SIMULATION OF PHYSIOLOGY EXPERIMENTS – AN ALTERNATIVE TO ANIMAL USE

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Abstract : Amphibian experiments on nerve-muscle preparation and heart are essential as per first year MBBS practical syllabus, for learning basic concepts in Physiology. Need was felt to design and develop computer based simulation software as an alternative to animal use, due to growing concern and stringent laws imposed by animal ethical bodies. Computer algorithms were developed for 13 amphibian experiments, by manually tracing the graphs obtained through mechanical experimentation and storing the X, Y coordinates for the end points of each line segment as data base tables. By retrieving the data base tables, one for each experiment, the computer simulated graphs were drawn using Visual Basic 6 with timer control and Macromedia Flash for animation effects. A CD-ROM consisting of the software for computer simulation of all the amphibian experiments, as an alternative to the conventional animal experiments, has been developed for the benefit of medical students across the country, as a useful active learning tool.

Key words : simulation software   computer algorithms
                    virtual amphibian experiments

INTRODUCTION

Use of animals in undergraduate medical course curriculum is basically to comprehend and conceptualize the fundamental physiological processes occurring within the body. The medical students can understand these processes more thoroughly through animal experimentation. The same experience can be applied to deal with real life situations / diseases in patients at a later stage of the medical education programme. However, hands on experience and the acquirement of skills through animal

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experiments using live animals vis a vis skills on human patients for treatment is debated (1). There is a global trend in reduction in animal experiments in medical undergraduate training (2). Physician Committee for Responsible Medicine (PCRM) in US is stressing upon replacement of animal labs with non-animal alternatives. Majority of medical schools in USA (68%) are not using live animals now in any of their physiology, pharmacology or surgery courses (3). Moreover, in a recent study about students' views on animal experiments in medical undergraduate curriculum, 84 percent of students felt that animal experiments involved needless pain and suffering to the animals (4). In a retrospective survey, 27% of surveyed students reported of having exclusively negative reactions to dissection and 38% reported both negative and positive reactions (5). With this background, reduction, replacement and refinement of animal experiments can be achieved as described by Russell and Burch (6). This could gain larger significance in undergraduate medical education compared to any other field (veterinary for example), where the primary focus is the animal itself.

The opportunities associated with development of computer based technology in contributing to effective life science education have grown exponentially within the last decade. Inter NICHE; The "International Network for Humane Education" is an organization that supports progressive science teaching and the replacement of animal experiments by working with teachers and students (1). NORINA database is an online database, containing information on audiovisual alternatives to animal use in teaching (7). For the purpose of teaching anatomy and physiology, computer based stereoscopic 3D images of the process of cadaver dissection have been generated and demonstration of underlying anatomy related to speech mechanisms has been done (8). Computer simulation of animal pharmacology experiments involving all or none responses using Applesoft BASIC programme has also been designed (9). Active participation of the students by using graphical interface on the computer stimulates the visual and kinesthetic forms of learning (1). In a study, undergraduate students using computer simulations performed equally well as students using traditional approaches in physiology and pharmacology laboratories (10). In another study, medical students used both computer demonstrations and animal (dog) demonstrations and rated the former higher for learning cardiovascular physiology (11).

There are 13 amphibian experiments on frog skeletal muscle and heart, in the practical syllabus prescribed for first year MBBS. The medical students are to use live animals for these experiments. Thus, the number of frogs that are used in an year, by a class of 50 medical students is more than 500. However, during last few years, the use of animals for amphibian experiments has been reduced and the experiments have been converted to "Demonstration experiments" performed by the instructors. The students are also provided with the graphs for the demonstration experiments. This is mainly due to difficulty in procuring the animals and also due to stringent laws imposed by animal ethical bodies. Therefore, a need was

felt to replace the existing system with computer based experiments by developing software that could simulate the animal experiments. This simulation package is made available to the students in the form of CD-ROM. The demonstration of amphibian experiments on CD-ROM is of utmost benefit to first year medical students as they can perform the experiments using the concept of virtual laboratory.

Goals/Objectives

1. To encode the procedures followed in mechanical experiments to computer algorithms after thorough understanding of input parameters/values, output parameters, graphical forms of output and the static or dynamic type of recording conditions.

2. To be able to plot and understand output characteristics of dose-response curve for exploring mechanism of action of various drugs, variation in temperature on biological tissues and understanding various physiological principles underlying the mechanical responses of biological tissues.

3. To make the amphibian experiments available on CD-ROM for the medical students, as an alternative to animal experiments.

METHODS

All the required steps in software engineering namely, system requirement specification, analysis, design, implementation and validation were followed in developing the simulation software.

In the system requirement specification, various steps followed in the manual experiments were observed and the details were well understood. In the analysis phase, different techniques to digitize the analog plots were explored. The graphs were manually traced and digitized. Though the method of obtaining digital values by scanning the plots could be an alternative, it was not used due to accuracy of points required. In the design phase, screen layout design, programme design, user interface design and so on were considered in detail. The system was implemented by using the software and hardware. Finally, the system was tested for validation and required changes were made in an iterative way until the output of simulated system was obtained as desired.

Procedure adopted and design used for simulation

After tracing a number of manually obtained graphs on the trace paper, the graphs are split into smallest possible straight line segments. However, to obtain the best fit graph and make the graph appear as a smooth plot, the minimum distance between two points varies for different graphs. The x, y coordinates for the end points of all line segments are written down. The information regarding the x, y points required to draw the graph of simple muscle twitch or any other graph is stored in the form of records in a database table using MS-Access 2000. The data from this table is retrieved for reconstruction of the graph. The x, y points in the records are accessed one by one and each tiny line of graph is drawn using Visual Basic 6 (VB6). Same procedure is repeated with data of normal cardiogram,

for obtaining graph of normal cardiogram. Once all the recorded data is plotted, the real time display of the graph and observation/ inference is done by VB 6 and Macromedia Flash 5. Algorithm used for this purpose is shown in Fig. 1.
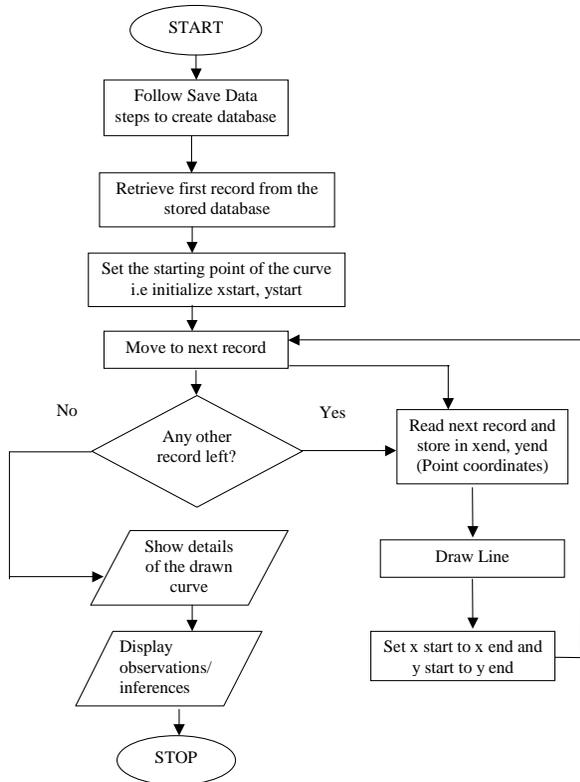

Fig. 1: Algorithm for recording the simple muscle twitch/normal cardiogram.

Following specifications are required for the computer- Pentium IV processor or equivalent, Windows 98 operating system or higher, minimum of 256 MB RAM and a high resolution color monitor.

STEPS FOLLOWED FOR EXPERIMENTS

Various icons appear on the startup screen as "Read Me" to know about system requirements, "About us" to know about the developers' team and "Nerve-muscle" and "Heart" experiments.

Step 1 : When the startup screen opens, read the instruction carefully and click the nerve-muscle icon.

Step 2 : A Show box appears that contains four icons of "Apparatus, Reagents, Dissection and Contents".

Step 3 : Read instructions to go sequentially through "Apparatus", "Reagents" and "Dissection" before proceeding on to "Contents". Click apparatus first, then reagents and then dissection and the appropriate screen appears one by one.

Step 4 : Once you are through with them, contents icon will be enabled. Click it. Contents screen will appear. Contents section describes the experiment in a preordained manner.

Step 5 : Select any amphibian experiment and click on the procedure button to study its theoretical part.

The first experiment is "To record the simple muscle twitch". When the user clicks on the experiment, "Procedure" icon gets highlighted. The student clicks on this and the procedure appears on the screen. After going through the procedure, the "Show graph" icon is highlighted and the student clicks on the same. The experiment screen opens for that particular experiment. The student now clicks "Draw curve" or "Show effect" and then "Observations", "Inference"

and "Exit". An interpretation is given for the recorded observations and at the end, through "Exit" button one can exit from that particular experiment.

In this way, each experiment is described under the heading of Form Name, Data base tables, Form description and the graphical interface depending on the experiment. For example, for the experiment on "Effect of load on muscle contraction", the user can select from the two options regarding type of load provided at the top of the form i.e. free load and after load. Then the user is allowed to select or increase the load by means of next button and separately view the effect of applying each load. The load is labelled by means of "Load Marker" under the curve. In next step, Calculations /Details can be viewed by clicking the Observations/ Inference button for showing the effect of pre/after load on muscle performance. Similar steps can be followed for the other load.

Similarly for the heart experiments, user goes to the startup screen and now clicks on the "Heart" icon. A Show box appears that contains four icons–Apparatus, Reagents, Dissection, and Contents related to heart experiments. Content form contains the list of all the frog heart experiments. User can select any experiment from the given list. Once the selection is made the user is provided with three choice modules :

1. "Procedure" contains the steps to be followed for each of the experiment. For different experiments the procedure will contain different contents.

2. "Show Graph" displays the curve corresponding to the experiment selected.

3. "Exit" is to exit the chosen screen.

Each experiment is described in the same manner under the heading of Form Name, Data base tables, Form description and the graphical interface depending on the experiment. For example in the experiment "To study the effect of drugs on frog's heart", the user clicks on any of the drugs option from the selection list shown in the form and the effect appears in the form of graphical recording. In the next step, the user can go for the observations and then inference by clicking the respective icon.

Error handling

There are proper steps for error handling and appropriate dialogue boxes appear like- "Click over the listed experiment to proceed" when the user tries to click on some other item while having opened the "Nerve Muscle" or "Heart experiments". Also for the "Effect of temperature" experiment, when the user clicks on other options while the curve is being drawn, a message box appears as "Error ! Curve is not complete yet".

Advantages of the project

This project can be of use as the experiments can be demonstrated through computer to any number of students any number of times while an animal experiment may be done, only once. The user friendly interface allows varying the parameters with a click of the mouse and enables to observe the corresponding results. Such interactivity helps students to understand the concepts easily. Moreover, the hassles involved with procurement and maintenance of animals can

be lessened much to the satisfaction of the animal welfare activists. The system can be extended to demonstrate various similar experiments on mammals also. It provides compactness to the system as there is no need of maintaining bulk of papers, files and notes etc. and also fast processing of all the tasks. It is cost effective in long run as the costs involved in procurement, care and housing of animals can be decreased. Moreover, to utilize the software, a general purpose computer is sufficient and also a single CD can be used for demonstration to a number of students. In a study, it was observed that six undergraduate students working independently with a computer program gained equal knowledge, at one-fifth the cost, as did eight supervised students using freshly killed rats (12).

Potential impact of the simulation project on school of medicine

The technology so developed can be made available to medical students in the form of CD-ROMs through wide dissemination to medical colleges across the country. There will be active involvement of medical students in learning through interactivity as the students can perform experiments using the concept of virtual laboratories. Further progression of the implementation is possible with student feedback and their innovative ideas leading to planning of more such proposals in future.

Feedback from students and faculty

Few medical students and the faculty went through the simulation software. They opined that the software was comprehensive in clearing the concepts, was user friendly, self explanatory and was good for learning as well as for revision.

Scope for further research

At present, the areas that are apparent to the authors where further research is possible are:

1. Other Physiology (mammalian) experiments like recording of blood pressure and respiration in rabbits and the effects of variables on it, effect of variables on isolated organ (heart and intestine) of rabbit, can also be simulated.

2. Alternative methods can be used for simulating the curves e.g. image processing techniques can be used in digitizing the graphs and to generate database of points or using analog to digital converters and the digital data stored on the computer can be used for plotting the curves.

3. Based on the averages collected from different outputs of the same graph, keeping the input parameter constant, mathematical equations can be generated. Once these equations are derived, the x and y coordinates can be easily calculated and the graphs can be accordingly drawn.

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REFERENCES

1. Jukes N, Chiuia M. From guinea pig to computer mouse. 2nd ed. Inter NICHE, England 2003.

2. Barnard ND, Stolz J, Baron L. Use of and alternatives to animals in laboratory courses at U.S. medical schools. *J Med Educ* 1988; 63: 720–722.

3. Hansen LA, Boss GR. Use of live animals in the curricula of US medical schools: survey results from 2001. *Acad Med* 2002; 77: 1147–1149

4. Arora R, Berry V. Animal experiments in Medical undergraduate curriculum -assessment of students' views. *Health Administrator* 2005; XVII(1): 63–67

5. Bowd AD. Dissection as an instructional technique in secondary science: choice and alternatives. *Society and Animals* 1993; 1: 83–88.

6. Russell WMS, Burch RL. The Principles of Humane Experimental Technique. London: Methuen, 1959. Facsimile edition, Potters Bar, Herts: Universities Federation for Animal Welfare (UFAW) 1992.

7. Smith AJ, Smith K. The NORINA database of audiovisual alternatives. In: Animal Alternatives, Welfare and Ethics, ed. L.F.M. van Zutphen & M. Balls. Amsterdam, The Netherlands, Elsevier 1997, 511–515.

8. Jamie P, David K, Langlois R. Teaching Anatomy and Physiology using Computer-Based, Stereoscopic Images. *Journal of College Science Teaching* 2007; 36: 18–23.

9. McGilliard, KL. Computer Simulation of Quantal Dose-Response Relationships. *Physiologist* 1985; 28: 449–450.

10. Dewhurst DG, Meehan AS. Evaluation of the use of computer simulations of experiments in teaching undergraduate students. *British J Pharm Proc Suppl* 1993; 108: 238.

11. Samsel RW, Schmidt GA, Hall JB, Wood LDH, Shroff SG, Schumacker PT. Cardiovascular physiology teaching: Computer simulations vs. animal demonstrations. *Advances in Physiology Education* 1994; 11: S36–S46.

12. Dewhurst DG, Hardcastle J, Hardcastle PT, Stuart E. Comparison of a computer simulation program and a traditional laboratory practical class for teaching the principles of intestinal absorption. *Am J Physiol* 1994; 267: S95–S104.