WEB-BASED VIRTUAL LABORATORY FOR GENETIC ALGORITHMS

Adem TUNCER[a], Mehmet YILDIRIM[a]

[a]Networked Control Systems Laboratory, Kocaeli University, 41380, Kocaeli, Turkey

adem.tuncer@kocaeli.edu.tr , myildirim@kocaeli.edu.tr

Abstract

Recent developments in the internet technologies differentiate in learning needs, and demands of more flexible and individualized learning environments lead to provide a basis for the implementation of internet-based distance learning models. Distance learning is categorized in various disciplines, and remote virtual laboratory applications are assumed within such categories. In this study, an experiment system was prepared to implement a remote virtual laboratory application comprising sample experiments on Genetic Algorithms (GA). Generally, GA is one of highly theoretical courses and it is too difficult a student to write a GA application in programming languages. It also time consuming work to find the best values of parameters in GA which includes the parameters of population size, crossover rate, mutation rate and coding scheme. After the realization of these challenging steps students can investigate the study of GA. However, in our study, students are provided with internet access to the remote virtual GA laboratory for monitoring GA's operation and performance without writing a single line of code. In the study, software packages and tools like Matlab, Matlab Web Server, Apache Server, HTML, PHP, and Javascript are used.

Keywords: Web-based education; Virtual laboratory; Genetic algorithms; Optimization

WEB TABANLI SANAL GENETİK ALGORİTMA LABORATUARI

Özet

İnternet teknolojilerindeki gelişmeler, öğrenme ihtiyaçlarının farklılaşması, bireylerin daha esnek ve kişiselleştirilmiş bir öğrenme ortamını talep etmeleri internet tabanlı uzaktan öğretim modellerinin oluşturulmasına zemin hazırlamaktadır. Uzaktan eğitim kendi arasında çeşitli kategorilere ayrılmakta, uzak sanal laboratuarlar da bu kategoriler arasında ele alınmaktadır. Bu çalışmada, genetik algoritmalar (GA)

konusunda örnek deneyler içeren uzak sanal laboratuar uygulamalarının gerçekleştirildiği bir deney sistemi hazırlanmıştır. Genelde, GA son derece teorik derslerden biridir ve bir öğrencinin programlama dillerinden herhangi birinde GA uygulaması yazması oldukça zordur. Ayrıca, yazılmış bir programda; nüfus büyüklüğü, çaprazlama oranı, mutasyon oranı ve kodlama biçimi gibi parametrelerin en iyi değerlerini bulmak zaman alıcı bir iştir. Bu zorlu adımların gerçekleştirilmesinden sonra, öğrenciler GA'nın çalışmasını irdeleyebilmektedirler. Oysaki çalışmamızda, öğrenciler tek bir satır program kodu dahi yazmadan, İnternet üzerinden uzak sanal GA laboratuarına erişerek, GA'nın çalışma ve performansını inceleyebilmektedirler. Çalışmada; Matlab, Matlab Web Sunucu, Apache Sunucu, PHP ve Javascript gibi yazılım araçları kullanılmıştır.

Anahtar Kelimeler: İnternet tabanlı eğitim; Sanal laboratuar; Genetik algoritmalar; Optimizasyon

1. Introduction

Recent developments in the internet and computer technologies have paved a path for the design of internet-based learning and tutoring systems. Internet-based distance education is an educational system fashioned by exploiting the wide range resources of the internet.

Distance education is a training scheme that makes interaction among educational policy makers, tutors and learners by means of specially designed learning environment and various types of media. Distance education occurs when in-class activities can not be carried out due to limitations in traditional learning and teaching means. The "same time, same place, only some people" traditional instructional method is giving way to "anytime, anyplace, anybody" educational models [1].

Another advantage of the distance education is the ease of access to laboratory resources remotely. The laboratory is important element in science, engineering and technical educations. It allows application and testing of theoretical knowledge in practical learning situations [2]. Laboratory sessions provide examples that students can see, feel, and hear, and provide an alternate mode of learning to those for whom reading the textbook or hearing lecture is insufficient. However, hands-on laboratories are not always an option due to space, cost, and time constraints. Thus alternative means of

providing laboratory experience and of making labs accessible at any time and from any location are desirable [3]. Laboratories are essentially the most crucial components in making students gain experience through hands-on practice.

In distance education, laboratory applications are generally used in two ways, i.e. remote access to real laboratory hardware, and designing a virtual model of the real laboratory settings in computer environment. Regarding remote labs, different applications can be found in the literature for several disciplines and using different tools. Some examples can be found in references [4-5]. There are many approaches to the design of internet-based remote laboratories. Early systems required specialized platform-dependent software running at the client computer. Later approaches moved towards browser-enabled technologies for the client, including Java applets, static and dynamic HTML pages, and scripts [6]. Virtual laboratory applications are discussed under internet-based teaching. For instance, there are a choice of virtual laboratory applications in varied disciplines like physics, chemistry, electrics, medicine, electronics, and control. Some examples can be found in references [7-10]. Some researchers have expressly focused on developing web-based virtual labs for distance education and have already refined a number of projects in this regard. A virtual laboratory enables users to have full-time access to simulation processes on a remote server. Simulations on the server can be executed via Matlab or identical software.

In this study, an experiment system comprising of sample experiments on GA for remote laboratory applications was programmed. In this remote virtual laboratory system, software like Matlab, Matlab Web Server, Apache Server, PHP and Javascript are used. The system provides students with internet access to the remote virtual laboratory for monitoring GA's operation and performance without writing a single line of code, by utilizing independent parameters for standalone experiments. In addition, the system incorporates administrative components that enable instructor to supervise the experiments completed by students via control pages.

2. Remote Virtual Laboratory

Recent technological improvements provide designing and conducting virtual experiments as an uncomplicated task. Remote virtual laboratory is a system that

facilitates conducting experiments in various places independent from any time or place constraint. It is an innovative learning and teaching solution that with the help of technology convenes students, tutors and resources each situated at a different location.

Simulations play a vital role in engineering education especially in laboratory exercises. Edwin Link in 1928 developed the ''Link Trainer''(Flight Simulator), believed to be the first simulation program used in ''Blue Box''. The simulator was used to train thousands of military pilots before and during World War II [11]. Remote virtual laboratory is a computer environment that provides real-time simulation opportunities for conducting experiments. Taking reference of the data and information obtained from traditional laboratory research, relevant laboratory tools and equipment are created in computer environment to conduct virtual experiments.

In remote virtual laboratory applications, students have internet access to remote virtual laboratory needing not any further software but conventional internet browsers (like Internet Explorer or Netscape) to conduct experiments on the server and obtain test results. Remote virtual laboratory is constituted of simulation software of experiments and a web interface for providing result feedback for the student. Experiments can be carried out as real-time and interactive if needed. All results obtained from experiments are recorded in a database at the server side, facilitating smooth and efficient testing and assessment procedures.

Remote virtual laboratory enables students all over the world to conduct joint experiments in real-time and allows them to share test resources, making it unnecessary to transport resources in physical sense. The real-time experiment can be run anywhere at any time across the internet, it may be assigned as homework, without the need for scheduling physical meetings between students and instructors [12]. Students are able to work in a more flexible environment and throughout a proper time span.

It is difficult to record time graphs and to form data tables in experiments conducted in real laboratory environments. However, in computer environment, the entire data can be recorded for observation on changes and time-dependent physical magnitudes can be interpreted through graphs and summarized as tables. It is also possible to transfer such data to a range of software.

Remote virtual laboratory is a system which relieves students from operating mathematical formula to make calculations or writing programming code to conduct a

test, all such typically uphill tasks for many students. In real laboratory applications, test conditions are not ideal and this may affect test results negatively, whereas in computer environment, all conditions are ideal and no unforeseen results emerge. The masses, sizes, types and physical values of test materials to be used in real laboratory environment are limited. In computer environment, material sizes and options among types are more in number compared to the real laboratory environment.

Using software on desktop computers to convert the computers into virtual instruments dramatically reduces the cost of laboratory equipment maintenance and replacement [13].

3. Genetic Algorithms

GA is a parallel and global search technique that emulates natural genetic operators. Because it simultaneously evaluates many points in the parameter space, it is more likely to converge toward the global optimum. It is not necessary that the search space be differentiable or continuous. GA applies operators inspired by the mechanics of natural selection to a population of binary strings encoding the parameter space. At each generation, it explores different areas of the search space, and then directs the search to regions where there is a high probability of finding a better solution.

The overall GA optimization system is described by the flowchart given in figure 1. GA starts with an initial population of coded strings, which are generally called individual or chromosome and randomly selected. An individual is a potential solution of the problem and represents a set of parameters. The size of population varies from one problem to another.
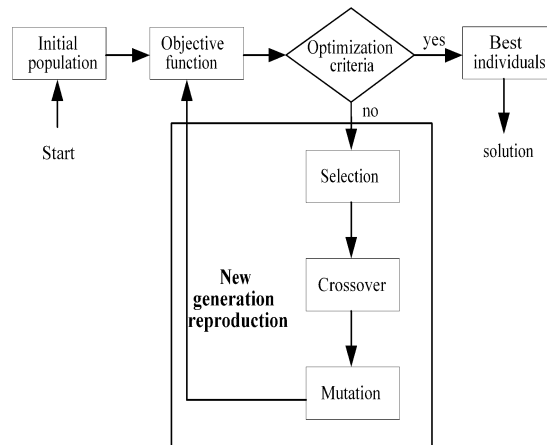
Figure 1. Flowchart of genetic algorithms

Each individual in the population is then assigned a probability of survival, in other words fitness, according to the objective function values of that and other individuals. To maintain uniformity over various problem domains, objective function value is rescaled to a fitness value [14]. Candidate individuals that might survive into the next generation are selected based on their fitness values. Roulette wheel selection is a commonly used method for selection. After the selection, crossover and mutation operations take place respectively. Generally, crossover combines the features of two parent chromosomes to form two offspring, as shown in figure 2, with the possibility that good chromosomes may generate better ones [15]. The bits of two individuals after the crossover point are swapped with a probability of crossover rate [16]. Crossover operation expands the search space around the fittest individuals [17].


```
                        crossover
                         point

                           |
                           |
   Parent-1     0 1 1 1 0 0|1 1 0 1 0
   Parent-2     1 0 1 0 1 1|0 0 1 0 1
                           |
                           |
   Offspring-1  0 1 1 1 0 0 0 0 1 0 1
   Offspring-2  1 0 1 0 1 1 1 1 0 1 0
```
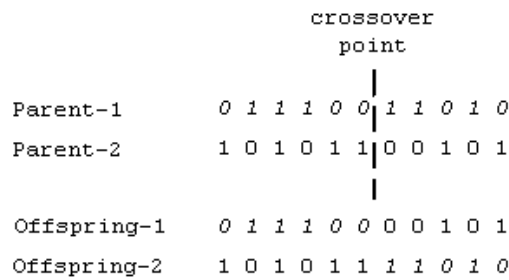
Figure 2. Crossover for binary individuals

Next, all candidate individuals in the population are subjected to the random mutation. This is a bit-wise binary complement operation, as shown in figure 3, applied uniformly to all bits of all individuals in the population with a probability of mutation rate. The mutation operation expands the search space to regions that may not be close to the current population, thus ensuring a global search [18].

```
   Before Mutation   0 1 1 1 0 0 0 0 1 0 1

   After Mutation    0 1 1 1 0 0 1 0 1 0 1
```
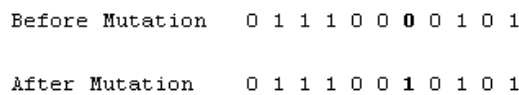
Figure 3. Mutation for a binary individual

In the case of generation replacement, the individuals in the old population are replaced by the offspring. The cycle of evolution is repeated until a desired termination criterion is reached. This criterion can be set by the number of evolution cycles (computational runs) or a predefined value of objective function [19].

4. Web-Based Virtual Laboratory Application for Genetic Algorithms

For remote virtual laboratory applications in the literature, software and statistical tools like Matlab, LabView and Vlew are extensively used. In the same vein, throughout this study, Matlab and Matlab Web Server are used in addition to Apache Server, PHP, and Javascript.

Matlab (MATrix LABoratory) is an interactive programming language developed to be utilized in mathematical and especially in matrix-based environment. Besides being a multipurpose tool open for use in engineering, statistics, data solutions and graphics, Matlab also has special-purpose modules called toolboxes. Windows based Simulink software provides great facility for preparing and running interactive simulations.

In this work, Matlab Web Server is used to receive user data in HTML format through Apache Web Server and display the results in HTML format to users. Matlab Web Server makes use of TCP/IP protocol to convey the data between the user and the Matlab. Matlab Web Server applications are built from the combination of m-files, HTML and graphs. Matlab application can run only on remote laboratory server. System administrator can limit any unauthorized user accesses to the application, Matlab command lines, and source codes. Matlab Web Server also makes way for adding graphics to applications. Results can be displayed over HTML either as processed data or graphs.

General architecture of remote virtual GA laboratory is shown in figure 4. When users want to log in to experiment system locally or remotely via internet, they are connected to the Apache web server. Only the users who have access permission can connect to the experiment system. After connecting, users can transmit the experiment data to both database and Matlab Web Server via HTML, PHP and Javascript. After processing the data in experiment simulation program, which runs on Matlab, results are retransmitted to Matlab Web Server. The experiment results then transmitted to the user Internet browser via Matlab Web Server. Likewise, results are saved in database.
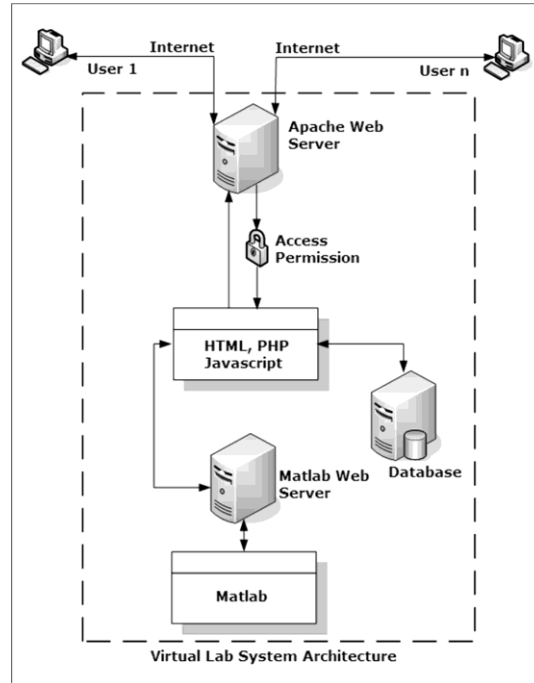
Figure 4. General architecture of remote virtual laboratory

In the study, six different experiments on virtual genetic algorithm laboratory are constituted. These experiments include three Dejong's functions [20] for testing genetic algorithm software. Both binary and real coding of individual representation are used for each functions. Dejong's functions used in the experiments are as below:

Function 1: $f(x_i) = \sum_{i=1}^{3} x_i^2$ (1)

Finding the values for x_1, x_2 and x_3 which make the function minimum in the range of $-5.12 \leq x_i \leq 5.12$

Function 2: $f(x_i) = 100(x_1^2 - x_2)^2 + (1 - x_1^2)$ (2)

Finding the values for x_1 and x_2 which make the function minimum in the range of $-2.048 \leq x_i \leq 2.048$

Function 3: $f(x_i) = \sum_{i=1}^{5} \text{int}(x_i)$ (3)

Finding the values for x_1, x_2, x_3, x_4 and x_5 which make the function minimum in the range of $-5.12 \leq x_i \leq 5.12$

Figure 5 exhibits the main page of the program. In order to log on to the experiment page, students must enter the user name and password assigned by the

supervisor. In the same manner, the supervisor is able to log on as an administrator through her user name and password.
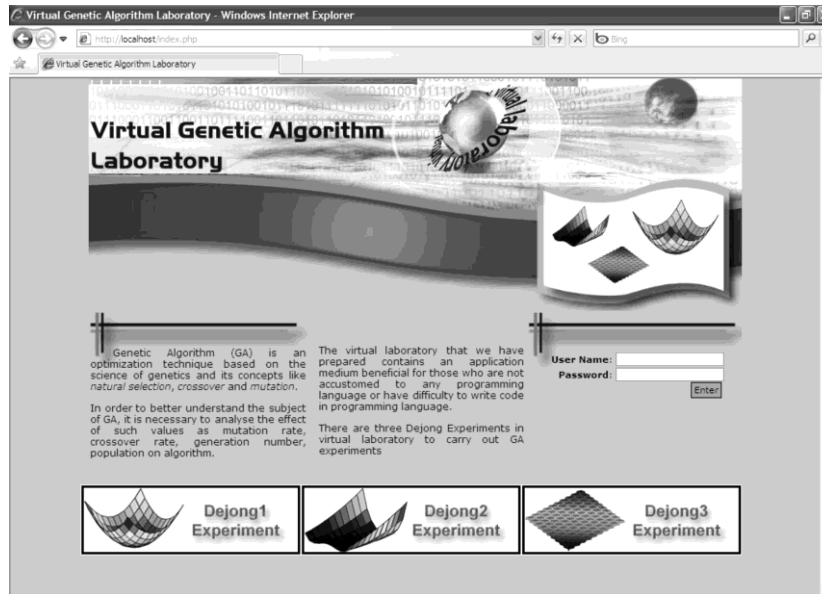

Figure 5. Remote virtual GA laboratory main page

After log on, the experiment screen shown in figure 6 is appeared to choose the experiment and enter the required data. Experiment menu is at the left side of the screen. A student chooses one of the six experiments on the drop-down menu. When needed, the student can use the button below the experiment menu to change her log in password. Students can securely log off by clicking the Exit button. The figure shows an experiment that chosen as function-1 and binary coded, along with the parameter entry fields for the experiment. The student is to enter parameters like length of genes, size of population, maximum number of generation, mutation rate, and crossover rate to conduct the experiment.
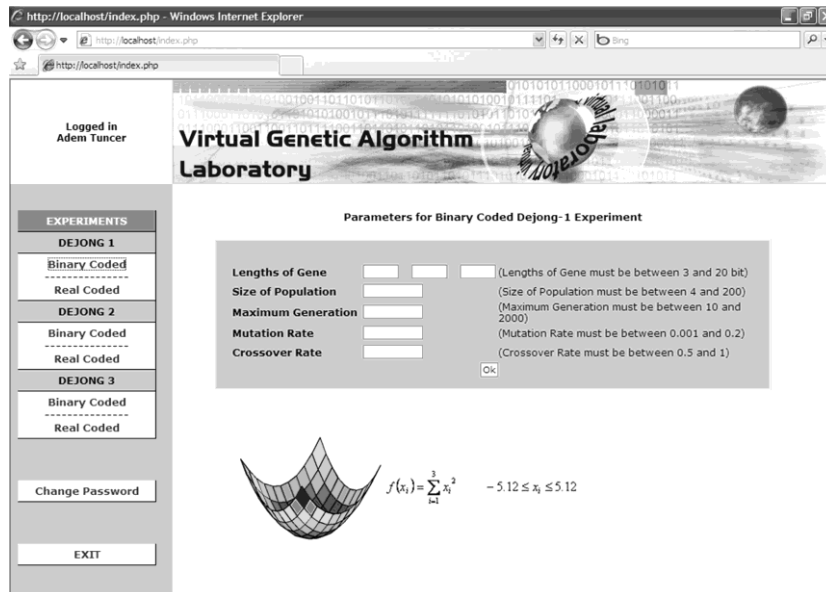
Figure 6. Fields for entering parameters of GA experiment

When the student keys in experiment parameters and runs the experiment, the screen exhibited in figure 7 is displayed, providing the student with the entered parameters, the best solutions for the variables x_i of the function, and graph of objective function values at each generation. Furthermore, the student can select another experiment from the drop-down menu and run it.
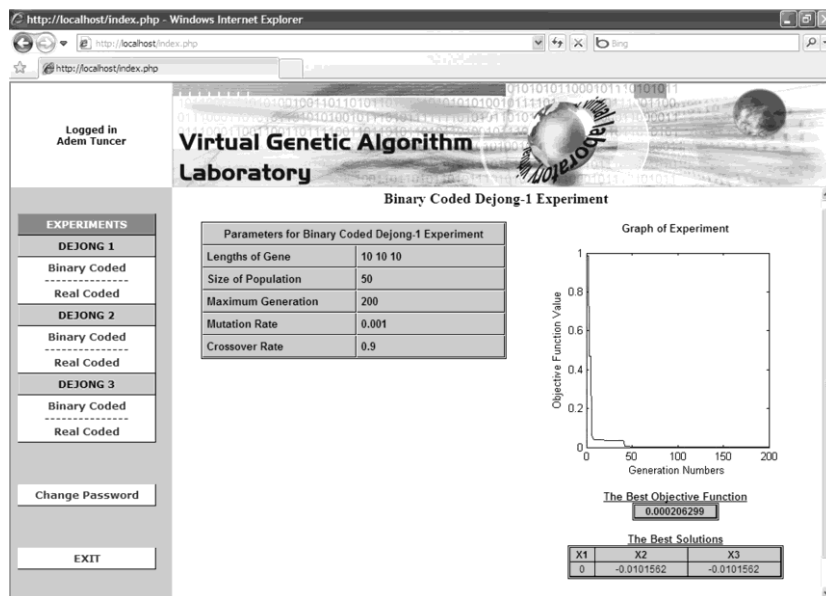

Figure 7. GA experiment result page provided for student

On the management page for supervisors, the supervisor can go through the name of the student along with the date and title of experiments conducted by each student. See figure 8 that shows the queries on experiments conducted by any student on

a particular date. Figure 9 shows the name of the student with respect to her completed experiments. Moreover, the supervisor can also register or remove a user.
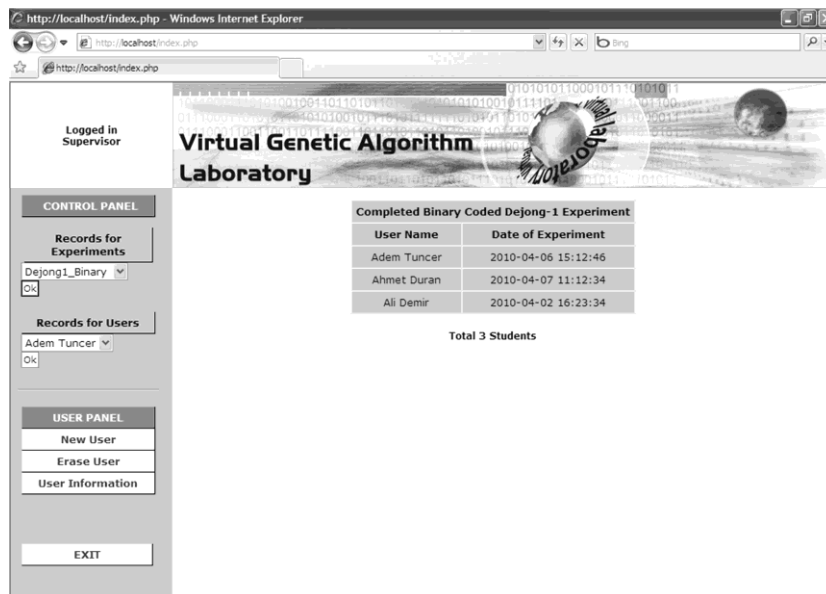

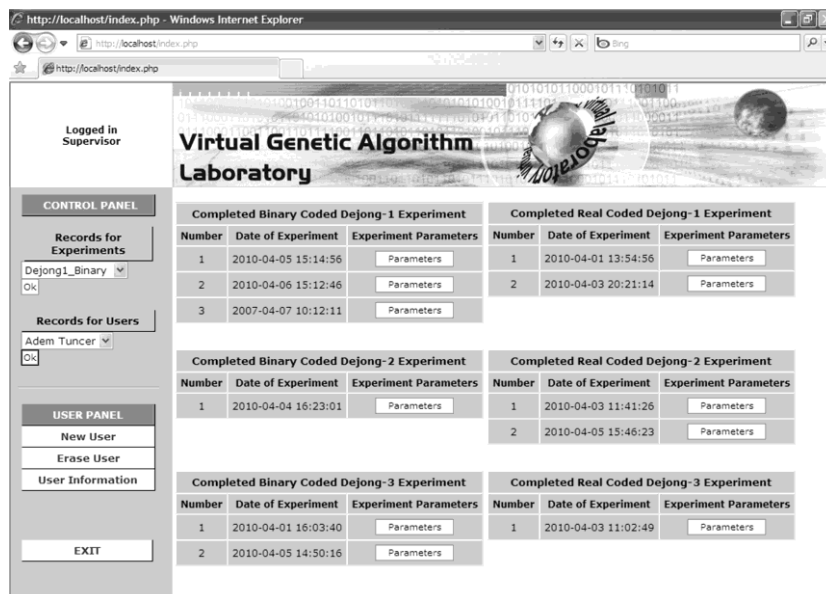Figure 8. Control page for supervisor

Figure 9. Control page for supervisor.

5. Conclusion

Distance learning is categorized in various disciplines, and remote virtual laboratory applications are assumed within such categories. In this study, an experiment

system was prepared to implement a remote virtual laboratory application comprising sample experiments on Genetic Algorithms (GA). In this remote virtual laboratory system, software and tools like Matlab, Matlab Web Server, Apache Server, HTML, PHP, and Javascript were used. Students are provided with internet access to the remote virtual GA laboratory for monitoring GA's operation and performance without writing a programming code. Students can investigate the study of GA and analyse the effects of population size, crossover rate, mutation rate and coding scheme. In addition, the system incorporates administrative components that enable the supervisor to control the experiments completed by students via management pages.

References

[1] Huang SH, Su Q, Samant N, Khan I. Development of a Web-based integrated manufacturing laboratory. Comput Appl Eng Edu. 2001; 9(4): 228-237.

[2] Auer M, Pester A, Ursutiu D, Samolia C. Distributed Virtual and Remote Labs in Engineering. Industrial Technology, 2003 IEEE International Conference on. 2003; 2: 1208-1213.

[3] Bhargava P, Antonakakis J, Cunningham C, Zehnder AT. Web-Based Virtual Torsion Laboratory. Comput Appl Eng Edu. 2006; 14(1): 1-8.

[4] Corradini ML, Ippoliti G, Leo T, Longhi S. An Internet Based Laboratory for Control Education. Proceedings of the 40th IEEE Conference on Decision and Control. 2001; 3: 2833-2838.

[5] Casini M, Prattichizzo D, Vicino A. The Automatic Control Telelab: A Remote Control Engineering Laboratory. Proceedings of the 40th IEEE Conference on Decision and Control. 2001; 4: 3242-3247.

[6] Viedma G, Dancy IJ, Lundberg KH. A Web-Based Linear-Systems in iLab. American Control Conference, USA. 2005; 7: 5139-5144.

[7] Chetty M, Hu S, Bennett J. An interactive Java-based educational module in electromagnetics. Int J Elec Eng Educ. 2003; 40(1): 79-90.

[8] Martín AJL. Web-based remote learning of communication systems: a successful experience. Int J Elec Eng Educ. 2003; 40(3): 169-174.

[9] Collier M. A picocontroller training simulator in a web page. Int J Elec Eng Educ. 2003; 40(2): 158-170.

[10] Chung TS. A computer-based voltage control experiment for advanced power system operation teaching. Int J Elec Eng Educ. 2001; 38(3): 199-209.

[11] Balamuralithara B, Woods PC. Virtual Laboratories in Engineering Education: The Simulation Lab and Remote Lab. Comput Appl Eng Edu. 2009; 17(1): 108-118.

[12] Guo J, Kettler D, Al-Dahhan M. A Chemical Engineering Laboratory Over Distributed Control and Measurement Systems. Comput Appl Eng Edu. 2007; 15(2): 174-184.

[13] Powell RM, Anderson H, Spiegel JV, Pope DP. Using Web-Based Technology in Laboratory Instruction to Reduce Costs. Comput Appl Eng Edu. 2002; 10(4): 204-214.

[14] Man KF, Tang KS, Kwong S. Genetic Algorithms: Concepts and Applications. IEEE Trans. Ind. Electron. 1996; 43(5): 519-534.

[15] Herrera F, Lozano M, Sánchez AM. A Taxonomy for the Crossover Operator for Real-Coded Genetic Algorithms: an Experimental Study. Int. J. Intel. Syst. 2003; 18(3): 309–338.

[16] Spears WM, Anand V. A Study of Crossover Operators in Genetic Programming. In: Proceedings of 6th Int Symposium on Methodologies for Intelligent Systems. Springer-Verlag, 1991; 409-418.

[17] Kristinsson K, Dumont GA. System Identification and Control Using Genetic Algorithms. IEEE Trans. Syst. Man. Cybern. 1992; 22(5): 1033-1046.

[18] Yildirim M, Erkan K. Determination of Acceptable Operating Cost Level of Nuclear Energy for Turkey's Power System. Energy. 2007; 32: 128-136.

[19] Zhu F, Guan SU. Ordered Incremental Training with Genetic Algorithms. Int. J. Intel. Syst. 2004; 19(12): 1239-1256.

[20] Goldberg DE. Genetic Algorithms in Search, Optimization and Machine Learning. Addison-Wesley Publishing Company Inc; 1989.