The Development of Remote Teaching Laboratory Access Software for Multi-Slice Computed Optical Tomographyfor Use in Undergraduate Nuclear Education

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Summary

Internet-based laboratory exercises were developed for a course on biomedical imaging at the University of Ontario Instituteof Technology. These exercises used a multi-slice computed optical tomography machine named*DeskCAT* to instruct students on the principals of computed tomography. User management software was developed which enabled course instructors to quickly set up a computer to accept a series of scheduled remote user connections for a classroom. Laboratory exercises using the DeskCAT machine were developed to be conducted remotely.

1. Introduction STOPPED HERE

Multi-slice Computed Tomography (CT) is a technique in which digitally reconstructions three dimensional objects. To do this, the object is rotated by a scanning head and imaged at series of angles. Each of these images is called a *slice*. These slices are processed in a reconstruction algorithm to produce a digital model of the actual three dimensionalobject. This technique is often uses x-rays so that digital reconstructionsof internal organs and skeletal structures can be produced for diagnostic purposes. These x-rays can deliver a significant dose to those who operate the CT scanner and those whom the CT scanners are operated upon. As such, it is a common task for medical health physicists to work with such machines. To prepare health physics students to use computed tomography machines, the University of Ontario Institute of Technology (UOIT) offers a course on biomedical imaging techniques to students in which a number of labs are devoted to the use of CT scanners.

Traditional teaching laboratories require both instructors and students to be in a physical laboratory together in order to conduct the laboratory exercises. An alternative to this traditional method is the use of internet based laboratory exercises in which students remotely access laboratory equipment and perform experiments over an internet connection.

There are many unique advantages internet based laboratories offer over traditional laboratories. Traditional laboratories are conducted by a teaching assistant at a pre-determined time and pre-determined location whereas internet based laboratories can be accessed remotely from anywhere in the world at any time. Furthermore, due to lack of equipment, traditional laboratories often involve a teaching assistant performing a demonstration on a given piece of equipment. Internet based laboratories, on the other hand, enable students to have direct one-on-one access to the laboratory equipment. This direct access enables students to be able to experimentwith laboratory equipment at their own pace without the need for a teaching assistant. Internet based laboratories also enable so called *discovery-based* learning, a type of learning where students are given the tools to answer a question, but the methodology to answer the question is left up to the *discovery* of the student.

Several internet based laboratory exercises were developed for DeskCAT, a miniature multi-slice optical computed tomography (CT) device produced by Modus Medical Devices. The purpose of these labs is to demonstrate various aspects of CT imaging to students. These laboratory exercises include the determination of linear attenuation coefficient, the determination of mass attenuation coefficient, and the employment of a contrast enhanced subtraction algorithm on remotely acquired CT images.User management software was developed to aid instructors in the execution of these internet based laboratories.

2. Materials and Methods

The DeskCAT scanning machine is a small desktop sized optical CT scanner (see figure one) which consists of the scanning chamber and the scanning head. A sample jar fits into the scanning head (see figure two) which rotates the sample jar about its central axis for slicing. The scanning chamber houses a grayscale camera and light source. The rotating sample jar is situated in-between the camera and light-source (see figure three).

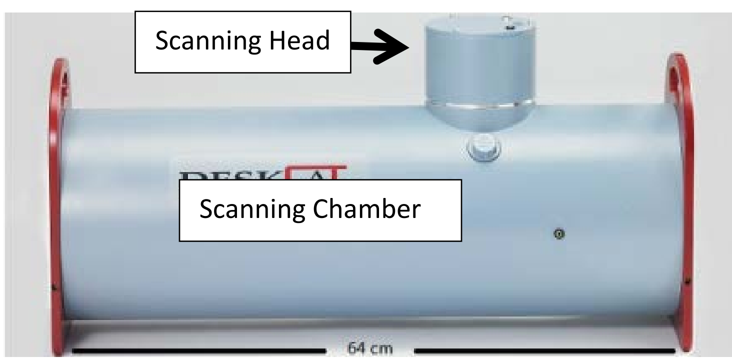

Figure One: DeskCAT scanning machine

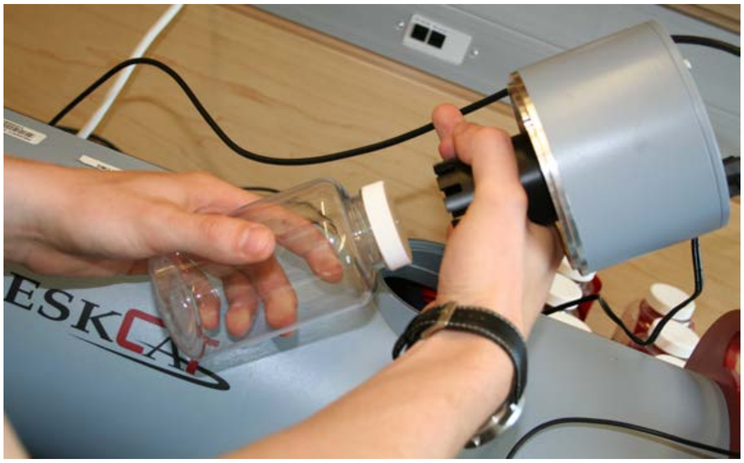

Figure Two: A sample jar being fit into the scanning head

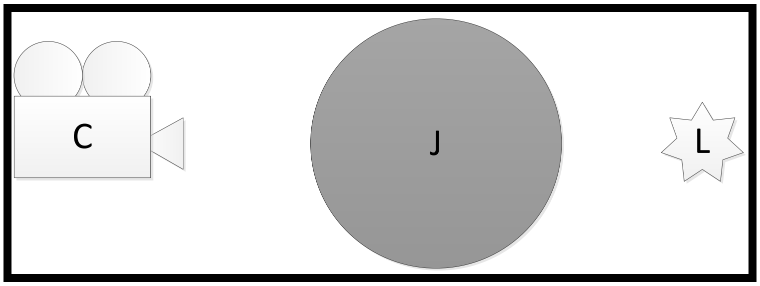

Figure Three: A representation of the inside of the DeskCAT machine with Camera *C*, rotating sample jar *J* and light source *L*.

The DeskCAT software is proprietary Microsoft Windows® based software which reconstructs the acquired images from the DeskCAT machine into 3D models. The software acquires data from and controls the DeskCAT scanner through two Universal Serial Bus (USB) connections (one for the camera, and another for the rotating head). The DeskCAT software stores data as 16bit grayscale bitmaps in its program directory. Since Windows has no native support for 16bit grayscale bitmaps, the open source software program ImageJ was used for image processing and viewing.

The remote laboratory was set up so that only one user can access the DeskCAT machine at time. Access was controlled by user accounts in the Windows Active Directory service. Accessible hours were set via thelogonHours attribute to a time the course instructor would determine beforehand. The intention was to have an environment in which a course instructor could write a file which contains the names of all the students in the class and the times during which each student can access the lab equipment. A programwould then run read the instructor written file and set up user accounts for each of the students on the laboratory computer.

Software was written to create, delete, and modify access times for user profiles en-masse using Microsoft Visual C# Version 4.0,*System.DirectoryServices.AccountManagement* .Net namespace, and Alain Lai's *ADPermittedLogonTime*interface [1]. Users and their access times are read in via a LINQ query from an instructor created XML file. The *PermittedLogonTimes* member of the *UserPrincipal* class is used to set the times during which a user can logon to the computer; however, this member is undocumented by Microsoft. Alain Lai has written an interface which has a static method called *PermittedLogonTimes* (note the name overloading) which accepts a *list* structure containing *System.DateTime* pairs (one to indicate the beginning of the session, one to indicate the end of the session) and outputs a byte mask for the *UserPrincipal.PermittedLogonTimes*memeber. This *PermittedLogonTimes* interface is used to set the times which each user can access the computer. Each user is stored in in a *list* structure after it is read in and the byte mask generated. These users are then added to the local machine's Active Directory and its *Remote Desktop Users* group principal.

The open source FTP server 'Filezilla' was used to enable file transfer between the remote lab computer and the computer of the student. The size of the raw data produced by the DeskCAT scanning software was in the order of hundreds of megabytes, so it is essential that both the student and lab computers be on broadband internet connections.

4. Laboratory Exercises

4.1 Linear Attenuation Coefficient Laboratory

In the linear attenuation coefficient laboratory, students determined the magnitude of the linear attenuation coefficient, μ, used in the linear form of beer's law of light attenuation (equation one).

$$I = I_0 \exp(-\mu x) \tag{1}$$

This laboratory is conducted by inserting a sample jar covered in a series of celluloid sheets. These celluloid sheets ranged from a single sheet in thickness to many layers in thickness. Students acquired an image of each of the steps of celluloid thickness using the DeskCAT machine. These images were then opened in ImageJ and a five pixel Gaussian filter was used to remove any noise in the image. A profile line was then drawn across the surface of the sample jar and pixel intensity was plotted respect to pixel position along the profile line. The maximum value of this intensity-position plot corresponded to the centre point of the sample jar at that thickness of celluloid since it is at the center point through which the most light passes. These intensity values were plotted against celluloid sheet thickness on a log-linear plot and a line of best fit was fit to the data by the method of least squares. The slope of this line of best fit gave the linear attenuation coefficient for the celluloid.

4.2 Mass Attenuation Coefficient Laboratory

In the mass attenuation coefficient laboratory, students measured the mass attenuation coefficient, α,used in the mass form of beer's law of light attenuation (equation two)

$$I = I_0 \exp(-\alpha C x) \quad (2)$$

Where C is the concentration of the attenuating substance in solution, and x is the distance through which light travels in the attenuating medium. In this laboratory, students prepare a series of samples jars containing a solution of a varying amount of dye concentrate. The intensity of light traversing the sample jar is measured in a manner similar to that in the linear attenuation coefficient laboratory. The mass attenuation is determined in a method similar to the way in which the linear attenuation coefficient laboratory determined the linear attenuation coefficient – by plotting the intensity of a sample on a log-linear plot with respect to concentration, fitting a line of best fit, and measuring the slope of this line.

4.3 Contrast Enhanced Subtraction Laboratory

Contrast enhanced subtraction is a common technique used in CT scanning which extracts out an area of interest from a scanned sample. To do this, a *pre-contrast* scan is first taken of the sample. A liquid contrasting agent is then injected into the area of interest to highlight it. A *post-contrast* scan is then taken of the sample with the contrasting agent injected. The pre-contrast image is then subtracted from the post-contrast image, and the resultant image is only the area of interest

Software was written which performed the contrast enhanced subtraction technique on data acquired by the students. This was accomplished by first normalizing the intensity of each pixel in each slice of the pre-constrast and post-contrast against a maximum intensity value. Element-wise subtraction was then performed on the post-contrast image from the pre-contrast image to produce a resultant slice which is the post-contrast image. (IE post-pre=result)

5. Conclusion

The contrast enhanced subtraction and mass attenuation coefficient determination exercises were bit amenable to conduct remotely since they needed direct access to the laboratory equipment; however, since the linear attenuation coefficient determination laboratory required no physical intervention it was congruent with the methodology of remote laboratory exercises. Nevertheless, emote laboratory instruction can provide a hands-on experience for students conducting laboratory exercises without the need for a physical presence in the laboratory.

6. References

[1] Alan Lai *"Active Directory Permitted Logon Times with C# .Net 3.5 using System.DirectoryServices.AccountManagement" September, 7, 2011 located at* http://anlai.wordpress.com/2010/09/07/active-directory-permitted-logon-times-with-c-net-3-5-using-system-directoryservices-accountmanagement/ *First accessed June 2012.*