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# Secure Internet examination system based on video monitoring

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## Keywords

Video, Worldwide web, Online operation

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## Abstract

The use of the Internet for Web-based teaching and learning is fast becoming a reality. However, since it is difficult to verify the identity of the student through a simple user ID and password system on the client side, performance evaluation through test and examination through the Internet is still in its infancy. To overcome this main hurdle, a system has been designed and developed where a camera at the client computer is used to capture the student's face and posture at random intervals during the test. The captured images are stored at the server and can be used to verify the identity of the person taking the test if the need arises. The system developed has been successfully used in a randomized multiple choice test in a course on analog and digital signals involving 450 students.

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## 1 Introduction

Spurred by development in computer science and network technology, the use of the Internet has been expanding exponentially. It is now extensively used as a connectivity and reference tool for numerous commercial, personal, and educational purposes. In education, the Internet opens a variety of new avenues and methodologies for enhancing the experience of learning as well as expanding educational opportunities for a larger pool of students. Specifically, distance education and non-traditional classrooms have the capability to reach more students using specialized instruction and self-paced learning (Chou, 1999; Ko *et al.*, 2000, 2001).

As Web-based learning takes root, the use of the Internet for formal test and examination becomes an interesting challenge. Ideally, if it is possible for students to take a test as and when they are ready, and for them to obtain test results immediately, the experience and cycle of learning, getting feedback on what has been learned, and re-learning will be very much enhanced. Also, a system that incorporates test, marking and analysis capability may be able to detect weakness and tailor the teaching in a more personal, flexible and effective manner to build a stronger foundation and make learning more interesting.

Some works exploring Web-based test systems have been presented by Brown (1997), Thelwall (2000), and Tartaglia and Tresso (2002). These systems share a number of common features, including attempting the test anywhere anytime, remarking the test automatically and instantaneously, and using commonly used Web browsers as the running platform. The use of these reduces grading, recording, analyzing, and other time consuming examination related operations. Also, as with other computerized tests, questions based on special visual effects such as 3D and objects in

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motion can be included. In addition, it is also quite easy to generate different versions of the same question for different students. As an example, McGough *et al.* (2001) use Java applet to generate dynamic questions on-line for an examination on mathematics.

Apart from just being used for test and examination, a Web-based assessment system can also enhance the experience of learning, and can be regarded as an important part of self-paced learning. As an example, Chetty (2000) discusses a Web-based system that is designed for control engineering students to assess their level of understanding and make relevant preparation for an experiment before actually carrying it out in the laboratory.

In formal tests and examinations, Web-based assessments can play the same role as classroom-administered practice examinations, as analyzed by Chien (2000). However, as such assessments can be carried out anywhere anytime, the problem of security is the main concern that needs to be overcome. Shafarenko and Bansky (2000) discuss a secure scheme that ensures secure transactions between the examination server and the candidates by employing special authentication protocols in a Web-based examination system. In the NetExam system discussed by DePiero (2001), system security is achieved by having a physically secured laboratory room and using a private network instead of the Internet.

While these systems address the issue of security from a technical and communication point of view, the main problem can be envisaged to be one to prevent students from cheating. This is a very difficult problem to solve by using a simple user ID and password system. For example, the student taking the test may have the correct ID and password, but may be aided in the Web-test, which can be conducted anytime anywhere, by friends or other fellow students.

As an attempt to solve this problem, we present in this paper e-Test, a secure Internet examination system based on the use of video monitoring. We use a camera installed on the client computer to capture the student's face and posture at random intervals during the test. These captured images are stored in the server

for the examiner to verify the identity of the student when there is doubt on his or her identity or the circumstance under which the test is taken.

While video monitoring for surveillance and building security is well established and extensively employed (Taylor, 1990; Robertson and Monro, 1997; Greiffenhagen *et al.*, 2001), the use of digital video technology for e-assessment over the Internet for the purpose of identification and monitoring is actually very different in terms of the application scenarios, challenges, requirements, and limitations. Specifically, the former may be based on analog or digital recording technology, may have to work under indoor or outdoor conditions, may need lengthy recording at full resolution, and may not need to be very intelligent in terms of network set up, connections, and flexibility. On the other hand, while the working environment may not be as hostile and the security level not as high, the latter is perhaps more complicated in terms of the extensive interaction between multiple clients and the server through the Internet. In particular, since bandwidth is limited and the video data stream has to share the same channel as that for the assessment but the purpose is just to prevent cheating, capturing short video clips at random intervals should be able to accomplish the system objectives.

In addition to the novelty of using random video monitoring, e-Test has been designed to provide friendly Web interfaces for academic faculty to add and modify test questions and view test results as well as for the system administrator to manage student accounts. Specifically, PDF file formats are adopted for the test questions and the possibility for uploading hundreds of student records through a standard text file is provided.

The rest of the paper is organized as follows. In Section 2, the hardware and software structure of e-Test is described. Section 3 discusses the software installation, the video transmission, reception, and testing modules for students. Section 4 discusses the system administrator and academic faculty modules in e-Test. Section 5 gives an example where e-Test is used and evaluated. Finally, conclusions are drawn in Section 6.

## 2 System structure

### 2.1 Desirable features

Before describing the design and development of e-Test in more detail, we would like to highlight the following important novel features that may be desirable for any Internet-based assessment system:

- *Accessibility.* To achieve distance learning objectives across perhaps different time zones, the assessment should be accessible anytime anywhere.
- *Identification.* For obvious reasons, the system must be able to identify the student taking the examination. While this can be done by using the standard student user ID and password system, it is not difficult to envisage that some students may just let their friends use their user IDs and passwords for the purpose of getting good grades in important examinations. We attempt to solve this problem by using a camera to capture the student's face in addition to the standard user ID and password system in the initial logging on process.
- *Monitoring.* Ideally, any formal examination should be monitored to prevent students from cheating. This is especially important for an Internet assessment system, as the identified student taking the test may simply seek some other students help during the examination. We attempt to solve this through the use of random video monitoring where the student's face and posture are captured at random intervals and sent back to be stored on the server. In cases where there are doubts on the circumstances where the test is taken, the captured video footages can be retrieved as evidence. Through informing students taking the examination of this monitoring process and any penalty, such as disqualification or re-examination, that may be incurred in the event of doubts or cheating, the system prevents cheating from happening in the first place.
- *Management.* The system should include useful features for the management of the examination and student accounts. Academic faculty should be able to upload

test questions and answers, while system administrators should be able to upload and manage student's accounts in a secure manner through the Internet.

### 2.2 Hardware structure

We have designed and developed the e-Test system with the above features in mind. Specifically, Figure 1 shows the hardware structure of the system, which includes a server, client computers, and the Internet.

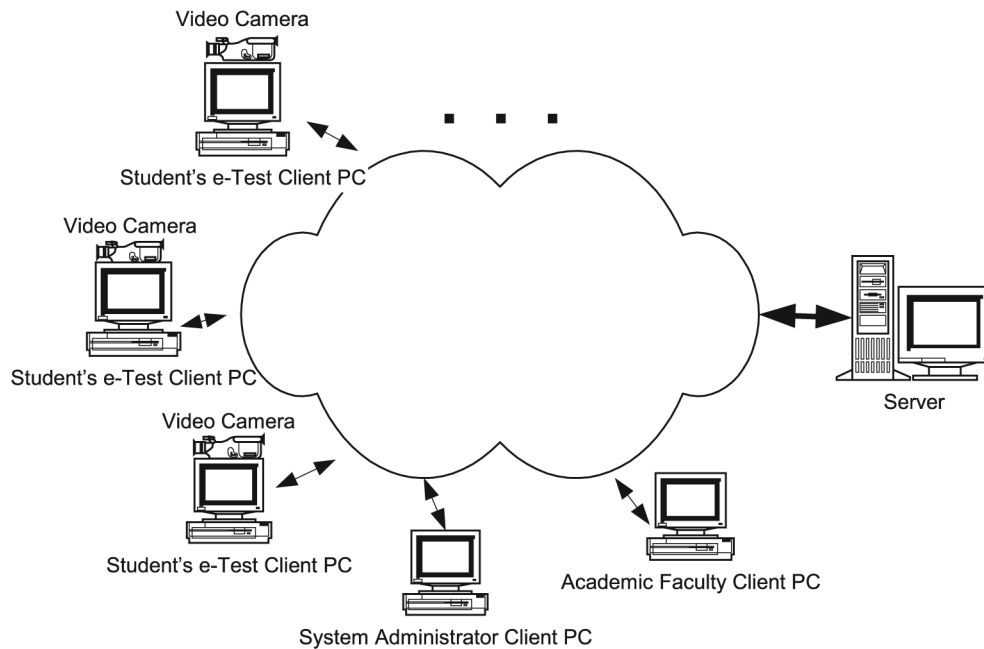
Client computers that students use for the assessment may correspond to workstations in a computer room or laboratory or simply students' notebooks. For the purpose of e-Test, a low cost video camera has to be connected to each of these clients for the purpose of identification and monitoring as described. As an example, Figure 2 shows a client computer with an attached camera in an e-Test setup to be described later.

The images and videos captured by the camera will be transmitted to the server computer through the Internet. The server hosts the entire system, which includes test installation, question and account management, in addition to storing the captured images and videos for students who have taken the test.

Thus, in addition to client computers used directly by students in e-Test, the server can also be accessed by other client computers used by the teaching academic faculty and system administrator for the purpose of uploading test questions, managing student accounts, viewing test results and the captured images and videos. As depicted in Figure 1, access by the faculty and system administrator can be done using any computer with an Internet connection. Authentication is done based on the use of the standard user ID and password system.

### 2.3 Software structure

Figure 3 shows the overall client-side software structure of e-Test, which includes three main interfaces for the academic faculty, system administrator, and students. The administrator interface is for the system administrator to maintain and manage the user accounts and video receiver; the faculty interface is for academic faculty to upload questions, view test results, and the captured video footages; and

**Figure 1** Hardware structure for e-Test, an Internet video-based secure examination system

the student interface is for students taking the test. Some simple software installation for the Java Run-Time Environment (JRE), Java Media Frame (JMF) and video transmitter (ETEST) are accomplished through the student interface.

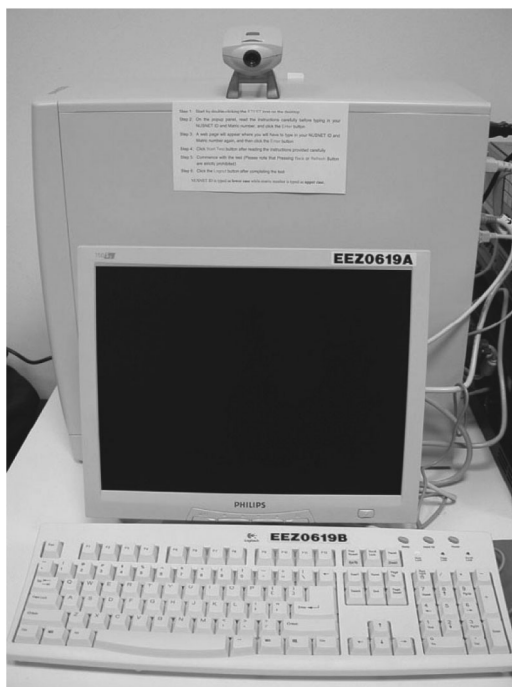
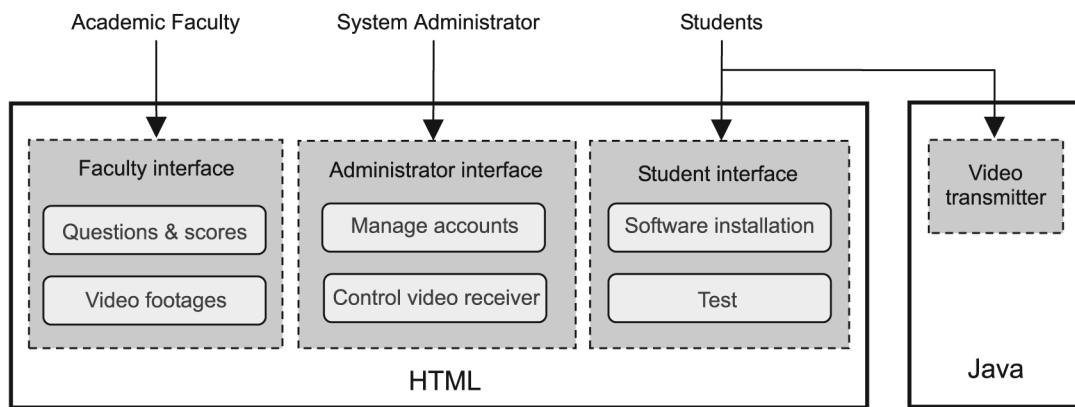
**Figure 2** Client computer with a low cost camera for identification and monitoring

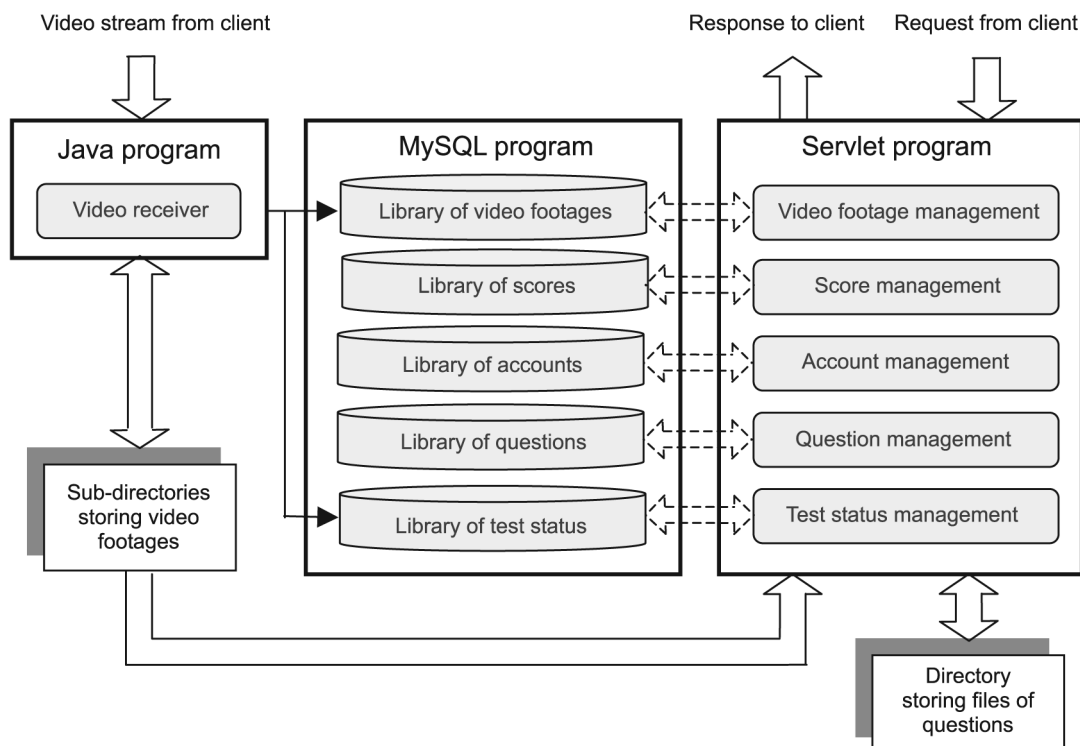
Figure 4 shows the server-side software structure of the system, which includes a servlet program, relevant libraries, a MySQL program, and the video receiver. In the servlet program, five important database modules on video footage, score, account, question, and test status management are provided.

The video footage management module handles queries of the captured video footages from the academic faculty and system administrator. The score management module manages the answers submitted by students, calculates the test results, and saves these into or retrieves them from the library.

The account management module manages all student accounts and includes tasks such as checking student user IDs and passwords. The question management module executes a random selection algorithm for generating the appropriate questions for a specific test session from the question library. Such an algorithm is essential to ensure that different tests administered at different times do not consist of the same set of questions. The module also handles the uploading of questions from the academic faculty. The creation of questions in the system includes storing relevant information such as titles and question numbers for ease of retrieval and reference by both academic faculty and students.

**Figure 3** Client-side software structure for e-Test

The main purpose of the test status module is to keep track of the status of each test session to ensure that the video camera functions normally during the test and that normal inputs and abnormal terminations are properly handled. In particular, the module interacts with the video receiver to receive video streams from clients which have been appropriately set up, and saves the captured video footages into the respective sub-directories maintained by the video footage library. Auxiliary information stored for each footage includes student user ID, a time stamp, and a sequence number for

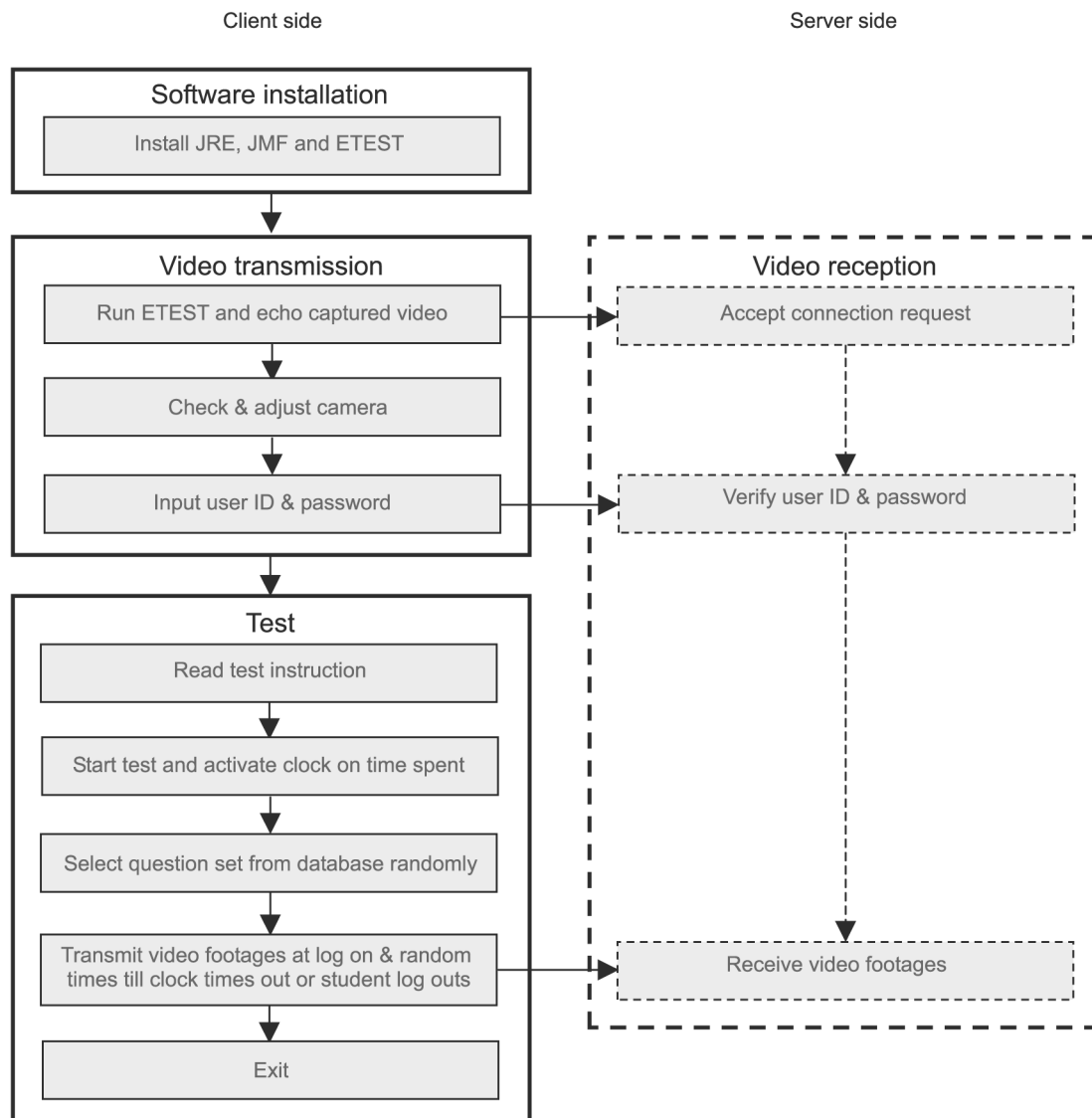
**Figure 4** Server-side software structure for e-Test

the purpose of viewing by academic faculty and system administrator.

We will now give a more detailed description of the system and important functional modules as seen and used by the students, academic faculty, and system administrator.

### 3 Interface and functional modules for students

To take e-Test, a student needs to follow the procedure depicted in Figure 5. Four important

**Figure 5** e-Test procedure and processing for students

steps and functional modules on installation, video transmission, reception, and test are involved.

### 3.1 Software installation

The random capturing and transmission of video for identification and security is the most important component of the e-Test system. For this to be carried out, a program ETEST has to be installed and run before a student logs on to take an actual assessment on a client PC.

Installation of ETEST can be easily performed in a few steps after downloading from the server. As ETEST is developed using Java components such as JRE and JMF, the

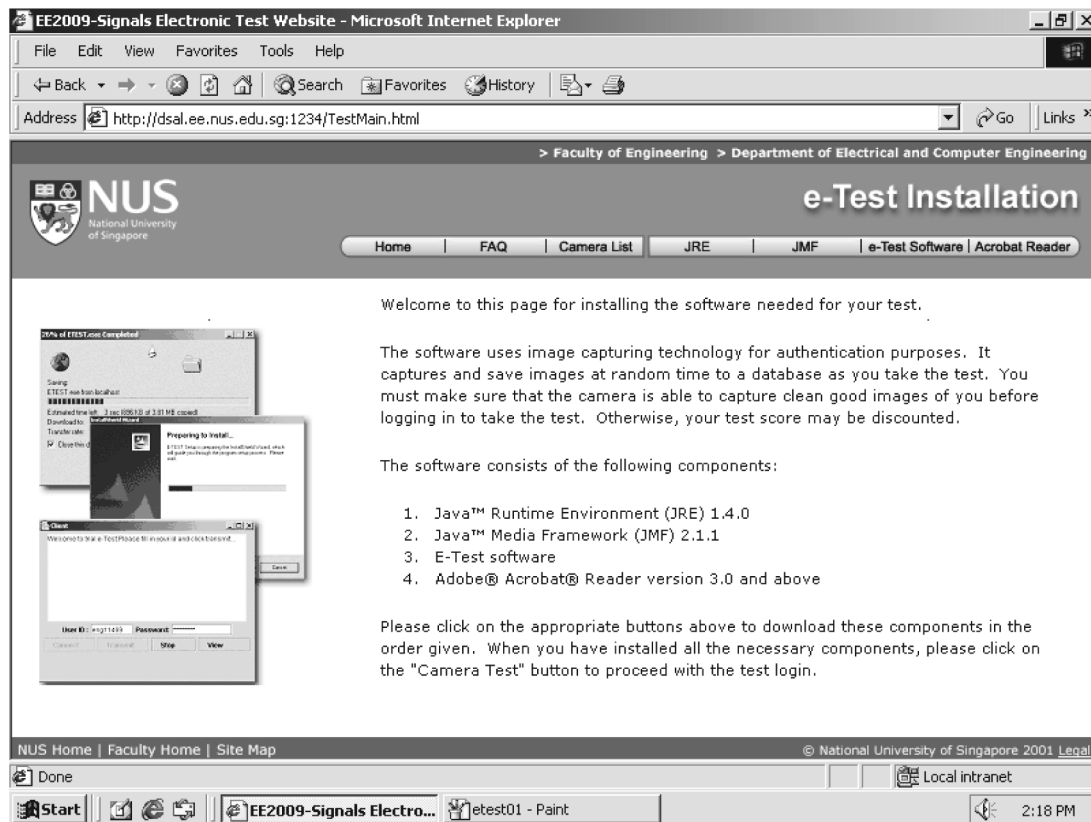
latter two plug-ins are also installed in the installation process.

The installation procedures are described in the home page of the e-Test Web site at <http://dsal.ee.nus.edu.sg:1234/TestMain.html> and is shown in Figure 6. Once the software has been installed, an icon shortcut named ETEST will be created on the desktop of the client computer. Students can then start to log on, adjust the camera and proceed to carry out the assessment by double-clicking this icon.

### 3.2 Video transmission and reception

With ETEST installed, the client PC is available for any student who may like to take

Figure 6 Installation interface for e-Test



an assessment under the e-Test system. The process is similar to other on-line test systems, with the major difference being the use of random video transmission for identification and security purposes in e-Test.

After the ETEST icon has been clicked, the system will first attempt to detect the presence of a camera on the client computer. Then, for identification, the student is asked to check and adjust the camera so that his or her face is well captured as depicted in Figure 7. The student is then requested to enter his or her user ID and password which will be saved together with the captured video on the server.

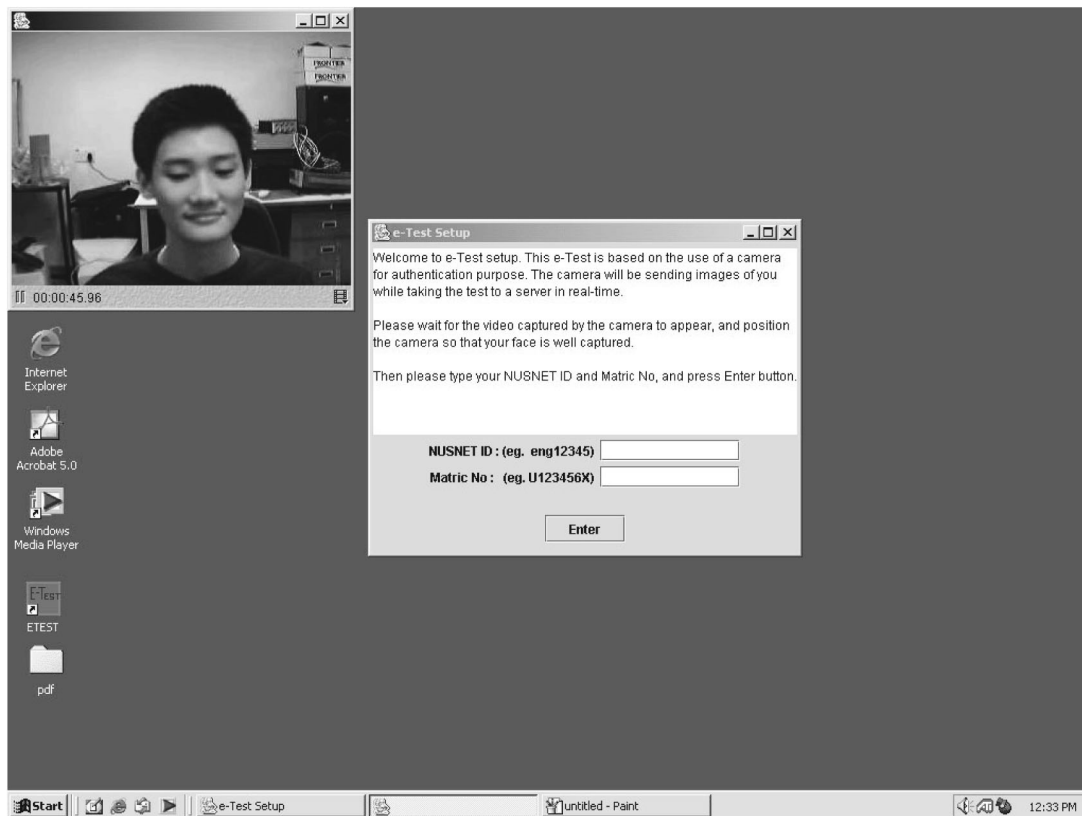
After successfully detecting a camera and verifying the user ID and password, the instruction page for the test will be shown for the student to read. No video is sent during this reading period, when the student learns to get familiarized with the test format and other test related information.

At the end of the reading period when the student is ready to take the formal test, he or she will click the start test button. An

examination clock will start to run and students will be shown random test questions. To prevent cheating, video footages of the student taking the test will be captured by the camera and transmitted back to be stored on the server at random times during the test.

The transmission of video footages at random times helps to save network bandwidth and reduce the workload of the server. The effect of having only a random sequence of video footages is deemed to have the same effect as capturing the whole test process. This is because the student will not know when footages will be captured. Specifically, the most important objective of being a cheating deterrent will still be achieved by informing students that random video footages of them taking the test will be captured and stored.

Video footages from e-Test client PCs will need to be properly processed and stored on the server for subsequent retrieval if needed. However, since multiple video streams from many client computers may arrive simultaneously, the video reception module on

**Figure 7** Identification through video transmission, user ID and password

the server is designed to function in a multi-user multi-tasking mode. As a result, a server socket object is used in the design of this module, and multiple threads are activated when the module is run.

Typically, each video footage lasts one to two seconds. After processing a footage from a client, the thread processing the connection to the client will sleep until the next footage arrives from the same client. The video reception module is also designed to detect and process a variety of operating states such as login, exit, and some erroneous operations from the client PC.

The captured video footages are saved into the respective folders of the video footage library created using information extracted from the students' accounts. Subsequently, when the need arises, they can be retrieved to verify the identity of the student taking the test as well as to see if cheating has occurred during the test.

### 3.3 Test

After entering the user ID and password but before the assessment formally commences, a

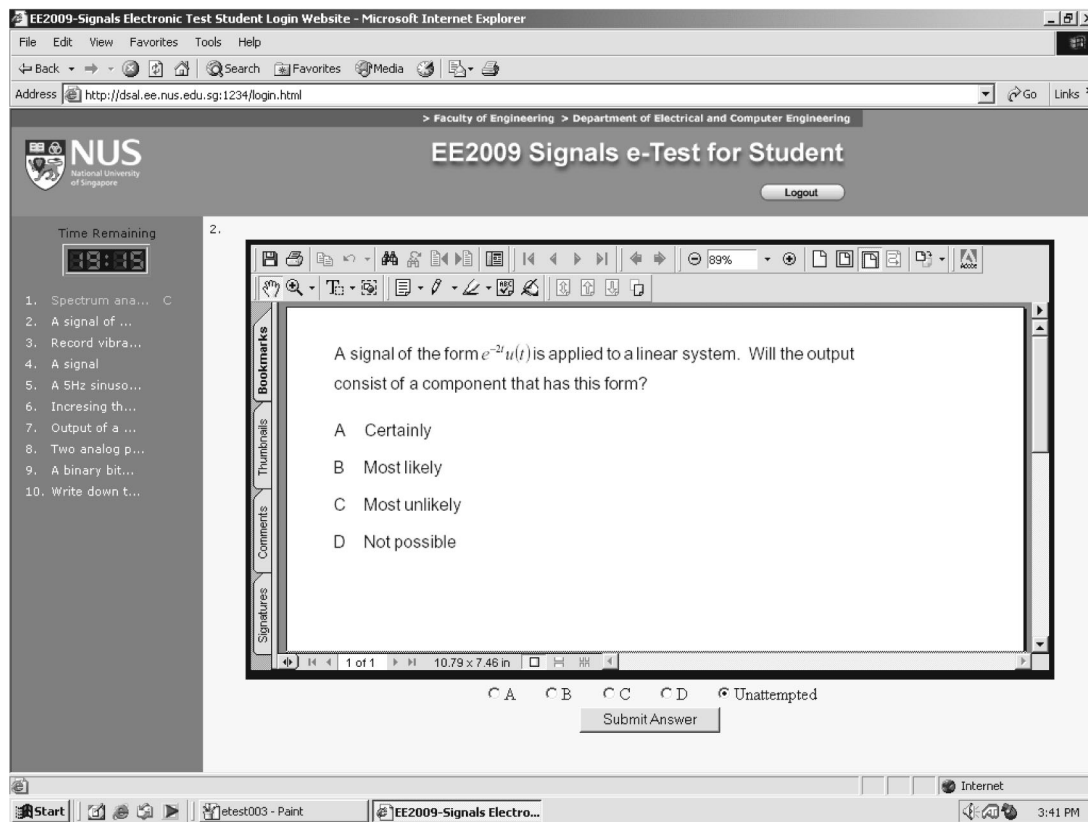
student taking e-Test will be shown an instruction page giving clear instructions on how the system works, how to submit answers and exit.

Having read through the instruction page, the student can start the test formally by clicking a "Start Test" button. The system will select a random set of questions from a large question library (so that every test session will be different) and the test interface as shown in Figure 8 will be displayed on the client PC.

The left hand side of the test interface gives a list of question titles with a selected one highlighted, while the right hand side shows the content of the selected question. The student can move from one to another question freely by using the mouse. A clock that shows the time remaining for the assessment is also provided on the top left hand corner of the interface. Once this counts to zero, the student will be logged out automatically by the system. The student can also exit at any time by clicking the "Logout" button.

In the current configuration, the assessment consists of multiple-choice questions, where



**Figure 8** Interface for student taking an assessment under the e-Test system

one out of four answers has to be chosen. To submit an answer, the student has to click the corresponding radio button and press the “Submit Answer” button. After an answer has been submitted and accepted by the server, the color of the question title will be changed to reflect that it has been answered. This change in color is just for the purpose of reminding students, and answered questions can be re-attempted in the same way as unanswered questions. All submitted answers are stored in a temporary library created using the student’s account on the server.

After completing the assessment, the student can click the “Logout” button to exit, which will result in a confirmation message. An automatic timeout and log off mechanism is also implemented to take care of the possibility that the student leaves without pressing this button. The overall score will be calculated automatically once the student logs out or when the academic faculty retrieves the student’s answers for viewing. All programs will be shutdown automatically when the student

logs out or when an automatic logs out is activated by the system.

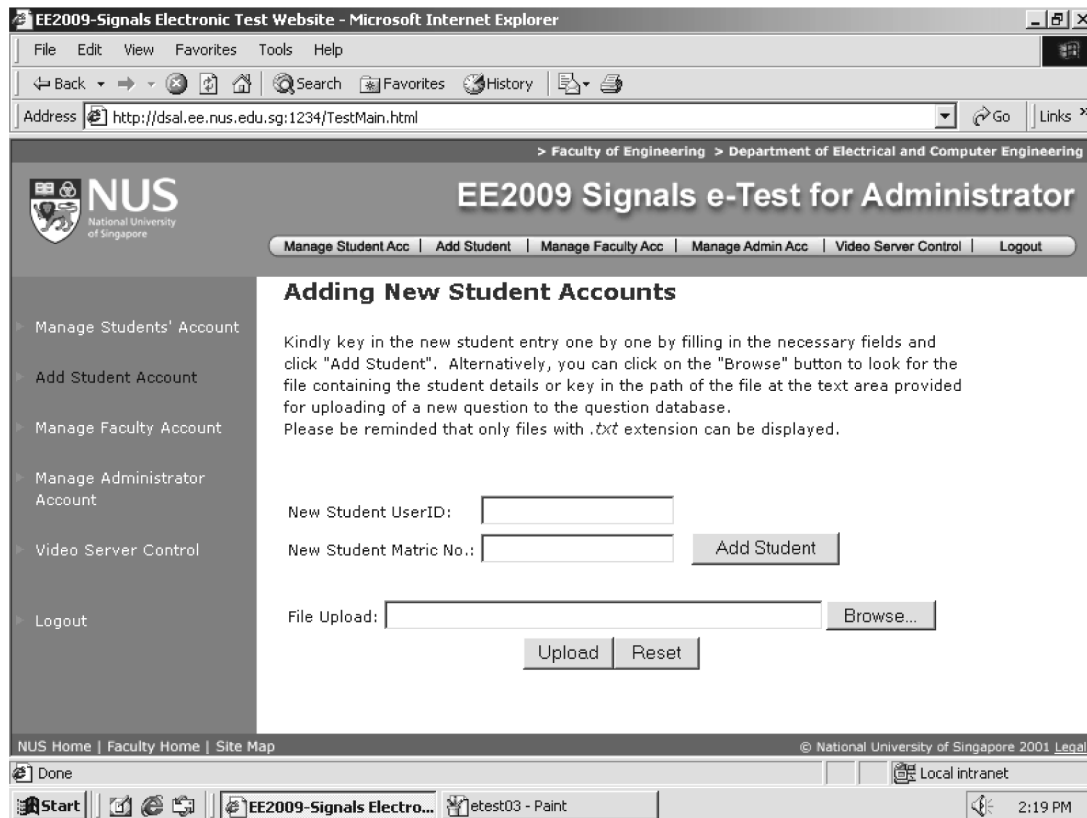
## 4 Interfaces and functional modules for management

Having described e-Test from a student viewpoint, this section will provide a more detailed description of the system from the points of view of the academic faculty and system administrator.

### 4.1 System administrator

The system management functions of e-Test are provided in an administrator management module. These functions include managing student accounts, academic faculty accounts, and controlling the video receiver. In general, all the relevant accounts must be created before a formal test commences.

The various system management functions are activated and controlled through a number of system administrator interfaces. Figure 9

**Figure 9** Administrative interface for managing student accounts

shows one such interface, that for managing student accounts.

Typically, a large number of student accounts need to be created before any formal examination starts. To save manpower in this effort, e-Test has the capability to create student accounts in a batch mode. The principle is depicted in Figure 10. A text file containing student accounts to be created is uploaded to the server, which will sort and store them in the account library.

#### 4.2 Academic faculty

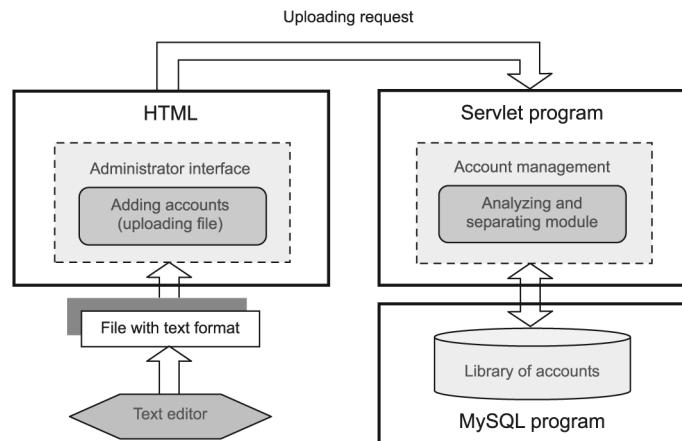
In addition to account and system management, e-Test also includes an academic faculty module for managing academic and examination issues. The module provides functions for adding questions for the test to the server, viewing or downloading students' scores, setting test time, and specifying the number of test questions. Furthermore, it provides important functions for viewing the stored video footages to verify the identity of the student and to see if cheating has happened.

For the purpose of uploading test questions to the server, an interface based on the use of a PDF file format is adopted. This enables the use of common word processing and presentation tools for preparing test questions.

To verify the identity of the student and check if cheating has occurred, the interface shown in Figure 11 has been developed for academic faculty to view video footages captured during the selected session. The numbered footages have time stamps and can be viewed in any order. The answers and overall score of the student involved in the test session are also shown on the interface. In addition, the system provides a convenient capability to download a file containing the scores in all test sessions.

#### 5 e-Test experiment

e-Test has been used in the assessment for a course on analog and digital signals at the Department of Electrical and Computer

**Figure 10** Working principle for adding a large number of student accounts in batch

Engineering, National University of Singapore (NUS). The formal assessment involves 450 full-time undergraduate and part-time evening students in 550 individual test sessions lasting a period of one month. Since the two groups of students are large and the part-time students are actually holding full-time jobs in industry, e-Test serves as a convenient secured platform

for providing continuous assessment for the entire group with minimal logistical problems and substantial manpower saving.

In terms of hardware setup, we have provided ten Pentium 4 PCs with low cost video cameras in our laboratory for the test. This is shown in Figure 12. The client PCs are connected to the server in another room through the Internet.

**Figure 11** Interface for verifying identity and reviewing answers

No.	Question Description	Answer
1	The time origin	A
2	Reflection and multipath	A
3	The sound	A
4	Local AM radio broadcast	C
5	Single sideband AM	C
6	Two complex sinusoids	C
7	Spectrum analyzer	Unattempted
8	A signal of the form	B
9	Spectrum analyzer	D
10	A 5Hz sinusoid	B

**Figure 12** Part of test site for EE2009/TE2009

The server is also hosted on a Pentium 4 PC, but with more RAM and a larger hard disk. It is implemented using Tomcat under Windows 2000.

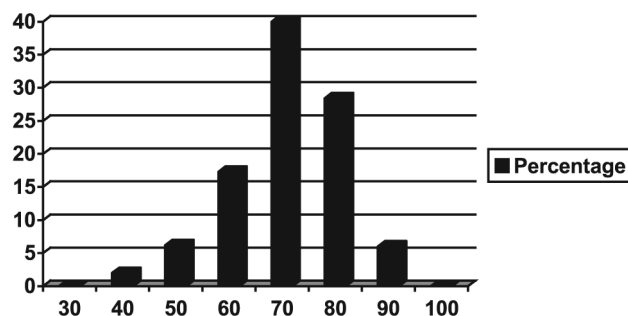
One of the objectives of having the setup described is to evaluate the system and to ensure that the server and the various components work without any glitch. After resolving some initial software bugs as a result of multiple-thread problems in video reception, the system runs throughout the formal assessment period very well with no technical and academic supervision in the test sessions.

Figure 13 shows the distribution of the marks from the test, which is a difficult one with many questions requiring in-depth knowledge of a variety of concepts and not having been discussed in lectures. As can be seen, the scores follow a distribution which is roughly Gaussian, an indication that the e-Test

produces results that are quite similar to a normal one.

The distribution in Figure 13 also shows that there are few students with scores higher than 80. This, together with the fact that no student has the perfect 100 mark, is an indication that despite the test being a difficult one, the system is robust enough that there is perhaps no cheating in the absence of supervision. A stronger certification that this is indeed the case is obtained when we examine the captured video clips for those with scores higher than 80 and also when we carry out some sporadic spot checks of the test site.

Overall, students find the system easy to use and the possibility to take the assessment as and when they are ready, to be a very helpful factor in their academic studies. From an academic and manpower point of view, the system has the capability to prevent and detect

**Figure 13** Mark distribution for EE2009/TE2009

cheating and save manpower in invigilation and marking.

## 6 Discussions and enhancements

The design and development of a secured Internet-based e-assessment system is a complicated endeavor, although such a system is an essential component in any complete e-learning package. While this paper has described some initial efforts and experiments in this direction, enhancements can be made to overcome possible shortcomings in certain areas or for the setting up of more sophisticated systems.

The capture of sound in addition to video will be useful and may be necessary to increase the security of the system in case someone at a distance is reading aloud. This is despite the fact that, in the e-Test experiment that we have conducted, such a behavior would probably alert other students and laboratory users.

For the academic faculty, the effectiveness of the system can be greatly enhanced through the use of AI techniques to detect problem cases. As an example, it will be nice if the system can automatically generate a set of problem cases to be reviewed based on test scores, test timing, and the detection of abnormal behavior as captured on successive video and sound clips. Nevertheless, the latter would probably require some kind of system training.

Other enhancements may be to include the use of smart card access to the test facility, the incorporation of a wide-angle camera that captures the entire test site, and the integration of the various data sources to increase the security level of the system.

## 7 Conclusions

A secure video-based Internet examination system has been designed and developed. A video-based monitoring scheme is adopted for the purpose of verifying the identity of each student and to prevent and detect cheating during the test. The system has been successfully deployed in a course on analog and digital signals involving 450 full-time and

part-time students in 550 individual test sessions.

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