Tele-Collaboration System in CVLab

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This work is part of a learning environment that has virtual laboratories that are designed for distant practical work (Tele-PW). In these environments, Tele-PW is performed in two modes: individual and/or collaborative. In this paper, we are concentrating on the tele-collaborative distant practical work model. The work, presented in this paper, proposes an artificial agent called Synchronizer Coordinator Agent (SCA) to synchronize and coordinate the activities of a cognitive process in order to build and maintain a shared conception of a distant practical work between a set of learners. This agent provides certain features such as managing groups of learners, coordinating tasks, shared workspace among members of the Working Group. It is also responsible for the synchronization of workspace agents when they want to manipulate shared virtual objects simultaneously. We have chosen Petri nets to illustrate the principle of granting access to shared objects in the case of simultaneous requests. Experimental results show the effectiveness, of the artificial agent within any tele-collaborative/tele-cooperative learning situation. Several situations describe the geographical/time dispersion of learners and tutors in our system are considered during the system design phase.

Povzetek: V članku je opisan sistem za telekomunikacijsko sodelovanje pri virtualnih laboratorijih.

1 Introduction

The main purpose of practical work (PW) is to compare the knowledge of learners to reality. In this work, we bring an extra dimension: the distance, by focusing on practical remote education. The qualitative "experimental" is applied to training situations where the learner manipulates and interacts with virtual objects and compares the results to theoretical models.

Virtualization [1] associated with remote access provides a relevant solution to the simulation problem of practical work. Not only it allows to reconstruct classical (face to face) teaching situations (traditional rooms for PW), but also to exceed the limitation related to these situations (ex: the large number of students in the lab area with COVID-19 pandemic) [2], and even to consider some uses specific to the exploitation of computers completely paperless, anytime and anywhere.

The environments where we performed the lab experiments are either virtual known as virtual labs [3, 4]; where the objects manipulated in lab activities are totally virtual (virtual resources and remote/local access), or remote labs [5]; where the learners manipulate remotely real devices (Real resources and remote access) or hands-on labs known as traditional labs (Real resources and local access). The three mentioned types of labs have described in [6, 7, 8]. In the review [9], authors presented both virtual and remote labs for different disciplines such as VISIR lab in engineering [10], programming robots [11] and biology [12]. In [13], authors presented an exploratory analysis of two remote labs that are photovoltaic panels and electric machines labs to measure their acceptance, in terms of usability and usefulness, by students in higher education. A virtual biomaterials lab [14] has been proposed during COVID-19 Pandemic to overcome the difficulties when applying the previous models. A virtual pathology lab [15] brings reality, efficiency, and opportunities for collaborative learning that pathology education did not widely used before. An approach that uses virtual and remote labs in Mechatronics Education based on Cloud Services is proposed in [16].

For the three labs categories cited previously, collaboration/cooperation constitutes a key element for conducting lab experiments efficiently.

Tele-collaborative distance Practical Works (tele-collaborative Tele-PW) [17,18,19] are a form of teaching that requires group work where the learner performs tasks, expresses ideas, shares tools, communicates with other learners etc. The evolution of technologies created new forms of collaborative work with their own specificities. Two learners who work together to achieve remote labs share different information about their common goal. But exchanging of information remotely may quickly become laborious and prevent them from accomplishing their

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activities. Implementing this type of Tele-PW adds new challenges: organizational, human, and of course techniques. As examples, we cited the management of concurrency: Simultaneous execution of transactions over a shared databases or tools between learners can create several data integrity and consistency problems, communication between learners and teachers. In this case, learners/tutors will be confronted with a new work environment. Therefore, personalized solutions must be proposed to respond to their specific needs in terms of tele-collaborative work.

Many scientific productions present the socio-constructivist theories that the learning process is a collaborative and constructive process with directions how to overcome the eventual lack of support of those features in virtual and remote labs as deploying those laboratories into education management systems, supporting the labs to be operated by multiple users at one time, embedding the labs into virtual, etc. [20]

In our previous works, we implemented CVL@b: an agent-based platform of Virtual Laboratory [21]. This platform is a distributed digital environment that contains a space for editing documents describing Tele-PW, an electronic library and a space where the experiment is performed. It enables learners to achieve their distant practical work and teachers to assist the learners during their work sessions. However, the activities carried out in this environment are individual.

To remedy this individual learning situation and the challenges mentioned above, a centralized original solution represented by the creation and integration of the SCA agent in our system will be the aim of this article. This solution enables the synchronization of the Tele-PW that is the synchronization of the concurrent access to virtual objects, which are considered as critical resources. The objective of this work is to show clearly these agents' roles, their functionalities and interactions with the set of existing agents in CVL@b.

The remainder of the paper is organized as follows. In section 2, we describe the collaboration models used. Section 3 presents the context of our work. In section four, we tackle tele-collaborative tele-PW challenges. Our contributions are detailed in Sections 5, 6, and 7. In Sections 8 and 9, we present the implementation. In section 10, we evaluate the performance of the proposed VL plateform CVL@b. Finally, we conclude the paper.

2 Collaboration models

The proposed classification is based on the attributes identified in [22,23]. The attributes that can be used to characterize the collaborative work are the division of tasks, the dimension space/time of interactions. In addition, we considered the number of actors involved in the collaborative work to be important so we include it as an additional criterion of this classification. Indeed, there is a distinction between collaborative situations involving a small group of participants (two to four participants) and those involving a larger number of actors (example projects).

2.1 Division of work

When discussing the collaboration in terms of the division of tasks, there are two forms:

2.1.1 Collective (collaboration)

Learners share the same task. The tasks of each learner in this case are interdependent and learners' roles are interchangeable. Indeed, tasks allocation is dynamic (managed in real time based on the current context). This can be explained by the fact that the collaborative work is dynamic. It is difficult to distinguish the contribution of each participant in the final result.

2.1.2 Distributed (collaboration)

Learners are semi-autonomous. They divide tasks among themselves and work separately. The sub-tasks must be independent of each other. We can distinguish the contribution of each of participants to the final result. In addition, the tasks allocation, in this case, is often static (prior to the action). During the execution of tasks, participants are not necessarily aware of the existence of their partners nor informed of their current activities.

2.2 Space and time dimension of interactions

2.2.1 Space distribution of collaborators

It depends on the location of each participant in the collaborative activity. Two possible forms can be distinguished: face to face situation where group members are in the same location. In this case learners can interact freely. The remote locations (or distributed) where learners of the group are distributed in remote locations, whether located within the same country or spread across continents.

2.2.2 Time distribution of collaborators

This situation is based not only on the activities of the group but also the data transmission techniques (synchronous or asynchronous transmission). This leads to two types of collaboration: real-time collaboration and deferred time collaboration.

In the first form, the groups' activities are performed in real time. Any action taken by a member of the group is immediately sent to other members. It is then a synchronous collaboration. While in the second form, the group members act in deferred time. The actions are spread over the time scale and any member of the group who was not present when the actions were performed; he/she will see the end result of actions performed before his/her arrival. It is then necessary to maintain the system status at any time. Notifications are sent to users to highlight the changes made between two visits made of the same user. In this case we should be to tell who is currently connected. This is called asynchronous cooperation.

2.3 Actors number

Obviously in collaborative practical works, the number of learners is limited. The interactions within a group are affected by its size. This influence concerns in particular the group's performance, decision making and communication. The increase of the group size makes the communication more difficult (less interactive) and can thus affect the working relationship that has been established between the group members.

3 Context

CVL@b is an environment for distance teaching and learning, especially to help learners performing their Tele-PW. It offers on one hand, learners with the opportunity to register, consult the description of practical work, perform the practical work etc., and on the other hand, it offers teachers/tutors a space for the management of educational content, monitoring and evaluation of learners.

CVL@b is structured based on a three levels architecture (GUI, CVL@b kernel and storage space). The kernel is composed of two main systems CVL@b-LCMS (Learning Content Management System) and CVL@b-LMS (Learning Management System). CVL@b-LCMS is designed around a learning content management (LCMS-PWS) and documents management literature embodied in an electronic library (LCMS-EL).

CVL@b-LMS is responsible for the management of learning process through a set of sub-systems: 3D environment for practical work, supervision & control system [21], evaluation system and tele-collaboration system. In this paper, we concentrate on CVL@b-LMS and more precisely on the tele-Collaboration system (LMS-SCA).

4 Tele-collaborative tele-PW teaching problems

For a long time, theories of collaborative learning have focused on the question of how the individual works within a group. Cognition was seen as a product of individual processes and the context of social interaction was seen as a simple background. Recently, the group itself has become the unit of analysis and the perspective of research has shifted to the properties of interaction emerging in the social context [24]. In terms of empirical research, initially the goal was to determine whether collaborative learning was more effective than individual learning and under what conditions. Researchers controlled several independent variables (group size, group composition, task nature, communication media, etc.) that interact with each other in a way it was almost impossible to establish causality links between conditions and effects of tele-collaboration [25,26].

In a conventional PW, learners engage each other in a coordinated effort to solve a practical problem together; they exchange knowledge about the PW and perform the required tasks by PW by sharing the necessary tools for the experiment. So, a space for a collaborative Tele-PW is a digital environment designed to facilitate information exchange, discussion and coordination within a group and the sharing of resources being manipulated. This work focuses on developing a space for tele-collaborative Tele-PW where nature of the tasks accomplished and their complexity differ from distant courses, distant supervised work, etc. This difference requires a specific mode of tele-collaboration, which is the objective of this work.

In our previous work, we proposed an agent-based architecture for a virtual laboratory for the realization of Tele-PW. This architecture is very well suited for individual Tele-PW, however, it has some drawbacks in the case where groups want to cooperate and when the same group of learners wants to work in a collaborative manner. This is a situation where learners share the same workspace. Then, the problem is how to ensure mutual exclusion in accessing shared virtual objects. Also, how to coordinate tasks between learners?

5 Contribution

We had to come up with a new architecture that will solve the problem of simultaneous request of virtual objects and tasks coordination. A new agent called SCA is added whenever a working group is created. This agent is always active as long as there is a learner from any group connected. Its role is to:

- Encapsulate the tasks of group management and coordinate the group implementation of the experiment (each group has its own agent SCA).
- Control the sharing of the work area.
- Allocate and destruct virtual objects.
- Synchronize the access to resources or shared virtual objects in the case of collaborative and/or cooperative Tele-PW.
- Update the overall state of the common workspace.
- Disseminate the overall state to different learners' workspaces.
- The presence of SCA in this architecture has led to several changes:
  1. Implementation of Tele-PW in a collaborative fashion and reduction of the server agent use, that agent is now used only for the extraction of different databases.
  2. When the distant PW is group based, SCA is involved to ensure the synchronization of workspaces agents seeking virtual objects and/or other critical resources. It will make a decision to deny or approve the request.
- The procedure of real-time monitoring has been changed. In the original approach, the supervisor agent communicates directly with the sensor agent to start capturing screen shot of the workspace. There was only one learner and thus a single sensor, but now it is not the case anymore because Tele-PW is group-based work and therefore the number of learners is more than one, which means several sensors (there are as many sensors as the number of members of the group). Therefore, in this case the SCA finds the concerned sensor agent.

- Any change of state of the shared environment of the experiment will be broadcasted by the SCA to the various learners of the same group.

6 SCA structural model

SCA is divided into a set of modules, each module provides some functions: group management, tasks coordination, workspace sharing, virtual objects allocation and synchronization of agents' workspace, update the global state of overall common workspace and its dissemination.

6.1 Group management

When a learner registers, SCA is responsible for assigning it to a group:

- If the learner chooses voluntarily a group with the consensus of other members of the group, then SCA agent only validates this option.
- Otherwise, the choice of the group is systematic.

When a learner connects to the CVL@b, the SCA agent adds her/him to the list of online learners. It then proceeds to announce its presence to the tutors to enable them to supervise the groups of learners and to the members of connected groups so that the collaborative aspect is concretized. The same process is executed if a tutor is connected; an information message is broadcasted by SCA to the connected learners so that they can benefit from her/his assistance.

6.2 Update and dissemination of the workspace global state of the same group

SCA receives changes made to the virtual objects in different workspaces. Then, it saves them (update the global state of the graphical environment) to maintain a global state for workspaces of the group members who decided to share their workspace. After that, it informs the other workspaces of the changes that have happened to the object, then informs the learners who connected and who are interested in sharing of this state. For more details, see section 6.3 (Figures 5 and 6).

6.3 Workspace sharing

A workspace is a graphical environment where experiment takes place. It contains a set of educational elements called virtual objects manipulated by groups of learners during a session of Tele-PW. During this session, members of the same group can collaborate so they share their workspace. This sharing involves the simultaneous manipulation of virtual objects contained in the common workspace. As a result, we are faced with a situation that raises issues related to the synchronization problem of workspace agents, which access concurrently different resources (selection of the same object with the mouse, moving an object and updating of an object). Therefore, one of the main tasks of SCA is to manage and control concurrent access to different virtual objects. The next section describes in detailed how does the SCA agent do the allocation and workspace agents synchronization.

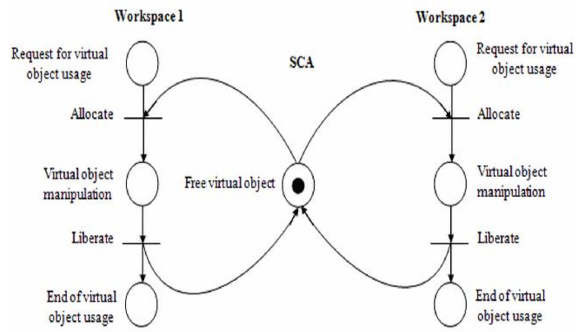

Figure 1: Petri Net for Allocating Common Object.

6.3.1 Design of resources allocation using Petri nets

In the context of concurrent programming, resource allocation is the process of allocating resources to a particular process. This operation is necessary to ensure appropriate access to shared resources between multiple processes. Such an operation is not required for non-shared resources. In our situation, we opted for a formal model for modelling the generic problem of allocating virtual objects between different workspace agents when requesting to manipulate these resources simultaneously. This model is the petri net, which is a directed bipartite graph where tokens constitute the marking.

The Petri net (Figure 1) shows the principle of allocating virtual objects in our system. When learners want to manipulate a common virtual object at the same time, they send a request to SCA agent. This agent acts as an allocator of resources where the token represents the shared virtual object. It allows the use of a common virtual object according to the FIFO strategy: the first request that arrives is the first one served. The mutual exclusion property is guaranteed by the exclusive use of the virtual object. When manipulating a shared virtual object, any modification of its properties will be sent to all other workspaces by the SCA agent.

6.3.2 Virtual objects matrix

It is a static structure of type two-dimensional array whose rows represent the various learners' workspaces of the same group and the columns represent the virtual objects created in each workspace and their properties (objects type, object coordinates on the interface workspace, busy or not, etc.). In addition, this matrix represents the graphical state of the learner's workspace who have started a training session of type Tele-PW. The agent SCA supplies the matrix of virtual objects.

6.3.3 Learning situations

1st case: individual Tele-PW: Figure 2 represents a learning situation in which each learner works locally on her/his own workspace.

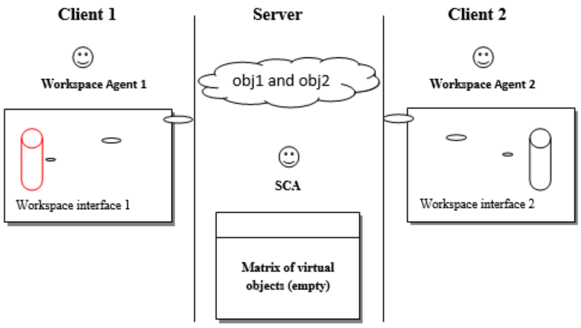

Figure 2: Individual Learning Model.

Workspace 1 and workspace 2 respectively contain the virtual objects obj1 and obj2. In this case, the SCA agent does not intervene, and therefore the matrix of virtual objects is empty.

2nd case: collaborative Tele-PW: Each learner has his\/her own virtual objects in his\/her workspace. If a learner i (Workspace$_i$) wants to share his workspace, he sent his\/her request to the SCA agent who is responsible for updating the matrix of virtual objects and disseminates the new state to the concerned learners (Figure 3).

In this case, the virtual objects will become common so synchronization is needed to ensure they are used properly (mutual exclusion). The SCA agent via its matrix of objects can resolve any problem accessing the same object simultaneously.

This matrix contains a column that shows the state of the object (free or busy) and this column is filled based on the result of the Petri net that we discussed earlier. For the implementation of shared workspace and mutual exclusion, the following algorithms in Figure 4 are used.

6.3.4 Dynamic aspect of SCA

When the workspace agent receives a request to manipulate a virtual object from the learner interface agent, it locates the SCA agent of the concerned to which belongs this learner because each group has its own SCA agent. After, it sends to the SCA agent a message to allocate the desired virtual object and waits for its reply. SCA makes a decision to allocate or not the desired object based on the content of the matrix of virtual objects. If the desired object is busy, the workspace agent receives a negative response and goes in the final state; otherwise,

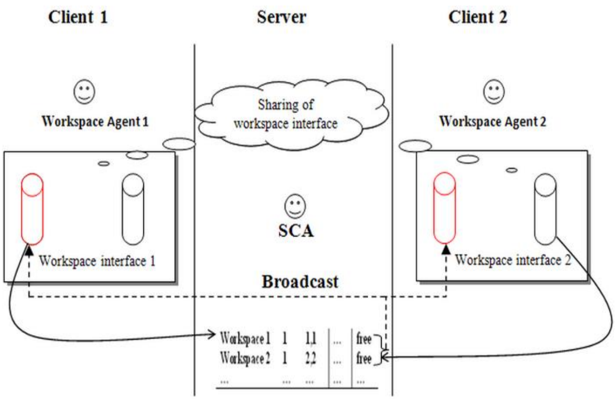

Figure 3: Collaborative Learning Model.

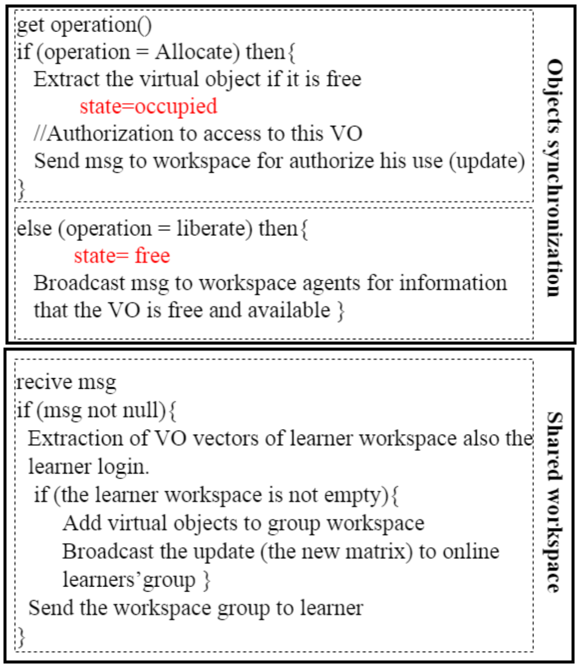

Figure 4: Sharing workspace and achieving mutual exclusion.

(when the object requested is available) the SCA agent changes its status in order to lock it and a notification message (positive answer) is sent to the requesting workspace agent. This allows the learner to manipulate the object in its interface (see Figure 5).

During the manipulation of virtual objects, their status will change. These changes are sent by the workspace agent to SCA agent to update the states of the manipulated virtual objects in the matrix of resource allocation. Also, it gets the list of workspaces for different learners in the same group and broadcasts to them the latest updates of the global workspace. Requests for release of virtual objects will be forwarded to the SCA who will execute them (SCA is responsible of adding/releasing virtual objects informs experiment workspace) as shown in Figure 6.

6.4 Coordination task

This task is implicitly the responsibility of the SCA agent throughout its life cycle. It coordinates the various tasks assigned to the artificial agents present in a session of activities related to a Tele-PW.

7 Tele-collaboration/tele-cooperation tools

In tele-Collaboration environment [27], learners meet virtually, is the place where they talk. This is where the group is crystallized and be allowed to exist and live. Tele-Collaboration is essentially made of interaction and dialogue. Learners/tutors can share a digital workspace where they express their ideas, communicate and exchange resources (to share costly equipment and resources, which are otherwise available to limited number of users due to constraints on time and geographical distances). In this space, learners

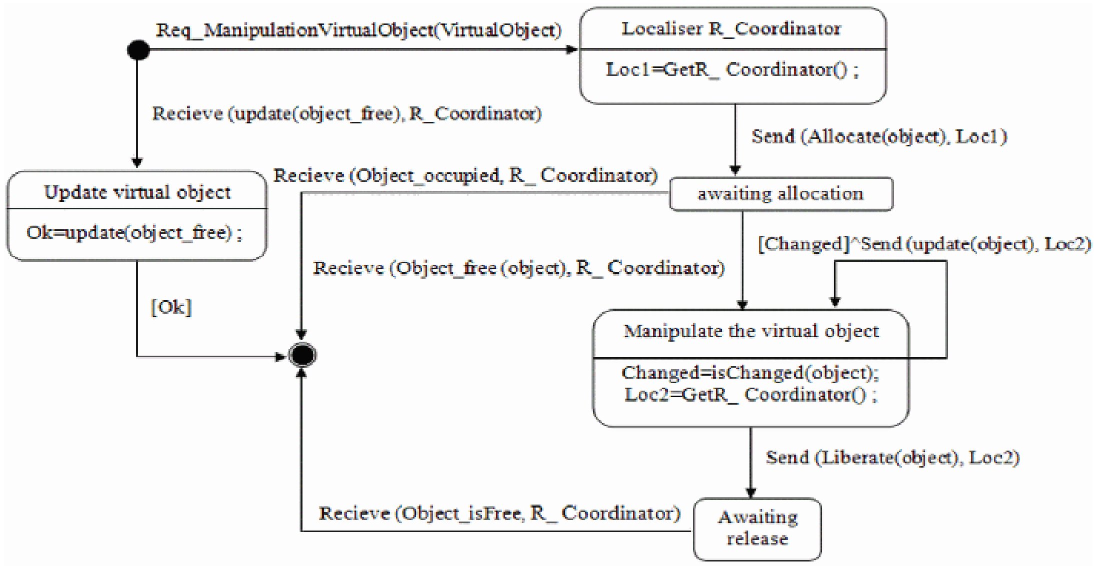

Figure 5: State-transition of Workspace.

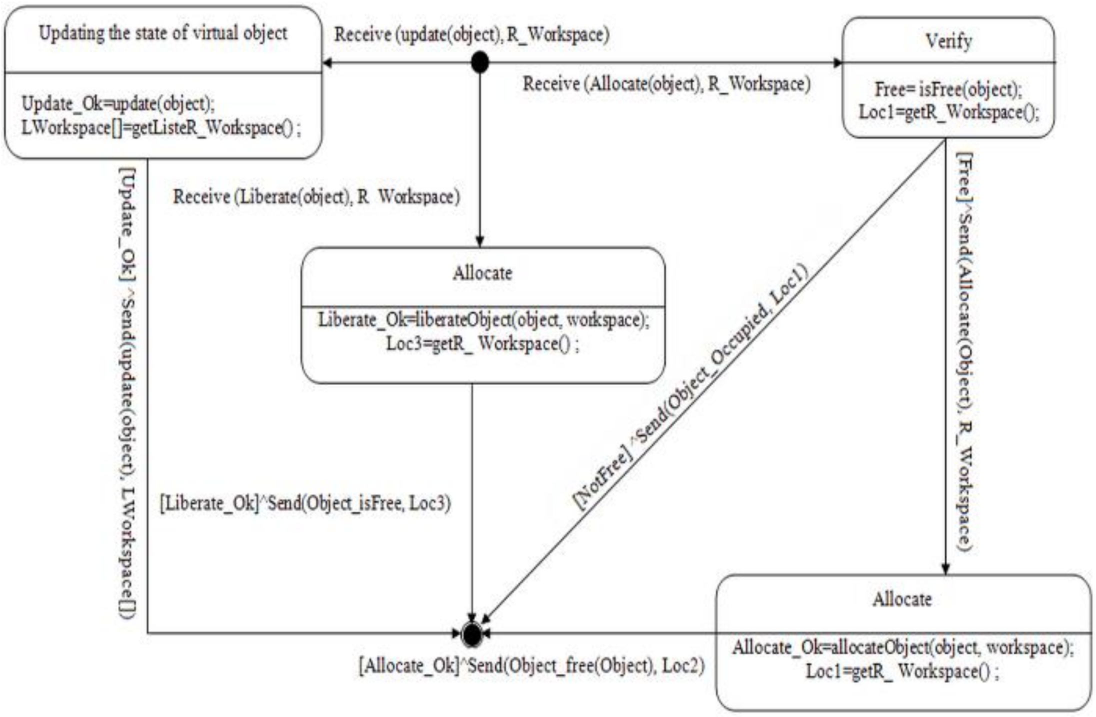

Figure 6: State-transition of SCA.

communicate synchronously or asynchronously, in written or spoken natural language. The communication space includes tools and is prepared for this purpose. The tools most commonly used are chats, email, discussion boards, wikies and on-line forums, etc. In CVL@B, a chat tool based on peer-to-peer architecture is available for the learners so that they can interact and work together which make the resources more efficiently.

All members of the group remain in regular contact; each contributes to the group by performing its actions. Everyone can contribute to the actions, being performed another group member, to increase the performance, interactions are permanent. In addition to communication tools, a shared space for creating/editing reports and a shared workspace favouring the Tele-immersion are available for use by various learners. Regarding tutors, dynamic or evolving situations of teaching/learning require from them a certain number of specific activities to build cognitive skills.

The use of ICT in CVL@B offers the tutor means of supervising, controlling Tele-PW activities, and giving effective feedbacks [21]. The tele-cooperative mode, in CVL@B, is provided by individual learners' workspaces who will act independently. The interactions are concerned to the organization, coordination and monitoring of progress (often under the responsibility of a chosen member of the group who is charged with the responsibility to ensure the individual performance of each group member). Everyone's responsibility is limited to ensure that its actions are achieved: the continuous and coordinated combination of the sub goals, achieved by each member, will lead to the achievement of the expected goal of Tele-PW.

8 Length of agents' life

The agents' life length (Figure 7) in the system varies based on the agent's role. The connector, archivor and server agents are created when the system is launched and remain during the life cycle of the server application.
These agents communicate with another server of type databases to extract and safeguard data. This communication is done through a well-specified protocol (for example: JDBC for Java).

On the other hand, the supervisor and helper agents are created at the time of, respectively, a request of assistance or supervision. Their deletion from the system is carried out as soon as they finish the task that was assigned to them. The learner interface, teacher interface, SCA, and sensor agents are created when the human actor (Learner/Teacher) has successfully connected. They remain active during this session. SCA remains until all active members of the same group are disconnect.

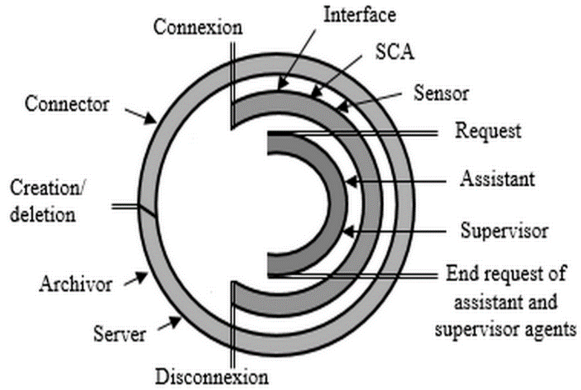

Figure 7: Length of Agents' life.

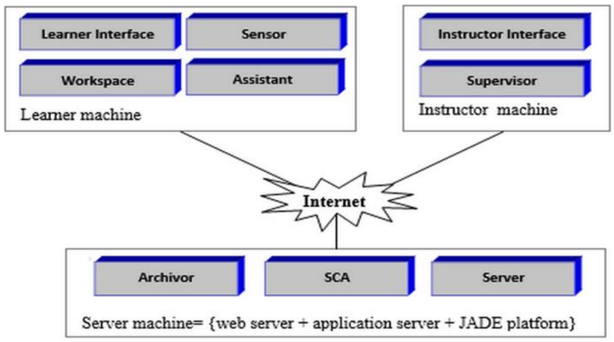

Figure 8: System Logical architecture.

9 Implementation

Software architecture as illustrates Figure 8 shows the number, types, and locations of agents in our system, each human actor has his own artificial agents: learner/teacher interface, workspace, sensor, assistant, and supervisor. They run on the client and are responsible for the management of user interfaces and interaction with other agents located on the application server. Server agent, archivor agent and SCA remain on the server and are responsible for providing the various resources made available by MySQL database server.

The best approach to construct a multi-agent system (MAS) is to use a platform, which represents a set of tools necessary for the construction and the activation of agents.

JADE (Java Agent DEvelopment framework) platform is deployed for the execution of our MAS. The communication between artificial agents is based on the communication protocols inter-agent, which follows the standard model FIPA ACL.

9.1 Sample interface

When a user wants to connect to his/her personal workspace, he/she enters his/her user's name and password. After its identification, his/her personal workspace (tools bag) is loaded based on the type of user (learner or teacher). This space offers the learner the necessary tools from consulting Tele-PW sheet until the completion of the Tele-PW.

In case the user is not registered, he/she has to register so that he/she can access his/her work later and make use of the available features offered by the platform. In order to check the new design of our SMA, an instance of Tele-PW of collaborative/cooperative nature has been implemented.

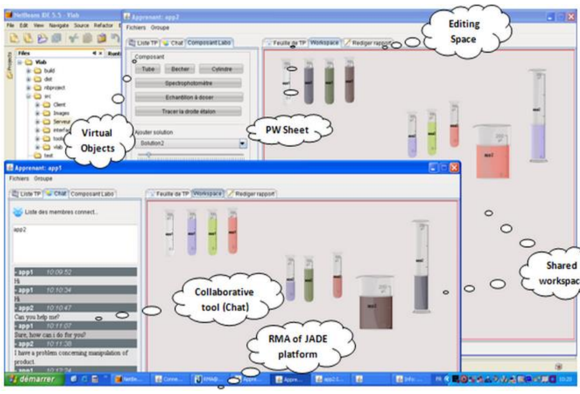

Figure 9: Shared Environment of Tele-PW.

The screen above (Figure 9) represents a distant experiment that takes place in a biochemistry virtual laboratory. Each leaner has a bag of tools.

An interface that contains a shared workspace where the experiment takes place, a panel of virtual objects, a communication space (Chat), list of Tele-PW done earlier and a new one which have been loaded on the system, an editing space, and a display space for the content of Tele-PW documents.

10 Performance evaluation of LMS-SCA

10.1 Parameters to be evaluated

In order to show the effectiveness of LMS-SCA, various parameters were taken into account. In this study, the selected criteria will make it possible to validate the

Situations	Spatial distribution		Temporal distribution	
	Learner/Learner	Tutor/Learner	Learner/Learner	Tutor/Learner
Situation 1	Present	Remotely	Synchronous	Sync/async
Situation 2	Remotely	Present	Sync/async	Sync/async
Situation 3	Remotely	Remotely	Sync/async	Sync/async

Table 1: Pedagogic situations in LMS-SCA.

framework taking into account the quality of training resulting from the use of this system. We describe below the selected criteria:

- Satisfaction: It is important to know if the user is overall satisfied with the use of LMS-SCA.
- Ergonomic: It makes it possible to evaluate the man-machine interaction of a computer system. This criterion takes into account the ease of use, the user-friendliness and the system usefulness. Since LMS-SCA consists of a set of systems, each system will be assessed in an independent way, in addition to the overall assessment.
- Tele-Collaboration/Tele-Cooperation: It is important to measure the level of users' participation.

This factor includes the individual and collective participation in the training. This means that the learner has contributed to the realization of the Tele-PW, participated in the discussion with his/her colleagues about the practical problem and helped them during the activity.

10.2 Experiment Conditions

10.2.1 Population and Groups Structuring

In order to evaluate LMS-SCA, we have used a questionnaire to collect the opinion of 34 participants. Before we start to collect the data, two categories of participants were identified: learners and tutors. The group members and their tutors were distributed in the space. The learners and teachers/tutors gave their impressions about the various functionalities offered by the system.

Each group has between 2 to 3 learners. Tutors have had previous experience on how to form learning groups. Participants (learners/tutors) have never participated previously in a remote experience. The experiment took place in a computer room where all learners were present. The room is equipped with 15 PCs connected by a local area network and an Internet connection. Due to electrical problems, PCs going down, the unavailability of learners at the same time, and each student having a computer, the experience took a long time. To calculate the reliability of the questionnaire, we used the test (Cronbach's Alpha), which gave the value 908 for a population of 34 participants. This value, which showed that there is a harmony between the different items of the questionnaire therefore, the reliability of the result is acceptable.

10.2.2 Pedagogic Situations (tutor versus learner)

According to the dimension space/time of the interactions, there are two distributions: spatial distribution and temporal distribution. Each one contains also two situations. The different educational situations we have considered are summarized in Table 1. These situations allow synchronous and asynchronous tele-collaboration (spatial and temporal dimension), require a limited number of learners per group and the learners work remotely.

10.2.3 Pedagogic Scenarios

The different educational scenarios used in this experimental protocol are summarized in Table 2. From this table, and from the point of view of division of tasks, learners work in tele-collaboration and/or tele-cooperation. But the interaction between tutors and learners is done in a tele-collaborative way only. This is due to the summative/formative evaluation of learners' work.

10.2.4 Pedagogic Content

The choice of the pedagogical scenario for the experiment is not easy at all. This is due to the numerous disciplines that are situated in the experimental sciences. Thus, to choose a discipline, we took the following factors in consideration: degree of interactivity during the activities of Tele-PW and the low level of abstraction of the latter. Biochemistry discipline has met the criteria mentioned in our approach by the nature of its PW which are concrete, do not deal with abstract phenomena and have a very high degree of interactivity. Learners collaborate with each other for the implementation of distant PW tasks. The tele-collaboration/tele-cooperation aspect is one of the main features of distant PW studied. First, learners in the same group cooperate in the implementation of distant PW. Each learner is individually responsible for executing different steps of the affected phase. After the completion of individual tasks, learners, in a collaborative manner, proceed to the combination of the intermediate results to write the distant PW report which will be sent to the tutor for possible evaluation. These distant PWs points of tele-cooperation/tele-cooperation are illustrated in Figure 10.

Scenarios	Learner/Learner	Tutor/Learner
Scenario 1	Tele-collaborative	Tele-collaborative
Scenario 2	Tele-cooperative	

Table 2. Pedagogic scenario in LMS-SCA.

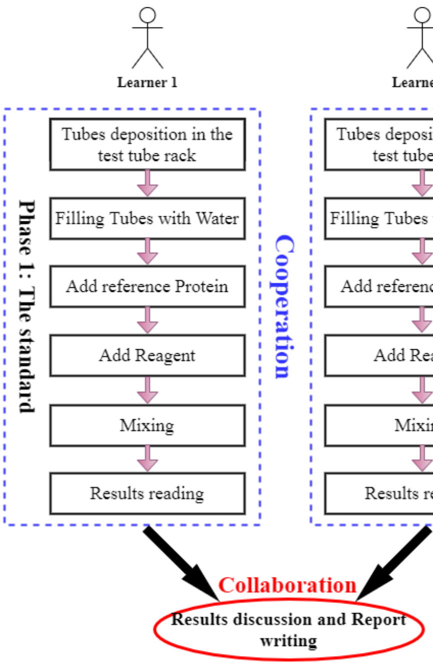

Figure 10: Pedagogic Content.

10.3 Results

To measure each criterion and be able to analyse results, we assumed that the sum of (a lot & complete) gives a positive appreciation and the sum of (not at all & average) gives a negative one. The communication tool used is found to be very useful (71.5 %) and very easy to use by 93 % of the group members and tutors. Most users (76.5 %) find the interface to be friendly. The group that accessed the system remotely believes that the communication delay is acceptable. The results of this evaluation are presented in Table 3.

The statistical results obtained are reported in Figure 11. Analysing the results, for the textual tele-collaboration illustrated by the clarification of the Tele-PW statement (76.3 %), discussion of the results between learners (84.2 %) and drafting of the report (79 %) either Tele-immersive collaboration (68.9 %) by using shared workspace. Thus, in the summary, the level of textual/Tele-immersive collaboration was considered important. In addition, more than 90 % felt the presence of other colleagues using the system that is a good indication that the users of our system did not suffer from loneliness that is a serious problem with online learning.

The space of the experiment was considered very easy to use by 83.44 %, friendly to use by 75.92 % and offers a set of virtual objects that are necessary to the realization of a distant PW as shown in Table 4.

Criteria	Negative		Positive	
	Not at all	Average	A lot	Complete
Easy to use	7	-	26.5	66.5
Utility	2.5	26	21	50.5
Convenient	2.5	21	15.5	61

Table 3. Communication evaluation.

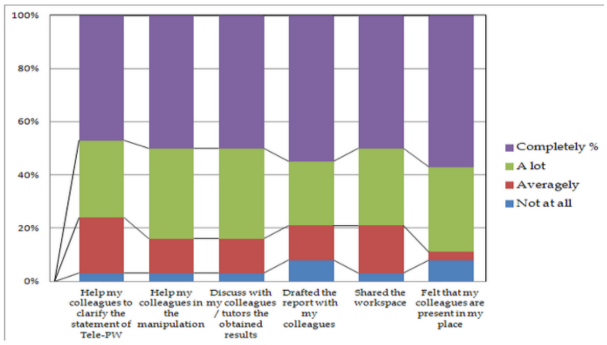

Figure 11: Evaluation of CVL@b tele-collaboration System.

Criteria	Negative		Positive	
	Not at all	Average	A lot	Complete
Easy to use	4.73	11.9-	18.94	64.5
Convenient	4.73	19.34	30.92	45
Provided tools	2.36	19	23.95	54.6

Table 4. Workspace evaluation.

10.4 Discussion

The overall result of the evaluation shows that LMS-SCA is an acceptable tool. The majority participants find it easy to use, useful and convenient. LMS-SCA was well appreciated and it answers the requirements of learners/tutors. The results were very satisfactory and validated that our design was well adapted to the collaborative Tele-PW. The degree of interaction is considered to be important. Almost all participants think LMS-SCA could be used to help learners/tutors in Tele-PW laboratory. But 28.9 % of the participants think that it does not improve the quality of collaboration and does not replace the classical collaboration at all.

11 Conclusion

Our work is in the context of a tele-collaborative learning system for Tele-PW. The tele-collaborative/tele-cooperative aspects relevant to the learning process, presents difficulties in terms of their implementation, the management of concurrent access and shared workspace, and sharing the communication tools among learners etc. In this paper, we presented an approach for synchronization of tele-collaborative Tele-PW. It is an artificial agent SCA, which ensures the smooth running of collaborative activities of a Tele-PW. This agent manages and controls the various accesses of competing workspace agents to the shared virtual objects and shared virtual workspace while coordinating the tasks performed by the set of agents involved in this process. In order to validate our work, we tested the system by implementing a biochemistry experiment. The results show that the tele-collaboration increases the flexibility of the process of accomplishing a Tele-PW. Nevertheless, in the future, we plan to make our agent more intelligent by developing their skills and make our platform more efficient.

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