ANNUAL REPORT

RAPPORT ANNUEL

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RÉSEAU QERRAnet

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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 22 members from three institutions – 12 full members from McGill University, 9 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, 9 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**
Alexandra Branzan-Albu	**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 2003-2004, the student population of QERRAnet consisted of 82 Master's students, 48 PhD students and 5 Postdocs. Scientific contributions by members comprised of 29 articles in refereed journals and 76 articles appearing in refereed conference proceedings. Additionally, the network held approximately 30 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 2003-2004, le nombre d'étudiants membres de QERRAnet s'élevait à 82 étudiants à la maîtrise, 48 étudiants au doctorat et 5 stagiaires postdoctoraux. Les contributions scientifiques des membres comptent 29 publications dans les revues scientifiques et 76 publications dans des comptes-rendus de conférences. De plus, le réseau a tenu 30 séminaires sur des sujets pertinents à sa

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 2003-2004 is approximately $4.6M/year. This funding is broken down into $3.5M/year in grants from Federal agencies, $.3M/year from Provincial agencies and $.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, and initial implementation was carried out in the summer of 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.

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 2003-2004 était d'environ $4.6M/an. Ce financement comprend $3.5M/an en subventions de recherche provenant des agences fédérales, $.3M/an provenant des agences provinciales et $.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 a été effectuée en 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.

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.

Management and Administration: 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.

Professional and Technical: 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	Professionel de Recherche:	Sylvain Comtois
Administrator:	Cynthia Davidson	**Membres du corp professoral:**	**9**
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.

Funding Sources
(per annum)

DIRECT REVENUE SOURCES				
FQRNT-Regroupement Stratégiques				$233,250
Inter-institutional Support				$130,000
				$363,250
DIRECT EXPENDITURES				
Salaries		$344,000		
Contribution to employee benefit plan		90,000	$434,000	
Training and Development: (conferences,workshops etc)		240,000		
Materials and Supplies		38,000		
Equipment		97,200		
Other		40,000	$415,200	$849,200
SUPPORTING SCIENCES				
NSERC				
	Discovery	708,436		
	Strategic	756,417		
	NCE	532,000		
	Collaborative	332,150		
	Research Chairs	400,000	$2,729,003	
CFI -- McGill		426,000		
CFI -- Un. Laval		349,438	775,438	
FQRNT				
	Team	69,565		
	Other	155,400	224,965	
VRQ		33,000	33,000	
Industrial Contracts		395,250		
Other		92,900		
TOTAL REVENUE		**$4,250,556**		**$4,613,806**

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

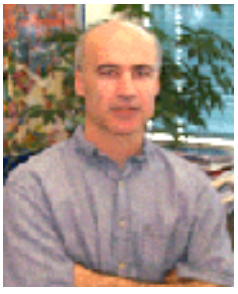
Computer Vision

- 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

Branzan-Albu, Alexandra 418-656-2131, ext 3556 branzan@gel.ulaval.ca

Computer Vision
- Pattern recognition
- Image and video processing
- Motion analysis and tracking
- Medical imaging
- Virtual reality and simulation

Buehler, Martin (on leave) 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

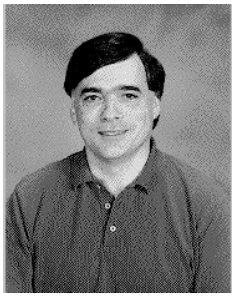
Navigation

- 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
- Virtual reality and simulation

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

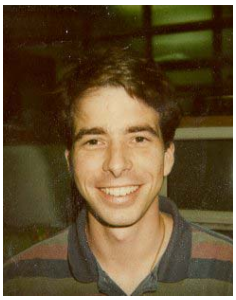
Computer graphics and image processing

- 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

Initiatives

New Member

The QERRAnet Laval group added a new member to their team this year. Dr. Alexandra Branzan-Albu's research interests are computer vision and pattern recognition. She participates actively in projects on medical imaging and medical image analysis, more precisely on the development of automatic segmentation algorithms of liver tumors in MR images and on the 3D reconstruction of the shoulder skeletal complex. She also works on the application of medical imaging to virtual reality and simulation. Additionally Dr. Branzan-Albu leads projects on motion analysis and tracking and on high-level description of motion.

QERRAnet Workshop, November 14, 2003, Québec City

The first Annual QERRAnet Workshop was held on November 14, 2003 at the Musée de la Civilisation in Québec City. Hosted by the Computer Vision and Systems Laboratory of Laval University (CVSL) and the Centre for Intelligent Machines (CIM) of McGill University, this workshop provided the first showcase for the students and researchers to share information on the objectives of QERRAnet and its complementary research interests. About 100 participants, including attendees from NATEQ and industry, listened to technical talks given by both researchers and students. Developmental issues were discussed as part of a parallel session set up for the QERRAnet Advisory Board.

The workshop provided an important framework for the official launching of QERRAnet and set the stage for future initiatives.

Ultra-Videoconferencing Events Linked to QERRAnet

January 26 – 30, 2004: A Workshop entitled *Introduction to Parallel Programming using MPI* was organized by CLUMEQ—a consortium involving Laval/UQAM/McGill and Eastern Québec that provides High Performance Computing to academic institutions.

The QERRAnet team provided technical support, expertise and software to enable the successful bi-directional transmission of this Workshop to QERRAnet members in Laval from its location at McGill. Twenty five participants from McGill (local) and Laval (remote) attended the 5 half-day sessions.

The Workshop's description is as follows: introductory course to parallel programming through the Message-Passing Interface (MPI), a standard library of subroutines (Fortran) or function calls (C) that can be used to implement a message-passing program, found on all parallel supercomputers.

Following this event, at 4:00 pm on January 30, 2004, several QERRAnet members participated in a 45 minute ultra-videoconferencing session from the same location at McGill to discuss issues of relevance to QERRAnet's future development.

This low latency, bi-directional streaming of video and audio technology, developed at the Shared Reality Environment of McGill University, will be utilized for future seminars, workshops and experiments as part of QERRAnet's objective to enhance collaboration between groups.

Innovation

The Laval group participated in two major new CFI grants.

The first, IDAPT, proposes to create an infrastructure to support the development of assistive devices for individuals with disabilities. IDAPT will be unique in the world and will consist of six components: 1) the Challenging Environment Assessment Laboratory (CEAL) will simulate diverse environmental situations and conditions that other simulators are unable to reproduce, 2) the Rapid Prototyping Workshop (RPW) will enable prototypes of new assistive devices to be manufactured with unprecedented speed, function, sophistication, and style, 3) the Stakeholder Rooms (SR) will provide suitable

environments for our researchers to record carefully the expectations and perspectives of consumers and other stakeholders, 4) the Intelligent Environment Laboratory (IEL) will be the first Canadian prototype of a new generation of homes that use vision sensors and artificial intelligence to 'learn' about an individual's movements and functions and to provide self adaptive automated verbal and visual prompting to assist people with cognitive impairments to complete tasks safely, 5) the Physical Function Laboratory (PFL) will provide an increased understanding of the interaction between people and the environment that is needed before new solutions can be designed, 6) the Communicative Function Laboratory (CFL) will focus on the development of new technology to assess and augment communication in natural environments.

IDAPT is led by Dr. Geoff Fernie, VP Research, Toronto Rehabilitation Institute, Professor, University of Toronto and is composed of researchers from the University of Toronto, the University of Waterloo, McGill University, Dalhousie University, the University of Alberta, Laval University, and Simon Fraser University.

The team at Laval University is participating in the IEL and, more precisely, aims at developing computer vision tools for providing home support for elderly people suffering from mild cognitive problems.

The second, MONNET, which stands for "Monitoring of Extended Premises: Tracking Pedestrians Using a Network of Loosely Coupled Cameras," aims at developing a computer vision system for surveillance applications. The most interesting feature of MONNET is that it adopts a serverless architecture and that it implements an adaptive communication strategy between nodes in the surveillance system. A node is comprised of a video camera, an infrared camera, and a processing unit. A node can connect to or disconnect from the system at any time without affecting the overall performance of the system

On the McGill side, Professors Gregory Dudek and Frank Ferrie received support for a new NSERC Strategic Grant, this time under the project name DRMS –Distributed Range Management System.

Objectives: The project deals with the collection, integration and interpretation of sensor data, and particularly range data from a network of spatially distributed sensors. For sensors that are near one another the problem is one of data fusion and interpolation to produce a consistent description of the local environment. For sensors that are located at a further distance from one another, we deal with the problem of interring their relative positions in either a metric or topological framework. Techniques: The project is broken down into a variety of sub-projects which include probabilistic inference using stochastic sampling methods as well as established methods for range data fusion developed in our group over several years. The results are being evaluated in a combination of contexts including a network of small sensors that can be either heterogeneous or homogeneous and which include laser range scanners, stereo vision heads, cameras and other embedded devices.

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., Teneon Software, ART Advanced Research Technologies, Immersion, Coronado Systems Inc and Real-Contact, out of a total of about 20 over the past decade.

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

This company, called SimActive Inc., develops software products for 3D modeling. SimActive is one of only a handful of companies in Canada to receive funding under the Market Development Fund of the National Centres of Excellence GEOIDE program in 2003-2004. This program is intended to assist young entrepreneurs in the development of business strategies and marketing tools to apply effectively in the competitive marketplace.

Funding

The average annual funding to the members from all sources in 2003-2004 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: $.7M/year from various NSERC research grants: $.5M/year from IRIS National Centres of Excellence program; $1.0M/year in NSERC Strategic/Collaborative grants; and $.7K/year from CFI grants.

- PROVINCIAL AGENCIES: $.2M/year from FQRNT, and $ 3K/year from VRQ and other provincial sources.

- Industry: $.3M/year from various sources, such as CAE, Pratt and Whitney Canada Inc. 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. Although in its final year, 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.

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 30 seminars were held on related topics during the past year.

In 2003-2004, the student population of QERRAnet consisted of 82 Master's, 48 PhD's and 5 Postdoctoral Fellows, as well as 1 Visiting Scientist and 6 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.

Scientific Output

Faculty Members	22
Technical Staff	4
Administrative Staff	3
Postdoctoral Fellows	5
Visiting Scientists	1

PhD Students	48
M.Eng. and M.Sc. Students	82
Research Associates / Engineers	6
Visiting Research Students	2
Undergraduate Project Students	31

Refereed Journals	29
Refereed Conferences	76
Book Chapters	6

AWARDS TO FACULTY MEMBERS

Jorge Angeles	Fellow	Royal Society of Canada
	Holder	NSERC Engineering Chair
	James McGill Professor (Mechanical Engineering)	McGill University
Tal Arbel	University Faculty Award	NSERC
Benoit Boulet	William Dawson Scholar	McGill
	Best Presentation: An LMI Approach to IMC-Based Tunable Control	American Control Conference, June 2003, Denver, CO
	Best Poster of Conference: Interior Noise Environment of Future Automobiles	AUTO21-NSE, Niagara-on-the-Lake, ON June 2003
Alexandra Branzan-Albu	University Faculty Award	NSERC
Peter Caines	James McGill Professor	McGill
	Fellow	Royal Society of Canada
Clément Gosselin	Mechanical Engineering Canada Research Chair in Robotics and Mechatronics	Government of Canada/NSERC/CFI
Vincent Hayward	Keynote Speaker	Eurohaptics, Munich, Germany, June 2004
	Outstanding Reviewer	Journal of the Int'l Federation of Automatic Control 2003
Michael Langer	Best Paper: Estimating Camera Motion Through a 3D Cluttered Scene. R. Mann and M.S. Langer	1st Canadian Conference on Computer and Robot Vision, CIPPRS, London, ON. May 2003
Denis Laurendeau	Elected: Secretary	International Association for Pattern Recognition (IAPR)
	Award for Outstanding Services to IAPR for the Organization of the ICPR 2002 (International Conference on Pattern Recognition) Conference in Quebec City	IAPR
	Appointed as the Technical Program Co-Chair for the ICPR 2008 Conference	IAPR

Xavier Maldague	Canada Research Chair: MiViM: Multipolar Infrared Vision - Vision Infrarouge Multi-polaire	Government of Canada/NSERC/CFI
	J.J. Archambeault Eastern Canada Council Merit Award with the following citation: "for dedication to IEEE and engineering progress."	IEEE
	"Major Event Ambassador Award" for having attracted the IEEE OCEAN 2008 in Quebec City	Quebec City Congress Center
Kaleem Siddiqi	FCAR programme stratégique de professeurs-chercheurs	FQRNT/NATEQ

AWARDS TO STUDENTS

Marc Bédard	Postgraduate Scholarship A	NSERC
Hanifa Dostmohamed	Scholarship	Precarn
Stéphane Drouin	Postgraduate Scholarship A	NSERC
	Bourse de doctorat en recherche	FQRNT
Nicolas Dubé	Bourse doctorat	Hydro-Québec
Christian Gagné	Postgraduate Scholarship A	NSERC
	Bourse de doctorat en recherche	FQRNT
Melita Hadzagic	Award	IPS-NSERC
Philippe Lambert	Bourse de Maîtrise en recherche	FQRNT
Valérie Lavigne	Bourse de Maîtrise en recherche	FQRNT
Vincent Lévesque	PGS – B Scholarship	NSERC
	B2 – Scholarship	FQRNT
	Scholarship	Precarn
Jean-Nicolas Ouellet	Bourse Guglielmo Marconi 2003	Gouvernement de l'Italie
Jérôme Pasquero	Scholarship	IRIS/Precarn
Ioannis Poulakakis	Tomlinson Award	McGill
Régis Poulin	Postgraduate Scholarship A	NSERC
Sébastien Quirion	Bourse de Maîtrise en recherche	FQRNT
	Récipiendaire de la mention Rouge & Or, volet académique Baccalauréat en Informatique Promotion 2003	Laval
Alessio Salerno	Major Fellowship	Hydro-Quebec/McGill
Dragan Tubic	Bourse de doctorat en recherche	FQRNT

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

SEGMENTATION DE SÉQUENCES VIDÉO DE SCÈNE STATIQUES POUR LA RECHERCHE D'INFORMATIONS VISUELLES

Mehran Yazdi, André Zaccarin

Ce projet présente un système intégré permettant la segmentation d'une scène statique en objets à partir de multiples prises de vues (fragments) de cette scène, acquises de différents points de vue. Le résultat de cette segmentation est une décomposition hiérarchique de la séquence vidéo en fragments, régions et objets. Nos efforts se sont concentrés sur l'étude et le développement d'algorithmes de segmentation de séquences en fragments, de segmentation d'images en régions, de regroupement des régions en objets et de l'appariement des régions dans et entre fragments. Pour ce faire, les vecteurs de mouvement de blocs de pixels, les caractéristiques chromatiques des images selon les composants HS, et deux caractéristiques physiques (rapport de réflectivité et profil d'intensité) obtenus à partir de l'information d'intensité des images (composante V de l'espace HSV) seront utilisés. Ce système permet d'identifier les objets dans la scène (en présence d'occultation), de déterminer la liste des trames dans lesquelles ces régions et objets sont présents (malgré leur apparence différente) et d'arriver à la segmentation robuste des images en objets.

L'identification d'un objet/région dans des scènes vidéo capturées sous différents angles peut être utilisée dans des applications de recherche ou d'identification à partir de bases de données vidéo, ou comme support à des travaux de modélisation 3D à partir de séquences 2D.

SYSTÈME D'IDENTIFICATION DE PERSONNES PAR VISION NUMÉRIQUE

Alexandre Lemieux, Marc Parizeau

Ces travaux de recherche présentent l'intégration complète d'un système d'identification de personnes par vision numérique. Conçu pour opérer dans un contexte de surveillance, le système a pour tâche d'identifier les personnes circulant dans une zone d'intérêt, et ce, à partir des informations contenues dans une base de données préalablement construite. Les techniques de reconnaissance sélectionnées utilisent uniquement le visage comme caractéristique discriminante. Le système réalise par ailleurs l'identification en quatre phases principales, soient l'acquisition, la détection du mouvement, la détection des visages et l'identification des personnes. Les images couleurs, acquises à l'aide d'une caméra web abordable, sont prétraitées par un algorithme de soustraction de l'arrière-plan et soumises à une méthode hybride de détection du visage. Les résultats obtenus sont ensuite acheminés à un module de reconnaissance multi-classifieurs utilisant des notions de patrons de design orientés-objets. Ceux-ci permettent entre autres une gestion efficace des classifieurs ainsi qu'une simplification du processus d'expérimentation des différentes combinaisons et des fonctions de décision. Finalement, la validation des techniques sélectionnées est réalisée à l'aide des banques d'images FERET et AR-face contenant respectivement les photos de 1196 et 135 individus. Les configurations multi-classifieurs procurent des améliorations substantielles du taux de reconnaissance par rapport aux classifieurs individuels notamment dans le cas de la FERET.

SEGMENTATION ET SUIVI SEMI-AUTOMATIQUES D'OBJETS: NOUVEAU CADRE DE TRAVAIL ET APPLICATIONS

Luc Martel, André Zaccarin

Le présent travail propose une nouvelle méthode générique de segmentation en objets. La méthode tente de séparer la complexité de la tâche en deux étapes. La première étape étant une segmentation en régions uniformes utilisant des modèles de Markov et la deuxième étant un ensemble d'opérations performées sur les régions uniformes provenant des premières segmentations, le tout présenté à l'intérieur d'un formalisme rigide décrivant les règles de regroupement et de division ainsi que l'algorithme utilisé pour séquencer l'application de celles-ci.

La thèse propose aussi une analyse de l'homogénéité d'une image et introduit différentes mesures d'homogénéité. Elle présente une méthode de minimisation utilisant cette mesure d'homogénéité pour déduire les conditions initiales de segmentation. Il est expliqué que cette méthode tente à stabiliser les paramètres de la fonction d'énergie à minimiser et ce dès le début du processus de segmentation. De plus cette méthode ne requiert aucun estimé à priori sur le nombre de régions contenu dans la scène.

Utilisant cette méthode, deux algorithmes de segmentation en régions sont proposés: un algorithme de segmentation d'intensité et un algorithme de segmentation de mouvement. De plus l'algorithme de segmentation de mouvement diffère des méthodes présentées jusqu'ici par la façon dont il calcule et met à jour les paramètres de la fonction d'énergie.

Les résultats des deux algorithmes sont par la suite utilisés comme entrées de l'algorithme de haut niveau. Dans ces travaux, quatre règles simples de regroupement sont présentées ainsi qu'une règle de division. Toutes ces règles sont définies en utilisant le nouveau formalisme présenté.

Les résultats démontrent que les scènes peuvent être bien segmentées en objets utilisant des règles très simples. Les résultats laissent aussi croire que la puissance du formalisme présenté repose aussi dans sa capacité à pouvoir s'adapter à différentes scènes.

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

Development of software tools: 1. Develop a C++ EA framework that is versatile, easy to use and robust. 2. Develop tools to efficiently distribute evolutions on several CPU. 3. Develop graphical tools to visualize and analyze evolution results.

Application to hard problems: 1. Demonstrate applicability of EA, particularly genetic programming, to the solving of hard problems. 2. Using EA to solve hard problems of pattern recognition. 3. Using EA to solve hard problems of optical design.

Evolutionary re-engineering: 1. Develop generic methods of re-engineering with EA. 2. Understand and analyze the generic methods developed for re-engineering. 3. Apply re-engineering methods to hard problems.

Expected results: 1. Generic, robust, and distributed software infrastructure of EA, used in the scientific community. 2. Solving hard problems of pattern recognition and optical design with EA. 3. Development of generic methods allowing an efficient evolutionary re-engineering of existing solutions.

ENGINEERING AND QUANTIFICATION OF A PARALLEL AND DISTRIBUTED MASTER/SLAVE SYSTEM 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.

ADDITION OF A VIDEO QUALITY EVALUATION MODULE TO AN MPEG ENCODER

Sébastien Lafontaine, André Zaccarin, Thierry Eude

Problem: Video compression algorithms have become very common these days. Videos on internet, DVDs as well as game kinematics widely use well documented techniques. However, there are very few tools available for measuring the quality of a video sequence produced by an encoder. These tools are used on encoded sequences. If there were a way to control an encoder with an algorithm evaluating the quality of a video sequence, then the encoder could generate a high quality video sequence with maximum compression.

Motivation: DVD, Internet, game kinematics, home video, etc.

Approach: The approach used aims to attach a video quality evaluation module to an encoder to enable the latter to vary the compression ratio to be used.

Challenges: This type of program is very rare. The main challenges involve the difficulty of evaluating the quality of a video sequence as well as performing modifications directly within a video encoder.

Applications: DVD, Internet, game kinematics, home video, etc.

Expected results: The expected result is a compressed video sequence whose quality is such that if a lower rate of compression had been used, the human eye could not detect any loss of quality in the video sequence.

MAESTRO, UNE ARCHITECTURE DE CALCUL DISTRIBUÉ GÉNÉRIQUE À ALLOCATION DYNAMIQUE

Nicolas Dubé, Marc Parizeau

Problème: En milieu académique et corporatif, les besoins toujours grandissants en puissance informatique alimentent et poussent vivement le champ de recherche des systèmes distribués. Il faut donc trouver des mécanismes et des algorithmes qui nous permettront d'opérer un changement de paradigme vers un super-calculateur réparti.

Motivation: À l'heure actuelle, l'approche la plus courante vers la course au TeraFlops est l'achat de gigantesques fermes d'ordinateurs à des coûts faramineux. La plupart de ces super-calculateurs étant financés par des fonds publics, les organismes subventionnaires souhaitent voir un partage entre les ressources de calcul des différentes entités de recherche. Malheureusement, ce partage suppose une gestion des comptes usagers, des permissions et de la sécurité qui rendent la chose peu courante en pratique. Parallèlement, de nombreux ordinateurs de bureau pourraient être reliés à un super-calculateur externe si on pouvait garantir au propriétaire la sécurité de son environnement et la validité des tâches qui y seraient calculées. On a donc 2 contextes à prime à bord différents, mais avec le même problème de confiance. Il faut donc trouver un mécanisme de gestion de la confiance qui pourrait s'installer sur la couche supérieure à celle des comptes usagers des différentes fermes et ordinateurs. Ce premier axe de recherche vise donc à utiliser des mécanismes d'authentification et d'encryption connus (SSL, RSA, AES, etc.) pour les appliquer à un meta-ordonnanceur de calcul distribué, une percée qui pourrait donner aux centres de recherche aujourd'hui déconnectés, un super-calculateur à l'échelle nationale.
L'ordonnancement de processus est une science qui ne date pas d'hier et de nombreux travaux ont été réalisés afin de modéliser le comportement d'un ordinateur à un ou plusieurs processeurs. Dans le domaine du calcul distribué, on a passablement modélisé le comportement de réseaux fortement couplés aux latences et bandes passantes prévisibles. Qu'en est-il quand on relie ensemble quelques fermes d'ordinateurs distantes de centaines de kilomètres? Quel serait l'ordonnancement idéal sur un tel système très hétérogène? Ce second axe de recherche vise à paramétrer les facteurs influents pour ensuite développer un ordonnanceur adapté.

Applications: Nombreuses sont les applications pouvant tirer profit du calcul distribué, nous nous concentrerons à prime abord sur des problématiques reliées à la programmation génétique et à la reconnaissance des formes.

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FAST ACTIVE OBJECT RECOGNITION IN AN UNCERTAIN AND OPEN WORLD

Tal Arbel, Catherine Laporte

Problem: Automatically optimizing observation parameters for the task of multiple view object recognition and learning.

Motivation: In applications such as mobile robot navigation and image-guided surgery, it is useful to have the ability to automatically recognize visual structures in the world. The object recognition problem involves identifying objects as instances of a database of known objects based on acquired sensor data. Because most recognition approaches to the problem are based on single observations, they often fail to disambiguate objects which appear similar to one another in certain points of view. A multi-view strategy that accumulates evidence over time and actively makes decisions as to how to adjust the sensor parameters can help tremendously in resolving those ambiguities. In many contexts, it is also desirable to have the ability to determine whether a structure currently being observed is new to the recognition system, learn about previously unseen objects and add them to the database.

Approach: Recently, we have developed an active object recognition strategy that allows the identity and pose of objects to be estimated accurately by acquiring multiple observations of the world from different points of view and combining the evidence in a probabilistic fashion. A viewpoint selection process was developed that guides the camera towards viewpoints which facilitate distinction between pairs of competing hypotheses. This decision making process was shown to be computationally efficient relative to popular strategies presented in the literature, making it useful in contexts where both time and observations are expensive. We hope to extend this active vision method to the problem of detecting objets that are not part of the system's knowledge database.

Challenges: Object recognition is an inverse problem and as such, it is fundamentally ill-posed. In particular, because of the loss of information inherent in the measurement process, different objects may yield identical or similar sensor measurements, and the measurements themselves may be corrupted by various forms of noise. The problem of actively optimising the sensor parameters is also challenging as it typically involves a trade-off between the number of measurements required to converge to a final assessment and the amount of time required for decision making.

Applications: The framework was shown to provide an efficient and accurate means of performing object recognition in a constrained environment, and hence is readily applicable to an industrial inspection context. Other potential applications arise in medical imaging, where an important problem is the identification of brain structures. Using the proposed active vision strategy, one could automatically determine where to move an ultrasound sensor in order to best identify a brain structure of interest, depending on some prior anatomical information.

DETERMINING OPTIMAL MODELS FOR PROBABILISTIC IMAGE CORRESPONDENCE

Tal Arbel, Matthew Toews, Frank Riggi

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: To date, we have developed a technique of feature point selection that uses information theory to automatically select optimal points for probabilistic image correspondence, and have validated the technique both in terms of correspondence quality and the processing speed. Different feature points are selected based on the image similarity measure used for correspondence and the set of images to be matched. We envision extending our results 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 illposed, 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. 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. We have obtained promising results for multi-modal MRI matching, where traditional methods of feature point selection tend to fail. Furthermore, we are applying our approach to multi-scale image correspondence, in order to select the optimal feature point scale in addition to location. 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, Rupert Brooks, D.L. Collins

Problem: Image-Guided Surgery of the Brain and Spine - where to best acquire images?

Motivation: Surgeons often rely upon pre-operative images, such as patient MRI or CT, in order to identify and locate tissues of interest during surgical procedures. However, patients are flexible, and movements of tissue during the operation reduce the effectiveness of the preoperative plan. For this reason, surgeons often make use of intra-operative images (e.g. ultrasound images) in order to estimate the position of interesting structures during the procedure. Specifically, we are interested in positioning of the lumbar vertebrae during pedicle screw placement and in tracking the movements of brain tissue during craniotomies (i.e. open brain operations).

Clearly, 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 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 or CT in order to determine the position of the lumbar vertebrae during pedicle screw placement. This application lends itself well to development as there are existing techniques which are accurate but slow that can provide a "gold standard" for comparison. The method will be extended to 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.

VIRTUAL BRAILLE DISPLAY

Jérôme Pasquero, Vincent Lévesque, Vincent Hayward

Problem: Eighty characters of computer driven Braille display typically exceed the cost of more than 10 personal computers.

Motivation: Open unexplored frontier in achieving an alternative solution for the electronic display of Braille and create new access to vision-based print data.

Approach: When a progressive wave of localized deformations occurs tangentially on the fingerpad skin, one typically experiences the illusion of a small object sliding on it. This has potential application to the display of Braille. A device was constructed that could produce such deformation patterns along a line. This enabled us to test blind subjects' ability to read the truncated Braille characters ' ', '4', 'a', and 'c'. While subjects could identify two-character strings with a high rate of success, several factors need to be addressed before a display based on this principle can become practical.

Challenges: Achieve similar reading rate as with real Braille. Display graphic data for the blind.

Applications: Leveling the playing field in Braille literacy for the blind in Canada, and the world.

HIGH FIDELITY RENDERING OF HAPTIC TEXTURES

Gianni Campion and Vincent Hayward

Problem: Haptic device's performance is rarely specified in a meaningful manner. For example, we found that the highest performing devices known to date were unable to render such basic signals as a 1 mm periodic grating. This is due to fundamental limitations due to space and time sampling combined with noise amplification in the closed loop.

Motivation: To date, this problem has been universally ignored.

Approach: Identify system's signal transfer properties. Identify critical operating regions. Introduce and design proper noise-suppressing filters in the rendering loop which act outside the critical operating regions.

Challenges: No ready-made existing theory seems to exist for this particular problem.

Applications: All high-fidelity haptic simulators concerned with rendering the texture of materials. Scientific study of touch where the stimulus has to be accurately specified.

FINITE ELEMENT ANALYSIS OF GLABROUS SKIN

Andrew H. Gosline and Vincent Hayward

Problem: Human touch is mediated by a variety of receptors located in the skin. The glabrous skin, in particular, is innervated in a highly organized fashion which is thought to play a role in the manner in which touch signals are transduced.

Motivation: Existing simulations have ignored both the geometry and the nonlinear characteristics of tissues.

Approach: Perform dynamics finite element analysis of the finger pad sufficiently accurately to account for the detailed geometry of the ridges and subcutaneous papillary ridges.

Challenges: Find meaningful approximations of the microgeometry of the skin and of the materials properties. Set up of a simulation.

Applications: Optimal design of tactile displays and scientific study of touch.

HAPTIC DISPLAY OF SHAPE BY CONTACT LOCATION TRAJECTORY

Hanifa Dostmohamed and Vincent Hayward

Problem: Almost all existing haptic interfaces to date rely on the notion of force feedback which implicitly imply the existence of a "virtual tool". However many "haptic tasks" rely on the fact the fingertip directly interacts with an object but no device exists that can account for this.

Motivation: Create a new class of haptic devices which do not assume the existence of a tool between the subject and the object being touched.

Approach: Haptic curvature perception can result solely from the trajectory of the deformed region of the fingertip due to contact with an object during tactile exploration. To test this, we built a servo controlled 2-degree-of-freedom spherical mechanism which operates by rolling a flat plate on the fingertip during the exploration of a virtual surface. We found that subjects were able to perform curvature discrimination at levels comparable to those achieved when using direct manual contact with real objects, and that the highly simplified stimulus provided was able to give the illusion of touching three dimensional surfaces.

Challenges: Extend this concept to other perceptual dimensions.

Applications: Surgical trainers. Three dimensional data set display.

AUGMENTED SURGICAL TOOLS

Hsin-Yun Yao, Vincent Hayward, Randy E. Ellis (Queen's University)

Problem: Robotic and VR technologies often lead to complicated systems which can delay their introduction into practice.

Motivation: Design a low-cost hand-held device that can record, replay, and amplify tactile signals during arthroscopy.

Approach: The MicroTactus detect signals arising from the interaction of a tip with soft or hard objects and magnifies them for haptic and auditory reproduction. An enhanced arthroscopic surgical probe was built and tested in detecting surface defects of a cartilage-like material. We found that both haptic and auditory feedback significantly improved detection performance, which

demonstrated that an enhanced arthroscopic probe provided useful information for the detection of damage in tissue-like materials.

Challenges: The system operates in a feedback mode and is subject to lock into limit cycles due to the nonlinearity of the process. The challenge is to quench those limit cycles while preserving the amplification properties.

Applications: Minimally invasive procedures and dentistry.

INTERACTIVE EDITING OF SPACE TRAJECTORIES

Diana Garroway, Vincent Hayward (In collaboration with MPBT Inc. and SoftImage Inc.)

Problem: Animators working with 3D models and data typically are still bound to 2D interaction.

Approach: We suggest a new multimodal interface for editing 3D motion data using a haptic device. In the basic mode, the haptic device guides the hand of the user along a trajectory that was previously recorded or specified. Any sign cant deviation from the initial trajectory instantly results in permanent (i.e. plastic) changes made to this trajectory. This interface provides a simple, intuitive method for the user to actually experience movement other than visually for purposes of creation.

Challenges: Interfacing this technique with existing animator software.

Applications: Creation of animated graphics, cartoons, and so-on.

NEW TECHNIQUES FOR THE CONTROLLED STIMULATION OF THE SKIN

Qi Wang, Vincent Hayward, Allan M. Smith (Université de Montréal)

Problem: Traditional methods of skin stimulation for psychophysical, neurophysiologic studies and other investigations involve the use of indentation. Yet indentation rarely occurs during normal tactile interaction with objects.

Approach: We designed an apparatus intended to cause skin tangential deformation in a controlled manner, which is motivated by much recent evidence suggesting that such stimulation is both behaviorally and physiologically relevant. We designed the lateral skin stimulator to have a programmable mechanical impedance. This enables us to test the response of the skin neurophysiologically, mechanically, behaviorally and with a wide range of conditions.

Challenges: Perform the measurement with the required resolution something which is difficult when dealing with living tissues.

Applications: Design of optimized tactile displays and scientific study of touch.

REGION OF INTEREST CODING

Jeremy Cooperstock, Stephen Spackman

Transmission of the entire data content of a video stream does not take into account the potentially diverse interests or capabilities of heterogeneous clients nor the relative importance of different components of the scene. Attempts to date to address the former concern appear limited to the sole factor of varying bandwidth capability, for example, the scalable bitstreams of H.26x and MPEG audio and video codecs. A base layer provides a minimal quality representation of the entire signal, and clients may optionally receive supplemental layers that provide added quality, uniformly distributed over the image. This seems to be a reasonable starting point, but it offers the clients only passive control over the quality of the reconstructed signal without any ability to specify

regions or content of greater interest or importance.

This point has been addressed in part by the content description scheme of MPEG-7, but this is aimed primarily at describing content, rather than permitting control over the quality at which different portions of the scene are transmitted or rendered. A more apt example of client-based control over the allocation of data to such content is the User-Centered Video of Yamaashi.

In Yamaashi's case, the system allowed the client to allocate bandwidth as desired over multiple parallel streams or within a particular region of a single stream, as appropriate to the interests of the client. Assuming operation on a multicast network, the challenge here is to ensure that individual client requests are balanced against overall system constraints, such as total available server bandwidth and limit of multicast channels. Our long-term goal is for such region selection to be automated with the assistance of intelligent agents, possibly given some hints from the user, for example, "I'm interested in this person's face" or "follow that object."

HAND GESTURE DETECTION

Jeremy Cooperstock, Siu Chi Chan

In augmented reality environments, traditional input interfaces such as the keyboard-mouse combination are no longer adequate. We turn, instead, to gestural language, long an important component of human interaction. In earlier hand gesture systems, hand tracking and pose recognition are achieved with the assistance of specialized devices (e.g., data glove, markers, etc.).

Although these provide accurate tracking and shape information, they are too cumbersome for use over extended periods. We are researching more suitable alternative by employing computer vision techniques to perform hand tracking and gesture recognition, assuming, for our prototype, that there exists a video camera with a reasonable view of the user's palm.

Our first attempt to solve the hand location problem employed skin-color segmentation on the video frames, taking the largest blob as the hand region. While simple to implement, this algorithm was entirely dependant on stable lighting and unsuitable for most augmented reality environments. Our more recent approach employs edge detection for foreground segmentation and tracks the wrist location with a particle filter. The initial results from this wrist tracker are highly promising.

Based on the wrist location and orientation, we then determine the positions of the fingertips, exploiting their semi-circular shape by modelling the fingertip extremities as a circular arc. The fingertips can be located by looking for maximal responses of a circular Hough transform, applied to the hand boundary image, followed by several heuristic tests to filter out false positives and duplicate detection.

MULTI-OBJECT TRACKING

Jeremy Cooperstock, François Cayouette

We are developing a generic object tracker capable of following, in real-time, multiple objects in a dynamic, real-world, possibly cluttered environment, in which lighting levels can change dramatically, for example, a classroom where the instructor walks in front of a projection screen. Our tracker uses a combination of movement detection and feature extraction to locate and maintain objects within the camera's field of view. A final step matches the various features found in the current image with the objects previously identified by the system.

When a new frame is acquired, motion detection is performed by image differencing, that is, subtracting the contents of the previous frame. As this is done in order to increase the regions of currently tracked objects and to identify new objects of interest, the differencing is only performed on regions that did not previously

contain tracked objects. When movement between successive frames, appearing in the difference image as blobs, is detected close to previously found objects, the region from which extracted features are obtained is increased, whereas isolated blobs indicate new regions where an object could be recognized. If no objects are currently being tracked, the motion detection step is skipped and instead, feature extraction is performed over the entire image.

For each region deemed interesting by the motion detection step, a feature extraction phase, currently employing Canny edge detection, is used to segment objects from the background, while a simple statistical sampling process is performed in parallel. The statistics extracted from each region are later used to help match features with those of previously tracked objects. Since we expect these objects to differ from the background, edges are good markers to identify the outer bounds and inner features, and we use an aggregation of such edges to construct a tentative representation of each object. Short edges, typically symptomatic of noise, are discarded.

The matching process uses the locations and statistics to recognize which aggregate best matches a previously seen object. However, since the Canny Edge detection process is imperfect, the recognition process occasionally separates an object into two aggregates if an edge is incorrectly identified. Occlusion poses a further problem, in particular when tracking multiple objects. To provide continuity in the event of a future disocclusion, the matching process maintains labels of merged objects, including feature extraction and velocity statistics.

As desired, our tracker is relatively insensitive to varying lighting conditions, easily coping with gradual or abrupt changes. These are perceived as movement within the scene, resulting in additional processing as the algorithm attempts to identify meaningful features. Thus, we may experience a slight performance degradation for one or two frames, provided that the illumination level does not saturate the camera, but the algorithm is able to maintain the objects previously being tracked.

The tracker is presently constrained to relatively static backgrounds, as a background map is first generated to identify those edges that are ignored in future processing. Our ongoing work intends to adapt to varying backgrounds in order to remove this constraint.

IMPROVED GROUP INTERACTION THROUGH REMOTE COMMUNICATION

Jeremy Cooperstock, Stephen Spackman

Although computation in the form of audio and video codecs has long been employed to lower the bandwidth requirements for videoconference communication, we argue that this approach is fundamentally unsuitable for the purpose of fostering improved social dynamics in group dialogue and a greater sense of belonging. The reason is simple: while compression substantially reduces the bandwidth required to transmit an acceptable representation of the signal, doing so does not improve the quality of communication, rather it introduces excessive latency, anathema in most settings to effective human interaction.

We suggest that given sufficient bandwidth, computational power should instead be devoted to active mediation of the communication channel, as required, for example, to support acoustic echo suppression, gaze awareness, high-resolution synthesis of life-size displays, and spatialized audio rendering. Audio or video encoding, if employed, should be concerned more with issues of tolerance of data loss and scalable data representations suitable for multicasting to a pool of heterogeneous clients. In the latter case, these representations should allow for the balancing of conflicting demands of optimal immersive quality, minimal latency and maximal reliability.

We explore these issues in the context of several distributed interactive applications in which we have been engaged, in particular, music teaching and distance performance. From the perspective of both sensory acuity and sensitivity to timing, these are perhaps two of the most demanding, and therefore, of greatest interest for study.

GESTURE-BASED VIRTUAL INTERACTION

Jeremy Cooperstock, Mike Wozniewski

When designing new interaction techniques for technical or artistic computing applications, the incredible skill and versatility built into human hands must be considered. There is a specific structure to interacting with two hands, with each hand having preferences for certain tasks. These bimanual properties can offer constraints for the design process and can also be exploited to make the interaction as natural and effective as possible. The Shared Reality Environment provides an excellent framework to examine new metaphors and paradigms for gesture-based interaction. The immersive nature urges users to employ natural two-handed interaction as there is no keyboard or mouse available.

The acquisition of a hand model for describing the pose of a human hand is necessary to recognize gestural symbols, emblems, and other primitives performed by changing the shape of the hand. Although video-based methods are being explored, they typically do not yield a sufficiently accurate representation, and as such, we conducted an initial investigation with sensor-infused gloves.

For localizing the position of each hand in space, we employ purely video-based tracking. This is a design goal that we have set for ourselves, which allows a user to instantly control aspects of the system without needing to don any extra input devices. We call this the "walk-in-and-use" requirement. The interaction will be simple, using only diectic (pointing) types of gestures.

For such untethered, walk-in-and-use interaction, we employ a generic menu-like paradigm. The user interacts with the system with gestures, but those gestures control gestural widgets which in turn have a resulting effect in the application. This allows for rich interaction with a simple gesture set that is easy to track and recognize.

CONCEPTUAL ASPECTS OF GENERIC INTERACTION PARADIGMS IN A LARGE SCREEN ENVIRONMENT

Jeremy Cooperstock, François Rioux, Mike Wozniewski, Frank Rudzicz

Virtual interaction metaphors for two-handed control have been studied in the past primarily in terms of speed and efficiency, and in this paper we concentrate our analysis on the cognitive effects such metaphors have on users within a large screen environment. Specifically, based on a series of experiments we draw conclusions as to how best to manage the division of labour between hands in order to minimize conceptual error. Empirical evidence suggests that the proficiency of bimanual paradigms, such as toolglasses or pieglasses, varies according to a number of factors, for instance the amount of effort required by the non-preferred hand. Finally, we discuss the applicability of the various studied paradigms in terms of the type and location of the tasks performed. This work leads to a better understanding of the cognitive aspects of various interaction paradigms, and provides results that may be used to improve the design of interaction schemes

ALGORITHMS FOR HYBRID SYSTEMS COMPUTATION AND CONTROL: FROM EXPONENTIAL TO QUADRATIC COMPLEXITY

M. Shahid Shaikh, Peter E. Caines

Problem and Motivation: We study hybrid optimal control problems (HOCPs) and propose efficient computational algorithms for their solution. Hybrid systems possess continuous and discrete components and system evolution occurs in both continuous and discrete time. A brute-force hybrid optimization results in geometric computational complexity (i.e. $O(|Q|^L)$), where Q denotes the discrete state set of the hybrid system and L is the number of switching times; this is

mainly due to the search for optimal discrete state sequences. Hence efficient computational algorithms are required to solve medium to large scale HOCPs.

Approach: In our previous work we derived a set of necessary conditions for HOCPs which constitutes a general Hybrid Maximum Principle (HMP); based upon this, we constructed a class of efficient Hybrid Maximum Principle (HMP) algorithms and established their convergence. We next introduced the notion of optimality zones (OZs) as a theoretical framework enabling the computation of optimal schedules (i.e. discrete state sequences with the associated switching times and states) for HOCPs and presented the algorithm HMPZ which fully integrates the prior computation of the OZs into the HMP algorithms. Including the computational investment in the construction of the optimality zones for a given HOCP, the computational complexity of the optimal schedule, optimal switching time-state sequence and optimal continuous control input algorithm (HMPZ) is quadratic (i.e. $O(L^2)$) in the number of switching times L; this is to be compared with the geometric (i.e. $O(|Q|^L)$) growth of a direct combinatoric search over the set of schedules.

Challenges: Key challenges are reduction in the set-up computational cost and the application of algebraic geometry to study the properties of OZs.

Applications: When fully developed this methodology and algorithms will have application in many economically important industrial areas, for example, chemical process control.

SEMANTIC FEEDBACK FOR A RECOMMENDER SYSTEM WITH EXPLANATIONS MOVIE RECOMMENDER SYSTEM

Matt Garden, Gregory Dudek

Problem: Collaborative filtering is a method for search in which similar users are identified and items are recommended based on the preferences of those similar users, rather than matching an explicit user search query to the content of the data ("content-based filtering"). The more general term "recommender system" refers to a search system which uses a method such as collaborative filtering, often in conjunction with a traditional method such as content-based filtering.

Motivation: Several authors have stressed that in addition to increasing the accuracy of recommender systems, it is important to increase user trust as well. An accurate system will be useless if no one wants to use it or does not believe its predictions. We believe that having knowledge of the reasoning behind preferences we will be better able to predict future preferences, and be better able to justify the predictions at the same time.

Approach: Many approaches seek to find hidden variables in the ratings of items which "explain" patterns in rating; however, methods which are able to find these variables generally appear as black boxes to the users of the system, and do not inspire confidence. In our approach the users provide information about the hidden variables directly by giving feedback on the reasons behind their preferences, providing descriptions of the items in our system in the process. We use this extra information to gain a better understanding of the similarities and differences among users, which allows for more accurate recommendations, with a good understanding of why the system is making those recommendations. The combination of accuracy and good explanations should inspire user confidence.

Challenges: Learning preferences is very difficult because the data is very subjective. It is also common for the domains used in recommender systems to contain very large numbers of items, which means any user will only have provided feedback on a small subset of these. The end result is data which is extremely sparse and noisy. This makes it hard to find functions which predict preference, and hard to determine the similarity between users.

Applications: Our system is currently applied to the domain of movies with the objective of providing recommendations of movies through a website interface. However our system is not limited to a particular domain and future plans include expanding our system to domains such as images, books, and anything else we can think of,

but especially domains in which content-based filtering is currently not possible due to the difficulty of automatically extracting features. Our approach likely has applications in related areas such as personalization, where more feedback from the user could potentially be useful in customizing various interfaces.

A MACHINE LEARNING FRAMEWORK FOR THE CLASSIFICATION AND REFINEMENT OF HAND DRAWN CURVES

Saul Simhon, Gregory Dudek

Problem: We are examining the problem of classifying and refining pen based inputs under different contexts. This problem is integral in our efforts for developing a "smart interface" that automatically identifies user intentions from rudimentary or incomplete inputs. We are investigating a system that can learn from examples both how users draw curves and what they "really mean" when they draw those curves. We are also examining how this learned knowledge can be used in order to classify and fill in the details that are missing from the users rudimentary input.

Motivation: Gesture based interfaces provide users with a natural method of interacting with computer systems. In particular, pen based systems such as tablet PC's or electronic whiteboards are becoming popular tools for users with different degrees of expertise. While such systems may soon become common HCI devices, the research dealing with processing and analyzing pen strokes is still in its infancy. Further, most of the existing systems that have been developed use specialized constraints that are both specific to a particular domain or require trained users. This research is aimed at developing a machine learning framework for solving problems in this domain.

Approach: Our approach is based on statistical analysis of a set of examples that show the desired curves and how users would actually draw them. Using a Hidden Markov Model (HMM, a two layer probabilistic model) and a wavelet representation of curves, our system learns multi-scale constraints on curves belonging in a particular context (or class). When the user draws a curve, the system classifies and refines it by applying well known HMM Evaluation and Decoding algorithms. Further, the system is generalized by extending the dimensions of the state space, allowing it to simultaneously learn multiple curves or multiple curve attributes such as color, thickness, pen-pressure or speed.

Challenges: Some of the key challenges in this work include the development of a learning framework that can be combined with specialized constraints. This was complicated by the need to accommodate for both multi-scale and multi-dimensional constraints that needed to be propagated over the entire input curve. For this, a regularization framework was used to solve for maximum likelihood solutions that considered both criteria over the entire curve. Another challenge was the efficient implementation and evaluation of our system. Various approaches were taken in order to provide for a practical implementation and empirical evaluation of results.

Applications: Because the system learns from examples, there are no application specific constraints. This allows us to apply the system to a wide array of domains where curves play an integral part. This includes robot path planning and control, artistic drawings, sketch to prototype systems, motion in animation as well as edge de-blurring. Further, since the system is, in theory, extendable to arbitrary dimensions, we can learn supplementary curve attribute or provide control of systems with high degrees of freedom.

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

SEGMENTATION DE BAS NIVEAU ET SUIVI DE PERSONNES À L'AIDE D'UN RÉSEAU DE CAMÉRAS INDÉPENDANTES

Nicolas Martel-Brisson, André Zaccarin

Problème: La détection et le suivi de personnes dans des environnements intérieurs et extérieurs a été l'objet de travaux et de nombreuses publications pour une multitude d'applications. La complexité de la tâche dépend de plusieurs facteurs dont le type d'arrière plan (fixe, mobile, évolutif...), la qualité de la segmentation désirée (avec ou sans ombre, seulement visage…) et la complexité de la cible à suivre (contraste avec l'arrière fond, immobile, plusieurs personnes…).

Motivation: L'automatisation du domaine de la surveillance vidéo est intrinsèquement liée à la capacité de repérer des cibles présentes dans l'image. Dans le cadre du projet MONNET - (Monitoring of Extended Premises: Tracking Pedestrians Using a Network of Loosely Coupled Cameras), nous désirons segmenter les gens de l'arrière-fond, les suivre d'un champ de vue à l'autre et analyser leurs mouvements à l'aide d'un réseau de caméras où chaque unité d'acquisition et de traitement est indépendant. Cette indépendance permet de transférer le minimum d'information entre les nœuds de traitement. La segmentation des personnes est l'étape initiale à une multitude d'algorithme et d'analyse de mouvements et de tracking.

Approche: Afin de segmenter adéquatement les silhouettes présentes dans le champ de vue de la caméra, nous modélisons l'arrière-plan avec une somme de distributions gaussiennes. À ce modèle statistique, nous voulons y jumeler un estimateur de mouvement basé sur l'association de bloc « block matching ». Cet estimateur permettrait un traitement spatial de la segmentation, déficient à la modélisation statistique. Ensuite nous voulons suivre les cibles détectées tout au long de leurs présences devant les caméras en suivant les vecteurs de mouvements et être capable de les reconnaître devant d'autres caméras en étudiant leurs distributions statistiques .

Défis: Le principal défi de ces travaux est de jumeler adéquatement les divers algorithmes de modélisation et de suivi dans le but de les rendre coopératifs.

Applications: Ce projet permet de nombreuses applications tant dans les domaines de la surveillance que de la vision artificielle.

HIGH RESOLUTION INFRARED MOSAICING USING GEO-REFERENCED IMAGES

Valérie Lavigne, André Zaccarin

Problem: Search and rescue operations are often carried out at night or under other conditions of poor visibility such as smoke, fog or snow. This is why military surveillance and detection systems are generally equipped with infrared detectors. Detection requires a wide field of view whereas identification requires a high resolution. This presents a great challenge because these concepts are opposed and it is generally necessary to carry out a compromise between the two.

Motivation: The Infrared Eye project was developed at DRDC-Valcartier to improve the efficiency of airborne search and rescue operations. A high performance opto-mechanical pointing system was developed to allow fast positioning of a narrow field of view with high

resolution, used for search and detection, over a wide field of view of lower resolution that optimizes area coverage. This system also enables the use of a step-stare technique, which rapidly builds a large area coverage image mosaic by step-staring a narrow field camera and properly tiling the resulting images. The resulting image mosaic covers the wide field of the current Infrared Eye, but with the high resolution of the narrow field. This technique could eventually lead to a lighter and more compact system with the elimination of the wide field camera of the IR Eye.

Approach: First, a model of the complete system was created. Using this model we have built a flight image taking simulator that was used for the strategy conception and testing. A dynamic strategy that adapts itself to the operational context was favoured. It selects the next image position to minimize the presence of holes and the prisms displacement and to maximize the refresh rate. Image positioning in the mosaic is achieved using projection coordinates and homography methods.

Challenges: When we are in an airborne platform, the point of view of the camera changes constantly and images that were taken previously must be corrected to reflect the current point of view. Since the narrow field can be positioned anywhere within the wide field coverage, we need an acquisition strategy to decide where to take the next image.

Applications: This step-stare technique will be used to improve airborne search and rescue missions. The dynamic strategy developed is general enough to be used with other flight systems in any wavelength if corresponding Risley prisms can be found and flight data are provided to the algorithm.

Expected results: The step-stare technique enables the detection capability equivalent to that of the narrow field in the whole large area image. A dynamic strategy that enables the mosaic creation for display on the operator's console and controls the prisms to select the images to take was developed. A numeric simulator was also created and used to conceive, optimize and test the mosaic building algorithms.

Calendar: The strategy developed will be the object of a presentation at the SPIE Defense and Security Symposium in Orlando, Florida taking place on April 12 - 16, 2004. The next step will be to test the strategy with a real system. One important factor to evaluate is to what extent do errors of measure affect the display. If errors are too visually unpleasing and distractive, correction methods could be added to the algorithm. Realtime experimentation is planned using a camera and a Risley prism set from a previous version of the IR Eye, and a rail with carriage mounted on the roof of a building to simulate scaled down flight displacements.

Support: This project is developed in collaboration with Defence R&D Canada - Valcartier. Financing is also provided through a FQRNT scholarship.

VIRTUAL TOURS WITH FREEDOM OF MOVEMENT

Mario Petitclerc, André Zaccarin

Problem: Creating virtual tours of houses with several panoramic images (cylindrical). The user will be able to walk and watch in any direction, without abrupt transitions.

Approach: Select sections from two panoramas that cover the same scene, observed by the user, unwarp them, then, proceed to a view morphing operation, to create the image that should be obtained by a camera positioned where the user is.

Challenges: (1) Finding epipolar geometry from two views of a scene that have been obtained from uncalibrated cameras. (2) Adapting to any light and depth conditions. (3) Creating and unwarping mosaics (panoramas). (4) View Morphing. (5) Obtaining results in realtime.

Applications: Real estate, tourism, video games based on real environments...

TELECOLLABORATION IN THE CONTEXT OF AUGMENTED REALITY: APPLICATION TO THEATRICAL PRODUCTION

Pierre-Alexandre Fortin, Patrick Hébert, Denis Laurendeau, Louis Borgeat

Problem: More and more, large-scale theatrical productions are produced through a collaboration of artists coming from all corners of the globe. These collaborations lead to the challenge of uniting all of the designers in one place at the same time with the same material.

Motivation: The use of an instrumented castelet would allow these artists to work from a distance on common projects through the application of technologies of telecollaboration and augmented reality. A castelet is a reduced model of a stage which facilitates the design of a theatrical production. In this context, one designer moves a camera in front of the castelet to provide a point of view which will be shared among the collaborators working at a distance. The image is augmented with the help of virtual objects which can be manipulated by the designers.

Approach: We want to create an augmented reality system which will allow the real point of view of the castelet to be projected onto a screen and allow the encrustation of virtual objects possibly involved in the theatrical production. To this end, methods of camera calibration must be studied and applied in order to obtain a rapid and precise positioning of the cameras in the castelet environment. To obtain satisfactory results, the error of superimposition of virtual objects in the augmented view must be evaluated with respect to the position of these objects in the real scene. The occultation of objects must also be taken into account during the rendering of the augmented scene. Tools developed at NRC for the sharing of virtual objects via a collaborative environment must also be integrated to enable users to work at a distance.

Challenges: The main challenge is to design a system enabling a satisfactory augmentation for the users. This requires precise and rapid camera calibration based on easily identifiable characteristics of the castelet. Moreover, the augmentation must be performed while taking into account the occultation of real objects on virtual objects. Another challenge will be to allow the sharing of objects between at least two users.

Applications: Within the context of this project, the first application will be the castelet environment. The techniques used could be applied to most projects which require the use of augmented reality techniques (applications in medicine, architecture, mechanics, entertainment, etc.)

Expected results: It is expected that a tool will be designed whose efficiency will be evaluated by potential users. One user will be able to move the camera in a castelet environment while both users will be able to position virtual objects and observe the result on a screen. The quality of the augmentation and the result obtained will also be evaluated.

DÉVELOPPEMENT DE SYSTÈMES SCÉNIQUES À GÉOMÉTRIE VARIABLE

Jean-Philippe Jobin, Clément Gosselin

Depuis une dizaine d'années, l'utilisation de plateaux mobiles dans les spectacles est devenue chose courante. Malgré tout, les technologies utilisées sont souvent restrictives d'un point de vue artistique. Le développement de nouvelles scènes à géométrie variable, plus versatiles, plus dynamiques (mouvements en temps réel) et mettant en oeuvre une multitude de degrés de liberté serait donc un outil scénographique très intéressant pour les créateurs de chez nous, leur procurant un avantage compétitif marqué. À titre d'exemple, on peut mentionner la part importante qu'ont les nouvelles applications technologiques de ce type dans le succès des entreprises telles que le Cirque du Soleil et Ex Machina.

Le but de ce projet est donc d'étudier différents mécanismes permettant de déformer et d'animer une surface dans le plus de configurations possibles. Plus spécifiquement, on s'intéresse aux surfaces relatives au domaine artistique telles que le plancher et les murs d'une scène de spectacle. Ces travaux sont réalisés sous la supervision du professeur Clément Gosselin, responsable du

Laboratoire de robotique de l'Université Laval et titulaire d'une chaire de recherche du Canada en Robotique et Mécatronique depuis janvier 2001. De plus, le LAboratoire des Nouvelles Technologies de l'Image, du Son et de la Scène (LANTISS), nouveau groupe de recherche de la Faculté des Lettres de l'Université Laval, est partenaire dans le projet depuis ses débuts, soit à l'automne 2003.

D'un coté pratique, les travaux sont réalisés afin de s'agencer aux objectifs du LANTISS. À cet effet, une première maquette sera construite à l'automne 2004, permettant de valider les concepts retenus et d'expérimenter différents mouvements scéniques. L'étape suivante sera la conception de la scène mobile du castelet électronique du LANTISS prévu pour l'hiver 2006. Ce castelet est en fait une maquette réduite à l'échelle dix pour un d'un espace scénique comprenant plusieurs éléments technologiques: éclairage motorisée, projection d'image, réalité augmentée, scène déformable, etc. Ce castelet pourra ensuite servir de lieu de création - les metteurs en scène pourront alors préparer les différents tableaux de leur spectacle avant même l'entrée en salle - ou de lieu de diffusion, avec des marionnettes par exemple. Finalement, l'étape ultime sera la conception d'une scène dynamiquement reconfigurable grandeur nature.

D'autre part, les surfaces déformables développées dans le cadre de ce projet pourront également profiter aux secteurs industriels dans des applications telles que le moulage de composantes. D'autres applications peuvent aussi être envisagées en optique par exemple (miroirs déformables) ou en robotique (manipulation complexe). On peut aussi penser à des applications en simulation de mouvement (simulation de voitures ou autres véhicules).

Finalement, mentionnons qu'étant donné le caractère innovateur du projet, autant d'un point de vue artistique que technique, il est d'un grand intérêt pour le laboratoire de robotique de poursuivre les recherches proposées dans ce projet.

MONNET SIMULATION

Richard Drouin, Denis Laurendeau

Problem: Tracking people in complex environments is an important problem in several areas: security in public places, military interventions in urban areas or in assisting people experiencing a loss of autonomy. Our project is part of the MONNET project which aims to develop a system for tracking people. This system is composed of an ensemble of nodes each equipped with visible and infrared cameras as well as a calculation unit for the treatment of video sequences. These nodes are connected together in a network and exchange information on people who are moving within their field of view. The network is composed of these nodes which are loosely coupled since each node is an independent component of the network, but is able to exchange information with the other nodes so as to enable a more complete tracking of people. Moreover, the fields of view of the nodes are not necessarily overlapping, which implies that the system must be able to treat information while taking into account the non-observed zones of the environment. Our project consists in studying the aspects related to the communication… between loosely coupled nodes and to define an exchange protocol enabling the nodes to exchange relevant information regarding the static and dynamic appearance of people who are moving within their field of view.

Motivation: In the literature most visual systems enabling the tracking of people are described as being based on a central server which is responsible for managing the interactions between nodes. The system described herein is significantly different from these systems since it is based on a network of loosely coupled cameras.

Approach: The research methodology consists in carrying out a literature survey on comparable systems. We will then perform an analysis of the needs relative to the desired application and define a software architecture responding to these needs. A simulation environment with different possible solutions will be implemented on the APIA simulator presently available in the Laboratory. The implementation of this architecture will be carried out using the C++ language and the prototype will be tested with simulated data as well as data provided by the algorithms of artificial vision developed by other members of the research team.

Challenges: The main challenge of this project consists in developing a flexible, robust and evolving inter-node communication module.

Applications: The results of our work will be integrated into the research involving the MONNET system.

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.

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, Denis Laurendeau, 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 m2, 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.

ALGORITHMES DE QUANTIFICATION DE DÉFAUTS AUX FORMES COMPLEXES

Lilia Najjar, Xavier Maldague

Dans ce projet, on s'intéresse à de nouveaux lgorithmes 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

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ÉTUDE ET MODIFICATION DE L'IMPULSION DE CHAUFFAGE UTILISÉE EN ÉVALUATION NON DESTRUCTIVE

Adel Ziadi, Xavier Maldague

En général, l'impulsion de chauffage utilisée en thermographie infrarouge appliquée à l'évaluation non destructive (ÉND) des matériaux a une forme rectangulaire. Quantitativement, cette impulsion n'atteint pas la totalité de profondeur du spécimen à inspecter à cause de la forte atténuation du front thermique lors de sa propagation. Ainsi, l'utilisation de cette forme d'impulsion pour détecter la présence de défauts localisés à différentes profondeurs s'avère difficile. Le travail présenté vise alors à proposer un nouveau modèle pour remédier à ce problème. Il s'agit d'utiliser la transformée de Fourier rapide (TFR) pour modéliser la forme de l'impulsion. Après avoir complété la modélisation et à partir de quelques résultats, la forme de l'impulsion de chauffage a été expérimentalement modifiée pour maximiser la réponse de l'échantillon à la stimulation thermique. L'une des applications possibles de cette nouvelle approche est l'inspection de matériaux utilisés dans l'industrie aérospatiale comme l'aluminium et la fibre de carbone.

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.

ÉVALUATION NON DESTRUCTIVE DE LA RUPTURE DES ARMATURES DE PRÉCONTRAINTE DES OUVRAGES D'ART PAR MAGNÉTOSCOPIE

Matthieu Klein, Xavier Maldague, Benoît de Halleux

Dans le contexte d'un besoin croissant d'évaluation par voie non destructive de l'état des ouvrages d'art comme les ponts routiers, la présente étude porte sur une technique de contrôle qui serait applicable à la détection des ruptures des armatures de précontrainte. Leur rupture par corrosion ou fissuration par hydrogène est un problème d'actualité. Elle résulte de l'effet combiné de l'eau et d'agents chimiques tels les sels de déneigement. La méthode de contrôle

proposée est la magnétoscopie. Elle consiste à détecter à distance les flux de fuite du champ magnétique qui se produisent au droit des ruptures des armatures des structures en béton précontraint. Le but de l'étude est de mettre en évidence les performances à attendre de son application. Nous rappellerons les principes de magnétostatique et montrerons les analogies et différences dans l'application de la magnétoscopie aux cas respectifs des pièces mécaniques en acier et des ouvrages d'art en béton précontraint. Une simulation par calcul permettra de prédire les flux de fuite aux ruptures et ce, en fonction de paramètres caractéristiques tels l'épaisseur d'enrobage, le diamètre de l'armature, son environnement ferromagnétique ou l'écartement des surfaces de rupture. Une vérification expérimentale en réalisant des mesures avec un magnétomètre permettra de démontrer la validité de la simulation par calcul. Enfin, le problème inverse consistera à détecter les ruptures par analyse des flux de fuite en surface des éléments des structures en béton précontraint. Nous proposerons trois méthodes de résolution du problème inverse.

ÉTUDE DE LA CORROSION EXFOLIANTE SUR DES SPÉCIMENS EN ALUMINIUM, À L'AIDE DE LA THERMOGRAPHIE PULSÉE

Marc Genest, Xavier Maldague

Problème: Les techniques d'évaluations non destructives permettent l'inspection de systèmes ou de composantes sans en altérer les propriétés. L'avantage de la technique par thermographie est qu'elle permet l'inspection de grandes surfaces et est une technique sans contact. La présente étude s'intéresse à l'inspection de la corrosion exfoliante sur des spécimens d'aluminium. Le but est de quantifier les dimensions et la profondeur atteintes par la corrosion. Puisque l'aluminium possède une faible émissivité, une partie de l'étude consiste à essayer divers types de revêtements pour augmenter l'émissivité tout en s'assurant que celle-ci est uniforme.

Motivation: La corrosion entraîne une détérioration du métal et par conséquent des structures qu'il compose. Cette détérioration affecte la sécurité des personnes qui utilisent la structure corrodée, entraîne des coûts de réparations et peut causer d'autres dommages aux structures. En effectuant l'évaluation non destructive (ÉND) par thermographie, on peut estimer les caractéristiques de la corrosion présente dans la composante inspectée. Cette évaluation permet de savoir quand la corrosion devient dangereuse pour la structure. De plus, le fait de détecter la corrosion dans un stade initial et d'en faire le suivi, permet d'avoir une rétroaction de l'évolution de la corrosion du spécimen par rapport à son environnement d'utilisation. Ce qui peut amener une meilleure compréhension du phénomène de corrosion et par conséquent, un meilleur système de contrôle et un meilleur système de prévention de celle-ci.

Approche: L'utilisation de la thermographie pulsée (TP) permet de relier le temps de propagation de l'onde thermique avec la profondeur du défaut. De plus, la variation de température atteinte par les zones contenant des défauts dépend aussi de la profondeur du défaut. La TP semble donc une approche intéressante pour quantifier la profondeur des défauts. La TP permet aussi d'estimer les dimensions des défauts.

Défis: La différence d'émissivité sur un spécimen peut faire en sorte que les données soient mal interprétées par l'opérateur. Lorsque la surface inspectée est recouverte par un revêtement d'émissivité uniforme, on enlève cette source d'erreur. L'opérateur peut donc supposer que les différences de températures apparentes sont dues à des défauts dans le matériau au lieu de provenir d'une différence d'émissivité. Puisque la corrosion exfoliante survient près de la surface et que l'aluminium est un très bon conducteur thermique, la majeure partie des informations est contenue dans les premières images. Le taux d'acquisition de la caméra infrarouge doit donc être suffisamment rapide pour voir l'évolution de la température pour le laps de temps qui nous intéresse.

Applications: Le problème de la corrosion est présent dans l'industrie aérienne, car certains métaux, comme l'aluminium, entrent dans la fabrication des avions. L'inspection non

destructive par thermographie permet d'inspecter une large surface sans avoir besoin de contact et sans nécessiter le désassemblage de l'appareil, contrairement aux techniques par ultrasons ou courant de Foucault qui sont les techniques les plus souvent utilisées pour l'inspection de métaux comme l'aluminium.

MODELING OF THE POSITIONING AND 3D ACQUISITION SYSTEM OF THE BRAIN

Philippe Lambert, Patrick Hébert

Problem: The systems which nature has conceived are always an inspiration. My project on the positioning of a camera in an unknown environment and the 3D modeling of environments will thus attempt to apply the methods which the brain itself uses for positioning. The hypothesis which I would like to verify is that positioning and modeling are in fact connected and inter-related in the methods which the brain uses for positioning.

Motivation: This research therefore implies an analysis of the human positioning system to enable an improvement and proposal of new methods for the positioning of cameras. Moreover, since our hypothesis is that 3D modeling plays an essential role in positioning, this area will also be studied. The possibility of carrying out a treatment in real time is also an important objective for all of the algorithms which will be developed. In fact, by using the human system as a model, we are directing our research towards real time treatment.

Approach: We propose to use an electronic set-up which resembles that of the human brain, i.e. a stereo pair which is coupled with a gyroscope and accelerometers so as to imitate the human eyes and the vestibular system. This set-up is based on work carried out by Martin Labrie (see: http://vision.gel.ulaval.ca/fr/Projects/Id_182/Projet.php). This research, which will involve psychology and biology in addition to computer systems, will enable me to use the electronic system to experiment on new approaches using this configuration. The 3D representation used will also be of great importance. The most appropriate representation is probably the one developed by D.Tubic(http://vision.gel.ulaval.ca/fr/publications/Id_460/PublDetails.php). The platform of applications used will involve augmented reality tools so as to communicate the information acquired by the system to the user. For example, the model of the environment which is created by the system could be superimposed on a real environment so as to allow for comparisons. The application to augmented reality will also enable a link to the Lantiss project (Lantiss = Laboratoire des nouvelles technologies de l'image, du son et de la scène) which could benefit from the research performed.

Applications: This project will lead to a better knowledge of the human brain and may lead to a source of inspiration for different representations and algorithms than those presently used.

CALIBRATION AND POSITIONING OF MOBILE RANGE SENSORS

Jean-Nicolas Ouellet, Patrick Hébert

Problem: Over the past few years, a large variety of systems capable of producing 3-dimensional images have been developed. A crucial point for mobile systems is the quality of the measurements in a global coordinate system. This quality is directly related to the positioning system used and to the precision of the calibration.

The first problem we are interested in is to provide a calibration system which allows a precise modeling of the behaviour of a camera. This problem has already been studied; however, our goal is to simplify the calibration procedure while maintaining the quality and to avoid the use of expensive equipment. During calibration, a 2D or 3D target is observed and the position of the characteristics must be recognized and associated with a theoretical model of the target. One characteristic could be, for example, a white circle on a black background. The association between the theoretical model of the object and its image is often an operation which requires a manual intervention. We wish to automate this step. Our objective is then to simplify the object. The idea is

to combine a very simple and compact object with a simple pattern printed on a piece of paper.

The second problem consists in positioning a sensor in a global coordinate system. To provide a 3-dimensional model of an object, several series of data are generated by the sensor from different positions. The combination of data obtained at each of these positions is a long and complex process when these positions are not known in a global coordinate system. We have a network of reconfigurable ultrasound emitters-receptors. Our goal is to design a robust system able to calibrate the network and to find the position and orientation of the sensor in the global coordinate system.

Approach: The calibration problem of a sensor will be approached on the basis of a photogrammetric model developed by J. Heikkilä for cameras. The detection and estimation step of the position of the characteristics of calibration in the image is fundamental and will be the object of a detailed analysis. We also want to verify if it is possible to improve the accuracy of the measurements by integrating several images of the object taken at different positions.

The automatic matching of characteristics consists in estimating a rough geometric model of the object from the observed image. By estimating the size of the characteristics which are approximately known and by using nominal parameters of the cameras, it is possible to estimate the position and the orientation of the camera and to find the 2D or 3D position of each of the observed characteristics. The matching will thus be direct. This technique is applicable for a complete view of the object or for a partial view. The cases of images taken by a hand-held sensor or a sensor on a tripod will be analyzed and compared. We will then propose a simplified object consisting of a pattern printed on a piece of paper. Since the pattern will only have an approximately known size, a calibration rod of known length will serve as a metric reference.

The positioning problem will be solved in cooperation with the University of Florence in Italy. This university has developed a distance measurement system using ultrasound. A combination of ultrasound emitters-receptors are placed on fixed towers and on the mobile sensor. As with a GPS, a combination of distance measurements allows the position and orientation of the sensor to be found in a global coordinate system. The system will be able to function in a noisy environment and provide an estimate of the quality of the solution obtained.

Challenges: Precision vs. simplicity: Several calibration systems already exist, the challenge is to provide a system and a projection model of high precision, which is both simple and rapid. Precision vs. time: The main constraint of the positioning system is the time required to obtain a precise position. Since several 3-dimensional sensors operate in real time, this time must be as short as possible.

Applications: Range sensors allow the measurement of geometric shapes of a large variety of objects in sectors as varied as those of industrial manufacturing or the documentation of patrimonial objects. Our collaboration with the University of Florence deals with objects of the latter type. In several sectors, the quality, the portability and simplicity of execution have become necessary. The development of new methods accompanies the development of new architectures of sensors.

AUTOMATISATION DES SCÉNARIOS D'ENTRÉE ET DE SORTIE DES VÉHICULES DANS UN STATIONNEMENT PAR UN CAPTEUR INFRAROUGE

Amar Al Maadi, Xavier Maldague

Description: La vidéosurveillance est en plein essor, et les systèmes vidéo sont de plus en plus présents. Cependant se sont encore pour la plupart des cas des hommes qui surveillent des écrans et commandent les caméras dans des salles de contrôle. La tendance actuelle est à l'allégement des tâches effectuées par l'homme en intégrant de l'intelligence dans ces systèmes.

Dans un cadre de vidéosurveillance, on s'intéresse à l'évaluation de l'infrarouge pour une automatisation des scénarios d'entrée et de sortie des véhicules dans un stationnement, et ce à partir d'une séquence vidéo de scène extérieure sollicitée par différentes conditions climatiques et d'éclairage comme le vent, neige, la nuit et le jour.

Les acquisitions seront réalisées à partir de capteurs visible et infrarouge simultanément, et ce pour éventuelles applications.

Méthodologie:
1. Une revue de littérature sur les systèmes de surveillance infrarouge et visible existants, ainsi que les différentes méthodes de détection dans le contexte de la vidéosurveillance. 2 Acquisition des séquences d'images à partir de scène extérieure affectée par différentes conditions climatiques et d'éclairage. 3. Faire des corrections ou des ajustements si nécessaire. 4. Mise au point d'un algorithme de détection. 5. Validation sur les séquences d'images prises durant l'étape "2".

FUSION D'IMAGES INFRAROUGES ET VISIBLES POUR LE SUIVI DE PERSONNES

Vincent Grégoire, Xavier Maldague, Denis Laurendeau

Résumé : Mon projet consiste à développer des algorithmes et améliorer ceux existants pour faire la détection et le suivi de personnes par vision par ordinateur à l'aide de caméras visibles et infrarouges thermiques. Par la suite ces algorithmes seront intégrés au prototype de système développé pour le projet MONNET. Mon travail s'inscrit donc dans le cadre de ce projet, qui consiste en la conception d'un système automatisé de surveillance par ordinateur composé d'un réseau d'ordinateurs possédant chacun les deux types de caméra.

Problème : La surveillance automatisée par vision par ordinateur est un sujet qui fait l'objet de nombreuses recherches ces derniers temps. L'efficacité de tels systèmes augmente continuellement, mais elle est limitée par l'information acquise par les caméras. La qualité de l'information acquise par une caméra visible est grandement affectée par l'intensité lumineuse et par le contraste de couleur entre les vêtements portés par le sujet avec l'arrière-plan. Dans cette optique, l'utilisation combinée de caméras infrarouges thermiques et de caméras visibles permet de recueillir davantage d'information.

Motivation : Ce travail s'inscrit dans le cadre du projet MONNET (Monitoring of Extended Premises : Tracking Pedestrians Using a Network of Loosely Coupled Cameras) dont l'objectif est la réalisation d'un système de surveillance utilisant un groupe de nœuds faiblement couplés. Chaque noeud est composé d'un ordinateur, d'une caméra visible et d'une caméra infrarouge. Toutefois, pour tirer avantage de ces deux caméras, il faut être en mesure de fusionner l'information que chacune apporte pour en tirer le maximum de résultats. De cette fa¸con, il est possible de continuer de suivre une personne dans le noir ou dans le vent (alors invisible à l'infrarouge). Cette méthode a été étudiée par Hélène Torresan dans le cadre de son projet de maîtrise. Le projet courant est une continuité de son projet.

Approche : L'approche du projet consiste à traiter séparément les images provenant des deux caméras. Dans chacune des images, on tente de détecter des personnes et de les caractériser le mieux possible. Ensuite, on fusionne ces résultats pour pouvoir faire le suivi des personnes dans le temps. Pour chaque personne suivie, on construit itérativement une fiche descriptive de la personne. Les informations contenues dans ces fiches sont utilisées pour améliorer le suivi, par exemple pour la gestion des occlusions. Lorsque la personne quitte le champ de vue des caméras, la fiche correspondante est envoyée aux autres nœuds du réseau, permettant ainsi le suivi d'une personne d'un nœud à l'autre.

Défis : Les défis sont nombreux dans ce projet, mais il y en a trois principaux. Premièrement, il faut être en mesure de détecter et de caractériser les piétons aussi bien dans les images visibles que dans les images infrarouges. Plusieurs publications présentent des méthodes pour les images visibles, mais pour les images infrarouges la littérature est rare. Deuxièmement, il faut être en mesure de mettre en correspondance les piétons dans les deux images provenant de capteur non coalignés et ce même s'ils ne sont pas entièrement détectés. Finalement, il faut être en mesure de faire le suivi quand la personne n'est visible que pour une caméra ou même quand elle disparaît pendant quelques instants à cause d'occlusions.

Applications : Un tel système comporte plusieurs applications possibles pour assurer la sécurité des personnes et des infrastructures. On peut facilement penser à deux types d'utilisations, le premier étant la surveillance pour empêcher les méfaits en détectant les personnes suspectes, notamment pour prévenir le terrorisme, la

deuxième étant la surveillance pour détecter automatiquement les personnes en besoin d'assistance, par exemple dans une résidence pour personnes en perte d'autonomie.

SIMULATEUR DU MICROPROCESSEUR EN TRANCHE AMD2900

Lubna Semlaji, Xavier Maldague

Le projet consiste à créer un simulateur du microprocesseur en tranche AMD2900 dans le logiciel Xilinx Integrated Software Environment (ISE)-project navigator, en utilisant le langage VHDL. Ce simulateur, qui reproduit de manière la plus similaire possible chacun des modules de ce microprocesseur, vise à aider les étudiants en génie dans leur apprentissage de la microprogrammation du microprocesseur AMD2900.

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.

A FRAMEWORK FOR THE DESIGN AND CONTROL OF A MACRO-MICRO MANIPULATOR SYSTEM

Jorge Angeles, Alexei Morozov

Problem: The need to service, maintain and repair large-scale structures while keeping the human operator at a safe distance from the scene.
Motivation: The need to service, maintain and repair aircraft, space facilities and large-scale structures at large has called for a new generation of manipulators that are characterized by a long reach and a highly redundant architecture. The main problem here is to produce a mechanical system capable of accurate tasks in the presence of a flexible structure. Current designs of such systems exist, but they are limited to tasks that are error-tolerant, e.g., cleaning.

In cleaning tasks, for example, the end-effector is supplied with a highly compliant tool, a cylindrical brush rotating about its axis that does the cleaning, the inherent compliance thus being capable of compensating positioning errors. Besides, these tasks are quite tolerant in terms of speed accuracy. Other tasks required in the servicing and maintenance of aircraft are more demanding in terms of accuracy, e.g., stripping, de-icing, and painting. Stripping requires more accuracy in the execution of the task, in that the tool is rigid and sharp, positioning errors thus becoming dangerous, for they can lead to damage of the fuselage.

Deicing requires a uniform application of the solvent, which calls for moderately accurate positioning but highly accurate velocity control. Painting, in turn, is the most demanding of these tasks, for it requires an accurate velocity control of the painting nozzle with the purpose of guaranteeing a uniform application of the painting, besides requiring a highly accurate positioning control. This requirement becomes critical when the painting involves the tracing of regular geometric shapes on the fuselage, like curves that appear projected as straight lines or circles. These requirements motivated the need for a light, and hence, flexible structure, while at the same time capable of executing accurate positioning and velocity control.

Approach: We introduce here a modular approach to the design of the mechanical structure of an 11-axis robotic system (the M^3 System) with the purpose of obtaining accurate positioning and velocity-controlled tasks in the presence of a flexible substructure. The system is designed as a cascade of three modules, the proximal one being termed the Macromanipulator, and comprising four revolute axes aimed at realizing four-dof positioning tasks of the type proper of what are called SCARA — Selective-Compliance Assembly Robot Arm — systems. The Macromanipulator is responsible for a long reach (about 3.5 m) and a high flexibility. The other two modules, comprising the seven-axis micromanipulator, are responsible for the accurate positioning of the tool attached to the end-effector. Of these, the intermediate module is a four-axis architecture responsible for the positioning of a point of its terminal link, which plays the role of the centre of the parallel, three-degree-of-freedom spherical wrist. Both the intermediate module and the spherical wrist are designed with an isotropic architecture for highest positioning accuracy.

Challenges: In order to accommodate the structural and motion-capability requirements, we propose an innovative motion-generator for the production of SCARA motions. As a means to add robustness to this system, we devised an innovative drive subsystem comprising two cascaded units, each with two identical motors, both fixed to the same base. Here lies the innovation of the subsystem, for current SCARA systems are invariably driven by four distinct motors of disparate force and motion capabilities, with a mixture of three revolutes and one prismatic joint. The Agile Wrist (AW) module is a three-dof orienting module. The AW has a parallel, isotropic architecture for highest orientation accuracy. Its design is based (with some modifications) on that of the Agile Eye developed by Prof. Gosselin and his team. The redesign of the AW aimed at adapting the original mechanism to specific task requirements. Collaboration with Laval University's Prof. Gosselin was crucial here.

Applications: From the applications viewpoint, the major significance of this project is its potential for direct application to robotics-related problems of industrial relevance. In fact, the project was originally funded by Bombardier, as a feasibility study. Bombardier's interest arose from potential robotic applications in aircraft maintenance, servicing and repair, e.g., in such activities as paint-stripping, painting, de-icing, inspection, and shot-peening. Another direct application of the outcome of this research is in the control of the Space Station Remote Manipulator System (SSRMS). This is an M^3-type system whose "micro" manipulator is the Special Purpose Dexterous Manipulator (SPDM), consisting of two seven-dof arms. Besides, the interest of the Canadian Space Agency is in helping us to exploit the results of this project in terrestrial applications such as in vibration suppression in "cherry pickers" and cranes.

CONTROL OF STRUCTURE-INDUCED NOISE IN AUTOMOBILES

Jean-Gabriel Roumy, Dany Dionne, Marie-Pierre Jolicoeur, 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. Linear quadratic and H-infinity control strategies were developed and simulated.

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. Yet, we were able to achieve a 10dB reduction in the magnitude of most flexible modes in the closed-loop sensitivity.

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

MODELING, IN-CYCLE CONTROL AND CYCLE-TO-CYCLE CONTROL OF THE THERMOFORMING PROCESS

Mark Ajersch, Guy Gauthier, Ammar Haurani, Benoit Boulet

Problem: Thermoforming is a process in which useful 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. Accurate 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. Radiant energy penetrating the sheet was found to be a significant mode of heating. Then, the model was linearized and various controllers were designed and some of them experimentally tested.

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.

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. We tested our tuning strategy against the more ad hoc QFT technique, and showed that our technique is much easier to apply.

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

MODELLING AND CONTROL OF THE LARGE ADAPTIVE REFLECTOR

Alexandre Boyer, Benoit Boulet, Meyer Nahon

Problem: The Large Adaptive Reflector (LAR) design, if proven feasible, would constitute a breakthrough in the design of very large radio telescopes, at a reasonable cost. In the LAR design, the reflector is made up of moving panels that, when properly controlled together, gives the reflector its time-varying paraboloid shape for real-time start tracking. The receiver antenna hangs from the tethers of an aerostat filled with helium. A crucial question to be answered is whether the receiver can be positioned to cm accuracy over a wide operating space. This is an extremely challenging design and control problem.

Motivation: The cost of a classical radiotelescope with a 200m reflector is estimated at 1B$. This cost is due to the huge structure needed to support and move the reflector. In comparison, the cost of an LAR of the same size is estimated at 32M$ only.

Approach: We have looked at the problem of controlling the position of the receiver by using the tether lengths as control inputs. The tethers are modeled using finite elements of varying size as the tethers elongate or retract. We designed robust mu-synthesis controllers for the receiver's position that work well in simulation. We also solved the reflector panels kinematics problem for slewing maneuvers and star tracking using an optimization technique.

Challenges: The dynamical model of the tethers is of high order and parameter-varying, which makes this problem very difficult.

Application: The next generation of very large radio-telescopes that will see further back in time, at the dawn of the universe.

STOCHASTIC CONTROL OF NETWORKS AND COMPLEX SYSTEMS

M. Huang, Z. Ma, R. Malhamé, L. Mason, W. S. Wong, P. E. Caines

Motivation: We are undertaking fundamental studies of distributed, hierarchical and networked structures in contemporary technological systems; such structures play a crucial role in the analysis, design and control of systems which often are of enormous complexity; familiar examples of this are provided by the Internet, cellular phone power control and electrical energy distribution networks.

Approach: Our work on cellular communication systems exploits a stochastic diffusion channel model accounting for lognormal fading effects in such communication systems; it is formulated in terms of centralized stochastic control problems wherein the performance function penalizes power consumption while optimizing quality of service (QoS) requirements. A singular Hamilton-Jacobi-Bellman (HJB) equation associated to the resulting stochastic control problems has been obtained and the associated viscosity solution has been mathematically analyzed and studied via simulations. The centralized utility function in this case has a natural decomposition into individual utility functions. For an associated class of linear quadratic Gaussian (LQG) systems with large populations, the distributed features of centralized optimal solutions and their corresponding game theoretic properties have been analyzed. Two notable features emerge: first, when the population members follow their (centralized) optimal control policies, the control of any given individual has the form of a state feedback of its own state plus the feedback of an aggregate variable which (in the population asymptotic limit) evolves as a massive single player with a deterministic trajectory; second, within the decentralized (game) version of the problem (where individual utility functions correspond to the natural decomposition of the cost function into individual costs) there exists an e-Nash equilibrium in which each agent's control is of an individual feedback plus massive player tracking form quite distinct from the centralized case.

Furthermore, stochastic approximation and stability methods have been used to establish the robust asymptotic (in time) convergence of a completely decentralized power control algorithm where each agent attempts to maximize its own QoS in stochastic fading channel environments. The steady state solution has Pareto and Nash solution interpretations.

Challenges and Applications: Within the framework of the control of complex communication systems we are currently building a research effort focused on game theoretic and market pricing based approaches to Internet traffic control. The first key challenge is the problem of partial information in network control, i.e. the fact that the individual agents or nodes have only local observations on the entire network (which has a huge state space). This leads to the analysis of various methodologies for state estimation including approximate and reinforcement learning methods, and various new strategies for state aggregation. The second central challenge is to introduce in an effective way the notions of market mechanisms, for instance, prices, auction mechanisms and other devices, for the management and optimization of the inherently competitive behaviour of network agents. A further feature to this problem is that the preferences of other agents are not necessarily known to any given agent. The current research program is believed to be the first to address the stochastic dynamics and equilibria of auctions and related schemes in order to analyse the market management of networks and networked systems.

TOWARDS DIRECT MOTION AND SHAPE PARAMETER RECOVERY FROM IMAGE SEQUENCES

Stephen Benoit, Frank P. Ferrie, Prakash Patel

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.

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.

ANALYSIS OF IMAGE STATISTICS

Marcel Mitran, Frank P. Ferrie

Problem: There is an on-going effort in the field of computer vision and image processing to provide a framework for detecting and locating important elements in an image, called feature points. Feature points are expected to be associated to interest points in the scene via the image formation process.

Motivation: Traditional feature detectors seek to provide a heuristic for identifying salience over the set of all natural images. Such detectors are absolute with respect to the particular characteristics of the image, and hence, generally do not provide a true measure of salience over the actual image under observation. Hence, it can be said that global characteristics of such an image are neglected implicitly (think about it!).

Additionally, when considering characteristics of the scene, an absolute form that tries to capture all possible underlying events will generally not provide a tight representation of the significantly smaller set of interest points actually represented in the current image under observation.

If we consider further that the recovery of underlying scene structure, through shape-from-motion or baseline-stereo, generally involves some form of constrained motion (after all there must be features to match between views), it is acceptable to suggest that the set of images features used to recover scene information does not change significantly over the actual group of images under observation. Again, the choice of an absolute feature representation is generally not a tight representation.

Approach: We introduce a new approach for feature selection that is based on the actual content of the image under observation. As such saliency is defined specifically by the image itself using a non-parametric approach rooted in information coding theory. Our basis is a vectorial decomposition of local image patches into pseudo-independent descriptors. The image is then characterized by the statistical distribution of each descriptor over the image space, providing an empirical global probabilistic distribution. These global descriptors are then used to qualify 'significance' of the different descriptors, and hence, provide an estimate of the corresponding minimal descriptor length. This length is associated directly to the salience of the image patch.

Challenges: Computational complexity in both space and time. Data-driven approaches such as this one can be computationally intensive, e.g., statistical enumeration. Results thus far are very competitive as far as saliency and accuracy are concerned, but effort will be required to adapt these techniques to real-time environments such as the QerraNet context.

Applications: This framework is used for compression of images by removing non-salient features. Effectively, the result from an intuitive perspective is the removal of unnecessary detail. Another interesting use of this new feature set is the computation of semi-dense shape-from-motion parameters for arbitrary motion. A third application for these features is the automatic selection of scale. The features lend themselves naturally to the estimation of entropy in an image. For a scale-space representation of the image, it would be possible to select the scale at which entropy is greatest, hence, in which the most significant level of salience is found. Finally, this framework also lends itself to computing change in salience for 'pseudo-smooth' morphing images using an estimate of the Kullback-Liebler distance. As such, given a view-sphere about an object, it should be possible to identify canonical points-of-view for which salience remains pseudo-constant.

PASSIVE 3-D MODEL ACQUISITION VIA HYBRID MODELING

Shufei Fan, Frank P. Ferrie, and Zeeshan Anwar

Problem: Obtain a complete 3-D surface reconstruction of a stationary 3-D object from observations acquired by a moving observer or a moving 3-D object from a stationary observer. Data are acquired by a passive sensor such as a CCD camera, enabling texture acquisition.

Motivation: State of the art active sensors, such as the color laser scanning technology developed by the Institute for Information Technology at the National Research Council of Canada, are capable of acquiring metrologically accurate 3-D surface and texture samples of opaque objects (including deformable). Our goal is to approximate this impressive performance with off-the-shelf passive sensors. Neither passive stereo nor space carving approaches by themselves have been completely successful in this regard. Stereo still remains an open problem, although very good algorithms presently exist for aptly textured surfaces. Volumetric approaches have resulted in robust, computationally efficient algorithms for recovering the visual hull of an object.

Approach: We have begun to investigate a hybrid approach to surface recovery based on simultaneous application of space carving and correspondence. A motion capture facility has recently been acquired that will enable us to collect video sequences from multiple viewpoints, providing input for a Kanade style recovery algorithm. Stereo data will be used to identify the loci of the visual hull and to provide the complementary surface information. A novel aspect of this research is the use of visual feedback to adapt data acquisition so as to optimize model recovery (active vision).

Challenges: While impressive results in 3-D scene reconstruction have been reported in the literature using a variety of different approaches, the "camcorder" scenario still remains an open challenge – walk through a scene with a handheld video recorder and recover a virtual model of the experience (so-called virtualized reality). Such a system would have to cope with camera calibration issues, correct estimation of camera motion, scale and sampling ambiguities, to name but a few.

Applications: The primary application of this research is in model recovery for simulation environments and for reverse prototyping applications.

SCENE UNDERSTANDING FROM SENSOR WEBS

Albert Law, Philip Mbonye, Marcel Mitran, Frank P. Ferrie

Problem: Given a collection of sensors with potentially different modalities and unknown fields of view with respect to each other, what inferences can be drawn about the structure/content of the surrounding environment based on local inference and exchange of information between sensor nodes.

Motivation: In contrast to problems in which the image formation process is known in some detail

(camera location, camera calibration parameters), sensor webs usually involve a larger number of camera systems (>3) for which only little or approximate information is known. Hence the inference process involves determining an imaging model in addition to recovering scene structure. Examples range from surveillance systems (approximate camera location, some knowledge of camera parameters) to more complex problems involving sensors at unknown locations with limited knowledge about sensor characteristics. In all cases, it is through exchange of information that constraints can be determined (e.g. correlation of data to determine relative camera directions).

Approach: Given the generality of the problem domain (e.g. tracking objects in natural scenes), we have begun to investigate data-driven approaches to feature identification (information theoretic measures such as mutual information, entropy, etc. on local image statistics) and inter-frame tracking (particle filters). Our initial goal is to build robust algorithms for finding image correspondences at variable time scales. Work to date has been highly successful in devising novel interest operators for localizing significant scene events. Our work will then focus on using such correlates to infer the topological and geometrical structures of the underlying web which will ultimately lead to higher level problems such as dynamic scene understanding.

Challenges: This area of research is relatively new and remains largely unexplored. There are also significant technical challenges ranging from data management over IP networks (a recurring QerraNet theme) to the computational complexity of dealing with large amounts of data in real-time. The latter is a particular challenge in the statistical approaches that we have adopted.

Applications: We are currently investigating an application in traffic monitoring – determining traffic flow from observations from overhead camera systems in Montreal area expressways. The primary challenge is that camera position and focal length are not known a priori, and must be determined as part of the inference process. However, since these parameters are controllable (open loop), we are investigating how an active vision approach can be used to simplify the pose determination problem.

STRUCTURE FROM MOTION IN CLUTTERED 3D SCENES

Michael Langer

Problem: When a camera moves through a 3-D scene, it records images from several vantage points and 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, since discontinuities need to be considered.

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. We have shown how to recover camera motion in such scenes. Our next set of problems concern how to recover 3D structure. Knowing the camera motion constrains the solution significantly, since the motion of each pixel is reduced to a local epipolar line (1D), rather than a local 2D image neighborhood.

Challenges: Because the sizes of objects in the scene and number of discontinuities are not known in advance, the vision system does not know at what spatial scale to process the image. The only prior information about scale comes from the camera motion, since this motion determines the range of image speeds that are

present at each image position as a function of depth.

Applications: The main application of the project is automatic 3D reconstruction of cluttered 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. Commercial applications are varied and range from entertainment, to architectural visualization and urban planning, to scientific visualization of arbitrary 3-D cluttered data sets.

This is joint work with R. Mann at U. Waterloo, V. Chapdelaine-Couture and Sebastien Roy at U. de Montreal.

IMAGE BASED RENDERING OF MOTION PARALLAX AND DYNAMIC SHADING

Michael Langer, Linqiao Zhang, Javeen Pereira, Aditya Bhathia, Dipinder Rekhi, Daria Gipsman, Yousef Farasat

Problem: To render a detailed virtual scene so that it appears real, one needs to specify much information about surface shape and reflectance, and lighting. Such details are unnecessary for many applications, e.g. if the human user only needs to use the virtual world to accomplish some task, but does not need to be fooled into thinking that the virtual world is real. The problem to be solved is: how much visual information needs to be rendered in order to provide the user with basic cues about shape, reflectance, and lighting?

Motivation: Besides understanding what visual information a human observer needs, we also wish to develop models of visual motion that are general enough that they can be used in computer vision. The idea is that by showing how certain visual cues such as motion parallax and dynamic shading are sufficient for the human user, one can gain insight into how these cues could also be sufficient for guiding a computer vision system on a robot.

Approach: We assume the human user only needs to know about its own motion relative to the 3D world, the rough positions and shapes of surfaces, and the reflectance of surfaces. This requires that we investigate the visual information conveyed by occlusions, specularities, and dynamic shading. We recently developed several models of these phenomena, based on spatiotemporal frequency analysis.

Challenges: Understanding the effectiveness of a visual cue for a human user is non-trivial. One can try to quantify the amount of information in a stimulus, but this does not guarantee that the human user uses this information in a predictable way.

Expected results: We hope to develop methods that can be used by the computer graphics community. As such, our concrete goals are to publish our ideas in leading computer graphics conferences, and to have the methods used in computer games and other animation applications.

OBJECT RECOGNITION USING SHOCK GRAPHS

D. Macrini, A. Shokoufandeh, S. J. Dickinson, J. Zhang, 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. We are also currently investigating the use of this framework for matching and retrieving 3D graphical models described by their underlying medial representations.

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

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WHITE MATTER FIBRE TRACT RECONSTRUCTION

Jennifer Campbell, Peter Savadjiev, 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. We are also developing novel techniques for the regularization of the initial orientation estimates using geometric constraints.

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

Maxime Descoteaux, D. Louis Collins, Kaleem Siddiqi

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

Motivation: 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. Also, most of these methods are tailored to angiographic data and thus would fail on the case of standard MR images.

Approach: To address this problem we combine the gradient flow which maximizes the rate of increase of flux of an appropriate vector field through a curve (in 2D) or a surface (in 3D), with multi-scale estimates of vessel centerlines based on the Hessian matrix. We show that this approach can be applied to both angiographic data as well as to proton density weighted MR images and gadolinium enhanced MR images. In both of these modalities blood vessels cannot be identified by contrast alone.

Challenges: Whereas we have carried out a cross validation of the technique on different modalities, one of the key remaining challenges is to evaluate the method against a notion of ground truth. Unfortunately the ground truth vessel boundaries are generally not known. We are thus carrying out

validation study on subject data where the vessels have been segmented manually by an expert.

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, 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 obtain fly throughs of tubular structures which can be used for virtual endoscopy.

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.

AN EMPIRICAL STUDY ON CAMERA CALIBRATION

Jeremy Cooperstock, Wei Sun

While a large number of vision applications rely on the mapping between 3D world coordinates and their corresponding camera image coordinates, there appears to be a lack of literature guiding researchers on the requirements of performing an accurate camera calibration.

To address this need, we conducted a thorough study investigating the effects of training data quantity, pixel coordinate noise, training data measurement error, and the choice of camera model on camera calibration results. Results were obtained for a simulated camera system and then verified through carefully controlled experiments using real-world measurements. For these experiments, three of the most popular and representative camera calibration algorithms, Tsai and Heikkilä's world-reference based approaches and Zhang's planar calibration method were investigated.

The study includes a detailed comparison of various camera models, in order to determine the relative importance of the various radial and decentering distortion coefficients. Our results indicate that the second order radial distortion and the two decentering coefficients are by far the most significant in terms of effect on accuracy.

Through these experiments, we also found that Tsai's method yielded the most accurate results among the three methods when trained on data of low measurement error. This, however, is difficult to achieve in practice without an expensive and time-consuming setup. In contrast, Zhang's method, although sensitive to noise in training data, takes advantage of planar constraints of the

calibration pattern and requires only relative measurements between adjacent calibration points, which can be accomplished at very high accuracy with trivial effort. Thus, in the absence of sophisticated measurement apparatus, Zhang's calibration results may easily outperform those of Tsai.

OCCLUSION DETECTION IN FRONT PROJECTION DISPLAY ENVIRONMENTS

Jeremy Cooperstock, Nadia Hilario

In a front projection environment, occlusions occur when a user interacts directly with the display via gestures or tangible bits, or inadvertently blocks the projector. Differences in depth, surface shape, and reflectance properties between the display surface and the occluding object can lead to distortions in the projected image. As well, shadows are often introduced on the display, resulting in loss of information in the occluded region.

However, sufficient knowledge of these occlusions allows for a corrected projected display in which overlapping projectors can fill in the occluded region, thereby producing an apparently unoccluded display. Occlusion information can also be used to assist in such tasks as body or hand tracking, and to avoid projecting distracting light on users. As another interesting application, an occluding object itself could potentially be augmented by customizing the projected imagery in the corresponding display region.

Our goal is to implement a camera-projector system that performs occlusion detection in a front projection display environment. We hope to obtain a flexible algorithm that can be applied as a preliminary step to various image processing tasks, as required for generic front projection applications. We also demonstrate the use of this detection algorithm in a multiprojector shadow removal system.

Our approach is based on a camera-projector color calibration algorithm that estimates the camera response to projected colors. Predicted camera images are then generated for each projected image and compared with observed camera images to locate occluded display regions. Such regions can be due to the occluding object itself or to the shadow it produces.

The algorithm begins with an off-line geometric registration step, followed by color calibration, in order to establish the relevant camera-projector transformations. The results of these steps are applied at runtime to generate predicted camera images of the projected scene. In order to locate occluded display regions, pixel-wise differencing between predicted and observed camera images is performed for each video frame. Such regions may be due to the occluding object itself or to the shadow it produces on the display surface.

The occlusion detection algorithm can be used for various applications, such as shadow removal. Shadows caused by occluding one projector can be filled by a second redundant projector, in order to minimize loss of displayed information.

MULTI-PROJECTOR DISPLAY SYSTEM

Jeremy Cooperstock, Daniel Sud

The goal of this project is to transform the walls of a room into a single logical display using multiple projectors in a front-projection environment. The output of each projector needs to be warped to correct misalignment and the intensity must be reduced in regions where multiple projectors overlap to create a uniformly lit display. When the display is in use, occlusions must be detected and compensated for in real-time to avoid shadows on the display resulting in loss of information.

With two fully overlapping, calibrated projectors, it is possible to keep every pixel visible when either projector is occluded. By projecting the same image at half-intensity with each projector, everything remains visible when a single projector is occluded. It is possible to completely remove the shadowed region by increasing the intensity of

that region in the unoccluded projector. Unfortunately, detection is made more difficult by the fact that occlusion does not cause the image to disappear in certain regions., but only, to diminish in intensity. Another problem arises when both projectors display the same content at half intensity. It is not possible to determine which projector is being occluded without trial-and-error. We propose a new passive shadow removal technique that does not require any guesswork to identify the occluded projector. Instead of displaying the exact same image on each projector at half intensity, one displays the red channel at full intensity and the other the green and blue channels, also at full intensity. With this method, part of the information is available at each pixel when one projector is occluded. When either projector is occluded, we can immediately determine which one by observing the missing color component.

With occlusion detection, it is possible to completely remove occlusion by adjusting the intensity in each projector in real-time. To demonstrate detection and removal of occlusion, we developed a simple two-projector system where each pixel is illuminated by a single projector at full intensity. Initially, one projector illuminates all the pixels and the other only projects black. At each frame the occlusion map in camera pixels is warped for each projector and XORed with their current intensity map of that projector to remove occlusion. We chose this method to prototype the detection and removal closed-loop system because occluded pixels will appear as black and are easier to detect than when using either passive shadow removal scheme. Ongoing user tracking and 3d reconstruction efforts at the Shared Reality Lab will hopefully lead to a predictive occlusion removal algorithm.

ROBUST ESTIMATION FOR ORIENTATION ANALYSIS

Jeremy Cooperstock, Shawn Arseneau

From trivial edge-detection techniques to the use of a quadrature pair of Gabor filters, the status quo in orientation analysis entails some form of convolution over a window of interest. Although Gabor filters have increased in popularity, most likely due to its computationally efficiency as well as being a viable model for the human visual system, it is not without its flaws. Most prominent of those are the inherent smoothing of high gradient regions resulting from its embedded Gaussian window, as well as its dependency on the single-orientation constraint, which is often violated in the presence of occlusion and motion transparency. We propose a practical alternative to Gabor-type approaches that allows for the presence of multiple orientations, offers increased robustness to noise while preserving such crucial scene elements as lines and edges.

HIGH-RESOLUTION VIDEO SYNTHESIS FROM MIXED-RESOLUTION VIDEO BASED ON THE ESTIMATE-AND-CORRECT METHOD

Jeremy Cooperstock, Stéphane Pelletier

In order to generate a video frame, imaging devices accumulate photons over a 2D matrix of light sensors, whose number determines the maximum achievable resolution of the camera. The exposure (or integration) time of a single frame must be chosen so that each such sensor receives a sufficient number of photons to allow for a statistically accurate measure of the light intensity at its location. This is partly dependent on the surface area of the sensor. A physically smaller element requires a proportionately longer exposure time to produce a usable image, which, in turn, determines the maximum frame rate that can be achieved by a camera; shorter exposure times allow the video device to produce frames at a higher rate. One approach to reducing the exposure time is to increase the size of the lens in order to focus a greater number of photons onto the matrix of light sensors. However, this entails increasing the physical size of the camera and is not well suited for applications requiring near-field focus, as this may result in image distortion. Another solution is

to employ an auxiliary light source to illuminate the scene. This may be limited only to certain applications where additional illumination is both feasible and acceptable.

To increase the frame rate at high resolution of CMOS image sensors, we propose using their non destructive read-out capabilities to simultaneously generate high-resolution frames H at frame rate h and low-resolution frames L at frame rate l. Since low-resolution frames involve the accumulation of incident photons over a larger sensor surface for each pixel and, thus, require less time to integrate than high-resolution frames, the frame rate l of the low-resolution sequence is naturally higher than h. The high- and low-resolution frames represent the same scene and are used respectively to capture high-frequency details and object motion. Our method applies an image-processing algorithm to both sequences of frames H and L in order to synthesize a high-resolution video sequence S, at high frame rate l, containing the detail of the high-resolution frames H and the motion dynamics of the low-resolution frames L.

A motion evaluation algorithm is used to evaluate pixel motion in a coarse manner between the last interpolated (synthesized) high-resolution frame S_{t-1} and the current low-resolution frame L_t generated by the camera. The technique takes advantage of a subsequent correction process to reduce the computational cost of the motion evaluation step without excessively degrading the quality of the synthesized frames. The result is an interpolated frame containing mostly high-resolution and some low-resolution features. The latter, which are smoothed by simple interpolation, tend to appear when abrupt motion occurs in the scene. Because high-resolution frames require a longer exposure time, these are more sensitive to motion blur and thus, the algorithm includes a step to reduce blur to a level equivalent to that of the low-resolution frames.

TOPOLOGY INFERENCE IN DISTRIBUTED SENSOR NETWORKS

Dimitri Marinakas, Gregory Dudek

Problem: We consider the problem of inferring a topological (i.e. qualitative) map of an environment given a set of sensors with non-overlapping fields of view. In this way, without prior knowledge of the environment nor the exact position of sensors within the environment, one can infer the connectivity of the environment, and common traffic patterns within it.

Motivation: Our work considers the self-calibration a sensor network by exploiting existing agent motion in the environment. For many outdoor applications such as large scale monitoring or tracking, a desired property is ad hoc deployability, and yet the sensors will generally be too small and inexpensive to employ advanced Positioning techniques such as GPS. In addition, even if GPS is available, it can not be used for estimating traffic flow or connectivity information. Our method can be used extract connectivity information automatically.

Approach: We describe the problem of topology inference in terms of the inference of a weighted directed graph which captures the spatial relationships between the positions of the sensors' nodes. We model the motion of agents in the environment as a hidden Markov process and then employ a stochastic version of a statistical technique known as Expectation Maximization (EM) to iteratively improve our guess of the underlying Markov parameters.

Challenges: We attempt to solve the network topology problem using very weak assumptions about what the individual sensors are capable of discriminating, and so the main challenge of our work is associating the motion of a particular agent with a given observation. All we demand of the sensors is that they can probabilistically detect and signal the passage of an agent through the region at which they are stationed. Therefore, in addition to the connectivity parameters, we must also solve the data association problem linking particular agents in the environment to observations collected by our sensors.

Applications: The simplest notional application of the work would allow a set of sensors to be ``dropped'' into an environment and to automatically learn the topology of their layout. Additionally, monitoring applications such as those aimed at vehicle traffic flow will be directly interested in inter-sensor connectivity information and parameters further describing vehicle motion.

COOPERATIVE LOCALIZATION IN A SENSOR NETWORK OF CAMERAS

Ioannis Rekleitis, Gregory Dudek

Problem: Consider one or more service mobile robots moving in an indoor environment eg. an art gallery. A network of security cameras is already in place and they are connected to the same network as the robots. The robots move through the environment performing their tasks (cleaning, maintenance, monitoring, surveillance, etc.). The robots communicate and use the cameras in order to augment their environment awareness and also to reduce their positioning uncertainty. The first step toward the realization of the above scenario is to place the cameras in the same frame of reference as the mobile robots. The camera's position and orientation is estimated in the robots world coordinate frame.

Motivation: As cameras are becoming commonplace in many public areas they are yet another resource that can be utilized by an autonomous vehicle. Cameras can be exploited (or are already in use) for environmental observations (e.g. near-shore monitoring), surveillance (indoor and/or outdoor), highway traffic monitoring and control, in intelligent spaces, etc. In most cases though, the cameras are placed in locations that are convenient for human operators with little consideration (or even thoughts) regarding their use by an autonomous mobile robot. In most cases the exact location and orientation (3D pose) of these cameras is not even known with respect to the vehicles frame of reference. In some cases, even the coarse position of such cameras may not be known (i.e. during the setup process). By establishing a common reference coordinate system for all the cameras in a network, as well as for mobile robots moving in the same environment, we can leverage the respective advantages of both the robots and sensors.

Approach: We employ a network of wireless (and wired) cameras dispersed in the environment (two adjoined laboratories) in unknown positions with no overlapping fields of view. A mobile robot equipped with a calibration pattern navigates through free space and stops every time it passes through a camera's field of view. After obtaining a number of images the internal and the external parameters of the camera are estimated. Finally, the 3D pose of the camera is recovered as a function of the pose of the robot for each of the images taken. Different motion strategies employed result in different camera localization accuracies.

Challenges: Creating an automated target detection algorithm that would be robust to varying distances, illuminations and orientation is one of the many challenges of this project. After the process is automated, finding optimal trajectories for the robot in order to minimize path travelled and maximize localization accuracy is a very interesting problem that can be used in a variety of other applications.

Applications: With the introduction of mobile robots in a variety of roles (cleaning, vacuuming, surveillance, environmental condition monitoring) even preexisting surveillance cameras, as well as other sensors, can be utilized to improve robot pose estimation and to contribute additional sensory input.

UNDERWATER VISUAL SERVOING FOR AQUA (AN UNDERWATER ROBOT)

Junaed Sattar, Gregory Dudek

Problem: Detection and tracking of pre-determined targets is an important application in robotics and vision, as well as many other fields of engineering. Different algorithms and techniques exist, but none so far for underwater visual target tracking. The underwater environment creates interesting and often difficult challenges for both visual tracking and robot control that also need to be addressed.

Motivation: A simple line following behaviour has been implemented for the RHex hexapod robot, enabling it to follow a line drawn on a flat terrain. To accomplish this, the vision sensors on the robot were programmed to generate proper control signals for controlling the robot gaits dynamically. Underwater mobile target tracking and following for the AQUA robot requires tighter

coordination between the vision and control modules.

Approach: A detailed study of existing methods of visual servoing and robot control systems were undertaken. Based on this study, a visual target tracking algorithm is being developed taking into account the unique characteristics of the underwater environment. This tracker is used to generate control signals and gait selection commands for the control mechanism on board the AQUA robot. To select proper gaits based on the output of the vision module, a mapping from higher dimensional parameter space to a particular gait needs to be performed.

Challenges: The underwater environment poses unique challenges to vision and control realms, rendering a lot of existing algorithms inapplicable. The robot moves around in six degrees of freedom, therefore the issue of stability is a major concern for any control algorithm. The visual tracker needs to track and generate control signals within a real-time constraint. Choosing the proper gaits for a given output from the tracker is also a problem requiring thorough analysis.

Applications: Direct applications of this work may be found in marine biology, underwater exploration, search-and-rescue operations and many more.

PROCEDURAL TEXTURE MATCHING AND TRANSFORMATION

Eric Bourque, Gregory Dudek

We have worked on an area of computer graphics which relates to the appearance of surfaces in 3D rendered images. Conventionally, the appearance of surfaces is controlled through the application of what are known as texture maps, that is, digital images which are applied directly to the surface in the model. For example, to simulate wood grain on a table, one would take a suitable digital image and apply it to the plane representing the table's surface. This method of texturing is costly both in terms of time and storage since each image must first be found and then stored with the model.

More recently, a technique has been developed which can generate suitable textures on the fly, without the need for finding and storing large texture images. This is called procedural texturing, a process whereby the appearance details of a particular surface are modeled implicitly. There are numerous advantages to using procedural textures, notably, they can be rendered at arbitrarily high resolutions without losing detail (needed for motion pictures), and they are very compact, and hence do not require a lot of storage. The main disadvantage of procedural texturing is that it can be difficult to determine the parameters necessary to replicate a desired appearance.

In general, selecting a procedural texture from a library, and finding the correct parameters to produce a good perceptual match to a given target texture sample can be complex and time consuming. Our work has addressed this problem using a two-stage search strategy: first a global search is performed to find the best candidate parameter vectors based on a perceptual similarity function, and secondly, a local optimisation step is performed on the top candidates in order to refine their appearance to best match the target texture. The perceptual similarity function is based on histogram matching of Laplacian pyramids corresponding to the images being compared. The method has been further extended to create temporal textural transformations, such as might be necessary for rendering animations of objects whose properties change over time.

Transformation between two textures is achieved procedurally, while enforcing perceptual similarity constraints between adjacent texture frames. We proposed a technique for efficiently sampling the parameter domain of a procedural texture based on a texture similarity function to create a smooth path through its texture range. In the case of evolving between several procedural textures, we developed a method to obtain the best jump-points which can be used to connect different procedural textures smoothly in texture space. This work was recently published in "Computer Graphics Forum", an international graphics journal.

RANGE SYNTHESIS FOR MOBILE ROBOT ENVIRONMENT MODELING

Abril Torres-Méndez, Gregory Dudek

Problem: We address the problem of inferring geometric structures from images. Specifically, we solve the problem of synthesizing range data to enhance the reconstruction of a 3D model of an indoor environment. We allow a mobile robot to rapidly collect a set of images and very limited amount of range data from the environment and then infer the rest of the map it does not capture directly.

Motivation: Our goal is to facilitate the building of 3D environment models by exploiting the fact that both video imaging and limited range sensing are ubiquitous readily-available technologies while complete volume scanning is prohibitive on most mobile platforms. In robotics, the fusion of ranged data with visual information for navigation and mapping is particularly appealing, as it can be used for several important applications. However, it is often hampered by the fact that sensors that provide complete (2 1/2D) depth maps with a resolution akin to that of a camera are prohibitively costly or otherwise impractical. Stereo cameras produce volumetric scans that are economical, but they often require calibration or produce range maps that are either incomplete or of limited resolution.

Approach: Our method is based on learning a statistical model of the (local) relationship between the observed range data and the variations in the intensity image and uses this model to compute unknown depth values. The spatial relationships between the variations in intensity and range can be efficiently captured by the neighborhood system of a Markov Random Field (MRF). In contrast to classical approaches to depth recovery (i.e. stereo, shape from shading), we can afford to make only weak assumptions regarding specific surface geometries or surface reflectance functions since we compute the relationship between existing range data and the images that we start with.

Challenges: The problem of inferring the 3D layout of space is a critical problem in robotics and computer vision, and is often cited as a significant cognitive skill. In the vision community, solutions to such "shape from X" problems are often based on strong prior assumptions regarding the physical properties of objects in the scene. In the robotics community, such depth inference is often performed using sophisticated but costly hardware solutions. We seek to reconstruct suitable 3D models from sparse range data while simultaneously facilitating the data acquisition process. In our method, we exploit the assumption that range and intensity images are correlated, albeit in potentially complicated ways and we do not depend on prior knowledge of reflectance or on surface smoothness or even on surface integrability (which is a technical precondition for most shape-from-shading methods, even where not explicitly stated). Additional challenges include the registration of the two sensors with respect to each other, the integration of all range-intensity maps to a common coordinate frame, and the final compact 3D model representation of the environment.

Applications: A large number of indoor mobile robots rely on environment maps for navigation and so be able to achieve their task. Also, 3D models are useful for a range of applications, such as building design, architecture, rescue tasks, virtual reality, etc.

SENSING FOR UNDERWATER ROBOTS (AQUA)

Gregory Dudek, C. Prahacs, M. Jenkin (York), E. Milios (Dalhousie), I. Rekleitis and others

Project AQUA is a joint research project between Dalhousie University, York University, and McGill University involving the development of an autonomous underwater hexapod robot. Several McGill projects relate to AQUA including the design and development of the vehicle itself, the swimming mechanism, the vision-based localization methods and 3-D inference from underwater monocular images.

Theme 3
Integration of Human Inhabitants in Virtual World

HUMAN HEAD POSE TRACKING IN THE CONTEXT OF CAR DRIVING

Martin Breton, Denis Laurendeau

Problem: The goal of this project is to determine the head pose (orientation and position) of a person in the context of car driving. The human head being able to move from left to right, up and down, the system must be able to determine the orientation on about 180 degrees about all axes, or the equivalent of half a sphere.

Motivation: Car driving is a task that implies a strong perceptual component. It is intuitive to think that there is a direct relationship between the deterioration of many visual capabilities and the possibility of having an accident.

In the case of our elders, even though they show a deterioration of many visual capabilities (acuity, greater glare and contrast sensibility), very few direct relationships have been established between these measurements and road accidents.

This project is part of a collaboration with the GRAME (Groupe de Recherche en Analyse du Mouvement et Ergonomie) and will be part of an instrumented simulator developed to measure the behaviour of the driver in a controlled virtual environment.

Approach: A static and calibrated pair of cameras will be used as well as a target with markers in the form of a hat worn by the driver. The cameras will be placed on each side of the driver, facing him/her so that we can see the face from two different angles. This will allow the 3D position of the markers and thus the pose of the head to be obtained.

Challenges: It can happen that part of the driver's face is not visible from one of the cameras. The system has to estimate a pose nonetheless. The system must also be robust and precise.

Applications: The results will be used by the researchers of the GRAME in their study on Car driving and getting older.

Expected results: The head pose is expected to be found for each video frame of the sequence.

CONCEPTION LOGICIELLE EN RÉALITÉ VIRTUELLE APPLICABLE AUX ARTS DE LA SCÈNE

Christian Dompierre, Denis Laurendeau, Alexandra Branzan-Albu

Problème: Dans le cadre des travaux du LANTISS (Laboratoire des nouvelles technologies de l'image, du son et de la scène), l'équipe du Laboratoire de vision et systèmes numériques travaille à la mise au point d'un outil pour la mise en scène collaborative. Cet outil est formé de deux composantes: i) un castelet réel, sorte de théâtre miniature permettant aux metteurs en scène d'avoir une réplique en taille réduite de la scène et ii) un castelet virtuel, qui est une représentation virtuelle du castelet réel. L'avantage de disposer d'un castelet virtuel est qu'il rend possible à plusieurs utilisateurs d'intervenir à distance, via le réseau Internet, pour modifier le contenu du castelet électronique et ainsi à collaborer à une mise en scène. Or, dans de telles applications, il est important qu'il existe une adéquation entre le contenu du castelet réel et du castelet virtuel. C'est ce problème que nous abordons dans le cadre de notre projet de maîtrise.

Motivation: Notre projet de recherche s'intéresse à trois aspects du projet de castelet électronique. Le premier aspect porte sur le tracking, via des caméras 2D, d'objets se déplaçant dans le castelet réel. L'objectif de cette partie du projet est d'estimer la position et l'orientation d'objets dans l'espace cartésien à trois dimensions et de

transmettre celles-ci aux objets correspondants dans le castelet virtuel. Le deuxième volet du projet vise à déplacer des objets dans le castelet virtuel (les objets sont ici visualisés en 3D grâce à des lunettes stéréoscopiques) et, via une interface 3D, de permettre à l'utilisateur de déplacer les objets du castelet réel afin que leur position et leur orientation correspondent à celles des objets du monde virtuel. La vision artificielle sert ici d'interface avec le monde virtuel. Le troisième volet de notre projet consiste à rendre collaborative les interactions réel-virtuel mentionnées ci-dessus. Cela implique que l'environnement virtuel est maintenant partagé par plusieurs utilisateurs et que ceux-ci peuvent travailler en collaboration sur une mise en scène via le réseau tout en conservant une réplique du castelet réel en parfaite correspondance avec celle du castelet virtuel.

Approche: Les étapes principales du projet sont les suivantes: 1. Familiarisation avec les algorithmes de tracking d'objets en 3D par des caméras 2D (exploitation de ARToolKit); 2. Familiarisation avec les outils de visualisation graphique 3D dans les environnements virtuels (VTK); 3. Familiarisation avec les outils d'interaction avec les environnements virtuels (spacepuck, gant de VR); 4. Mise en oeuvre des algorithmes de tracking 3D par des caméras 2D et transfert de la position et de l'orientation à leurs correspondants dans le monde virtuel.

SEGMENTATION ET DESCRIPTION DES MOUVEMENTS CYCLIQUES D'OBJETS ARTICULÉS À PARTIR DE SÉQUENCES VIDÉOS VIA UNE REPRÉSENTATION SQUELETTIQUE DE L'OBJET

Sébastien Quirion , Robert Bergevin, Alexandra Branzan-Albu

Problème: La reconnaissance d'activités par un système de vision numérique fait l'objet de plusieurs recherches depuis quelques années et plusieurs y ont déjà apporté des solutions intéressantes. Toutefois, dans la majorité de ces recherches, les solutions proposées fonctionnent sous l'hypothèse qu'il n'y a qu'une activité dans la séquence vidéo analysée. Par contre, dans une application réelle, que ce soit pour un système de surveillance localisé dans un aéroport ou dans un système d'assistance aux personnes âgées, les séquences vidéos analysées peuvent comporter un grand nombre d'activités exécutées les unes après les autres (ex.: marcher, courir, puis saluer). Nous nous proposons donc d'extraire automatiquement les activités d'une séquence vidéo en utilisant l'information fournie par un modèle de squelette représentant l'évolution temporelle d'un être humain ou d'un autre objet articulé. Notre méthode s'appliquera à n'importe quel format de squelette décrit en terme de joints reliés par des segments de droites. Nous pourrons donc fournir des séquences ne comportant qu'une seule activité aux algorithmes de reconnaissance d'activités, remplissant ainsi leur hypothèse de départ.

Approche: L'approche proposée est basée sur une analyse de périodicité de signaux 1D. Cela nous permet d'utiliser des théories propres au traitement de signal, un domaine largement plus exploré que celui de la segmentation temporelle de séquences vidéos. Notre approche se divise en quatre étapes. Dans un premier temps, nous devons identifier quels signaux 1D, de ceux pouvant être déduits d'une séquence de squelettes (ex. : angle entre deux joints du squelette à chaque temps, vitesse du centroïde de tous les joints, position en X d'un joint à chaque temps, etc.), portent le plus d'information quant aux activités effectuées par le squelette. La deuxième étape consiste à élaborer un algorithme permettant une segmentation robuste d'un signal 1D en parties cycliques. Suite à cette étape, nous devons élaborer un algorithme permettant de combiner les segmentations obtenues sur tous les signaux retenus afin d'obtenir une segmentation unique pour la séquence vidéo traitée. L'étape finale consiste à fournir une description des activités isolées par notre segmentation de façon à exprimer quels signaux contribuent à chaque activité et dans quelles proportions.

Défis: Bien que cela soit très simple pour un être humain, la segmentation automatique en activités d'une séquence vidéo comporte plusieurs difficultés. Afin de pouvoir segmenter efficacement des vidéos montrant un sujet humain, notre système devra être robuste aux petites variations qu'un être humain peut introduire dans différents cycles d'une même activité. Il devra aussi tenir compte de la possibilité pour un être humain, ou un autre objet articulé de superposer plusieurs activités (tel que marcher en saluant). De plus, afin de ne pas limiter ses possibilités d'application,

notre système devra tenir compte du bruit dans les signaux d'entrée. Ce bruit se traduit visuellement par un mauvais positionnement du squelette par rapport à la position du sujet dans l'image d'origine. Tout dépendant du processus d'ajustement du squelette, ce bruit peut avoir plusieurs origines. Par exemple, il peut provenir d'un processus de soustraction d'arrière-plan qui fournira une silhouette difforme ou encore d'un processus d'ajustement d'un squelette sur une silhouette, qui peut mal interpréter une silhouette et y ajuster un squelette erroné. Notre système devra donc faire preuve d'une grande robustesse face à ce bruit quasi-inévitable dans nos séquences. Finalement, un défi de taille sera d'assurer la validation des algorithmes développés.

Applications: Notre projet de recherche fournira des descripteurs robustes aux systèmes de classification et de reconnaissance d'activités. Notre contribution originale se situe au niveau de l'extraction des caractéristiques pour la reconnaissance statistique des formes appliquée à l'analyse de mouvement.

INTERFACE HOMME-MACHINE PERMETTANT À L'UTILISATEUR D'UN ENVIRONNEMENT VIRTUEL DE SIMULER L'ACTION DE MARCHER DANS UN MONDE VIRTUEL AINSI QUE DE RESSENTIR LA TOPOGRAPHIE DE CE DERNIER

Régis Poulin, Denis Laurendeau, Clément Gosselin

Les chercheurs du Laboratoire de robotique (Directeur Dr. Clément Gosselin, Département de génie mécanique) et du Laboratoire de vision et systèmes numériques (Directeur Dr. Denis Laurendeau, Département de génie électrique et de génie informatique) sont actuellement à développer une plate-forme de marche ("locomotion interface") permettant à un utilisateur de se déplacer dans un environnement virtuel comme s'il se déplaçait dans un environnement réel. La plate-forme de marche sera dotée d'une interface réseau lui permettant de transmettre les paramètres de marche de l'utilisateur sur un réseau local (réseau Ethernet). Ainsi, la position, l'orientation et la vitesse de l'utilisateur pourront être connues de l'environnement virtuel et, en contrepartie, le contenu de l'environnement virtuel sera également connu de la plate-forme de marche qui pourra ainsi recréer le profil du terrain pour l'utilisateur. L'utilisation de plusieurs exemplaires de cette plate-forme permettra de créer des scénarios réalistes d'opérations de groupe impliquant plusieurs personnes oeuvrant dans des environnements virtuels. Les applications militaires en milieu urbain ou les applications de recherche et de sauvetage sont des exemples concrets d'applications de la plate-forme de marche avec interface réseau.

De plus, la plate-forme de marche pourra être utilisée dans des applications de réadaptation car elle offrira aux thérapeutes un environnement parfaitement contrôlé grâce auquel ils seront en mesure de planifier les exercices de marche adaptés au patient.

L'architecture qui a été retenue pour la plate-forme se démarque significativement des systèmes proposés actuellement dans la littérature, notamment les systèmes basés sur les tapis roulants omnidirectionnels. En effet, la plate-forme proposée repose sur deux mécanismes parallèles à six degrés de liberté actionnés par des câbles (un mécanisme par pied). Le mécanisme parallèle présente de nombreux avantages dont une bande passante mécanique élevée et un contrôle de grande précision. L'utilisation de câbles comme actionneurs permet d'autre part de réduire le poids et l'encombrement du mécanisme.

Mon projet s'inscrit dans le cadre du projet décrit ci-dessus. Je devrai d'abord étudier les exigences que doit satisfaire la plate-forme par rapport à l'application de marche et ainsi définir l'enveloppe de travail requise pour recréer un environnement de marche réaliste. Ensuite, je devrai étudier les différentes approches permettant de garder la plate-forme de marche dans sa position optimale de fonctionnement tout en faisant en sorte que l'utilisateur ait l'impression de marcher sur une surface infinie alors qu'il ne se déplace en réalité que très peu. Les filtres utilisés dans les simulateurs de vol sont des exemples dont je pourrai m'inspirer.

La troisième étape du projet sera de participer, avec d'autres chercheurs, à la conception et à la mise au point d'un prototype miniaturisée de la plate-forme et à la conception et à l'implantation des algorithmes de contrôle de celle-ci.

MODELING A HUMAN SILHOUETTE USING A SKELETON AND ITS PARTS

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 are feasible.

Applications: Applications of such a project are numerous. For instance, parking lots, airports and other public areas surveillance, assisted car driving, perceptual man-computer interfaces and learning of sport movements to name only a few.

MODELING MULTI-PART MANUFACTURED OBJECTS

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 are perceiving 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 are based on the second theory. Hence, the theoretical representation model is an attributed graph where the nodes are simple volumetric primitives and the arcs reflect the spatial arrangements of the volumetric primitives. The second theory is used in the algorithms for building the model. The volumetric primitive 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 requires 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.

CHARACTERIZATION AND MATCHING OF IMAGE REGIONS FOR THE COMPARISON OF HUMAN SILHOUETTES

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.

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.

MANAGEMENT OF THE TEMPORAL CONFORMITY OF A DYNAMIC VIRTUAL ENVIRONMENT

Éric Boivin, Denis Poussart, Denis Laurendeau

Problem: To be able to update a virtual environment (VE) scenario while it is being used is a most attractive concept. This would allow interruptions in the virtual experience to be avoided following the application of a modification in the VE. Several software strategies, such as the dynamic upload of components, have enabled the modification of a scenario to become an easily executable operation. However, these modifications must be monitored to a high degree to ensure the maintenance of conformity with the defined virtuality.

Motivation: The progress in the modelling of dynamic environments has given rise to several VE challenges. In addition to the reuse of models, any form of dynamism can have positive effects on the dynamic scenario, the consolidation of persistent VEs and the improvement of the accessibility and emergence of a profitable business model.

Approach: The development of VEs has been heavily laden with a past motivated by distribution. Initial motivations concentrated their actions on technology considerations which have changed significantly over time. The proposed project will be oriented towards a more conceptual approach where influences associated with technology and distribution will be more discrete.

Challenges: The classification of various forms of dynamism, the clarification of the dependence phenomenon between models of a VE, the maintenance of conformity with the defined virtuality and the gradual automation of the planning of the execution sequence are all necessary objectives when striving towards a dynamic VE. In this regard, the understanding of various sub-concepts associated with dynamism, such as the scale, the extensibility, the interoperability and the ability to build virtual models are unavoidable prerequisites.

Expected results: In order to restrict the research area, aspects related to distribution such as parallelization, load balancing, the addition of resources and remote users will not be dealt with. Moreover, finding a real-time solution is not a priority.

MODELING THE GAIT AND APPEARANCE OF A PERSON FROM A VIDEO SEQUENCE

Frédéric Jean, Robert Bergevin, Alexandra Branzan-Albu

Problem: The tracking and detection of people by means of a computerized system of cameras has been the subject of many research projects in the recent time. Several techniques have been developed to solve this problem, in a more or less efficient manner. It would be interesting to be able to detect and track people using more natural criteria, such as the gait and appearance of a person. A person's gait is mainly characterized by the position of each of his limbs and the movement he carries out over time, whereas the appearance is associated with colours and textures. Consequently, the problem consists in modeling the gait and appearance of a person using a sequence of skeletons as well as colour and texture descriptors obtained from a video sequence.

Motivation: This problem is part of the MONNET project (Monitoring of Extended Premises: Tracking Pedestrians Using a Network of Loosely Coupled Cameras) whose primary objective is to develop a computer vision system enabling the tracking in real time of people in various locations for security and surveillance reasons. The system consists in a network of cameras linked to loosely coupled computing nodes which can communicate among themselves the information they have gathered in order to detect and track people.

Approach: The problem involves several steps. First a filtering and prediction of a sequence of skeletons in real time must be carried out so as to eliminate or modify the undesirable cases (outliers). Then, the particularly interesting skeletons must be identified (for example, those where the face is clearly visible) and a list of prototype skeletons must be defined which represents all of the skeletons within a certain time interval. Finally, the filtered sequence of skeletons will be used to develop a model of the gait and appearance of a person. These models can then be used as a comparison when viewing the gait and appearance of people.

Challenges: This type of system is not easy to design since it must function in real time, be robust and have a minimum of constraints. The system will be composed of several modules which must be executed one after the other in a minimal time frame for each of the images in a video sequence. The system will be confronted with a variety of situations such as the differences in the distance of people with respect to the cameras, the different points of view in which people will be observed, the occurrence of certain particular movements (picking up an object), the colour of the clothes (for example clothes whose colour is similar to that of the background), etc. All of these situations will make the task of modeling the gait and appearance of people more challenging. Moreover, the choice of models is a challenge in itself and will greatly influence the results obtained. This is also the case for the choice of the time scale (or window) in which the calculations will be conducted.

Applications: This system will enable the tracking and detection of people in various environments for particular applications such as the surveillance of public areas in order to prevent or detect unexpected and potentially dangerous events. The system could eventually be used in airports, schools, retirement homes, 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 conçue. 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.

SOFTWARE INTERFACE FOR DISTANT CO-OPERATIVE WORK IN AN AUGMENTED REALITY CONTEXT

François Dinel, Denis Laurendeau

Problem: Cooperative remote work implies that several users in different physical locations interact simultaneously in the same augmented reality environment. The goal of this project is to develop a software platform enabling two users in two different physical locations to manipulate simple objects belonging to a virtual environment residing on a server. The first part of the project involves the development of a portable software interface facilitating the use of a glove in the context of object manipulation. The second part of the project involves the development of a software platform enabling two users to visualize the virtual environment on two different 3D displays (and connected to the server containing the description of the virtual environment via a high speed Ethernet link) and to manipulate the objects located in this environment using the glove.

Motivation: Cooperative remote work in the context of augmented reality enables tasks to be performed which require cooperation between users in different locations. Numerous reasons can prevent several users from being at the same place at the same time. This project aims towards allowing these tasks to be completed despite distance barriers.

Approach: The research methodology consists in carrying out a literature review of comparable systems. We will then analyze the needs with respect to the application considered and define the software architecture which will address these needs. The architecture will be implemented using C++ and the prototype will be tested on the virtual reality platform of the Computer Vision and Systems Laboratory at Université Laval.

Challenges: The main challenge of this project involves the development of a software platform which will take into consideration the inherent constraints in the use of a network and exploit the quality of service resources offered by different communication links.

Applications: Cooperative work in the context of augmented reality is at the forefront of technology, allowing interaction with other people and/or objects in complex simulations in several areas such as national defense, urban operations and medicine. In fact, this project is being carried out in cooperation with the RDDC-DRDC Valcartier.

Expected results: It is expected that the software interface for the glove will be completed, as well as the software interface for remote work. This project will be carried out using the methodologies proposed by software engineering.

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.

AUTOMATIC SEGMENTATION OF THE BONY STRUCTURE OF THE SHOULDER

Nhat-Tan Nguyen, Denis Laurendeau, Alexandra Branzan-Albu

Problem: Many problems in endoprosthesis placement are due to limited pre-operative insight into the patient's state. Most patients have rheumatoid arthritis, which affects the quality and shape of the bone: often the glenoid cavity at the shoulder blade has receded. Preoperatively, the operation plan must be devised on the basis of 2-D Roentgen images. During surgery, the operation field is very limited, only the articular surface of the scapula is exposed. The patient is positioned on his side, with the affected shoulder pointing upwards, resulting in a downwards slide of the shoulder blade. During surgery, the most commonly used technique is to remove the remaining cartilage, mill the endoprosthesis shape in the trabecular bone, apply a certain amount of bone cement, place the endoprosthesis and insert screws for early fixation. Others approach the operation field from the back side of the patient by splitting the scapula in two pieces. A preferred technique will support the endoprosthesis on the cortical bone, and try to restore a functional position and orientation. Therefore, a custom-sized prosthesis has to be used, and a good view of the shoulder blade is needed.

Motivation: Automatic segmentation of bony structures in MRI angiography datasets is an essential pre-processing step necessary for most visualization and analysis tasks. In order to have a better understanding of the healthy and pathologic arthrosis shoulder, this project will develop a method to segment the structures of the shoulder from MRI datasets.

Approach: Finding suitable techniques for segmenting the scapula and humerus in a bidimensional MRI data-set is a major part of this project. Currently we focus on contours-based segmentation techniques, i.e., first a point of the bone is identified. The bone boundaries are extracted in a second step.

CATEGORISATION PAR REGROUPEMENT PERCEPTUEL METHODOLOGIE ET SEGMENTATION

Vénérée Randrianarisoa, Robert Bergevin

Problème: Les recherches en psychologie cognitive ont établi que même en absence de connaissances de haut niveau de la scène observée, le système visuel humain organise naturellement les éléments selon des lois appelées lois de regroupement perceptuel. Ainsi, le système visuel humain tend à grouper ensemble deux éléments qui sont symétriques, similaires, proches, parallèles, etc.…. David Lowe en a tiré sa théorie de non-accidentalité. Cette théorie stipule que des primitives ou des groupes de primitives ayant des caractéristiques perceptuelles telles que la similarité, le parallélisme, la symétrie, etc.… ne sont pas présentes par hasard dans l'image mais qu'ils doivent être issus d'un même objet ou d'un ensemble d'objets dans la scène.

Le but du regroupement perceptuel est alors d'exploiter ces caractéristiques perceptuelles pour extraire une organisation structurelle qui représenterait un objet ou un groupe d'objets perceptuellement significatif.

La plupart des méthodes de regroupement perceptuel existantes utilisent des caractéristiques perceptuelles unaires ou binaires. Par ailleurs, elles suivent une hiérarchie ascendante : ainsi, les primitives les plus saillantes respectant les lois de regroupement perceptuel sont groupées pour former un groupe qui devrait être perceptuellement significatif. Le problème qui apparaît dans ces approches est qu'elles ne proposent pas des critères globaux permettant d'évaluer la qualité globale du groupe perceptuellement saillant, car elles utilisent essentiellement des critères locaux liés aux caractéristiques perceptuelles locales.

Par ailleurs, très peu de travaux utilisant des critères globaux proposent des méthodes qui traitent des groupes larges, c'est à dire formés par un grand nombre de primitives, la plupart traitent de groupes simples tels que des groupes convexes, des rectangles, des polygones…

Motivation: Notre approche diffère essentiellement de ces approches de par le fait que nous proposons de déterminer un ensemble de critères perceptuels globaux qui permettent d'extraire une catégorie d'objets. Ces critères permettront d'évaluer la qualité de la segmentation afin de déterminer si le groupe formé est perceptuellement significatif d'une part, et s'il a une bonne forme perceptuelle d'autre part.

Approche: Notre approche consiste à déterminer des critères optimum d'un objet multi-parties par des observations subjectives humaines, à formaliser les critères de qualité globaux définis par l'humain, à extraire les primitives qui optimisent ces critères de qualité globaux.

Pour déterminer ces critères globaux, nous utilisons une méthodologie appelée méthodologie SAFE (Subjectivity and Formalism Explicitly). Le but de cette méthodologie est de valider le jugement humain que nous appelons SGT (Subjective Ground Truth) par le jugement issu de calculs formels que nous appelons FGT (Formal Ground Truth).

Ainsi, la comparaison du jugement subjectif humain à celui du jugement formel permet d'utiliser une vérité-terrain subjective (ground truth) utile pour évaluer et valider l'algorithme proposé.

Afin de mettre en oeuvre la méthodologie SAFE dans le cadre du regroupement perceptuel, nous avons mis en place un nouvel outil, SAFE-T, avec un étudiant au deuxième cycle, Jean-François Bernier. Cet outil interactif permet de générer manuellement et automatiquement des groupes formés de primitives à courbure constante (arcs de cercle et segments de droites).

Défis: La catégorisation d'objets devrait utiliser les mêmes critères que le système visuel humain pour classer un objet comme appartenant à un groupe donné. L'extraction d'un groupe perceptuellement significatif (gestalt) est un défi important mais encore plus est l'évaluation perceptuelle de ce groupe, telle que sa bonne forme représentée en psychologie cognitive par le « pragnanz ».

Application: Nous appliquons notre approche dans la recherche des critères perceptuels globaux pour trouver la silhouette d'une catégorie d'objets, à savoir des objets multi-parties. Toutefois, l'approche pourrait être affinée par la suite vers la catégorisation d'objets plus spécifiques. Une des applications est la recherche d'images par le contenu (CBIR).

Résultats attendus: Les résultats attendus de ce projet sont la définition et la validation d'un ensemble de critères perpectuels globaux afin de catégoriser des objets multi-parties.

MODÈLE DÉFORMABLE 2D ET 3D POUR L'AIDE À LA PLANIFICATION ET AU DIAGNOSTIQUE EN IMAGERIE MÉDICALE

Geoffroy Rivet-Sabourin, Alexandra Branzan-Albu, Luc Beaulieu

Le projet consiste à élaborer des modèles déformables 2D et 3D pour la planification de l'intervention de curiethérapie et pour le diagnostique de maladies valvulaires.

Dans un premier temps, il s'agit d'élaborer un modèle de déformation de la prostate sur une période de 30 jours suivant l'intervention de curiethérapie en utilisant un modèle déformable 3D. Une fois ce modèle réalisé il permettra d'ajuster la planification de l'intervention pour tenir compte de la déformation de la prostate dû à l'œdème post-opératoire.

Dans un deuxième temps le projet consiste à utiliser des modèles déformables 2D (contours actifs) pour l'analyse de la cinématique de la valve aortique. L'intérêt est de faire une segmentation automatique de l'ouverture de la valve sur toutes les trames d'une séquence d'échographie cardiaque. Cet outil nous permettra de tracer un graphique de l'aire de l'ouverture de la valve en fonction du temps.

LIVER TUMOUR DETECTION USING MR IMAGES

Chen Xu, Denis Laurendeau

The SKALPEL-ICT collaborative project aims at developing a Simulation Kernel Applied to the Planning and Evaluation of Image-Guided Cryotherapy. Input data for the design of this virtual environment consists in sequences of Magnetic Resonance (MR) images of liver cancer, image acquisition parameters, and measurements of mechanical tissue properties. The prototype system developed during this project offers three operating modes. The surgery planning mode computes the optimal configuration of the interventional cryoprobes by using geometric models of the liver, the intra-hepatic vascular system, and hepatic tumours. Predicting the spatio-temporal expansion of the iceball is relevant for this mode as well. The intra-operative assistance mode offers an augmented reality environment, providing additional information such as the dynamic temperature map inside the growing iceball. This information is essential for the success of the intervention, because cellular death occurs at beyond 0°C, where magnetic resonance does not exist. The training mode implements a virtual environment containing entities such as a virtual patient, virtual cryoprobes, etc.

As part of the SKALPEL research project SKALPEL, the main objective of the work is to develop automatic image segmentation and 3D reconstruction techniques used for liver tumour detection in a sequence of MR images. The detection procedure includes three parts.

First, the segmentation of the liver region in the MR image is performed. Then, the objects (tumour or blood vessel) inside the segmented liver region are detected and segmented by using some fully automated segmentation methods. The methods are designed such that no user intervention will be required.

The results of the 2D segmentation of liver objects are further used to reconstruct 3D objects in order to identify the liver tumour and blood vessel based on their different 3D geometric structures.

DISTRIBUTION DES CALCULS DE MODÉLISATION VISCO-ÉLASTIQUE NON-LINÉAIRE DES DÉFORMATIONS DU FOIE EN CRYOTHÉRAPIE

Clovis Simo, Denis Laurendeau

Pour la plupart des applications de simulation en temps réel, la parallélisation est vue comme une solution afin d'accroître la performance. Ceci est d'autant plus vrai pour les applications scientifiques et d'ingénieries qui demandent beaucoup de puissance de calcul. Nous nous intéressons plus particulièrement à un simulateur chirurgical pour déformation des tissus mous.

Dans le cadre du projet SKALPEL[1], le Laboratoire de Vision et Systèmes Numériques (LVSN) de l'Université Laval et le Centre Hospitalier Universitaire de Québec (CHUQ) ont comme objectif de développer conjointement un système de simulation de la cryochirurgie du foie. Ce simulateur permettra aux chirurgiens de s'entraîner et de planifier certaines interventions. La conception d'un tel simulateur implique de nombreuses contraintes telles que la disposition de modèles géométriques précis des organes, la modélisation de façon réaliste du comportement mécanique des tissus, le rendu graphique en temps réel à une fréquence d'au moins 30 Hz ainsi qu'un rendu haptique d'au moins 300 Hz.

Dans la suite des travaux réalisés par Jean-Marc Schwartz (JMS) au cours du projet SKALPEL, l'aspect temps réel de la simulation des maillages volumineux a été étudié en profondeur. L'objectif principal était d'obtenir une performance proportionnelle au nombre de processeurs utilisés. Afin d'y parvenir, les calculs ont été distribués sur une grappe d'ordinateurs de type Beowulf. L'équilibrage de charge statique a été rendu possible grâce à un partitionnement adéquat du maillage entre les différents nœuds de calcul à l'aide de la librairie METIS[2].

Nous avons conçu une architecture orientée objet robuste et flexible de type Client-Serveur. Cette architecture est constituée d'un module d'affichage, d'une sonde et d'un simulateur parallèle fonctionnant avec le système d'exploitation Linux. Le simulateur parallèle est composé d'un serveur et de plusieurs clients agissant respectivement en tant que maître et esclaves. L'exécution simultanée des calculs a été possible grâce à divers mécanismes de parallélisation tels que la synchronisation, l'ordonnancement, la collaboration et les communications inter-processeurs par passage de message en utilisant la librairie ACE[3].

Les résultats obtenus au terme de cette recherche prouvent que le modèle séquentiel développé par JMS est parallélisable, montrent qu'on peut obtenir une bonne capacité de mise à l'échelle et confirment la nécessité d'effectuer un équilibrage de charge dynamique sur les nœuds de calculs. Ce travail n'aborde toutefois pas l'implémentation de ce système de simulation temps réel dans un environnement de réalité virtuelle de même que l'intégration d'une interface haptique. Par ailleurs, on assume que la topologie du maillage est statique durant la simulation.

[1]http://vision.gel.ulaval.ca/fr/Projects/IdEns_11/index.php
[2]http://www-users.cs.umn.edu/~karypis/metis/
[3]http://www.cs.wustl.edu/~schmidt/ACE.html

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.

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

James J. Clark, Li Jie

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 remain 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). Past work in our lab has shown that microsaccadic eye movements are correlated with covert attention shifts. We have recently extended this work to the case of attention shifts during ocular pursuit of moving targets. 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. We are currently constructing a demonstration system using a simple video game, which will allow us to test how our attention-tracking techniques can be used to alter task performance.

ABNORMAL SITUATION DETECTION IN VIDEO SURVEILLANCE

James J. Clark, Vinod Nair, Sandra Skaff, Trevor Ahmedali, Carmen Au

Problem: Detection of novel or anomalous situations in a video sequence.

Motivation: In building security applications it is important to not present too many false alarms. We want to tackle this problem by detecting only those situations which are out of the ordinary.

Approach: Our approach is in two parts. The first involves detection of people in surveillance images. We have accomplished this with an on-line machine learning system that uses a cascaded classifier to distinguish people from the background. The second part involves a similarity filter, which looks at a video stream and passes through only those images which are determined to be sufficiently different than all images in the previous stream.

Challenges: The main challenges here are practical, involving reduction of computational load and managing memory requirements. Our intention is to implement our techniques in an inexpensive real-time system, where computation and storage requirements must be kept low.

Applications: The primary application is to area surveillance, such as in office buildings or warehouses. Other applications involve automatic video editing (such as re-run detection and commercial removal) and data mining (search for novel images in a database).

VIEW SYNTHESIS

Jeremy Cooperstock, Jianfeng Yin

Acquiring video of users in a CAVE-like environment and regenerating it at a remote location poses two problems: segmentation, the extraction of objects of interest, i.e. people, from the background, and Arbitrary View Generation or view synthesis, to render the video from an appropriate virtual camera. We wish to achieve these tasks at video rates in order to support real world applications.

As the background is dynamic and complex, naive segmentation techniques such as blue screening are inappropriate. However, we can exploit available geometric information when dealing with fixed screens or walls. Assuming our cameras are fully calibrated, we can register all background pixels with the environment empty and then, during operation, determine whether each pixel corresponds to the background through color consistency tests.

Arbitrary View Generation is traditionally accomplished in three steps: (1) Find pixel correspondences by a stereo matching algorithm, (2) Compute 3D point coordinates by triangulation, and (3) Re-project 3D points into a virtual camera.

Another approach is to build a volumetric model by voxel coloring or space carving methods. This approach discretizes the space into voxels and determines the occupancy and color of each through color consistency of the pixels that are its projections onto all the cameras. The quality of voxel coloring depends in part on voxel size, which is limited by computational power and memory. Texture mapping each face of the voxel may improve results. These approaches, however, are typically expensive.

We propose instead, a more efficient layered approach, in which each input image is warped into a sequence of planes in the virtual camera space. For each pixel in each plane, we determine its occupancy and color through color consistency, using this to compose the novel image in a back-to-front manner.

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
Breton, Martin	M.Sc.	Laurendeau	Human Head Pose Tracking In The Context Of Car Driving
Cantin, Benoît	M.Sc.	Gosselin	Étude des performances, analyse et optimisation d'un mécanisme parallèle spatial à 6 degrés de liberté actionné par cables
Dinel, François	M.Sc.	Laurendeau	Software interface for distant co-operative work in an augmented reality context
Dompierre, Christian	M.Sc.	Laurendeau / Branzan-Albu	Conception logicielle en réalité virtuelle applicable aux Arts de la Scène
Drouin, Richard	M.Sc.	Laurendeau	MONNET Simulation
Dubreuil, Marc	M.Sc.	Parizeau	Engineering and quantification of a parallel and distributed Master/Slave system for evolutionary computation
Dupuis, Jean-François (jan. 2004)	M.Sc.	Parizeau	Entraînement d'un robot mobile à la réalisation d'une tâche visuelle
El Maadi Amar (jan. 2004)	M.Sc.	Maldague	Automatisation des scénarios d'entrée et de sortie des véhicules dans un stationnement par un capteur infrarouge
Fortin, Pierre-Alexandre	M.Sc.	Hébert / Laurendeau	Telecollaboration in the Context of Augmented Reality: Application to Theatrical Production
Genest, Marc	M.Sc.	Maldague	Étude de la corrosion exfoliante sur des spécimens en aluminium, à l'aide de la thermographie pulsée
Grégoire, Vincent (jan. 2004)	M.Sc.	Maldague / Laurendeau	Fusion d'images infrarouges et visibles pour le suivi de personnes
Jean, Frédéric	M.Sc.	Bergevin / Branzan-Albu	Modeling the gait and appearance of a person from a video sequence
Jobin, Jean-Philippe	M.Sc.	Gosselin	Développement de systèmes scéniques à géométrie variable

Student	Program	Supervisor & Co-Supervisor	Topic/Thesis
Khoury, Richard	M.Sc.	Hébert	A self-referencing hand-held 3D sensor
Klein, Matthieu	M.Sc.	Maldague	Évaluation non destructive de la rupture des armatures de précontrainte des ouvrages d'art par magnétoscopie
Labrie, Martin	M.Sc.	Hébert	Module de positionnement inertiel pour améliorer la robustesse du suivi de points de référence dans une séquence d'images
Lafontaine, Sébastien	M.Sc.	Zaccarin	Addition of a video quality evaluation module to an MPEG encoder
Lambert, Philippe	M.Sc.	Hébert	Modeling of the positioning and 3D acquisition system of the brain
Lantagne, Michel	M.Sc.	Parizeau / Bergevin	Characterization and matching of image regions for the comparison of human silhouettes
Lavigne, Valérie	M.Sc.	Zaccarin	High Resolution Infrared Mosaicing Using Geo-Referenced Images
Lemieux, Alexandre	M.Sc.	Parizeau	Système d'identification de personnes par vision numérique
Martel-Brisson, Nicolas	M.Sc.	Zaccarin	Segmentation de bas niveau et suivi de personnes à l'aide d'un réseau de caméras indépendantes
Najjar, Lilia	M.Sc.	Maldague	Algorithmes de quantification de défauts aux formes complexes
Nguyen, Nhat-Tan	M.Sc.	Laurendeau / Branzan-Albu	Automatic segmentation of the bony structure of the shoulder
Ouellet, Jean-Nicolas	M.Sc.	Hébert	Calibration and positioning of mobile range sensors
Petitclerc, Mario	M.Sc.	Zaccarin	Virtual tours with freedom of movement
Poulin, Régis	M.Sc.	Laurendeau / Gosselin	Interface homme-machine permettant à l'utilisateur d'un environnement virtuel de simuler l'action de marcher dans un monde virtuel ainsi que de ressentir la topographie de ce dernier
Quirion, Sébastien	M.Sc.	Bergevin / Branzan-Albu	Segmentation et description des mouvements cycliques d'objets articulés à partir de séquences vidéo via une représentation squelettique de l'objet
Semlaji, Lubna	M.Sc.	Maldague	Simulateur du microprocesseur en tranche AMD2900

Student	Program	Supervisor & Co-Supervisor	Topic/Thesis
Simo, Clovis	M.Sc.	Laurendeau	Distribution des calculs de modélisation visco-élastique non-linéaire des déformations du foie en cryothérapie
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	Modeling a human silhouette using a skeleton and its parts
Ziadi, Adel	M.Sc.	Maldague	Étude et modification de l'impulsion de chauffage utilisée en Évaluation Non Destructive
Bernier, François	Ph.D.	Poussart	Amélioration de la réutilisation, de la composition, de l'extension et de la modification des environnements virtuels en cours d'exécution
Bilodeau, Guillaume-Alexandre	Ph.D.	Bergevin	Modeling multi-part manufactured objects
Birglen, Lionel	Ph.D.	Gosselin	Étude des mains robotiquessous-actionnées
Boivin, Éric	Ph.D.	Laurendeau / Poussart	Management of the temporal conformity of a dynamic virtual environment
Drouin, Stéphane	Ph.D.	Parizeau / Hébert	Description of a moving person observed by a multi-camera system
Dubé, Nicolas	Ph.D.	Parizeau	Maestro, une architecture de calcul distribué générique à allocation dynamique
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
Martel, Luc	Ph.D.	Zaccarin	Segmentation et suivi semi-automatiques d'objets: Nouveau cadre de travail et applications
Rivet-Sabourin, Geoffroy	Ph.D.	Branzan-Albu / Beaulieu	Modèle déformable 2D et 3D pour l'aide à la planification et au diagnostique en imagerie médicale
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)
Tubic, Dragan	Ph.D.	Hébert / Laurendeau	Quality, Efficiency and Reliability of 3D image surface reconstruction
Yazdi, Mehran	Ph.D.	Zaccarin	Segmentation de séquences vidéo de scène statiques pour la recherche d'informations visuelles

McGill University

Student	Program	Supervisor & Co-Supervisor	Topic/Thesis
Ahmedali, Trevor	M.Eng	Clark	Multi-camera Video Surveillance Systems
Ajersch, Mark	M.Eng	Boulet	In-Cycle Control of a Thermoforming Machine
Anwar, Zeeshan	M.Eng	Ferrie	TBA
Ayoub, Omar	M.Eng	Hayward	TBA
Bhatia, Aditya	M.Sc	Langer	TBA
Boussemart, Yves	M.Eng	Cooperstock	Gesture-based Scene Editing and Control
Boyer, Alexandre	M.Eng	Boulet	Control of the Large Array Reflector
Campion, Gianni	M.Eng	Hayward	High Fidelity Computer Graphics for Surgical Simulation
Cardou, Philippe	M.Eng	Angeles	Rigid-Body Pose Estimation Using Point-Acceleration Measurements
Chan, Siu Chi	M.Eng	Cooperstock	Hand-Gesture Tracking and Recognition
Descoteaux, Maxime	M.Sc	Siddiqi	Blood Vessel Segmentation
DiMarco, Paul	M.Sc	Dudek	TBA
Dimitov, Pavel	M.Sc	Siddiqi	Shapes, Parts and Recognition
Dostmohamed, Hanifa	M.Eng	Hayward	Haptic Display of Shape without Force Feedback
Farasat, Yousef	M.Sc	Langer	TBA
Garden, Matthew	M.Sc	Dudek	Learning-Based Recommender Systems
Garroway, Diana	M.Eng	Hayward	Haptic Interaction for 3D Animation
Georgiades, Christina	M.Eng	Buehler	Simulation and Control of a Six-legged Robot in a 3D Environment
Gipsman, Daria	M.Sc	Langer	Critical Points of Shading on Intensity Maxima

Student	Program	Supervisor & Co-Supervisor	Topic/Thesis
Haccoun, Laurent	M.Eng	Boulet/Michalska	Prognostics and Health Monitoring of Turbine Engines (project)
Hadjimichael, Basil	M.Eng	Boulet	Manufacturing Execution Systems
Harmouche, Rola	M.Eng	Arbel	Automatic MS Lesion Detection in MRI
Hilario, Maria Nadia	M.Eng	Cooperstock	Camera-Projector Calibration
Houde, Geneviève	M.Eng	Angeles	TBA
Jolicoeur, Marie-Pierre	M.Eng	Boulet	Robust Feedback for Cabin Noise Reduction
Lalli, Dominic	M.Eng	Boulet	Extrusion Blow Molding
Lalli, Gino	M.Eng	Boulet	Cycle -to-Cycle Control for Extrusion Blow Molding
Laporte, Catherine	M.Eng	Arbel	A Fast Discriminate Approach to Active Object Recognition
Laprise, Pierre-Olivier	M.Eng	Clark	FPGA-Based Video Processing
Law, Albert	M.Eng	Ferrie	TBA
Liu, Guoxin	M.Eng	Angeles	Design Optimization of a Six-Degree-of-Freedom Robot (project)
Liu, Jinbo	M.Eng	Boulet/Michalska	Design of a Magnetic Levitation Device
Liu, Shuo	M.Eng	Boulet/Michalska	Temperature Control using a Heat Exchanger
Ma, Zhongjing	M.Eng	Caines	State Aggregation for Controlled Markov Chains with Applications to Communications Networks
Marinakis, Dimitri	M.Sc	Dudek	TBA
Mbonye, Kwizera Philip	M.Eng	Ferrie	TBA
McCallum, Jacqueline	M.Eng	Buehler	Rhex Downstairs Climbing
Nair, Vinod	M.Eng	Clark	Neural-Network Based Video Surveillance
Ndrialisoa, Rija Y	M.Eng	Angeles	The Design of a Parallel Shoenflies-Motion Generator (project)

Student	Program	Supervisor & Co-Supervisor	Topic/Thesis
Neville, Neil	M.Eng	Buehler	Dynamic Behaviors for the RHex Hexapod Robot
Patel, Prakash	M.Eng	Ferrie	TBA
Pereira, Javeen Carl	M.Sc	Langer	TBA
Perez, Michael	M.Eng	Cooperstock	Automated Door Attendant
Phillips, Carlos	M.Sc	Siddiqi	View-based Object Representations
Qin, Zhongkai	M.Eng	Angeles	Design and Analysis of a Two-dof Novel Drive Unit for Parallel Robots
Qu, Wei Clare	M.Eng	Caines	Dynamics of Market Regulated Internet Systems
Rajwade, Ajit	M.Sc	Dudek/Levine	Facial Pose Estimation and Face Recognition from 3-D Data
Rao, Malvika	M.Sc	Dudek	A Randomized Algorithm for Robot Localization in a Self-similar Environment
Rekhi, Dipinder Singh	M.Sc	Langer/Siddiqi	TBA
Riggi, Frank	M.Eng	Arbel	Probabilistic Graph Matching for Image Correspondence
Rioux, François	M.Eng	Cooperstock	Manual Gesture Recognition and Interpretation
Roumy, Jean-Gabriel	M.Eng	Boulet	Modelling and Control of a Car Suspension Testbed
Rudzicz, Frank	M.Eng	Cooperstock	Multimodal Interaction
Sato, Akihiro	M.Eng	Buehler	Development and Control of a Bipedal Robot using Electric Motors
Sud, Daniel	M.Eng	Cooperstock	Overlapping Rectified Multi-Projector Scene Display
Wozniewski, Michael	M.Eng	Cooperstock	Gesture Acquisition and Toolglass Interface Design
Yao, Hsin-Yun	M.Eng	Hayward	Tactile Amplifying Diagnostic Probe for Orthopedic Applications
Zhang, Linqiao	M.Sc	Langer	Rendering Falling Snow Using an Inverse Fournier Transform

Student	Program	Supervisor & Co-Supervisor	Topic/Thesis
Zhang, Xiang	M.Eng	Angeles	The Innovative Design of Planetary Cam-Roller Trains
Zhu,Yibin	M.Eng	Angeles	The Optimum Design of a Parallel Shönflies-Motion Generator
Al-Widyan, Khalid	Ph.D	Angeles	A Theoretical Framework for the Robust Design of Robotic Mechanical Systems
Arseneau, Shawn	Ph.D	Cooperstock	Multiple Target Tracking by Spatiotemporal Volumes
Bégin, Isabelle	Ph.D	Ferrie	Learning-based Methods for Integration and Super-resolution of Images
Benoit, Stephen	Ph.D	Ferrie	Towards Direct Motion and Shape Parameter Recovery from Image Sequences
Bouix, Sylvain	Ph.D	Siddiqi	Medial Surfaces and Applications
Bourque, Eric Howard	Ph.D	Dudek	Automated Parameter Estimation for Procedural Texturing
Brooks, Rupert	Ph.D	Arbel	Active Vision for Optimal Sensor Placement in Image Guided Neurosurgery
Cadotte, Patrick	Ph.D	Boulet/Michalska	Optimal and Robust Control
Cayouette, François	Ph.D	Cooperstock	Real-Time Human Motion Tracking
Drissi-Smaili, Fatima	Ph.D	Clark	Differential Invariants of 3-D Surfaces
Duan, YingXuan	Ph.D	Boulet	Robust Tunable Control
Ehtiati, Tina	Ph.D	Clark	Contextual Object and Scene Recognition
Fan, Shufei	Ph.D	Ferrie	TBA
Gauthier, Guy	Ph.D	Boulet	Iterative Learning Control
Gosline, Andrew	Ph.D	Hayward	TBA
Haurani, Ammar	Ph.D	Boulet/Michalska	Robust Control of Time Delay Systems

Student	Program	Supervisor & Co-Supervisor	Topic/Thesis
Hernandez-Alonso, Diana	Ph.D	Clark	Statistical Models of Image Feature Context
Huang, Minyi	Ph.D	Caines	Stochastic Control for Distributed Systems with Applications to Wireless Communications
Jie, Li	Ph.D	Clark	Attention Tracking
Khan, Waseem Ahmad	Ph.D	Angeles	The Conceptual Design of Robotic Mechanical Systems
Lala, Prasun	Ph.D	Ferrie	Content-Based Video Indexing: Motion Characterization using Psychophysical Correlates
Lévesque, Vincent	Ph.D	Hayward	TBA
Li, Muhua	Ph.D	Clark	Learning of Invariance Using Temporal Stability
McCloskey, Scott	Ph.D	Langer	TBA
Mitran, Marcel	Ph.D	Ferrie	TBA
Nasrallah, Danielle	Ph.D	Angeles/Michalska	Dynamics and Control of an Anti-tilting Two-Wheeled Mobile Robot on Uneven Terrain
Nava-Hernandez, Sergio	Ph.D	Angeles	The Optimum Design of Epicyclical Trains of Spherical Cam-Roller Pairs
Pasquero, Jérôme	Ph.D	Hayward	TBA
Pelletier, Stéphane	Ph.D	Cooperstock	High-Resolution Video Synthesis
Qi, Zhi	Ph.D	Cooperstock	Efficient Stereo Matching and View Reconstruction
Salerno, Alessio	Ph.D	Angeles	Design, Dynamics and Control of a Fast Quasiholonomic Robot for Human Augmentations
Shaikh, Shahid Mohammed	Ph.D	Caines	On the Optimal Control of Hybrid Systems: Theory and Algorithms
Simhon, Saul	Ph.D	Dudek	Sketch Interpretation and Refinement Using Statistical Models
Skaff, Sandra	Ph.D	Clark	Similiarity Filters

Student	Program	Supervisor & Co-Supervisor	Topic/Thesis
Sun, Wei (Victoria)	Ph.D	Cooperstock	Parallel Distributed Camera Arrays for Intelligent Multi-Camera Target Tracking
Toews, Matthew	Ph.D	Arbel	Information Theoretic Image Registration
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

Angeles, Jorge

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Boulet, Benoit

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Branzan-Albu, Alexandra

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