Developing a Tool for Real-Time Data Assimilation, Visualization and Storing in the Framework of "Lab of Tomorrow"

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ABSTRACT

Lab of Tomorrow (LoT) is an IST European Project concerning the implementation and dissemination of an innovative system for the acquisition and handling of data streams coming from a non conventional experimental activity. A dedicated SW tool has been developed to handle both the LoT system and the basic LoT user needs. In this article, the LoT system innovative concepts, educational approach and architecture will be presented. The LoT system user interface will be presented as well, pointing the attention on the adopted design principles and on the features provided to the final user.

INTRODUCTION

In the framework of the "School of Tomorrow" action of the IST (Information Society Technology) European Programme, a new educational tool and learning environment, called "Lab of Tomorrow" (LoT), has been made up by a partnership of Universities and schools from various countries[1]. A family of tiny, programmable computational devices (the "axons"), embedded in everyday objects and cloths, was developed as well as a user interface for data assimilation, analysis and presentation. Our task, among the many related to the LoT Project and allocated among the partners, was the development of the LoT user interface (UI). The present paper will focus on our research and on the work developed in performing such task: our main aims, the problems to be faced and the solutions adopted, the actual structure chosen, its main features and capabilities, implementation in the classroom and evaluation.

LOT PROJECT PRINCIPLES

The most characterizing features and underlying concepts of this Project follow from the needs of the main educational aim of the Project, that is the learning of the modern scientific method via the direct interaction of the user with a data acquisition system. Being present such system, the cycle of observation, theory, test-against-observations can be repeated until the investigators achieved a complete understanding of the phenomenon being studied. Making and using conceptual models of real world entities is from Newton's to our time central to scientific thinking. In fact, the Newton method depends on a constant interplay of observation and theory in a modelling cycle.

(From the motions of material bodies Newton infers the forces and from the forces infers - and so predicts - their motions.)

The LoT system approach to the analysis of physical phenomena is quite different from the conventional approach adopted in the school. In fact, the LoT system is designed to handle experimental activities in an open field, without a clear separation between the data sources and the experimenters. This effect is a consequence of another characterizing concept of the Project: the embedding of technically advanced objects into everyday life objects. Combining this concept and the appeal needs towards young learners has lead to the choice of sport related objects (a volley ball and a shirt) as "sensors containers".

Finally, basic features of the system are also the keeping of a low-cost profile and the easiness of use and installing.

Educational use of the LoT system

According to the spirit of constructionist philosophy, knowledge is not transmitted from teacher to student; rather it must be reconstructed by each student individually. Students have their own ideas and beliefs about science-related phenomena which students hold before experiencing relevant formal science teaching. The way students react to, construct, link or even reject new ideas is influenced by their belief and attitudes.

LoT can help the students to understand the nature of knowledge and the process of knowledge production. In fact, it comes as a surprise to many students that knowledge is produced like automobiles or clothes and not discovered like iron ore or oil.

Doing LoT, the students get experience of the science production on many levels:

- They will play the role of the empirical "scientist" who collect and process the experimental data.
- They will interpret the results using models and theory as theoretical "scientist".
- They will not only be observers but also a living part of the experiments.

In the LoT Project, the application of worthwhile science knowledge to the world outside the classroom is the main source of content:

- By applying science to student's sport activities, LoT deals with content that has immediate and obvious personal relevance to the learners.
- LoT begins as an extension of what the learners already know from their experience prior to schooling.
- The learning of practical and cognitive skills flows naturally from the nature of the topics chosen that are relevant and meaningful to the students.
- Assessment can recognise both the prior knowledge that the learners already have of the phenomena and their subsequent achievements.

LoT system educational approach

The power of science derives from its tools, which have been forged by scientists. To transfer that power to students we need to make the tools available. LoT integrates authentic scientific tools into software that incorporates the structure of scientific knowledge. Scientific SW tools are generally of two kinds: empirical or theoretical. The empirical ones work as universal interfaces with laboratory instruments of every kind; they collect, process and display complex data from experiments and

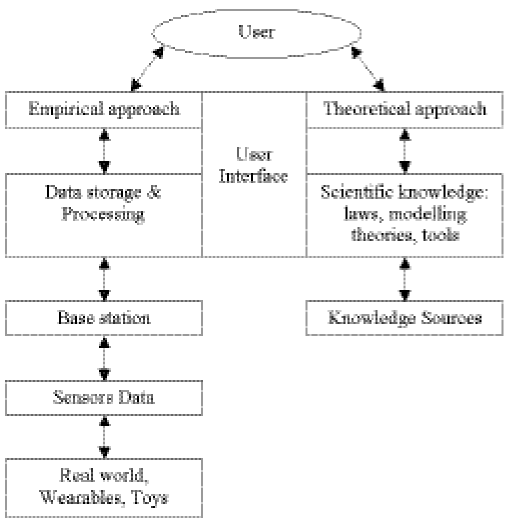
[1] Project coordinator Prof. N. Uzunoglu from the Technical University of Athens. Main partner Institutions: University of Dortmund (Germany, Prof. H. Fisher), University of Birmingham (UK, Dr. Baber), Polytechnic of Turin (Italy, Prof. G. Perona).

observations. The theoretical ones are used for calculation and simulation to explore the implications of mathematical models.

In the LoT system, an empirical face and a theoretical face are easy to identify.

- The ***empirical face*** uses empirical data/information directly imported through connection (via radio or via cable) from the sensor modules. The user can select and manipulate whatever data is of interest by acting on the so called "user interface". The empirical component depicts a shared experience of the real world as seen through the eyes of scientific instruments.
- The ***theoretical face*** provides access and control to scientific knowledge (relevant for LoT) as self evident and accessible as possible. Model specification is usually distributed over several representation modes: words, equations, diagrams, graphs, spread sheets, etc. Complete understanding of a model requires co-ordination of multiple representations.

The conceptual learning schema proposed via the LoT system can be summarized by the following figure:



The LoT system should be seen as a way to increase the observation capabilities of the user. Through the empirical interface, the user gains a view of the world from scientific instruments that surpasses human senses in sensitivity and range; through the theoretical interface, the user engages scientific modelling to his thinking.

The so gathered observations should then be checked against a theoretical approach. Also the inverse process is evidently possible, as well as cycles of both approaches as a way to produce a scientific model of the phenomena being studied. This approach points out the central role of the experiments in the production of scientific knowledge.

Canonical lab versus LoT lab

Lab experiment is fundamental to our present-day conceptions of scientific knowledge and scientific activity. Let us consider experiments or operations performed in the science laboratories. Results of such operations usually give numerical values attached to the measured physical quantities. Now, experiments in the lab may be repeated; at least, scientists make the assumption that it is possible to go through the same set of operations getting again essentially the same set of data. Such data are usually arranged in an array of points using a mathematical graphical representation. When, repeating the experiment, the appearance of such points reveals a considerable similarity, assuming a functional relation among the measured physical quantities, results are then summed up in a single formula. When a large number of similar experiments with different initial conditions are performed, such description begins to be felt as having a great range of application and validity. Scientists then claim they have established a physical law. The repeatability of experiments underwrites the objectivity of scientists' findings. The best description of a routine experience will have its form determined to a certain extent by the degree of approximation of the routine. The more exactly the experiment is done and the more carefully controlled the various factors that enter into it, the more precise will be the resulting law. Thus the need to perform the experiment in the lab under controlled circumstances, so to identify all the parameters to be measured and to reduce the number of relevant variables. Finally, once we believe in a well-established law of nature, we feel assured that repetition of a certain experiment will yield a quite definitely predictable result. In principle, there is no difficulty in predicting from the law the final results if furnished with the initial conditions.

When we come to LoT activities, we need to realise that we use an extended concept of lab that does not fit well with the canonical one. Difficulties can arise, since the events under study can be mixed up with so many other events that the investigation may not be useful. In fact, LoT experiments take place in an open field, the number of parameters/variables is very large, there is not a clear separation between the apparatus and the observers in so far that the students are alternatively observers and also pieces of the apparatus themselves.

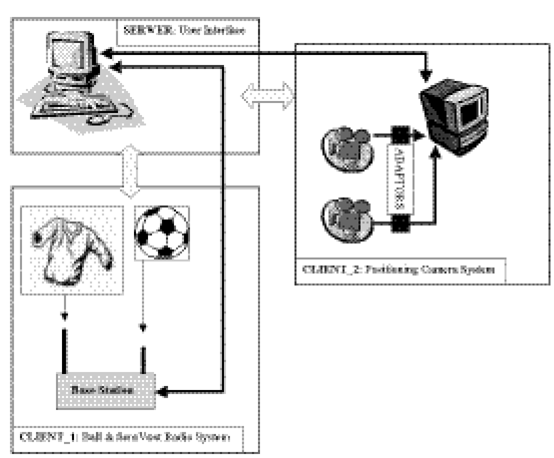
A main motivation for such a choice of having the students "inside the experiment" is the relevance of LoT to the real world and to students' interests. Such situation makes the activities much more appealing to the learner. On the other hand, the LoT workstation includes quite advanced modules that make measurements easily imported on the computer interface. The problem for the user is to: choose a significant activity, identify the relevant observations and measurements and separate them from other ones that have nothing to do with them.

Complex phenomena of everyday life are not suitable to derive a law of nature. On the other hand, it can be worthwhile to deal with such complex phenomena. Students should understand there is not such a thing as a "wrong" result in an experiment. However, particularly in LoT experiments, one must think very carefully about the interpretation of results.

We can interpret/explain the results of LoT experiments by using scientific knowledge. The theoretical approach can provide the learner with the appropriate tools and help to compare theoretical models and observational data.

LOT SYSTEM ARCHITECTURE

A general description of the LoT system architecture follows.



The LoT data acquisition system is based on a triaxial accelerometer, embedded in a ball, and on a variable number of modules (namely, the SensVest modules) embedded in a simple wearable, a shirt. Each SensVest hosts bi-axial accelerometric sensors for tracing of body, arm and leg accelerations, and two other sensors for reading of temperature and heart rate physiological parameters[2].

Moreover, a parallel video stream is gathered by two high resolution cameras dedicated to the evaluation of the data source position. These two positioning cameras are connected to a client PC to constitute the local positioning sub system (LPS), built by the ICCS team of the National Polytechnic University of Athens.

Finally, other LoT system devices are an high resolution accelerometer and a low resolution monitoring Web camera for qualitative experiment description purposes, both handled in a real time and built by the CoREP team.

Since the free motion possibility of the experimenters wearing the SensVest modules is a relevant feature of the Project, another essential LoT sub system is constituted by the devices necessary to establish and handle a radio link between the sensors set and the system workstation hosting the UI. In particular, the radio link sub system is constituted by a system Base Station handling the data streams coming from the Sensor Transmitter Modules connected to each SensVest module[3].

The user interface (UI) hosted on the system workstation drives the whole LoT system during the gathering of new experimental data. It interacts directly with the Base Station and the LPS sub system to handle both sensor data and LPS video streams.

It also handles the monitoring video stream and the high resolution accelerometer data stream. This same UI (responsibility of the CoREP team) provides also facilities for data storage and managing as well as some integrated educational features and tools.

LOT USER INTERFACE

The main aim in undertaking the design of the UI was to provide a general tool for interfacing a data acquisition system and its users. In particular, the UI design follows the logical steps involved into the performing of a new experiment and handling of stored experimental data. The users interact with the system through commands controlling the data assimilation process, selecting and graphically representing stored data streams, performing initial processing and finally exporting towards other applications or uploading to a Web-site. In order to develop such integrated approach to the above different tasks, a structure based on three main sections - indicated as “Data Assimilation”, “Data Browsing”, and “Pre-Processing” - was chosen. The guidelines for designing these sections were the ergonomics and easiness of use principles. A third guideline was the appeal to the final users, i.e. to secondary school students. The graphical aspect was designed accordingly: functional colors and shapes, commands and options directly visible on each section. Particular attention was devoted to the development of a dedicated high impact graphical sub system for the displaying of data and video streams coming from the sensors. Tri-dimensional data are also handled in an interactive true-3D environment.

All the features of the UI were discussed with other partners inside the LoT international development group and in particular with a group of teachers from the Pininfarina school - partner institute in the Project. Some preliminary trials in the classroom were performed with our SW and the test-runs for evaluation were performed by the schools educational partners in the Project.

[2]The design of the SensVests was care of Dr. Baber’s team from the University of Birmingham.

[3] Responsible for the setting up of the radio sub system is the Greek ANCO firm.

In the following, the main features of the UI in its present version are briefly described.

The start panel gives access to the three main sections, and to the UI tutorial. The user will select the “Data Assimilation” section to create new experiments, the “Data Browsing” section to select a stored experiment for viewing or uploading and the “Pre Processing” section to review or export the chosen experiment.

“Data Assimilation” section

The “Data Assimilation” section contains the whole routines and facilities concerning system initialization, sensor data stream managing (samples extraction and integrity check) and data storage into specifically formatted databases.

In particular, this section allows the set-up and control of the data acquisition system in use, typically a sensor based system for the gathering of experimental data. Real time visualization of incoming sensor and video streams is provided. The modular approach adopted for the developing of the UI allows the connection of any acquisition system once being specified its interface protocol. Moreover, assimilation routines for handling of standard radio protocols (such as the widely known Bluetooth™ protocol) and commercial data acquisition systems have been implemented. Together with the experimental data from the sensors, images from a Web camera (the so called “survey camera”) are also assimilated, in order to help the users in the reviewing phase and to provide a visual documentation of the performed activity.

“Data Browsing” section

The “Data Browsing” section provides tools to ease the selection of stored experiments, basing on the metadata set defined at the experiment creation phase. Importing of stored data streams produced by external SW, hosted locally or remotely, is always possible once specified the data format. Integrated Web upload/download features easily allow exchanging complete experimental data sets among all the users sharing the same remote resource. Furthermore, a dedicated Web-site (“www.LoTexperiments.net”) is also directly accessible. In this way, transparent handling of remote experimental data sets definitely separates the usability of the UI from the effective local availability of the acquisition system.

Finally, the possibility of selecting part of experimental data through a “segmentation” routine is also implemented. Through this feature, significant events can be extracted to perform a detailed data analysis.

“Pre-Processing” section

The “Pre-Processing” section includes the data visualization tools and an exporting tool. In particular, two different environments for representing 2D and 3D data streams, both with direct user interaction capabilities, are provided. Basic data pre processing routines (interpolation, resampling, integration and differentiation, …) can be applied to the data stream. Finally, selected and pre processed data can be exported in the most common Windows ©formats to be further analyzed using specialized SW like Matlab © or MS Excel © accordingly with various educational needs of the user.

EVALUATION AND CONCLUSION

The design of and rationale behind the LoT educational approach have been described above.

This system is intended to create an interface helping the users in performing high impact experimental activities, without having to face the technical aspects related to the use of complex data acquisition systems. So doing, we allow a better highlighting of the educational aspects of such activities.

The developed material has been exposed to extensive evaluation tests: the laboratory tests during the development process and the field tests in the classroom, as soon as the system had reached a reasonable level of usability[4]

During the development phase of the UI by CoREP, usability-engineering techniques were applied, implying an early feedback from the user, empirical measurements and iterative design.

The experimental method adopted was based on focus groups and sessions of user testing. In the focus groups methodology, a group of evaluators used the system with no predefined task, providing comments and observations about. The experiments were carried out on subsequent prototypes of the system and aimed mostly on identifying defects and shortcomings of specific functionalities of the various components. Indeed, conceptually, we considered the suggestions coming out from our partners meetings and from the meetings with the EU evaluators as part of the focus groups activities. Therefore, in general, the evaluators were experts from our partners in the Project or chosen from our researchers group; in particular, a few schoolteachers from local schools were included. So doing, we tried to first polish the interface from usability problems identified by focus groups before the release for end user testing.

Then a few sessions of user testing were organized in our lab with a group of users - students and teachers. The participants were asked to accomplish a set of tasks. Information was collected via questionnaires submitted during the experiments as well as via direct observations.

Demonstrations of the system in action were shown during a number of presentations: in particular, at the EISTA 03 Conference (Turso et al., 2003) and at the AIF 04 Conference (Perona et al., 2004). Feedback on the teachers reactions was collected during some teachers workshops with participants coming also from the European Network of Innovative Schools (ENIS)[5].

The results of our evaluation research will be the focus of a follow-up paper.

Acknowledgments

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Many thanks are due as well to students and teachers - Ada Sargenti, Claudio Ferrero – from Pininfarina School who took part in trials of the software and related materials.

[4] The main responsible for evaluation of test runs in the classroom is the group of Prof. H. Fisher from the University of Dortmund, partner in the LoT project

[5] Two ENIS school workshops about LoT were organized by Dr. D. Nucci from Indire in the framework of the VALNET validation Project.

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