, Stephen	Ph.D.	Ferrie	Direct Motion and Shape Parameter Recovery from Image Sequences

Student	Program	Supervisor & Co-Supervisor	Topic/Thesis
Bouix, Sylvain	Ph.D.	Siddiqi	Medial Surfaces and Applications
Bourque, Eric	Ph.D.	Dudek	Automated Parameter Estimation for Procedural Texturing
Brooks, Rupert	Ph.D.	Arbel	Active Vision for Optimal Sensor Placement in Image Guided Neurosurgery
Cayouette, Francois	Ph.D.	Cooperstock	Gesture Recognition using Multiple Cameras
Chen, Chao	Ph.D.	Angeles	The Conceptual and Optimal Design of Epicyclic Mechanical System
Drissi-Smaili, Fatima	Ph.D.	Clark	Object Recognition
Duan, YingXuan	Ph.D.	Boulet	Robust Tunable Control
Ehtiati, Tina	Ph.D.	Clark	Attention Models for View-based Object Recognition
Gauthier, Guy	Ph.D.	Boulet	Iterative Learning Control
Hafed, Ziad	Ph.D.	Clark	Motor Theories of Attention
Huang, Minyi	Ph.D.	Caines	Stochastic Control for Distirbuted Systems with Applications to Wireless Communication Systems
Lala, Prasun	Ph.D.	Ferrie	Conte Based Video Indexing: Motion Characterization Using Psychophysical Correlates
Li, Jie	Ph.D.	Clark	Statistical Modelling and Tracking of Covert Attention
Li, Muhua	Ph.D.	Clark	Maintaining Perceptual Stability across Self-Actions
Mitran, Marcel	Ph.D.	Ferrie	Active Surface Reconstruction From Optical Flow(M.Eng)
Nasrallah, Danielle	Ph.D.	Angeles/ Michalska	Dynamics and Control of an Anti-tilting Two-Wheeled Mobile Robot
Nava-Hernandez, Sergio	Ph.D.	Angeles	Optimization of Epicyclic Tranimissions of Spherical Cam-Roller Pairs
Ostrovskaya, Svetlana	Ph.D.	Angeles	Motor Theories of Dynamics of Quasiholonomic and Nonholonomic Reconfigurable Rolling Robots
Poulakakis, Ioannis	Ph.D.	Buehler/Sharf	On the Dynamics of Quadruped Running

Student	Program	Supervisor & Co-Supervisor	Topic/Thesis
Rekleitis, Iaonnis	Ph.D.	Dudek	Cooperative Localization and Multi-Robot Exploration
Romanovski, Iakov	Ph.D.	Caines	Multi-agent Product Systems: Analysis, Synthesis and Control
Salerno, Alessio	Ph.D.	Angeles	Design, Dynamics and Control of a Fast Two-Wheeled Quasiholonomic Robot
Shaikh, Mohammed	Ph.D.	Caines	Optimal Control of Hybrid Systems
Sim, Robert	Ph.D.	Dudek	On the Autonomous Construction of Visual Maps
Simard, Philippe	Ph.D.	Ferrie	Online Updating of Synthetic Vision Systems' Databases
Simhon, Saul	Ph.D.	Dudek	Sketch Interpretation and Refinement Using Statistical Models
Skaff, Sandra	Ph.D.	Clark	Recognition of Familiar Scenes in Video Sequences
Smith, James Andrew	Ph.D.	Buehler/ Sharf	Analysis and Implementation of Quadruped Four-Beat Gaits
Sun, Wei(Victoria)	Ph.D.	Cooperstock	Object Tracking with Multiple Cameras
Torres-Mendez, Luz Abril	Ph.D.	Dudek	Sensor Fusion for a 3D Environment Modelling
Wang, Qi	Ph.D.	Hayward	Tactile Perception
Yin, Jianfeng	Ph.D.	Cooperstock	Video Interpolation and Synthesis for View Reconstruction

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