Making scientific topics simpler: a web site for learning chaos

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Abstract

As many researchers have pointed out, information and communication technologies can be considered as cognitive amplifiers to support new ways of thinking in educational processes. This paper presents an application devoted to communicate scientific concepts. Linking educational materials based on multimedia technologies, a website, where virtual environments, images, videos, sounds, and music are collected together, introduces young generations to scientific topics such as Chaos theory and the Chua's circuit. It also allows them to experience the beauty, simplicity and creativity of Digital Art, which is the tool that consents to reduce the complexity of scientific topics and to give access to a systematic comprehension of difficult concepts. In the paper, a wholly description of the educational processes that the web site activates is given, together with some empirical results of the experimentation carried on with high school students.

Keywords: Chaos Theory, Advanced Technologies for Learning, Science Education

1. Introduction

The word media refers to any form of communication that reaches a large number of people, and it includes radio, TV, newspapers and magazines, movies, recordings and books and actually the Internet. A naive definition of media claims that they are simply technology, as they can be described in terms of their physical structure (hardware), in terms of modes of transmission (auditory, visual, or both) and of the users’ reception. But although the technology is obviously crucial to the contemporary mediated communication, the media cannot be understood simply as a technology. Instead it is necessary to consider the concepts that people have of them (Alan, 2006 and Chua, 1992a), the uses that they make and the social relations that they produce (Bilotta and colligues, 2007a) that promote usability by the users of this new system. How can we spend these new systems in the field of scientific communication, or as tools to achieve educational aims and express human creativity? How can we use the Internet and its related technologies (mobile, wikis and social networks) to connect people to science (Bilotta and colligues, 2007b)? Researchers, teachers and designers of educational resources are beginning to ask how this powerful medium might be used to support educational processes. In particular, research tries to investigate how it is possible to develop new ways of learning, from the proliferation of web site devoted to e-learning, to pleasurable learning (Bilotta and colligues, 2007,c), learning by doing, learning by collaboration, edutainment (Bilotta and colligues, 2007,d) or other forms that the web seems to offer. Media education research, like media research, is carried out in three phases (Bilotta and colligues, 2005). While in the past many pleasurable activities were intended to outdoor games, currently the Internet, video games and in general all the information tools play a crucial role in education. Some high specialized scientific topics, such as Chaos and Complexity Theories seem to be very suitable to be shown through the use of innovative educational tools that allow the students to employ mathematical concepts

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Available online at www.sciencedirect.com
Open access under CC BY-NC-ND license, doi: 10.1016/j.sbspro.2012.06.912
in a creative manner. In this way learning could become entertaining and enjoyable. In order to enhance young people’s motivation and attention on science studies, the website is made up by seven sections that we’ll introduce in the following sections. All multimedia materials stored in the website represent a metaphorical journey inside science and art that may arouse interest in users. The paper is organized as follows: in section two we’ll present a short introduction to chaotic systems, in section three we describe the web site, in section four we’ll conclude the paper, providing also some empirical results we’ll have obtained in providing the educational environment to high school students.

2. CHAOTIC SYSTEM AND DIGITAL ART

Chaos Theory considers non-linear dynamical systems with deterministic behavior, that evolves in an apparently random sensibility to initial conditions. Unlike random series, these systems always evolve in the same way for a given set of initial conditions and parameter values. This is, of course, impossible to witness in real-world settings, because we cannot have full knowledge of the system state, but it is theoretically possible in digital simulations. Chaotic systems create such a number of unpredictable forms and shapes, known as strange attractors. The complexity of the behavior is not in opposition with the stability of the system. Geometrically, an attractor can be a point, a circular orbit such as a limit cycle, or even a fractal-structured shape called strange attractor. Chua’s circuit (Bilotta and colligues, 2007) is a physical device able to reproduce chaotic behavior. Unlike the Lorenz attractor, which generates just a few kinds of dynamic pattern, Chua’s circuit and systems derived from the circuit, can produce a large number of chaotic structures of many different patterns and size (Bilotta and colligues, 2005). Recent years have seen the publication of Gallery of Chua attractors, including attractor images of extraordinary beauty, never previously seen in the chaos literature (Bilotta and colligues, 2007,d). Other studies have described the translation of these dynamic systems into generative music (Bilotta and colligues, 2007,d) and into natural languages (Bilotta and colligues, 2005). This research has made it possible to produce multimedia products in which users can display 3-D sound and music. By modifying the control parameters, users can produce fractal 3-D attractors in real time. As we already said Chua’s oscillator is a canonical system to studies the chaos, since it can be realized in a real world setting as a simple electronic circuit. The system has three degrees of freedom, and it is described by three state equations whose variables correspond to the magnitudes of physical forces. However, we use a dimensionless model to simulate it, with six parameters. Every set of parameters in the dimensionless model corresponds to more than one set of parameters for the physical model. Changing the set of the control parameters, the system can converge to a fixed point, show a limit cycle, or result in a strange attractor Fig.1.

![Fig.1 First route to chaos in Chua’s circuit](image)

Some sets of control parameters are, however, physically impossible, so the system is unstable and the numeric simulation diverges to infinity. As the control parameters and the initial values change, the dimensionless equations produce a large variety of strange attractors of different shapes and sizes. The dynamical system’s applications are
really a great number and for this reason are used like a creative source. From these two experiments we decided to create a web site in which students can learn to:

a. Build the Chua circuit and visualize its chaotic behavior with a simulated oscilloscope;

b. Simulate chaos by using the specific visualization environment on the site;

c. Understand the beauty, simplicity and creativity of chaotic behavior by using some software applications the site contains, in order to allow students to create digital art products related to sound, music and image digital art production.

3. WEB BASED APPROACH FOR SCIENCE DISSEMINATION

In this section we present the website and the several pages that compose it. The introductory page to the website shows various settings in which the attractors have been used: starting from the first route to chaos, three dimensional model of an attractor in rotation and finally some artistic metaphor of chaotic trajectories that become flowers or buildings into an imaginary world. The home page shows a menu where all the sections are linked with evocative icons contained in a circle. An intuitive and engaging graphical user interface has been realized by using Adobe Flash Player functionalities of transformation and animation. The aim of the home page website is to create a collection of information on the Chaos Theory, illustrating most advanced technologies devoted to the educational activities. To achieve this goal, the website interface has been designed using Human Computer Interaction approach. Human Computer Interaction (HCI) “attract innovation and creativity because of its multi-disciplinary nature, in computing and IT research and development. It inspired new solution especially for the benefit of the users as a human being, making users the focal point which technology should serve rather than the other way round” (Bilotta and colligues, 2007d). created with chaotic system. The following presents all seven sections trying to explain the content and the peculiarity of each interface. The first section presents Chaos Theory and the Chua's Circuit. This section starts with a theoretical introduction to the basic concepts of chaotic phenomena and it follows with a didactic activity called "Building Chua's Circuit". In this part we present a "step by step method" to build the circuit A specific characteristic that has made outstanding Chua’s invention is the possibility to reconstruct the circuit supporting a very low cost and succeed to compose the circuit correctly following the instructions (Chua, 1992a). The interface contains on the left a slide that shows where a final user can see the components and the steps needed to build the circuit. On the right of the screen, we put on a short video in which young people build possible for young students to acquire concepts as difficult as chaos usually take care of engineering or physical university courses. The physical construction of Chua’s circuit promotes the growth of a practical intelligence stimulating the productive dimension. From this derives a fundamental theoretical approach in cognitive sciences: the knowledge is not transmitted already organized, but everyone constructs under the expert supervision these methods, users become part of the learning process and are not just spectators. The second section shows the "Gallery of Chua's attractors" that represents a classification of the wide number of patterns coming from the scientific visualization of chaotic behaviors in Chua’s circuit. The mathematical models of the Chua's circuit have also been used to produce artistic objects. In accordance with the new architectonic tendencies which use dynamical systems to propose new architectonic vanguards, the third section of the site presents a short movie on the "City of Imagination", where Mathematics and Art are strictly linked. In this movie users can admire new attractive buildings created by exploiting the forms of chaotic attractors. The fourth section named "Virtual Worlds" presents 3D futuristic spaces. Here, the movies show synthetic scenarios based on chaotic forms, where mathematics is the basis for the artificial worlds and chaos becomes a fantastic representation of the real world. Since the circuit and its generalizations can create a broad range of acoustic signals and melodies, the fifth section is dedicated to music and sounds from chaos. Furthermore, through the use of MIDI instruments, many musical pieces have been already generated. Much sound architectures created in Pure Data allow users to produce sound and music from chaos. The sixth section presents some educational activities previously implemented. In the first section we explain a didactical methodology that has been already experimented in primary and high schools, in order to introduce Chaos theory to students. This part presents a four step teaching/learning method through activity reports, pictures, videos, and test results. The originality and beauty of the circuit attractors gave the idea for an exhibit, presented in the web site. Different virtual environments, as shown in the website, try to realize a concrete idea of edutainment tool that combines the educational and entertainment purposes. A session dedicated to Art & Science is
also linked to the educational activity pages. Here many creative interpretations of chaotic shapes are presented. The artistic creativity has allowed the realization of flowers, evocative images, painting with spots of color, Pollock like, that have departure forms of attractors. The seventh section presents the "Virtual Museum", which introduces a video of a 3D navigable application in which users can explore more than a thousand attractors as they were in a museum. The Virtual Museum of Chua's Attractors presents the collection of all the patterns produced by Chua's circuit, making them available to the non-specialist reader. It's an interactive environment, in which the final user can explore the extraordinary shapes Chua systems are capable of generating. The Museum consists of a single navigable space containing the Gallery's pictures. The setting consists of a navigable area divided by panels showing pictures of attractors and chaotic evolution. The visitor can control his or her position by using the general map of museum, located on the right bottom site of the screen. The museum symbolically contains five sections, like five different typologies of artistic productions coming out from chaotic system simulations. An avatar functions as guide in the space exploration. Two final sections allow the download of software applications related to attractors, music and sound creation and the exchange/sharing of artistic productions by using a wiki system respectively.

4. CONCLUSION AND FUTURE RESEARCH

This paper presents a website environment to learn chaos concepts. The purpose of the website is to deliver a wide public scientific topic, such as Chaos and Complexity; in order to create an alternative model of the learning processes based on the idea that students should be emotionally involved and interested by using tools and contents which allow them to develop their knowledge and creativity. By exploring and modeling the patterns of Chua’s attractors, transforming them into sound and music and using software for simulation processes, users will be able to discover how these concepts are simple and how to develop their creativity by using alternative tools such as music, sound and image production. The hands-on activity can provide a new, creative and enjoyable approach to science learning. Visual arts and music are two powerful vehicles to communicate scientific concepts. Exploring chaos on the web brings users into contact with stimulating mathematical ideas, allowing them to discover specific concepts related to emergence and complexity and attracting them in exciting and accessible activities, even for learners without a strong mathematical knowledge. Direct interaction with the virtual objects encourages learners to think, to formulate hypotheses and to test them through the experimentation. Many multimedia contents, such as 3D tools are presented in movies to show the artistic creations that it is possible to realize by using chaos and digital art tools. With this website we want to promote the awareness that artistic culture and contemporary science have a common matrix, thus overcoming the problems that scientific education has in this time and attracting young generations to science. Starting from chaos, one of the most important topics of contemporary research, and especially from the Chua’s circuit, that is the first analytically and numerically proven example of chaos, we have developed a non-conventional educational environment in which art and science meet together in order to promote an effective edutainment tool. The system has been proved by numerous schools which got in contact through the website. Many experiments have been undertaken to make this website usable in high school. Specific training sessions for teachers were also launched. Initial results of experimentation provide excellent outcomes both for the contents that students learnt and the motivation and enthusiasm they showed. Future experimentations foresee the development of a wiki-educational approach in order to develop contents of scientific communication on chaos, created by the students themselves.

References


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