A Generic 3D Environment to Remotely Drill and Practice on Embedded Automated Systems

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ABSTRACT: *Although the use of educational intranet and e-learning environments has become familiar by providing specific educational in-network solutions, it is not the same thing for the environments of online laboratories, which require much more complex computing developments. We know that on-line laboratories offer a student the possibility to perform such tasks using a network connection. In this paper we will present an approach differing from the available proprietary solutions, which have specific requirements in terms of software environment. Solutions presented in this paper are based on 3D languages such as VRML and Java3d used for Internet applications. Recognizing that in an environment of on-line laboratories an educational and generic dimension is added to the classic problems posed by systems of remote control, it will be necessary to apply rigorous standards to the learning objectives to meet required standards in terms of modularity and reusability for the 3D distributed interfaces used by students. Based on a virtual environment allowing the student a 3D visualization of the operative part of an embedded system (PLC, micro-controller) developed to allow programming of the control part of said system, this paper offers the possibility to: a) clarify in which interval one can use 3D standard languages to define a 3D library in which didactic components are granulized in order for an educational unit to consist of a set of elementary learning objects that student can recombine during a practical activity to meet different training needs; b) define in a global learning environment (including online course, online directed work, online project, etc.), a generic concept of an online laboratory.*

1 INTRODUCTION

The integration of a generic concept of online laboratory in a global learning environment arises two kinds of problems[4]:

- **A pedagogic problem.**

How an e-learning environment can integrate this kind of teaching based on lab works and how to practice remotely this kind of training reserved till now for teaching “in the flesh”? Must one reproduce remotely the system to be manipulated or inversely, we have to conceptualise it via a specific educational HMI[2] in a way that the remote setting doesn't prevent this learning?

To resolve this problem, we have made a first descriptive specification (Section 2) of a generic environment for remote lab works applied to embedded automated system. This specification will permit for us to identify the environment actors and their roles. Based on the result of this specification, we will propose according to a given pedagogic situation a 3D generic laboratory model (Section 3)that integrates actors and their roles.

- **A technologic problem**

Remote lab work sessions can involve a loss of control(from a distance, we can act directly on the system only by using the keyboard, the mouse, a joystick) and observability (degraded sensorial observation: sight, touch and hearing) with great difficulties (which maybe explain the observed delay) during the interconnection between the computer part related to the e-learning environment and the physical part of the lab work platform.

A part of the solution can be offered by the development of a specific HMI adapted at the same time to the remote control and to the didactic aspects. In this purpose we will go to demonstrate (Section 4) till

which point one can use the 3D languages like VRML and the oriented object design to define such type of HMI[2].
As shown in Figure 1, having a set of remote control components (micro-controller, PLC, etc.) we can perform lab work manipulations by combining a 3D representation of the operative part of an automated system with one of the remote control components.
This type of lab work session allows an informative reconstruction of the platform's operative part and of their states, through animations and interactive simulations based on 3D scenes[15]. Considerable educational advantages can be gained by a remote experimentation based on the integration of two classes of activities: the activities of " real laboratory " (in our case the programming of the control component) and activities " of virtual laboratory " (the manipulation of the operative part). The prototype of the 3D generic laboratory will have a representation on the network with which students can deal to remotely control a real platform of experimentation.

2 SPECIFICATION OF THE GENERIC 3D ENVIRONMENT

We have done a first specification[4] of the laboratory. We aim to specify the various constituents of the laboratory: the human actors who intervene and the material platform which is considered as an actor. These elements must be interconnected by the means of networks and interfaces.

a) The pedagogic situation

A remote lab work session can cover a great variety of educational situations defined according to: who and whom is at distance and if it is in real or virtual aspect. The combination of these possibilities gives a set of possible educational situations. In our case we have chosen the educational situation represented by the Figure 2.

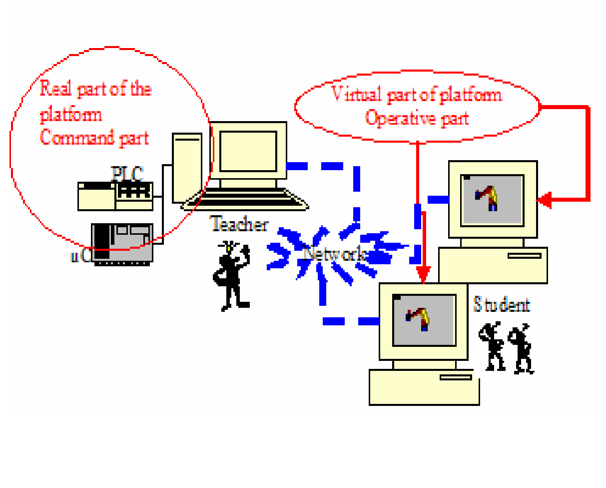


Figure 1. Architecture of the 3D generic online laboratory

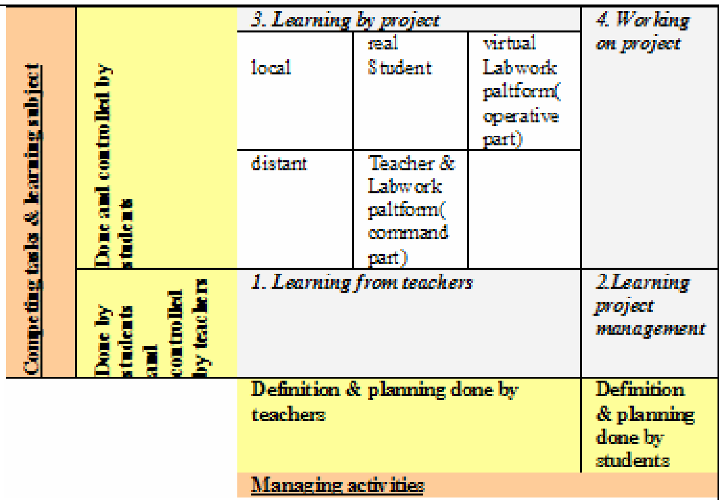


Figure 2. specification of the educational situation based on the ways using project based learning

Remote Lab-work-session can be considered as a project-based-learning because the using of the project concept (subject of the lab work session) exists. Figure 2 shows the four main methods of using the project. We are interested by the third one(learning by project) which is more suitable with the specified educational situation. The teacher defines and schedules project lab works. He use such schedule as basis for guiding students and providing them with supports. The students have to construct the operative part locally and to connect it with the distant command part which will be programmed remotely[9].

b) The system actors

- **The lab work platform:**

It is the central element of the remote lab work session: in our case we can limit the constitution of a platform dedicated for embedded automated system to mechanics elements (manipulator), sensors, actuators and an embedded control part .

in our 3D generic environment this platform is subdivided into two parts[2]:

- A real part which is the control component to be programmed.
- A virtual part which is the operative part represented in 3D.

- **The human actors**

In a remote lab work system, as in any e-learning's system, intervene the same actors that in classical teaching: students, teachers and eventually technicians. In remote lab work session, we find these same actors but in different spatial configurations(see pedagogic situation).

- **The students**

For them, a lab work session represents a situation in which they are confronted with reality: they practice the concepts already learned and they discover new things. The direct manipulation of a system helps students to understand well the environment in which they will progress and the limits of theory. They discover at this moment the suitable material, they apply a methodology of experimentation, they react face to precise situations (expected or not) and finally they perform their experiences.

- **The teachers**

They plan the lab work sessions, help the students during the performing of their lab works and evaluate their knowledge. Generally, we assign to the teacher the functions of the other contributors, such as the technicians, the designers of lab work and the responsible of the platform. In this case, the teacher can bring a material help to the students, supervise the platform, intervene in the case of sever problem, plan the lab work scenarios and manage the material platforms[14].

c) The roles of actors

for all of the actors, we distinguish five principle activities: the mounting of the manipulation and its perception, the piloting of the platform, the communication between the actors and the management of documentation. These activities and their modalities are summarised in Table 1. For each actor we have indicated if the activity is done by the student or by the teacher.

- **The mounting of the manipulation**

The construction of the operative part, the programming of the control part and the connection between them are the three principle activities in the mounting of the platform of the lab work session[3,14]. In our 3D generic environment, we propose to virtually construct the mechanical components of the operative part and then to connect it with the real remote command part (API or micro-controller). Afterward the student can program the control components and verify his code via a given 3D visualisation of the operative part behaviour.

According to this, each learner will dispose of graphical distributed interfaces (HMI), used for the construction of the virtual operative part using a 3D library in which didactic components are granulised in order, for an educational unit, to consist a set of elementary learning objects that student can recombine during a practical activity and to meet different training needs. The principal aim of a so kind of manipulation consists of the familiarisation with the programming of the command part of embedded system.

- **Perception of the manipulation**

The perception of the manipulation concerns all what permits for the student to be informed on the real state of the manipulation at a given moment. It is interesting to implement various approaches of perception according to the type of manipulation. Generally a perception of visualisation type is necessary. In our case it seems indispensable that student can visualise manipulation by means of a 3D reconstruction of the operative part and of its behaviour. The 3D visual interface also has the advantage of allowing additional, complex functionality useful for control: these include changing the viewpoint, zooming in/out of the scene, etc.The open technology VRML allows the virtual control environment to run on any type of computer platform.

- **system control**

The control activity aims to modify the state of the manipulated system. We can distinguish two modalities: the action is performed either in real time by a direct command, or via a program.

In our case, the first kind of action can be applied by the student on the 3D representation of the platform during the cosimulation of the control code[7].

Concerning the second type of action: it is the principal aim of the lab work session. The student introduces remotely the control code to be loaded in the memory of the remote command part and to be cosimulated via a 3D visualisation.

We find that a good alternative way to provide suitable control information to the student is by using an online 3D model of the operative part. Data transmission is restricted to small parcels defining the I/O signals exchanged between the O.P and C.P. Under this regime, the O.P. can be simulated successfully even when communication rates are extremely low.

- **Communication**

The activities of communication are multiple and have numerous modalities: the student can ask a question either in a synchronous way or in an asynchronous way. For remote lab work session, it is necessary to look for rich possibilities of communication between students and teachers or between students themselves.

- **Documentation**

We can distinguish three types of documents associated to lab works: the lab work plan describes the progress of the session, the technical documentation describes the material platform(structure of the operative part and nature of command part), and the course information which are necessary for understanding the proposed lab work activities. Gathering these documents on an electronic support makes it easy to go from conceptualisation to experimentation.

- **platform Management**

The management of lab work platform deals with:

- the addition, the remove and the modification of lab work plans
- the management of the users and their control access
- the planification of lab work sessions.

Table 1. activities in Lab work session

Distance activities	**Modalities**	**Student**	**teacher**
Lab work mounting			
Construction of the virtual part of the platform (Operative part)	Using HMI for connection, programming and for cosimulation	*	
Mounting the real part of the platform (command part)	Using control component tools		*
Preparing Lab work documentation	Using many external tools		*
Lab Work Perception			
visualisation of the embedded automated system	3D visualisation	*	*
Perception of the state of sensors/actuators	Graphic data or numeric data	*	*
Lab Work monitoring			
Control of the embedded automated system	By HMI user event	*	
	By program	*	
Write program		*	
Communication			
Communicate with a student	synchronous communication.	*	*
Communicate with the teacher	synchronous communication.	*	
Documentation			
Access to the labwork plan	Written or multimedia presentation, electronic or paper Support	*	*
Access to labwork other documentation	Written or multimedia presentation, electronic or paper Support	*	*
Management			
Add/Remove LabWork plan			*
Plan LabWork's sessions			*
Manage the control access			*

3 DESIGN AND IMPLEMENTATION OF THE GENERIC 3D ENVIRONMENT

To reach the generic aspect of the specified laboratory we have translated the previous specification into LTSA (Learning Technology system architecture) design known as one of scarce standards (IEEE 1484) that covers the architectural aspect of an e-learning system[11].

The implementation of the activities of the generic 3D laboratory can be done using a set of tools that we have called " LabWork management tools ". These tools can be classified in four different levels:

- Student Activity Management
- Teacher Activity management
- Control Component Interface management

These tools deal with the conception, the progress, the support and the evaluation of the labwork session. We can map these tools to the LTSA system components as shown in the figure 3.

"Parallel stakeholders " is an LTSA concept which can be flexible with all types of communication between the various actors of the laboratory.

The "parallel stakeholders" are characterised by the integration of multiple, active sessions of LTSA system components. The "parallel stakeholders" must synchronise, start, and stop multiple sessions. The "parallel" stakeholders must integrate, collaborate, and synchronise the feedback, coaching, and user interfacing. The LTSA components may be recursive by making one Learner play the role of a "non-Learner" for another Learner.

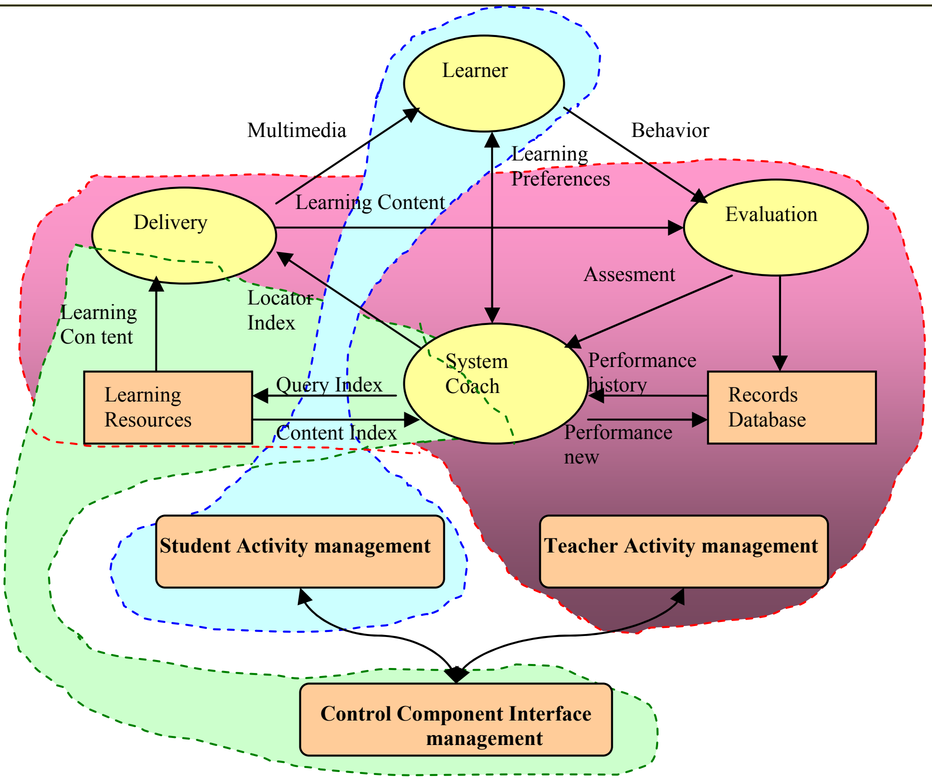
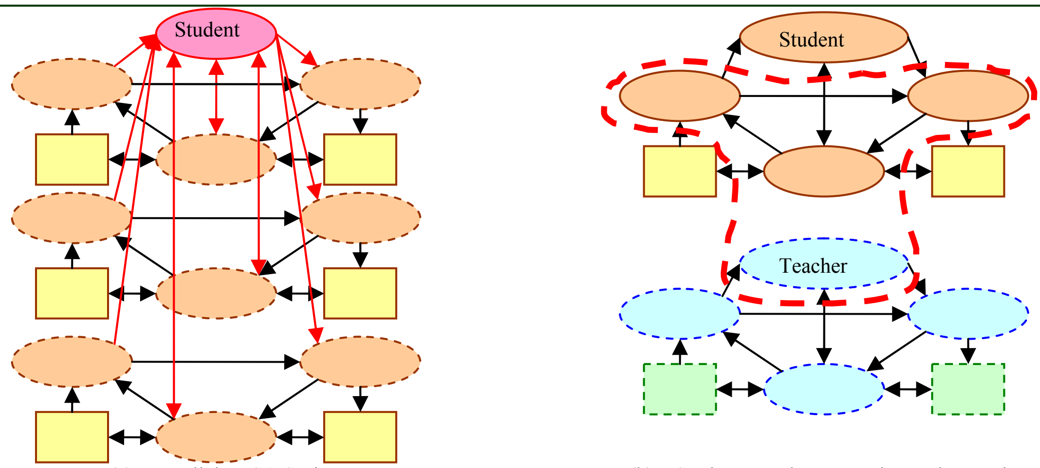


Figure 3. Lab work management tools mapped to LTSA system components

Figure 4 shows two types of "Parallel stakeholders ":

- Parallel Sessions for the Same Learner: useful for the communication between students (Multiple, simultaneous learning experiences) Figure 4 (a).
- Student Teacher: useful for the communication between the teacher and his students. The "student-teacher" in his both roles as "teacher" (one learning experience) and "student" (another learning experience) Figure 4 (b).



(a) Parallel LTSA Sesions (b) Student-Teacher as teacher and as student

Figure 4. LTSA Parallel stakeholders

Table 2 shows our implementation of the LTSA flows in the presented environment.

Table2. LTSA Flow Implementation

LTSA Flows	Implemented Flows
Behaviour	Control code O.P. assembly diagram 3D O.P Representation C.P-O.P map data link HMI user events Debriefing Response
Learning Preferences	Synchrone session Question Lab Work choice 3D Learning Object choices Lab Work Documentation control component choice Lab Work Documentation 3D learning Object list control component list Synchrone Session Responses
Multimedia	Assembly O.P Diagram HMI Data link map connection HMI Programming HMI Cosimulation HMI LabWork Documentation
Learning Content	Lab Work Assessment Criteria Lab Work Plan Activities Debriefing Questionnaire
Assessment	Lab Work Journal (performed activities)
Performance	Lab Work Journal (performed and non performed activities, Time /Activity).
Content Index	3D Learning Object Allocated Control Component Allocated List of Lab Work Doc. Retrieved
Learning Content	3D learning Object Lab Work documentation
Locator Index	Lab Work List Synchrone Session Responses

- **Student Activity Management**

As mentioned above, students work on tasks and produce deliverables. These activities can be done individually or in groups. While completing tasks, students need access to learning documents, resources etc.

The students activity management tool must therefore support all activities, documents and deliverables shown in Figure 5.

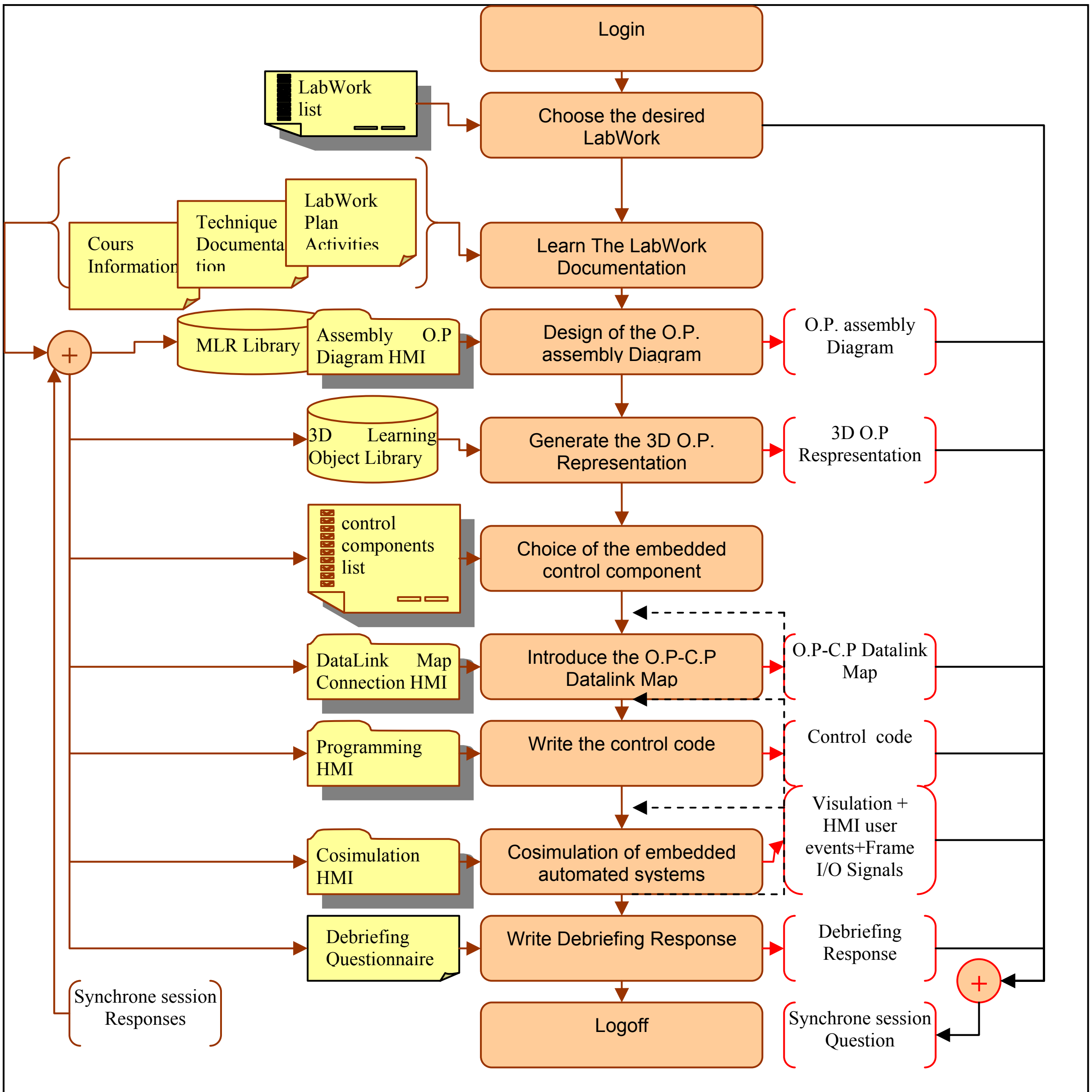


Figure 5. Student activities based on Student activity management

- **Teacher Activity Management**

This category of tools allow teachers to set up, control, monitor, and assess labworks. Within this category, we included not only activities carried out by teacher but also activities carried out by technicians, lab work designers and platform responsible. Figure 6 shows an overview of the constituents of the teacher subsystem. It consists of five main functions:

- Student/Laboratory management.
- LabWork management.
- LabWork Assesment.
- Platform management.
- **Control Component Interface management**

This tool allows the management of the material part of the platform. It allows some functions like material sharing, change of use mode, management of connection etc.
Figure 6 specifies all these functions.

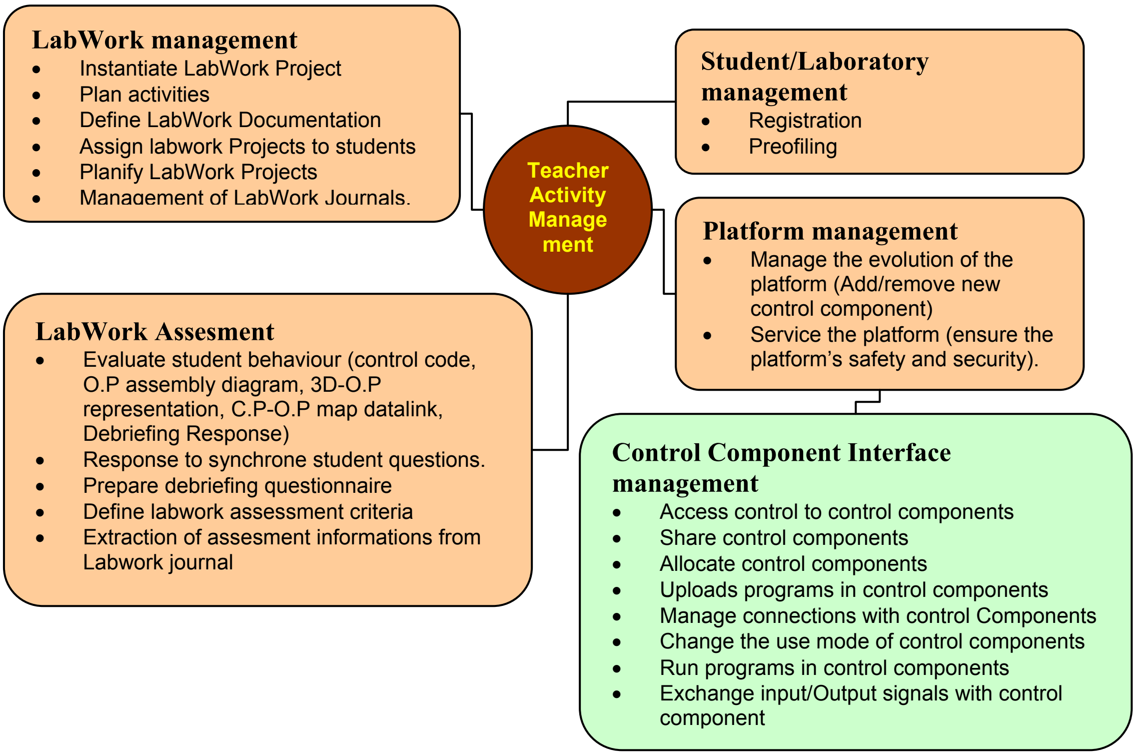


Figure 6. Teacher activities management and Control component Interface management

4 THE 3D ASPECT OF THE GENERIC ENVIRONMENT

We consider the virtual representation of the operative part of the labwork platform as a learning content that must be modelled. The need for a reference model for representing a didactic component is even more critical when the component is more complex and constituted of a variety of modules. In modeling the operative part and in order to have a valid virtual pattern, we have used advanced concepts in the simulation and visualization fields[1].

Among the recent research results in modelling and simulation, two concepts have strong relevance to this issue[8] :

- Object oriented modelling languages already demonstrated how object oriented concepts can be successfully employed to support hierarchical structuring, reuse and evolution of large and complex models.
- Non-causal modeling demonstrated that the traditional simulation abstraction (the input/output block) can be generalized by relaxing the causality constraints, i.e., by not committing ports to an 'input' or 'output' role early, so that this generalization enables both more simple models and more efficient simulation .

Examples of object-oriented and/or non-causal modeling languages include: ASCEND, Dymola, ObjectMath, Omola, , U.L.M., ALLAN, and VHDL-AMS etc. Having started as an action within ESPRIT project "Simulation in Europe Basic Research Working Group (SiE-WG)", a working group made up of simulation tool builders, users from different application domains, and computer scientists has made an attempt to unify the concepts and introduce a common modeling language. This language, called Modelica, is intended for modeling within many application domains (for example: electrical circuits, multi-body systems, drive trains, hydraulics, thermodynamical systems and chemical systems) and possibly using several formalisms (for example: ODE, DAE, bond graphs, finite state automata and Petri nets) [8].

We look for using this language to model the 3D representation of the operative part as a 3D library called "3DLearnObj". This library covers the basic concepts of modular robotics and offers a wide range of valid virtual robotic modules for labwork operations.

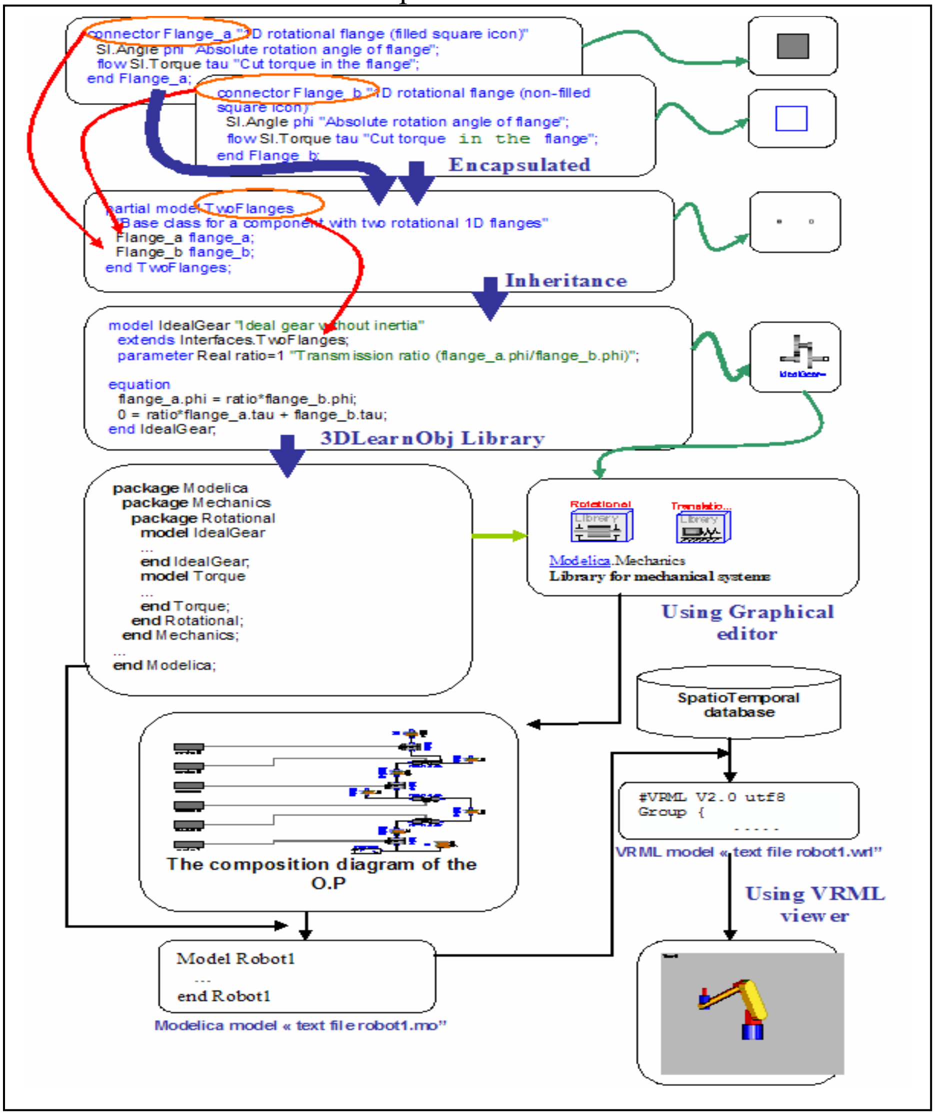


Figure 7. Design Steps of the operative part

- **The oriented object design of the operative part.**

In a first stage, 3DLeanObj library offers a family of robotic modules that allow students to make labwork manipulations applied to the embedded automated system by building operative parts (manipulators) adapted to their needs.

There are two types of 3DLearnObj modules: joints and links, both provided in a range of different configurations[10]. The joints are the components that constrain the motion between two frames and come in two types: rotary joints and linear joints. These active joints are connected together with passive link modules that provide the structural geometry of manipulator configuration.

Figure 7 shows a Modelica description of a rotary joint. It looks like An element defined by the production component-clause in the Modelica grammar. In Modelica, the basic structuring element is a class. There are seven restricted classes with specific names, such as model, type, connector. For a valid model it is fully equivalent to replace the model, type, and connector keywords by the keyword class, because the restrictions imposed by such a specialized class are fulfilled by a valid model. All properties of a class, such as syntax, attributes, methods, inheritance, genericity are clear in the Figure 7. When developing models of components , it is good to start by defining a set of connector classes. For the joint sample we have specified tow flange connectors. A common property of many robotic joints is that they have two flanges. This means that it is useful to define an "interface" model class(Two Flanges), that has two flanges (flange_a and flange_b). Through the inheritance concept, the model IdealGear extend this interface to constitute the joint model with the equation clause that defines the mechanical behaviour of the joint component.

The student starts by establishing the composition diagram of the operative part. This graphic description generates an (internal) textual description of the model in Modelica language. During this step a great part of the Modelica syntax will be hidden from the student because, generally, a graphic editor will be used to build the composition diagram by choosing icons to define the components(joins and links) of the manipulator and by using dialog boxes to specify the input parameters as well as to connect components graphically[12,13].

- **VRML Implementation of the operative part.**

To translate the Modelica description of the operative part into a format that can be simulated by an appropriate environment (VRML viewer), this requires sophisticated symbolic techniques of translation that aim to convert Modelica description of 3DLearnObj components into a VRML description[6,15]. This transformation is done by using a spatiotemporal data base that we have developed in a preceding work in order to store virtual didactic components[1].

Figure 8 shows correspondence between Modelica specification of component and its Vrml description.

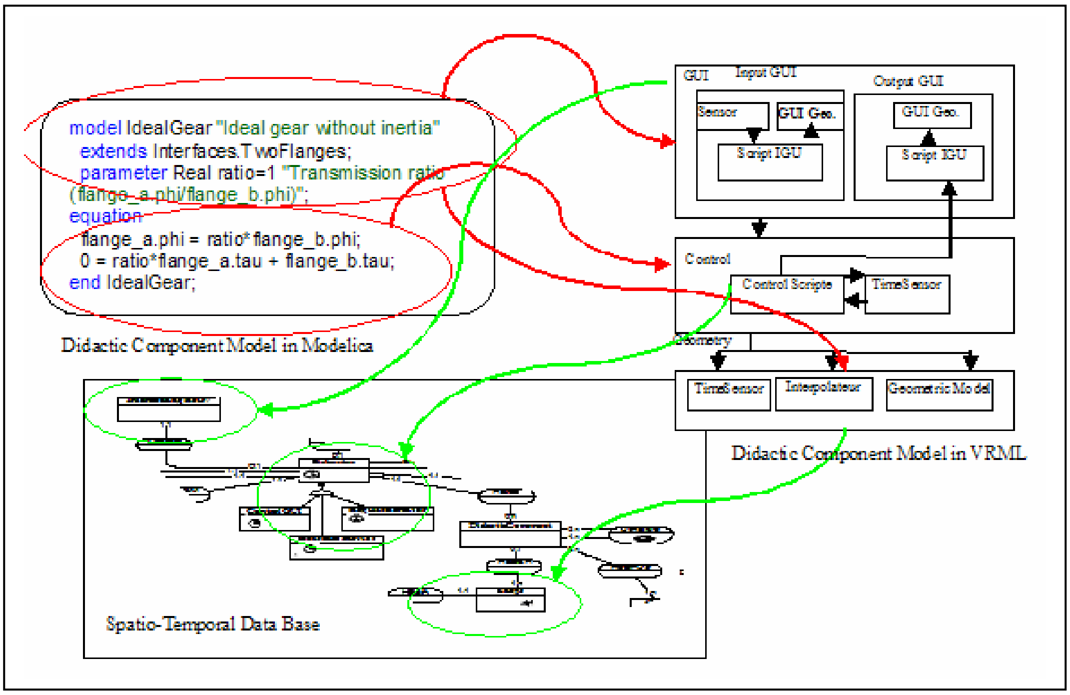


Figure 8. Didactic Component Model in modelica mapped to the Didactic Component Model in VRML and to Spatio-Temporal Data Base

Notice that the VRML Component model tends to regroup the visual data and their treatments within objects that encapsulate them. Generally such types of models can be divided into three components:

- the visual model (in our case, the geometrical part of the component) that represents the simulated component equations;
- the graphic user interface (GUI), used to control user input values, the visual representation and the simulation execution;
- the simulation control (the dynamic part of the component) that controls the simulation behavior in response to the user or other events.

5 CONCLUSION

The implementation of remote lab works in an environment of e-learning implies a supplementary difficulty compared to the other modes of e-learning rapidly expanding. Even in ordinary lab work, the control of a system in an educational context is not harmless: realism and performances should be considered strategically. If apparently distance can only damage the quality of the lab work, an exhaustive study of local and remote situations allows to perform this passage and to transform weaknesses related to the distance into an advatage for the actors of the system. Based on this analysis, we proposed a model for a 3D generic environment to remotely drill and practice on embedded automated systems. This paper discussed features and characteristics of this environment and it presented also the activities of teachers and students in this environment. This environment is based on the LTSA Model and can be used in a variety of situations and disciplines. Ongoing work is tackling the detailed design of the system.

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