CoLoS: Conceptional Learning of Science

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Abstract

The CoLoS group was founded in 1988[2] and today consists of 10 working groups from universities in seven European countries. CoLoS stands for “Conceptual Learning Of Science” and reflects our major goal: to use the potential of modern technology to improve knowledge and understanding of basic concepts in science and technology with a special focus on intuitive and qualitative approaches.

A general idea behind the CoLoS project was to stimulate the production and use of software for education at university level. Following a bottom-up approach, a group of motivated people from different fields in science and technology were brought together and equipped in such a way that, within a common framework, different software packages could be developed to meet local needs for teaching and research [1] [2].

By intensive use of network communication and semi-annual project meetings, the members have moved towards general solutions and cooperative actions. A set of tools to support the production of computer assisted teaching/learning material and a series of software packages on a variety of topics have been developed and will be evaluated during the near future.

1. Introduction

The exploitation of the didactical potential of modern technology for teaching within CoLoS is focused around two topics: tool development and application development.

The tool development is aimed at providing teachers as field experts (with a minimum of programing expertise) access to a programing environment offering a maximum of support with a minimum of restrictions for the implementation of specific ideas in computer assisted teaching/learning.

To find a balance between these two partly conflicting demands is one of our major concerns. In section 2 this tool development is outlined in more detail.

The second focus is related to application development serving the following goals:

- to increase the visibility of the didactical potential of this technology by demonstrating the state of the art of computer assisted teaching/learning material
- to aid in actual teaching to provide an increase of efficacy and effectiveness of the learning process
- to serve as a stimulus and support for individual teachers willing to develop and implement new and fruitful ideas in this field.

The general aspects related to this application development are specified in section 3. Questions related to evaluation procedures are treated in section 4 while a list of all CoLoS products with a

[1] with input from other CoLoS members

[2] supported by Hewlett-Packard

broader description of some typical examples can be found at the end of this paper together with a list of the CoLoS sites and contacts addresses.

2. Tool development

Experience shows a great reluctance of many teachers to the use of software in their teaching, especially if it is a foreign, “out-of-house” product.

As well as the usual conservative structure of the educational sector, the reasons for this reluctance may be seen as follows:

- In general it is a risk to one’s professional status to use a complex medium which one does not fully understand. Teachers in their exposed role as experts will not take this risk unnecessarily and therefore they will not use complex off-the-shelf products or easily accept tools developed by someone else.
- Teachers have a strong desire to give their presentation a personal look and feel, enabling them to concentrate on the content and on didactics and pedagogy instead of forms and models of presentation.
- Most software has been developed for widely available and less powerful platforms as found today in many schools. The look, feel and functionality of these products reflects these limitations. Teachers may be reluctant to get involved with a still developing medium, waiting for standards to stabilise.

A first decision taken within CoLoS to overcome these barriers was to use standards like X and Motif to guarantee a lasting value of investments. Second it was decided to use advanced workstations (the PC of tomorrow) to provide the possibility for a continuous and smooth adaptation to future technological progress.

The major solution for this problem is the development of tools for teachers to support the production of their own software packages. A major design decision to be taken for such authoring environments is related to the conflicting demands of maximum support and minimal restriction. For the development of the product Xdev, described in section 4, the decision was taken in favor of minimizing restrictions with a trade-off for higher demands on the side of the user. The teacher/author as such a user is expected to be aware of a subset of the C-language and to have acquired some basic knowledge about algorithm and programming. Some principles of Motif, for instance use of widgets and the functionality of callbacks is necessary. Once such basic knowledge has been acquired a maximum support is available for the production of individual simulations. A description of this programs is found in section 5.

The process of tool development supports the concept “Model - View -Controller” to organize application development. The “Model” represents the actual subject matter in the form of simulation algorithms or other descriptions of the topic at hand. The “View” contains the presentational and interactive software and the “Controller” directs the flow of presentations.

For a domain expert authoring courseware the only part of interest is the “Model”. A major objective of this project is to shield the author, teacher and student from having to write software dealing with the “View” and the “Controller” on anything but a superficial level. The existing Motif widgets and a number of generic widgets support automatic generation of “View” and of “Controller” software [3] [4].

The selection of tools to be developed has mainly been decided by local or individual needs in close consultation with the members concerned and in line with the intended bottom-up approach. These tools can be divided in three categories:

- a programming environment

- tools for support of graphical design
- widgets or libraries for special sub-tasks useful within the Motif environment

New requirements for further tools or widgets are developed mainly by teachers, while learning programming and authoring with Xdev. Such activities are in progress and serve as test bed for the environment as well as a source of new ideas and future requirements.

A second source for additional requirements is growing out of the subgroup of CoLoS members concerned with full time programing of complex applications (see next section). From the variety of tasks undertaken and solutions developed within this group and through a permanent exchange and discussion, a list of needs and standard solutions are developed.

3 Application development

3.1 Goals

It was stated above that teachers hesitate to use software “off the shelf” and that they should have the possibility of producing their own tailored teaching/learning material. This ideal approach has limits which have to be taken into account.

This period of technological advance offers an increasing spectrum of possibilities for didactics, which at the moment cannot be theoretically predicted and discussed but only explored in form of prototypes and tried out in practice.

There exists a spectrum of topics which due to their complexity of demands for visualization, interactivity and flow of control cannot be handled by a single person, particularly a non-programer. Examples of this category are an integrated simulation environment for mechanics, a tool for learning how to design integrated circuits or a packacke for studying neural nets (see next section). Such programs have to be developed by professional teams and should meet the following demands:

- demonstrate the spectrum of didactical possibilities of the computer as a new medium;
- demonstrate the high degree of interactivity possible with this new technology and its uses in the teaching/learning process for that field;
- offer the highest degree possible for customization to tailor for local needs and preferences.

With the growing expertise of teachers and the existence of convincing proof for the effectivity and efficacy of these programms in teaching/learning processes, the barrier to acceptance is expected to decrease and more use of these applications in a variety of situations is expected.

The applications developed within CoLoS can be roughly divided into two groups:

- applications trying to cover basic concepts in physics - especially mechanics and electricity
- applications of interest at the conceptual level to engineers and computer scientists like neural nets, seepage, integrated circuits.

Their specific didactical purpose is manifold and content dependent and will be briefly outlined in the following section.

3.2 Reduction of mathematical overload

Those who are concerned with teaching basic concepts in science, especially physics, criticise the early use of mathematical language and the use of highly abstract terms and constructs at the introductory level.

As many evaluation studies have shown, such teaching falls short of its expectation for many students. The mathematical equations get in the way of any deeper understanding of the physical world [5] [6] .

The advantage of simulations in overcoming these problems is seen as follows. In traditional teaching, explanations and predictions are based on mathematical models like differential equations or a system of such equations in coupled form. Going back to first principles and trying to copy natural processes as closely as possible, provides a more direct approach towards understanding and a substantially reduced demand for mathematical qualification.

It is possible, for instance, to cover a major part of basic mechanics by a numerical solution based on Newton's 2nd and 3rd law in connection with different force laws, both in the form of difference equations. Similar solutions are possible with retardation and transmission effects, covering the field of oscillations and waves.

The replacement of differentials by difference equations and the use of basic principles, often much closer to direct comprehension than definitions in mathematical form, should have an impact on the structure of the curriculum, the selection of topics and finally on the efficiency and effectiveness of the teaching and learning processes.

Such major changes in the curriculum cannot and should not occur fast but have to be carefully monitored. A description of plans within CoLoS to deal with this kind of question about implementation and evaluation will be found in section 4.

3.3 Support for theorizing experimental results

The foundation of each scientific course is the real experiment and the collection of measured data to judge the truth or falsness of assumptions. No simulation can replace such a base. However, the didactic value of experiments is often overestimated. What is visible and obvious to the expert within an experimental setup, is often covered by a complex machinery of devices and connections and can be rather opaque and confusing to the novice. The time scale of an experiment, enforced by laws of nature, and the effort required to repeat it many times, often set further limits to its didactic value.

Computer simulations in close relation to experiments offer an added value in many aspects. The experiment can be schematically reduced to reveal its basic structure, the time scale is under control and can be adapted to individual needs. Alternatives to the real world can be visualized on the screen for direct comparison with the real situation to make the important parameters for determining its unique appearance explicit.

New kinds of experiments, which would take an unreasonable amount of time or effort, are now possible at the click of a mouse and results can be compared with no time delay.

3.4 Support of spatial imagery by 3-dimensional representations.

In teaching physics and technology many explanations and thought experiments are based on the use of spatial imagery.

Before computers, visualizations were normally reduced to 2- dimensions and often only to 2-dimensional graphs. With the support of modern workstations it is now possible to use the animated 3-dimensional representation whenever topological issues are involved.

Students have differing abilities in applying spatial imagery. However, they are all capable of dealing with structures and moving objects in directly visible 3-dimensional space. Such computer supported 3-dimensional representations can now be used as a tool for beginners, using representations they are comfortable and capable of dealing with. These representations can be transformed, stepwise, to more abstract levels to support the interpretation of abstract representation and more formal thinking.

Use of 3-dimensional images or graphs is based on the assumption that for the majority of students such form of representation is more suitable and fruitful than abstract formalism. The proverb "a picture can say more than 10000 words", often reported to orginate from China, summarises this believe. As Larkin and Simon [7] have pointed out, there are some provisos. A picture is rather rich in information, especially if it is a moving one. It can put a high cognitive load on the observer and ask for an extended cognitive capacity to organize this flow of incoming information in a constructive way. While equations could be learned by heart with some chance for later comprehension, such method is no longer possible with the presentation of knowledge in visual and animated form.

One of the major aims of the future evaluation studies is to define the values and limits of this approach and to determine the amount of addtional support needed by students with different abilities and interests.

3.5 Understanding and dealing with complex systems

Simulations are perfectly suited to support topics like telecommunication, integrated circuits, neural nets and the like. Due to their inherent complexity, these systems have to be modelled in different ways according to perceived needs and purposes. Sub-systems have to be taken as black boxes with input and output to deal with more abstract relations and functionalities.

This complexity is a major barrier to understanding and successful learning, if only print media or static pictures are available. The flexibility of animated computer graphics, controlled by adequate models and adaptable to individual needs, represents a substantial enhancement of teaching and learning in this field.

It is well known that relations or connections between two objects or events are best learned if these two events or objects are presented as close as possible together in space and time.

Computer simulations allow a new and promising approach to put this principle into practice. They allow one to run different modelling procedures and interactive change of important parameters with immediate feedback for the user. This requirement sets the "teaching simulation" apart from the "design simulation" where the designer can attend to other tasks while waiting for the results.

Immediate visual feedback is a feature of computer simulations which have already proven their unique didactic value. Their importance will further grow with further advances in hardware and software.

3.6 Exercise and training

In contrast to the teacher-dominated introductory phase, when a new topic is introduced, the following phase of repetition, exercise and training is usually characterized by different needs of different students. Computer assisted learning material is well suited to cope with this problem.

At university level the traditional courses for practical work and exercise are seen as major application fields for this technology. The same basic programs, shown in the lectures and introductory courses, can be used during this practical work, adapted to different levels of student ability and surrounded with a variety of support material like worksheets, guided tours, help files etc.

The development of such support material in close cooperation with the involved teachers is actually of main concern at different CoLoS sites. From this experience a collection of typical student reactions, typical questions, typical misconceptions etc. will evolve and serve as base for the development of so-called “intelligent” training and exercise programs. We see the development of such material, based on practical experience, as a possible and valuable goal.

Today our simulation environments depend on the presence of a teaching person to guide and assist the activities of the students and to prevent them from getting lost and consequently demotivated. The goal for the future is to create proper support for different simulation topics to increase the range and efficacy of independent learner activities.

4. Evaluation

The CoLoS project started from practical needs and a broad base of different field and teaching expertise, striving for common products and standards of quality by continuous discussion and cooperation. In such a bottom-up approach exploration is the main characteristic of the first phase while critics and questions about common evaluation practice are withhold until a critical mass of ideas and methods have been developed.

Usability tests and case studies as part of an iterative design cycle have been carried out at most CoLoS sites in close cooperation between the teaching and programming experts. This and the regular discussions of the developed products at project meetings together with the implementation of a unified programming structure has paved the ground for further integration.

During the coming phase of the project further steps towards a meaningful standardization of products with common look, feel, and didactical quality will be implemented including the following measures:

External feedback

Feedback from external field experts will be collected, following a common rating scheme and based on a well prepared demonstration.

Tryouts with focus groups

Normally a focus group will consist of a group of up to 10 end-users with a moderator. The moderator guides the group through discussion of an agenda of questions, paced by the group. Often the group will have a working version of the software as a focus. Focus groups are audio/videotaped and the data can be subjected to a variety of analysis techniques. Group techniques have the advantage of allowing new solutions to emerge: group members remind each other of events, encourage reconstruction, explore gaps in thinking, and overcome the 'not worth mentioning' problem.

Automatic logging of usage data

It is possible to build a data logging facility into the software itself which will record usage data in detail. Errors, response times, keystroke data, hypermedia choices, even mouse movements can be recorded and the data presented in suitably processed form.

Application of learning effectiveness methods

For summative analysis some important questions will be:

- What exactly has been learned?
- How well integrated with other learning is it?
- How durable is the learning?
- Is the learning deep or shallow ?
- What effect did the courseware have on motivation to study?

To address these questions, focus groups (of students), questionnaires, self-assessment tests, and both pilot studies and field studies can be considered.

The latter depend strongly on the availability of sufficient working places for larger student groups and the possibility of cordinating the computer assisted learning material with the curriculum and the examination.

At some CoLoS sites, where these conditions are fulfilled, such field tests will be carried out and will yield interesting and fruitful information about how well this new media enables us to reach our goal of improving knowledge and understanding of basic concepts in science and technology.

5. List of tools (developed or projected)

From each of the three categories

- tools
- applications developed by programers
- applications developed under Xdev

two selected packages are described in more detail while additional lists provide a survey of all available programs. These list are of course continually changing.

5.1 The Developement Tool “Xdev” (Murcia)

Global Description

Xdev is an authoring system that simplifies the creation of simulation modules. It runs on HP workstations under X windows and Motif.

Xdev has an interface builder and an interpreter based on a subset of C with some extensions. These two elements support the development of a graphical interface as well as the code for the model of the simulation and the response of it to user interactions. The program can run in interpreted mode for the development and testing phase, but faster and independent executables can also be generated. Using dynamic linking, Xdev also provides hooks for the more experienced programers to include their own functions.

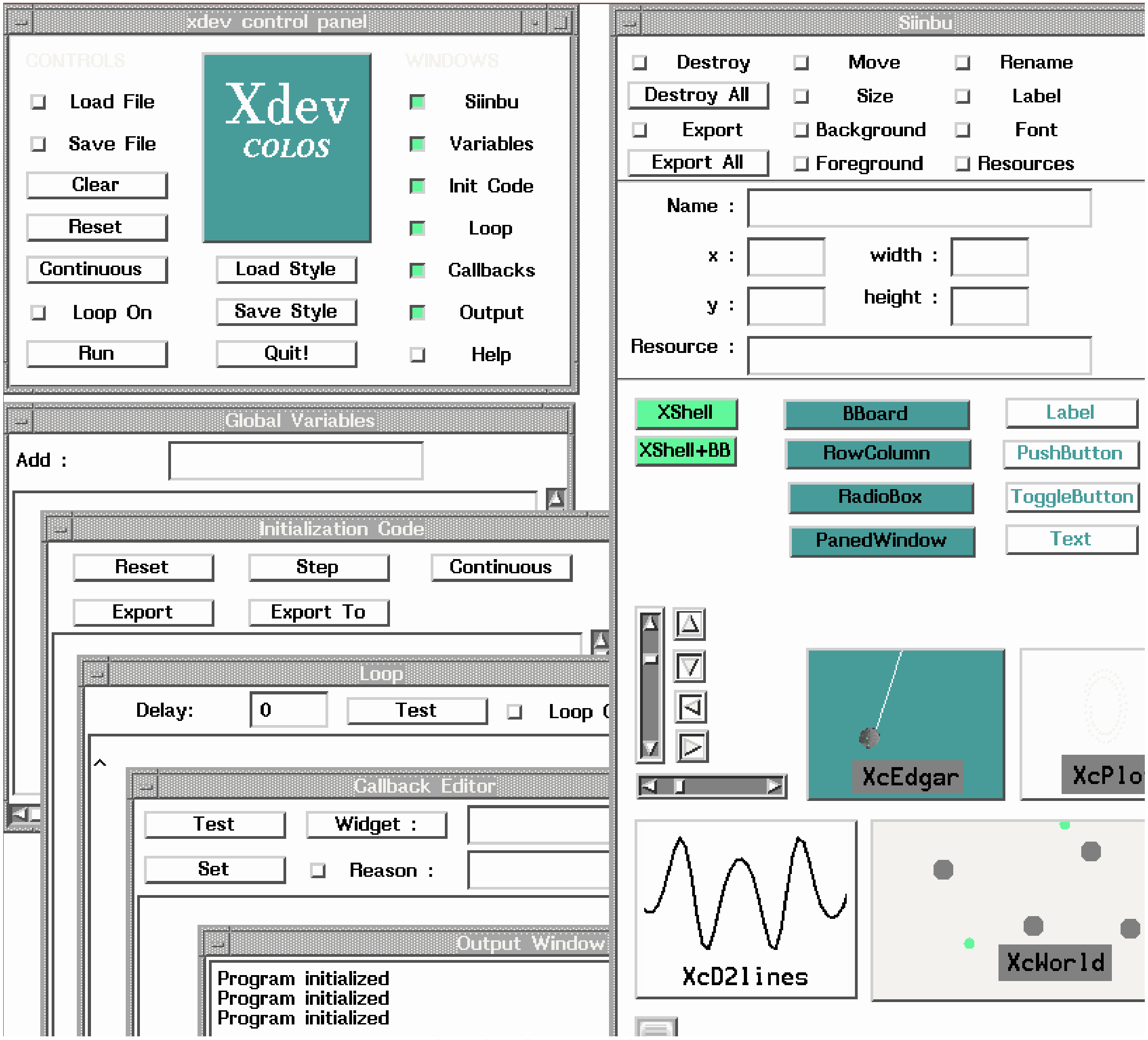
The whole system is extensible for new widgets and libraries, and is site and user customizable. The system is provided with some new widgets devoted to the display of scientific data in 2 and 3 dimensions, as well as new input widgets. [8]

Scope of Programming Work

Xdev hides most of the programming issues inherent to Unix, X-windows and Motif and lets the user concentrate on the model for the simulation. It is thus very well suited for beginners to this platform. It also speeds up the development of the interface and the assignment of callbacks (or responses to user interactions) and the setting of a periodic proccess, which makes it useful for expert programmers too.

Target group

Xdev is targeted to teachers of all kinds or science students, who are able to specify their algorithms, equations, models, in a high level computer language, but who are not expert programmers or Unix users. It allows them to access powerful machines and add relatively sophisticated graphical interfaces to their programs.



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Program initialized
Program initialized
Program initialized
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Fig.1: Xdev displaying all its components

Available help

Xdev comes with a manual in printed form and has some built-in browsers that help navigating through Motif graphical components or widgets, providing a list and a short description of their resources (customizable internal values) and callbacks (possible responses to user interaction). Most frequently used widgets are presented in a graphical way in a pick-and-use panel, thus facilitating access. There is also a tutorial to aid in creation of simple programs. A cook-book for individual components and of common interactive situations is being prepared. A set of complete examples, some of them of considerable complexity and of scientific interest is included in the distribution package.

Status

Xdev is now a stable product. It will be subjected to improvements suggested by users. Speed is not a critical issue because executables can be generated at any moment during the development phase, and these show the speed of the final product.

In general, it can be said that the system produces executables that are as fast as those generated by an expert programmer. Right now, the system runs only on Hewlett Packard series 700 workstations with X11 R5 and Motif 1.2. .

Because the system produces executables, the C development software package (which is not included in the standard HP-UX distribution) has to be installed on the system.

Evaluation

The program has been used extensively by a small group of teachers and students (both undergraduate and post-graduate) who have a basic knowledge of programming. On average, they were able to produce their first complete program in their own scientific domains in about 3 to 4 weeks (working 1 to 2 hours daily). The teachers who continued developing with Xdev become adapt and work faster. Because they had to concentrate more on their subject than on programming issues, they were very keen to use Xdev, and very pleased with their results.

5.2 The program specification tool “SoftSpec” (Cambridge)

Global Description

SoftSpec is a tool designed to improve communication in a group working cooperatively and perhaps remotely from one another. It is a tool to allow all those interested in the outcome of a software project to specify their requirements in a clear and logical way. The requirements specification document is upgradeable throughout the project and and is available in a simple easily readable form to all members of the project.

SoftSpec can also be used to monitor progress on upgrades or maintenance to software. It runs on HP workstations under X windows and Motif.

Scope of Programming Work

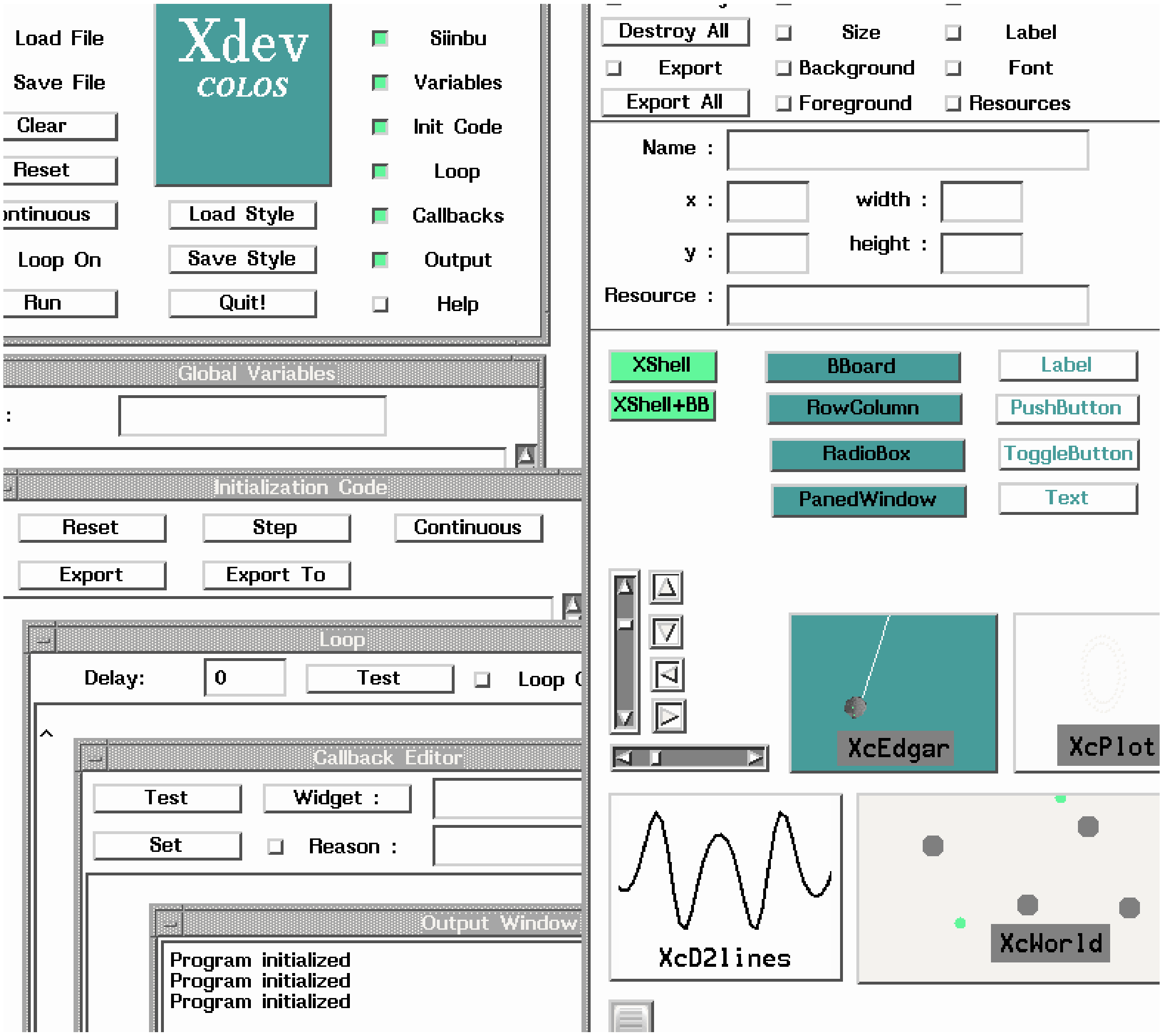
The work made easier by this product is the work that takes place before programming begins, i.e the production of the requirements specification.

During the requirements specification stage, information must be acquired from the various clients to define the final software product. Frequently there are incompatible requirements in a specification, which often do not become apparent until too late in the project to do much about them. SoftSpec provides clear evidence of conflicting requirements at the start of the project enabling misunderstandings and conflicts to be resolved before programming begins.

The requirements of a software project (tool or application) can be specified as a series of demands and wishes. Demands are requirements which must be met and wishes are requirments which, under ideal circumstances, should be met. Wishes are weighted according to their importance, thus aiding in trade-off between incompatible requirements and in the evaluation of potential solutions.

The requirements are grouped in various category headings such as “Timescales”, “Educational objectives” - these categories can be altered to suit the requirements of individual projects. Many users can contribute to a project specification, and the software keeps track of who specifies a requirement as well as the status of that requirement (pending, complete or obsolete)

The requirements document can be output as a .tex or .dvi file (easily convertable to postscript) and requirements can be sorted by category or in order of importance.



Delay: 0

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Program initialized
Program initialized
Program initialized
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Fig.2: Display windows

Target group

Any member of a project team can use SoftSpec to specify software requirements. No programming expertise is required.

Available help

Help on the use of SoftSpec is available on-line within SoftSpec.

Status

The tool is currently functional, but a number of modifications are planned to enhance its overall usability.

Evaluation

SoftSpec is used by students at Cambridge University Enginering Department as part of collaborative design projects where teams of engineering students work to build robots capable of performing a given task. (At least 24 students a year use SoftSpec). It will be used by the INTERACT TLTP project as a project management tool where it will undergo formative evaluation

5.3 List of further tools

The Programming Tool “Edgar” (Lyon)

Edgar stands for EDitable Graphics ARea, and is a Motif widget to display, animate and edit graphics. It is particularly well adapted to display moving or self-modifying shapes and to be used as the main display area of graphics editors.[9].

The Graphic Tool “Pixidor” (Kiel)

Pixidor is a general purpose pixel editor, supporting full scale pixmaps. It closes the gap left with X11R4 where no such tool is provided. Besides the basic drawing operations Pixidor offers different block operations and allows to handle a collection of pixmaps.

Stripchart recorder (Lyon, Berlin)

A Motif widget for recording values given by the simulaiton as function of time

Graphical data input device (Kiel)

A tool to allow the end user to interact graphically with the system for input of coordinates within a two dimensional diagram.

Line oriented editor (Lyon)

This application will enable the user to interactively create any graphics made of lines (i.e. no pixmaps) and to save them for later re-use inside of any application, provided that application uses an Edgar widget for display.

6. List of developed simulations

6.1 The simulation program “xyZET” (Kiel)

Global Description

The simulation program xyZET offers the possibility of visualizing animated objects in 3d and the simulation of attractive and repulsive forces. All didactically meaningful parameters are accessible for interactive variation. The program is intended to support the presentation of concepts during lectures and to form the base for the arrangement of exercise material to be worked at by individual students.[10]

Scientific Content - Important Features

The program covers a series of basic concepts of mechanics and electricity which form part of each introductory course in physics.

The main concepts are:

- Kinematics
- Kinetic energy
- Newtons laws
- Conservation of momentum
- Conservation of energy
- Hooks law
- Gravitation
- Charge, field lines
- Coulomb interaction
- Equipotential surfaces

Besides the introductory level, some more advanced topics from solid state physics (lattic symmetry, van der Waals forces) and relativity (relativistic addition of velocities, retarded potential) are included.

Didactical Approach

The standard approach in introductory courses in physics is based on demonstrations of experiments and direct comparison of the results with abstract mathematical expressions. This is accompanied by laboratory work, often not synchronized in sequence and time.

The simulation presented here as a new medium or tool for teaching, offers an intermediate step between real experiments and abstraction. By shifting all the mathematical overload towards the machine, the results can first be presented in visualised form, serving as pre-organizer for the learner to build a knowledge base of qualitative concepts.

The need for mathematical tools and integration of qualitative and quantitative methods for an effective reduction of complexity can be demonstrated convincingly.

Implementation

In its basic form the program presents a cube which can be rotated, zoomed in and out under various perspectives. The simplest use of this “world” is to load prepared files to present any kind of 3-dimensional object in animation (rotation).

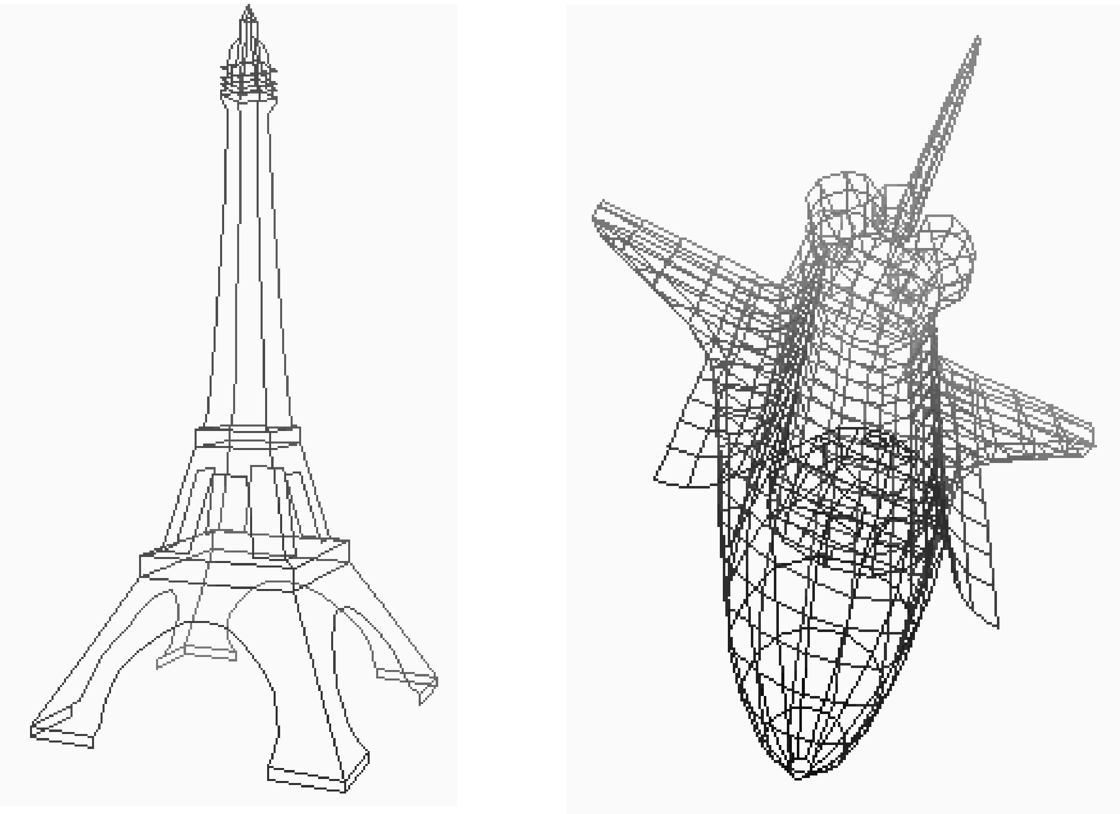


Fig.3: Objects displayed in 3D for rotation and zooming

As a more interactive use, small geometrically simple objects can be placed at any position with variable parameters like, coordinates, velocity, mass, charge. Forces of different kind like gravitation, Coulomb, forces of springs of different length (pull, push, both) can be set and monitored. The centre of mass can be indicated as well as the kinetic and potential energy.

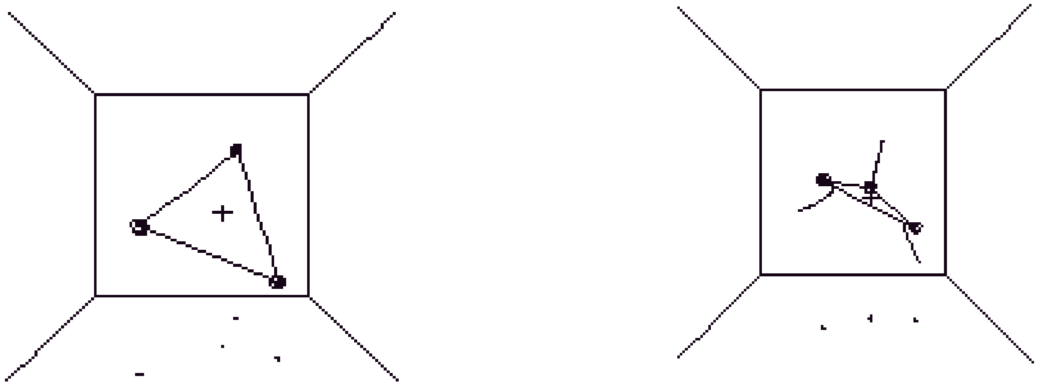


Fig.4: Motion caused by spring forces with center of mass at rest

This arrangement offers a variety of experiments like inclined throw, pendulum, collision, elastic deformation, vibration, waves, planetarian motion.

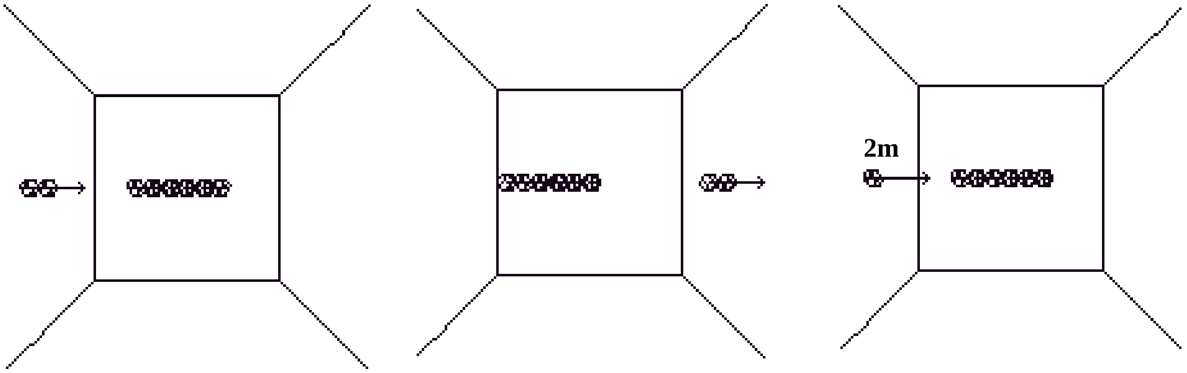


Fig.5: Collision of two balls same velocity - Collision of one ball doubled mass

The effect of Coulomb attraction and repulsion between particles, enclosed in different parts of the volume, can be shown, together with field lines or equipotential surfaces in animation.

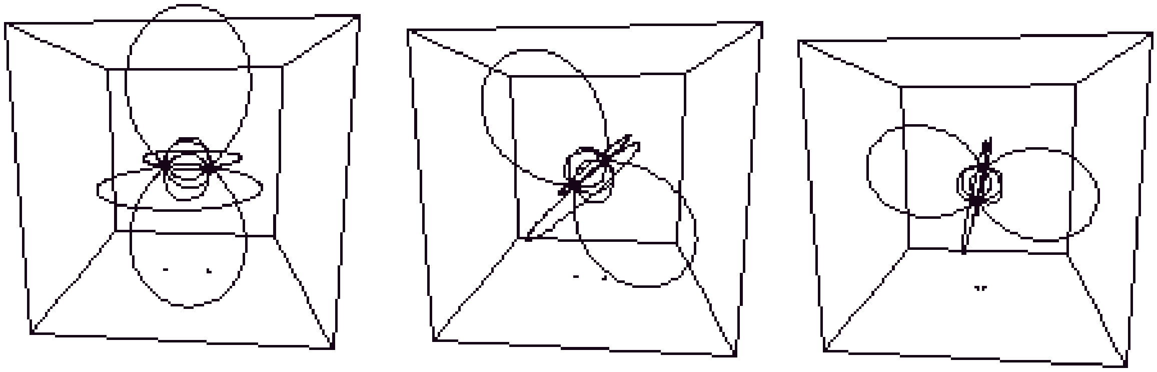


Fig.6: Dipole and field lines in motion

The model used is based on Newtons 2nd law, computing the forces (acceleration) for each particle, using finite differences to find the velocity and the displacement.

A high resolution screen is indispensable to give a satisfying presentation within a “3d-world” in animation. The influence of many particles (many = > 50) is necessary to demonstrate any effect due to bulk material. The computational power needed for this task is offered today only by high powered workstations.

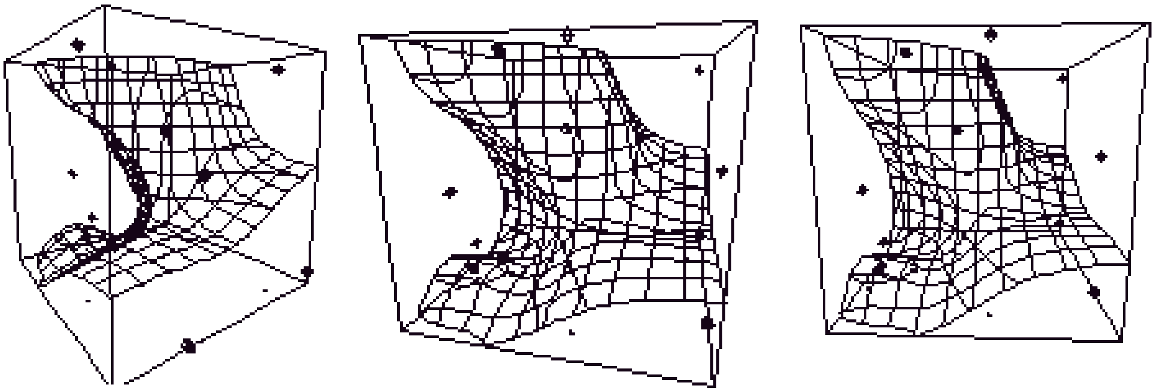


Fig.7: Surface of equipotential (3 positive and 3 negative charge carriers)

A documentation with a full description of the funtionality of the user interface, the didactical principles involved and a list of proposed student activities is being developed and will be available during spring 1994.

Target group

The simulation program should be useful during lectures, mostly on Sec. II and university level in parallel with experiments. It could also be integrated into lab work where additional support material would have to be provided by the teacher. It may serve as an environment for exploration and practice for the motivated individual learner.

Evaluation

Evaluation has been carried out during development in fragmented form and only with small groups. After finishing the documentation the program will be offered to selected teachers for testing. A controlled evaluation study will be carried out during 1994.

6.2 The simulation program “INNE” (Milan)

Global Description

The application INNE - Interactive Neural Network Environment - is a neural network simulation environment for UNIX workstations. Its aim is to provide a tool for modelling and experimenting neural networks: it allows the user to interactively design, train and test neural networks and to visualise their behaviour. The net editor allows the user to deal with large networks and to define their structure graphically.Different neural models are available to define the network behaviour.

Scientific Content

Neural networks are computational models that perform computation via a densely connected net of very simple processing elements. This idea is an abstraction based on the behaviour of biological nerve cells. The application provides the background to master with this paradigm of computation; it covers three basic models of neural computation: back-propagation networks, Boltzmann machines, Hopfield networks.

The back-propagation is one of the most popular neural network paradigm, and it is used successfully in many applications that require pattern-matching: after a supervised learning phase to establish the connections weights, the network responds to an input pattern by producing the corresponding output pattern.

The Boltzmann machine can be used to solve combinatorial problems by approximation: it implements a probabilistic optimisation algorithm, called simulated annealing, able to avoid locally optimal solutions. A learning algorithm allows to use this model also for classification problems, even though to this purpose the back-propagation learning algorithm is more efficient.
The Hopfield model can be seen as a particular case of the more general Boltzmann machine; it is able to find the locally optimal solution nearest to the starting solution. It performs a gradient descent method, which is the deterministic version of the Boltzmann machine simulated annealing.

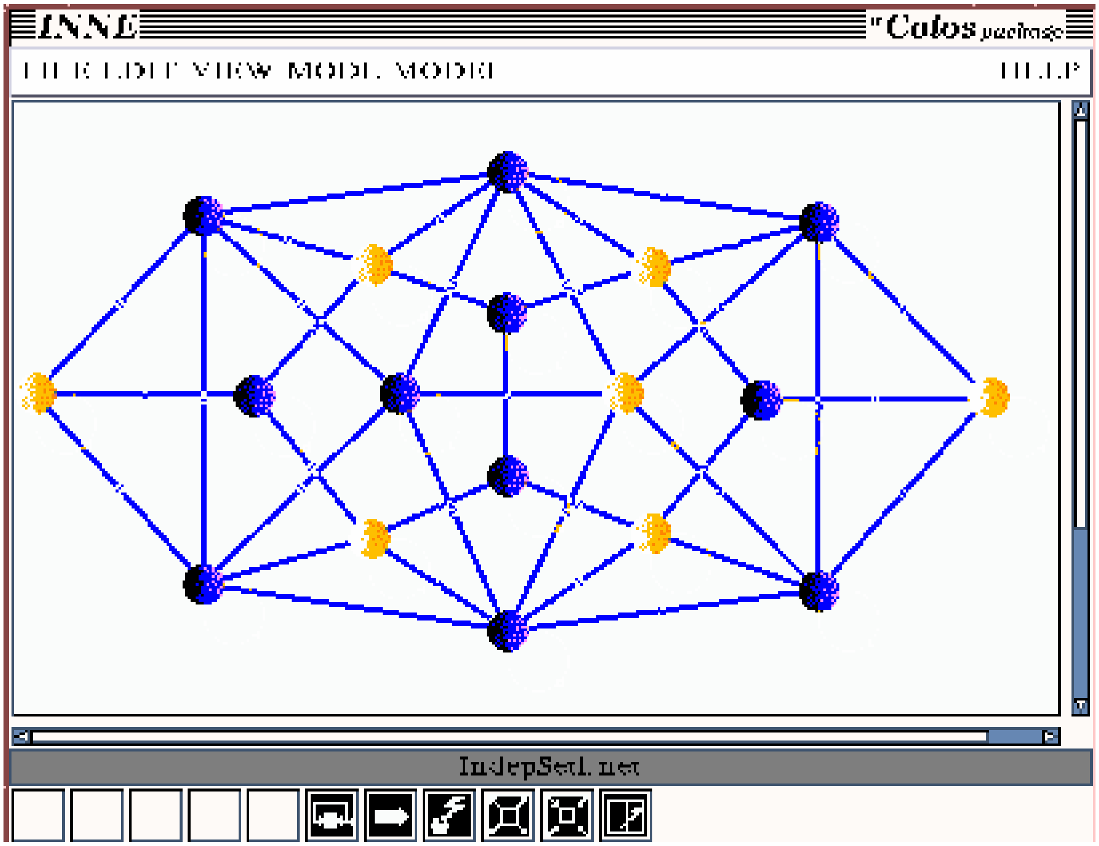
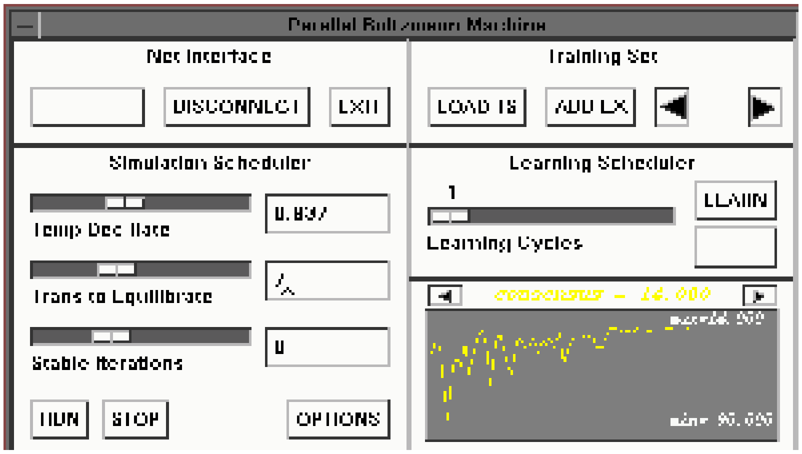


Fig.8: Example of a Botlzmann machine. The net solves the problem of finding the greatest node subset, which are not connected with each others



Temp Dec Rate 0.837

Trans to Equilibrate 4

Stable Iterations 0

Learning Cycles 1

Fig.9: Control pane

Didactical Approach

The standard didactical approach to this subject is mathematical: different models are introduced, formally analysed and some very simple examples are shown. In contrast the emphasis of this application is on experimenting and visualising. This last feature and the ease of interaction are the main difference comparing to other simulators. Learning session and computational processes can be stopped any time to allow users to modify the network interactively.[11]

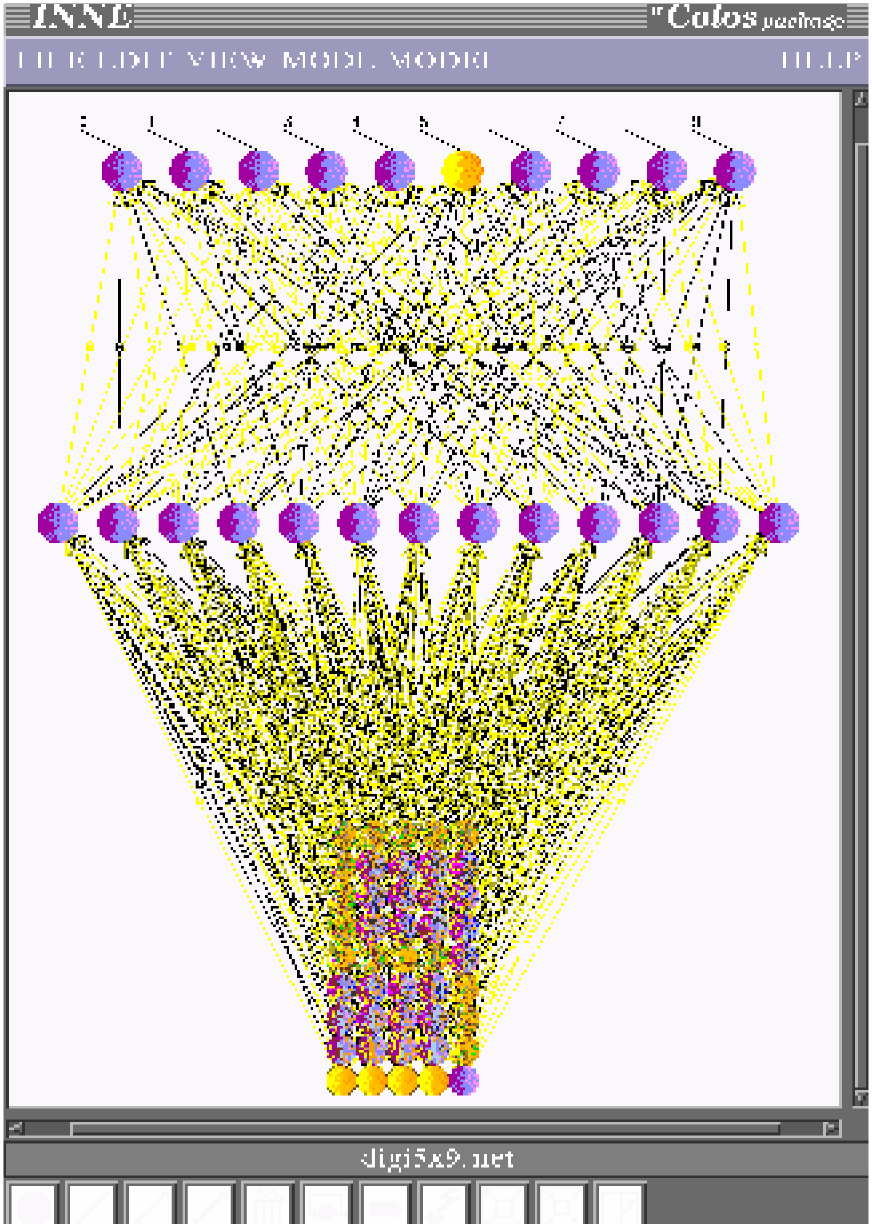


Fig.10: Example of a net trained by the back error propagation algorithm. The net recognises hand written digits: the input pattern is provided in the bottom node matrix and the output nodes are labelled on top.

During learning phase and simulation statistics are graphically displayed so that processes can be easily monitored. The most important educational aspect of the application is the possibility of exploring different models and different activation modes for the same model in a simple way and comparing them with each other.

Implementation

The application consists of several modules: - a simulator kernel, the main part of the application, that manages the net internal representation and the memory, written in C so that it is portable - the graphic user interface with the graphical net editor - the modules of the different neural models - some tools, such as: a text editor, and an example editor to edit easily the training set files.
The net editor is a very powerful tool to design neural networks, that typically consist of thousands of elements. Every implemented neural model has its simulation panel; a panel can be connected to the net and it is used by the user to drive the computation processes, and by the application to display simulation reports. Two original cooling schedules for the Boltzmann machine are implemented. This application requires high level workstation both because of the computation complexity and of the visualisation for educational aims.

Target group

The application is intended for students of computer science interested in neural computing. It covers topics usually introduced in university courses on neural computing. It can be used by students directly or by teachers in classrooms to show effectively different neural models. Students can explore the topic and implement in the environment significant neural networks to carry on projects that teachers can ask them to do.

Evaluation

The environment has been only informally tested by scattered group of teachers and students, while it was under development. It will be used in a course offered at the Cybernetics Department, , as soon as it will be robust enough for the didactic laboratory.

6.3 List of further applications

The simulation program “BRAKE / HEATFLOW” (Berlin)

This program simulation simulates the flow of heat in a cubic volume divided into prismatic elements with one of three possible shapes. It visualizes the temperatur behaviour of a disc brake as a funtion of distance and time.

The simulation program “ DACOTA” (Berlin)

An active interface, representing a RS232 connection between two devices, is presented to the end-user, offering different possibilities for change of parameters and visualizing the functionality of this interface.

The simulation program “SEEPAGE” (Cambridge)

SEEPAGE is a simulation application which allows the user to explore the migration of ground water through water retaining structures. The program does this by generating flownets for a series of commonly occuring geotechnical problems.

Integrated Circuits - VHDLEDIT/VHDLSIM (Delft)

The application VHDLEDIT/VHDLSIM allows the creation and simulation in pseudo real time of digital circuits. It uses a small sub_set of the hardware description language VHDL to describe the circuits and allows the creation and simulation of a lot of (basic) digital circuits. Pulse generators are available to provide continous input_stimuli to the circuits and stripchart recorders and number_displays to show results. The status of the ports is also shown in the circuit.

The simulation program “Phasor” (Edinburgh)

Phasor is a set of applications which enable the user to interactively build up an understanding of phasors and their uses in a wide range of electrical engineering areas. The presentation links the phasor and the time domain picture dynamically, allowing parameter changes to be explored. The use of multiple phasors allows both frequency and time domain illustrations to be displayed and ultimately signals to be introduced[12].

The simulation program “TeEl” - Transmission Line (Kiel)

This program simulates the transmission of voltage and current steps or continuous changes along a one dimensional double line, based on numerical solutions of the telegraph equations . All relevant parameters can be changed interactively, allowing for a broad spectrum of phenomena to be studied (dc, ac, high frequency) [13].

The simulation program “rectif” (Lyon)

“rectif” is a program to study the single-phase bridge rectifier. The switches may be either diodes or thyristors and the load may adopt several different configurations. The resulting waveforms are animated while time flows and to follow any input parameter interactively modified by the end-user[14].

The simulation program “mField” (Lyon)

“mField” is an application to study how to generate a rotating field inside the airgap of a rotating machine. The field may be generated using either one, two or three inducting currents, and the phase of these currents may be adjusted to result either in a pulsing or a rotating field.

The simulation program “Circuits” (Lyon)

Circuit is a microworld to study electrical circuits. The circuit can be interactively entered, stored on file, simulated and the simulation results may be graphically displayed and animated versus time or parameter change .

The simulation program “MICROWAVES” (Lyon)

“mWave” is a microworld to study the microwave distribution in a waveguide, which may be either of rectangular or circular cross- section [15] .

The simulation Program AUTOMATA (Milan)

AUTOMATA is a learning package for modelling automata and experimenting with grammars.

The simulation program SimCatS (Oxford)

A simulation of catalysis on surfaces is being developed, through which the user will be able to both study the molecular basis of catalytic reactions, and investigate the experimental consequences of changes in the chemical and physical parameters of the species involved.

The simulation program “elCur1-5” (Palo Alto)

elCur1-5 is a set of applications which allow the user to observe delayed interaction of electrons in conductors and to study the associated phenomena. The presentation consists of controllable dynamic graphics displays which provide means for interactive variation of relevant parameters.

The simulation program “TREEDEMO” (Paris)

This application supports the teaching of recursivity and binary trees concepts. It allows the user to visualize recursive tree traversal algorithms with a graphical representation of the data structure and the stack evolution.

The simulation program “POTENTIAL” (Paris)

This application allows visualization of trajectories of particles in a central field.

The simulation program “MAXWELL’S DEMON” (Paris)

This application demonstrates the dynamic statistical distribution of the velocities of colliding particles in an adiabatic container [16].

7. Applications developed by non-programming experts using Xdev

7.1 The simulation program “WAVES” (Murcia)

Global Description

The WAVES program is intended to support the presentation of concepts about waves during lectures. It has been developed with Xdev.

The application introduces the basic concepts of the topic providing an efficient tool to simulate different situations. A main window appears when the application is running with a display where waves under a string will be shown. A toggle button calls a control panel from which a wide variety of features can be selected and changed.

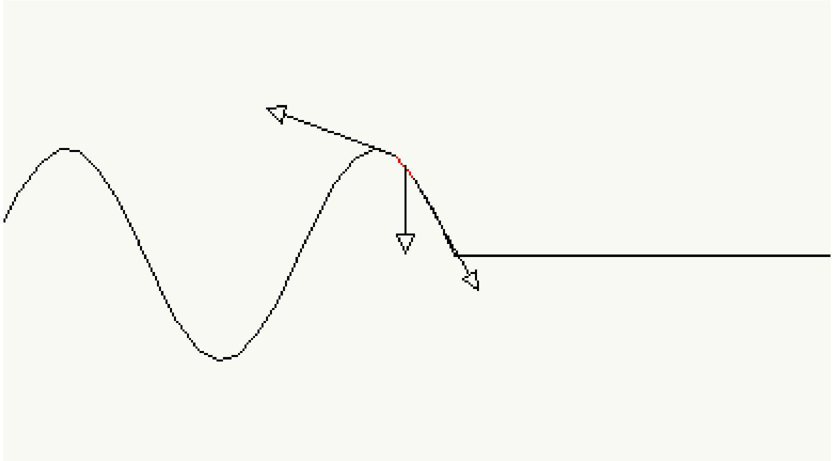
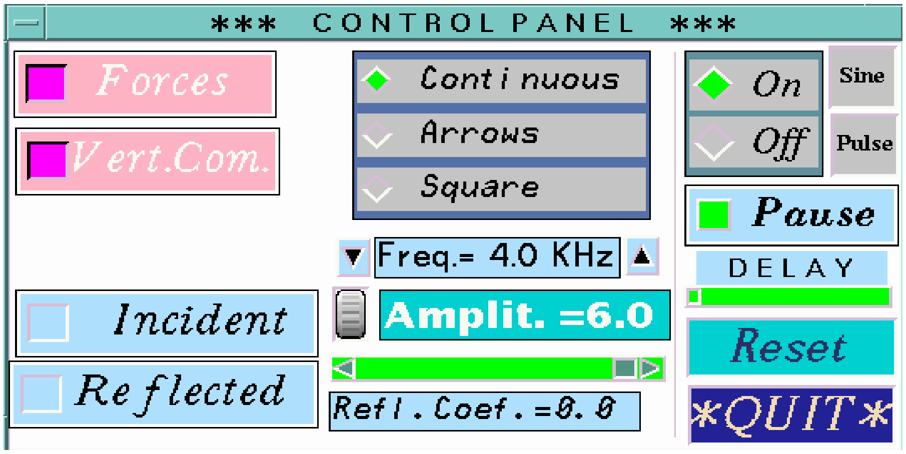


Fig.11: Display window



*** CONTROL PANEL ***

Freq.= 4.0 KHz

Amplit. =6.0

Refl.Coef.=0.0

Fig.12: Control panel

Scientific Content - Important Features.

WAVES can show the propagation of a perturbation, the dynamics of the propagation along a string, the superposition of travelling waves of opposite direction, reflection at the end of a string with different reflection coefficients and standing waves.

The topic is important for introductory courses and first university level. It should be of special interest for those students who do not have a deeper knowledge of mathematics but need to acquire a qualitative understanding about waves, e.g. students of life science.

Didactical approach

The standard approach to this topic is to introduce definitions and to use mathematics to describe the phenomenon.

Waves are a classic topic where animation is an important feature in the teaching process. Using the simulation program WAVES, teachers can use a dynamic medium to teach a dynamic phenomenon. Additionally they have the opportunity to explain these concepts without any mathematical overload. This program will be implemented within an Electronic Book about this topic.

Implementation

The model used in the simulation is based on a fundamental feature of waves: the perturbation in one point at an instant is equal to the perturbation one instant before in the preceding point.

To show three different displays with animation and modification in real time the parameters of the model makes use of high speed machines with outstanding graphic capabilities. These features are regarded as essential to achieve an adequate appearance of the simulation.

An online text describing the main aspects of the program is available.

Target group

The application is useful to teachers who want to introduce the basic concept of waves. It can support exercise material for self study.

Evaluation

An evaluation will be performed by some teachers and smaller groups of students. A chapter of an Electronic Book, written for this application, will be used. It is expected that the introduction of a qualitative understanding of basic concepts will support the later introduction of mathematical methods, especially the wave equation.

7.2 The simulation program “PARTICLES” (Murcia)

Global Description

The application „Particles“ allows the simulation of the dynamics of particles which can interact through different forces and/or by external fields.

“Particles” is an application developed with the CoLoS development tool Xdev.

It was originally developed in 2-dimensions and it is now also implemented in 3-dimensions. It takes many ideas from the “xyZET” application from Kiel.

Scientific content - Important Features

The application allows the design of different experiments covering several concepts in mechanics and electricity, at an introductory level:

- Kinematics (velocity and acceleration).
- Dynamics (Hooks law, gravitation).
- Energy concepts (potential and kinetic, conservation).

- Coulomb interactions.
- Magnetic force on moving charges.

Besides the already implemented interactions and external fields, the user, if an Xdev expert, can access hooks in the source program to add additional interactions or external fields. This make the application into a more general environment where the teacher can design his/her own class to cover a specific topic of interest.

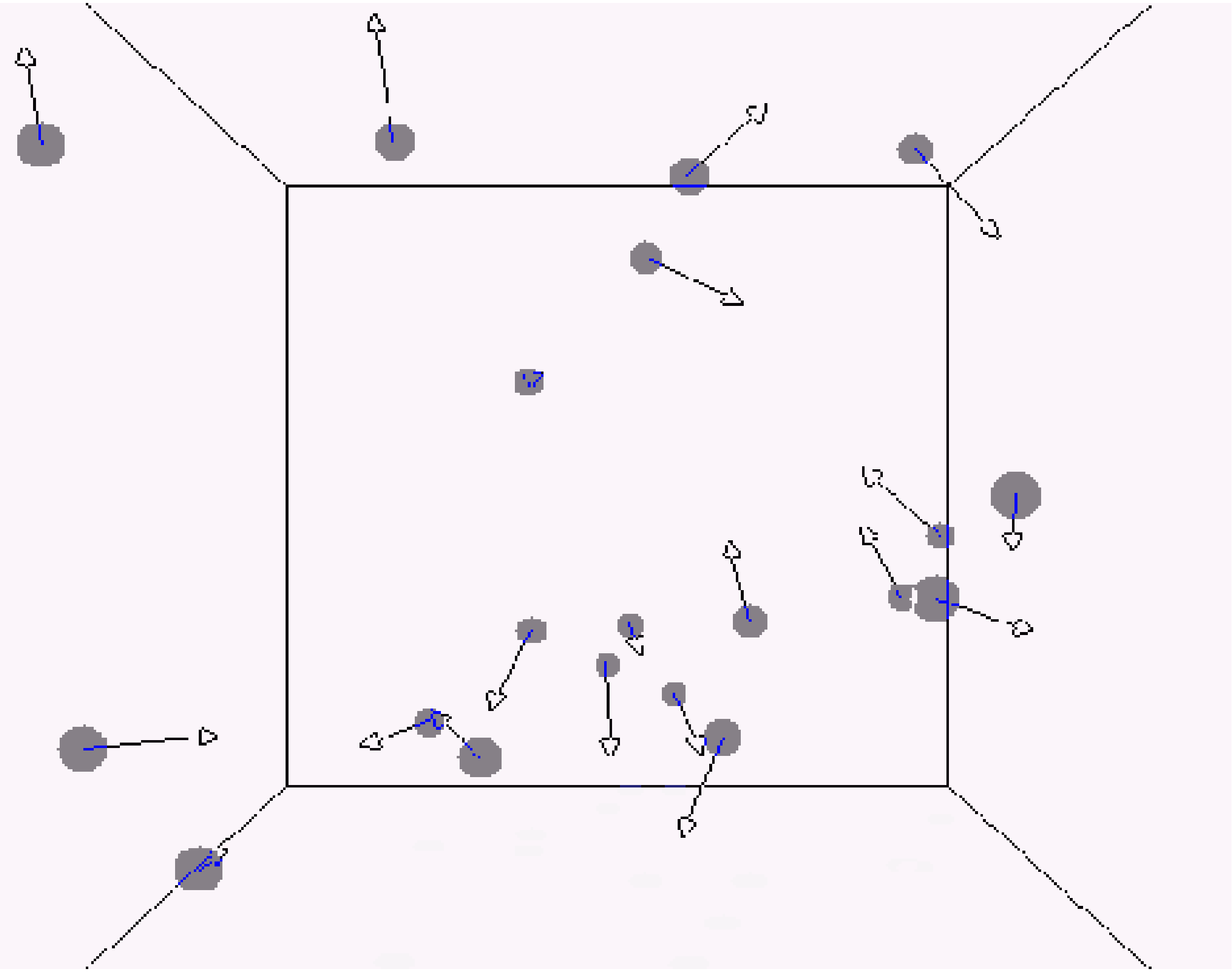


Fig.13: Display window
Particles with indication of velocity

Didactical Approach.

The standard approach to cover the above mentioned topics can be found in any general physics text book, where the student can find everything related to the mathematical description of forces and closed form solutions to different problems. Sometimes experimental work is available to show the behavior of very simple systems.

With this application, an introduction to the basic concepts can be made, which hides much of the mathematical load usually involved when teaching those concepts. The graphical animation also allows a deeper understanding of those concepts, preparing the student for a much easier introduction to the mathematics behind the formal approach. The behaviour of complex systems, difficult to be dealt with in terms of an analytical approach, can also be shown.

Implementation

This program has been developed with Xdev with extensive use of the XcWorld or Xc3DWorld Widgets.

The application shows two different panels. The first presents the simulation, the second is used as a control panel where the user interactively defines the kind of interactions or external fields acting on the particles. The velocities and acelerations for all the particles can be graphically displayed.

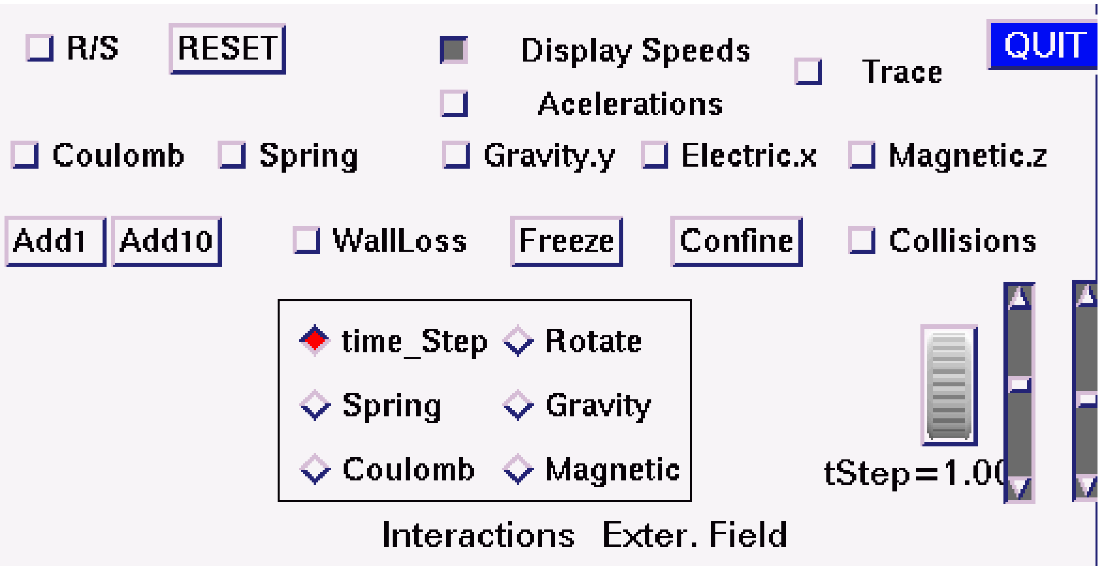


Fig.14: Control panel

The particles are mouse sensitive for moving and changing of velocity. A strip-chart recorder has been implemented to show different quantities (energies, positions), allowing the students to link the visualization on the screen to standard graphical representations found in text books.

A numerical finite difference algorithm has been implemented to integrate Newton’s second law: The force on a particle is first computed in terms of the present interactions and external fields. Then the new velocity is computed in terms of the aceleration and old velocity. Now the new position is computed in terms of the velocity and old position. This process is iteratively applied to all particles.

With a high powered workstation, the number of particles that can be involved in a simulation with no appreciable loss of speed is around 100. This is enough to get an idea of the behavior of complex systems. For instance, the electrostatic behavior of a conductor with fixed positive ions and free moving electrons can be easily shown.

No additional help, besides a self-explaining user interface design has been implemented.

Target Group

„Particles“ is intended to be used for three different purposes:

- As an environment for learning basic physics concepts at an introductory level, guided by a teacher or in a self-supporting way. For this last possibility, some additional support material should be provided by the teacher (parallel experiments, assignements, etc.).
- As example for Xdev users where a novice user of this authoring system can find many suggestions for solving his/her own design problems.
- As a general environment where the Xdev-expert teacher can design his/her own classes, by

modifying or adding interactions or external fields needed to show the particular phenomena under study.

Evaluation

Evaluation has been carried out only in the second modality mentioned above. This application was one of the first made with Xdev and has been taken as an example for different teachers to design their own software using Xdev.

It will be used during the present university course (introductory level), as support for teaching basic concepts in mechanics: velocity, aceleration, momentum and energy conservation. This will be done in combination with the Electronic Book application.

7.3 List of further programs developed under Xdev

The simulation program "CYCLOTRON" (Murcia)

The trace of a charge carrier within a cyclotron is simulated. Various parameters can be altered.

The simulation program "PARTICLE PHYSICS IN TWO DIMENSIONS" (Murcia)

The program allows the simulation of interaction between particles due to a variety of forces. Some topics that can be covered within this application are: Newtons Laws, planetary motion, Coulomb interaction, the concept of metal (electrostatic behaviour), cyclotronic movement, etc.

The simulation program "DIELECTRICS" (Murcia)

Two applications have been developed concerning the basic polarization mechanisms of dielectrics: electronic and polar (distortion and orientation).

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