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SLATE: Virtualizing multiscale CT training

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Abstract

Training on micro- and nano- computed tomography (CT) scanners has been traditionally conducted via extensive practice on the instrument. This entails presence of an instructor to guide through the training procedure, until reasonable experience is attained. Modern tomographic instruments being expensive to maintain, the operational costs escalates with increasing number of training conducted. In a pioneering approach, the technical know-how to operate such equipment has been partly imparted via virtual reality environment running on the Second Life grid. The experimentation has indicated a reduction of the total training time. The authors hope that in the long run, such techniques will aid in significant reduction of instruction time and costs associated with training.

Keywords

Virtual world; micro-CT; nano-CT; simulation; Second Life; CT (computed tomography); training

1. Introduction

The microCT and nanoCT (computed tomography) scanners are the state of the art instruments in X-ray microscopy. In operating these instruments, exhaustive training is a pre-requisite to necessitate smooth error-free functioning. Traditionally, users undergo several hours of training, familiarizing with the X-ray, cabinet and operator console. The high cost of maintenance, spares, and replacements for these instruments, has led to a need to find alternative methods to train new candidates. Also, many users have sporadically used the instruments. This has, on many instances, required them to undergo the training program again, to familiarize again with the instrument.

Second Life developed by Linden Labs. Inc., CA is a virtual world running on distributed computer clusters. This virtual world sees immense participation from around the world. A wide spectrum of population use SecondLife for uses ranging from social networking to trade & commerce. The authors have taken advantage of the unique settings provided by this

environment to create a virtual lab where CT operators can familiarize themselves and get rudimentary training, analogous to simulators used for flight training. *Second Life aided training and education* (SLATE) aims at serving these objectives – minimizing the actual use & accidental errors, and improving user efficiency & reliability.

The outline of the paper is as follows. In the first section, the authors have introduced the scope of virtual reality in education and outlined the history of its development. The advantages of using a virtual classroom settings vis-à-vis a conventional setting has been discussed as well. This section also highlights the public outreach offered by the SLATE program, and its uniqueness in comparison to SL programs hosted by other institutions. The Methods and Experimentation sections outline the setup of the SLATE space, and how a user is trained. The sections also discuss the stages of development of this space prior to its deployment. The experimentation section also defends our hypothesis of reduction of training time with aid of Virtual reality. Finally the overall usability and scope for improvement have been discussed.

2. Methods and organization

2.1. Virtual Reality in Education

Virtual worlds run on networked computers, where people using *avatars*, interact in a simulated 3D world. The idea is appealing since users only need to be registered through the worldwide web (WWW) to experience the virtual reality (VR) environment. The hosting and rendering of 3D details are done on the server side, removing the need to have high performance console or proprietary software at user end. This conceptualization was originally meant for 'massively multiplayer online role playing games' (MMORPG), but has since then gained popularity for socializing, education, and exploration [1].

In a virtual environment setting, students can meet online for lectures, discussion, case studies, and group activities. Classes in virtual worlds offer opportunities for visualization and creation of settings which are conducive for rapid learning [2,3]. In this regard, the Second Life (SL) VR environment created by Linden Labs Inc. is gaining popularity as an effective means of education and training. With a simple GUI, codeless creation of object models, and lucid scripts to animate these objects, this has become the platform of choice for many labs, corporations, and universities to conduct virtual sessions with students and trainees. The added functionality provided by VoIP and streaming video also has helped in bridging the gap where animation is difficult to create [4]. Some leading institutions, like Stanford University, the Massachusetts Institute of Technology, and the University of California, Davis, are actively engaged in outreach programs with the aid of *Second Life* [4,5]. These programs range from courses requiring advanced skills in engineering to public outreach programs. Independent studies, conducted by the University of Tennessee, Chattanooga, TN, and University of Wisconsin, Madison WI, have shown that the SL platform can help in delivering teaching/learning content, with appreciable clarity, with both inexperienced and regular users [4,6].

2.2. Organization of slate space

The Biomedical Imaging Division (BID) at SBES, Virginia Tech has developed a SL space geared to teach the basics of microCT & nanoCT, with elements of training involved. Though BID's initiative may be similar in many aspects to SL initiatives pursued by other prominent organizations (e.g. University of California Davis Medical Center and Center for Disease Control) towards increasing public awareness, there are significant differences in implementation. As an illustration, the virtual space operated by UC Davis and CDC have been about schizophrenic hallucinations and epidemic & disease control respectively, providing instructional posters about the respective topics. SLATE objective not only aims at educating potential users on the principles of X-ray microscopy, but also, training them on the fundamental techniques involved in operating the instrument [7]. The lab tools in question are microCT and nanoCT supplied to Virginia Tech by Xradia Inc., and the VR environment is ideal to showcase their roles in multiple disciplines of research and development. Though the SL programs, employed by both universities, aim at increasing participant awareness, the program pursued by Virginia Tech is unique in its objectives to replace conventional training in favor of the Second Life based training, bringing the technical knowhow to users regardless of their geographical location. This SL program also is unique, in simulations of equipment which are of critical and sensitive nature.

The SLATE estate, designated as 'BID SBES VTWFU' [8], in Second Life domain, has 3 distinct areas – Gallery, Presentation area, and Training Space.

2.2.1. Gallery—As shown in Fig. 1, the gallery area has a set of posters from conferences and journals which have used the Xradia microCT or the nanoCT at Virginia Tech. It is designed in a fashion akin to conference venues where users can view descriptions of multiple projects in the same place. The user can download these posters if needed.

2.2.2. Presentation area—The presentation area which is depicted in Fig. 2 is designed to provide streaming pre-recorded lectures from instructors and speakers. The static content on this site is a set of lectures which have been recorded during workshops and guest lectures. These serve to illustrate the importance and functionality of the high resolution CT scanners. They also illustrate the scope of using these instruments.

2.2.3. Training space—The training space has a virtually working replica of the equipment. The various parts of the equipment have been made interactive by means of scripts which provide animations on the SL environment. The use of such scripts provides the experience of using these simulations as close as possible to the actual operating nature of a particular feature (more details in Phases of Developing SLATE).

The user is provided a menu introducing the user to the instrument. The menu usually begins with highlighting the various parts of the instruments. As the training progresses, the user can learn about the different motions relating to the parts. The simulation also highlights safety procedures, preventing the user from turning on X-rays or moving the source-detector assemblies incorrectly, just like in the real world scenario. The user can repeatedly go through any part of the SL space at his/her convenience, thus eliminating reliance on a trained operator to guide at every single step. The tutorials and simulations can serve to

teach the fundamentals of operating the instrument, reducing the training burden and costs. The training thereafter can be expedited.

2.3. Phases of developing slate

The development of the SLATE space has proceeded along three phases.

2.3.1. Creation of scanner model—The bodies of the scanners were built first, as cabinets, mimicking the shape and form factor of the actual Xradia instruments. Thereafter, components were photographed individually and the interior structures of these lab-tools were built. Efforts were made to make them closely resemble the actual components. The components included the X-ray source and detector turret, the light towers, exterior consoles and sample holders (as shown in Fig. 3). Having created the model, scripting of various movable parts was done to add realism

The scanner's 3D replica was created to a high degree of visual resemblance. The resemblance is illustrated in Fig. 4. It was to enable users to start training, before other phases could be put in place.

2.3.2. Animation of the model using scripts—LSL (Linden scripting language) is the scripting language that can be used to provide dynamic behavior to otherwise static objects in SecondLife. The scanner model was animated using scripts developed in LSL which would replicate the actual functioning. This included physical operation of opening the cabinet, X-ray turning ON/OFF, reading the indication features on the panel during operation, and source detector assembly's movement. The script also used the standard practice of shutting down X-rays automatically during any manual operation within the scanner cabinet, akin to the normal operational characteristics of such a scanner.

Figure 5 shows a user interacting with the scanner. The user can first go through initial steps of familiarizing himself with the interior of the X-ray cabinet. The model highlights the various parts and indicator which the user should be aware of before setting up a scan.

Figure 6 shows the interface visible to a user to familiarize him/her to the actual movements which are possible with the microCT. The object model mimics the motion inside the X-ray cabinet and the various indicators on the console and the instrument's panel, very similar to what a user would expect to see in the actual console.

2.3.3. Enhancement—The enhancements included creating user spaces like the interactive screens, a virtual classroom with recorded talks from symposiums, and the viewing gallery, to supplement the scanner space. These have been made with the objective of enhancing the visual appeal of the virtual space and inviting more people in SL to visit & learn.

3. Validation and results

3.1. Experimental setup

Conventional training involves 3 phases – (1) familiarization with the scanner and basic controls, (2) setting up a scan to acquire a tomography, and (3) operating the reconstruction software to get the reconstructed volume data from the tomography. The 3rd step does not involve usage of the instrument, and can ideally be done on a completely different workstation. The aim of this work is to reduce the time required in steps 1 and 2 – which involve direct control of the instrument.

To test the effectiveness of SLATE in aiding training process, two groups of participants were formed from the candidates who had shown a keenness to be trained on the instrument. The applicant pool comprised of graduate students from various engineering and science disciplines, enrolled at Virginia Tech. The groups were kept homogenous in their composition by evenly distributing training applicants, so that neither group had majority of participants of a particular discipline. This was to prevent any bias in the experiment.

First group, comprising of 6 participants, was trained by conventional paradigms. Each candidate was trained individually. The second group of 5 participants had an additional step being familiarized with the SLATE environment without any instructor guidance. The second group was instructed to communicate in the virtual space amongst themselves and discuss the features and applications of the object models towards actual training. Thereafter these training candidates were given specific instructions on operating the instrument as described for the first group.

3.2. Results

The time to train each candidate was recorded in each instance, for both the groups. The data is summarized in Tables 1 and 2 respectively. The time calculations have been rounded to the nearest 5-minute interval for brevity. It was found that candidates who got trained on the SL platform first, were able to comprehend the instructions faster, and consequently the time used to train them was lesser. The candidates, who were trained by conventional paradigms, took more time in getting adapted and familiarized. The SL group also showed higher cognition of different parts and their usefulness in scan procedures in comparison to the group trained conventionally with aid of manual and figures.

It was observed that the group familiarized on SL first had a mean time of 97 minutes to get be able to setup a successful scan, following all the safety guidelines and procedures. Under similar conditions, the average time for a conventionally trained candidate to learn and setup a scan was found to be 121 minutes. Hence there was about 19.8% reduction in training time considering SL as a platform.

A paired T-test was performed as well to ensure the certainty that the results differed statistically, if it were to be conducted over a large number. Since the sample number was different in the groups by 1 candidate, Group A being more in number, the maximum time recorded in Group A data was discarded. It was with the assumption that skipping the highest valued data would place the lower bound on the T-test – skipping other data points

would yield results even more favorable to our hypothesis. The null hypothesis H_0 assumed was that the information in the 2 time plots had similar means. Significance Level, (α) was set to 5% (0.05). Any variation beyond 5% was to invalidate the Null hypothesis H_0 , and rather follow the alternate hypothesis H_a , that means of the two time samples vary beyond 5%. The results of the Student's T-test are summarized in Fig. 5 and Table 2. All numbers indicate value in minutes.

A low value of probability (0.0093) indicates that our chosen Null hypothesis (H_0), that the 2 set of statistical time data could be elements of the same distribution, was false. The hypothesis could be true only in 0.93% of the cases; hence conclusively proving that SL based technique would reduce the operator training time and filament usage time in long run and reducing the costs involved in the pedagogical interests of BID at SBES.

4. Discussion

With deployment of the SLATE training platform and its subsequent use, the feedback has generally been positive, though deficiencies do exist. This is common in educational scenarios [9], where different techniques & teaching methodologies need to be implemented and improvised time to time, towards an efficient teaching/learning model. The primary deficiency which remains in the system is the inability to emulate preparing the scanner model (akin to the real scanner) for a tomographic scan. The biggest portion of training time on a real scanner is spent on imparting skills regarding positioning of samples, choosing magnifications and exposure, and finding center-shifts for accurate reconstruction. Virtual reality can't replace the experience of precision alignment procedures in these instruments, and being able to judge the optimum parameters towards a good quality image. But it does justice in reducing the learning curve nevertheless, by making the user familiar to the instrument and simulating basic operations.

Future work which has been planned on the SL system includes refining the model quality of the system to match the real system. The model at present is a close replica of the actual system. However with cooperation of the scanner manufacturers (Xradia Inc., CA) an intricate set of component models can be fashioned. This will improve the user experience and reliability of the platform to closely deliver the experience of handling the scanner. In addition to graphic improvement, the scripting of the nanoCT scanner model has been proposed to include sample positioning and aligning the source-detector optic train. The ability to position the optic train for a good focus could vastly reduce the valuable scanner time, reducing filament cost, and nearly taking care of the entire training process in making users capable in operation.

The SLATE platform also intends on having some scripted avatars, which will be present always to guide new users, and show how every particular feature could operate. Alternatives to the above methodology, could be inclusion of flash animations and embedding them at many identified points which are difficult to understand without any assistance. For simplicity of operation, the current system allows trainees to proceed/review any part of the training program – without evaluating whether the trainee completed the previous level satisfactorily. This could be a potential loophole if a trainee wishes to skip parts of the

training program. By skipping portions, important safety procedures might be overlooked. A more foolproof training program can be designed by including certain features, by which the user will be able to proceed only after feedback and evaluation at each stage.

In summary, this paper describes a SLATE based training platform which has the potential of changing the way future candidates will be trained for operating microCT, nanoCT and similar advanced instruments. In addition to bringing the knowhow of operation, it also reduces dependence on availability of a trained operator vastly by incorporating all major aspects of the training in the virtual world. Furthermore, it has proved that it has the potential to significantly reduce the costs associated with training the users and lessening the chances of the user making catastrophic errors, which could cripple the functioning of the lab-tool. This platform has enabled the operators at BID to be able to familiarize people who are at remote locations without their physical presence. Further developments and improvements are being planned which would improve educational outreach of the facility.

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Fig. 1.
The SLATE gallery which allows users to view technical posters in an environment akin to conference venues.

Fig. 2.
Presentation area where users can watch lectures on various topics related to micro- and nano- computed tomography.

Fig. 3.
Model of the scanner which offers the user dynamic access to the training material depending on phase of training.

Fig. 4.

(a) Actual interior of micro-CT scanner, and (b) replication in Second Life model of scanner.

Fig. 5.
First stage of training – familiarization with interior of instrument.

Fig. 6.
Second stage of training – usage of the motion control system.

Fig. 7.
Comparisons of mean and std. dev. in time required in training by conventional and Second Life aided methods.

Table 1

Training by (Col. A) Conventional Paradigm & (Col. B) Aid of slate

Conventional training		SI aided training	
User	Time hh:mm (Total minutes)	User	Time hh:mm (Total minutes)
A1	2:15 (135 min)	B1	1:45 (105 min)
A2	1:50 (110 min)	B2	1:10 (70 min)
A3	1:50 (110 min)	B3	1:30 (90 min)
A4	2:00 (120 min)	B4	1:30 (120 min)
A5	2:30 (150 min)	B5	1:40 (100 min)
A6	2:10 (130 min)	–	–

Table 2

Results of T-test

	Conventional training* (min)	SI aided training (min)
Maximum value	135	120
Minimum value	110	70
Range	25	50
Mean	121	97
Standard deviation	11.40	18.57
Probability of Ho being true	0.0093	
Result	Alternate hypothesis (H_a) true. Null Hypothesis (H_0) rejected.	

* Indicates truncated data set.