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Sticky Notes – a Tool for Supporting Collaborative Activities in a 3D Virtual World

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***Abstract*—In this paper, we present the design rationale and evaluation of the Sticky Notes tool that we designed within the 3D virtual world of vAcademia based on our original method of using stream processors for displaying a large amount of media contents in a 3D environment. We explore the facilitation of creative collaborative activities, such as brainstorming, round-table discussions, and project work. This type of activities usually requires a large amount of media content to be displayed and available for modification in a shared space. We argue that 3D virtual worlds can be successfully used for facilitating such activities and can potentially be superior to the commonly used technologies, as they allow the sense of immersion close to reality and tools that might be even more convenient than in reality. The evaluation results demonstrate performance superiority of the method over those commonly used and the pedagogical value of the tool developed.**

Keywords-3D virtual worlds; collaborative work; collaborative learning; stream processors; sticky notes; vAcademia

I. INTRODUCTION

Creative collaborative activities, such as brainstorming, round-table discussions, and project work are becoming increasingly common in both the university education and in the industry. Such activities usually require proper facilitation, as cooperation problems among the students are rather common and often lead to frustration and disruptions in the learning process [1, 2]. More and more often creative collaborative activities are conducted remotely using various technologies.

Three-dimensional Virtual Environments and Social Virtual Worlds (3D VWs) have been employed for supporting such activities. Despite the repeated positive conclusions, 3D VWs have not become as widely used as other technologies, and researchers often report that their studies have experimental nature. The most common problems with applying 3D VWs in everyday teaching and learning are steep learning curve and demand for computational and network resources [3]. While the computers and networks are constantly improving, the 3D VWs also need improvement to make them more convenient for students and educators and to explore new scenarios that may become possible.

In the work presented in this paper, we explore enabling learning scenarios that require creative collaboration and work with large amounts of media content in a shared space. In particular, we aim at implementing scenarios that are based on the use of sticky notes. Based on the review of the current implementations of this tool, we conclude that there is room for improvement. We developed a tool that supports synchronous collaborative activities with sticky notes in the 3D VW of vAcademia. In this paper, we present the details of the design of this tool and its evaluation.

II. BACKGROUND AND RELATED WORK

A. Learning Tools in 3D Virtual Worlds

VWs provide a unique set of features that can be used for learning, such as low cost and high safety, 3D representation of learners and objects, interaction in simulated contexts with high immersion [4].

One of the most serious challenges in adapting 3D VWs for learning is the lack of features that educators use in everyday teaching: “Most virtual worlds were not created for educational purposes. Second Life, nonetheless, is being adapted by educators […]. Many of the features educators take for granted in Learning Management Systems do not exist in Second Life” [5]. There is a belief among educators that the 3D VWs should be better used for simulating situations that are difficult or impossible to implement in reality, and not replicating the real-world educational structures [6]. However, most of the educators implement or obtain some of the tools they use in other learning settings, such as media screens, bulletin boards, and voting and testing systems. The absence (or inaccessibility) of familiar and convenient learning tools in the 3D VWs is also contributing to the general attitude towards the technology.

B. Implementations of Sticky Notes

Using sticky notes has become a popular method of supporting collaborative activities both in technology-enhanced and face-to-face settings [7]. Sticky notes can be used in a wide range of educational activities, including brainstorming, project-work discussions, and SCRUM sessions [8, 9].

There have been many attempts at simulating the collaboration mechanism based on sticky notes (often together with other interactive classroom tools) using various technologies. Some of such implementations will be briefly described below. One example is a web application Scrumblr – a tool dedicated to supporting scrum planning. It creates a web site with a screen to allow posting, locating, editing, and deleting sticky notes. Another example is an online brainstorming and planning tool called Stormboard. It allows synchronous collaboration with sticky notes, including posting, sharing, commenting, and voting. Our third example is GroupScribbles – a tool that implements key features of paper sticky notes avoiding some of their physical constraints [10]. This tool provides a possibility to work both individually and share the notes in a public screen area, position them there, relative to others' postings, and take them back for modification.

The systems presented above are typical web-based sticky note implementations and simplicity is their advantage. At the same time, they have clear limitations, such as the lack of awareness support and the absence of synchronous communication tools.

Many 3D VWs offer the "virtual screen" functionality. The simulation of virtual sticky notes on such screens is considered an effective and advanced tool. Generally, the features of the virtual screens often have inferior implementation because of performance limitations related to the use of CPU for processing images. The functionality of the sticky notes is often affected by these limitations. For example, the 3D VW "Sametime 3D" built on Open Simulator platform has a tool for working with sticky notes. However, the notes can only be placed on special square slots, their size is constant, and there is no possibility to use any other tools on the same screen (e.g., drawing). These limitations obstruct the effective use of the tool. Another example is the IBM virtual brainstorming studio built in Second Life. In this implementation, the sticky notes can also be placed only on square slots, and the screens are dedicated to the notes only [11].

The examples of sticky notes implementation in 3D VWs presented above demonstrate that this tool can be implemented and used for facilitating collaborative activities. At the same time, we can observe several directions for improvement, such as increasing the number of screens for the sticky notes, varying their size and location, and allowing synchronous use of multiple notes on the same screen.

C. *Processing Learning Content on Stream Processors*

Processing large amounts of images in 3D VW is mostly required when working on serious tasks, such as collaborative work and learning. In other tasks, displaying images, video or animation is also often required; however, the amount of the content is smaller. Usually, an image is calculated on a CPU on client side (e.g., in Second Life™ and Blue Mars™) or server side (e.g., in Open Wonderland™) and then loaded into the stream processor memory as a texture.

Stream Processors (SPs) are specialized processors that are widely applied in graphics adapters, and therefore, their main tasks are related to processing 3D graphics [12]. Due to the focus on the highly parallel computing tasks, these devices have many hardware constraints [13]. Therefore, most of the classical algorithms that can be executed on CPU cannot be executed on SPs without modification.

III. THE GROUNDING OF STICKY NOTES IN VACADEMIA

A. *Motivation for a new technological approach*

Sticky Notes is a tool aimed at supporting creative collaborative activities that are normally conducted synchronously. Usually, many sticky notes are constantly created, moved, edited, and deleted in the process. It is reasonable to assume that when such activities are conducted in a 3D VW, the content of the screen with sticky notes needs to be updated frequently (e.g., when one of the users makes changes to a sticky note, it should be updated immediately and for every user). This entails the need for high-speed texture generation that is implemented using the method we suggest.

In the modern systems, such image-processing tasks are not suitable for being calculated on CPU. 3D visualization in similar tasks is hardware-based and conducted on SPs. This implies that processing images using the capabilities of SPs *directly* can be efficient, especially given the fact that their computing power usually exceeds the capabilities of CPUs tenfold. However, the SPs have some serious hardware limitations. This means that most classical image processing algorithms require modifications or new approaches.

B. *Interactive Virtual Whiteboard of vAcademia*

The Sticky Notes tool we describe in this paper is implemented within the interactive virtual whiteboard (VWB) in vAcademia – an original educational 3D VW [14]. VWB is the main tool (or a container of tools) for collaborative work on 2D graphical content in vAcademia. Multiple VWBs of different sizes can be set up in any location of vAcademia. In addition, every participant can set up an extra VWB during a class and present some content on it. Multiple users can stream or share their content simultaneously [14, 15].

We developed most of the underlying models and methods we used for the Sticky Notes tool earlier for the VWB, but some others are original.

C. *Underlying mathematical and programming models*

The image generation for the Sticky Notes tool was designed based on the mathematical and programming models developed earlier for the VWB [16]. In this section, we present those parts of the models that are necessary to understand the functioning of the Sticky Notes tool.

The programming model is based on four main objects (Texture, Drawing Target, Filter, and Filter Sequence).

Texture is an image in format (1) of the mathematical model [16]. It is stored in the SP memory. This object is used for the 'writing surface' of the sticky notes and for an image if it is contained in a sticky note.

$$U(x, y) = \{f_R(x, y), f_G(x, y), f_B(x, y), f_A(x, y)\} \quad (1),$$

where U(x, y) is a function defining the image and f(x, y), are discrete functions defined by tabular procedure and corresponding to the color channel with values.

Filter is a subroutine that defines the image transformation (2) of the mathematical model [16] and returns the color of a point for the given coordinates. All parts of the sticky notes are generated using a filter that implements alpha blending. The result of transformation G of image A based on image B is a modification of (1):

$$R = G\,(A, B, x, y) \qquad (2),$$

Drawing Target is an object that defines the resultant image and configurable features of SPs. They include hardware scissors that limit the area on the resultant image that can be influence by the filter restricting the text area on a sticky note within a VWB. Therefore, (2) becomes (3):

$$R = G(A, B, x, y, x_1, y_1, x_2, y_2) = \\ = \begin{cases} \mathrm{G(A, B, x, y), if\ x} \geq x_1, x \leq x_2, \mathrm{y} \geq y_1, y \leq y_2 \\ \mathrm{A(x, y)}\ otherwise \end{cases} \qquad (3),$$

where (x1, y1) is the top left corner of hardware scissors and (x2, y2) is the bottom right corner.

The text itself is generated as a set of polygons with texture coordinates and the corresponding font textures [16].

Filter Sequence (FS) is a sequence of Filters with parameters to be used for complex transformations. It presents the complete 2D scene of the VWB with sticky notes. The order of the filters in the FS determines the order of visualization of the sticky notes. The texture generation time for the VWB with sticky notes is defined by (4):

$$T = T_{TR} + T_1 * W * H \qquad (4), \text{ where}$$

T_{TR} – time of preparation for transformation,

T_1 – time of calculating the color of one pixel, i.e. calculating (2),

W and H – width and height of the processed image.

D. Applying the Processing Static Images Method

The design of VWB is based on using a dynamic texture with two independent layers which are combined in one static texture when rendering. Generally, it allows having a temporary dynamic figure over lower-level contents (e.g., sticky notes). In other cases, the lower level may contain a dynamic image, while the upper level may remain unchanged (e.g., for commenting on top of a screen with sticky notes).

All the VWB tools can be classified into three groups by the method of generating the resultant image. In this paper, we will present only one of these methods that implements the Sticky Notes tool. This method includes two designs and several implementations (tools). We will present them briefly, as we used them in some of the evaluation sessions along with the Sticky Notes tool.

Requirements: The system should support simultaneously changing static images on five VWBs within the visibility area. The average performance degradation should be less than 10% and peaking performance degradation less than 15%. The requirements are based on preliminary testing.

Design 1 is based on resizing the source image, applying Filters, asynchronous unpacking, and uploading it. This design implements Slideshow, Area print screen, and Image insert.

Design 2: Processing static images from 2D scene is based on an FS of a high number of alpha-blending Filters with different source images, blending settings, and hardware scissors. A 2D image or a rasterized image of a letter is taken as an input parameter. This design implements Backchannel and Sticky Notes tools.

IV. Working with Sticky Notes in vAcademia

A. Visualization of Graphical and Textual Sticky Notes

We started the design with two types of sticky notes: textual and graphical. Both types of sticky notes include a background image. In addition, a textual note includes a user text element and a graphical note – a user image. These components are generated based on a set of input parameters.

The surface of the VWB with sticky notes is a 2D-image (texture) which is applied when rendering the 3D scene. The visualization of a sticky note is done based on a set of parameters, including coordinates x and y, width, height, depth, background color, font color, and the username of the owner. In addition, user text is used for a textual note and an image for the graphical one.

The user text and image are automatically fit into the sticky note. Depending on the size of the note and the amount of the text, the font size is applied. The user can upload an image of any size into a sticky note, but it will be changed to match the size of the note (64x64, 128x128 or 256x256). The scaling is done keeping the proportions of the original image and positioning it in the center of the note.

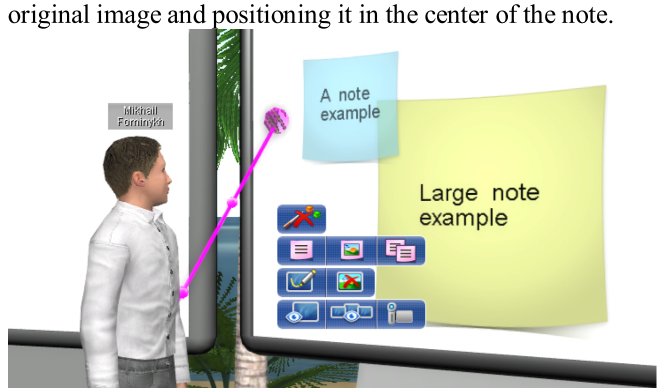

Figure 1. Examples of sticky notes and the tool's context menu

B. Synchronization of sticky notes

vAcademia synchronization system allows only one user to actively work (change synchronized properties) with an object (e.g., a VWB). At the same time, some of the tools are designed for collaboration, and the Sticky Notes is among them. Therefore, we applied a specific approach for synchronization of sticky notes. First, a unique synchronized invisible object (SIO) is created for each sticky note. Second, SIO is attached to the VWB where the note was posted. Third, SIO contains all synchronized properties of the sticky note it was created for. In such a way, each sticky note is synchronized separately. Therefore, several users are able to work with a single VWB synchronously (with one sticky note each). Forth, all SIOs are registered to belong to VWBs they were posted on (or moved to), and each VWB creates visual representations of SIOs – sticky notes.

C. *Posting, previewing, and editing sticky notes*

Any user can activate the Sticky Notes mode on any VWB. When the mode is activated, all users can synchronously add new sticky notes, move, edit, and delete own notes, and see the actions of other users in real time. It is possible to move sticky notes between VWB where the corresponding mode is activated. At the same time, the drawing tool is still available on top of the sticky notes.

When adding or editing a sticky note, a user can type the text (or select and image) and choose the size and color of the note. There is an option to preview the note before posting it. Another function allows saving a VWB with all sticky notes into a resource collection for further use. The author of the virtual class (usually a teacher or a facilitator) has additional features available, such as moving, editing, and deleting all sticky notes, and activating the private Sticky Notes mode, when students see only their own notes. When the private mode is disabled, all sticky notes become visible.

vAcademia allows placing a large number of VWBs in a single location (e.g., a virtual meeting room or a classroom) and has dedicated mechanisms to switch the view between them. This enables specific collaborative learning scenarios that are difficult to implement in both face-to-face and technology-enhanced settings. For example, a group of students could work in a single virtual location, and each of them could have a screen with a multimedia presentation and an additional sticky-note screen for feedback.

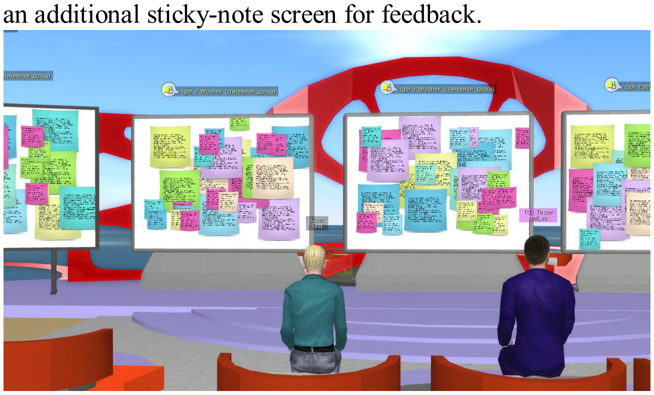

Figure 2. Testing large amounts of sticky notes in vAcademia

V. Evaluation and Discussion of the Results

The technical evaluation of the Sticky Notes tool has been conducted with a series of test runs (Fig. 1). The results of the testing demonstrate that the tool can be used simultaneously by more than 10 users without a significant drop in performance. These results could not be obtained without the use of the original methods (Section III C).

First, we compared the performance of the algorithms using SPs and CPU. Second, we explored the general efficiency of the system, i.e. performance degradation when using many tools simultaneously, measuring the average and peak values. In both cases, we present the average results acquired by running the system on 20 different hardware configurations with Intel CPU and NVidia / ATI graphics adapters from the same price range. On each hardware configuration, 10 runs were conducted for each condition. The third step is the ongoing user evaluation of the tool in the educational process.

A. *Performance of the Algorithms on SPs and CPU*

We compared the performance of the algorithms by SPs and CPU and confirmed the rationale behind using SPs (instead of CPU) for image processing in vAcademia [16]. Although such comparison does not provide insight into the overall improvement in the software performance, it can be considered for evaluating the power of SPs for the Sticky Notes tool.

In addition, we measured the texture generation time as a function of the number of sticky notes on a single VWB. We took these measurements for our algorithms implemented using SPs and CPU. The results demonstrate that the texture generation time grows slowly with the increasing number of sticky notes when using SPs (Fig. 3). We explain it by two facts. First, the preparation for transformation time T_{TR} in (4) is significant. Second, the complexity of calculations for generating the texture on SPs is relatively low, with leads to low values of $T_1 * W * H$ in (4).

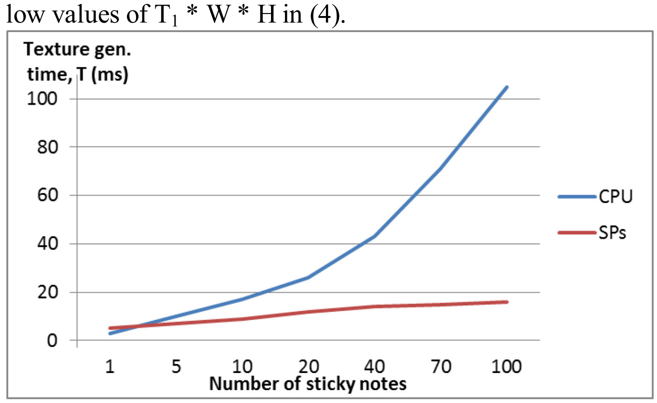

Figure 3. Texture generation time as a function of the number of sticky notes

B. *General Efficiency of the System*

The data acquired from comparing the performance of the algorithms on SPs and CPU do not fully demonstrate how the performance of the whole system changes. That is why we tested the general efficiency of the system when the suggested approaches were implemented and applied [16]. We used large numbers of VWB where we activated different tools implemented based on the same method as the Sticky Notes tool. This implies a scenario when several VWBs would be used for displaying sticky notes when several others were used for displaying other media contents implemented using the processing static images method [16].

We present the results by demonstrating the ratio of the average and peaking performance degradation to the number of simultaneously working VWBs (Fig. 4). The results reveal that 50 simultaneously working VWBs reduce the performance of the client software by no more than 7%, which is a satisfactory result (Fig. 4).

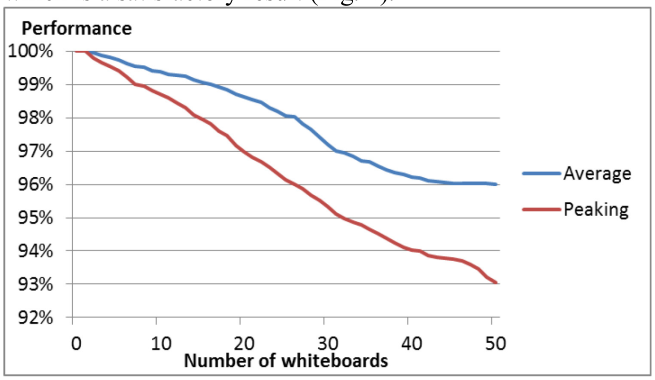

Figure 4. Average and peaking performance degradation as a function of the number of VWBs

C. User evaluation

The user evaluation of several vAcademia tools is in progress. During the first stage, we evaluated the general convenience of the environment employing several tools. In addition, we tried implementing collaborative learning scenarios involving large amounts of media content (e.g., each student working with a personal VWB in a shared workspace). The results of the user evaluation demonstrate that the VWB successfully performs its functions: the features can be easily accessed, the content is displayed clearly, and no visible delays occur. It has pedagogical value, as most of the students consider that it was convenient to use it, and the vAcademia's workspace is more comfortable than traditional tools. At the same time, the first stage of the user evaluation was rather simple and had some limitations [16].

During the second stage of the user evaluation, we have conducted collaborative activities among students of the Volga State Technical University, Russia, the Norwegian University of Science and Technology, and Malta University. We employed the Sticky Notes tool for brainstorming, planning, and giving feedback (Fig. 5).

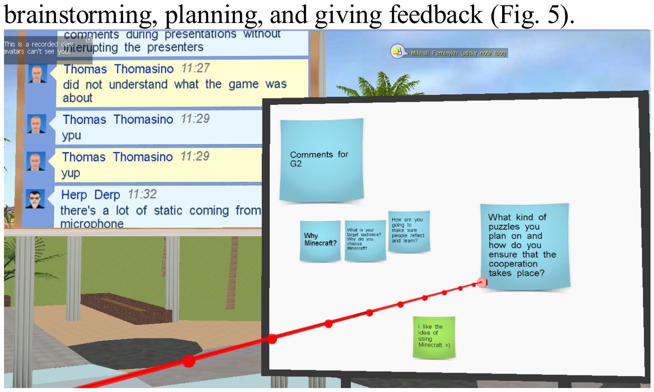

Figure 5. Feedback sticky notes during a virtual presentation seminar

VI. Conclusion

We presented the design rationale and evaluation of the Sticky Notes tool that we designed within the 3D VW of vAcademia based on our original method of using SPs. The tool performs smoothly on average computers and quickly becomes one of the favorite among students. Our current and future work includes collecting and analyzing user feedback.

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