Virtual Apparatus: Use of 3D Computer Graphics for Computer Assisted Learning

Russel Ahmed Apu, Tamnun E Mursalin, and M. Rokonuzzaman
Department of Computer Science, North South University, Banani, Dhaka, Bangladesh
Emails: russel_ahmed_apu@hotmail.com , rzaman@northsouth.edu, tmursali@northsouth.edu

Abstract: *Computer assisted learning is relatively a new field of study. When applied, the advantages of Computer Assisted Learning can greatly enhance information content of learning by augmenting and substituting conventional learning methodologies. This paper develops a framework for the use of 3D computer graphics in the process of learning, which can provide realistic experience of the concept being learned. The principle focus of this research is confined by the area of "Computer Assisted Learning for Physics" (CALP). Its development enables us to augment and substitute a controlled real world event with only a finite number of variances to its proper virtual representation in a graphics world. This paper demonstrates several potential application contexts for the use of virtual apparatus to conduct such constrained simulation in the light of CALP.*

Keywords: *Computer Assisted Learning for Physics (CALP), Graphical world, Augmentation, Substitution, Virtual Apparatus, Discrete Event System (DES).*

1. INTRODUCTION

Computer assisted learning for Physics (CALP) involves the training process to exhibit a sequence of activities to carry out certain constrained event through the assumption of a simplified system of cause and effect with only a finite consideration to variances and noises. In other words CAL augments a number of entities of real world meaningfully involved into producing certain physical effect, to a virtual world by substituting a number of apparatus by their synthetic counterparts [4]. A flight simulator for instance, teaches the use of tools and perception cues to fly an intended air craft [7]. Nevertheless, a flight simulator substitutes a number of apparatus and sensory feedback displays, augments various entities both of terrestrial and aerial origin, adopts the mathematical models to associate events to their causes and replicates entirely the attributed experience of flying in a meta-realistic environment.

In the conventional process of learning, the pupils are subjected to applying imagination and considerable level of abstraction, and conceive a phenomenon through ambiguous linguistic expressions [11]. Although the process is sometimes enhanced through the use of figures and charts, learning efficiency still remains low. The use of 3D interactive computer graphics can bring about more realistic experience of certain events that resembles a real world perception. Interactive 3D graphics augmented to such system improves man-machine communication. While interacting seamlessly with a virtual environment, they gain the advantage of first hand experience. Therefore interactivity can help increase information content to a startling factor. Our primary focus in this research is to incorporate the basic infrastructure (figure – 1) for the implementation of such artificial apparatus in the context of simulating listed experiments in the area of physics and chemistry. The work carried out in this context will also be listed and highlighted to explore their potential and relative competence with real experiments.

2. ROLE OF 3D INTERACTIVE GRAPHICS

Prior to this paper, a preliminary study of CAL conference [4] shows that current CAL systems are mostly 2D and non interactive. Even though they provide visual cues, they cannot be accounted for a substitution of real world first hand experience. Our study shows that visualization of most interactive CALP software are too abstract to help any useful learning objective [16][6][5][13][8]. Nevertheless, in the last few years significant improvement in computing technology has given us the power to incorporate the concept of modern computer graphics with high level of interactivity.

A conventional "Chalk and talk" class room starts with a concept through abstract text and figures. The session then proceeds with idea development, inquiries and finally rectification of concepts (Figure 1). This learning cycle relies too much on imagination. Therefore the CAL system provides a visualization system to conceive first hand idea around the concept being learned.

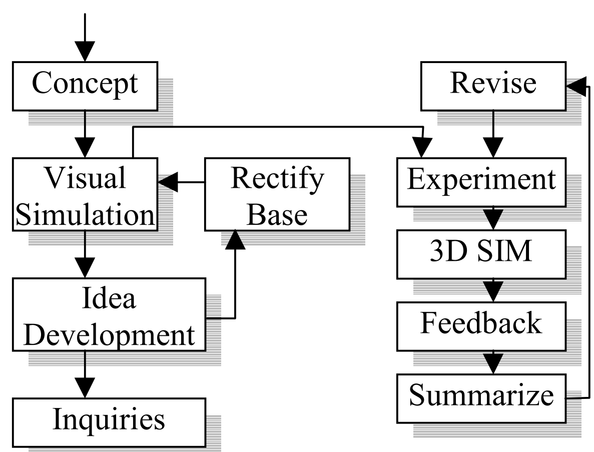

Figure 1. Computer Aided Learning Cycle

Our research augments this learning process for CAL by additional CALP simulations (figure 1). The students can rectify their base automatically through the process of interaction with the CALP 3D-interactive systems. And after rectifying their base with a number of CALP runs, they can proceed with problem solving and other aspect of learning. This approach increases the quality and information content of learning enormously. Therefore it substitutes the conventional role of teachers and concentrates on learning through experience.

3. SALIENT FEATURES OF 3D INTERACTIVE COMPUTER GRAPHICS FOR CALP SYSTEMS

The most prominent feature of CALP is interactivity [2]. The simulation provides feedback and enables learning through experience (Fig. 2). Not only as observers but also as active participants, the students can alter course of actions in an experiment and experience the feedback. This process greatly enhances the quality of learning. Therefore student have a better understanding of the effect of possible actions, thus understanding the necessity of specific course of action.

3D interactive computer graphics enhances the learning capacity [15]. In order to understand how, we must establish the benefits gained over conventional method. Firstly, 3D graphics augments to the concept of learning (Fig. 2). For example, consider two persons who need to learn about volcanic eruption and one of them have actually experienced the phenomena. Therefore this person will learn much faster, since she can relate to cues and perceptions already gained with that of theoretical concepts and abstract figures.

Although it might not always be feasible to bring the students to volcanic eruption, we have the option to bring the eruption to the students [14]. And that's how 3D computer graphics augments to the process of learning. Augmentation is further achieved by use of simplified conceptual model-views. Such views, combined with interactivity, can abstract unimportant factors from the real world and permits only those that effectively influence the phenomena under consideration. For example, the magnetic field lines may neither be experienced in real-world nor it can be produced in 3 dimensions in any feasible experimentation [12]. Therefore generating 3D electric/magnetic field lines can augment to the learning process with considerable gain both in terms of information content and quality of learning. In short CAL makes us see what we cannot see.

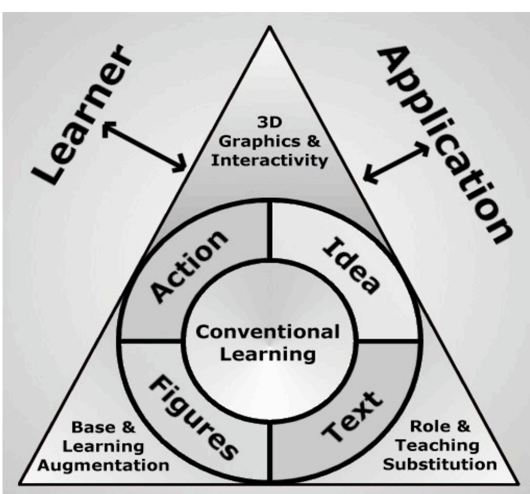

Figure 2. CAL Framework

A more passive effect of interactive 3D graphics is the process of substitution where the role of the teacher shifts from the abstract illustrative part to a more interactive consultative one (Fig. 2). Since the 3D interactive simulation can produce visual cues of an event through interactive feedback, the use of imagination and descriptive illustration is no longer necessary in full extent. The illustration may proceed superficially around the demonstration, and then the teacher may concentrate more on concept and problem solving. Therefore the process of substitution brings two desirable effects. Firstly, it speeds up the learning cycle. Secondly, it increases the quality of learning by providing elements of visual experience.

4. APPLICATION FRAMEWORK

A computer display system is nothing but a 2D raster plane. In order to implement 3D applications, we must incorporate projection systems by squashing a scene into a plane – a process known as rendering. In order to rasterize the plane we adopt one of the widely recognized industrial standards, namely, the OPENGL (v1.2) graphics platform [1][10] (Figure-3).

5. SYNCHRONOUS TIME QUANTIZED DISCRETE EVENT SYSTEM

A computer is a discrete machine with only a finite number of states. Therefore naturally an abstraction of quantized time and space applies to all computer simulations [1][9]. Error can be limited firstly by placing a finite boundary on space extents, and secondly by using floating point formats to the formal definition of coordinates. Time on the other hand is emulated through a sequence of quantized frames. The system of assumption that abstracts the occurrences of finite events only within frames, are called discrete event system. The DES is governed by the law of instantaneous trigger mechanism. This means that the event is assumed to occur in an instantaneous moment rather than an infinitesimal interval.

6. ABSTRACTION AND USE OF SIMULATED ERROR CORRECTION MECHANISM

In a CALP system, errors due to abstraction occur both in base level and conceptual level. In the base level error accumulates due to time/space quantization and DES assumptions (Figure-3). In the conceptual level error accumulates due to the abstract mathematical model and elimination of chance causes.

Therefore compensation with error correction mechanism is necessary to prevent the system from entering false states [4] (Figure-3). A false state is governed by the triggering of an event or a checkpoint which is unlikely to occur in a real world experiment.

In CALP simulation there can be two levels of error correction. If the Application is just for visualization, only intermittent error correction is required. For more precision applications where accuracy of extrapolation is imminent, per-frame correction is unavoidable.

7. NATURAL ABERRATIONS

Many of the cases, simulations overlook idealized model for the inclusion of natural aberrations [1][12][4]. For example almost all optical experiments on lenses assume a thin lens, but many of the practical lenses actually violate this assumption. Thus simulation must incorporate the model of refraction and ray-tracing rather than using simplistic equations. Any simulation designed in this manner may relate to a larger class of problems than those that conceive simplistic mathematical forms. Natural aberration and noises with proper statistical model can greatly enhance the accuracy of the simulation resulting in more realistic learning experience.

8. DEMONSTRATION OF USE OF 3D GRAPHICS FOR LEARNING

In the light of Computer assisted learning we have carried out a number of demonstration that highlight experiments and concepts from the field of high-school physics and chemistry [12].

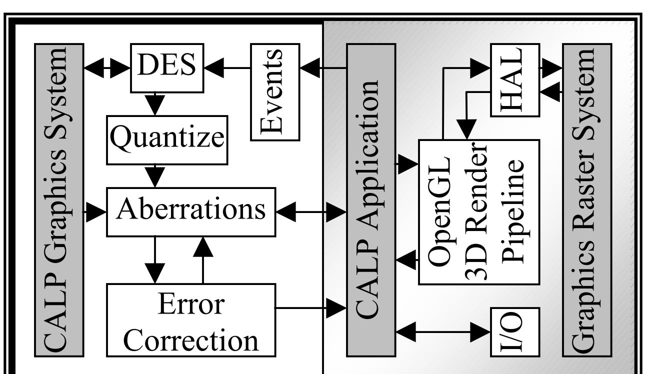

Figure 3. CALP Application Framework

8.1 3D Magnetic Field Simulation

A conventional field line experiment cannot be performed in open 3D space. The magnetic field line simulation offer a complete 3D perspective of magnetic field lines (Fig. 4). The software can take multiple magnetic poles with various flux densities and generates color coded field lines. All sort of camera manipulation allows complete freelance navigation through the world of magnetic fields. This project augments the learning process to a huge proportion. The project however deals with ideal magnetic poles with a given flux density. Thus field lines for a dipole vary slightly from that of a real bar magnet. However the anomaly dissipates at sufficient distance from the poles.

8.2 Ripple Effect

This Application takes the learning of wave theories to a new dimension. It is capable of generating the effects of ripple waves from a source point over a liquid surface (Fig. 5). The user can use the interactive panel to create countless cases of ripples, interferences and wave dampening. User can change wavelength, amplitude and other properties of waves. The simulation is capable of demonstrating interferences through superposition principle of waves. For pupil, who want to understand the nature of waves and their behaviors, this application can prove to be an invaluable asset.

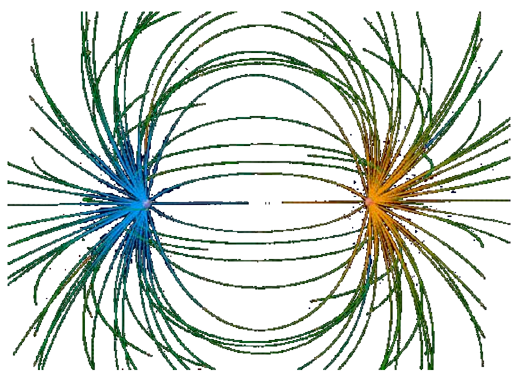

Figure 4. 3D Magnetic Field Lines

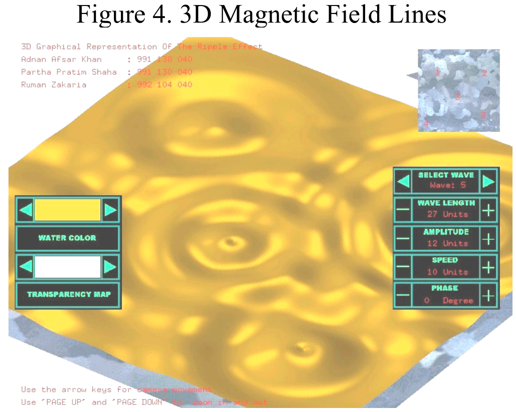

Figure 5. The ripple Effect

8.3 The Lathe

This is a project that visualizes the effect of revolving a surface around an axis. The program generates a 3D model of the object generated by surface revolution (Fig. 6). This project can help the student of mathematics specially that of calculus to understand how solid cavity are formed. From its nature the project is formally named as “The Lathe”. This project is of great importance to the field of Solid Geometry.

8.4 Convex Lens Experiment

The Convex lens Experiment incorporates the abstract model of refraction to demonstrate various optical experiments conducted with a convex lens (Fig. 7). It can greatly enhance the learning experience of the students by providing a base for virtual laboratory for optical experiments.

Future enhancement of this software has been made by augmenting generic lens type, and reproduction of projected image. The lens-focus effect is visualized through fast tracking of rays and blurring of image.

8.5 Simple Pendulum

Initially designed for Simple pendulum simulation under various environmental conditions, the Pendulum Application is capable of simulating pendulum motion under any gravitational force and considers air drag dampening. This Project (Fig. 8) can be used to conduct pendulum experiments with high level of interactivity.

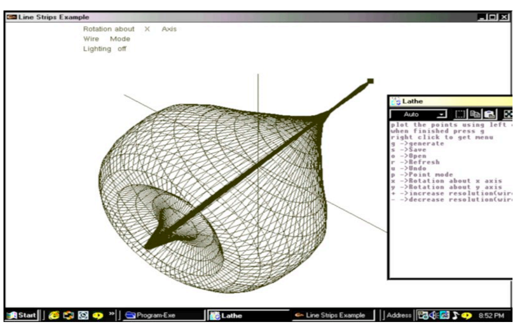

Figure 6. The Lathe

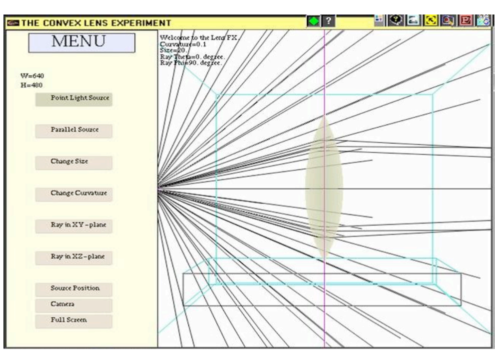

Figure 7. The Convex Lens Experiment

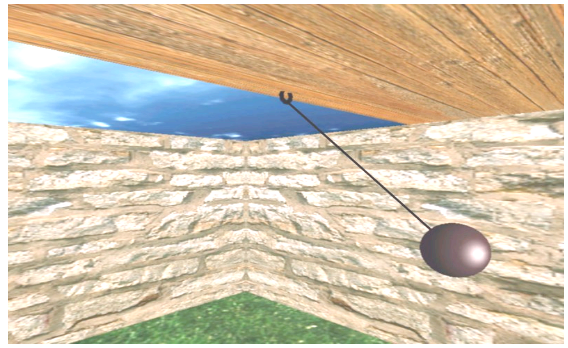
Figure 8. Simple Pendulum

8.6 Crystalline Salt Structure

This is an application that can help the students of chemistry enormously. It demonstrates various molecular lattice structures of salt crystals by an interactive 3D software (Fig. 9). The free rotation of structure and shaded graphics can greatly simplify the hurdle of understanding 3D lattice structure of salt molecules.

8.7 Simulation of PN Semiconductor junctions

This is an abstract and simple representation of the PN junction of a semiconductor that animates the effect of flow of charges and transference within the depletion region (Fig. 10). It can help the students of physics greatly to understand the nature of semiconductor devices.

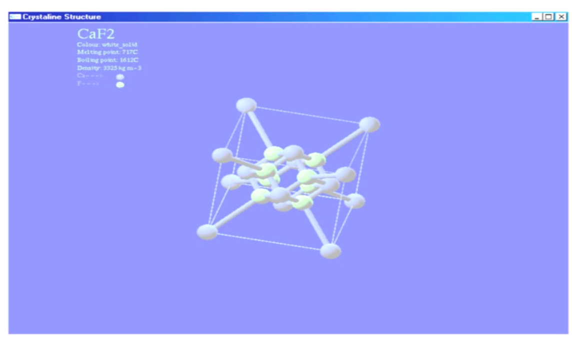

Figure 9. Crystalline Salt Structure

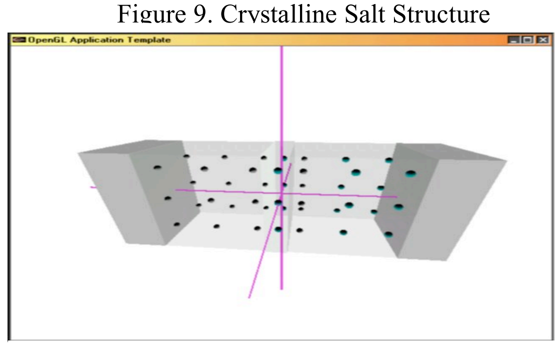

Figure 10. Semiconductor Devices

8.8 Solar System Simulation

This is a virtual planetarium that provides the user a walk through our solar system and passes by various planets. The planets are textured with planetary maps downloaded from NASA and therefore contribute to a tremendous gain in information content (Fig. 11). This project can help the student know our solar system through first hand navigation experience.

8.9 Earth Quake Simulation

This simulation demonstrates the structural stress on a building inflicted by earth quake in different scales of frequency, amplitude and Richter scale (Fig. 12). The user can choose between different structural property such as elasticity, threshold and tension and experience the real-time experience of earth quake from different view points.

8.10 Other Applications

We carried out several other projects in the light of computer assisted learning for physics (CALP), all of them cannot be mentioned for time and space shortage. Among them, Simulation of various combustion engines (Fig. 13, 14) and robotic and organic devices are significant. These projects greatly enhance the learning process in advanced level.

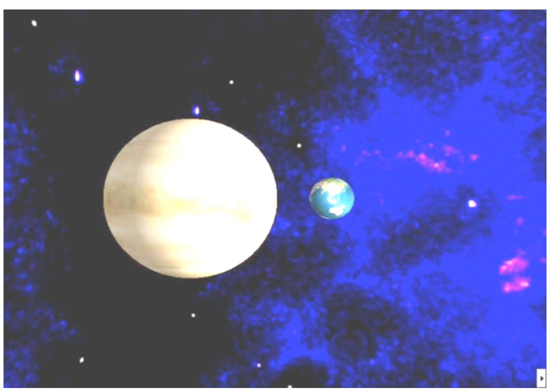

Figure 11. The Solar System

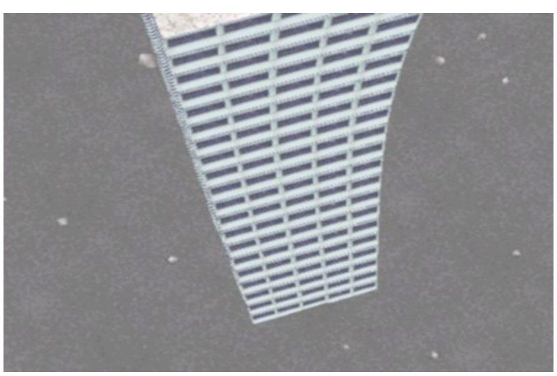

Figure 12. Earth Quake Simulation

9. SUMMARY

In short, this paper Shows the framework and benefit of 3D-interactive CALP applications over conventional CAL systems, and highlighted the potential. The benefits of Computer aided learning are summarized in figure-1. CALP system, if combine with interactive 3D graphics with events and cues can produce first hand learning experience. It can augment and complement learning process enormously, and can act as a complimentary bridge between conventional process of learning and expectations from a student of 21st century. The work that has been demonstrated is only in its incipiency compared to potential this field holds for us.

10. Future work

It is simply tomorrow or the day after when the way we learn is going to change. The future improvement for 3D-CALP lies in the development of perception systems. Use of VR-equipments, synthetic worlds, force feedback, robotics and multimedia will change the learning process and learning will tend to incline towards experience from conventional use of imagination. We look forward to incorporate a new age for learning.

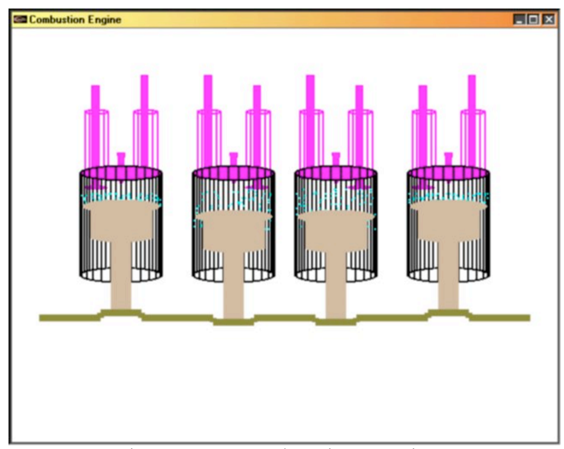

Figure 13. Combustion Engine

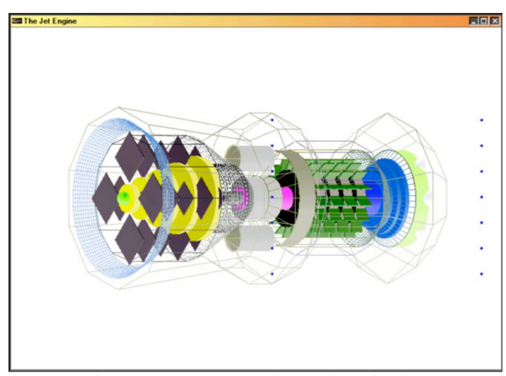

Figure 14. Jet Engine Simulation

11. CONCLUDING REMARK

In the last two centuries education methodology has largely remained unchanged whereas the expectations from students have grown out tremendously. Students are expected to conceive complex systems of mathematical cause and effect through the conventional method of "Chalk and Talk" in a classroom of "Desk and Text". Compensating these discrepancies, the use of 3D interactive simulations can drastically change the scenario.

The reason that 3D graphics complement learning process is versatile interactivity. The user interacts with a virtual world that coheres with the idea of real world entities. Since the 3D graphics can recreate the experience within the passage of time of an event, the learning becomes first hand and efficiency multiplies. Future works and researches in this potential field will change the way we learn forever.

ACKNOWLEDGEMENT

We would like to thank the department of Computer Science, North South University, for their support, also our heartfelt thanks to those students who worked day and night on their graphics project and developed potential applications governed by 3D-interactive CALP methods.

REFERENCES

[1] Roger T. Stevens, Christopher D. Watkins, *Advanced graphics*, 1st Ed., M & T Publishing Inc., New Delhi, India – 1993

[2] Prof. Hossein Arsham, *Computer assisted learning: concepts & techniques*, Website Link: www.ubmail.unalt.edu/~harsham/opre640c

[3] Harst Schecker, "Computer in physics education", IDP, Web: www.physik.uni-bremen.de/physics.education/niedderer/projects/cip

[4] KTH, Stockholm, *Conference on flexible learning in physics*, Nov 1998, Web: www.atom.kth.se/~berg

[5] Edusoft, www.edusoft.co.za/

[6] Fun@Learning.physics, Simulation Applets (JAVA), www3.adnc.com/~topquark/fun/

[7] Helix flight simulator, Simulation Website Link: Member.tripod.com/~helix-fs/

[8] Interactive Learning, www.highergrades.com

[9] M. Rokonuzzaman, F. Hwang, J. King, R.D. Hale, R.G. Gosine, "Mobile robotics based distributed system: discrete event system perspective", *Proc. Of ICCIT 2000*, pp 235-239, Dhaka, Bangladesh, 2000.

[10] Richard S. Wright, Jr. Michael Sweet, *OpenGL super bible*, 2nd Ed., Macmillan Computer Publishing, USA, 2002.

[11] M. Euler, A Muller, *Physics learning and the computer: a review, with a taste of meta-analysis*, IPN Kiel, Germany.

[12] Frederick J. Bueche, David A. Jerde, *Princliples of physics*, 6th Ed., McGraw-Hill, Inc., New York.

[13] QCOTMS, www.qcotms.com

[14] Strombolian Eruption Simulation. Web: www.montana.edu/cybertour/science/kto5/hodged

[15] Dr. Theodore Raphan, Oren Marciano, "Virtual multi-media internet laboratory", Institute of Neural & Intelligent systems, Department of Computer and Information Science, Brooklyn College of City University of New York.

[16] Virtual Physics, www.ippex.pppl.gov/