Evaluation of Cooperative Software in Distributed and Asymmetric Collaboration

Jingjie Jiang

Supervisor: **Professor François Charoy**

INRIA-LORIA Research Center, Nancy, France

Contents

1. Introduction

Distributed collaboration is when people collaborate remotely on different sites. Researchers on distributed groupware focus on making distributed work feel as natural and efficient as co-located collaboration. The typology of CSCW groupware is illustrated in Figure [1]. Territoriality and workspace awareness are the main topics in this area [2,3]. P. Tuddenham et al. [4] has already evaluated the difference between co-located collaboration and distributed collaboration in terms of these two concepts. Another area in distributed collaboration which has drawn a lot of attention is related to network delay [5], including its effects and proposing different methods to alleviate those effects [6,7].

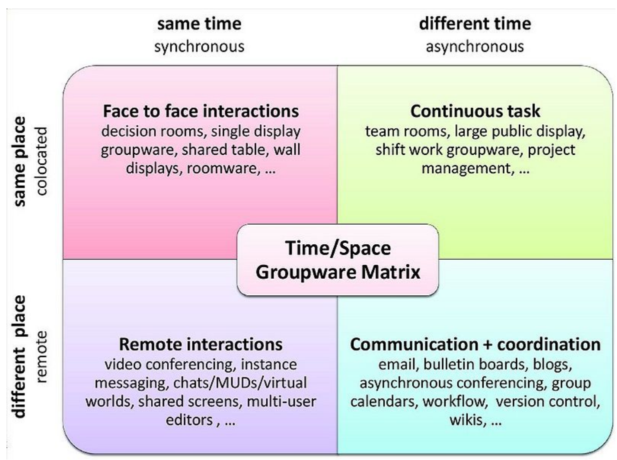

Figure.[1] Typology of CSCW software [1]

Asymmetric collaboration occurs when a group of people with a numerical advantage collaborate with a colleague located remotely. During this type of collaboration, sometimes the group will ignore actions from the single participant. As a result, the single person cannot contribute to the collaboration as much as those who are working together. SAP Research has developed a software called IdeaWall to facilitate distributed and asymmetric collaboration based on post-it notes[8]. The software and hardware settings of IdeaWall are illustrated in Figure.[2] and Figure.[3]:

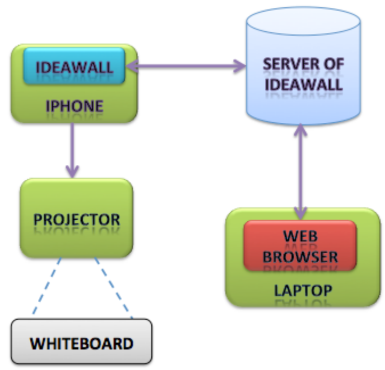

Figure.[2] The software and hardware structure of Ideawall

The IdeaWall runs on an IPhone which connects to a projector. The projector will project a small screen, which is a virtual whiteboard. Within the virtual whiteboard, users can post sticky notes on it. The camera on the IPhone will capture all images of the notes, and uploads them to the server of IdeaWall. The users, who work with laptop or any other devices which can access network via a web browser, can view the images from the web browser. Also, they can add virtual notes on the browser. The virtual notes can be shown in the virtual whiteboard displayed on the real whiteboard.

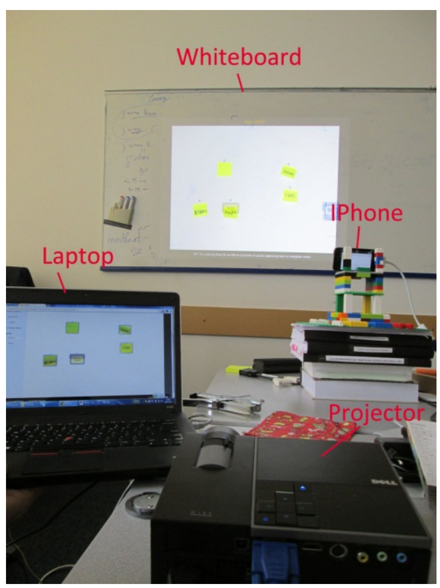

Figure.[3] IdeaWall's settings in the lab

One goal of the project is to evaluate whether IdeaWall can actually support distributed and asymmetric collaboration based on post-it notes, especially for the remote person. We want to figure out whether it will impact the processes and results of the collaboration compared to the co-located case. Another object of the project is to see what the effects are when using heterogeneous device in distributed and asymmetric collaboration based on post-it notes. And eventually propose a way or tool to alleviate the negative effects if some exist.

The rest of the report is organized as follows: Section 2 gives a short introduction about the background. Section 3 shows details of methods we used when design the experiments for evaluating IdeaWall. Section 4 presents the results received and the corresponding analyses. Finally, in Section 5, we discuss the assumptions we can make according to the current results.

2. Background

Systematic evaluation of groupware is a difficult task, especially for distributed collaboration. C. Gutwin et al. [9] introduced a conceptual framework for developing discount usability evaluation techniques that can be readily applied to the iterative development cycle of groupware. The framework is based on support for the mechanics of collaboration, i.e. the low level actions and interactions that must be carried out to complete a task in a shared manner, including communication, coordination, planning, monitoring, assistance, and protection. The framework also contains three general measures of these mechanics: effectiveness, efficiency, and satisfaction.

However, the discount usability evaluation techniques need the teamwork to be well modeled. As a result, a new modeling technique called Collaboration Usability Analysis (CUA) was developed [10]. It grounds each collaborative action in a set of the mechanics of collaboration and provides evaluators with a framework in which they can simulate the realistic use of a groupware system and identify usability problems that are caused by the groupware interface.

Mix Presence Groupware (MPG) is the collaborative software that supports both co-located and distributed participants working over a shared visual workspace in real time [11]. Researchers have done a great amount of work to design and implement MPG for tabletop collaboration. Most of the researches regarding MPG focus on mitigate the presence disparity which means that collaborators' awareness of others' presence is different between co-located tabletop collaboration and remote tabletop collaboration. A.Tang et al. [11,12] proposed four design principles for mitigating presence disparity and realized them by using digital arm shadows. P. Tuddenham et al. [13] used arm shadows as remote embodiments in their Distributed Tabletops system that was created to validate the seven design guidelines which was proposed for the system that supports mix presence tabletop collaboration. In comparison with direct touch technology, relative input technology has no limitation of the work space where participants can reach, but it lacks of awareness information. Consequently, D. Pinelle et al. [14] studied the virtual embodiments to try to enhance group awareness for the tabletop groupware which uses the relative input technology.

However, there are few papers we can find which focus on evaluation methods for groupware which support distributed and asymmetric collaboration based on post-it notes.

3. Methods

To see whether heterogeneous devices can impact processes and outcomes of distributed collaboration based on post-it notes, five observational studies have been conducted. The scenario designed for the studies is that participants need to estimate the population of fifteen cities and rank the cities according to their estimates within 15 minutes. We followed two rules when designed the task: it must be suitable to the participants' background, which will make them easy to do; it must force a group of participants to reach a consensus.

3.1 Subjects

The subjects studied were five groups of paid college students. Each group had four college students enrolled from TELECOM Nancy with age ranges from 18 to 25, for a total of 20 students (3 females and 17 males) involved in the experiments. The details of gender composition of each group are shown below:

Table [1] Gender composition of five groups

	Gender Composition
Co-located Collaboration Group 1	1 female, 3 males
Co-located Collaboration Group 2	4 males
Active Distributed Collaboration Group 1	2 females, 2 males
Active Distributed Collaboration Group 2	4 males
Passive Distributed Collaboration Group	4 males

3.2 Variables

The observational studies have three independent variables: co-located collaboration, active distributed collaboration and passive distributed collaboration. Co-located collaboration means that the whole group is located in one place. "Distributed" refers to members of a group being located remotely in different places. As “passive” and “active”, indicate whether or not remote participants can use tools to post virtual notes.

The observational studies also include four dependent variables: time to reach an agreement, ranking results, number of turns and number of posts.

- **Outcome Measures**
  - **Time to reach an agreement**

This is the total time spent by each group to estimating and ranking the populations of all the cities on the list. When all the members agree with the ranking, then the task is finished.

  - **Ranking results**

The ranking results reflect how the final ranking that a group makes for the list of cities based on their population estimates compares to the standard ranking.

- **Process Measures**
  - **Number of turns**

After one participant voices his opinion, another participant may say something. When this happens, it is counted as one turn. A "turn" is defined in the sense of conversational turn-taking. When one participant voices his opinion, and another participant begins to speak, the first participant's turn has ended.

  - **Number of posts**

This is the number of times that one participant posts real or virtual sticky notes on the whiteboard. If one participant exchanges former rankings of two cities, it is counted as two posts.

3.3 Design of the experiments

The study used a nested between groups design, with subjects nested within groups employing either co-located collaboration, active distributed collaboration, or passive collaboration. The design of the study, as well as the gender distribution of subjects within the groups, is illustrated in Figure.[4].

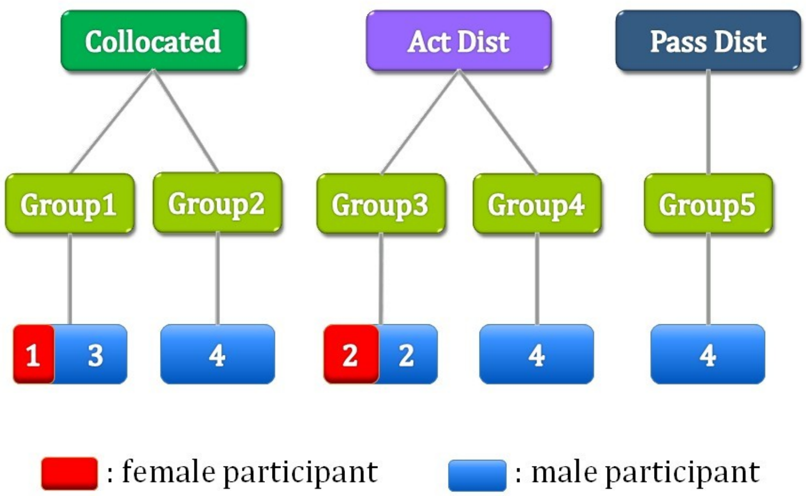

Figure. [4] Design of the experiments

A between groups design is an experiment that has two or more groups of subjects each being tested by a different testing factor simultaneously. To be exact, in this design, five groups were assigned to do the experiments under different independent variables. Group 1 and Group 2 were allocated to do experiments of co-located collaboration. Group 3 was assigned to perform passive distributed co-located collaboration, and the remaining two groups were assigned to the active distributed collaboration condition. Also, the gender compositions of the groups in the co-located collaboration were different, which can be seen in Figure.[4].

3.4 Procedure

Before the experiments, the moderator drew a table on the virtual whiteboard of IdeaWall, listed all the cities in the table and provided numbered post-it notes from one to fifteen. During the experiments, participants needed to post a numbered note next to each city to indicate the rank of the city. The agreement needed to be reached within 15 minutes.

There are some general rules, the participants must obey during the experiments: they could only discuss topics related the task; they could not stand in front of the projector, as the IPhone needed to capture the images of sticky notes posted on the virtual whiteboard; and the participants were to continue until they reached an agreement or the experiment time surpassed fifteen minutes.

Participants in co-located condition and in the distributed had different rules.

- **Co-located participants**

(1) The participants could only use real notes and marker pens for writing something on the notes;

(2) The video projector projected a small virtual whiteboard on the real whiteboard. During the experiments, participants should have only posted their notes in the area of the virtual whiteboard;

(3) Any information should only have been written on the notes and then post it in the area of the virtual whiteboard;

(4) The writings on the notes should have been appropriately sized; otherwise, the other groups working with laptops would not be able to see the contents written on the notes;

- **Distributed participants**

In active distributed collaboration, the remote participant could use virtual notes, use the mouse to draw lines and use the keyboard for inputting information; in the passive case, the remote participant could not post virtual notes and only communicate with local participants by speaking.

3.5 Environment

The materials used for the experiments included an IPhone, a video projector, a whiteboard, a laptop and IdeaWall.

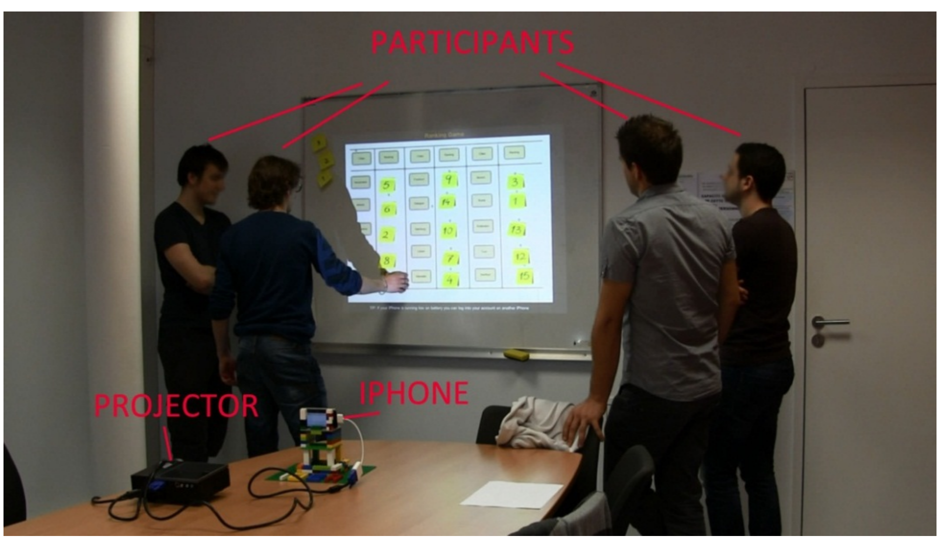

Figure. [5] Environment for collocated collaboration

3.5.1 Setting for co-located collaboration

Four participants are divided into two sub groups. Each sub group had two people and they stood on the different sides of the whiteboard. In this setting, participants could only use numbered real notes to rank the cities. The setting is illustrated in Figure.[5].

3.5.2 Settings for distributed collaboration

In the distributed collaboration conditions, three participants worked cooperatively on the whiteboard and another participant worked on the laptop as a remote participant. Although ideally, the "remote" participant should have been located in a different room, the quality of the network could have negatively impacted the communication between the co-located participants and the remote participant. Therefore, the "remote" participant stayed in the same room, but was unable to see the whiteboard. The setting of the distributed collaboration is shown in Figure.[6]:

Figure. [6] Environment for distributed collaboration

4. Results

Four kinds of data were collected for each experiment: time to reach an agreement, number of turns, ranking results and number of posts.

4.1 Ranking results

The ranking results of all five groups are shown below:

Table [2] Ranking results of five groups

Cities	Standard answers [15]	Co-collab G1	Co-collab G2	Act dist collab G1	Act dist collab G1	Pas dist collab
Athens	01	03	06	02	05	05
Rome	02	02	01	01	01	01
Hamburg	03	11	10	08	11	10
Barcelona	04	12	02	04	02	04
Munich	05	09	03	06	04	06
Brussels	06	06	08	03	07	03
Turin	07	13	12	12	13	12
Marseille	08	07	04	10	03	10
Amsterdam	09	01	05	11	06	11
Frankfurt	10	10	09	09	09	09
Rotterdam	11	05	13	13	12	13
Glasgow	12	14	14	14	14	14
Copenhagen	13	04	11	07	09	07
Lisbon	14	08	07	05	10	05
Sheffield	15	15	15	15	15	15

4.2 Outcome measure

Spearman's rank correlation coefficient is used to evaluate the ranking result of each group to the standard answer. Spearman's rank correlation coefficient assesses how well the relationship between two variables can be described using a monotonic function. If there are no repeated data values, a perfect Spearman correlation of +1 or −1 occurs when each of the variables is a perfect monotone function of the other. The formulas of Spearman's rank correlation coefficient are shown below:

$$\rho = 1 - \frac{6\sum_{i=1}^{N} {d_i}^2}{N(N^2 - 1)} \quad (1)$$

$$d_i = x_i - \bar{x} \quad (2)$$

Comparing the Spearman's rank correlation of each group with time spent to reach an agreement of each group, we can get a table shown as blow:

Table [3] Relation between Spearman's correlation and time spent

	Spearman's rank correlation	Time spent
Co-located gourp1	0.25	06.25m
Co-located group2	0.63	08.25m
Active dist collab group1	0.65	13.00m

Active dist collab group2	0.65	13.10m
Passive dist collab group	0.58	08.00m

We can see from the table that the Spearman's rank correlation of co-located group 1 is much less than the results received from other groups, so it is considered as an outlier. In the rest of the report, the data related to co-located group 1 will not be used. The table also indicates that when participants do experiments in an active distributed collaboration environment, they take much more time to reach an agreement than in the co-located and passive distributed cases. Also, groups involved in active distributed collaboration achieve more accurate ranking results.

Is there any correlation between the two figures? The formula which is used to calculate the Pearson's correlation between Spearman's rank correlation and time spent is shown below:

$$\mathrm{r} = \frac{\sum \frac{(x - \mu_x)(y - \mu_y))}{\sigma_x \sigma_y}}{N - 1} \quad (3)$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \mu)^2}{N}} \quad (4)$$

The μ represents the mean of a data set. The σ means the standard deviation of a data set. The result of correlation efficient is approximately equal to 0.81. Therefore, we can say that the time spent to reach an agreement is highly correlated to the ranking results, i.e. the less time used, the worse ranking results received.

4.3 Process measures

Two measures were included to evaluate the experiments processes used by the participants, i.e. number of posts and number of turns. The details of these two kinds of data of each participant are shown in Table [4]:

Table [4] Process measure outcomes

	Number of Posts	Number of turns
Co-collab group 1		
Female Participant A	19	41
Male Participant B	5	25
Male Participant C	0	20
Male Participant D	0	10
Co-collab group 2		
Male Participant A	5	34

Male Participant B	8	39
Male Participant C	6	13
Male Participant D	0	8
Active dist collab group 1		
Female Participant A	0	29
Male Participant B	7	57
Male Participant C	0	35
Female Participant D	14	72
Active dist collab group 2		
Male Participant A	22	76
Male Participant B	0	48
Male Participant C	0	11
Male Participant D	7	29
Passive dist collab group		
Male Participant A	16	35
Male Participant B	2	30
Male Participant C	7	23
Male Participant D	0	30

4.4 Process measures

To measure processes of the experiments, four kinds of data were calculated, include: ANP (Average Number of Posts), standard deviation of ANP, ANT(Average Number of Turns) and standard deviation of ANT. The standard deviation of ANP and the standard deviation of ANT, means the variability of number of posts between members of a group and the variability of number of turns between members of a group, respectively. The details of these data are shown blow:

Table [5] The statistical data of experiments processes

	Average Number of Posts(ANP)	Standard deviation of ANP	Average Number of Turns (ANT)	Standard deviation of ANT
Co_Group1	6	7.78	24	11.20
Co_Group2	4.75	2.95	23.5	13.24
Act_Dist_Group1	6.36	5.80	48.25	17.224
Act_Dist_Group2	7.25	8.98	41	24.07
Pass_Dist_Group	6.25	6.18	29.5	4.27

It can be seen from the Table [5] that in the active distributed condition, groups posted more notes and took more turns in discussion than in other two conditions. The standard deviations of ANT under active distributed collaboration are also much higher than the others. If we compute the Pearson's correlation between ANP and Spearman's rank correlation, the result is approximately equal to 0.21. Similar result which is 0.19 can be got by calculating the Pearson's correlation between standard deviation of ANP and Spearman's rank correlation. According to the results, a hypothesis can be proposed: ANP or standard deviation of ANP is weakly related to ranking performance. Therefore, we can say that number of posts has nothing to do with group's performance on the task.

However, different results can be received by calculating the Pearson's correlation between ANT or standard deviation of ANT and Spearman's rank correlation. For ANT and ranking performance, the correlation is 0.60. The data can lead to a hypothesis that: ANT is moderately correlated to ranking performance. As standard deviation of ANT, the correlation is 0.92, which means that standard deviation of ANT and ranking performance is very highly correlated.

5. Discussion

The results showed that in active distributed collaboration, when participants only used virtual notes, they took much more time to reach an agreement than the group in the passive distributed collaboration condition. Therefore, we can make an assumption: by using IdeaWall, it will be faster for a group to finish cooperative tasks in a distributed work environment. Also, as the remote participant could not really participate in collaboration, another assumption can be made as well: if a tool can enable all participants to contribute in collaboration, better performance can be received.

However, the correlation between task performance and time spent shows that the less time was spent on the task, the worse the outcome. As the remote participant in passive and active condition are not equal, we cannot make an assumption that IdeaWall will lead to less time needed to finish a task, but worse ranking performance. More experiments should be conducted by letting groups in the active distributed condition use both virtual tool and IdeaWall to do the ranking task.

We can also see from the results that in each experiment of the active distributed condition, there was one participant in each sub group with numerical advantage who used the mouse to post virtual notes more than the other group members and took many more turns to speak than the others. On the contrary, in the experiments using IdeaWall, turns are taken by the members of the sub group more equally. Therefore, an assumption can be made: the IdeaWall can promote people more contribution to collaboration.

During the passive distributed collaboration, sometimes, the remote participant's speaking was ignored by the sub group with numerical advantage, which will affect the remote user's ability to contribute to the task. More experiments are needed to confirm whether this finding is normal in such asymmetric collaboration and confirm that whether IdeaWall can alleviate it.

Correlation between standard deviation of ANT and ranking performance shows that when there are strong leaders who control the discussion in a group, better results can be observed. In the meantime, a phenomenon should be noticed that the strong leaders can be the remote participants, which means, in the passive case, if one of the strong leaders is the remote one who cannot contribute as in the active distributed condition, it will affect the group's collaboration performance. Hence, an assumption is: IdeaWall allows the remote participant to contribute as if it is co-located. If he or she is co-located, the IdeaWall ensures better performance than the passive distributed collaboration.

6. Conclusions and future work

We have studied state of the art and found out that there are few research focus on evaluation methods for groupware which support distributed and asymmetric collaboration based on post-it notes. We conducted five observational studies to confirm that IdeaWall can support distributed support distributed and asymmetric collaboration based on post-it notes, and it allows the remote participant to fully contribute to the task. By analyzing the data collected from the experiments, e.g. calculating Spearman's rank correlation and Pearson's correlation, we have made some assumptions: the figures regarding number of posts are not related to the ranking performance; the use of IdeaWall can ensure better performance than in passive distributed collaboration.

However, all the assumptions we made here are based on the results received from only five experiments which are not enough. In the future, we need to conduct more experiments to confirm all the assumptions. Also, we need to conduct experiments by using heterogeneous devices to evaluate its effects to distributed and asymmetric collaboration.

7. References

[1] Baecker, Ronald .M.; Jonathan Grudin, William Buxton and Saul Greenberg (eds.) (1995). Readings in human-computer interaction: toward the year 2000. Morgan Kaufmann Publishers. ISBN 1558602461

[2] Stacey D. Scott , Karen D. Grant , Regan L. Mandryk, System guidelines for co-located, collaborative work on a tabletop display, Proceedings of the eighth conference on European Conference on Computer Supported Cooperative Work, p.159-178, September 14-18, 2003, Helsinki, Finland

[3] C. Gutwin and S. Greenberg. The importance of awareness for team cognition in distributed collaboration. In E. Salas and S. M. Fiore, editors, Team cognition, APA Press, 2004.

[4] Philip Tuddenham , Peter Robinson, Territorial coordination and workspace awareness in remote tabletop collaboration, Proceedings of the 27th international conference on Human factors in computing systems, April 04-09, 2009, Boston, MA, USA

[5] Saul Greenberg , David Marwood, Real time groupware as a distributed system: concurrency control and its effect on the interface, Proceedings of the 1994 ACM conference on Computer supported cooperative work, p.207-217, October 22-26, 1994, Chapel Hill, North Carolina, United States

[6] Dane Stuckel , Carl Gutwin, The effects of local lag on tightly-coupled interaction in distributed groupware, Proceedings of the ACM 2008 conference on Computer supported cooperative work, November 08-12, 2008, San Diego, CA, USA

[7] Yamashita, N., Kaji, K, Kuzuoka, H., Hirata, K. (2011). Improving visibility of remote gestures in distributed tabletop collaboration. In Proceedings of CSCW 2011, Hangzhou, China, March 19 to 23, 2011. ACM Press: New York, pp. 95–104

[8] Kowalkiewicz M. IdeaWall:bridging the digital and non-digital worlds to facilitate distant collaboration, 2012 6th IEEE International Conference on Digital Ecosystems Technologies (DEST), IEEE, 2012: 1-5

[9] Carl Gutwin , Saul Greenberg, The Mechanics of Collaboration: Developing Low Cost Usability Evaluation Methods for Shared Workspaces, Proceedings of the 9th IEEE International Workshops on Enabling Technologies: Infrastructure for Collaborative Enterprises, p.98-103, June 04-16, 2000

[10] David Pinelle , Carl Gutwin , Saul Greenberg, Task analysis for groupware usability evaluation: Modeling shared-workspace tasks with the mechanics of collaboration, ACM Transactions on Computer-Human Interaction (TOCHI), v.10 n.4, p.281-311, December 2003

[11] Anthony Tang , Michael Boyle , Saul Greenberg, Display and presence disparity in Mixed Presence Groupware, Proceedings of the fifth conference on Australasian user interface, p.73-82, January 01, 2004, Dunedin, New Zealand

[12] Anthony Tang, Carman Neustaedter and Saul Greenberg. (2004) Embodiments for Mixed Presence Groupware. Research Report 2004-769-34, Department of Computer Science, University of Calgary, Calgary, Alberta, Canada. December 21.

[13] Tuddenham, P., and Robinson, P. Distributed Tabletops: Supporting Remote and Mixed-Presence Tabletop Collaboration. (2007) In Proc. Tabletop 2007, 19--26.

[14] David Pinelle , Miguel Nacenta , Carl Gutwin , Tadeusz Stach, The effects of co-present embodiments on awareness and collaboration in tabletop groupware, Proceedings of graphics interface 2008, May 28-30, 2008, Windsor, Ontario, Canada

[15] http://en.wikipedia.org/wiki/Largest_cities_of_the_European_Union_by_population_within_city_limits