Proposal: Collaborative Access to Information about Physical Objects through See-Through Displays

INTRODUCTION: RELEVANCE TO THE TARGET AREA AND RESEARCH TOPICS

Access to information about objects anytime and anywhere is no longer a luxury, but often a requirement for many users. Being able to tap into information about objects in our physical world depends heavily on advanced *information and communication technologies*. While the era of mobile devices has ushered access to information "anytime", novel disruptive technologies are required to facilitate access to information about "anything", including physical artefacts in our environment [DB11][1]. For example, in August 2006 Polo Ralph Lauren's Rugby Store in New York, unveiled an interactive smart shopping window (Figure 1-left). Shoppers can view items of clothing, get access to information about any item, and at the same time use an interactive touch screen displayed on the window to purchase items. This form of information access through an already present window can generate significant revenues [F11]. However simple touch displays consume precious real-estate on windows that are intended to generate maximum profitability for the space allotted to it. In environments involving rapid movement of viewers, such as an art gallery, touch-screens are not practical as information access could be monopolized by a select few. Instead, what is needed are displays that do not consume extra real-estate, that facilitate rapid interactivity and that allow multiple users (and not only one user) to get access to information (at their own pace) about objects within these windows.

With rapid developments in liquid crystal display (LCD) technologies, powered lenses and micro-level controlled lighting, one viable possibility is the use of see-through LCDs for simultaneously displaying an object and information about it (Figure 1-right). For example, a shop window or an exhibit in an art gallery can benefit from the large space devoted to already existing windows, to present relevant information. Such innovations are being entertained by multi-national firms such as Samsung [E11], but such systems have only approached the problem in a limited manner. In particular, existing see-through displays are limited to a single user [FK03, HKY03, W04]. This limits who controls and accesses the information. The most beneficial (and yet largely ignored) aspect of such see-through glasses in museums and retail settings is in their ability to potentially support multiple users. Without such multi-user capabilities, these displays are restricted to a limited number of applications and environments.

To succeed, we have composed a multi-disciplinary team of highly experienced researchers and industry partners. The mix includes experts in interactive and visual technologies (Dr. Irani and Dr. Subramanian), an expert in liquid crystal displays (Dr. Hegmann from chemistry), award winning graphic content designers (industry partner C3A, Fung Lim) and high profile end-users, including one of Manitoba's largest shopping centres (St. Vital Mall), the Winnipeg Art Gallery (WAG), and a world renown medical imaging company (IMRIS). This project will develop an entirely new line of research in see-through display interaction. Our objectives are captured by the following target area in the *Information and Communications Technologies (ICT)* theme for NSERC Strategic Projects.

NSERC Strategic Topic (f) Human Interaction with Digital Information, summarized as *"The goal of research on this topic is to enhance users' experience with and confidence in digital systems by investigating hardware and software systems that make data more accessible, understandable and useful. The emphasis should be on disruptive technologies that will dramatically change how people interact with digital information in their personal, social and professional environments."*, captures the essence of our objectives. Being able to access information about physical objects through disruptive technologies, such as see-through displays, has the potential to transform how we interact with objects in our environment. Furthermore, the proposed technology and its outcomes are potentially a cornerstone in the evolution of converging technologies, such as window-commerce.

[1] References are labelled with initials of authors' last name and publication year.

SECTION 1: OBJECTIVES, APPROACH, WORKPLAN, ROLES OF TEAM MEMBERS

1. Motivation, overview and scientific impact ("originality of the research")

In this proposal we seek funding to investigate the use of see-through displays, based on optical systems (multiple liquid crystals in particular) and combined with multi-user interactive capabilities to enrich peoples' engagement and access to information in complex settings. This would give users access to information about items they can see, but cannot directly touch. Surgical training is one notable example where students and others outside the operating room (in a control room) may require resources to augment their viewing experience. Galleries, museums and shopping windows are ideal outlets for the exploitation of such technologies. We will explore the potential of see-through interactive surfaces in these complex domains to provide richer ways of perceiving and accessing the space beyond.

We aim to support multiple users interacting with large see-through displays. Single user displays do not give a group of bystanders the freedom or ability to explore information content independently, thus limiting what and how information is accessed. Our goal is to create a system that can enable techniques and technologies for walk-up and use interaction that is not intrusive and provides for more variable forms of group interaction as envisioned in Fig. 1 (right). Here four individual users can look at the same museum piece and pull-up different information content that each can view without interrupting the other's experience (viewers on the left have a separate view than those on the right). This will enable new forms of collaborative experience, that are currently not possible without including multiple displays, each consuming far more space than allowable.

Fig 1: (Left) The current state of technology: The window display active at the Ralph Lauren Store. Only one user can interact at any given time, limiting the potential for integrating rich group interactions. The display takes over the window space intended for the clothes behind the window. (Right) A conceptual rendering demonstrating the ability to access information about physical artefacts by numerous users. This intended installation will be tested in public, at our partner sites.

This is one of the first projects to examine the multi-faceted challenges of supporting multiple users and multi-user interactions for objects behind see-through displays. The novelty appears on several levels: in developing innovative hardware solutions to support simultaneous viewings; in creating proper user interfaces and interactions; in studying the outcomes outside a laboratory environment. This work is both novel and extremely timely as firms are considering how to go beyond single user see-through displays for real-world usage. The project offers both near-term practical benefits, as evidenced by industry involvement, and long-term outcomes through exploration of new forms of interactions.

Beyond developing the physical prototypes for allowing multi-view see-through systems, we will also study and implement multi-user interactions around such systems. We do not possess any design guidelines for how such interfaces should respond to multiple users around them. A key component will be to implement and deploy our hardware and software prototypes in close consultation with our strategically selected partners. For example, the WAG is excited at the prospect of having an installation before Fall 2012, a date marking its centennial celebration. They envision such a display to mark their entrance into their second centenary, with an outlook at integrating technology into art exhibits. The St. Vital Mall will install and deploy a demonstration prototype in its centre court, a location that attracts as many as 170,000 shoppers a week. This will allow shops at the mall to test first-hand the usability and commercial viability of integrating the system in the stores. To deliver suitable content we have included C3A in our team. C3A has on its staff a roster of award-winning graphic designers. They will convert information content from the WAG and St. Vital into multimedia pieces that will then be integrated into our prototypes. Without this form of high impact “content glue” our prototypes will only be perceived as rudimentary showcases of technology in the process of maturing. All partners are key, without which our project will take longer to succeed. We have consciously chosen to limit our partners to end-users of this system, rather than display technology companies as these will be the primary users who will guide us in choosing the right interactions and subtleties of the physical prototypes we will develop. Additionally, this approach will foster our graduate trainees to become entrepreneurial during the course of the project. With the limited number of display companies operating in Canada (Smart and Christie, being notable exceptions), we believe the moment is right to encourage our graduate students to take on projects that have the potential to be turned into spin-off ventures.

2. Theoretical framework, related work, and proposed methodology (“quality of the research”)

(2.1) Framework and related work. This proposal is inspired by work on: see-through displays; support for multiple unique view; novel forms of user interactions and validation of user performance in varied settings. See-through displays have been proposed since the 1980’s in the form of optical (and video) see-through head-mounted displays (HMD) to support mixed-reality applications such as medical visualization, virtual museum exhibits [BFSE01], and robot path planning [A97]. While past technical solutions to augmenting physical objects have mostly focused on using head-mounted displays and other kinds of mixed-reality, we are primarily concerned with digital augmentation that does not rely on wearing or carrying special devices. DigiScope [FK03] is an early implementation of a system that uses a transparent see-through display to allow users to see information and physical objects through a transparent screen (similar to Fig 1). Wilson [W04] and Hirakawa et al. [HKY03] propose image-processing solutions to allow users to point at the screen or at the physical object behind the screen.

For a see-through display to support multiple users simultaneously viewing different digital content, one would need to provide some form of a mask (using for example, polarizers, parallax barriers or lenticular lenses) that mediates visual resources associated with the same spatial location that might be different for different visitors. One approach is to use polarized light to control viewing of various light sources [SKSK08] but they’ve often been limited to at most three independent users and require users to wear glass (active or passive depending on the type of polarization). An alternative approach that has been used to create 3D displays is to use lens arrays in front of the LCD display [FRSL08, MP04, NNMSD01]. Optical devices such as polarizers, diffusers and lenticular lenses offer a wide range of possibilities to enhance user experiences with an interactive surface. The normal use of this technology is to produce 3D displays of virtual objects. However this project will leverage these technologies to build see-through interactive surfaces that augment real physical objects. Aside from the display, we will track user input in one of several ways: using image processing systems with infra-red light and high-resolution cameras to track user’s hands on a see-through display [W04]; Frustrated Total Internal Reflection (FTIR) of infra-red light to enable multi-touch on a glass surface [H05]; or even to use common 3D depth sensing cameras such as the Microsoft Kinect.

In a wide range of domains users of different kinds need to view and access objects and materials, but for various reasons cannot have direct physical access with them. Retailers, auction houses, science centres, museums and galleries, for example, display many of their goods and exhibits behind see-through surfaces like shop windows and glass cases. These kinds of displays encourage an activity that is often described as window shopping or browsing [BRS89]. Retailers and museums have recently used novel technologies such as touch-screen systems and mobile devices to enliven the objects or by showing them in use. The design and development of these solutions tend to focus on the individual and neglects how people talk and interact when they perceive objects [FD00]. Studies of the museum experience, in common with those of shopping and browsing behaviour, largely overlook the fact that visitors and customers are often with others when they view displays; people interact with companions as well as shop assistants and tour-guides [D97]. Despite the important contribution of two decades of developments in digital technologies in the heritage sector, digital technologies have met with limited success in enhancing visitors' engagement, and the more successful developments have been experimental and severely limited [H06]. In certain critical domains users need to view and in some cases examine the activities of others while having limited direct access to those activities. For example, certain phases of surgical training require students and junior colleagues to view operations outside the surgical room, but with simple glass windows knowledge acquisition is limited. These and other object-rich environments provide an important challenge that demands understanding multi-user conduct around such artefacts, and innovative technical solutions.

(2.2) Objectives and methodology. Our ***long-term objective*** is to investigate the use of see-through displays with liquid-crystal "sandwiches" to provide resources to enrich user access to information on objects of interest placed behind a glass screen. We will achieve this through a series of ***short-term objectives***: that require (A) understanding users; (B) developing novel hardware prototypes; (C) implementing key user interactions; and (D) validating our innovations, both in the lab and with the public. We describe our methodology here and follow with task assignments in our workplan.

Objective A: Understand user tasks. We need to first identify requirements, design considerations and criteria that will inform our proposed interactions (Objective C) and that could be used to assess our solutions (Objective D). The requirements specification will be developed iteratively and collaboratively throughout the course of the project by observing and engaging with domain experts (Objective A1). The initial studies will largely be undertaken in the WAG which has given us access to a subset of gallery artefacts (sculptures of Native art) for our see-through display. Since we seek to understand how user groups communicate and interact around a display, we will begin with observations of visitors at the WAG. Note-taking will be the primary form of data collection, which we will then be translated into task and design requirements. We will focus our observations primarily on how visitors to the WAG, on their own or with others, use the resources provided (such as labels, mobile systems and interactive technologies), how they orient around displays and how others in the local environment might be sensitive to the conduct of fellow visitors whom they are not 'with'. We will perform similar observations at the St. Vital mall, to focus on ways in which customers, both alone and with others, examine and access information concerning merchandise, through shop windows. Based on these initial observations and the ensuing task taxonomy, we will conduct a series of "guessability" [WARM05] studies to identify what sorts of interactions best match certain information access. "Guessability" studies are promising for identifying how user gestures could map to specific tasks [WMW09]. The gestures and collective interactions we gather in this phase will feed directly into Objective C.

Objective B – Designing the see-through hardware system. The main outcome of this phase will be a series of see-through display prototypes. A key aspect of this objective is the creation of a see-through display system where multiple users can look at physical objects behind a glass window and at the same time pull-up digital content on objects within the encasing cabinet. Our approach is to have a "sandwich" of two liquid crystals (LC) with a gap between them. We will use the back LC as the data display whereas the front will be the mask. The mask will be calculated using the optimization function that maximizes data visibility for specific zones while minimizing conflicts [PKGG07]. This will be the most generic system that, in the final instance, will allow multiple users to look through the glass cabinet onto a physical object while users at each viewing zone are looking at different forms of digital data.

We will explore our design in three steps with increasing complexity. In the first step (B1) we will get the liquid-crystal system to work for a single user with the main focus on getting the hardware to work reliably. In the next step (B2) we will extend the system to support multiple users at fixed zones. Here the focus will be on making modifications to the hardware to create dynamic masks and on creating a basic software system to compose images for different users. In the final step (B3) we will continuously calculate the liquid-crystal mask through a real-time optimization algorithm to support multiple users who enter and exit the space in front of the cabinet without being tied to any specific zone.

Objective C – Multi-user interactions with see-through displays. This objective has two main activities. In C1 we will implement new interactive techniques as identified from Objective A. We will begin with some already known interaction styles, but the major challenge will be in incorporating the "feeling" of interacting with physical objects themselves. Some styles involve direct interaction: pointing to the surface of the glass as if the object were part of a traditional display (as in Fig 1-right); pointing 'through' the glass to the object as when talking to a human; or gesturing in front of the glass as if the object were virtually on the user's side of the glass or to 'magically' extend the user's arms through the glass. Indirect manipulation will also be experimented with, for example to indicate interest on displayed views of the objects. Additionally, we are interested in ways in which primary user interactions impact bystanders [BR03] whether they serve to attract others to use the system and help them understand how to use it [DS08] or whether they interfere or undermine the experience of others. In C2 we address the visualization challenges of these newly implemented technologies. To successfully display product related information to a viewer, the positioning of this information will be crucially important. Label placement strategies have been explored in augmented reality research [A97], but prior work did not address concerns of parallax present with multiple user views. Although our display can transmit light directionally, giving some control over the range of positions of the observer, the exact placement of the observer relative to the screen and the objects behind the screen will need to be constrained further. We will explore combined hardware/software approaches to allow information to be presented in front of the object and close to the viewer.

Objective D – Validation in the lab and in public. The project will involve successive evaluations of the prototype systems and solutions at the completion of each phase. From initial Objective A we will collect criteria through which the prototypes and solutions will be assessed, and each successive evaluation, will inform the further development of the system. These will be of gradually increasing sophistication and fidelity. We will begin with quasi-naturalistic experiments to support the development of the requirements and understand the initial challenges of using see-though displays. We will undertake experiments where simple applications are developed using preliminary prototypes. These experiments will be undertaken in Irani's and Subramanian's laboratories. Aside from in-lab evaluations, we will also perform naturalistic evaluation, or validation "in the wild", with the public. This will involve analyzing more robust prototypes. Each test site will have content relative to its "business". We will deliver prototypes in environments with increasing complexity and risk. The first instalment will be at the WAG by summer 2012, the second at St. Vital mall in 2013, and the final at IMRIS for surgical training rooms. Each of these environments require different content, which will be designed by C3A and the MSc student. We will gather a range of data on ways in which the system is used by participants, alone and in collaboration with others. Data will include observations, video-recordings, user activity logs, interviews and discussions with end-users. We will not only assess how the system is used but also evaluate its contributions and limitations for understanding how information access on location-dependent artefacts is facilitated.

3. The Research Team (expertise, roles, collaboration and project management)

The team is highly multi-disciplinary with expertise in interactive technologies, chemistry, liquid crystal displays, electrical engineering, and graphic design. We describe the roles of each team member next.

Dr. Pourang Irani is an Associate Professor at the University of Manitoba (UM) with expertise in interactive technology and user interface design and evaluation. He was recently awarded a ~$1M CFI project to implement state-of-the-art infrastructure in collaborative visual analytics (CoVA lab). Research in the CoVA lab will be of value to this project, such as studies to investigate multi-user interaction styles or positioning of content on shared public displays. His recent work on collaborative viewing of 3D objects and animation on shared displays [STI10, STI11] and on tangible interactive tools for 3D interaction on tabletops [WYPU11] will be valuable to this project. Irani received the prestigious Rh Award in the area of Applied Sciences, given to researchers in Manitoba showing exceptional promise in their career. He was also awarded an NSERC Discovery Accelerator Supplement, given to 100 researchers from among a pool of over 700 applicants in his application year. **Primary management:** Irani will manage the project, co-supervise the students, and direct the research interactions with industry partners. Each student will be responsible for presenting their progress at bi-monthly team meetings attended by all faculty, students and as many industrial partners as possible. Irani will ensure that outcomes are packaged for dissemination and/or commercial opportunities.

Dr. Torsten Hegmann is an Associate Professor in Chemistry at the UM with a specialization in liquid crystals, liquid crystal displays and nanomaterials. Hegmann is a world-wide leader in liquid crystal nanocomposite (having written several influential reviews and research papers) and owns significant intellectual property covering research results from his group on nanomaterial-doped liquid crystals for display applications. Hegmann is working with multi-national firms such as Merck KGaA (the global leader in the production of liquid crystal mixtures for LCDs) and US-based companies such as LC Vision with a research focus on ferroelectric and deVries type liquid crystal mixtures. He is the recipient of an NSERC Discovery Accelerator Supplement, an award given to only a select group of researchers nationwide, a recipient of an Ichikizaki Award from the Canadian Society for Chemistry for unique achievements in basic research, recipient of a CNC IUPAC Award (from the Canadian National Chapter of the International Union for Pure and Applied Chemistry), and a recipient of two CFI Awards totalling $1.25 Million. Hegmann will provide directions on how best to combine the liquid crystal displays for creating see-through displays, a key role based on his background in this domain. His expertise is key for Objective B and will work closely with PhD-2 and the team on assembling the see-through displays.

Dr. Sriram Subramanian is a Reader (equivalent to Canadian Senior Associate Professor) in the Computer Science Department of the University of Bristol where he co-directs the Interaction and Graphics Group. Before joining Bristol, he worked as a senior scientist at Philips Research Eindhoven, Netherlands and as an Assistant Professor (July 2003 to Dec 2006) at the CS department at the University of Saskatchewan, Canada. He also holds adjunct positions at the University of Manitoba in Canada, Tohoku University Japan and Chalmers University, Sweden. His research is in designing novel interaction techniques/systems and understanding in-context use of these devices through careful evaluations. Dr. Subramanian was an academic member of the hugely successful NSERC grant – NECTAR involving 14 academics across Canada. He has held NSERC Discovery and equipment grants. In the last three years he has received over £2 million in research funding from UK funding bodies to explore novel display and user interaction issues around mobile devices and multi-touch tables. Subramanian has a background in electrical engineering which will be valuable for the development of our physical prototypes (Objective B). Subramanian and Irani have worked closely in the past on several projects and have patented technologies they jointly developed.

Mr. Fung Wee Lim, VP Creative Services of C3A Inc. is an award winning graphic designer and has an extensive portfolio covering a wide range of creative design works. He has over 10 years of industry experience in multidisciplinary design and online development projects. As VP of Creative Services at C3A, Lim will work closely with the MSc student in developing multi-media content from raw source materials provided to us by the WAG and St. Vital mall.

Dr. Hossein Pourreza, R&D manager of C3A Inc. is a specialist in distributed computing and networking, and PhD graduate from the UofM. Pourreza will coordinate research activities at C3A, will be involved in HQP supervision and participate in dissemination of our results where appropriate.

4. Proposed Workplan (activities, milestones, budget, equipment, and infrastructure)

The following table summarizes our workplan.

		Year 1	Year 2	Year 3
HQP	PhD 1 (UM)	A1 & A2	C1 input methods	C2 display placement
HQP	PhD 2 (UM&Bristol)	B1 single user see-through	B2 multi-user, fixed zones	B3 multi-user, variable zones
HQP	PhD 3 (UM&Bristol)	D1 validating B1 setup	D2 validating B2 setup	D3 validating B3 setup
HQP	MSc 1	D 1 content for, single user (WAG)	D2 content for multi-user, fixed zones (St. Vital)	D3 content for multi-user, variable zones (IMRIS, WAG and St. Vital)

Objective A – Understanding users and their interactions. In this activity we will study user interactions around shopping windows or gallery exhibits with the goal of understanding how groups of users socialize and communicate around displays and how we can then translate these into concrete interactions for our interface implementations in Objective C.

A1 – Observational studies in the public around windows. PhD-1 will observe people's interactions in public, in particular at the WAG and the St. Vital mall. Such observations can lead to insightful conclusions about how users communicate in groups around such public settings [PBOS10] and their treatment of sociofugal spaces [S67].This will be supplemented with short interviews with end-users to see how they may wish to get access to additional information through these windows.

A2 – Classification of user identified interactions. With requirements collected from A1, we will identify and classify user interactions types. We will deploy the single user see-through bookshelf [OFS08] at the UM lab and we will classify gestures based on guessability methodology [WMW09].

Objective B –Designing the see-through hardware system. Designing our hardware prototypes will be done in phases with increasing complexity. This objective will begin in year 1 with PhD-2 closely supervised by Hegmman and Subramanian.

B1 – Supporting a single user with a liquid-crystal display. We will start with overlaying the cabinet glass with an arrangement of a liquid-crystals to support the projection of digital data on the cabinet. The primary step will be to ensure that the liquid-crystal is lit from the side while not affecting visibility of the physical object. Focused lamps mounted on the side of the cabinet will be used to direct light to the liquid-crystal as with a projector but with minor adaptations. The lamp's light will be blocked by an external clock when the liquid-crystals are opened to let all light pass through. This will ensure that physical objects behind are always visible without the lamp flooding the cabinet glass with white light.

B2 – Supporting multiple users, at fixed zones. In this activity we will "sandwich" two liquid crystals (LC) with a small gap between them. We will use the back LC as the data display whereas the front will be the mask. The mask will serve as a parallax barrier allowing users in zones in front of the sandwich to see different parts of the data. The LC sandwich will be lit by a light source as described in B1. Here the mask will be calculated assuming user groups will be limited to fixed zones in front of the display. When a zone is active (i.e., there are users standing in front of it) the mask will be recomputed using the optimization algorithm described in [PKGG07]. We will use simple social tricks like placing barricades (users usually walk right-up to such barricades) in front of the display to encourage users to stand at specific zones, thus identifying (using installed cameras) whether users are in a certain zone or not.

B3 – Supporting multiple users, at variable zones. In this activity we will expand the algorithms from B2 to include arbitrary zones. User groups can be positioned anywhere in front of the display sandwich and the optimization algorithm will dynamically compute the appropriate mask for the front LC to support multiple viewers. A Kinect based vision tracking system will be used to estimate the distance and number of users in front of the display sandwich. Using principles of proxemics [H6, GMB11] we will estimate if users are from the same group or different groups and calculate masks appropriately. The key contribution of this activity will be the dynamic calculation of a mask that includes heuristics about whether users belong to the same group (and so should view the same content) or different groups.

Objective C – Multi-user interactions with see-through displays. Based on results from A2 we will identify a key set of multi-user interactions. We will implement different solutions for the see-through display and experiment with gesture tracking algorithms for various user configurations ranging from a single user interacting alone to multiple users interacting simultaneously with the system.

C1 – Input styles. Numerous styles of input will be possible. Informed by gesture sets from A2, PhD-1 at UM will study direct, indirect and hybrid direct+indirect methods of interaction [FVB06]. Full body interactions [STB07] based on distance [VB05] away from the window will also be studied in this activity. Irani will directly supervise PhD-1.

C2 – Display placement. Placing the images on the window will be challenging as it should be between the user and the physical artefact. Cameras used for the interactions will also be able to sense the position and height of the user and based on the object being probed, the display will be positioned for ideal viewing positions (identified through in-lab experiments). PhD-1 will also experiment with various placement strategies and coordinate these with input methods.

Objective D: Validation in the lab and in public. We will create prototypes that will be used for engaging the public to not only inform them about our research findings but to also involve them in our research. We will need rich content for any given installation, either at the WAG, St. Vital mall or IMRIS. The MSc student will work closely with Fung Lim (C3A) to develop the content. PhD-3 will mostly work in qualitative research methodology and will work closely with all other HQP.

D1 – Validation of single user see-through display. PhD-3 will test the hardware design as well as the interactions designed for single user interaction. This validation of the interactions will take place on our currently developed single user see-through display. The validation will also take place outside the lab, at the WAG, in preparation for the centenary celebration of this partner.

D2 – Validation of a multi-user, fixed zone solution. On completing the development of the multi-user see-through system in phases B1 and B2, PhD-3 will then evaluate the effectiveness of our interactions (derived from objective C). This validation will also take place at the St. Vital mall, with shoppers. Data collected from this validation phase will feed into our iterative development cycle, and particularly into objectives B3 and C2, enabling refinement and improved results.

D2 – Validation of a multi-user, variable zone solution. This validation will be testing the final solution we deploy in this project. IMRIS is an ideal candidate as they deal with multi-display imaging systems. By 2013, we expect to have also garnered the interest of other partners, such as the Canadian Museum of Human Rights, opening in Winnipeg in 2012. Being able to evaluate our systems in such a high profile institution will require prototypes that work flawlessly and with content (generated with C3A) that marvels visitors and entices them to acquire information through our multi-user see-through displays.

SECTION 2: TRAINING PLAN

Our project is tailored to train Highly Qualified Personnel with a unique opportunity for students to work in a highly multi-disciplinary team, tightly knit with industry partners and to participate in an end-to-end applied research process. C3A is located in the University of Manitoba SmartPark, less than 1.5 kms away, i.e. walking distance to Irani's and Hegmanns' labs, facilitating frequent visits and exchanges. Similarly, the St. Vital mall is located in the south end of Winnipeg, making it easy for students involved in the in-situ experiments to commute to the mall via public transport. Such an opportunity to work closely with our partners, to test our innovations in the "wild" and outside the laboratory is an experience that will foster strong research and development skills in our students. For any prototype to work outside the lab, to be tested with actual user scenarios, requires highly advanced research along with sound development practices. Working closely with award winning multi-media experts at C3A will allow our students to learn directly how research can be transferred to real use cases.

Funding is requested for graduate research associates. We expect up to three PhD students and one MSc student to be involved in the research at any given time. Irani has successfully supervised many students at all levels who are now working in academic or industrial research positions. He is currently supervising 7 MSc (5 are graduating in 2011), two PhD students (1 graduating in 2011) and one post-doctoral fellow. Hegman has supervised numerous PhD and postdoctoral students, and Subramanian has supervised a significant number of students, both in Canada and the UK. Irani and Subramanian have in the past jointly supervised 7 students working on 5 different projects and their students have been involved in joint patent applications. Our training plan is multi-faceted and allows HQP to develop unique skills through: (a) active exposure to advanced human-computer interaction technologies, and (b) industrial experience.

Active involvement in all aspects of the research. Student RAs will learn our methods by immersion as they advance the project both in the lab and in practice. Because HCI is multidisciplinary, students will be exposed not only to new concepts in their chosen knowledge domains, but also to theories and practices in interactive technologies, hardware design, liquid crystal technologies, multi-media practices, and visualization. Students will be fully included in all phases of the proposed research. On-site observations at the St. Vital mall and the WAG, along with follow up interviews with visitors at these sites will expose them to direct engagement with end-users to collect specifications for tasks, requirements and better understanding of user behaviours. More importantly, they will develop skills to match interactive designs to suit user needs. PhD-1 will develop skills in interviewing, observations and development and evaluation of advanced interfaces. PhD-2 will develop a strong background in hardware integration, an in-depth understanding of liquid crystal display technologies, and free hand input technologies. PhD-3 will mainly develop qualitative research methods skills for interactive design. Finally, the MSc student will develop skills in applied perception (to allow visual content to be overlaid on displays with physical objects behind), in multi-media design, and evaluations practices. All these skills are highly valued in industry and across all levels of education (from Bachelor's to PhD).

Exposure to industry. The proposed project offers students opportunities to work with industry. Students will be actively involved with all our partners and working with them will give them a broader perspective of how technology can affect the lives of end-users. We will encourage our HQP to develop entrepreneurial skills, especially since advances in display technology are not as rapidly growing in Canada as elsewhere. Many outcomes from this project will be sought for commercialization (our partner C3A will be actively involved in transferring ripe prototype technologies, into viable products) and students will be at the forefront of such developments. Our training will help students develop skills that go beyond just becoming good researchers but also aspiring entrepreneurs as they will navigate a maze of multi-dimensional issues, going from concepts in the lab to working prototypes in the wild. These skills will reward them and their employers at future job prospects.

SECTION 3: INTERACTIONS WITH SUPPORTING ORGANIZATIONS

Our industrial partners, and our working relationships with them, are key to furthering the research proposed. The WAG, St. Vital Centre, and IMRIS are ideal test sites to validate the research and to refine our prototypes. As part of Objective A, students and faculty will work closely with these organizations to collect user behaviour practices in public, and around physical artefacts. Students will spend weeks at some of these sites, collecting all the necessary data that gets fed into our prototype development. From our partner sites we will also collect raw source materials which will then be provided to C3A, and with the help of the MSc student converted into visual media content. The MSc student will develop skills in identifying how to blend visual content on see-through displays, with objects behind these so that all items are still visible. In this regard working with C3A is key. With their VP for creative services (Mr. Fung Wee Lim), we will deploy visual materials (images, video, and audio) that will entice participants to interact with our see-through displays. This is essential, as without appropriate materials and presentation methods for this, end-users will disregard the presence of our technology. Irani's lab is a short physical distance away from C3A's offices allowing our students to spend considerable time with this entity to deliver on the outcomes of the project.

Aside from developing the important content that gets displayed with our technology, C3A's role is instrumental in at least two other ways. The first role (and C3A has already fostered this) is one of gathering industrial partners. With the exception of IMRIS (who initially contacted Irani for collaboration on this and other projects), C3A garnered the interest of the WAG and St. Vital Centre for this project. The enthusiasm generated by C3A about the prospects of our technology attracted these two other vital organizations. In like manner, C3A is proposing to approach a number of other organizations, including a world renowned fashion store based in Winnipeg, Nygaard, the Canadian Museum for Human Rights (opening in Winnipeg in 2012), and MTS/Allstream (leading provider of telecom products in Manitoba). The second role C3A has shown interest in is to commercialize our work by integrating their suite of media convergence technologies and using the see-through display as one of many platforms they operate on (including IPTV). C3A has in the past dealt with our technology transfer office, which will be key in spinning our ideas into innovations. Wing Kwong (President of C3A) will contribute his expertise and insights of business-to-consumer e-commerce and media convergence, gained from over 20 years of working in the telecom, IT and e-commerce industries in both technology, business and product development capacities. Wing will work primarily with the marketing managers at the WAG and St. Vital Centre to understand and define the marketing tactics and translate them into practical product features and functionalities. Working with a partner interested in licensing the technology will accelerate the potential commercialization process.

We intend to organize local workshops to which all our supporting organizations will be invited. The first will provide an overview of our work to date, with the goal of identifying opportunities for closer collaboration and synergy creation between our partners. Representatives or our Technology Transfer Office (TTO) with whom Irani has strong relationships, will also be invited to these workshops to identify any opportunity for commercializing elements of our research. These workshops and meetings will enable knowledge and technology to be transferred to the organizations capable of commercializing our ideas, and will introduce each of our partners working in inter-related areas to exchange experiences. Our HQP will also attend and plan such one-day workshops to foster in them the importance of touching base with our sponsors. Each of our partners will provide staff time and physical space to ensure the project succeeds. St. Vital Centre's space is of prime value and their commitment will allow our displays to be exhibited in their centre court for high traffic exposure. We will also hold follow up discussions with retail outlets at the St. Vital Centre that choose to adopt our display technology. There is currently discussion between C3A and St. Vital Centre to approach a few retailers to potentially showcase our systems. We expect this will continue and further interactions will support such engagements.

Beyond regular lab meetings or conference calls, we will also take advantage of our attendance at annual conferences in our field, to meet amongst academic team members, to reassess goals and objectives in context of recent developments in the field. Our team has extensive experience collaborating over distance on prior projects, a skill we will build on to further our objectives.

SECTION 4: BENEFITS TO CANADA AND TO THE SUPPORTING ORGANIZATIONS

Benefits to Canada. With the outcomes of this project, Canada will exploit its expertise in interactive technologies and become a world leader in the emerging area of see-through displays. Most work on shared display technologies in Canada is being done in research labs, such as in Irani's. In the US and the EU there are far more organizations involved in the development and marketing of shared display systems, such as large wall displays, tabletops, and soon see-through displays, including the development of custom display solutions. The timing of the application is critical. We will be the first in Canada to develop an end-to-end prototypical multi-user see-through system. This will have significant impact on the IP that can be generated from our outcomes and the resulting benefits to our economy.

Our current plan includes training our HQP toward taking their inventions and finding potential applications in real world problems. This we believe will encourage an environment whereby research results will be considered for business ventures. It is estimated that roughly 50% of all PhD students carry on toward an academic or industry sponsored research environment [TS 2008]. Our project also tailors to the other 50% of HQP who will become leaders and innovators in industry, by learning how to harvest and exploit prime intellectual property. Given the heavy investment from our partners, students will experience first-hand know how on interacting with industry at various levels. Finally, the moment is ripe for exploiting innovative display solutions. With the costs of LCDs shrinking, and other factors converging, the potential for see-through displays to become a disruptive technology is significant. We expect this project will capitalize on this opportunity.

Benefits to supporting organizations. Our industry partners are enthusiastic about the potential prospects of our technology. They will directly benefit from showcasing their products through our display, thus enhancing their marketing objectives. Our team is uniquely positioned to carry out this research. We have extensive experience in interactive technologies and display systems (Irani, Subramanian and Hegmann have numerous patents on novel display and interactive technologies). Initial prototypical tools as we propose to develop will greatly advance the competitiveness of our partners. We cover a wide spectrum of application domains given the three very different "businesses" we are working with (museums and art galleries, shopping centres, and medical companies). *Museums and galleries* offer very rich environments to explore interactions with exhibits, where objects cannot be touched or manipulated and yet visitors require information about these to enrich their cultural experience. The WAG is keenly interested in our system, primarily as we would be able to deploy a working showcase in their gallery before the marking of their centennial in the Fall of 2012. Such systems will greatly enhance the cultural experience visitors gain and will likely increase traffic through such venues. *Retail settings*, such as St. Vital Centre seek to extend and enhance their displays of goods by the use of new technologies. These may involve customers engaging in market-driven activities such as to ensure that commercial transactions can take place through the glass-screen of the display, for example to purchase clothes, outside the store. St. Vital Mall is currently identifying innovative methods to match their shoppers experience with technologies of the 21st century. They view the see-through interactive system as a key commercial component in their current marketing agenda. Finally, complex workplaces, such as *surgical control rooms*, as with IMRIS allow users to view scenes to which they do not have direct physical access. Surgical training is one notable example where students require additional resources to augment their viewings. Our see-through interactive surfaces will be key elements in such setups. Finally, C3A has a determined view in commercializing our inventions from this project. C3A's involvement will provide the "content glue" to allow us to deploy our systems into the real world and outside the laboratory for testing and validation, and as such will be generating significant revenues through interactive shopping transactions, or through advertisements and other marketing ploys possible with such environments. These direct and tangible benefits will provide manifold returns to enhance the local, city and provincial, economy.

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