Natural Sciences and Engineering Research Council of Canada | Conseil de recherches en sciences naturelles et en génie du Canada

Committee / Panel	1507
1507	
Date	2010/10/25

Institutional Identifier

System-ID (for NSERC use only): 145584087

FORM 101
Application for a Grant
PART I

Family name of applicant	Given name	Initial(s) of all given names	Personal identification no. (PIN)
Booth	Kellogg	KS	**Valid** 10455

Institution that will administer the grant	Language of application	Time (in hours per month) to be devoted to the proposed research / activity
British Columbia	[X] English [ ] French	60

Type of grant applied for	For Strategic Projects, indicate the Target Area and the Research Topic; for Strategic Networks indicate the Target Area.
Discovery Grants - Individual	

Title of proposal
Collaboration technology and multi-user interfaces

Provide a maximum of 10 key words that describe this proposal. Use commas to separate them.
augmented reality, collocated teamwork, computer-supported cooperative work, document authoring, instructional technology, interaction design, multi-touch, participatory design, shared display, usable security

Research subject code(s) Primary	Research subject code(s) Secondary	Area of application code(s) Primary	Area of application code(s) Secondary
2700	1605	1207	802

CERTIFICATION/REQUIREMENTS

If this proposal involves any of the following, check the box(es) and submit the protocol to the university or college's certification committee.

Research involving : Humans [X] Human pluripotent stem cells [ ] Animals [ ] Biohazards [ ]

Does any phase of the research described in this proposal a) take place outside an office or laboratory, or b) involve an undertaking as described in Part 1 of Appendix B?

[ ] NO [X] If YES to either question a) or b) – Appendices A and B must be completed

TOTAL AMOUNT REQUESTED FROM NSERC

Year 1	Year 2	Year 3	Year 4	Year 5
74,100	74,100	74,100	74,100	74,100

SIGNATURES (Refer to instructions "What do signatures mean?")

It is agreed that the general conditions governing grants as outlined in the NSERC *Program Guide for Professors* apply to any grant made pursuant to this application and are hereby accepted by the applicant and the applicant's employing institution.

Applicant

Head of department

Dean of faculty

President of institution (or representative)

Applicant's department, institution, tel. and fax nos., and e-mail
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SUMMARY OF PROPOSAL FOR PUBLIC RELEASE (Use plain language.)

This plain language summary will be available to the public if your proposal is funded. Although it is not mandatory, you may choose to include your business telephone number and/or your e-mail address to facilitate contact with the public and the media about your research.

Business telephone no. (optional): 1 (604) 8228193

E-mail address (optional): ksbooth@cs.ubc.ca

Interaction techniques for shared displays in collocated environments present a number of challenges. The proposed research examines the affordances of tabletop, large wall-mounted, and hand-held displays to determine how each best supports specific tasks during face-to-face collaboration, and how each can augment the other. Investigations of novel multi-touch interaction techniques and techniques for use at a distance from the display are being conducted, especially in collaborative environments where mutual awareness of each other's workflow must be traded off against interference and distraction by one user's interaction with another's workflow. Privacy and security issues arise in ad hoc collaborations, where mutual trust cannot be assumed. In these situations the usability of privacy features becomes an important concern that is being studied.

Classroom and meeting room presentations on shared displays are of special interest. Research in actual classrooms with special-purpose software to support multiple projectors extends standard PowerPoint presentations to much larger screen areas more like traditional multi-blackboard "chalk talk" lectures. Specific pedagogical hypotheses and new ways to engage students as active participants, rather than simply passive receptors, will be tested. Novel uses of personal response systems ("clickers") to support "hands on" learning by large groups of students are being designed to examine how technology can enrich classroom experience.

Augmented, mixed, and hybrid reality each offer another avenue for research on shared displays. In this case the displays are super-imposed or embedded in physical objects. Interaction techniques that flow seamlessly back and forth between the real and virtual representations of the objects or the information underlying them are being studied. Recent work on multi-projector augmented reality techniques for architectural plans will be continued in a number of directions.

Other Language Version of Summary (optional).

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Valid 10455	Booth

Before completing this section, **read the instructions** and consult the *Use of Grant Funds* section of the NSERC Program Guide for Professors concerning the eligibility of expenditures for the direct costs of research and the regulations governing the use of grant funds.

TOTAL PROPOSED EXPENDITURES (Include cash expenditures only)

	Year 1	Year 2	Year 3	Year 4	Year 5
1) Salaries and benefits					
a) Students	42,500	42,500	42,500	42,500	42,500
b) Postdoctoral fellows	12,000	12,000	12,000	12,000	12,000
c) Technical/professional assistants	7,500	7,500	7,500	7,500	7,500
d)	0	0	0	0	0
2) Equipment or facility					
a) Purchase or rental	2,000	2,000	2,000	2,000	2,000
b) Operation and maintenance costs	500	500	500	500	500
c) User fees	1,400	1,400	1,400	1,400	1,400
3) Materials and supplies	1,200	1,200	1,200	1,200	1,200
4) Travel					
a) Conferences	4,000	4,000	4,000	4,000	4,000
b) Field work	1,000	1,000	1,000	1,000	1,000
c) Collaboration/consultation	1,000	1,000	1,000	1,000	1,000
5) Dissemination costs					
a) Publication costs	1,000	1,000	1,000	1,000	1,000
b)	0	0	0	0	0
6) Other (specify)					
a)	0	0	0	0	0
b)	0	0	0	0	0
TOTAL PROPOSED EXPENDITURES	74,100	74,100	74,100	74,100	74,100
Total cash contribution from industry (if applicable)					
Total cash contribution from university (if applicable)					
Total cash contribution from other sources (if applicable)	0	0	0	0	0
TOTAL AMOUNT REQUESTED FROM NSERC (transfer to page 1)	74,100	74,100	74,100	74,100	74,100

Budget Justification

The budget on the previous page has the following components.

Salaries

The bulk of the funds requested in this application are for personnel, mostly stipends but also for conference and other travel related to the research. Funding requested for student stipends is the full-time equivalent of NSERC support for two master's and one doctoral student per year. Usually students are supported from more than one source, depending on their research. This represents about 40% of the total annual costs for 5-6 graduate students and 1-2 undergraduate students per year, which is the average I expect to have over the five years.

A Discovery grant is rarely substantial enough to fully fund a postdoctoral fellow. The requested funds will provide partial support for a shared postdoctoral fellow, with additional support coming from other grants that I hold, grants held by a co-supervisor, or funding obtained by the postdoctoral fellow (NSERC PDF or other sources). I hope to have one postdoctoral fellow working with me at all times, typically co-supervised by one or two other faculty working on collaborative projects.

A similar situation exists for research technicians. They are essential for large research projects, but cannot be supported solely by a Discovery grant. Again, I expect to pay just part of the salary for a shared technician who supports a larger set of researchers and their students.

Equipment

Most equipment used in my research is either commodity computing (laptops or off-the-shelf input devices) or is specialized equipment obtained through NSERC RTI grants, CFI, or similar sources.

Purchase of the equivalent of one laptop computer or a small number of input devices is anticipated each year, mostly for use by students.

Operation and maintenance costs cover repairs and servicing of existing and future equipment.

User fees pay for centralized printing, file storage, and other direct costs of research provided through the departmental infrastructure.

Materials and Supplies

Cables, adapters, connectors, and other small components are often required, and from time to time physical support structures (made of wood or shelving components) are necessary to conduct experiments mimicking workplace settings, or to provide experimental control of stimuli. One example is a set of wooden supports suspended from the Unistrut grid in the ceilings of our lab. The supports were used to mount Polhemus Latus sensors for a VR experiment – wood was required because the Polhemus senses a magnetic field, so the metal Unistrut could not be used directly, hence the need for a custom solution built by one of my graduate students.

Travel

Conferences where my students and I present papers include the annual ACM CHI, UIST, and CSCW conferences, and the Canadian Graphics Interface conference. UIST (User Interface Software & Technology) is a primary venue for research on new interaction techniques and devices; CSCW (Computer-Supported Cooperative Work) focuses on various aspects of collaboration; and CHI (Computer-Human Interaction) is the premiere international HCI conference. Graphics Interface, sponsored by the Canadian Human-Computer Communications Society, is the longest running conference in the area of computer graphics and interaction. It provides excellent opportunities for students to present their work and meet with their peers from other Canadian research labs as well as other international attendees.

I endeavor to provide at least partial support for each supervised graduate student to attend one conference each year, and additional conferences if they are presenting a paper or attending a workshop or doctoral symposium.

The cost of conference travel for students is reduced when students are student volunteers (most of my students apply for this and many are selected), or when university travel grants are available if students present their own work. This still totals about $1000 per student per year after other sources are taken into account. The funds requested in this application will only pay a portion of the total travel costs. I expect other grants to cover the costs for conference travel related to research funded under those grants.

Postdoctoral fellows require travel funds for conferences, and to enable them to serve on program committees (postdoctoral fellows supervised by me have served multiple times as poster or demo chairs for various conferences, and in some case have been on paper selection committees). Again, the funds requested in this application pay only a portion of these travel costs.

Dissemination costs

Dissemination of results is largely in digital formats, with most conference and journal papers submitted electronically as PDF files. These have little or no incremental cost. Printing and laminating for posters, and occasional shipping costs for equipment used in demos at conferences, are the only significant dissemination expenses. To illustrate new interaction techniques, videos are often produced. Students usually shoot and edit these using in-house facilities, sometimes incurring modest user fees. Distribution is often via YouTube, which is free. The funds requested in this category are therefore modest.

Note: The NSERC Discovery Grant application I submitted last year was rated OUTSTANDING for Excellence of the Researcher and OUTSTANDING for Training of Highly Qualified Personnel, but only MODERATE for the Merit of the Proposal. The Evaluation Group indicated the primary shortcoming was "limited details provided with respect to the proposed work" and that "[a]n award of one-year is offered to the applicant to allow him to submit an enhanced new application."

RESEARCH SUPPORT

The research proposed in this application continues my multi-year research program. I am a full-time research faculty member. I plan to start phased retirement in 2015. I currently have one funded project that just completed, one continuing funded project under the GRAND NCE, and my Discovery grant for which this application is a renewal request. The other two grants have the following relationships to the proposed research.

NSERC Strategic Project: ARTIFACT

A four-year strategic project grant led by Dr. Sheryl Staub-French (Civil Engineering, UBC) with co-investigators Dr. Rachel Pottinger (Computer Science, UBC), Dr. Melanie Tory (Computer Science, UVic), and me examined how advances in information and communication technology (ICT) can be used to improve construction technology. This grant terminated September 30, 2010.

My role in ARTIFACT was largely focused on collaboration technology, and (with Dr. Tory) visualization techniques appropriate for various stages of construction planning and management. Some of this was an outgrowth of a recently completed five-year NSERC strategic network (NECTAR); technology initially developed under funding from NECTAR was adapted and deployed for use in construction planning and management activities. There has been, and continues to be, a synergistic interplay between the project-specific applied research in ARTIFACT and the more basic research supported by my NSERC Discovery grant.

NCE: GRAND

I am the scientific director for a new NCE on New Media, Animation and Games (GRAND). This responded to the targeted call for letters of intent by the NCE Program on December 1, 2008. Funding for GRAND was announced, on December 1, 2009.There are currently 63 principal network investigators and another 50 or more collaborating network investigators spanning nineteen universities who participate in GRAND.

As scientific director, 75% of my time is spent as a researcher and a manager/administrator in GRAND. I have a reduced teaching and administrative load in my department to accommodate this. Much of my manager/administrator duties involve aspects of my research, so there is considerable overlap between this time and my research time. Because of this I am still devoting roughly the same amount of time to research as I have in the past.

I expect to receive approximately $45,000 per year for research I conduct as a network investigator in GRAND. This is about the same amount I received each year over the five years that NECTAR (the NSERC strategic network) was funded.

The NCE Program is very clear in specifying that is does ***not*** fund the full costs of research. Network investigators are expected to have other sources of funding, such as Discovery grants, which the NCE Program leverages through its incremental funding. This is definitely true in my case. Roughly half of the funding for my students, and a portion of the funding for a postdoctoral fellow, is expected to come from this NCE funding.

The research related to large wall-sized and tabletop displays proposed in this application for an NSERC Discovery grant will be significantly enhanced by complementary multi-university research conducted as part of a project on shared displays that will be funded through GRAND. I expect that some research currently funded under the ARTIFACT strategic grant will continue under GRAND as well.

In addition to the research on shared displays, as scientific director I am involved in two projects within GRAND that examine how web-based collaboration technology and social networking software can be utilized to increase the effectiveness of the NCE by supporting cross-university and multi-disciplinary engagement in the research. These are outgrowths of my existing research interests, but are largely disjoint from the research proposed in this application, except for some potential application of the ideas under development that relate to previous research on structured annotations for co-authored documents.

Note: Citations in **[brackets]** refer to entries in this Form 101's references; those in **{braces}** refer to entries in the accompanying Form 100.

1. PROGRESS IN THE RESEARCH PROGRAM

My research builds and evaluates interactive systems for tasks undertaken by groups of people, the subset of ***human-computer interaction*** (HCI) known as ***computer-supported cooperative work*** (CSCW). The primary focus over the past six years went into research on ***shared displays*** for face-to-face (collocated) in meeting rooms and classrooms. Affordances of shared displays were studied to design new interaction techniques for large wall-sized displays and multi-touch tabletop displays that appear in three primary venues: ***meeting rooms*** (work), ***classrooms*** (education), and ***rec rooms*** (entertainment). LACOME (§1.3) addresses work, MULTIPRESENTER (§1.4) addresses education, and two projects funded by Panasonic addressed entertainment. The current focus is meeting rooms and classrooms.

A series of master's theses and doctoral dissertations explored issues such as (1) what information is to be shared? (2) how might information be better presented to those who are not the owners? and (3) who gets to control which information is seen and why does it matter? Seven steps in this program are summarized, in roughly chronological order.

1.1 MIGHTY MOUSE. Various students and I developed a system to allow multiple users to control each other's desktops (or laptops) while viewing them on shared projection displays **[3].** This addressed each of the three issues above. This first step was the basis for subsequent research that looked at problems we found.

1.2 Role-based viewing. Understanding the needs of different viewers is important. A secondary display serves a different purpose than a primary display. Ordinarily only the owner sees the primary display, so it is optimized to make menu and command selections quick and visually non-intrusive. Someone watching will find it difficult to know what operations or data are involved. MSc student Berry changed temporal and spatial characteristics to provide a better fit between displayed information and the roles each viewer has **{12, 30, 33}**. The owner sees everything on his/her laptop, others see an altered version that hides sensitive information but augments salient information that might otherwise be hard to understand.

1.3 LACOME. Motivated by findings that large displays provide a qualitatively different experience from desktop or single projector displays **[1,17]**, MSc student Liu developed the second-generation <u>L</u>ocal <u>A</u>rea <u>CO</u>llaborative <u>M</u>eeting <u>E</u>nvironment using standard VNC to share multiple desktops on a very large wall-sized display **{26,28}.** Privacy and security problems identified in Berry's work led us to use VNC as a platform-independent mechanism for screen sharing, with a separate control layer we added. MSc student MacKenzie examined window management specific to LACOME.

1.4 MULTIPRESENTER. PhD student Lanir extended these techniques to support multiple projectors in classroom presentations **{3-5, 29, 37}**. We assessed pedagogical advantages of extra screen real estate and usability issues from both instructor and student perspectives.

1.5 SHADOW REACHING. PhD student Shoemaker used body gestures as the primary input technique to overcome limitations of WIMP-based large screen systems **{2, 6, 35, 36}**. This resulted in a comprehensive architecture and framework that will be applied to LACOME and MULTIPRESENTER.

1.6 WHALE TANK VR. MSc student Maksakov **{27}** examined how two users share a wall-sized touch screen, each with different head-coupled views of a 3D scene that "blend" to a common view when users look at the same portion of the screen. An experiment showed a user's ability to monitor peripheral activity of another user was not reduced with the two-view approach that applies role-based viewing to fish tank VR.

1.7 Haptic augmentation. PhD student Swindells assessed affective aspects of touch for use in shared displays **{1, 8, 10}**. Recent work by MSc student Fernquist looked at constraint techniques for direct multi-touch tabletops (haptic by nature) where indirect mouse-based techniques do not work. We continue to explore how haptic feedback enhances coordination.

2. OBJECTIVES OF THE RESEARCH PROGRAM

My long-term goal is learning how to better design and implement interactive systems to support particular workflows. A focus on single-user tasks has shifted to collaborative tasks. Multiple users, each with different expertise and playing different roles, interact with each other supported by technology. This includes both ***same-time*** and ***different-time*** (synchronous and asynchronous) as well as ***same-place*** and ***different-place*** (collocated and distributed) scenarios. Synchronous, collocated interaction using large wall-sized and tabletop displays has four main research threads that often intertwine: (1) collaboration tools for large shared displays, (2) virtual and augmented reality techniques to support richer interfaces to information, (3) authoring and presentation tools for digital media, and (4) multimodal interfaces, especially those involving touch.

3. LITERATURE PERTINENT TO THE PROPOSAL

There is a rich literature on collaboration technology, especially for large shared displays, dating back almost two decades **[6, 16]**. Winograd's group at Stanford developed the iRoom with tools to support face-to-face collaboration on both wall and tabletop displays using a combination of built-in computer infrastructure and ad hoc connections to personal laptops and hand-held devices **[10, 12, 15]**. Key issues include understanding the ***social conventions*** and expectations of shared displays **[5, 21]**, how to interact with parts of a large screen that cannot be easily reached through either hand or mouse movement **[2, 4, 19]**, and how to integrate ***personal hand-held displays*** into these environments **[13]**. Han's recent introduction of ***frustrated total internal reflection*** (FTIR) to enable vision-based sensing for multi-touch surfaces **[9]** led to a flurry of research that is still in its infancy. Approaches such as the Stanford iRoom **[10]** and tools like VNC **[14]** have an all-or-nothing approach to sharing – if information on a laptop has sensitive information, don't share the screen view; otherwise, let everyone see the entire screen. There are situations where this does not work: some information may be highly sensitive and not relevant to the current task, while other information may not be sensitive but definitely necessary for the task. A solution similar to ours has been used to share astrophysics data **[20]**.

4. METHODS AND PROPOSED APPROACH

HCI requires a variety of quantitative and qualitative methods. CSCW especially needs this because of the complex social dynamics often involved **[8]**. My research starts with ***observations*** of existing work practices: interviews, field studies, and formative laboratory experiments to establish baseline performance and identify areas of concern. An ***iterative design*** cycle follows, often using participatory design where clients are part of the team rather than just objects of study. ***Prototypes*** are developed and evaluated with a range of informal to formal techniques: field deployments, controlled lab experiments, and (sometimes) longitudinal studies. Most projects are done over a number of years, with different graduate students involved in various steps.

Three primary projects (§4.1-4.3) are described in detail. Three secondary projects (§4.4-4.6) are also being pursued. Each explores a different but related facet of an ***integrated*** research program on collaboration technology and multi-user interfaces.

4.1 On-going research on LACOME. Five aspects of the LACOME software require further work. These apply to other systems too.

(a) Continued refinement of basic features to increase usability. Considerable effort has gone into designing how LACOME users interact with a shared display. Improvements are still required: (i) Can users easily determine whether their mice and keyboards control their local machines, the shared display, or some other user's machine? (ii) Is it easy to know which user controls a particular shared window? (iii) How quickly can users join existing sessions in a strange network environment? Each of these requires careful design and evaluation, characteristic of the HCI research I do.

(b) Improved manipulation of shared windows. Our new window manipulation technique **{40}** will be further tested in experiments that simulate collaborative usage and then in field deployments to evaluate actual use in meetings and later in classrooms. The first experiment will repeat our previous single-user study but with multiple users each working on different tasks that require periodic changes to the window arrangement. This will test whether the single-user advantages we found persist in collaborative settings. Further experiments will test whether the techniques promote awareness of each other's work, an essential component of collaborative tasks.

(c) Sharing audio as well as visual information. Audio feedback from multiple laptops can be mixed and played through meeting room speakers, but may produce a cacophony of sound. Dolby 5.1 can make audio come from the location on the display of the window with which it is associated, or from where its laptop is located in the room. Simultaneous alerts from multiple laptops can be separated in time (one of them delayed), but it may then be necessary to re-time the accompanying visual events. Both issues are complicated by a third: determining the "purpose" of individual audio (alert or background sound). Ad hoc solutions for specific situations may lead to an audio architecture more closely resembling modern windowing systems that isolate visual information to specific regions of the screen appropriate to the underlying application.

(d) Ameliorating privacy & security concerns. We will analyze usage scenarios to determine potential privacy and security vulnerabilities and decompose LACOME into components each known to be trustworthy by a different group of users who trust each other, but where groups do not trust other groups. An example is negotiations or other adversarial situations where which users should be allowed to control which other user's laptops is an issue. We currently use VNC to "publish" a laptop's desktop because each user can select his/her own trusted version of VNC with no trust required of the LACOME software. But when VNC is configured to allow external control the LACOME server needs to be trusted to allow only authorized users and block others (not addressed by **[20]**). Our approach will build on our work in usable Firewall security **{1}**.

(e) Supporting distributed groups. We expect a similar component-based architecture will provide a distributed version of LACOME. In this case the components will serve to "federate" LACOME servers at multiple locations. Better means for maintaining awareness may be necessary to compensate for the lack of physical co-presence. Solutions for shared audio may also need to be revisited because some of the laptops will not have a local spatial presence and thus that option will not work in its simplest form.

4.2 Promoting student classroom engagement. We want to enhance students' interactions with lecture material, expanding on Truong et al.'s Classroom 2000 **[18]** and later systems. MULTIPRESENTER currently allows students to post material on the screen using simple copy-and-paste metaphors. We are extending this so students can navigate back and forth through slides and other material on the classroom screen when they are asking questions.

(a) In-class exercises. We are adding multi-person input techniques patterned after cooperative games so one or more students work out solutions to problems posed by the instructor using student response systems (commercial I>CLICKER devices) now in use at UBC and many other universities. An example is a prototype we have developed to test understanding of node insertion into a singly-link list. Using I>CLICKER buttons students can step through changing links until a new node is in its correct position in the list. This allows a student or group of students to "demonstrate" proficiency much like working out a problem on the blackboard. We are planning similar exercises for binary trees, parsing, and other "classic" data structures and algorithms.

(b) Using competition to engage students. We are adapting the I>CLICKER by modifying the open source software to enable "races" to solve multiple instances of the same or similar problems. This requires consensus among some or all of the students before each step is accepted. Determining the threshold for consensus is one of the questions we will pursue. Setting the threshold low might allow some students to "coast" whereas setting it high might make it too difficult.

(c) Revisiting role-based views. An important question is how algorithm steps should be displayed so that all students understand what has been done so they can participate in the solution. We will adapt earlier techniques developed with Berry **{16}**. Both student-controlled and instructor-controlled turn-taking will be examined. Most importantly we will test whether techniques we develop actually lead to better learning outcomes. Studies similar to one by Lanir **{37}** will be conducted with colleagues specializing in educational technology.

4.3 Pointing on large wall displays. PhD student Shoemaker discovered limits of a classic Fitts's law model (1956) $MT = a + b \log(A/W)$ to predict movement time (MT) as a function of movement distance or amplitude (A) and target precision or width (W) when pointing on large screens. Welford's model (1968) $MT = a + b_1 \log(A) - b_2 \log(W)$ works better. A quite unexpected result is that $k=b_1/b_2$ increases linearly with control/display ratio (gain). If either A or W is constant a two-part Welford model simplifies to a one-part Fitts model **{46}**. Even if A and W both vary, for gain where $k \approx 1$ a two-part model degenerates to a one-part model because $b_1 \approx b_2$. But if A and W both vary and $k \neq 1$, the two-part model is required. Our re-analysis of data from other researchers might explain reports in the literature of non-Fitts behavior. The following questions arise.

(a) Parametric laboratory experiments. We will examine a broad range of gains, changing the "gear ratio" between how much a user's arm moves compared to how much an on-screen cursor responds. A large range of A and W values will be used to avoid problems with studies in the literature with limited ranges.

(b) Separable stages of pointing. Findings by collaborator and SFU Kinesiologist C. MacKenzie show there are two separable stages of pointing governed by A and W, which suggests different contributions by b_1 and b_2. We will replicate studies of angular dependence in large display pointing **[11]** to see if b_1 and b_2 depend on "local" values of gain by testing for asymmetry between movement starting on-axis directly in front of the user and terminating off-axis to one side, versus movement starting off-axis and terminating on-axis.

(c) Three types of pointing. We will look at mouse-based pointing where gain is set in software, "mid-air" pointing where user's hand motion is tracked directly and gain is again set in software, and hybrid pointing where software gain combines with perceptual gain depending on the distance between the user and the display. Our goal is to verify the linear relationship between gain and the ratio $k=b_1/b_2$ and to determine how each of b_1 and b_2 vary as a function of gain.

4.4 Grid constraints for direct touch. Fernquist and Shoemaker's tabletop "snapping" technique **{44}** for grid or object constraints will be extended to large wall displays and mid-air pointing to see it works without the tactile feedback on a direct touch tabletop display.

4.5 Stereo Whale Tank VR. The investigation by Maksakov of shared 3D viewing did not use stereo, just head-coupling. Stereo is known to be problematic because of focus-convergence conflict. We will investigate whether Fleet and Ware's "cyclopean " technique **[7]** is suitable for shared 3D viewing environments using a multiple object tracking task **{20}**.

4.6 Keyboard-based techniques to augment GUIs. Further work on Hendy's keyboard-based accelerators for GUIs will be pursued. Research to date has focused on desktop systems. Our next step will examine how hand-held devices (such as cell phones) can be integrated with large shared public displays to allow casual use of GUI-based apps for real-time text input.

5. ANTICIPATED SIGNIFICANCE OF THE WORK

My work on collaboration technology has both theoretical and practical importance. There are more than a dozen users of MULTIPRESENTER at UBC. Integrating LACOME, MULTIPRESENTER, and classroom I>CLICKERS could have a strong impact on future classroom teaching by providing a middle ground between blackboard-based lectures and PowerPoint-based presentations, both known to have limitations.

The discovery that Fitts's law needs to explicitly incorporate gain is potentially a very important finding. Research over the next two-three years will be actively pursuing this.

6. TRAINING HIGHLY QUALIFIED PERSONNEL

The highly interdisciplinary nature of my research provides opportunities for students to bridge between computer science and other disciplines. Past collaborations with architecture, business, civil engineering, education, electrical and computer engineering, fisheries, kinesiology, landscape architecture, medicine, and psychology have allowed computer science students to learn computational aspects of important problems such as climate change or factors influencing fishing policies.

Students participate in a weekly Interaction Design Research Group (IDRG) to discuss a broad spectrum of topics in the HCI literature. This builds analytic skills and experience critiquing theirs and others' work.

In addition to experience working in multidisciplinary teams and learning about the research literature, most of my students attend international conferences to gain insights and inspiration from leading researchers in the field of HCI. This provides opportunity to exchange ideas with students from other universities and countries. Subject to available funding, I encourage each of my graduate students to attend one research conference every year. Often they serve as student volunteers, which enriches the experience for them and provides reduced or waived registration fees and sometimes subsidies for meals and accommodations. Many of my PhD students participate in doctoral symposia and workshops associated with conferences. These provide focused opportunities to seek advice from top researchers in their areas of interest.

Travel is increasingly costly. Leveraging university travel funding for graduate students who present their work at conferences, student volunteer subsidies from conferences – and opportunities to participate in research consortia meetings such as for the NECTAR strategic network over the past five years and the GRAND NCE over the next five years – makes it possible to provide these opportunities for students. The payback from this investment is a higher success rate for student publications and students' development of their own peer networks within their fields of interest.

Note: Throughout the application, citations in **[brackets]** refer to entries in the list of references on the next page; those in **{braces}** refer to entries in the Personal Data Form 100.

1. ANDREWS, C., ENDERT, A., & NORTH, C. (2010). Space to think: large high-resolution displays for sensemaking. *CHI 2010*, 55-64.
2. BAUDISCH, P., CUTRELL, E., ROBBINS, D., CZERWINSKI, M., TANDLER, P. BEDERSON, B., & ZIERLINGER, A. (2003). Drag-and-Pop and Drag-and-Pick: Techniques for accessing remote screen content on touch and pen-operated systems. *Interact'03*, 57-64.
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APPENDIX A (Form 101)
Environmental Impact

Complete this Appendix if you have checked the "YES" box under Certification/Requirements on page 1, Form 101. Include activities that will take place in Canada **and/or abroad.** This information will assist NSERC in determining whether a screening is required under the *Canadian Environmental Assessment Act.* (See the "Requirements for Certain Types of Research" in the NSERC *Program Guide for Professors*.)

Family name of applicant	Given name	Initial(s) of all given names	Personal identification no. (PIN)
Booth	Kellogg	KS	**Valid** 10455

Name of applicant's organization
British Columbia

Title of proposal
Collaboration technology and multi-user interfaces

Name of other participating organizations (if applicable)
(none)

Name of Location (Please complete an additional copy of Appendix A for EACH location at which research will be undertaken.)
The University of British Columbia

1. Main characteristics of the location (i.e., physical description & coordinates)

Some of the research will take place in classrooms and meeting rooms that are not formal research laboratories or offices.

Continue on page 3 of this Form (if necessary).

NOTE: There is a potential to generate several Appendices A. **Please ensure that all Appendix A pages are numbered consecutively in the space provided in the upper right corner of the form. IF YOU FORESEE THE NEED FOR MORE THAN 3 (THREE) APPENDICES A, PLEASE CONTACT NSERC'S ENVIRONMENTAL ASSESSMENT UNIT BY TELEPHONE AT (613) 992-3612 OR (613) 995-8079, OR BY E-MAIL AT enviro.assess@nserc-crsng.gc.ca.**

The information contained in this form will be used by NSERC to determine any potential environmental effects.
(See the "Requirements for Certain Types of Research" in the NSERC *Program Guide for Professors*.)

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Personal identification no. (PIN)	Family name of applicant
10455	Booth

APPENDIX A (Form 101) CONTINUED

2. Principal activity(ies) and activity component(s).

Informal testing and formal field studies (deployments) of technology developed or being evaluated in the research will be conducted in classrooms and meetings rooms at The University of British Columbia.

Continue on page 3 of this Form (if necessary).

3. For each principal activity and activity component, list the environmental elements affected and provide a description of those effects.

No environmental elements will be affected beyond what would occur for research conducted in a laboratory or office setting.

Continue on page 3 of this Form (if necessary).

4. Mitigation measures.

No special mitigating measures will be required.

Continue on page 3 of this Form (if necessary).

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APPENDIX B (Form 101)
Canadian Environmental Assessment Act
Pre-Screening Checklist

Complete this Appendix if you have checked the "YES" box under Certification/Requirements on page 1, Form 101. Include activities that will take place in Canada **and/or abroad.** This information will assist NSERC in determining whether a screening is required under the *Canadian Environmental Assessment Act.* (See the "Requirements for Certain Types of Research" in the NSERC *Program Guide for Professors.*)

Family name of applicant	Given name	Initial(s) of all given names	Personal identification no. (PIN)
Booth	Kellogg	KS	**Valid** 10455

Name of applicant's organization
British Columbia

Applicants are responsible for verifying whether permits are required for any of the activities listed below. Please indicate yes (Y), no (N) or unknown (U) by checking the appropriate box for EACH of the listed activities.

Y	N	U	DESCRIPTION OF ACTIVITY
Part 1. - Determination of Physical Work under the CEAA			
X			Does any phase of the proposal involve the **construction, operation, modification, decommissioning, abandonment or other activity** in relation to a built structure that has a fixed location and is not intended to be moved frequently?
Part 2. - Determination of Assessable Activities under the CEAA			
	X		Activity takes place in a National Park or National Nature Reserve in Canada
	X		Activity takes place on First Nation lands
	X		Activity takes place in the North (Yukon, Nunavut, or the Northwest Territories)
	X		Activity takes place in or within 30 metres of the right-of-way of a power line, a natural gas line, or a railway line
	X		Activity takes place in or adjacent to a water body, resulting in harmful alteration, disruption or destruction of fish habitat (including the removal or damaging of aquatic vegetation)
	X		Destruction of fish other than by fishing
	X		Sampling or prospecting for ores or minerals
	X		Disposal of a prescribed nuclear substance other than in a laboratory equipped for such disposal
	X		Deposit of a deleterious or other substance into the environment (in the earth, air, or water)
	X		Any kind of remediation of contaminated land
	X		Deposit of oil, oil wastes or any other substances harmful to migratory birds in waters or in areas frequented by migratory birds
	X		Killing or removal of migratory birds, their nests, eggs, or carcasses or other physical activities that may require a permit or other authorisation under the *Migratory Birds Regulations* or *Migratory Bird Sanctuary Regulations*
	X		The removal or damaging of vegetation and/or the carrying on of agricultural activities or the disturbance or removal of soil in a wildlife area that requires a permit under section 4 of the *Wildlife Area Regulations* under the *Canada Wildlife Act*
	X		Physical activities that are carried on in Canada and that are intended to threaten the continued existence of a biological population in an ecodistrict, either directly or through the alteration of its habitat
	X		Establishment or operation of a field camp in a single location that will be used for 200 person-days or more within a calendar year
	X		Seismic surveying involving more than 50 kg of chemical explosive in a single blast; or marine or freshwater seismic surveying, if during the survey the air pressure measured at a distance of one metre from the source would be greater than 275.79 kPa (40 lbs/sq in)

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Personal identification no. (PIN)	Family name of applicant
Valid 10455	Booth

APPENDIX B (Form 101) continued

Are any authorizations, permits, or licences required to undertake any activity for any phase of the proposal? If **yes**, list them below, along with the name of the issuing agency(ies). If **no**, please state "None required" and submit this page with the rest of your proposal.

Behavioural Research Ethics Board approval for research involving human subjects

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