# Cooperative Distance Learning with an Integrated System for Computer Assisted Laboratory Work.

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**Key Words:**
Computer Assisted Instruction, Computer Assisted Laboratory, Cooperative Learning, Distance Learning.

**Abstract:**
We are introducing a really integrated system for Computer-based Experimental Science Learning which contains all the required hardware and software components. Unlike simulation systems, our system allows for the possibility of performing real laboratory experiments. The system has a multilevel structure, separating in each level the corresponding physical and logical components, allowing the use of several educational techniques and methodologies: Discovery Learning, Distance and Cooperative Learning.

## 1. Introduction.

The aim of this paper is to present an integrated system designed for help in the development of laboratory student work called ED-SIPLAC (in Spanish: Sistema Integral de Prácticas de Laboratorio Asistidas por Computador -Computer Assisted Integral Laboratory Work-), whose main aim is to provide teachers all the necessary instructional tools for performing real scientific experiments with their students. In the actual version we restricted the facilities to physical matters: electrical fields, magnetic fields, mechanics, thermometry and thermodynamics, continuous and alternate current circuits and geometric optics. Now we are developing new different prototypes.

The ED-SIPLAC system has a modular architecture, so that each prototype consists of several modules and some of them could be used in other prototypes. The hardware and the software components in the system have been designed to work together within such modular architecture, which means that each physical or logical component will belong to a module. In this way, future users in schools will be allowed to obtain complementary components already available.

In terms of user interaction, the system is divided into levels; from the one that accomplishes the experiment's physical control (the internal one) to the one which carries out the interaction with the user-student (the external one). It is then possible to establish a pedagogical strategy adapted to the particular situation in each school. For example, we could perform the experiments in a minilab (with only one prototype and a PC), allowing the students to review their experimental results at some other time and place. They will be able to visualize, analyse or draw their conclusions with a personal computer.

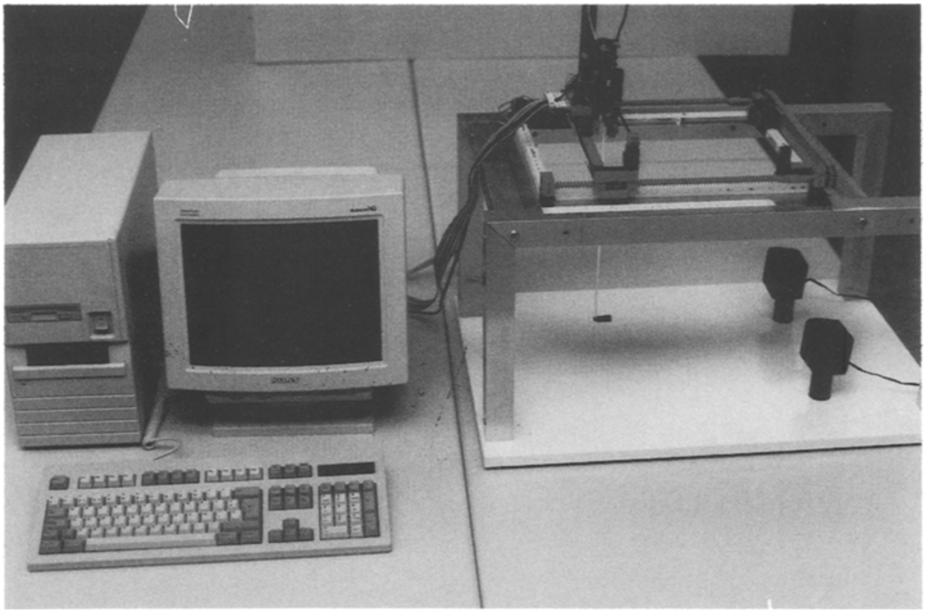

**Fig. 1.** A PC with the ED-SIPLAC System.

## 2. The System's Architecture.

As we said before, ED-SIPLAC has a modular architecture, so that the prototype designed for each subject matter (see figure 1) contains several modules which could be specific for this prototype or reusable within another.

In these applications the most frequently used modules are the following:

- *Experiment Tray*: This is a three-dimensional tray where experiments take place. The measurements are always taken in 3-Dimensional space and they could be visualized, animated or processed in 3-D.
- *Mobile Robot*: Could be common for several prototypes. It is possible to move the robot in the 3-D space inside the experiment tray. The movement mechanisms are coupled inside the tray.
- *Mobile Sensors*: Depending on each prototype, the mobile robot includes a sensor to catch the corresponding measurements.

- *Fixed Sensors*: In other prototypes where the mobil robot is not used, there are fixed sensors installed and connected inside the tray.
- *Robot Control Card*: This has been developed (microprogrammed) as a part of this project, allowing the robot's general control from the PC.
- *Sensor Control Cards*: Some other cards have been developed for sensor control for those prototypes not using the mobile robot (see figure 2).

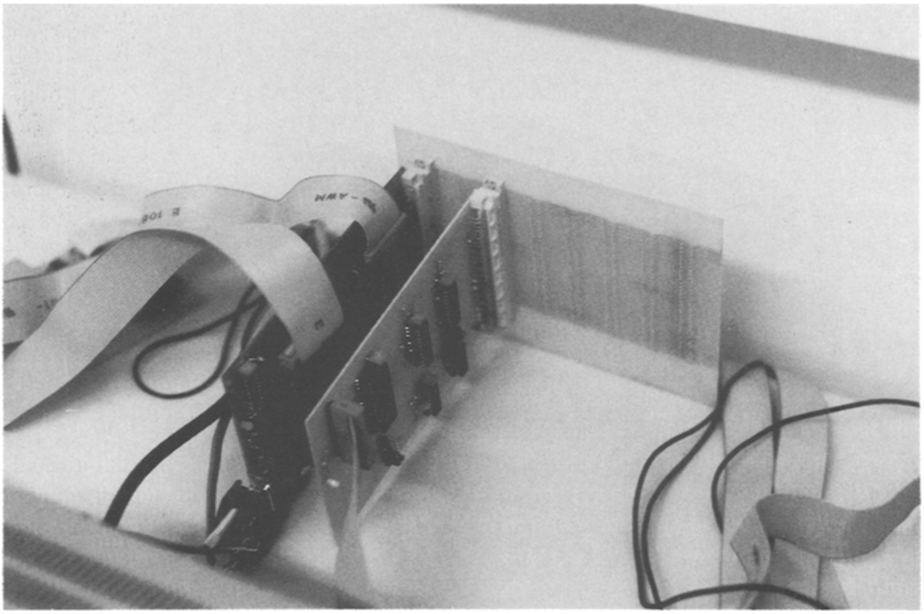

**Fig. 2.** Ultrasonic Control Cards for Experiments in Mechanics.

- *Control Software*: Allows the researcher (teacher or student) to interact with the system and control the experiments.
- *Analysis Software*: Designed in a thoroughly visual and graphic environment, it permits visualization in 3-D or 2-D, to make animation (temporary replay), and calculate or represent physical magnitudes (see figure 3).
- *Complementary Parts*: There is a complementary set of resources for each prototype that can be used in different experiments depending upon their specifications.

For instance, for the experiments in 'Mecanica' - movement analysis of one or several mobiles with ultrasound technical mediated detection (Flores, 1993) - the system is extended with fixed ultrasonic sensors and mobile ultrasonic emitting.

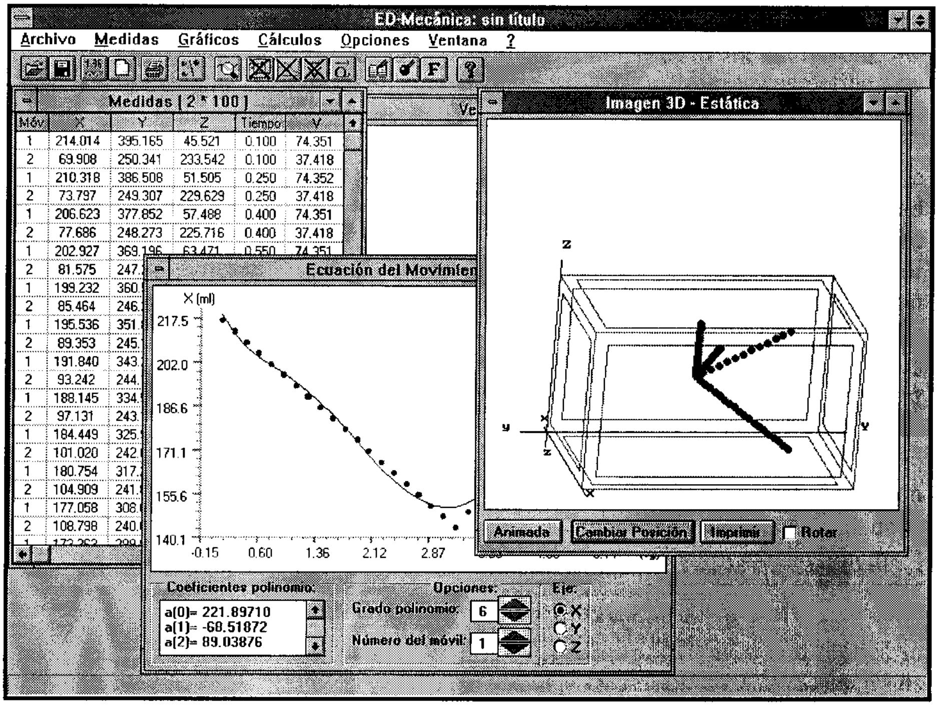

Fig. 3. User Interface for 'Mecanica' (spanish version).

## 3. Educational Facilities.

*The multilevel modular architecture of ED-SIPLAC system allows for the physical and/or temporal separation of the real experiment from the student's observations and study.*

The teachers could design their own 'experiment libraries', and then the students could record their experimental results and use them later with the analysis software. The students will have a collection of experiments on each topic, and will be able to reproduce, visualize and analyse them with a simple PC any time. The data is always real, not simulated. The student will always find the same situation that could be found in a real experience in the laboratory.

Experiments with an element of risk or danger can be avoided. Students must not necessarily be present in their performance. Similarly, it's possible to avoid situations with inadecuate live time (dificulting human observation).

All of these characteristics allow the teacher the use of the following educational resources.

**Discovery Learning:**

Tutorial systems have been criticized in a global review of the learning process, so that the student becomes a more active agent in knowledge acquisition. There are now available several discovery learning environments (de Jong, 1993): Hypertexts, Concept Maps, Microworlds, Simulations, and Model Construction Systems...

ED-SIPLAC allows the use some ideas from simulation environments because we can reproduce real systems with computers. The main difference here is that reproductions are exact ones and not based on approximations, although in both cases it is necessary to build some model of the reality (physical laws controlling the experiments). We may then use the well-known research results on learning with computer based simulations (of Jong, 1991).

Our system could be used efficiently for developing the processes of scientific discovery, using experimentation strategy (Kulkarni, Simon, 1988). The students may visualize their results (the values of significant physical magnitudes in the experiment) in the form as tables with numerical data or with graphs, being able to deduce the corresponding physical laws.

**Cooperative Learning:**

The modular architecture of the system and, especially, the software design with levels, allows for building cooperative work techniques. The capacity for exact reproduction of experiments (really the results of concrete experiments) makes possible two ways of cooperative learning:

- A group of students working together, interacting with a single PC on a concrete experiment.
- Several students working separately with their own computers, but studying and analyzing the same experiment for later discussion, trying to come to the unified conclusions.

**Distance Learning:**

ED-SIPLAC allows certain modules to be executed in computers, other than the one that actually controls and performs the experiment. This allows for the distance learning uses, which means that students and their teacher may work separately in space and/or time (Perraton, 1988); although in this case, we should consider that the physical place of the experiment can be separated simultaneously from the student's and the teacher's places (we have together the advantages of a real experiment with real data, and the advantages of the virtual laboratory metaphor).

From this point of view, we will have two kinds of computers:

- *Server PC*: A PC with the full ED-SIPLAC system to develop the laboratory practices (experiments).
- *Client PC*: A PC with the ED-SIPLAC analysis module, that is to say, with all the necessary software allowing the user to analyze and visualize the experiment's results.

If we use a communication system connecting the PC's, for instance a LAN or a modem, it could be possible for a client PC to obtain the results of experiments developed in the server PC. This functionality makes possible several group dynamics. For instance, the teacher performs the experiment in the laboratory using the server PC. The students can then observe it (or not) and thereafter work with the experiment results, each one with the client PC connected to the server.

## 4. Some Experiences in Real Environments.

ED-SIPLAC first prototypes were tested during the 1994/95 academic year in a junior high school with 28 students, ages 15 to 17. They developed nine experiences (three experiments with each one of the available prototypes: Mechanics, Electrical Fields and Magnetic Fields).

The steps followed with each experience were:

1) The teacher 'runs' the experiment in the server PC installed in the laboratory.
2) Each student followed the experiment and then checked results in his/her cliente connected with the server in a LAN. They are allowed to make copies of the experiment's library to work by themselves, for instance, at home.
3) The students meet in groups of four to make a group summary of their individual conclusions.

The fundamental results of this experiences are exposed in the next paragraph.

The experiences were controlled and conducted with the collaboration of 2 high school teachers with sufficient computing knowledge. The teachers analyzed the students conclusions, and wrote a general report about the system's behavior. The students received and completed some surveys with questions about the advantages and problems they encountered using ED-SIPLAC compared to traditional methods.

During 1995/96 the industrial partner of this project is carring out a wider experiment (with 12 high schools) including the corrsponding statistical analysis.

## 5. Conclusions and Future Works.

We presented here the main ideas of an integrated system for supporting laboratory experiments with computers (ED-SIPLAC), constructed with a modular hardware and software architecture. It offers teachers a pedagogical tool for performing laboratory experiments in experimental sciences using new didactic aids: Experiment Libraries, Discovery Learning, Collaborative Work and Distance Learning.

Tests demostrated that ED-SIPLAC fulfills quite satisfactorily the main design aims, specifically in the following positive aspects:

- It is an integrated system containing absolutely all the necessary components (hardware, software and documentation) to put it to work.

- It has the possibility of reproducing real experiments not easily performed because of their long (short) time execution, possible danger, etc.
- It is possible to reproduce exactly the same experiments as many times as wished using simple personal computers.
- The system provides very intuitively and friendly user interface and environment.
- Students may understand better some physical concepts (angle acceleration, interferences, gradient, ...) thanks to the 3D and 2D visualization from different points of view.

The students may have access to the experiments through computer communication networks.

The main deficiencies observed in the first tests were:

- There is not a tool to share information.
- There isn't a language or method to represent the student's normalized knowledge, and therefore there is a problem with the proper interpretation of their own conclusions.
- The physical laws are restricted in their mathematical formulation: polynomial, logarithmic, potential, trigonometrichal, Fourier series, ...; since it is impossible to support all situations in numerical calculus routines for approximations.

The possible extension and improvement perspectives of the system (now being defined) are:

- Extend the ED-SIPLAC software with some communication system (electronic mail,...) to allow a better and comfortable way of student-teacher interaction and collaboration (Verdejo, Abbot, 1991).
- Incorporate a distributed architecture in the control software, so that the user could control the experiment with a computer different from the one in which the physical experience is being held.
- Incorporate some artificial intelligence computer aided instruction techniques to make possible the system adaptation for particular students. We are studying the introduction of a student modeling component used in ITS's (Fernández - Castro, Díaz-Ilarraza, Verdejo, 1993), trying not to create contradictions with the opened nature of ED-SIPLAC.
- Improve better distance cooperative learning possibilities so that several students could work together in the same experiment, from different client PC's . We are considering the use of some process models (Wan, Johnson, 1994) and the incorporation of distance shared information tools such as WhiteBoards (Verdejo, Cerri, 1994).

**Authors Note:**

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