LaSMUDE
Large Scale Multi-User Design Environment

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Abstract. With the emergence of multi-touch solutions, tabletops provide an interesting platform for collaborative work. Although there is a large field of work that covers collaborative work on tabletops, most are focused on how people can share resources but do not address the problem of exclusive resources.

The work presented in this paper addresses the problem of sharing exclusive resources within a collaborative environment. We present a study where four different non-verbal approaches are presented as solutions to share exclusive resources in a tabletop scenario. With these mechanisms, we expect to improve the usage of these resources and support the execution of concurrent tasks while stimulating the collaboration between users.

1 Introduction

The combination of multi-touch technology with a large area of interaction makes Tabletop devices as an attractive solution to support collaborative tasks. In such environment, several users can interact in parallel executing concurrent tasks and sharing application resources. Therefore the system is designed to support multi-user from the input detection to the application layer. Compared to traditional desktop displays, the Tabletop shape and the multi-input support encourage collaborative practices where several users can be located around the Table. Additionally, the presentation of graphical resources should be flexible to be reoriented facing the user during the interaction.

To handle multi-user interaction, most of existing application relies on object behavior and duplicate resources when they need to be used by more than one user. However, this redundancy is not always possible and exclusive resources may still exist that need to be shared by users. This work studies how such resources should be handled and presented to users in order to minor inactive interaction periods due to locking problems. In this paper, we propose three
mechanisms and assess their influence by analyzing users performing concurrent
tasks while interacting with a Tabletop device. Our approach aims at addressing
the existing challenges and stimulates the sharing of exclusive resources on a
collaborative environment.

2 Related Work

One of the first studies on collaborative environments using Tabletops was pre-
sented by Brave et al. [1] in 1998. This paper describes an initial study on how
user’s behavior is influenced by the presence of others. They use tangible objects
to increase both the remote collaboration and the communication between users.
However, users do not share the same physical space such as in our scenario.

Tang et al. [2] suggest an approach to improve the collaboration of users when
interacting with a Tabletop display. They propose three different styles (filter,
 lens and regions) which segment spatially the data allowing concurrent manipu-
lation. They study how groups of users work with spatial data and with tightly
shared data not completely uncoupled. In [3], Wilson et al.analyze how the type
of information influences collaborative tasks in large scale public areas. Present-
ing public and private information, they study how users exchange information
and check if these actions are valid or not. Finally, Morris et al. [4] present how
controls and menus can change the behavior of users when sharing pictures. They
present two solutions, one centralized and another which replicate the controls.
Their study concludes that users strongly preferred replicated controls since they
do not like to interfere with other users actions, even accidentally.

More recently, two works address the problem of territorial coordination when
using touch tables. Tuddenham et al. [5] present an example of remote collabora-
tion where they evaluate how the working space is shared between users. They
present a set of solutions to the user increasing the awareness of concurrent ac-
tions. Piper et al. [6] present a set of coordination techniques based on the level
of protection of objects. When the object is further from the user, the level of
protection is minned and it is increased when the object is closer providing a
better coordination between users.

The study presented by Morris et al. [4] is closer to our problem. However they
do not evaluate why users prefer replicated resources compared to un-replicated
controls and menus. In addition, they only present one alternative to the replica-
cation. Our work tries to address this point by proposing three alternatives to
deal with exclusive resources without needing their replication.
3 Collaborative Environment Concepts

Collaborative environments support people in their individual and cooperative work. Existing work in this field have presented several concepts to classify user actions. The category **User** refers to concepts related with the user and which tasks he is working on. The category **Information** includes the information that the user sees or hears, providing feedback on the state of the system and performed actions. The class **Activity** defines which actions can be performed, where and their execution order. The group of concepts **Position** describes how the position from users to virtual objects relying on the table interferes with the collaboration. The category **Cooperation** includes concepts related to collaborative actions, such as users working collaboratively in the same space. The group **Artifact** can itself be considered a concept, but can be divided into two types, physical and virtual. Finally, the **Communication** category describes the ways that users use to communicate with other actors in the collaborative act.

<table>
<thead>
<tr>
<th>Category</th>
<th>Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>User</td>
<td>Presence, Authorship, Postion, Ownership, Intension, Reach</td>
</tr>
<tr>
<td>Workspace</td>
<td>Sound, Feedback, Territoty, Feedthrough</td>
</tr>
<tr>
<td>Activity</td>
<td>Action, Sequence</td>
</tr>
<tr>
<td>Cooperation</td>
<td>Coordination, Antecipation, Request, Management of Coupling, Assistance, Communication, Compreention</td>
</tr>
<tr>
<td>Artefact</td>
<td>Virtual, Physic</td>
</tr>
<tr>
<td>Communication</td>
<td>Intensional Communication, Deictic Referneces, Speech, Gesture, Consequencial Communication</td>
</tr>
</tbody>
</table>

*Table 1. Concepts agrouped in six categories.*
By combining these concepts, different approaches can be prototyped on how exclusive resources are shared. The following section presents our approach to address these concepts by combining them into four different approaches.

4 Proposed Approaches

We intend to consider approaches that relate the above categories, proposing solutions that provide better results to users in their collaborative tasks. All categories will be considered in each approach, but there will be small differences for each concept from Activity, Position and Cooperation categories. We propose four different approaches to overcome the challenge of sharing exclusive resources on a multi-touch Tabletop. These are depicted in Figure 1 and briefly described below.

Direct Approach - Figure 1(a) This is intended to create the simplest scenario in which two or more users are conducting collaborative tasks on the Tabletop without any help from the system. In this scenario, users will have to communicate with each other to share the centralized resource.

Implicit Approach - Figure 1(b) This approach is based on the application logic to foster collaboration among users with implicit movements of the resource from the system. The basic idea is that when the resource is released by the user after its usage, the application will automatically move the resource to some important and accessible area of the application. These areas could be the center of the screen or near to users with a minor time of usage.

Waiting List Approach - Figure 1(c) In this scenario, there are several representations of the resource near each user, with the objective to help requests of the un-replicated resource without having to communicate verbally with other users. This approach focuses on what happens when a user ends the usage of the main resource. While a user is using it, others may use its representation to request its use when it becomes available. Thus, when a user finishes the usage of a resource, the widget moves automatically to user that requested it.

Replicated Approach - Figure 1(d) Using waiting list with the ability to pre-execute actions (Figure 1.d): The idea of this approach is the concept of first-in-first-served. Moreover, it allows users to command a series of actions to be performed while they are waiting for the resource to be released. To achieve this,
the resource is replicated among users. However the exclusivity is still checked since only the slave instance commits actions when the master is free.

**Puck Approach - Figure 1(e)** The position of the resource is controlled by an object on the surface. The remaining behavior is equal to the direct approach.

![Images of the five approaches](image_url)

**Fig. 1.** The five approaches presented in this document.

## 5 Evaluation

To evaluate our approach, we performed a user test session using a *toy problem*. In this section, we describe our test methodology and present the results and its analysis. Our testing prototype consists of a two user-situation painting game, around the table. For this task, users have at their disposal a color palette where they can change the ink color to be applied in the drawing. The toy problem
is similar to paint by number problem. However, we present as a reference the painted version of the drawing. The goal is to paint the drawing with the correct colors (the reference drawing is shown on the left side of the drawing). To entice users to the collaboration, the system gives points to the pair of users when each area is painted.

Painting is achieved by touching directly with one finger over the drawing. After it, the points will be awarded according to the proximity of color painted to the picture guide. Figure 2 portraits the layout and user placement during the game. To change the color, the user must have the palette near you and then select the color and control the sub-menu to choose the intensity.

![Fig. 2. The layout of the application used in user test session.](image)

These theses session, a new approach was added, with the main objective to examine whether the proximity of the exclusive resource helps a user to attain them. The approach consists of a small change in the Implicit approach that approximates the action of the user interacted with the resource less often.

5.1 User Tests

We conducted the user test upon the four collaborative approaches using the toy problem described in the previous section. The test session was performed with sixteen users, randomly grouped in pairs. Each session started with a brief explanation of the rules and the main purpose of the user test. After it, we let users to read the testing script where each approach is explained and how to play the game. When they finished, each user was encourage to play the game with a tutorial mode during five minutes with the objective to learn how to interact with the application.
After finishing the training phase, the test session starts with the pair of users. On each task, users are asked to paint the drawing accordingly, sharing the palette between them. The order of the several collaborative approaches was randomly chosen, but each session starts with the simplest approach (Figure 1.a). Each game party has a maximum duration of four minutes. Thus when this time is reached, the user which gathered more points during the task wins the game. At the end of testing the four approaches, each user fills a simple questionnaire to know some personal opinions about the tested approaches. Figure 3 depicts a user test session.

Fig. 3. Users testing proposed approaches in the toy problem scenario.

To reduce the effect of learning curve on the results, each user tested approaches with different drawing. Thus, besides the approaches have been randomly tested, each test also occurred with a different drawing.

5.2 Results Analysis

From this user test session, we were able to draw important conclusions regarding the proposed approaches. To evaluate these data we propose an assessment based on six metrics. The metrics presented are:

- **Palette Usage Time**: Time of game used to interact with the palette;
- **Painting Time**: Time of game used to interact with the drawing;
– **Time without doing action**: Playing time without performing action;
– **Number of Palette Exchanges**: Number of changes of the resource between users;
– **Average Waiting Time**: Average waiting time of a user by the resource;
– **Total Waiting Time**: Total waiting time of a user by the resource;

That way, we can validate what approach towards the unique resource sharing is more in comparison with the appropriate simplest scenario. From the data collected we were able to draw the following chart. The graph in Figure 4 presents data collected in this test session, which allows us to calculate the comparative value of evaluation metrics.

![Graphs](image)

**Fig. 4.** Examples of the charts used to calculate the evaluation metrics values.
By analyzing the data collected during the tests, we were able to compare the fairness of the various approaches. Through an analysis of the results, we conclude that the best approach was **Waiting List**. This approach ensured the longest use of the resource and the shortest time without performing actions, while maximize the number of exchanges and reduced waiting times by the exclusive resource.

Another important conclusion comes from the variation of the **Implicit** approach, which we called the **Implicit-Balance**. After analyzing the results it was realized that the fact that the unique resource capability to move closer to the user who used less often, did not result in better results than the original approach.

Regarding the **Replicated** approach, we observed that users understand the concept, allowing users are less time without performing actions, maximizing the time that the user could interact with the drawing.

Finally, the **Puck** approach, where the position is controlled through the use of an object, did not have advantages in solving the problem of sharing the unique feature. However, this advantage was not transported to the problem studied in this dissertation.

### 6 Conclusions and Future Work

With this work we have concluded that users strongly prefer to use some approach which helps their collaborative tasks without needing any verbal communication with other intervenient in the system to share the exclusive resource.

For the next steps of our study, we will evaluate our approaches in an industrial environment with real users. To that end we will integrate them into the prototypes developed within the MAXIMUS\(^1\) European Project. In this context the end users are architects that use a tabletop to assist them in design review activities. In this project, they will use a non-collaborative resource to control a large screen where 3D representations of their plans are displayed while they can edit these plans collaboratively.

In this more realistic application, we will test the proposed approaches in an environment where users face problems with the sharing of non-collaborative

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\(^1\) **MAXIMUS** - *MAXimum Fidelity Interactive Multi User display Systems* - is a European research project that wants to give architect and automotive designer's better ways to interact and visualize information. More info in [http://www.maximus-eu.info/](http://www.maximus-eu.info/).
operations such as navigation and object manipulation. From this evaluation we expect to obtain additional results that validate the proposed approaches in real working scenarios.

References