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An Approach to the Evaluation of Ownership Management Techniques in Collaborative Virtual Environments

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Abstract

Several ownership management techniques have been proposed for maintaining consistency, one of the main factors in Collaborative Virtual Environments. However, few studies address the effect that network latency has on these mechanisms, as it can influence both the development of the tasks by users and their view of the system. This paper describes an experiment that tackles this issue, and shows how users get frustrated and tend to think that the system is not reliable as the amount of latency increases.

Categories and Subject Descriptors (according to ACM CCS): C.2.1 [Network Architecture and Design]: Network communications C.2.1 [Organizational Impacts]: Computer-supported collaborative work

1. Introduction

One of the main concerns in a Collaborative Virtual Environment (CVE) is to guarantee consistency in such distributed simulation. Due to network latency, consistency problems may raise. Surprisingly, Roberts et al. [RW04] comments that consistency control is not usually tackled in most CVEs. This may be explained by the simplicity of interaction techniques supported by most CVE or the social protocols that users are expected to follow. Only few studies have faced the problems of latency in object-focussed interaction [RWS03] and task performance [PK99], where it is experimentally showed that latencies over 200ms (without jitter) increase the task completion time.

However, as CVEs become more complex, inconsistencies are more likely to happen. To combat this, different Ownership Management Techniques (OMTs) have been proposed. According to [GM94, GPS00], the different OMTs can be classified as: *Pessimistic:* only one user is able to modify a shared object each time, based on the concept of transferable ownership; *Optimistic:* some algorithms are used to predict which user will own the object next, so if the prediction is wrong the system will have to undo the changes already made; *Hybrid:* using the most appropriate according to different stages of the simulation [DWM06]. As OMTs are introduced in more CVEs, better knowledge is needed with regards to the effect that latency can have on different OMTs, and how its consequences can influence the work performed by users of these systems. For all these reasons, this paper is focused on this issue, presenting a first experiment where several users collaborate in a shared space to assemble an object under different network latencies, intended to serve as the basis for a more complete study in the future.

2. Design of the experiment

A within-groups experiment was designed in order to evaluate one OMT -this time, a pessimistic one- under different network latencies. For this purpose, a CVE was developed, rendering a single room where three users meet, each user being at a different desktop VR client in the same LAN, but all having their avatars seated around a shared 3-sided table. On that table, users found an car model to finish, and a box with spare pieces. For each trial, users formed an assembly line around the table, requesting the ownership of the car model, picking one piece from the box, placing it in the model, and then passing the model to the next user. The trial ended when all the pieces were assembled (9, 3 per user). Five groups of three participants used that CVE to repeat the same task four times, each time with a different amount of latency. To simulate different latency conditions, the implementation relied on a client-server architecture, where the server delays all requests for a certain amount of time. The delays introduced increase each round-trip time by one of the following amounts: *None* means that no delay is added; *250ms* was chosen so that the maximum recommended latency for VR applications is exceeded; *1000ms* is a high and noticeable latency, as in satellite communications; *4000ms* represents a really high latency, degrading user experience to an unacceptable level.

3. Results

In all cases participants successfully completed the task. The mean task completion times are plotted in Fig. 1, together with a reference time, using as a base for this time the shortest completion time gathered in this experiment, then adding to it the result of multiplying the minimum number of ownership requests required to complete the task (36, 12 per user) by the latency artificially added to these requests by the server. The graph also shows the mean number of errors, considering that an error ocurred each time a participant requested the ownership of the same object for a second time instead of waiting for system response. While the

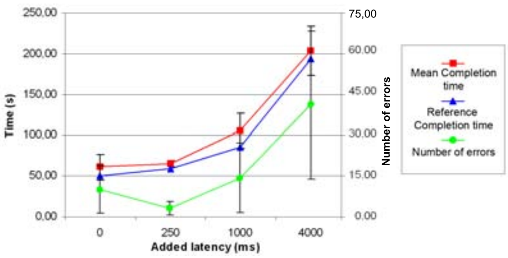

Figure 1: *Mean completion times and errors.*

graphs indicate a trend for all tasks of worse performance when latency is increased, the error bars indicate substantial variance, in particular in the recorded errors. A two-way ANOVA was applied. As regards the task completion time, the analysis backs the idea that time significantly increases when higher latencies are introduced, with $F(3,12) = 74.5$, $p < 0.05$. As for the mean number of errors, the results are only significant to some extent, with $F(3,12) = 4.05$, $0.01 < p < 0.05$. This fact can be explained having a look at Fig. 2 (showing the answer to a set of questions taken from the Questionnaire for User Interaction Satisfaction - QUIS, [Shn86]-): instead of making more mistakes, users started to feel more frustrated -QUIS 3.2-, blaming the system for the errors and its bad performance -QUIS 7.1.1-, and feeling that it was more difficult to use the shared workspace -QUIS 11.6.4-. Interesting to note, it was observed that some users adapted their action sequences, anticipating actions rather than waiting for the system delayed response.

4. Conclusions and future work

This paper has described an experimental evaluation of a networked CVE using different amounts of simulated latency, intended to better understand how latency affects to OMTs, in particular a pessimistic one. The results showed that latency has a bad influence on task performance when it affects the requests of ownership over an object, though it does not boost the number of ownership requests in the same way, as users seem to learn to wait and even anticipate their actions. As a future work, it is planned to carry out a more extensive study, evaluating the effect on other OMTs, especially those that could mask the latency by using a less conservative approach.

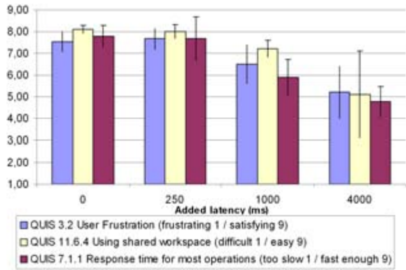

Figure 2: *Results for some QUIS questions.*

5. Acknowledgements

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