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Asynchronous Immersive Classes in a 3D Virtual World: Extended Description of vAcademia

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Abstract. vAcademia is a 3D virtual world designed for collaborative learning. It enables a new approach to educational activities in virtual worlds, which is based on a new vision of content and learning process. The most distinct feature of vAcademia is 3D recording which allows capturing everything in a given virtual world location in dynamics. The resultant recordings can be not only watched later, but also visited, providing students with a collaboration space and giving a sense of presence. 3D recording is conceptually different from video recording or screen capturing. In such a manner, vAcademia supports a new type of digital content – 3D recording or virtcast which is created based on synchronous activities. In addition, this platform has an integrated set of tools for collaborative learning which substitute those commonly used in physical classrooms, but also allows implementing new learning scenarios that are not possible or costly in reality. In this paper, we present the functionality, scenarios of use, and the initial evaluation results of the vAcademia virtual world.

Keywords:3D recording; vAcademia; learning in virtual worlds; virtcast

1 Introduction

Many studies report the potential of three-dimensional virtual worlds (3D VWs) for educational activities [1]. This technology can benefit educational process in many ways. Most of them are considered to exploit advantages of the 3D VWs, such as low cost and high safety, three-dimensional representation of learners and objects, and interaction in simulated contexts with a sense of presence [2,3]. However, this technology is far from becoming a mainstream in education, as there are a number of challenges in applying it for learning.

Despite the demand and interest from educators, in most cases, 3D VWs are adopted for educational purposes, but not specially created for them [4]. Cooperation and co-construction in 3D VWs is a complex task, it needs to be supported and requires additional tools [2]. The design of environments or 'learning spaces' within 3D VWs is considered to be important, however, there are no strong guidelines [5]. In addition, 3D VWs are mostly used for synchronous activities and lack support for learning in the asynchronous mode.

In this paper, we present a new vision and approach to educational activities and content in 3D VWs. This approach is based on an original technological feature – 3D recording. The nature of this feature is difficult to grasp. 3D recording is often misunderstood and treated as an embedded screen capture mechanism. However, it is conceptually different from the video recording or screen capturing. A replayed 3D recording does not only delivers a virtual camera image and a synchronized communication messages, but much more. A 3D recording contains the entire 3D scene with all 3D objects and avatars. It can be entered by a group of avatars. All the actions of the avatars and in the environments are also saved in a 3D recording. These actions happen again when a 3D recording is replayed or, better to say, visited. In such a way, this feature allows creating a new type of content that comprises both space and time.

Traditional learning approaches require resources, such as teacher time, textbooks, and auditoriums. However, in traditional learning there are little problems with creating content. The product of traditional learning is a live synchronous face-to-face class. Countless classes are conducted in universities and companies all the time, but, unfortunately, most of the classes disappear after ending together with information and experience created by the participants.

E-Learning offers some technologies for getting content out of traditional classes, such as video recording of face-to-face lectures or recording of web conferences (or webinars). These methods allow creating cheap educational content for asynchronous learning [6,7]. However, video lectures and web conferences change the context of learning. These technologies do not provide the same level of immersion or sense of presence, a possibility for collaborative work or a method for further developing the content, except for commenting and annotating it.

3D VWs are also used for generating educational content. Even though this technology allows creating full context of the real-life educational process, it is usually recorded as 'flat' 2D video, which eliminates many advantages of the technology, such as sense of presence [3]. For example, this approach is used in Machinima – collaborative film making using screen capture in 3D VW and games [8].

As presented above, educators are trying to use various technologies for creating content out of synchronous learning activities. However, there is a clear possibility for improvement. In addition, new theoretical approaches to learning also need to be developed. As of now, there are no systematic approaches for combining synchronous and asynchronous learning paradigms [9].

We propose that 3D recording in 3D VW may solve the challenge presented above, as it offers an easy way for creating advanced content out of synchronous activities. This feature allows capturing and saving all educational information together with the context. It allows the students to come back into an immersive environment with more participants, experience the class like a live event, and continue the discussion in both synchronous and asynchronous modes. Using 3D recording, the students can refine acquired knowledge. In such a way, the approach combines rich interactivity of the 3D space and convenience of the video. Besides that, in practice, 3D recording of classes in 3D VWs can provide an unlimited source of educational content.

2 Related Work

2.1 Learning in 3D Virtual Worlds

3D VWs have been attracting attention of educators and researchers since their appearance. This technology provides a unique set of features that can be used for educational purposes, such as low cost and high safety, three-dimensional representation of learners and objects, interaction in simulated contexts with high immersion and a sense of presence [2,3].

Possibilities for synchronous communication and interaction allow using 3D VWs by various collaborative learning approaches [10]. In addition, possibilities for simulating environments on demand and for active collaborative work on the content allow applying situated learning [11] and project-based learning [12] approaches.

Constructivist approaches, such as problem-based learning, are also popular among the adopters of 3D VWs [13]. Social constructivism is often called an ideal approach for learning in a 3D virtual environment, as the technology allows learners to construct their understanding collaboratively [14,15]. In addition, 3D VWs are used for educational simulations [16] and demonstrating complex concepts [17,18].

2.2 Recording in 3D Virtual Worlds

The demand for methods supporting asynchronous activities in 3D VWs and creating content out of synchronous activities was acknowledged as early as in the late 90s, e.g. by developers of CAVE and MASSIVE systems. MASSIVE-3 supported a mechanism called 'temporal links', which allowed "real-time virtual environments to be linked to recordings of prior virtual environments so that the two appear to be overlaid" [19]. CAVE Research Network soft system had an application called Vmail which supported recording of an avatar's gestures and audio together with surrounding environment [20].

Another example is the system called Asynchronous Virtual Classroom or AVC. The developers were focused on solving the problem of time-sharing in distance learning. AVC allowed learners to watch a video image of a certain lecture and to control it, while software agents were playing some of the displayed participants and created a presence effect [21].

Later, N*Vector (Networked Virtual Environment Collaboration Trans-Oceanic Research) project was focused on developing a virtual reality technology for overcoming time-zone differences and time management problems. Within the project, there were developed three approaches to support annotations for asynchronous collaboration in virtual reality. These approaches included: VR-annotator – an annotation tool that allows collaborators to attach 3D VR recordings to objects; VR-mail – an email system built to work entirely in virtual reality; VR-vcr – a streaming recorder to record all transactions that occur in a collaborative session [22].

More recently, an Event Recorder feature was implemented (however, not developed further) within the Project Wonderland (later, Open Wonderland™, http://openwonderland.org/). Event recorder provides an implementation of the recording and playback of the 'events' caused by activities of users or agents in such a way that during playback a user is able to view the activities that those events caused. It achieves this by recording the 'events' in the world into an external form that can then be replayed to all the users that are engaged in the world. The invention also includes a mechanism to record the current state of a virtual world to use it as the starting point to play back the recorded events. In addition, a specialized plugin mechanism records the state and transitions of objects, which cannot be represented in terms of events, for example, the audio conversations.

2.3 Tools for collaborative work on 2D content in 3D Virtual Worlds

One of the most serious challenges in adapting 3D VWs for learning is the lack of features that educators use in everyday teaching [4]. The integration of such features is of high value, as they ease collaborative process and reduce the necessity of using additional software or web services. Implementing tools that are familiar to educators can facilitate the process of adapting the system into practice. In such a way, a set of tools for collaborative learning can have a significant value. It is so, even though the strongest reason for using 3D VWs as learning environments is often referred as simulating situations that are difficult or impossible to implement in reality, and not replicating the real-world educational structures [23].

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 flash is also often required. However, the amount of the content is smaller. Usually, an image is calculated on a CPU on client side (for example, in Blue Mars™) or server side (for example, in Open Wonderland™) and then loaded into the stream processor memory as a texture.

2.4 Web and 3D Virtual World integration

Educational process is not usually limited with activities in a 3D virtual environment. It requires a web-based complement, since in some cases a web tool is preferable, especially in organization and management. There exists a significant demand for integrating virtual worlds with web-based learning systems [24]. There were attempts at integrating a web support for educational process conducted primary in a 3D VW. A well-known example is Sloodle™ – a free and open-source project that integrates the multi-user virtual environments of Second Life™ and/or OpenSim™ with the Moodle Course/Learning Management System (CMS/LMS).

3 Virtual Academia

Virtual Academia (vAcademia) is an educational 3D VW developed by Virtual Spaces LLC in cooperation with the Multimedia System Laboratory at the Volga State University of Technology (former Mari State Technical University), Russia. The system is currently under beta testing and free to use, however, it is planned to be commercialized.

3.1 Functionality of the 3D Virtual World: 3D Recording

The most distinctive feature of vAcademia is 3D recording, which allows capturing everything in a given location in the VW in process, including positions of the objects, appearance and movement of the avatars, contents on the whiteboards, text and voice chat messages. Similar functionalities were realized earlier in few VWs or desktop virtual reality systems. However, 3D recording was never developed into a convenient tool and never adopted for specific use as in vAcademia. In addition, no convenient tools for working with the resultant recordings were developed.

3D recording of classes allows getting a new type of learning content and involving students in new types of activities. We propose to call it 'virtcast' – a 3D recording of activities in virtual reality or a series of such recordings [25]. This type of content is user-generated, since the process of creating and sharing 3D recordings is fully automated and simple.

A user can attend and work at a recorded class, not just view it as a spectator. In addition, any recorded classes can be attended by a group of users. A new group can work within a recorded class and record it again, but with their participation. Thus, there is an opportunity to build up content of recorded classes and layer realities on top of each other.

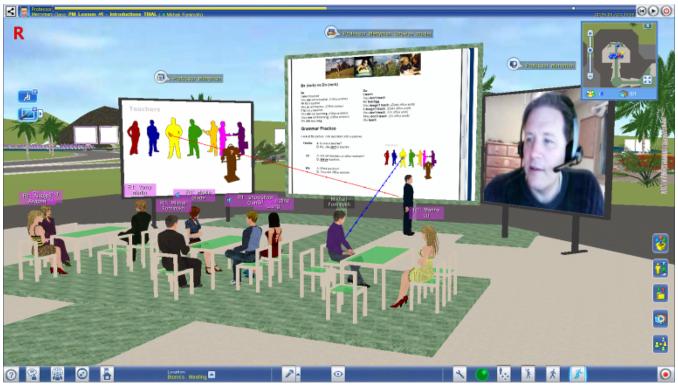

Fig. 1. 3D recording in vAcademia

From the user point of view, 3D recording control is very similar to the regular video player (Fig. 1, top). A 3D recording can be fast-forwarded and rewound, paused, and played again from any point of time. A replayed 3D recording looks exactly like a real class. Of cause, the recorded avatars will always act the way they were recorded. However, it is possible to use all the functionality of the VW inside a recording. Moreover, a replayed 3D recording can be recorded again together with new actions. In such a way, new recordings and new content can be created based on the same original event.

Some of the 3D recordings (for example, the most interesting ones, featured or advertised) can be made ‘periodical’ and replayed constantly in the locations. This feature makes it possible to create a better atmosphere in the VW, since a visitor of vAcademia does not observe empty constructions, which often happens in other 3D VWs. Instead, visitors can explore some of the classes going on with teachers and students involved. This might attract their attention and trigger curiosity.

3.2 Functionality of the 3D Virtual World: Teaching Tools

Interactive whiteboard. Interactive whiteboard is the main tool for collaborative work on 2D graphical content in vAcademia. It can be used for displaying and annotating slides, sharing the desktop, sharing the application that runs on the teacher’s or student’s computer, sharing the web camera image, drawing figures, typing text, and inserting text or graphics from the clipboard.

Image generation and processing is implemented with stream processors in order to free the CPU for supporting other functions of the system. Stream processors are highly parallel computing devices designed for various tasks in 3D graphics. These devices have many hardware constraints [26,27] and their cores have relatively simple architecture [28]. Therefore, most of the classical algorithms that can be executed on CPU cannot be executed on stream processors without modification.

Image processing on stream processors is implemented by using shaders and an original programming model, which is based on four main objects (Texture, Drawing Target, Filter, and Filter Sequence). *Texture* is an image stored in the streaming processor memory. *Drawing Target* is an object that defines the resultant image, color mask, and settings of other configurable features of stream processors. *Filter* is a function in GetColor language which returns the color of a point for the given coordinates and defines the transformation of the image in the form of XML. *Filter Sequence* is a sequence of filters with parameters for complex transformations.

The design of the interactive whiteboard is based on using a dynamic texture with two independent layers which are combined in one static texture when rendering. vAcademia tools for collaborative work on 2D graphical content can be classified into three groups by the method of generating the resultant image. The tools in the first two groups generate a dynamic image, while those in last group – a static image.

Sharing changing blocks group of tools uses the lower layer of the interactive whiteboard and processes a dynamic image. The list of tools is presented below.

- Sharing of an application window
- Sharing screen area
- Sharing web-camera image

The implementation of this group of tools is based on an algorithm for discrete wavelet transformations for image compression with quality reduction which is adapted for stream processors. It identifies the changing rectangular parts of the image by using occlusion query [29]. The algorithm is based on a cascade of filters that allows implementing the direct discrete wavelet transformation in one pass.

Sharing attributed vector figures group of tools uses the upper layer of the interactive whiteboard and processes a dynamic image. The tools are presented below.

- Drawing figures and typing text on the whiteboard
- Inserting text from the clipboard

The drawing support is implemented based on triangulation of vector primitives with attributes for one- or two-way rasterization. Displaying (both typed and inserted) text is implemented by using font textures, rasterizing each symbol on demand.

Processing static images group of tools is implemented by resizing the source image, applying filters, asynchronous unpacking, and uploading it. The list of tools is presented below.

- Slide presentations
- Area print screen
- Pasting images from clipboard on a whiteboard

Multiple whiteboards of different sizes and designs can be used in any locations, and users can focus their view on them, by special controls. In addition, every participant can set up an extra whiteboard during the class and present some content on it. A colored pointer can be used for focusing attention on a certain element of the board.

Content storages. Conducting learning activities in 3D VWs often requires sharing different types of educational content. The two tools that vAcademia offers for these purposes are described below.

- *Object Gallery* allows extending educational environment by locating additional objects. The Object Gallery of each user contains a choice of 3D objects that are usually required for conducting simple virtual classes. These include the interactive whiteboard (with different design and same functionality) and various objects for accommodating participants, such as chairs.
- *Resource Collection* can be used for uploading, storing, and sharing educational materials. This is an individual repository where each user can store presentations in PPT format, documents in PDF, pictures in PNG and JPEG, test templates in XML, test results in CSV (can be opened in Excel), and 3D objects in Collada and 3DS. In addition, the Resource Collection is able to store any other types of files, however, only for uploading and downloading. The files can be accessed from the interface of the vAcademia VW and from the website.

Control and feedback tools. vAcademia has a set of tools for classroom control and feedback. These tools reduce the workload of the teacher, help keeping the students engaged, and make the interaction more efficient.

- *Class Control* tool gives a teacher the ability to control students' access to the interactive whiteboards, ability to use their microphones, and ability to use virtual laser pointers. In addition, this tool allows the teacher to expel a disturbing student.
- *Notes* allow enhancing classes and 3D recordings with additional information. vAcademia supports three types of notes: textual, graphical, and sound. A note

may be posted on any object in the 3D environment, during a live class or in a 3D recording. In addition, users can post comments to any note.

- *Backchannel* allows displaying text-chat messages on an interactive whiteboard. This tool helps the teacher to have a better contact with the audience during classes without being interrupted.
- *Clicker* allows conducting quizzes (polling or voting) based on single-choice and multiple-choice techniques. In addition, the tool allows displaying the results immediately on any interactive whiteboard in the form of several types of diagrams.
- *Testing tool* supports several types of tests, such as multiple choice with one or several correct answers, and allows assessing the students. Educators can create tests using the Test Designer tool and save them in their Resource Collections. Each test question can be supplemented with a picture. The results are available in the form of tables, bar charts, and pie charts. They can be displayed on an interactive whiteboard board or saved in text format for further use.

3.3 Functionality of the 3D Virtual World: Locations

Common Space, Temporary, and Standard Locations. vAcademia VW has a single island 600 by 600 meters called *Common Space*. It can be used for communication between classes and serendipity meetings. If necessary, users can create their own *Temporary Locations* in the Common Space, by drawing a rectangle anywhere on the ground. Such a location can hold any objects from the Object Gallery or the Resource Collection. However, it is removed when the user who created it goes offline.

The Common Space has over 80 different preliminary-made *Standard Locations* on it. These locations are different in their thematic design, setup, and size. This provides a possibility to conduct formal and informal activities, lectures and active classes, and accommodate small and large groups. Some of the *Standard Locations* have plenty of empty space to be augmented with user objects or, for example, additional interactive whiteboards.

The *Standard Locations* can be used on different levels of reality. A teacher can create an instance of a Standard Location, so the number of live classes in each of them is not limited.

Locations "My Home". In addition to the Standard Locations, each vAcademia user has a personal location, called *My Home*. This location is separated from the Common Space and has a size of 100 by 100 meters. Such location is created automatically and individually for each new registered user. Initially, there are no objects in a *My Home*, just a flat surface. However, users can build their own educational arenas for conducting classes taking standard objects from their Object Galleries or upload own objects. The owner can set the properties of *My Home* to make it accessible only if there is a class scheduled to be held there or to allow or disallow other users to visit it.

Each *My Home* is technically implemented as an independent reality and on a separate island that significantly reduces the restrictions on the total amount of polygons of the user 3D objects, as they do not interfere with the activities of other users in other locations. In addition, much less computational power is required to display a *My Home*, as it has no nearby locations, which is the case in the Common Space.

Location templates. All types of locations in vAcademia can be customized. Users can add objects to the locations for creating the necessary settings and context for a particular course or a single class. However, such customization does not affect the original set up in the Standard Locations and exists only in the particular instances of virtual reality. Location template is a tool that allows saving the custom setup and applying it later. Location template remembers all custom objects placed in the location with all their properties. A location can be saved at a certain point, and applied when necessary (objects from the template will be re-created and placed in accordance with their properties). This tool allows to change or recover the whole 3D-scene quickly during a class.

A location template is technically created by serializing the list of objects and their properties into a JSON-object (JavaScript Object Notation). Simultaneously, a 2D preview of the template is automatically rendered and uploaded to the Resource Management Server (see section 3.8). Serialized data, path to the preview, and the name of the template are saved in the database.

When applying the template, the serialized object list is requested from the object placement service (see section 3.5). After receiving the list, the data is deserialized, then the objects are created, synchronized, and finally their properties are applied.

Communication areas. In vAcademia, voice communication is available for the users that are in the same location or within 50 meters in the Common Space. This approach suits most of the learning activities when all the students should be in one place and hear each other. However, some of the learning scenarios require forming groups of students which should work separately for some time.

In order to ease the implementation of such scenarios, vAcademia offers the tool called Communication Areas. Using this tool, users can create areas inside a location that do not allow sound to pass in or out. Such an area can be created by simply drawing a rectangle on the ground. The users inside a Communication Area are provided with an additional text chat that works only in the area. When attending a 3D recording of a class where the Communication Areas were used, visitors get the text and voice communication from the area in which their avatars are located.

3.4 Functionality of the 3D Virtual World: Navigation

vAcademia has two types of maps. The mini-map provides an overview of the nearest space around the avatar and helps navigating within the current location. The large map of the VW displays the entire Common Space and helps navigating between the locations. It also displays two numbers for each currently running live or recorded class – the number of live and recorded participants in the location. Users can teleport to any place of the Common Space or a location by clicking on the map.

Several mechanisms are available to help managing the users and raising awareness. The *Visitors* menu displays the locations which have live or recorded avatars, allows seeing public profiles of these avatars, sending messages or teleporting to them. Another service allows searching for online users and inviting them to a certain location or a scheduled class. In addition, while in the Common Space, each user is notified about the nearby classes that are currently running or periodically played.

3.5 Functionality of the 3D Virtual World: User objects

Setting up a new place for classes, users can take advantage of the models in their Resource Collections. They can upload own 3D objects, set up their properties, and use for creating specific learning environments.

User objects uploading subsystem. vAcademia allows uploading 3D objects in Collada and 3DS formats. Resource Management Server (see section 3.8) supports the upload and passes the model for recognition and after that to the 3D model converter. The 3D model converter is a separate application that converts the model into BMF5 format and the textures to PNG and JPEG formats with the resolution up to 1024 to 1024 pixels. These formats are natively supported in vAcademia. The converter also checks if the model satisfies the requirements for maximum polygons (up to 50000) and number of textures (up to 12).

If the model is converted successfully, it is registered in the Resource Management Server and becomes available for placing in the 3D space of the VW. The legitimacy of the uploaded content is regulated by the user agreement; however, in addition, it is controlled by moderation.

Supporting user objects in Collada format allows using the Google 3D Warehouse™ library. 3DS format is considered one of the most popular on the Internet – many free models can be found in online libraries. If the required model cannot be found in free access, it can be designed from scratch using any popular 3D-modelling software. For example, Google SketchUp can export to Collada, while 3ds Max, Maya, and Blender can export to 3DS, without installing additional plugins.

User objects placing subsystem. User objects may be placed only in a scheduled class (in a Standard or My Home location) or in a Temporary Location of the Common Space. This limitation is caused by the fact that user 3D objects may be not optimized in the number of polygons. Simultaneous use of several such objects is the Common Space may lead to a serious performance degradation of the VW.

There is another limitation for setting user objects in locations – the platform supports a maximum of 50000 polygons for all objects in instances of Standard Locations and 100000 polygons in My Home locations.

In order to reduce the risk of the overloading by (possibly inappropriate) user content, it is allowed only in instances of Standard and My Home locations. In such a manner, user content can affect only visitors of certain classes.

User objects properties subsystem. User objects have many properties that can be set up. The general properties include enabling/disabling shadows, selecting collision type (no collisions, bounding box, sphere, or polygonal model), and allowing/disallowing other users to move, rotate, scale, remove or change any other properties of the object. It is also possible to set up sitting places on a user object, change or modify the textures, setup autorotation, and make the object play a 3D sound.

In addition, several interaction properties are available. They allow triggering one or several actions by clicking on the object. Assigning interactive properties disables the default action for clicking – moving the avatar to the point. Some of these actions are executed only for the person who clicks on the object. They are presented below.

- Displaying a text message
- Teleporting the user into a specific location in the Common Space
- Teleporting the user into a specific 3D recording
- Opening a URL link in a web browser

The other actions are executed for everyone in the current location.

- Replacing any texture on a surface of the object with pictures uploaded in advance
- Playing a previously uploaded or recorded sound
- Automatic rotation of the objects around three axes with the defined rotation speed
- Rotating the object along the vertical axis by holding the left mouse button

Once set, the specific interactive properties are saved in a template of this object in the Resource Collection. This allows creating different interactive objects from a single 3D model and re-using them at any time. The above list of standard interactive actions is created based on the user feedback and will be extended.

3.6 Functionality of the 3D Virtual World: Avatars

The platform provides a set of preliminary-made avatars which can be customized. The skeleton-skin approach is used for the design of the avatars. The skeleton allows playing motion capture animations, such as common gestures. The skin allows creating and modifying avatars easily. The avatar is divided into parts: body, face, hair, clothing, and shoes. Their shapes can be modified by morphing geometry. vAcademia supports generation of avatars with random selection of all available parameters.

Lip synchronization system is automatically adjusted to the avatar. Voice volume decreases with distance, and cuts off automatically when an avatar leaves a location.

3.7 Website support

vAcademia has strong web support. While the main function of the 3D environment is offering tools for online classes, the website provides support for planning and managing classes and courses, and searching and organizing 3D recordings. In addition, the website has social networking functionalities (http://www.vacademia.com/).

The main page of the website has the *Activity* section, which syndicates what happens in the vAcademia community. It displays the main activities of vAcademia users, including scheduling meetings, publishing 3D recordings, and sharing text messages written directly into the section, plus messages from Twitter™ and Facebook™. Activity messages appear on the front page after moderation. Registered users can subscribe and follow activities of other users.

The website provides support and information about the VW. In addition, a CMS/LMS is developed and available through the site. The website has several sections that provide particular functionalities.

The *My Account* section contains personal information and provides access to the friend list, the list of communities, access to the Resource Collection, internal messages, and the list of 3D recordings created by the user. The users can also fill in additional information oriented toward the community of teachers and learners. The *Study* section gives the learners access to the list of all attended classes, lists of peer participants, the list of favorite classes, and the schedule. The *Teach* section provides a tool for planning classes and courses, lists of conducted classes and their 3D recordings, the register of classes' attendance, and a tool for managing groups of learners.

In addition, vAcademia provides a possibility for integration with external CMS/LMS. This allows introducing new possibilities that 3D VWs can provide in an already smoothly working learning process. The following plugins were developed to allow using some of the vAcademia functionality in any Moodle-based course.

- A plugin for scheduling vAcademia classed and binding them with Moodle classes allows adding a vAcademia class as a resource for a Moodle class and set parameters directly from Moodle, including class topic, description, date and time, location in the VW, number of allowed participants, and expected duration of the class.
- A plugin for inserting vAcademia 3D recordings as resources into Moodle courses

In order to have a flexible way to work with 3D recordings, each of them is complemented with a 2D Flash-based preview that is recorded automatically. Such a preview consists of the audio of the class, synchronized text-chat messages, and a series of pictures, which are taken from different cameras: for each whiteboard, for the stage, and for the audience. The previews are available on the vAcademia website, but can also be embedded in any web page, blog or a social networking website. The preview player has a toolbox which allows opening recordings in the 3D mode if the vAcademia client is installed.

3.8 System Architecture

vAcademia was developed from scratch using previous experience in developing educational 3D environments. Most of the system components were also developed from scratch. However, many well-known libraries and components, such as audiere, freetype, freeimage, and curl, were used for programming the networking, image processing, and sound. vAcademia has a client-server architecture (Fig. 2) and works on Windows operating system. The main components of the system are briefly described in the list below.

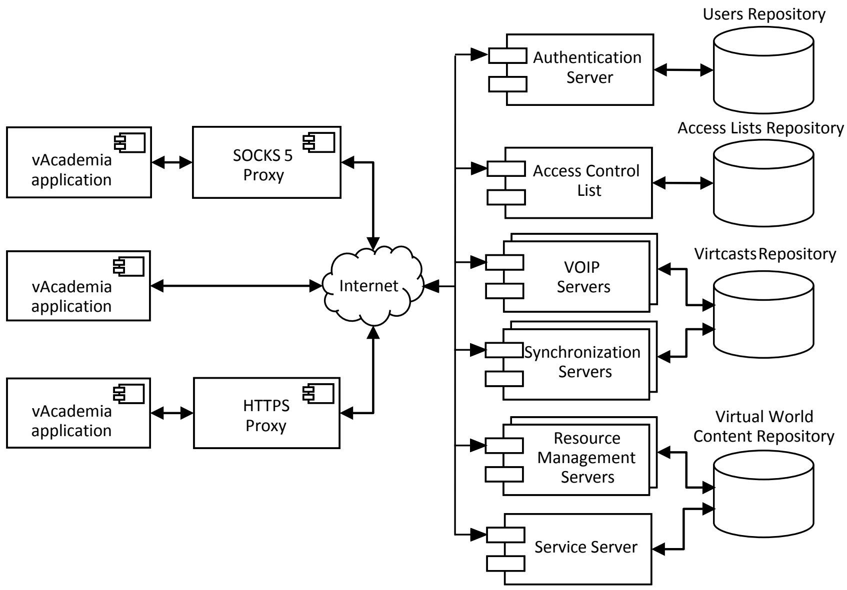

Fig. 2. vAcademia system architecture

- vAcademia application – client software that visualizes the VW and provides all functionality for conducting classes.
- vAcademia servers – a scalable system that supports network interaction. In order to ensure stability and data processing speed, the platform uses multiple servers.
  - Authentication Server supports registration and authorization of the users.
  - Resource Management Servers support access to the VW data and user objects in the Resource Collections.
  - Synchronization Servers support networked interaction between users.
  - VOIP servers support voice communication.
  - Service Server implements mechanisms of scalable services based on SOAP model (Simple Object Access Protocol). These servers are used for several components, such as text chat, Resources Collection, and list of recordings.
- Access Control List (ACL) – a system that manages user access permissions for the resources, such as scheduling and accessing classes, 3D recordings, number of objects in My Home locations, and capacity of Resource Collections.
- Virtual World Content Repository – a storage system for the 3D world data (geometry and textures) and user objects. These resources are divided into separate entities called modules. For example, all the resources that are uploaded by a specific user are stored in a separate module.
- Virtcast Repository – a storage system for 3D recordings. This storage is distributed to a number of different servers and stores all media resources of the 3D recordings, such as the state of objects and avatars, text and voice communication.

The graphical engine of vAcademia was developed specially for the project based on OpenGL. vAcademia has four levels of the graphics quality. The quality changes according to these levels, including the number of objects and polygons in them, quality of textures, antialiasing, and the distance of visibility. In addition, vAcademia uses levels of details for 3D objects and avatars, simplifying the geometry of the long-distance objects for better performance.

For implementing interactivity in vAcademia, a Jscript-based scripting language is used. It can later be given to the users for programing the behavior of 3D objects.

4 Scenarios of Use

In this section, we elaborate some scenarios of use to illustrate the current functionality of vAcademia. The application domain of vAcademia is defined by the teaching tools integrated in the world and the 3D-recording feature. While teaching tools allow using approaches that are used in the face-to-face and virtual modes, the 3D recording opens a new direction in e-Learning the methods for which are yet to be developed.

Learning activities with 3D recordings can be conducted in two basic formats: first – visiting a 3D recording, and second – creating a new 3D recording while conducting activities being inside one.

Visiting a 3D recording is similar to working with a recorded lecture or a webinar. A 3D recording can be watched at any time focusing on specific parts, but it can also be visited by a group of learners who can actively work inside. All the objects are on the same positions in the 3D recording as they were in the live class at any point of time. All the interaction can be observed in the same way as in the live class. The only limitation is that the visiting avatars cannot interact with the recorded ones.

The second format – creating a new 3D recording being inside one – is even more different and promising. A teacher can enhance a 3D-recorded class by visiting it with another group of learners and recording over again. As a result, another 3D recording can be created, containing new discussions, questions, and comments. Working inside a 3D recording, users can set up and use additional tools and materials.

In addition, the teacher can guide learners only through some parts of the original class, for example, the unclear ones. It is possible to fast-forward a 3D recording through the places that should be skipped (see red pieces in Fig. 3). In such a way, the skipped places of the original recording will not appear in the new one (Fig. 3).

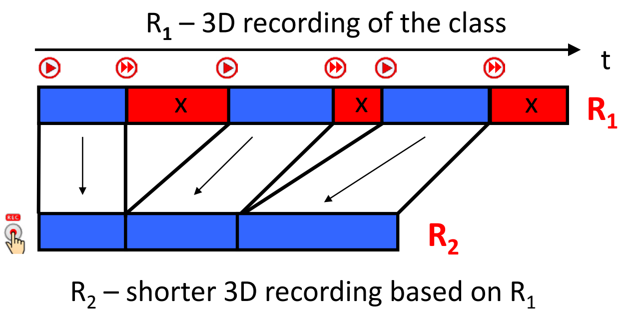

Fig. 3. New 3D recording with skipped parts

Alternatively, the teacher can pause the original 3D recording and add some missing material or discuss a particular part with the students (see green pieces in Fig. 4). Some parts of the original 3D recording can also be replaced. The new 3D recording will contain this additional material (Fig. 4).

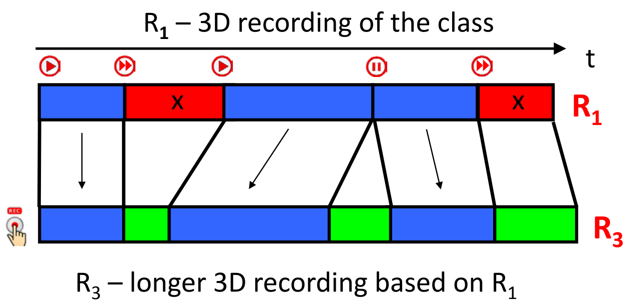

Fig. 4. New 3D recording with additional and replaced parts

In addition, 3D recordings can be enhanced with notes. Being in a 3D recording, users can add notes to any object in the recorded location. These notes can contain questions or additional clarifying material. When re-visiting the new 3D recording, the notes will appear in the same place and in the same moment of time (Fig. 5).

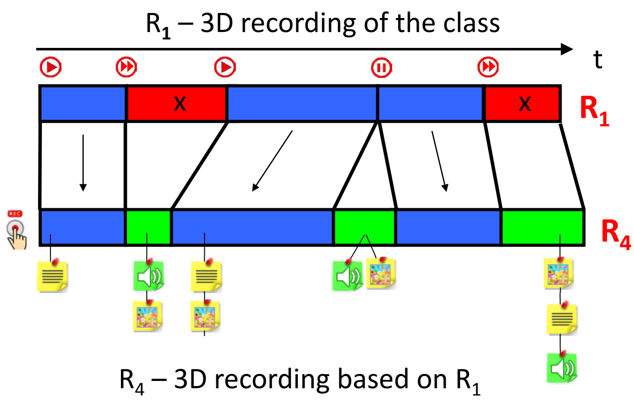

Fig. 5. New 3D recording enhanced with notes

Recording new activities being inside 3D recordings, the teacher will have additional virtual classes focused on specific parts which extend and improve the original class. In such a way, vAcademia allows editing the content of asynchronous recordings of synchronous activities. This feature is especially useful in the cases when a certain class has to be repeated frequently. For example, educators can create a template of a class with demonstrations but perform live discussions with each group of students reusing the content and avoiding unnecessary duplication.

3D recording creates new possibilities for combining synchronous and asynchronous activities within one scenario. Students might not even notice that they experience a recorded session which can be followed by another one which is live and interactive. For example, a class template can consist of three parts. In the first part, the students can attend a 3D recording prepared in advance, in which the teacher explains the material. In the second part, the students can work on practical exercises in groups and record them. In the third part, the students together with the teacher can visit all the 3D recordings created in the second part one after another analyzing and discussing positive and negative aspects.

5 Current Usage

Although vAcademia is currently under beta testing, possible scenarios of use are evaluated in the real educational process. The qualitative data is not presented in this paper but will soon be available.

The VW is used by university teachers for augmenting regular face-to-face classes. For example, vAcademia is used in several IT courses at the Volga State University of Technology. A number of different activities are conducted, such as lectures, seminars, project presentations, and study group discussions. Interactive whiteboards are used for live demonstrations of work in software development environments and the performance of resultant applications (Fig. 6). The number of visits to a 3D recording is approximately three times larger than the number of students in the corresponding live class.

Fig. 6. Developing Scratch applications class in vAcademia

Another example is the use of vAcademia at the Norwegian University of Science and Technology for teaching Cooperation Technology course in 2012. It was used as a platform for one of the lectures (3D VWs as a cooperation technology) and a virtual seminar with student presentations (Fig. 7). Attending the lecture in vAcademia allowed the students to get some practical knowledge on the topic. The virtual seminar pursued the same goal of providing students with experience of using one of the cooperation technologies (3D VWs), but it required active participation. The teacher made a tutorial about the vAcademia features. The students studied the tutorial visiting the 3D recording and practiced the features immediately. Half of the student groups pre-recorded their presentations, while the others performed live during the seminar. The feedback from the students indicated that vAcademia can be used as a cooperation technology, but a number of technical problems were mentioned.

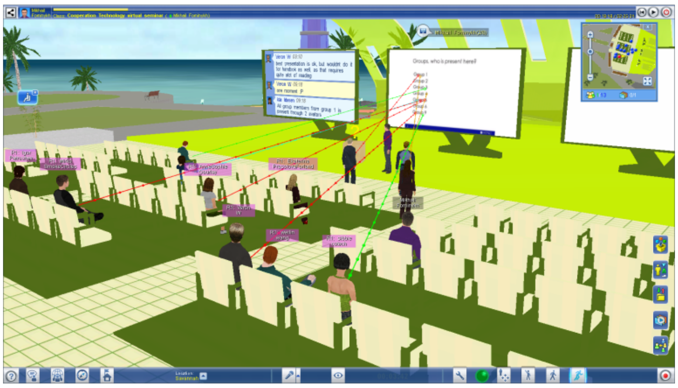

Fig. 7. Cooperation Technology seminar in vAcademia

The VW is also used by several independent educators from around the world who are exploring new ways of collaborative learning or searching for a new platform. For example, vAcademia had been used for language learning by several professors who taught English courses. Students and teachers from different countries took part in the courses. The teachers often provide positive feedback on the integrated CMS/LMS, convenient interactive whiteboards, and many other tools.

vAcademia is used in schools and as a distance learning platform. A number of courses and separate classes were conducted mostly as trials for science and language subjects. In these classes, both teachers and students were actively using whiteboards for displaying multimedia resources, presentations, and practical exercises. The user experience shows that classes in vAcademia are engaging for students, however, the possibilities of the new types of activities require more exploration.

6 Future Directions

Further development of vAcademia project will be focused on widening its use in education and will include the development of additional functionality for the 3D world, extending possibilities for accessing the platform, improving the social and community support, adopting new interfaces, and designing new learning scenarios which would benefit from integrating synchronous classes and 3D recordings.

The development of additional functionality for the 3D worlds of vAcademia will be focused on extending possibilities for using custom 3D objects uploaded by users and programming the behavior of such objects. This will allow creating custom learning environments which can be used, for example, for simulations. Another direction is improving the workspace and teaching tools to make them more convenient.

Extending possibilities for accessing the vAcademia platform includes developing client applications for different operating systems and a light version for mobile devices. The second direction is developing a browser-based client.

Improvements in socializing support include a text chat across the website and the 3D world and integration with popular social networking websites.

Adopting new interfaces includes two main directions that are currently being developed. The first direction is translating classes in the physical world into the virtual world by using input devices such as motion capture and (physical) interactive whiteboards. The first Kinect-based prototype is being developed. This will allow conducting classes with participants from both physical and VWs. vAcademia is also being adapted for CAVE facilities (cave automatic virtual environment).

The second direction of adopting new interfaces is transferring part of the functionality to the mobile devices, for example, allowing to control the interactive whiteboard located in the 3D space by using an auxiliary mobile application.

Designing new learning scenarios is necessary for discovering all the possibilities of 3D recording in VWs. There will be a possibility for creating a library of class patterns, which can be based on certain pedagogical scripts. Such patterns could provide a 3D environment, all necessary tools, and a timeline. Some scenarios can be based on 3D recorded classes playing the role of a new type of user-generated content. Educational simulations and serious games will provide additional value, for example, for later analysis, if they are 3D-recorded.

7 Conclusion

In this paper, we propose a new approach to learning in 3D VWs, which is based on virtcast – a new type of content that can be created by using the 3D recording mechanism and is available in vAcademia. We also present an extended description of the vAcademia system and its major functions.

3D recording of classes in vAcademia expands the educational potential of the 3D VWs by combining advantages of synchronous and asynchronous modes. It allows using new approaches that were not available before.

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