Exploring a New Interaction Paradigm for Collaborating on Handheld Computers

ABSTRACT

This paper describes a new interaction paradigm for handheld computing: the use of multiple interconnected devices to form a shared virtual workspace. Given the importance of rich, social interactions of children, we wanted to explore ways to effectively support children's collaboration on handheld computers. The notion of distributing shared information across handheld displays was investigated by applying user-centered design techniques for children. Based on these ideas, the WHAT-IF feature was developed to extend Geney™, a collaborative activity for handheld computers where children can explore genetics concepts. The WHAT-IF feature facilitated children's synthesis of information and discussion during the collaborative activity. An exploratory study was conducted to observe children's use of this new interaction paradigm, and gain feedback on the WHAT-IF feature. The results of this work illustrate the potential of handheld computers for supporting children's social interactions in collaborative learning activities.

Keywords

Computer supported cooperative work (CSCW), computer supported collaborative learning (CSCL), handheld computers, children, education, PDAs.

INTRODUCTION

As the prevalence of handheld computers grows, their small size and mobility provides new opportunities for children in educational environments. In particular, rich face-to-face interactions are possible by enabling children to be physically co-located while maintaining control over their own device. We investigated the use of multiple interconnected devices to form a shared workspace. This new interaction paradigm for handheld computing will extend the possibility of these devices for supporting collaborative interactions.

Face-to-face collaboration is an important aspect of children's work and play. However, children's rich social interactions have not traditionally been supported by technology. In response, researchers have explored mechanisms to support multiple people working together around a shared display [2, 11, 14, 18, 21].

Handheld devices also present a viable option for supporting children's social interactions; however, the small form factor of these devices often constrains users to individual activities. The small screen and limited viewing angles make sharing a handheld display is very difficult. As a result, the essence of the computer as a 'personal device' is often reinforced with handheld computers; evident in adults primarily using handheld devices for personal information management. If handheld computers are to be used in learning environments, it is important to investigate ways of supporting children's collaborative interactions which can lead to positive learning benefits [9, 12]. New interaction paradigms must be explored to effectively utilize handheld computers in collaborative activities. Instead of a 'Personal Digital Assistant' (PDA) we need to look towards a 'Portable Interpersonal Digital Device' (PIDD).

Our explorations grew out of a workshop on ubiquitous computing held at the CILT '99 conference. To examine the use of shared displays for educational applications, we combined the strengths of the EDGE Lab from Simon Fraser University (SFU), versed in design and evaluation of educational applications, with the GUIR Lab, a user interface group from UC Berkeley with expertise in PDA and mobile application development.

This paper explores the idea of supporting children's collaboration with handheld computers. Previous research on handheld computers for children is identified, followed by a discussion of Geney™, a collaborative handheld application developed in an earlier research. project at SFU. Through brainstorming and participatory design sessions with children, we investigated extensions to Geney to identify mechanisms allowing children to work through hypotheses and gather information to help with the problem solving aspect of the game. An exploratory user study was conducted to examine children's interactions with this new feature. Finally, implications for collaboration on handheld computers and future directions for this work are presented.

HANDHELD DEVICES FOR CHILDREN

Children are not novices in the realm of handheld computing. Handheld devices for children have already achieved great success in the marketplace. In 1998, Nintendo™ reported that over 65 million GameBoys™ had been sold [15]. Beyond the world of video games, other handheld electronic devices have also achieved commercial success, such as virtual pets like Bandai's Tamagotchi™, which sold over 40 million units worldwide in 1997 [22]. While these products have been extremely successful commercially, they have been designed primarily for entertainment purposes and most are limited in the scope of their functionality. Children are looking for more from their handheld devices and many have identified the desire to use portable handheld computers for creative activities beyond gaming [10]. Developers are responding to this interest. For example, Nintendo™ is moving outside the realm of video games with its recent release of a digital camera and printer attachment for GameBoy™ as well as new animation and music features [16]. Researchers have also begun looking at ways to incorporate handheld computers into educational activities [20].

Collaboration Using Handheld Computers

As handheld devices for children move into the general computing paradigm, support for collaboration will be an important obstacle to overcome. It is commonplace to see children clustered around a desktop computer screen, working or playing together. Collaboration is a significant part of children's interactions with technology and it is important that technology support children's natural social interactions. diSessa [19] comments that the single most important heuristic for evaluating software is simulation of the child's activity structures. In most cases, children's software (and hardware) do not effectively support the collaborative aspects of their interpersonal interactions.

A few researchers have begun to explore the collaborative potential of handheld devices, particularly for education and entertainment. Colella and colleagues [5] explored participatory simulations, utilizing interactive tags, where participants could role-play simulations from a first-person perspective. Musical Friendship Rings allow children to collaboratively play a piece of music on several Cricket-based handheld devices when they come in proximity to each other (e.g., each device plays one instrument). The DataGotchi concept sketches [3] illustrate several collaborative ideas for handhelds as data collection devices or integrated with other computational devices (e.g., shared displays, television sets, peripherals). These ideas form the basis for understanding how small, portable devices could be used to facilitate collaborative interactions.

GENEY

Geney [6] is an interactive game that assists children in exploring the concept of genetics. Geney simulates a gene pool represented by a population of fish. The fish are distributed across multiple handheld computers, each handheld representing a single pond of fish. Students can exchange fish with their friends through the handheld computer's infrared port. Fish mature at a constant rate (determined when the game is initiated), and players can mate fish within their pond. These fish will produce offspring that have genetic traits derived from their parents' genes. Given the complexity of genetics, a limited set of genetic traits are actually tracked and used to determine the offspring's characteristics. Family tree information can also be presented by linking the game with a desktop computer.

Students must collaboratively work together to produce a fish with a particular set of characteristics. Only by working cooperatively with other students playing the game can the class achieve the desired goal.

Geney is an innovative application demonstrating collaboration across handheld computers. Although students are collaborating to solve the overall goal of the game, all information for each pond of fish is local to each student's handheld computer. Students can send a fish to other players, but there is no sharing of information where multiple students work together with the same data.

TILED DISPLAYS

Observations of children playing Geney revealed that the children often looked at other players' screens, even though they each had their own handheld computer. This seemed to be a natural interaction as each screen contained local information. Children may have been curious to see what was on the other player's screen. The children tended not to use the family tree functionality for the PC, possibly because of the overhead involved in setting up the PC component or their desire to stay working on the handheld platform. The idea of physically connecting screens together and displaying information tiled across screens [3] seemed like a potentially useful feature for the Geney application. Tiled displays on handheld computers would be particularly useful for situations where participants were in the field and did not have access to a larger display to display shared information.

The idea of the tiled display was explored using participatory design (PD) sessions with students from Lord Nelson Elementary School in Vancouver, Canada. The students tried different configurations of multiple handheld computers to display information tiled across the displays. The students explored this concept using the Geney family tree, which would normally be viewed on a desktop computer (see Figure 1). The children found that the frames of the handheld computers interrupted the flow of information in a very disconcerting manner. The students also felt that attaching four handheld computers compromised portability. If mobility of the handheld computers was going to be forfeited, it would be better to take advantage of the graphics capabilities and screen real estate of a stationary display.

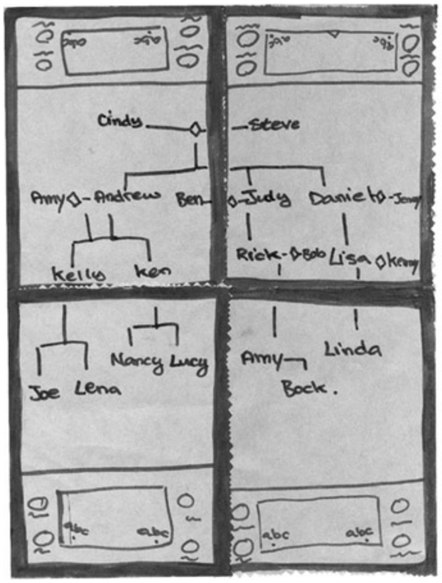


Figure 1: A student's concept of using tiled displays to visualize information across handheld computers.

Because of the difficulties uncovered in the PD sessions, we decided to focus on distributing information across handheld computers and structuring the collaborative activity to promote sharing of this information.

DISTRIBUTING INFORMATION ACROSS DISPLAYS

Observations of children playing Geney showed that children had difficulty deciding which fish to mate. Details were given about the traits of each fish, and family trees were accessible to view, but the children needed more information to resolve the complexities of dominant and recessive genes. To facilitate discussion of these concepts, we needed to develop a tool to address these complexities in a way that the children could understand.

Brainstorming and participatory design sessions were held to explore ways to scaffold the decision making process and help them decide which fish should be mated (scaffolding is an educational term that refers to providing support to learners while they engage in activities). Design activities with children can provide valuable insights into appropriate software design for children [8]. Students from a Grade Seven class at Lord Nelson Elementary School in Vancouver, Canada took part in the sessions. All of these children had previous experience playing Geney on handheld computers.

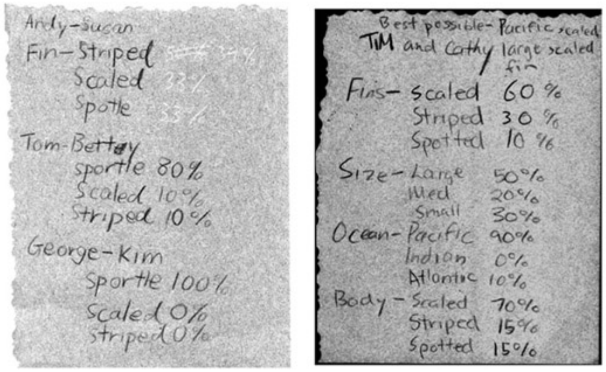
The idea of a tool to compare pairs of fish (without actually mating them) was conceived during the brainstorming sessions. One group of children designed a feature that allowed four children to work together. Each of the four players would have information on the potential outcome of one trait, for a number of pairs of fish (e.g., Mary would examine fish size for several of the pairs, Joe would examine fin types for these same pairs, see Figure 2a). Another group designed a feature where any number of children could participate and each player would have information on the potential outcome of all the traits but only for one pair of fish (e.g., Mary would examine size, fin type, body type, and body shape for one pair of fish, Joe would look at the same traits for a different pair of fish, see Figure 2b). Both of these tools would require the children to collaborate and discuss the possible outcomes. The children also explored different ways to present the trait information on the handheld computers. The most common method of presentation was a list with associated percentages (see Figure 2). Alternative suggested methods of presentation included bar graphs and pie charts.

The two methods of distributing information across handheld devices were presented to two different groups of students from the same class for further investigation. These groups explored the suggested interfaces using paper prototypes. The students found it more intuitive to have the potential outcome information of all the traits, for one pair of fish (see Figure 2b), rather than having the information of one trait for a number of pairs of fish. These children also made comments on the interface, preferring to visualize the information using the list format rather than a more visual format such as a graph. They also described how the tool should be accessed from Geney and what the interface might look like.

Based on the children's designs and suggestions, we implemented a feature called *WHAT-IF*.

The WHAT-IF Feature

The WHAT-IF feature provides information that children can use to make collaborative decisions on potential mating pairs. Children form ad-hoc groups of two to five players to use the feature. There are no restrictions on which children can participate and the groups can change with each running of the feature. One child in the group acts as the manager while the remaining children act as participants.



(a) (b)

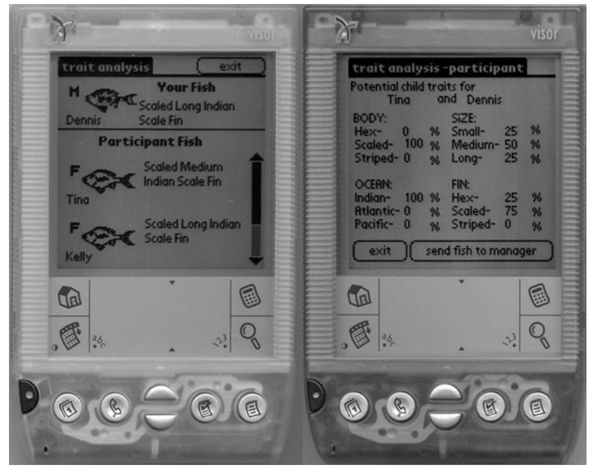
Figure 2: Interfaces designed by students to present information on the potential outcome of mating certain pairs of fish. a) Presentation of information for one trait for a number of pairs of fish. b) Presentation of information for a number of traits for only one pair of fish.

The manager chooses a fish they would like to find a partner for. Participants choose a fish in their pond of the opposite sex and each beam that information to the manager. The manager then returns the appropriate information to each participant. The manager's screen shows the traits of their fish and all the participants' fish (see Figure 3a), while each participant's screen shows detailed information about the potential outcome of mating their fish with the manager's fish in terms of traits passed to the offspring (see Figure 3b).

The players can use the WHAT-IF feature when trying to make a decision about a potential mate for their fish. For example, a player might have a male fish with two of the four traits of the target fish, while three other players have female fish with other target traits. The player with the male fish acts as manager while the players with female fish would act as participants. WHAT-IF does not provide a solution, but helps the children make informed decisions.

WHAT-IF as a Cooperative Learning Tool

The design and utilization of the WHAT-IF tool in Geney fits well within the theoretical model of cooperative learning. For over twenty years, researchers have reported on the positive academic and social benefits of cooperative learning including achievement gains and increased motivation [12]. However, many researchers feel that academic benefits are only achieved by properly structuring the cooperative learning activity [9]. In particular, positive interdependence (the notion that each child can only succeed if all the members in the group succeed), is often cited as being a core requirement of cooperative learning. By distributing information across individual handheld computers, the WHAT-IF tool helps promote interdependent goals, tasks, resources and roles.



(a) (b)

Figure 3: The analysis screens of the WHAT-IF feature. a) The manager's analysis screen in the WHAT-IF feature displays the detailed information of all of the participating fish. b) The participant's screen in the WHAT-IF feature displays information on the chances of certain traits occurring in the offspring of a given pair of fish.

Looking more closely at the information presented to the children in the WHAT-IF tool, there is no one 'correct answer' and the children must synthesize the information and decide between multiple solutions. Cohen [4] identifies this type of task as an "ill structured problem" and claims that rich interactions are critical for achievement gains in these situations. Resnick [17] also notes that it is important to look at the influence of social interaction on the constructive process, such as asking questions, arguing, and the elaboration of ideas. She claims that it is important to "seek mechanisms by which people actively shape each other's knowledge and reasoning processes." The WHAT-IF tool strives to provide children with activities to help achieve this goal.

Recently, Benford and colleagues [1] introduced the notion of shared interfaces that encourage collaboration. The WHAT-IF feature in Geney supports this by working together to perform a WHAT-IF analysis, children will not only learn which pairs of fish may be most likely to help achieve the desired goal, but they also gain insight into the dominant and recessive trait structure of their fish.

As a cooperative learning tool, one of the most compelling aspects of WHAT-IF analysis is it combines individual and social processes, both of which have been identified as being important to the collaborative process [7]. The children individually contribute fish (and the corresponding genetic information) to the activity and maintain information related to one pair of fish on their handheld computer. The social processes involve the group synthesis of information, discussion, and hypothesis generation on the best possible pairing(s) to make.

IMPLEMENTATION OF THE WHAT-IF FEATURE

The WHAT-IF feature was designed to allow multiple displays to form an interconnected virtual workspace. Because the feature calculates potential results based on both local and global information, a mechanism for passing information was required. Most handheld computers have an infrared port that is used to beam and receive information from other handheld computers. The ports must be aligned and the beam initiated in the software. We used the infrared ports for information sharing in Geney.

WHAT-IF was built on the existing Geney application [6] using Code Warrior™. Geney is initiated from a program written in Java™ which runs on a desktop computer. The program creates the original fish in each player's pond and stores them in a Palm™ Database File. The program also creates an empty database to log children's navigation information through the game. The log database, fish database, and the application are then installed on each handheld computer using the HotSync feature.

When the players initiate the WHAT-IF feature, shared information is pooled on each handheld computer via IR beaming. When running WHAT-IF, players want to test certain pairings without actually performing them in the game. In order to ensure that their actions do not result in mating, the shared information is temporarily stored in the dynamic memory of the device instead of using the fish database. When children have made a decision using WHAT-IF, they can beam the chosen fish to the manager. Following this, all players exit the feature and return to the game. Thus, long-term storage of the shared information is no longer required.

Log entries record the player's actions each time they interact with the game. Each entry is time stamped and installed in the log database. After the game has been played, the initial Java program can read and display the game log for each handheld computer.

EXPLORATORY STUDY

We conducted an exploratory user study to gain insight into children's use of the WHAT-IF feature and obtain feedback on its usefulness within Geney.

Participants and Setting

Seven students (five girls and two boys), ranging in age from 12 to 14, volunteered to participate in this study. The volunteers were students at a summer camp entitled 'Fun with Computers' at Simon Fraser University in Vancouver, Canada. Parental consent and consent from the children were obtained from all participants. The study was conducted in the EDGE (Exploring Dynamic Groupware Environments) Lab in the School of Computing Science at Simon Fraser University. Participants sat on cushions on the floor to create a relaxed, informal environment and facilitate interactivity (see Figure 4). All volunteers had previous experience with computers, although only one of the seven volunteers had previously used a handheld computer. Each of the students reported that they played computer or video games on a regular basis (more than a few times a month).

Figure 4: Students using WHAT-IF while playing Geney.

Experimental Design and Procedure

When the participants arrived, they each filled out a background questionnaire to gather information about their experience with computing platforms, games, and the Internet. In the first session, the children were given an introduction to handheld computers. They learned how to input using the virtual keyboard and Graffiti, and how to beam and receive information from other handheld computers. Next, the children were given a brief introduction to genetics to ensure they had enough background knowledge to understand the game concepts. Following this, the children were given an introduction to Geney and played together for 20 minutes to become familiar with the game. The participants did not use the WHAT-IF feature in the first session.

A second session was conducted in the same location the following week. In this session, the children were given an introduction to the WHAT-IF feature and played together for approximately an hour. After playing the game, the children filled out a post-study questionnaire designed to investigate their enjoyment, if they felt they learned anything about genetics, their opinion of the WHAT-IF feature, and how they felt about using handhelds collaboratively. Rather than using a numbered scale to rate statements, we devised a scale that was more intuitive for the children to use. Children circled one of the words: "NO, no, maybe, yes, and YES" in response to a statement. The questionnaire was followed by a 20-minute discussion that allowed the participants to make comments and the researchers to ask questions to elucidate interesting observations. The entire play session and discussion was recorded on video for subsequent analysis. Computer logging on the handhelds was used to provide detailed information about the tasks that the players were performing.

DISCUSSION OF RESULTS

The original goals in developing WHAT-IF were twofold. The foremost purpose was to explore handheld computers as a collaborative tool for face-to-face interaction. The second purpose was to aid children's decision-making processes in Geney. The following sections discuss insights gained from the exploratory study including field observations, video data, questionnaires, and log files.

Collaboration on Handheld Computers

There is a common perception that computers are an individual medium while video games are a collaborative medium. The background questionnaire in our study revealed that three of the seven children preferred using computers with friends, two others preferred playing with friends when they could have their own computer, and the remaining two preferred using computers alone. In contrast, all seven students reported that they would rather play video games with a friend than by themselves. This notion of video games being collaborative and computers being individual likely arises from the technological support for multiple users in these mediums. Gaming platforms often support multiple controllers, and interfaces for multiple players (e.g., split-screen display). Computers, on the other hand, provide little support for multiple users in a face-to-face environment.

After playing Geney utilizing our new interaction paradigm, all seven students reported that they would prefer to play Geney with a friend than by themselves. Like gaming platforms, children had access to individual controllers and a display of shared information. The children reported overwhelmingly that the face-to-face component was their favorite part of the experience. The children liked the fact that they could talk in real-time rather than use a chat application, could know who they were playing with, and could talk to their friends while playing.

Examination of the computer logs generated during the session revealed that the children spent a great deal of time interacting with each other. Each child performed a WHAT-IF analysis between two and nine times, and 12 different subgroups were formed throughout the session to explore the WHAT-IF feature. As indicated in Table 1, the composition of these subgroups changed often in terms of members and size. All children had the opportunity to be a manager and a participant. Table 1 shows that all seven students acted as participants and all but one student acted as manager. Subgroups that formed more than once to perform WHAT-IF are only included once in Table 1.

Although each child played using their own handheld computer, we observed that the children passed around their handheld computers from time to time and sometimes leaned-in to share a screen (see Figure 5). When asked about this behaviour, the children said that they didn't mind sharing their handhelds occasionally. Because all of the children had handheld computers and the fact that one player couldn't control more than one handheld in the game, the children didn't seem to be threatened when someone took control of their handheld computer.

Table 1. Different groupings of children when they used the WHAT-IF feature (M denotes the Manager and P denoted the Participants for each instance of WHAT-IF).

WHAT-IF Sub-Groups	Participants						
	1	2	3	4	5	6	7
1	P	P	P	M			
2					M	P	P
3			P	M			
4	P			M			
5		P	M				
6	P	P	M				
7					M		P
8				P		M	
9				P	M		
10	P	M					
11	M	P					
12	M			P			

Figure 5: Two students sharing a handheld computer to look at the WHAT-IF participant's analysis screen**.**

After playing the game, some children reported that they preferred the handheld computers to a desktop computer. Although this statement is application dependent it does reveal a higher initial comfort level factor. In particular, the children commented that they enjoyed using the stylus input and Graffiti and appeared to adapt well to this method of interaction. While the students thoroughly enjoyed using the handheld computers (they even wanted to carry them back to their lab after the session was over), they did acknowledge that a desktop computer does have the advantage of displaying and storing more information.

Enjoyment and Learning (Genetics and WHAT-IF)

Enjoyment and motivation can be an important determinant for success in a learning activity [13]. All of the seven children who took part in this study were extremely positive about their experience playing Geney. Six of the children ranked their enjoyment as either a four or a five on a five-point scale while the remaining child ranked their enjoyment as a three (mean 4.4). The children reported that they liked beaming information, especially trading fish. The fact that it was a collaborative effort that involved trading allowed them to really “get into it”. One female student vocalized that the best aspect of the game was the fact that they were working together to match different sets of information to try and solve a problem.

In terms of the WHAT-IF feature, the children reported that it was a useful feature and it did help them succeed in the game. On a five-point scale, four of the children ranked it as a five and the remaining three children ranked it as a four (mean 4.6). The children stated that the WHAT-IF feature helped them make decisions and that it would be difficult to decide without using this feature. The students were sometimes surprised when two fish had offspring that were different then what was expected based on the WHAT-IF.

CONCLUSIONS

This paper presents the concept of distributing related information across handheld computers as a new interaction paradigm to support collaboration. We focused on children’s rich social interactions in a learning environment because of the potential of handheld computing to support both individual and social processes.

Several key aspects of this research strongly suggest this is a viable direction to effectively support children’s collaboration. First, enjoyment and motivation is an essential part of the learning process. As observed in our initial user study, children were very excited by the notion of sharing information across handheld computers, and were very motivated to interact in this environment. Second, the rich face-to-face interactions can help children synthesize information, creating a dynamic and engaging learning environment. Our observations revealed that these rich interactions could be supported by distributing information across handheld displays to create a shared virtual workspace and that children can effectively make use of this type of information.

The next step in this research project is to develop a more seamless architecture to this interaction paradigm. The children in our study sometimes had difficulty shifting attention from the game to the beaming procedure. Given that the infrared port was used for beaming, the process was at times awkward and disconcerting. An important challenge is to disseminate the required information while allowing the participants to experience a seamless interaction. Because our goal for the present study was to examine the usefulness of sharing information across multiple handheld devices and how the collaborators interacted with each other, the current prototype focussed on how to best distribute information between participants rather than the dissemination technology. With the advent of the The Bluetooth™ specification for wireless data transfer, we enable us to provide a mechanism for seamless interactions between the users.

Children will soon be using handheld computers. Schools will soon be utilizing handheld computers to support learning activities. Rich interpersonal communication will continue to be an important part of our lives. As such, further research investigations of new interaction paradigms are required to better understand how to design and integrate technology into the lives of children.

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