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Collaboration in Parametric Design:
Analyzing User Interaction during Information Sharing

abstract: Designers work in groups. They need to share information either synchronously or asynchronously as they work with parametric modeling software, as with all computer-aided design tools. Receiving information from collaborators while working may intrude on their work and thought processes. Little research exists on how the reception of design updates influences designers in their work. Nor do we know much about designer preferences for collaboration. In this paper, we examine how sharing and receiving design updates affects designers' performances and preferences. We present a system prototype to share changes on demand or in continuous mode while performing design tasks. A pilot study measuring the preferences of nine pairs of designers for different combinations of control modes and design tasks shows statistically significant differences between the task types and control modes. The types of tasks affect the preferences of users to the types of control modes. In an apparent contradiction, user preference of control modes contradicts task performance time.

1 Introduction

"Architecture is primarily about communication" *(Verzijl 1997).* In architecture, design is collaborative when the architects share their ideas with peers through verbal and graphical media. Developments in computer aided design (CAD) both follows and leads changes in the working methods of architects. Advancements in communication technology allow architects to collaborate across time and space which, in turn, creates a need to develop collaborative tools specific to design. Such tools meet collaborators need by understanding their work environment and identifying what facilitates or hinders work during design collaboration *(Tang 1991)*.

In design, collaboration can be synchronous and asynchronous, although the majority of work of designers is asynchronous, and any team member can be working at various levels and in various roles in a design project. The updates of changes made to the design will also depend on the type of task performed. While the designer will not want to see every change a collaborator is making, the collaborator might want to see changes when required or necessary. For effective support of team collaboration, not only should the traditional automation of tasks be provided but also the ability for the user to control the sharing and receiving of information *(Park et al. 1994)*.

Recently, parametric modeling has become a principal type of CAD (Hernandez and Roberto 2006). Currently there are not many collaborative tools. In this study, our goal was to develop a collaborative tool for a specific parametric modeling system called GenerativeComponents (GC). Firstly, we studied the domain of parametric design with associated work methodologies. Secondly, we analyzed human work processes associated with the collaboration of sharing and receiving of update/change data, by using the aforementioned information sharing control system. In the experiment we studied four different information sharing control modes a) on demand push & on demand pull, where users share the information based on their needs or requests, b) on demand push & continuous pull: users share the information based on their needs but receive the information continuously c) continuous push & on demand pull: users share the information continuously but receive the information on demand d) continuous push & continuous pull: users share the information continuously. The results show that users prefer the control option allowing for continuous push and pull over the other control modes. The type of task influences the user preference of control mode. Though the users prefer continuous push and pull of information, other observations such as task completion time contradicts their choice of control modes.

2 Collaborative Design in Architecture

Collaborative design has become a part of the design process, where the design is communicated to the team through verbal or graphical information. The continuous development of communication technology has made architects use the computer not only for documenting designs, but also to share work with co-workers *(Gabriel and Maher 2002)*. When designing, collaborators have different tasks to accomplish though the goal is same; this is adjusted during team reviews of the design *(Broll et al. 2004)*. Sometimes a designer might make changes or modifications at the same time as another designer, whereas at other times (s)he might want to review and incorporate a change individually. Currently, designers use different software to share information during collaboration through databases, spreadsheets, data analysis and simulation programs, and internet access facilities *(Maher et al.1996)*. Though these methods are available it is important to create collaborative tools that would support the specific field and applications.

3 Collaboration in Parametric design

Parametric design allows for exploration and variation on geometries resulting in complex and sculpted forms *(Qian et al. 2007)*. Different elements in the design are related through an algorithmic expression which allows parametric changes on a part of design to affect another *(Amor et al. 2002, Woodbury 2010).* Robert Aish states that "the idea of a permanently shared repository with constantly updating short transactions is generally not thought to be appropriate to the work of design teams" because the collaborator making a change might not want to share the intermediate information nor does he wants to intrude the others with incomplete intermediate solutions *(Aish 2000)*.

This study was pursued to better understand the needs of the designers using parametric modeling during collaboration. The following were our initial research questions:

1. Do designers prefer continuous sharing of information over information shared on request?

2. Does the type of task affect the type of control mode used by designer during collaboration in parametric modeling?

4 Research Approach

The methodology we used in our study consists of two parts. First, we designed a prototype system with different control modes to share and receive the information while working towards a common goal. Second, we analyzed user interaction with the control modes through an experiment, which will enable us to better understand interaction in parametric CAD modeling.

4.1 Collaboration system prototype

A simple control system was implemented using a database system. User-accessible controllers were designed so that the user could decide when to push the data and pull the data. Push means to send information to the collaborator while pull means to receive information shared by the collaborator. The controller was incorporated into the interface of the application GenerativeComponents. Figure 1 shows the basic controller design which has two modes ON and OFF and a handle.

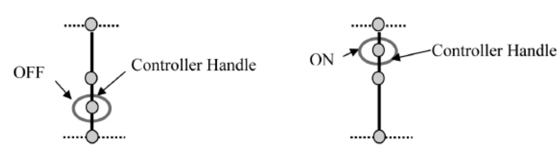

Figure 1. Basic Controller Design for collaboration

The handle controls these modes; if the handle is within the OFF half of the controller then the data is not being transferred. If the handle is within the ON half then the data is being transferred. There were two controllers on the interface, one was for PUSH and the other was for PULL. The controllers have four different options a) On Demand Push and On Demand Pull: the designer decides when to share and receive the information. b) On Demand Push and Continuous Pull: the user shares the information when he decides while he receives the information continuously. c) Continuous Push and On Demand Pull: the information is shared continuously while the user decides when to receive the data. d) Continuous Push and Continuous Pull: the receiving and sharing are continuous and the user need not interact with the controllers. Figure 2 shows the options.

Figure 3 shows the architecture of the platform we developed for collaboration experiments. The changes made to the design were updated through a design database. Designers were provided instant messaging through Skype to communicate with each other.

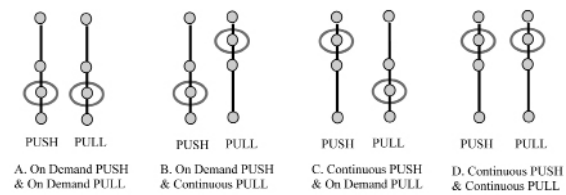

Figure 2. Shows The different options formed with the controllers. Push means to share the information and pull means to receive the information.

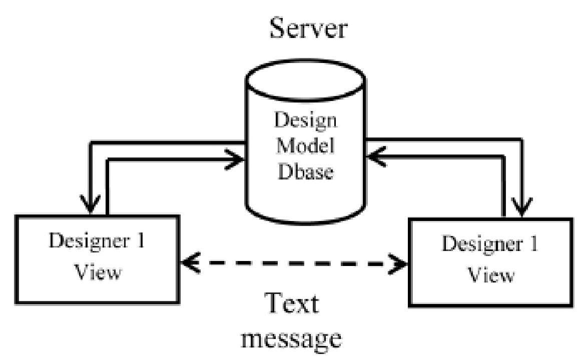

Figure 3. Architecture platform for collaboration

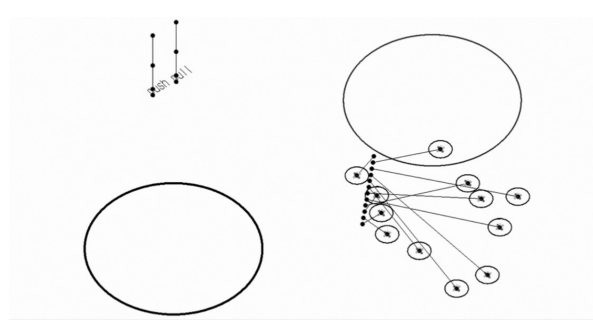

Figure 4. Snapshot of the GC interface with the control modes incorporated on the interface.

5 Experiment

The experiment was conducted with 18 participants with the participants paired together to perform the task collaboratively. The results were interpreted for individual participants and focused on analyzing the different control methods for sharing and receiving information during collaboration. The two hypotheses tested were:

H1: There are differences in user preferences among all control modes.

H2: The type of task affects the type of control mode preferred.

5.1 Participants

The participants were undergraduate and graduate students of Simon Fraser University. Participants were from nineteen to twenty-four years old. Participants had no prior knowledge of Generative Components, and since the experiment was to analyze control methods, the experience level of the participants is appropriate. The participants who were collaborating with one another had not worked together before and had no prior experience in collaborating.

5.2 Experiment setup

The experiment was conducted on two computers with a server used for design collaboration. The experiment was conducted using GC which had control modes for collaboration. The data was recorded by capturing the interface through video.

Participants were separated from each other, and were seated far away to reduce face to face communication.

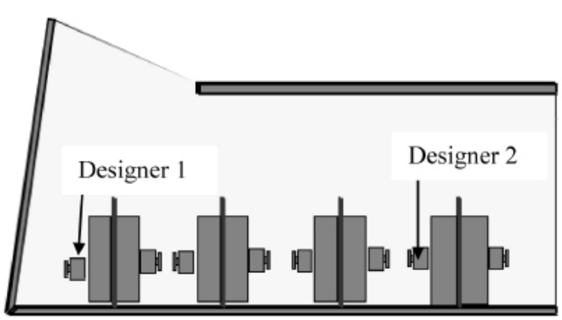

Figure 5. Designer's location during experiment

They were given the option to use an instant messaging client (in text mode only) to communicate with the collaborator. Figure 4 shows the location of the two designers. Figure 6 shows two different designers working on the tasks.

Figure 6. Two designers' are working on the given task.

5.3 Variables

The dependent variable was user preference, measured using a Likert scale from 1 to 5. The experiment investigates two types of independent variables: control modes and task type. The independent variable, "control mode" has four levels: On Demand Push & On Demand Pull, On Demand Push & Continuous Pull, Continuous Push & On Demand Pull and Continuous Push & Continuous Pull. Each participant completed eight tasks (four control modes times two task types). The independent variable, "task type" has two levels: related model and isolated model. Although sixteen possible task and control mode combinations can be performed when paired collaboration is considered, in order to complete the tasks in one hour and simplify the measurements, we opted to use only four combinations.

5.4 Design Brief

The participants were asked to complete these two types of tasks:

3) Task 1: Two participants collaborate on a design task where the models are isolated. The action of one designer does not affect what the other designer is doing, though they are working on the same model.

4) Task 2: Two participants collaborate on a model in which the elements in the model are related to each other. The action done by the participant on the model affects the second participant's model. The model imposes a cognitive load to design a form through collaboration between the participants.

5.5 Procedure

Participants were greeted, given a consent form to complete, and provided with an explanation of parametric modeling and collaboration. The participants were trained on the basic tools of GC and were taught how to use the control system designed for GC. The participants were given a demonstration of the model and sufficient time to train alone and as pairs to use the control system for collaborating. They were given time until they confirmed their comfort with the interface design and their readiness to do the tasks. It took around 20 to 25 minutes for the participant to get used to the interface. Each pair was asked to do all the control modes for the two types of tasks. The experiment required a group design task. Each participant performed the task for four control mode types. Challenges of a group design task are learning effects and the large impact of fatigue on participants. To control learning effects, a randomized order of control modes was given and sufficient training was provided to participants before the experiment in an effort to reduce learning effects during the experiment. Once the users completed the task they were asked to fill out a questionnaire and their preference on a Likert scale was collected for each control mode.

6 Results

Two way analyses of variance (ANOVA) were used to measure how the type of task affected the preferences of the participants. A test was also conducted to check whether there was significant divergence in the different control modes.

6.3 Statistical test

There are two predictor variables in this study, control mode and task type, and one response variable preference. The ANOVA showed a statistically significant interaction between the task type and the control mode with an F ratio of 2.85 and P value less than 0.05. Because of this significant interaction, the interaction plot was analyzed.

Table 1. ANOVAs effects table

Source	Nparm	DF	Sum of Squares	F Ratio	Prob>F
Model Type	1	1	1.361111	1.2747	0.2609
Control mode	3	3	60.25000	18.808	<.0001
Model Type* Control Mode	3	3	9.138889	2.8528	0.0397

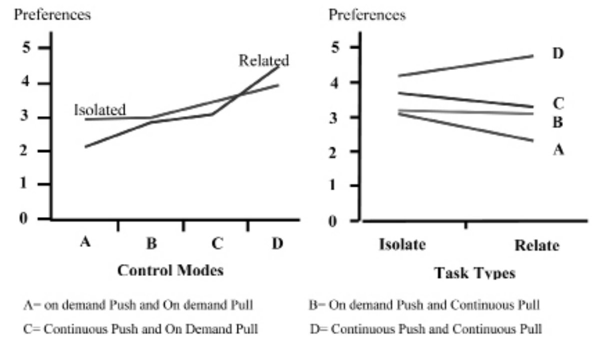

Figure 7. Interaction plot for the ANOVAs statistical test.

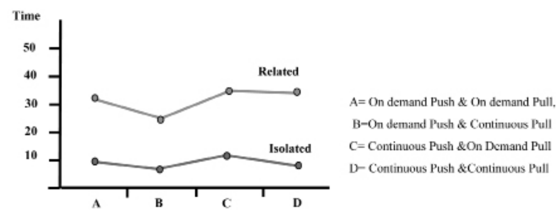

Figure 8. Mean of Task Completion in minutes

A = On demand Push and On demand Pull
B = On demand Push and Continuous Pull
C = Continuous Push and On Demand Pull
D = Continuous Push and Continuous Pull

The interaction plots suggest that the relationship between control modes and preference values depends on the level of the task type. This revealed a significant interaction between control mode and type of task, F (3,136) = 2.852, P is lesser than 0.05, MSE = 1.06, R2 = 0.04. The nature of the interaction is displayed in Figure 7. Subsequent analysis demonstrated that there was a simple effect for the mode of control at level A by the related type task, F (3,136) = 5.85, with p less than 0.05. As the figure shows the control mode D displayed higher preference scores than C, which in turn gained a higher preference score than B, which in turn showed higher preference scores than control mode A.

The hypotheses were analyzed and showed:

H1: The results show that users prefer Continuous Push and Pull. Hence H1 is supported and the null hypothesis is rejected. In Figure 7 we can clearly see that the preference is high for both the related and isolated task type.

H2: The results show that there was a significant interaction between the control modes and the task types. The null hypothesis was rejected, proving that the type of task affected the preference of the type of control modes.

6.4 Task completion time

The task completion time was analyzed for three pairs only due to data loss. The completion time data (Figure 8) showed that the users finished the task earlier in the On Demand Push and Continuous Pull, which contradicts the user preference of Continuous Push and Continuous Pull of data. This data information shows that this condition should be further tested.

The video analysis showed that users shared the information after completion of the task for the isolated model, while for the related model, they requested and shared information based on the need. The verbal text sharing for collaboration through Skype was less for the isolated model and more for the related model.

7 Discussion

7.3 Control modes

As shown in Table 1, the difference in means of preference for control modes is statistically highly significant. The interaction plot shows that there is not much difference in the preferences of users while performing the isolated task type. The related task type shows a significant difference in users' choices, where the Continuous Push and Continuous Pull of information is preferred over the On Demand Push and On Demand Pull.

7.4 Task type

The type of task determines the type of control mode. During the isolated task type users did not expect benefits from sharing information because their work was not dependent on each other. Though they were working towards the same goal, they had distinct parts to accomplish. In the related model type, the collaborators had to depend on each other's input; consequently, there was more conversation between the collaborators. Each had to know the input of the other designer because it affected their work. A post questionnaire showed some users found the Continuous Push and Continuous Pull annoying and confusing to their work. This is an important factor because in parametric modelling, a change in an element affects the whole model. Since the task used here was very simple, the annoyance level could not be adequately measured.

7.5 Limitations

The task type used to measure the data was very simple and at a low level. A higher design level might influence a change in the results.

7.6 Observations

While users were performing the isolated task type there was hardly any conversation through instant messaging. Interaction with the control was also much less, for users pushed the data when they completed their task. Some participants were so engrossed in their work that they ignored the instant messaging when they received it. When they were given the option of On Demand Push and On Demand Pull they pushed the information after they had completed their tasks because there was no necessity to see what the collaborator was doing. In the related task type, communication through the control mode and instant messaging was high because the information was related. While using the Continuous Push and Continuous Pull control mode we found that users were confused about getting constant updates of changes made by the other designer. They said it distracted them from their work.

8 Conclusion

We analyzed user preferences of control modes for sharing and receiving data during collaboration in a parametric modeling system. The results show that users preferred continuous sharing and receiving of information over other control modes. The task completion time analyzed for three pairs showed that they completed the task faster using the On demand Push and Continuous Pull control mode. This finding contradicts user preferences of Continuous Push and Continuous Pull. The results also showed that the type of task affects the type of control modes. This provides evidence that control modes in collaboration will enhance the user performance and satisfaction with the work environment. Therefore, the research hypotheses were supported.

The research will be furthered by conducting it with experienced designers. The complexity of the task will be increased to analyze how it affects selection of control modes and sharing of information. The post questionnaire revealed that participants were distracted and annoyed using the Continuous Push and Continuous Pull control modes. Hence these variables require further analysis.

Acknowledgements

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