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An E-Collaboration New Vision and Its Effects on Performance Evaluation

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***Abstract*: The current global dimension of human exchanges in any domain (work, commerce, learning, entertainment…) is accompanied by technologies that enhance synchronous and asynchronous communication thus facilitating both collaboration and competition: the two driving forces for progress since ages. Collaboration can be made essentially in asynchronous mode by e-mails, files and information exchanges, or in synchronous mode by organizing meetings where collaborators communicate directly. Geographical and temporal distance may be overcome by several ICT (Information and Communication Technologies) solutions, usually under the label of e-collaboration. This concept is based on a high number of interactions that could be classified in three types: (1) Computer to Computer Interaction, (2) Collaborator to Computer Interaction and (3) Collaborator to Collaborator Interaction. Consequently, performance evaluation of e-collaboration has to be considered as consisting separately on the evaluation of each of the three types of interaction. This view leads to focus on three main aspects: the first is the system's *efficiency* the second is the interface *ergonomics*, the third is the collaborator's behaviour during collaboration and its influence on the outcome of the joint effort: *effectiveness*. Three evaluation layers are so found. In this paper, we propose an appropriate evaluation method to each layer, so that future developments, applying the new evaluation method and exploiting results in actual settings, may improve separately efficiency, ergonomics and effectiveness of e-collaboration in a complementary way.**

***Keywords*: e-collaboration, performance evaluation, efficiency, ergonomics, effectiveness.**

I. Introduction

Electronic collaboration (or e-collaboration) can be defined as "the *collaboration among individuals engaged in a common task using electronic technologies*" [15]. Two centuries ago, collaboration was possible only between persons in the same place at the same time, then inventions followed and a primitive form of e-collaboration appeared by exploiting the telegraph then the telephone until, the mainframes. Despite these developments, e-collaboration was always quite difficult. With the advent of e-mail, e-collaboration has been remarkably favored. Subsequently, other technologies were developed such as Group Decision Support Systems [15]. The Web, in particular its technologies facilitating users that communicate both by reading and writing, accelerated tremendously the emergence of social networks of many kinds, where "easy" bidirectional communication by the "casual" user permits quite sophisticated forms of e-collaboration which allow:

- to break the geographical and temporal barriers;
- to reduce the costs related to traveling (saving energy in the mean time);
- to facilitate the human exchange and the sharing of expertise on the fly;
- to accelerate the effectiveness of cooperative work by sharing resources ***in the context*** (eg: documents); therefore to increase significantly the competitiveness of groups adopting e-collaboration technologies.

This concept has revolutionized many domains like e-commerce and e-learning; so its improvement and dissemination are very interesting and may be beneficial for any application domain. But it was surprising that in the state of the art, works on e-collaboration performance evaluation and improvement present still several limits and are not yet based on widely accepted criteria. This fact will, in our opinion, affect negatively the evolution of the concept. As a solution to this problem, we propose here an e-collaboration performance evaluation method.

This paper will be organized as follows. In section 2, we position the reader in the context by summarizing most of the existing work on e-collaboration. In section 3, we present the findings that led us to propose this work. In section 4, we detail the proposed new interaction view. According to this, a performance evaluation solution is proposed in section 5 dealing with three aspects: efficiency, ergonomics and effectiveness. In section 6, we explain the proposed evaluation method by applying it on an e-collaboration scenario. In section 7, and before concluding, we discuss the validation procedure of our method.

II. E-collaboration state of the art

The state of the art of e-collaboration is quite rich and the existing works can be classified into several categories according to the problem type. The first category consists of the conception and development of collaborative platforms providing services increasingly sophisticated like Agora [6]–[5], Access Grid [7] and AGrIP [12]–[13]–[18].

The second category focuses on the most suitable technologies permitting to improve and refine services offered by collaborative platforms. Two particular technologies were studied by the majority of these categories works and exploited by some collaboration developments [6]–[16]: they are Grid and Agent technologies. In fact, Grids are service oriented infrastructures for sharing resources and Agents are intelligent, autonomous and interactive entities having the capability to provide and use services. The concept of services that is the base of collaboration is declared in the paper referenced by [14] to be the intersection of Grid and Agent technologies. In addition, these two technologies 'need each other' and are described in the literature to be 'Brawn' and 'Brain' [9]–[10]. Grid infrastructures are robust, reliable and scalable so they can represent a Brawn and Agents are autonomous, problem solvers and flexible so they can represent Brain. The main conclusion that can be drawn from these works is the existence of a confirmed interest to base collaborative platforms on the compatible technologies of Grid and Agents. The third category of works deals with performance evaluation of e-collaboration. This concept has no general definition; it is characterized by its strong dependence on the studied domain's constraints. In general, technical evaluations are based on aspects dealing with the performance of the software, like computing time, results and accuracy: these measures can't be applied straightforward in collaborative contexts, because they don't adopt a holistic view of the socio-technical system (the system and the humans) and can't predict its future evolution. To obtain a realistic and useful evaluation, many other factors should be considered, like the objective of e-collaboration, and the actual data and resources (what is traditionally called the pragmatic context). One of the reasons underlying the emergence of a context is exactly this: on the future Web, technologies (infrastructures and applications) will not be fruitfully conceived, deployed and exploited unless a very accurate empirical (scientific) study has been associated that analyses the use of those technologies by societies of humans. It becomes therefore evident the profound conceptual shift from the classical "application context" to the future "requirement elicitation, evaluation and exploitation scenario of use" (http://webscience.org/home.html). The same "paradigm shift" is claimed by most of the scientists currently engaged in Service Oriented Computing. This strong dependence of e-collaboration from its context renders the evaluation of its performance rather difficult and the identification of general performance evaluation solutions not evident. In the literature [4], there are different types of evaluations: feasibility evaluation that is based on the cost, iterative evaluation that aims to improve collaborative platforms, comparative evaluation that compares systems and appropriateness evaluation that determines if a system is appropriate to a given organization's process. The most used performance evaluation approach is top-down; it consists on "identifying useful metrics from goals" [17]. There are many methods based on it, like Quality Function Deployment (QFD), Software Quality Metrics (SQM) and Goal/Question/Metric (GQM) [1]–[2]. But there are no largely known standard evaluation methods. The lack of standardization has the consequence that often developers of collaborative platforms provide *subjective* arguments about their performance tools. This is the principal motivation of our research work.

III. Motivation

In general, the establishment of new software is preceded by work steps like design and implementation. But even if these steps are rigorously realized, the test and evaluation remain necessary to the progress and continuity of the software. This is even more the case for interactive software. It is generally accepted that modern software on the Web is produced by adopting the spiral or agile software development models and not the more classical waterfall. This entails that each version of the software is revised after *evaluation* in order to produce the next version.

In the case of e-collaboration, there are many works on the development of new platforms offering more and more useful services and advocating positive performances without reference to any evaluation method. However, we believe that even a minor step towards a reasoned evaluation model for collaborative infrastructures and applications may improve significantly the confidence on the technologies and the positive effects of their exploitation in collaborative businesses.

IV. A view on performance evaluation

A. *Interaction view*

In order to evaluate e-collaboration, let's begin by analyzing and describing its properties in time. In general, an e-collaboration environment is supported by a distributed system, composed by human collaborators and disposes of software and hardware resources. It is characterized by one or many objectives and involves, to reach them, a certain number of exchanges between collaborators. A successful e-collaboration, is supposed to provide the most adequate conditions to the achievement of all needed exchanges. In fact, in order to communicate with collaborator B; the collaborator A needs to interact with its computer which needs to interact on his turn with the recipient's computer. From this description, three types of interactions can be identified during an e-collaboration session as shown by Figure 1: Computer to Computer Interaction, Collaborator to Computer Interaction, Collaborator to Collaborator Interaction. As e-collaboration is based on the overlap of these different types of interactions, its evaluation can be considered with respect to the evaluation of each type of these interactions. The evaluation of Computer to Computer Interaction judges the system's performance, i.e. e-collaboration's **efficiency**. The evaluation of Computer to Collaborator Interaction judges the interface of the platform, i.e. the **ergonomic** aspects and finally the evaluation of Collaborator to Collaborator Interaction judges the user's behaviour during collaboration and its influence on the global outcomes, i.e. e-collaboration **effectiveness**. This view will permit us to consider e-collaboration's evaluation as the analysis of the superposed layers [3].

Our contribution will not consist in proposing a new evaluation method for each layer; but in investigating the most adequate method for each one in the combination needed for accounting the previously explained superposition with respect to studied contexts (scenarios of use).

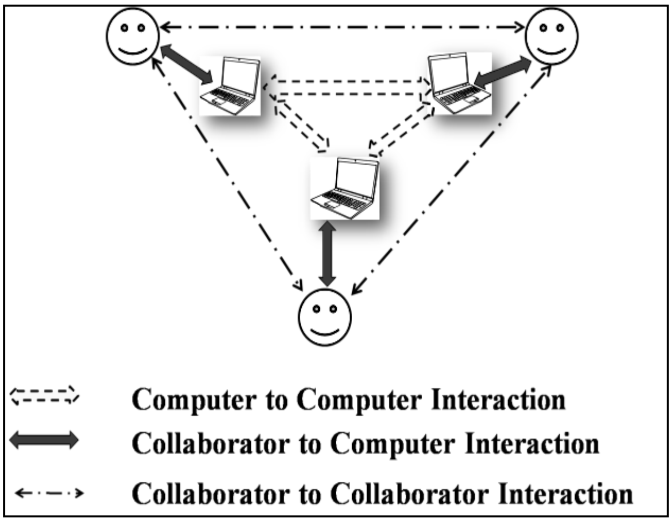

Figure 1. Interaction view

B. Interaction dependencies

In this section, we discuss dependencies between the three evaluation layers. In fact, in an e-collaboration context, as collaborators are geographically dispersed, there are no direct interactions between them. As shown in Figure 2, a communication process is performed as a result of:

- An interaction of a collaborator with his computer (sender);
- An interaction between a sender and a recipient computer;
- An interaction between the recipient computer and its owner.

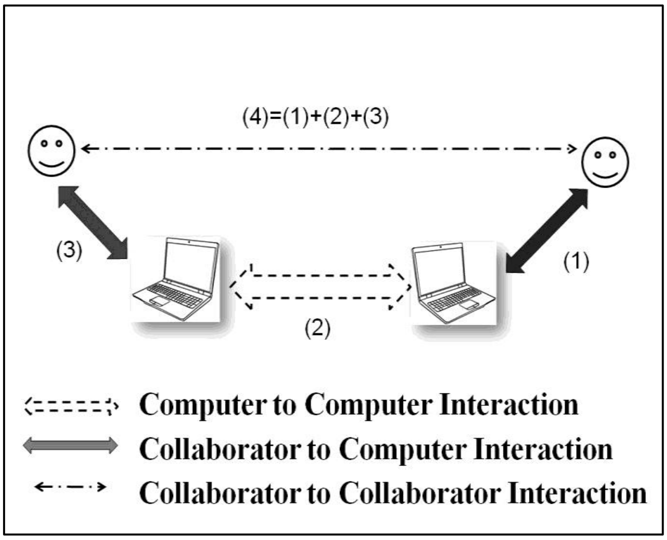

Figure 2. Interactions decomposition

This decomposition, leads us to affirm that collaborators interactions are dependent of the two other types of interactions so they are directly affected by possible problems on them. These dependencies have to be considered in the evaluation process.

V. Evaluation method

A. Efficiency evaluation

In the literature [11], the main performance evaluation techniques are analytic modelisation, simulation and measuring.

The first technique consists in representing the evaluated system by an abstract model based on mathematical concepts and serving to describe some aspects of the system as well as its whole behavior. The numeric analysis of the obtained model, gives performance parameters of the real system. Many methods are employing the analytic modeling:

- Markov chains for access resource modeling;
- Queuing theory for network modeling;
- Graphs for modeling communication and transport networks.

This technique presents the advantages of rapidity of implementation and precision of results. But its application to complex systems needs the emission of some hypothesis and approximations to make the analysis approachable.

The second technique consists in implementing a software model permitting to imitate in a simple manner the system highlighting its more important aspects. Simulation technique is interesting when the studied system is under construction, inaccessible or too complex to be handled directly. Many simulation tools exist in the literature like:

- NS2 for standard internet protocols behavior simulation;
- OPNET for computer and communication network simulating and evaluating;
- MATLAB and MATHEMATICA for complex system representation.

This technique is adequate when the system is physically difficult to deploy. But it does not often guarantee a faithful representation of the real system. To maximize its fidelity to the modeled system, a long execution time is required to insure that a sufficient number of events have occurred.

The third technique consists in measuring some characteristics of the system and analyzing the obtained results. These measures are computed by specific tools or done by the system itself. The advantage of this technique is to emphasize on the most essential criteria, to define a measure system to quantify them in order to give precise results. However, the task of measuring could disrupt the system functioning.

To obtain a reliable evaluation, we have to choose the technique representing the reality in the most faithful manner, namely, the measuring technique. Consequently, the presented efficiency evaluation will be based on it and we have to identify the significant measures to capture. We estimate that this layer must guarantee rapidity of communication and integrity of transferred data. To evaluate these two criteria, we propose to carry out some statistics on communication time and rate of losses having occurred during the collaboration. As shown in Table 1, we distinguish synchronous and asynchronous modes.

After the evaluation, obtained results have to be interpreted by comparing them to expected values. Since the reliability of evaluation depends heavily on the interpretation, these values have to be rigorously chosen.

The analysis of several series of experimentations has to be realized to fix these particular values.

Criterion	Mode	Formula
Communication	Synchronous Mode	Average response time to a synchronous request: $$TMR = \frac{\sum_{k=1}^{Ns} TRk}{Ns} \quad (1)$$ *TRk* is the response time to the synchronous request k and *Ns* is the number of satisfied synchronous requests.
	Asynchronous Mode	Average response time to an asynchronous request: $$TMT = \frac{\sum_{k=1}^{Nas} TTk}{Nas} \quad (2)$$ *TTk* is the response time to the asynchronous request k and *Nas* is the number of asynchronous transferred requests.
Losses	Synchronous Mode	Percentage of unsatisfied synchronous requests (having no response): $$P1 = \frac{Nns}{N1} * 100 \quad (3)$$ N_{ns} is the number of unsatisfied synchronous requests and N_1 is the total number of synchronous requests ($N_{ns}= N_1-N_s$).
	Asynchronous Mode	Percentage of asynchronous lost requests (not transferred): $$P2 = \frac{Np}{N2} * 100 \quad (4)$$ N_p is the number of asynchronous lost requests and N_2 is the total number of asynchronous requests ($N_p= N_2-N_{as}$).}

Table 1. Efficiency Measures.

B. *Ergonomic evaluation*

To evaluate ergonomics, many methods exist in the literature [20]. They can be divided in two categories: analytical and empirical. Analytical methods consist in the simulation of task executions without involving the user; they implement diverse methods like GOMS (Goals, Operator, Methods and Selection Rules), cognitive exploration and heuristic evaluation. While empirical methods observe users behavior during their interaction; they implement techniques like interviews, questionnaires and measuring through required time to execute a task, accuracy of results and number of errors.
Since this layer concerns Computer to Collaborator Interaction, its evaluation should be based on user’s behavior. So, we adopt the empirical techniques and we propose the following plan to the evaluator:

Before the beginning of e-collaboration work:

1. Designate a collaboration member mastering all the session details (objectives, constraints, members profile…) to give precise and correct responses when asked in the following steps and also in effectiveness evaluation. This member will be named *the collaboration leader;*
2. Determine the global and intermediate objectives of collaboration by interacting with *the collaboration leader;*
3. According to recovered information; identify the important tasks having to be carried out to reach collaboration objectives;
4. Select the elementary services offered by collaboration tool and needed by collaborators to perform the tasks determined in step 3.

During the collaborative session:

5. Analyze the collaborators' capacities to use the previously determined services.

After achieving the collaborative work:
Retrieve positive and negative collaborators' remarks about the system interface.

C. *Effectiveness evaluation*

In general, the success of an e-collaboration is related to the adequacy between the envisaged objectives and the ones actually attained. This adequacy depends on collaborators' behavior and their efficacy in accomplishing the work in question. The evaluation process is as follows:

Before the beginning of the collaboration work

1. Identify e-collaboration constraints by interacting with *the collaboration leader*. These constraints can consist, for example, in some dependencies between different collaboration steps or distinct collaborators. Their non-compliance could be the cause of unsatisfactory results;

After achieving the collaborative session

2. Verify by interacting with *the collaboration leader* if the global and intermediate objectives were attained and if the previously cited constraints were respected;
3. In this step, we propose to compute for each collaborator a set of measures supposed to reflect his behavior and to allow the detection of eventual anomalies of the analyzed collaboration.

4. These measures are collaborator's presence rate (PR_i), collaborator's participation rate (PA_i), and collaborator's exchange rate (EX_i). Their calculating formulas expressed in the equations (5), (6) and (7) use the following variables: PD_i representing the presence duration of collaborator i, ID_j representing the duration of the j^{th} intervention of collaborator i, N_i representing the total number of interventions for the collaborator i, NBX_i representing the number of exchanges of collaborator i, TD representing the total duration of the analyzed collaboration session and TE representing the total number of exchanges effected during the analyzed collaboration session.

$$PRi = \frac{PDi}{TD} \quad (5), \quad PAi = \frac{\sum_{j=1}^{Ni} IDj}{TD} \quad (6), \quad EXi = \frac{NBXi}{TE} \quad (7)$$

5. The final step of the whole evaluation procedure is to generate an evaluation report summarizing the detected failures as well as positive aspects at each level of the studied collaboration.

VI. Application on a collaboration scenario

To explain more the presented reusable evaluation steps in ergonomics and effectiveness evaluations; we detail, in this section, their application to a real e-collaboration scenario.

A. *Scenario description*

To renew his PhD registration, a student has to present the work he carried out during the previous year in front of a jury composed by a number of researchers. According to student progress during the previous year and to the work planned for the next one, this jury decides to accept or not a new registration for him. The jury members are: the PhD director and an external researcher denoted Researcher B and specialized in related domain to the PhD subject. As shown in Figure 3, different participants to this meeting are geographically dispersed; so they choose to collaborate in an electronic manner.

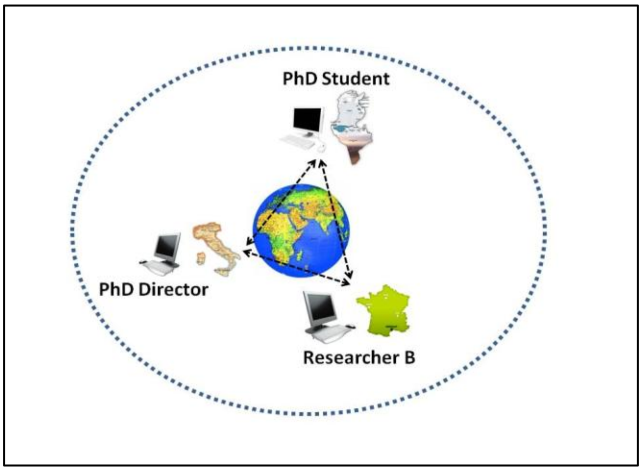

Figure 3. Collaboration environment

The PhD director proposed to use Flashmeeting arguing that he finds this tool easy to master and asserts that his main advantage is the record of collaboration sessions allowing to keep an historical trace on the work progress.

Figure 4, shows the record page of the studied scenario entitled "PhD Registration".

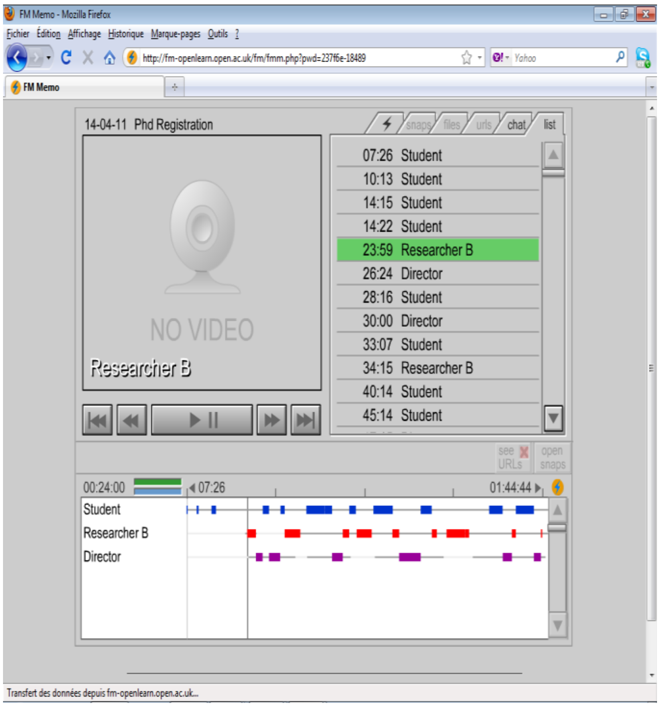

Figure 4. Record of "PhD Registration" scenario

B. *Explanation of the scenario evaluation*

The application of previously explained evaluation method begins by designing a *collaboration leader* and determining the global and intermediate objectives. This task will be needed for ergonomic evaluation as well as effectiveness one. The PhD director is aware of all details about this collaboration, so he is the natural *collaboration leader*. He affirmed that the global objective is to decide of student's registration in PhD and that the following intermediate objectives must be attained to reach the global aim:

- Mastering the use of Flashmeeting to allow all members to communicate easily;
- Judging student's progress in PhD work;
- Judging the future plan of work.

1) *Ergonomic evaluation*

From the presented aims, we can predict the following scenario. First of all, the student must present the work carried out during the previous year to other members who can ask him questions or suggest modifications or extensions to the work. Then, the work planned for the next year is also presented and discussed. Collaborators can have short written discussions when others are speaking. This evolution is based on the following elementary tasks:

- Request the turn to speak as Flashmeeting is based on speaking by turn;
- Leave its turn to let another person speaking;
- Send an instant message to one or many collaborators.

2) *Effectiveness evaluation*

In this layer, our concern is to study the progress of this virtual meeting and eventually detect particular behaviors having negative effects on the collaboration efficacy. This work is carried out to determine if the fixed objectives correspond to those achieved and to detect the failure causes in the case that objectives are not completely reached. The evaluation report, having to be automatically generated by the future evaluation system and aiming to summarize the evaluation results of each level, has the form shown in Figure 5.

Evaluation report

Efficiency evaluation

Ergonomic evaluation

Task \ Collaborator	Student	Director	Researcher B
Elementary tasks			
Request the turn to speak	Good	Good	Good
Leave its turn to let another person speak	Good	Bad	Medium
Send an instant message to one or many collaborators	Bad	Good	Good
Positive Remarks			
	-	-	Satisfactory interface
Negative Remarks			
	-	-	-

Effectiveness evaluation

Rate\Collaborator	Student	Director	Researcher B
Presence rate	100 %	66,28 %	68,96 %
Participation rate	30,69 %	22,54 %	35,45 %
Exchange rate	0 %	0 %	0 %

Figure 5. Evaluation report

In order to apply the effectiveness evaluation method on this scenario, it was necessary to be aware of all constraints having to be satisfied. For this aim, we contacted *collaboration leader* who explained that the work in this virtual meeting can't progress if one or more members are totally or partially absent. In fact, the student has to present his work, listen and eventually respond to questions, suggestions or comments of the two other members who must be present and follow discussion to be able to make a decision about student's registration at the end of this session. After recovering collaboration constraints, we computed the previously set measures. Results shown in Figure 5, enabled us to obtain a partial reconstitution of collaboration progress and the following findings have been made:

- Director as well as Researcher presence rates are very low;
- Student's participation rate is quite low;
- There are no exchanges in this collaboration session.

So the constraint on collaborators presence was not satisfied. In addition, student must have the greater part in intervention as he is the principal speaker but the found rate proves the contrary. The progress of collaborative work in the evaluated session was not consistent with what was expected. The partial presence of jury members (the director and the researcher) has necessary disturbed the work progress and caused a great waste of time. The student small intervention rate can also be justified by the previous anomaly as he can't progress in his presentation if any one of the other collaborators is absent. This anomaly detection is confirmed when PhD director affirmed that global objective was not been reached and that only the previous work was presented and commented. The future previewed steps of work didn't be discussed in this session; it's why another meeting was planned. Since there isn't any constraint on exchanges, we cannot interpret their absence in the studied scenario as an anomaly.

As our evaluation system is not still achieved, the efficiency measures having to be automatically captured (by the evaluation system) can't figure in this report. In ergonomic evaluation, collaborators ability to execute the identified elementary tasks is described by three distinguish appreciations translating three different levels of satisfaction: "Good" is an appreciation given to an execution within any hesitation; "Medium" is an appreciation given when the task is carried out with some difficulties and "Bad" is an appreciation given to a member who could not execute a task.

VII. Discussion

As explained in section 2, related works on e-collaboration present several missing conventions, standards, methods and even failures especially in performance evaluation of the socio-technical system consisting of machines and humans engaged in distant collaboration for performing jointly complex tasks. The conception of the presented evaluation method was motivated by the lack of clear guidelines in the literature and the conviction of the importance of validated criteria. Our contribution started by a new vision of the e-collaboration concept, then a new evaluation method was proposed, composed by three evaluation layers: efficiency, ergonomics and effectiveness. As many works have been done in efficiency and ergonomics evaluations, we were able, after some readings, to choose an evaluation method for each of the quoted aspects. The third aspect reflecting performance of collaborator's behavior is specific to e-collaboration: there is no work discussing its evaluation in the literature. So we proposed a new procedure to evaluate it. The overall method is so composed of the three proposed evaluation procedures.

The described evaluation is iterative: it does not stop at judging performances but also detects and explains problem origins enabling a more targeted improvement of the evaluated e-collaboration environment.

VIII. Conclusion

In this paper, we presented a theoretical work on e-collaboration evaluation. In order to be put in practice, this contribution has to be implemented in an evaluation system and validated by a number of different collaboration scenarios, each significant for a class of applications. This validation is intended to ensure that the application of the proposed evaluation method reflects correctly the collaborators' satisfaction and permits to detect the eventual collaboration problems. The interpretation process should be adjusted by means of real experimentations offering concrete feedback to subsequent versions of the collaborative software, as conceived by the quoted spiral and agile methodologies.

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Stefano CERRI (Parma, 1947) is a Professor in Informatics (1985 Milano, I; 1999 Montpellier, F). His main scientific contributions concern the intersection between Informatics and Human Learning, combining Computation, Cognition and Communication. He authored 30 papers in international journals, 57 in peer reviewed conferences, 40 chapters of books; (co-)edited 7 books; was invited speaker at conferences (15); at Universities and Industries (25); participated to more than 20 European R&D Projects. Between 2005 and 2010 he was Deputy Director of the Montpellier Laboratory of Informatics, Robotics, and Microelectronics: LIRMM: www.lirmm.fr; 400 researchers; that is a French cross-faculty research entity of the University of Montpellier and the National Center for Scientific Research (CNRS). His main commitment for the years to come is about Web Science and related fundamental studies about future connected communities and the way they work, play, learn and contribute to politics.