“This is Fun! We’re All Best Friends and We’re All Playing.”: Supporting Children’s Synchronous Collaboration

Kori M. Inkpen, Wai-ling Ho-Ching, Oliver Kuederle, Stacey D. Scott, Garth B.D. Shoemaker

EDGE Lab, School of Computing Science, Simon Fraser University

Abstract: As computers become integrated in our everyday lives, it is important that we do not limit computer-based collaboration to distributed settings. As the demand for collaborative applications grows, it is imperative that we investigate how to effectively support co-located collaboration and fully understand the consequences of this style of interaction. This paper presents preliminary results from a research study which examined pairs of elementary school children playing a puzzle solving game in various collaborative setups. Children's activity and engagement levels when playing on a computer with multiple input devices was compared to other traditional collaborative settings (paper-based, common desktop configuration). Preliminary qualitative and quantitative analyses revealed three main benefits of providing each child with access to a mouse and a cursor: (a) children exhibited a significantly higher level of engagement; (b) children tended to be more active; and (c) children significantly preferred playing on a computer equipped with multiple input devices and cursors.

Keywords: multiple input devices, single display groupware, co-located collaboration, children, education, games, groupware, gender

Introduction

The dominant paradigm in computer interaction assumes that one computer is dedicated to one user at any one time. This ignores the fact that in many social environments, such as school or the workplace, people are often required to communicate and work collaboratively. The research area of Single Display Groupware (SDG) (Stewart et al., 1999) attempts to address this problem by finding effective ways to allow groups of two or more people to collaborate using a shared computer display.

SDG applications could have a strong impact on many areas. Education, in particular, is an area well suited to this style of collaboration. Cooperative learning is a priority in many classrooms and emphasized by current curriculum standards (NCTM, 1989). In public schools children are often required to work together on computers. While this situation can be limiting for some activities, many children do enjoy working and playing together on a single computer. These practical and social issues reinforce the need for research in the area of SDG.

The study presented in this paper investigated children’s interactions while playing a cooperative puzzle solving game in various collaborative set-ups. The game required the children to recognize and complete a pattern using alien faces with different attributes. We assessed the children’s level of engagement and activity as they played a paper-based version of the game and a computer-based version with either one or two mice. Our preliminary results show benefits from providing children with multiple input devices and simultaneous cursors.

This paper presents a summary of recent work in the area of SDG followed by a discussion of the experiment performed, and results obtained. Preliminary conclusions are drawn from the data, and future paths of investigation are suggested.

Related literature

As mentioned previously, most computers found in homes, schools and workplaces are designed to accommodate single user interactions. A large amount of research and development in CSCW and CSCL perpetuates this notion by focusing on the one-person/one-computer paradigm, facilitating collaboration through networked distributed workstations. Single Display Groupware (SDG) is a class of applications that support multiple users interacting in a co-located environment on a single shared display with multiple input-devices (Stewart et al. 1999). By effectively supporting face-to-face interactions, SDG will allow users to interact more naturally and comfortably around the computer. An early SDG environment was the Multi-Device, Multi-User, Multi-Editor (MMM) developed at Xerox PARC (Bier & Freeman, 1991). MMM supported synchronous use of up to three mice, allowing users to focus on a shared task without having to shift between personal and shared displays. However, the MMM technology is no longer supported. Other researchers have also investigated technical issues surrounding support for multiple input devices (Bricker et al., 1995; Myers et al., 1998). Hourcade and Bederson (1999) recently developed an architecture to support the development of Java SDG applications.

Beyond the technical issues of enabling multiple input devices, previous research has suggested that supporting co-located collaboration can provide positive achievement and social benefits for children in educational learning environments. Inkpen et al. (1995) found that children were more motivated to play a commercial problem-solving computer game and were more successful in the game when playing together on a single machine as opposed to playing on side-by-side computers or by themselves. Inkpen et al. (1997) and Stewart et al. (1998) have also shown increased achievement and motivational benefits by providing better support for children's collaborative interactions in a computer environment.

Method

The study involved pairs of children playing a puzzle-solving activity using three different experimental set-ups: (1) a paper-based version of the game with physical pieces; (2) a computer-based version of the game with one mouse and one cursor; and (3) a computer-based version of the game with two mice and two cursors.

Participants and setting

The study took place in a public elementary school on the east side of Vancouver, British Columbia, Canada. The school is located in a lower-economic, culturally diverse area of Vancouver. The participants included forty children (22 girls and 18 boys) between the ages of nine and eleven from three grade four and five classes. Parental consent was obtained for all children who participated in the study. The study ran for three consecutive days in April 1999 in a small conference room that was located in the school library. The research area included two experimental set-ups, each consisting of an IBM-compatible PC, a video camera with two lavaliere microphones to capture the children's interactions, and a scan-converter to capture the computer screen. The two experimental set-ups were configured back-to-back so children working on one computer could not easily see the other computer.

Alien pattern game

The puzzle-solving game we developed for use in this study involved placing alien faces with varying attributes in a row according to a specific pattern. The alien faces had three possible head colours (blue, green, or red), three possible eye colours (black, green, or red), and two possible mouth styles (happy or sad). Each puzzle began with nine squares positioned in either a horizontal or vertical row with an alien face placed in each of the three center squares. The remaining six alien faces were randomly scattered around the playing screen. The object of the game was to place the remaining six alien faces in the correct squares according to a specific pattern (see Figure 1). Three sets of twenty different patterns were created. All sets had the same patterns with only the colour of the attributes changing between each set.

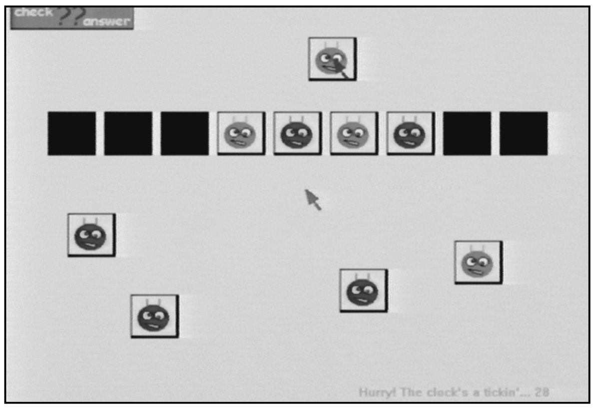


Figure 1. Sample puzzle screen from the computer version of the Alien Pattern game.

The paper-based version of the game was played on a 14” X 8” sheet of laminated paper (see Figure 2). The alien faces were mounted on 1” X 1” magnets to make them easy to handle. The alien faces were moved into place by physically positioning them on the paper. To check a solution, the players were required to ask a researcher whether or not it was correct. If the pattern was incorrect, the researcher asked the children to keep trying. If the pattern was correct, the researcher provided the children with the next puzzle in the game.

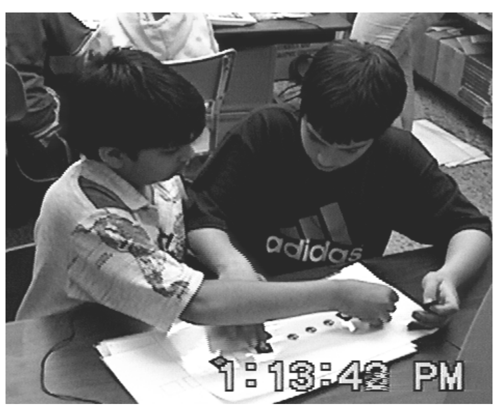


Figure 2. A pair of children playing the paper-based version of the Alien Pattern game.

The computer versions of the game were played on IBM-compatible PCs with 14” monitors. The alien faces were moved into place using a mouse. To check a solution, the players were required to click the “check-answer” button located on the top left-hand corner of the screen. If the pattern was incorrect, an error message appeared, asking the children to try again. If the pattern was correct, a congratulation screen appeared. Clicking on the right-mouse button from the congratulation screen advanced the game to the next puzzle. The software displayed a different colour cursor for every mouse attached to the computer. The software was developed using C++ and Microsoft DirectX and utilized input from one or more Universal Serial Bus (USB) mice.

Experimental Variables

A repeated measures design was used in this study with two independent variables: gender and collaborative condition. Both males and females participated in this study but only same-gender pairs were used. The collaborative conditions included (1) paper-based, (2) one-mouse/one-cursor, and (3) two-mouse/two-cursors. In the paper-based condition, pairs of children played using the paper version of the alien puzzle game. In the one-mouse/one-cursor condition, pairs of children played the alien puzzle game on a computer with one mouse and one cursor. In the two-mouse/two-cursors condition, pairs of children played the alien puzzle game on a computer with two mice and two cursors. All pairs of children played the paper-based version of the game first and the order of the remaining two conditions was counterbalanced. This allowed all children to become familiar with the game before playing the computer-based version to minimize the effect that learning may have had on the computer-based conditions. It also provided information on how each pair of children interact given a medium that affords multiple people interacting simultaneously.

The dependent variables analyzed for the two computer conditions were engagement and activity. Engagement was measured by the amount of off-task behaviour exhibited by the children, gathered through video analysis. Behaviour classified as off-task were actions unrelated to the game, including, looking around the room; talking to the other pair; playing with the microphone; and non-game-related discourse. Activity was measured as the number of actions exhibited by each partner and by the pair as a whole, collected through computer logs and video analysis. Actions included moving alien faces and pressing the "check-answer" button. Other quantitative data gathered included background information for the children (e.g. do they have a computer at home, how often do they play video or computer games, whether they prefer to play alone or with friends), and a post-session questionnaire, providing feedback on the session (e.g. preference of collaborative condition, reasons for this preference, and whether they would like to play the game alone or with friends). Qualitative observations were also gathered through video analysis.

Procedure

The children were randomly assigned a partner of the same gender from their class. Two pairs of children at a time were excused from regular class activities for one hour to take part in the study. The study began with welcoming remarks from the researchers, followed by the children filling out a short background questionnaire. The paper-based alien game was then described to the children and they were asked to play the game for ten minutes. All children played the same set of puzzles in the paper-based version. Following this, the children were told that they would be playing the same game two more times using a computer. It was explained that one computer had two mice while the other computer had one mouse, and that it was up to the children to decide how they would coordinate their play. One pair of children was randomly selected to begin with the one-mouse/one-cursor setup while the other pair began with the two-mouse/two-cursors setup. A random assignment procedure was also used to select which puzzle set each pair would use in their first computer condition (out of two possible sets). The children were allowed to play for ten minutes. After the ten-minute session, the pairs of children switched computers and played the game for another ten minutes using the alternate collaborative setup and puzzle set. Following the last experimental condition, the children filled out a post-session questionnaire and engaged in casual discussion with the researchers before returning to class.

Results

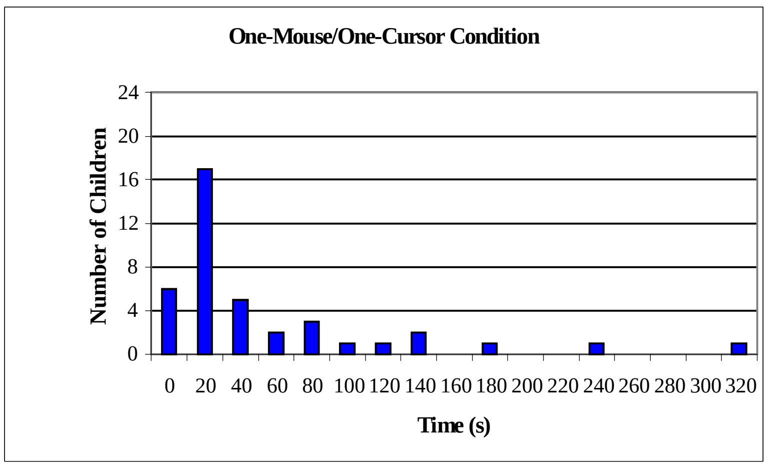
Preliminary results of the study provide background information on the children and data related to the children's level of engagement and activity for each player in a pair, based on their collaborative conditions. The background questionnaire revealed that 66% of the children who took part in the study had a computer at home and 79% had a video game machine at home. Two-thirds of the children stated that they used computers at least a few times a week and three-quarters stated that they play electronic games at least a few times a week. Most children appeared to be familiar with computers and during the experimental sessions, none of the children had difficulty using the computer or interacting with a mouse. Figure 3 shows children playing in the two computer conditions.

Off-task behaviour

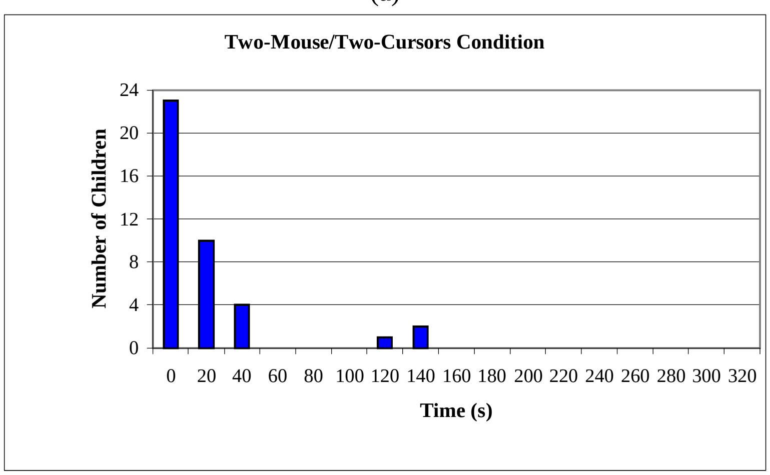
To analyze the amount of off-task behaviour, a mixed ANOVA was performed, with collaborative condition as the within-subjects variable and gender, order of condition, and order of puzzle set as the between-subjects variables. Results revealed a statistically significant main effect for the amount of time the children were not engaged in playing the game, $F(1,32)=9.835$, $p<.01$, with a power of 86%. Children in the one-mouse/one-cursor condition exhibited significantly more off-task behaviour than did children in the two-mouse/two-cursors condition as shown by the distributions in Figure 4. None of the between-subjects variables produced significant effects.

Qualitative observations from the video analysis revealed four main reasons for the children's off-task behaviour: boredom, frustration, monitoring the other pair's progress, and the occurrence of distracting events. Monitoring the other pair's progress and the occurrence of distracting events appeared to be independent of experimental condition while boredom was observed primarily in the one-mouse/one-cursor condition. In most cases, boredom appeared to be a result of a child not having control of the mouse. 82% of the off-task instances were committed when a child didn't have control of a mouse. The degree of boredom, in some cases, was quite extreme (e.g. children not participating at all when their partner was controlling the mouse). Frustration while solving difficult puzzles appeared to be the primary reason for off-task behaviour in the two-mouse/two-cursors condition. In the paper-based version of the game, only four instances (15 seconds) of off-task behaviour were observed.

Figure 3. Two boys playing in the one-mouse/one-cursor condition (left) and two girls playing in the two-mouse/two cursor condition (right).



(a)



(b)

Figure 4. Histogram distributions showing the amount of time children exhibited off-task behaviour in (a) the one-mouse/one-cursor condition and (b) the two-mouse/two-cursors condition.

Level of activity

The number of object placements and "check-answer" button clicks were recorded to investigate the level of activity for each child in the two computer-based conditions. A mixed ANOVA was performed, with collaborative condition as the within-subjects variable and gender, order of condition, and order of puzzle set as the between-subjects variables. Results revealed a statistically significant interaction effect between the collaborative condition and which condition the children played first as shown in Figure 5. A comparison of the simple main effects revealed that children who played using the one-mouse/one-cursor condition first, had a significant increase in their activity level when they played using the two-mouse/two-cursors setup in their follow-up session, $F(1,17)=59.147$, $p<.001$, with a power of 100%. In contrast, children who played using the two-mouse/two-cursors condition first, displayed no significant change in their activity level when they played in the follow-up one-mouse/one-cursor condition, $F(1,21)=1.414$, ns, with a power of 20%.

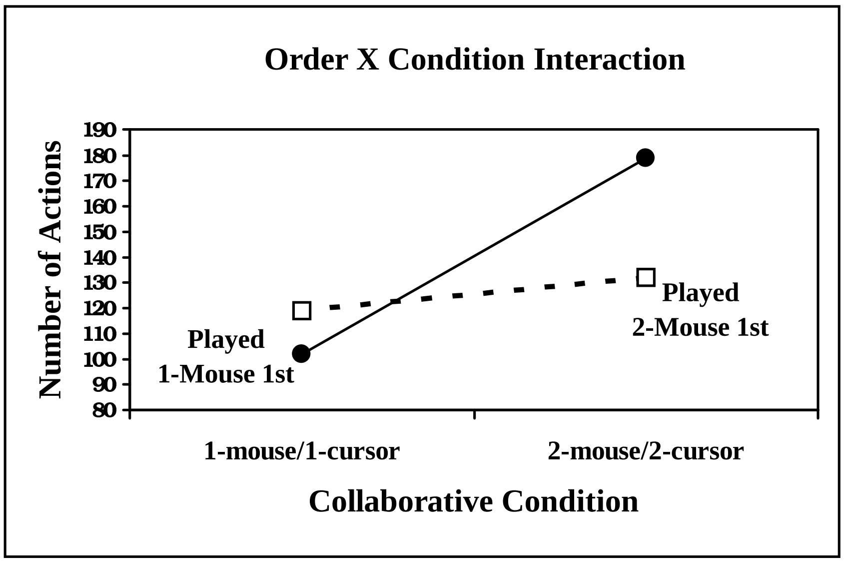


Figure 5. Interaction effect between the collaborative conditions and the assigned order of those conditions.

Qualitative observations from the video analyses revealed that when children played using two mice, both children were constantly interacting with the game. Both children tended to keep their hand on the mouse and continually interacted with it, either as a pointing device or to move puzzle pieces. When the children were forced to share a single mouse, some pairs found other ways to provide input such as pointing at the screen or giving verbal suggestions to their partner. Although these actions do indicate activity, they were not be captured by the computer logs.

Post-session feedback

Children's preferences concerning the three collaborative conditions are shown in Table 1. A Chi square analysis revealed that significantly more children preferred playing on the computer equipped with two mice over the other two setups, $\chi^2(2,N=40)=24.35$, $p<.001$. Nineteen of the twenty-eight children who preferred playing on the computer with two mice explicitly attributed this preference to the fact that two mice were available. In the background questionnaire, 67.5%

of the children stated that they preferred to use computers with friends as opposed to alone. In the post-session questionnaire, this percentage rose significantly to 82.5% when they were asked whether they would prefer to play the alien pattern game alone or with a friend, Z=-2.683, p<.01 (Wilcoxon Signed Ranks Test).

Table 1. Number of children who preferred each collaborative setup.

Collaborative Condition	Count	%
Paper-based version	5	12.5%
One-mouse/one-cursor version	7	17.5%
Two-mouse/two-cursors version	28	70.0%
Total	40	100%

$^{*}p<.01$

Discussion

The results of this study demonstrate that providing children with support for their collaborative interactions can positively impact their levels of engagement, activity, and motivation.

In an educational environment, minimizing the amount of off-task behaviour is extremely important. Our results strongly indicate that one way to help ensure children are engaged in a computer-based learning activity is to provide multiple children the ability to interact with the environment simultaneously. Having control of a mouse and a cursor was important to the children in our study. As one of the children mentioned, when there is only one mouse, “somebody that doesn’t play as much as the other person might not think it was fair because of being left out”. Others expressed that it was easier to solve the puzzles with two mice because they could work in parallel and did not have to take turns. It was interesting to note that when the children played the paper-based version of the game, off-task behaviours were very infrequent. This could be attributed to the fact that each child could easily interact with the game, and that the children always played the paper-based version first (i.e. early in the session) while the game was still a novelty.

Because of the significant interaction effect of collaborative conditions and the assigned order of those conditions it is important to examine the individual effects independently. When children were presented with the one-mouse/one-cursor condition first, the children were less active, possibly because their participation was hindered by limited access to the mouse. Then, when these same children played in their follow-up session, their level of activity rose significantly, even higher than those pairs that started with the two-mouse/two-cursors condition. It seems as if being constrained initially caused the children to take full advantage of their ability to interact simultaneously, later on. Children, who instead played the two-mouse/two-cursors condition first, on average, exhibited higher levels of activity in their follow-up one-mouse/one-cursor condition than those children who started with that condition. In this case, once both children were comfortable working simultaneously, this behaviour may have continued in the one-mouse/one-cursor condition, resulting in higher activity levels. This is an important result because being constrained to existing computer technology may limit the potential for higher levels of cooperative activity.

Children who participated in this study seemed to thoroughly enjoy working together on a computer with multiple mice. This may be attributed to its novelty, however many children are already familiar with these interaction paradigms from video game playing experience and tend to express a preference for multi-player video games (Inkpen et al., 1994; Lawry et al., 1995). Figure 6 demonstrates children's enthusiasm for playing with friends on the computer.

Figure 6. "This is fun. We're all best friends and we're all playing!"

As the results of this study are still preliminary, more detailed analyses are forthcoming. It is important that we gain a more complete understanding of the complex interaction dynamics exhibited in the various collaborative conditions. This will help us better understand how to effectively design and structure collaboration within SDG applications and what activities best fit this interaction paradigm.

Acknowledgments

This project was funded by Simon Fraser University, the Natural Sciences and Engineering Research Council of Canada, and the TeleLearning Networks Centres of Excellence. We would like to thank the students and teachers from Lord Nelson Elementary School, Dr. Sheelagh Carpendale, Lyn Bartram, Dr. Kellogg Booth, Dr. Christine MacKenzie, and members of the EDGE Lab (Exploring Dynamic Groupware Environments) and the SFU Graphics and Multimedia Research Lab for their valuable assistance on this research project.

Bibliography

Bier, E.A., and Freeman, S. (1991). MMM: A user interface architecture for shared editors on a single screen. *Proceedings of UIST '91*. 79-86.

Bricker, L.J., Tanimoto, S.L., Rothenberg, A.I., Hutama, D.C., and Wong, T.H. (1995). Multiplayer Activities that Develop Mathematical Coordination. *Proceedings of CSCL '95*. 32-39.

Ho-Ching, W. (1999). The Multiple Mouse Project [Online]. Available: http://www.cs.sfu.ca/~inkpen/Papers/ho-ching.pdf [1999, May 5].

Hourcade, J.P., and Bederson, B.B. (1999). Architecture and Implementation of a Java Package for Multiple Input Devices (MID). Tech Report HCIL-99-08, CS-TR-4018, UMIACS-TR-99-26, Computer Science Department, University of Maryland, College Park, MD.

Inkpen, K., Booth, K.S., Klawe, M., Upitis, R. (1995). Playing together beats playing apart, especially for girls. *Proceedings of CSCL '95*. Lawrence Erlbaum Associates, 177-181.

Inkpen, K., McGrenere, J., Booth, K.S., and Klawe, M. (1997). The effect of turn-taking protocols on children's learning in mouse-driven collaborative environments. *Proceedings of Graphics Interface '97,* 138-145.

Inkpen, K., Upitis, R., Klawe, M., Lawry, J., Anderson, A., Ndunda, M., Sedighian, K., Leroux, S., Hsu, D. (1994). "We Have Never Forgetful Flowers in Our Garden:" Girls' Responses To Electronic Games. *Journal of Computers in Math and Science Teaching*, 13(4), 383-403.

Lawry, J., Upitis, R., Klawe, M., Inkpen, K., Anderson, A., Ndunda, M., Hsu, D., Leroux, S., Sedighian, K. (1995). Exploring Common Conceptions About Boys and Electronic Games. *Journal of Computers in Math and Science Teaching*, 14(4), 439-459.

Myers, B.A., Stiel, H., and Gargiulo, R. (1998). Collaboration using multiple PDAs connected to a PC. *Proceedings of CSCW '98*. 285-294.

National Council of Teachers of Mathematics (1989). Curriculum and Evaluation Standards for School Mathematics.

Stewart, J., Raybourn, E.M., Bederson, B., and Druin, A. (1998). When two hands are better than one: Enhancing collaboration using single display groupware. *Proceedings of CHI 98*. 287-288.

Stewart, J., Bederson, B.B., and Druin, A. (1999). Single display groupware: A model for co-present collaboration. *Proceedings of CHI 99.* 286-293.

Authors' addresses

Kori M. Inkpen (inkpen@cs.sfu.ca)

School of Computing Science, Simon Fraser University; Burnaby, BC V5A 1S6. Tel. (604) 268-6605. Fax (604) 291-3045.

Wai-ling Ho-Ching (fhoching@sfu.ca)

School of Computing Science, Simon Fraser University; Burnaby, BC V5A 1S6. Tel. (604) 268-6605. Fax (604) 291-3045.

Oliver Kuederle (okuederl@cs.sfu.ca)

School of Computing Science, Simon Fraser University; Burnaby, BC V5A 1S6. Tel. (604) 268-6605. Fax (604) 291-3045.

Stacey Scott (sdscott@cs.sfu.ca)

School of Computing Science, Simon Fraser University; Burnaby, BC V5A 1S6. Tel. (604) 268-6605. Fax (604) 291-3045.

Garth Shoemaker (garths@cs.sfu.ca)

School of Computing Science, Simon Fraser University; Burnaby, BC V5A 1S6. Tel. (604) 268-6605. Fax (604) 291-3045.