Wearable Computer Supported Cooperative Work for Search/Collection Tasks

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Abstract

In this paper, we assess the value of a wearable computer based CSCW system for search/collection tasks. The prototype system implemented on actual wearable computer provides history information as well as real-time communication support. In the task called ADPA, workers searched and reconstructed right puzzle pieces from many dummies. The experimental results showed that the task completion time of the prototype system was not shorter than that of audio only tool. But the prototype system could support search/collection operation efficiently in terms of worker's movement and searching area.

1. Introduction

The features of wearable computers are that (1) they are always turned on and running, (2) allow hands-free operations, and (3) mobility[12]. These suggest that it is appropriate for outdoor tasks, and we have discussed a new collaboration called WCSCW: Wearable Computer Supported Cooperative Work, which supports cooperative outdoor activities among some workers using wearable computers.

Several studies have used wearable computers and mobile devices outdoors[9]. PIPS[5] is a system for industrial field operators, by which each operator can grasp the status of the task and instruct other workers. Pascoe et al.[11], Kristoffersen et al.[6] and Fallman [3] also introduced mobile computer systems for field-workers. These studies consider field-workers' individual task in large part. The task we focus on here is search/collection task, where some workers look for and collect distributed pieces outdoors.

In the search/collection tasks, non real-time communication is also important to complete the task quickly and efficiently. For example, accumulating each worker's activity information(who, where, when and what he/she found) which can be referred from other workers saves them from unproductive search and redundant communication. SpaceTag[14], GUIDE[1], Hyper Campus[10], and Sotto Voce[4] support such non real-time information associated with the location. Whereas those mainly consider for tour, shop or museum guidance. The objective of our study is to support completion of a task which has a concrete goal to collect all the parts of their targets fast and certainly.

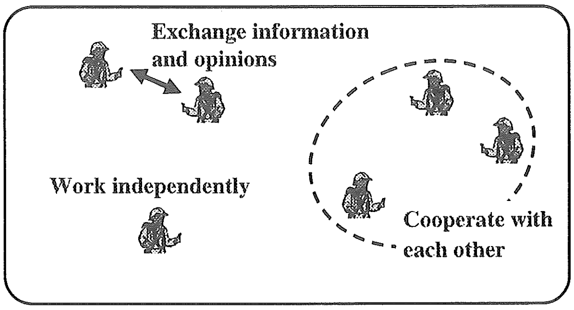

Figure 1. Distributed search task

Previously, We developed the prototype system on actual wearable computers that had history information[13]. Then an experiment was conducted to assess the value of a WCSCW system for search/collection tasks. In this paper, more complicated task was set up with the same prototype system to make an analysis from different view.

2. WCSCW

2.1. Search/collection task

In the search/collection task, each worker is at geographically distributed point and works independently to cooperate with each other for the completion of the common task. (Figure 1). For example, they exchange opinions and information they discovered, and gather to work together during the course of the task. Such cooperation is performed in disastrous search/rescue tasks.

2.2. prototype

Cooperative outdoor activities requires two functions; (i) positioning system to tell each worker's current position and (ii) real-time communication tool through audio, video and still image. Function (i) is generally implemented as

" shared map", on which workers can annotate with highlight marks and audio links. Function (ii) is implemented as video conference system[3].

However, workers can not be aware of where others already searched only with such real-time information. They may search the same area and ask others similar information about the target such as " Didn't you found the piece?". We developed a prototype system which provides the following two non real-time information support as well as real time communication described above.

Work information comprises what they found in the task. The prototype provides a button handling to take the snapshot and video clip of what they found. Then the work information is shared among all the workers through wireless network. Each worker can see targets in his/her unsearched area by referring this work information. Extra search and redundant communication can be reduced.

History information comprises the information of when, where and what each worker did. The prototype generates it for each worker, and then shares it among all. Each worker can easily be aware of where others less searched by referring it. Duplicate search area and extra movement can be reduced.

Figure 2 shows the software components of the prototype system a worker equips. It mainly consists of five parts, " History information generator", " History information communicator", "Synchronous communicator", "WCSCW server" and " WCSCW browser".

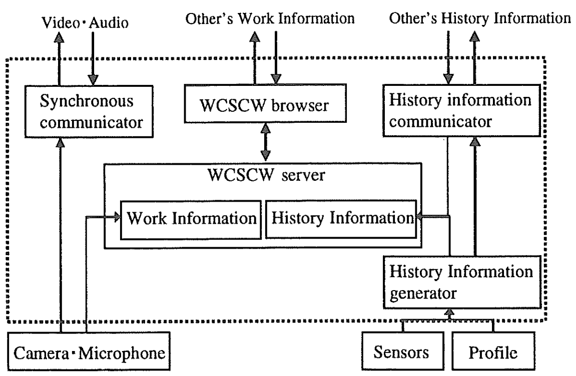

Figure 2. Software components of the system

1. History information generator
   It automatically generates history information from attached sensors and his/her own profile.

2. History information communicator
   It transmits his/her own history information to others and receives others' history information.

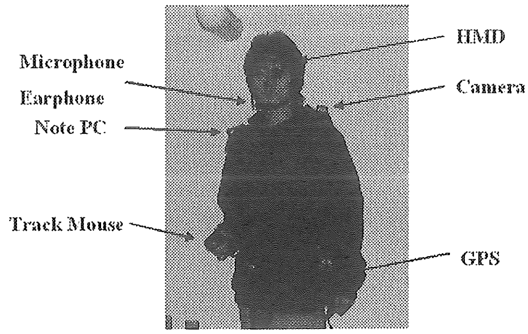

Figure 3. A user with the prototype system

3. Synchronous communicator
   It provides real-time audio and video communication with others using attached camera and microphone.

4. WCSCW server
   It collects history information that is received from other workers' and his/her own. As described in section 2, workers can record what they discovered with camera and microphone as " Work information". It is also accumulated in the WCSCW server.

5. WCSCW browser
   It is the user interface. The History information and the Work information can be accessed by it. It is also possible to access others' Work information.

The history information is described in ASCII code.

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NAME:LONGITUDE:LATITUDE:TIME:ACTION:URI
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NAME, LONGITUDE, LATITUDE, TIME indicate who/where/when creates the history information respectively. ACTION represents the category of worker's actions. The prototype has 4 actions; " Stay", "Moving", "Recording" and "Communicating". This ACTION is decided by the use condition of the prototype and the location data obtained from location sensor. If the ACTION corresponds to "Recording", a URL for accessing to the corresponding work information which the worker "NAME" recorded goes into the URI field.

Figure 3 shows a worker who attached the prototype. Each worker puts a laptop computer into a backpack. Shimadzu HMD(model Data Glass2), USB camera, Track mouse and Garmin GPS(model e-Trex) are connected to the computer. Each computer connects to wireless LAN.

Figure 4 shows the WCSCW browser projected on worker's HMD. It consists of four parts; "Member list", "Shared map space", "Work recorder" and "History graph".

In the "Member list", each worker's property and the picture are listed. Clicking this picture activates the multimedia communication tool with the corresponding worker.

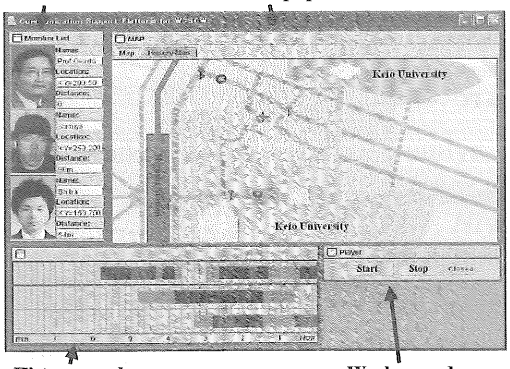

Figure 4. The screen image on the HMD

In the "Shared map space", two shared maps based on the non real-time information can be switched. "Current shared map" shows each worker's present position and an icon indicating where a worker recorded the work information (Figure 5). Figure 6 shows the worker's track.

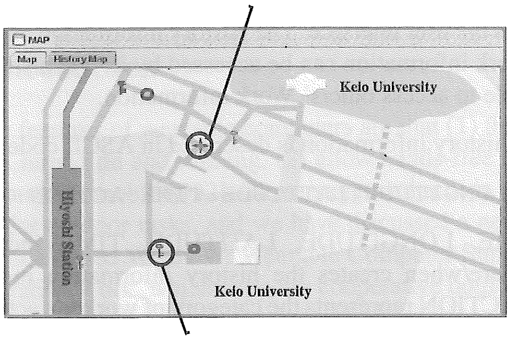

Figure 5. Current shared map

Each worker's movement is represented as aline. The point where a worker stop is represented as a rectangle. The color strength of it represents the period of time a worker stayed. The deeper the color is, the longer the worker stopped there. By Manipulating the GUI of "Work recorder" begins to record the work information using attached camera and microphone. After the recording event, other workers can notice it via the history information, and an icon will be shown at the relevant place in the current shared map. Corresponding work information can be browsed by clicking those icons.

The "History graph" represents all workers' 4 types of activities by the following colors; blue(moving), light blue(stay), red(recording) and yellow(communicating). If the warning color(red or yellow) appears sequentially, it indicates that the worker may find a important thing.

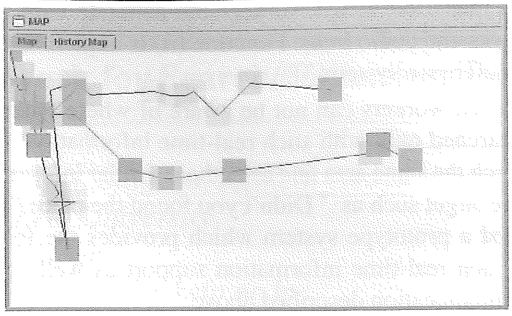

Figure 6. History shared map

3. Experiment

This section describes the task called ADPA(Advanced Distributed Puzzle Assembling) and the method.

3.1. Task

ADPA supposes search/collection operations. The rules are the following conditions. (1) Some workers search and assemble the pieces of puzzles scattered around an area. (2) The variety of puzzles are larger than the number of workers. (3) Each worker decides beforehand which puzzle he/she should pick up. (4) Each worker can move only the pieces of puzzle which he/she takes charge of. We think that associating the image of the puzzle pieces with the position where it was found is effective for improving task performance and communication efficiency.

However, contrary to our expectation, the work information was not used so much in our previous task called DPA[13]. In DPA, the number of puzzles and workers were the same. Since each puzzle piece is surely collected by someone, it is not necessary to record and share as work information. In ADPA, we introduces dummy puzzles. The importance of recording work information increases not only from a view point of performance but also it of accuracy of the work in order not to pick them up.

3.2. Environment

The experiment was conducted at a gymnasium, indoor condition. Figure 7 shows the layout of the testing ground. The size was 10m × 20m, and two obstacles with height of 1.5m and length of 6m were placed to interrupt face-to-face conditions.

Although in this paper we assume outdoor work, it is difficult to perform experiments in such a condition. When the

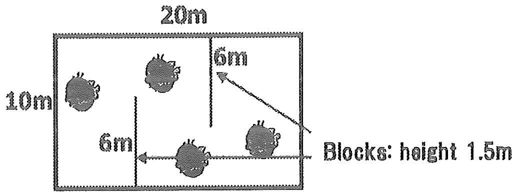

Figure 7. The layout of the testing ground

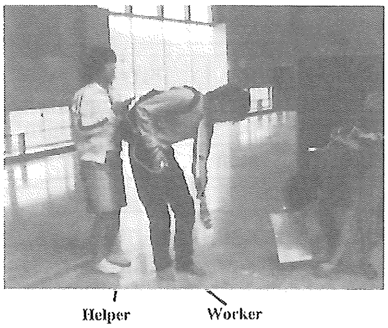

Figure 8. The examinees

testing ground is too large, repetition of the experiments become difficult because of troubles such as battery consumption, and occurring undesired displacement of the pieces due to the weather conditions. The GPS accuracy is not enough for the size of a puzzle piece. Therefore, the axis of coordinate is measured beforehand, and a helper who inputs current position is prepared for each worker. (Figure 8). Figure 9 shows the condition of the experiment. This is recorded through the experiment for post-experimental analysis of conversations.

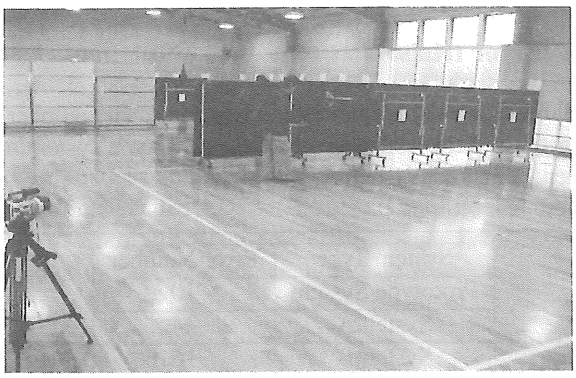

Figure 9. The condition of the testing ground

We used the puzzles which are world map. Each puzzle consists of 20 pieces. In this experiment, three workers searched and assembled three puzzles (60 pieces) out of the total of six puzzles (120 pieces).

3.3. Methods

We examined the task performance, work and communication efficiency in three conditions (Table 1).

function	Prototype	System A	System B
communication	audio/video	audio/video	audio
shared map	○	○	×
history graph	○	×	×
work information	○	×	×

Table 1. Comparison among three conditions

In the prototype system condition, the workers used the prototype of the WCSCW system which we developed. In the comparison system A condition, This system did not provide the " non real-time" history/work information. In the comparison system B condition, the workers used the system which provided only audio communication with others using transceivers. A total of 24 workers performed the task in these conditions. In past DPA, 4 sets of dependent measures were used; completion time, mean movement distance, duplicate search area and conversational segments. In this paper we tried to analyze the completion time in more detail and introduced new measure, error trial.

1. Completion times
   The period of time all the puzzles were completed from the start of ADPA. We hypothesized that the support of various functions would reduce the total time of the task. This can be a measure of task performance.
2. Mean movement distance
   The mean distance each worker moved around the field during the experiment. We hypothesized that non real-time information support would reduce the extra movement. This can be a measure of work efficiencly.
3. Duplicate search area
   The area where each worker searched redundantly. We hypothesized that non real-time information support would reduce the redundant searches. This can be a measure of work efficiency.
4. Error trial
   The number of dummy puzzles picked up by all workers during the task. We hypothesized that it would be reduced if the work information was used effectively. This can be also a measure of work efficiently.

5. Conversational segments
The number of conversational segments uttered by all workers during the experiment. This can be a measure of the efficiency of communication[10]. If there is many segments in the conversation, it isn't effective.

4. Results and discussion

4.1. Completion times

Table 2 shows the task completion times across the three conditions. Comparison system B resulted with the fastest completion time, and our prototype system was faster than comparison system A.

System Type	Completion Times[min]
Prototype System	9.7
SystemA	11.3
SystemB	8.9

Table 2. The time for the task completion

The operational problems and response delay of each function (mainly audio communication function) cause these results. Though workers practiced sufficiently, they required extra time to stop and look at the screen of the HMD to use GUI for performing each function. Audio function especially causes more response delay than that of the system B (transceivers). The shared map supporting history/work information enabled workers to be aware of the area where other workers have searched, hence workers with the prototype system could search puzzles faster than workers with the system A.

type of activity	time [min]
operation	1.1
move	5.6
puzzle pick-up	1.6
puzzle construction	1.2
puzzle exchange	0.2
sum	9.7

Table 3. The rate of the completion time

In the present prototype, table 3 showed the completion time was about 10 minutes and the system-operation time accounted for larger part of the time(11%). This results suggests that improvements of interface and input method for easy operation are required.

4.2. Move Distance and Duplicate Search Area

Table 4 shows the mean movement distance of the workers, and Table 5 shows the duplicate search area. The distance was shorter in order of the prototype system, the system B and the system A, and the area was also smaller in the similar manner.

System Type	Movement Distance[m]
Prototype System	65.6
SystemA	82.1
SystemB	76.4

Table 4. Mean move distance of workers

System Type	Search area[m^2]
Prototype System	63.0
SystemA	80.5
SystemB	78.5

Table 5. The area of the duplicate search

The prototype system could reduce the mean movement distance by about 15% compared with the system B, and 20% compared with the system A. As for the duplicate search area, the prototype system could reduce the area by about 20% compared with the system B, and 22% compared with the system A. This result suggests that workers could determine the next search area efficiently by referring to the work information and icons in the " current shared map " and " history shared map " . Since the communication method was limited in the system A and B, they often communicated with other workers in face-to-face condition for rich environment. This also caused the increase of the extra movement and redundant search.

4.3. Error trials

Table 6 shows the number of error trials. The number of error trials were less in order of the prototype system, the system B and the system A.

System Type	Error Number
Prototype System	10
SystemA	24
SystemB	16

Table 6. The number of the error trials

Workers with the prototype system could report the position of dummy pieces explicitly by the work information. Additionally, they could found the position implicitly by the history information of other workers. In contrast, in the system A and B, they visited searched area, and picked up dummy pieces. This indicates that the prototype could provide workers effective information for efficient search.

4.4. Conversational Segments

Table 7 shows the number of segments in the communication among the workers. The segments workers used was less in order of the system B, the prototype system and the system A.

System Type	Segments Number
Prototype System	62
System A	95
System B	87

Table 7. The number of segments in the communication among the workers

This result is differed from that of DPA. In DPA, the segment was less in order of the prototype, system A and B.

In the system B, some of the workers had found that the communication over the transceiver was not effective. They did ADPA in their own way without uttering a word after some trials. This resulted in little use of the tranceiver, accordingly the number of segments decreased. However, the prototype could reduce the number than that of system A, and measures about work efficiency got higher score than other systems. Workers with the prototype system could be aware of the place of the specific pieces by work information and the place to search next by the history shared map. This indicates that the prototype could reduce the number of segments effectively than the system A.

5. Conclusions and FutureWork

In this paper, we assessed the value of a WCSCW system for search/collection tasks. We developed a prototype system focused on history/work information and conducted a experiment called ADPA. The results showed that the prototype system could support efficient search/collection in terms of movement distance, duplicate search area and error trials. On the other hand, there's plenty of scope for improvement in terms of task performance and communication efficiency. For future work, we should refine the interface and conduct a new experiment in larger testing ground such as campus to reduce the influence which is unrelated to task essential operations.

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