SILAB
A System to Support Experiments in the Electric Power Research Center Labs

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Abstract: Companies, research centers, and universities are increasingly keeping in contact over time. Especially after Internet, the "Web Era" has contributed to a dynamic market as well as to a critical relation between management and engineering in industry. Thus, research centers can help companies in supporting and improving their activities and processes through innovation partnerships. In Brazil, the Research Center for Energy (CEPEL) is exploring information systems applied to its modernization. In this sense, this paper presents SILAB, a system to manage actions of clients and laboratories during processes of provision test and certification of equipment. SILAB was developed from an experience based on the govern-university partnership. The main focus is to support standards, transparence and productivity in a domain-driven workflow. Some experiences collected from SILAB's stakeholders are also discussed.

1 INTRODUCTION

The relation between companies and universities depends on innovation policies in order to promote competitive strategies for the former (SOFTEX, 2009). In addition, it stimulates the development of new researches for the latter. The dynamics in this relation are created due to a more competitive market since companies look for new knowledge produced by universities. An example is the Association for Brazilian Software Excellence Promotion (SOFTEX) whose objectives are to increase the participation of Brazilian Information Technology (IT) companies in the market and support the future of Brazilian software exportation driven by quality standards (SOFTEX, 2007).

This way, the interactions among those entities can be described in different ways, such as: (i) producing knowledge related to company's technologies (Klevorick *et al.*, 1995), (ii) training experts to work with innovative processes (Pavitt, 1984; Rosenberg, 1992); (iii) elaborating new scientific methods (Rosenberg, 1992); and (iv) creating companies named spin-offs lead by scholars (Stankiewicz, 1994); (Etzkowitz, 1999). Moreover, there are many initiatives related to the mapping of scientific research and modernization of companies. For example, investigation of papers cited in patents (Narin et al., 1997), research studies related to papers published by companies (Godin, 1996), and surveys and questionnaires applied to firms (Mansfield, 1991); (Klevorick et al., 1995); (Cohen et al., 2002) and scholars (Meyer-Kramer and Schmoch, 1998); (Schartinger et al., 2001; 2002).

In relation to Brazilian electric sector, Research Center for Energy (CEPEL) promotes several initiatives in modern laboratories to evolve this sector and enable Brazilian electric firms. This center is a part of a Brazilian company named ELETROBRAS (ELETROBRAS, 2013) that supports researches in energy sectors such as described in (Pereira, 1995), and also participates in technology policies (Saravia, 2005). Since there is a concern related to the development and use of information systems (ISs), CEPEL has investing in improving its services through the processes automation via software solutions. For instance, Oliveira (2010) uses simulation tools for conducting a comparative analysis related to the performance of current processes and redesigning them.

In order to improve the laboratory processes, this paper discusses a system called Information System

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of Laboratories (SILAB). It has been developed through a partnership between CEPEL and the Computer Science and Systems Engineering School (PESC/COPPE) of a Brazilian public university (Federal University of Rio de Janeiro). The goal is to manage clients and laboratories' actions during the processes of executing tests and certifying equipment (accomplished by the former). It aims at making the work of laboratory teams more efficient, providing appropriated information to managers and improving invoice payment services. SILAB is a transparent environment where clients make orders and follow laboratory processes related to tests and certifications, and also provide evaluation indicators of laboratory processes.

This paper is organized as follows: Section 2 summarizes the background related to IS-based scientific processes and experimentation; Section 3 presents an overview of SILAB and its requirements, architecture and goals; Section 4 present the results of a survey driven by SILAB features; and Section 5 concludes the paper, discusses lessons learned and points out future work.

2 BACKGROUND

Nowadays, ISs have been considered complex and fundamental artifacts for the modern societies. ISs are in all knowledge domains such as Education and Experimentation and are strongly applied to Web content management. This requires well-known and solid infrastructures, quality in software solutions and developer-oriented platforms (Stefanuto et al., 2011). On the other hand, ISs should consider both social and automated subsystems as happening in some IS categories, for example (O'Brien, Marakas, 2005): (i) *groupware*: IS that supports cooperation /collaboration; (ii) *knowledge management*: IS that supports information/knowledge storage/retrieval; and (iii) *workflow*: IS that supports planning and control of work tasks, activities and products.

IS focused on Web content management joins the characteristics of the three mentioned IS categories. Initially, these systems were labeled as Internet-based portals and have common requirements such as download and upload speed, support big data (i.e., data volume and accesses), easy communication, and tasks/artifacts coordination etc. (O'Brien and Marakas, 2005). Especially in experimentation domain in research laboratories, the empirical paradigm involves the collection and analysis of data and evidences that can be used to characterize, evaluate and show relations among technologies, practices, and experiences around a fact or artifact (Biolchini et al., 2007). This way, IS-supported empirical processes should be developed to control and manage the experiments lifecycle as well as their roles, activities and products.

Therefore, empirical results can compose a body of knowledge over time (Basili et al., 1999), i.e., providing a base to accepted and well-formed theories about some object of study. The empirical studies allow theories to be formulated, tested, and validated, evolving an experience report to a status of evidence (or not). Evidences are generated from characterizing, assessing, predicting, controlling, and improving products, processes, and theories. On the other hand, experiences can explore these studies towards the continuous improvement.

According to Basili et al., (1999), the central pillar is based on the main elements of an experiment: (i) *variables* correspond to the inputs (independent variables) and outputs (dependent variables) of an empirical study; (ii) *objects* are a target used to verify the empirical study's cause-effect relationship; (iii) *participants* represent the individuals selected from the population to participate in an empirical study; (iv) *context* consists in the conditions which the empirical study is done, and it can be characterized through the place (in vivo, in vitro, in-virtuo, and in-silico); (v) *hypotheses* correspond to theories being verified; and (vi) *empirical study project* defines the empirical study design (e.g., time, schedule, objects and participants).

These experiments can be associated to scientific workflows. According to Deelman and Gil (2006), the concepts of workflow have recently been applied to the automated large-scale science (or e-Science), coining the term "scientific workflow". The scientific work is based on conducting experiments; therefore, the workflow system should allow the same information to be shown at various levels of abstraction, depending on who is using the system.

Barker and Hemert (2008) discuss that the elements of the workflow should be in the context of the appropriate scientific domain and allow the scientist to validate a hypothesis. The validation of scientific hypotheses depends on experimental data, and scientific workflow tends to have an execution model that is dataflow-oriented. This is an essential feature which makes business and scientific workflows different. The former are based on the control-flow of patterns and events, and workflows in the scientific community involve the exchange and analysis of large quantities of data among distributed repositories. Scientists will have to schedule and fund the use of expensive resources, and then systems that support them will be robust and dependable. In addition, they should support incremental workflow construction and the output of workflows or themselves can be used as a basis for future research.

Finally, considering empirical processes related to the interaction among industry and research centers, the management pillar should be accomplished through a workflow system in order to treat each experiment as a project. Scope, time, cost, human resources, laboratory, machines, materials and methods represent some aspects that must be carefully treated by an IS for this domain. Since the industry has lead with real objects and needs that can have a significant impact at the society, these aspects should be planned and monitored over time.

3 SILAB

From the reformulation of the Brazilian electric sector in 2003, CEPEL back to its original objective of working which research lines, supporting the Brazilian electric companies. According to Burd (2005), SILAB is presented as a system that was initially developed to meet the requirements of commercial proposals, approval of customers in accordance with these proposals and documentation of laboratory services. Nowadays, the business requirement became more complex. Its functionalities are divided in three main cycles as presented in next sections.

3.1 Customer Cycle

The goal of this cycle is to manage all processes that involve national and foreign customer. It consists of the following modules: Order, Proposal, Company and Invoicing. *Order* allows the research center employees to manage customer orders. They are registered by customers through an external access module built directly to them. After their login, they have access to an environment where they can fill out and track their order states over time. Initially, the employee receives notification of new orders registered at SILAB. An order can present many statuses depending on customer goals. After an initial reading, it will be rejected if they do not meet the purposes of the existing laboratories. If it does not contemplate all initial requirements, a negotiation among them is opened in order to clarify information. They are forwarded to the analysis phase when all initial requirements are met. Additionally, this module supports a negotiation on the price estimates.

In the analysis phase, the orders are studied in more details and can also be rejected. They can involve activities related to one or more laboratories, and then they can be independently analyzed for different ones. If all requirements are met, this request becomes a proposal, i.e., an initial trade agreement among the research center and their customers can suffer changes over time. Besides, the employees themselves can act as customers and make internal orders. This event occurs when instruments used by the laboratories need to be calibrated outside.

Proposal is responsible for managing all states of commercial proposal until they are accepted by the client, initiating the laboratory activities. Firstly, during the editing phase, this proposal is filled with both activities that will be performed and the quantity of equipment expected by a laboratory (according to the request). After this phase, it is forwarded to approval by the superiors. Also, after successive and positive evaluations by them, the commercial proposal is forwarded to the customer. When it is accepted by him, activities described in this proposal are performed by the involved laboratory and the system tracks its history. It shows all the proposal phases in different laboratory accounts (responsible, observations, date, situation). Besides, the order history that originated this proposal is presented. The states showed in *Proposal* and *Order* history describe the process flow from the order editing to the proposal conclusion.

Company is responsible for managing customer data. A company has three states: inactive, active and pendent. The pendent state happens when the company's data are not validated yet. When data are validated against norms based on Web services, the state is active at SILAB. The validation process includes applying security criteria, such as fiscal situation or delinquency. If any data is incorrect or incomplete, the state will be inactive. Only active companies can make orders. To fill out an order, the company contact must have permission to do this, and then its data are validated too. Finally, the payments of values described in the commercial proposals are made through *Invoice*.

3.2 Laboratory Cycle

According to Deelman et al., (2009), scientific workflow can be defined as formal specification of scientific processes representing the steps which will be performed by a given experiment. These steps are usually associated to the data collection, analysis, and visualization. They are manually managed, or supported by scientific workflow management systems through executable artifacts (i.e., programs, services and scripts).

SILAB supports the execution of the scientific workflow during the test activities. In this phase, processes are related to conduct different electric experiments; to obtain high quality data; to analyze them according to the business requirement; and to generate a final report about them. This workflow should be reused, evolved and shared with other scientists in the field, as well as it must be fully reproducible. In order to support this, SILAB provides information about experiments. For example, it indicates the origin of the data, how it was modified, and which components and parameter settings were used to execute tests. This will allow other scientists to execute the experiment again in order to confirm the results.

This cycle is composed by following modules: Equipment, Test, Calibration, and Protocol. The last one represents protocols for different types of documents applied to SILAB. *Equipment* follows this object from its entrance in the research center (receive process) to its exit (devolution process), passing by several tests in different laboratories. *Test* is responsible for documenting all results obtained during test phase in a specific laboratory. Each test has its own data and they are verified by a reviewer – this employee is not the same one that executed the test. In addition, different reports are generated and they are revised. This system has a revision module that maps each data edition to different revisions. An important process during the test phase is *Calibration*, where all information related to the instruments used during the tests is documented.

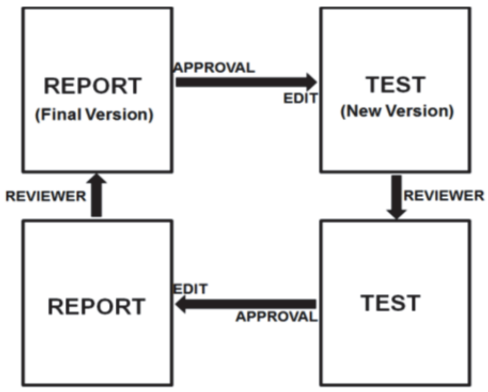

Figure 1: Revision process at SILAB.

The Figure 1 represents the cycle revision process after executing tests or certifications. First of all, the test data can be edited since it can be repeated to confirm the expected result (new version). When it is finished, these test data are reviewed by other researcher. After reviewing a test set, they cannot be altered and a report is generated and associated to them. It is composed by its data such as conclusions and observations, besides test data previously mentioned. This report is on editing state and it can be modified by a research that has permission for doing this. After all changes, this report is forwarded to another researcher to be evaluated. If a report is evaluated and approved, it will not be altered anymore (final version). This fact determines a revision cycle is finished. In each new cycle, all data changes in tests/reports are registered and informed to the customers in the final report.

3.3 Maintenance Cycle

This cycle involves all modules related to the research center's employee information, such as permissions, accounts and laboratories, besides their agenda describing the laboratory activities. SILAB offers different user profiles to access the system. In relation to the safety, all users' events in the system are registered and classified according to certain criteria based on their roles. The whole process related to an order and a respective proposal is mapped. This information about who analyses order requirements, dates about state changes, period of occupying laboratories, time of executing tests and time of elaborating reports are registered and represent by a timeline. The system also offers a module responsible for generating process indicators to knowledge experts.

3.4 Architecture

The architecture of SILAB is composed by a Web system, a mobile system, Web services, an e-mail server and databases (Figure 2).

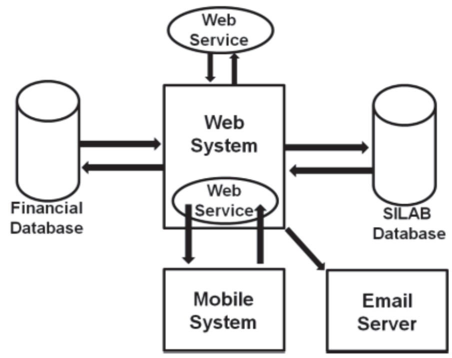

Figure 2: SILAB architecture.

The Web system communicates with SILAB database to access information about the laboratory and customer processes. All financial information such as invoice and payments are in another databases. The financial and SILAB data are shared with other systems. SILAB have a mobile component responsible for managing receiving and delivering of equipment. Its users are notified by the e-mail server about all changes in the processes states during executions.

4 SURVEY

The objective of this survey is to evaluate the characteristics of this system in order to verify the usability and effectiveness of SILAB considering its strong and weak points. This study will contemplate two types of stakeholders: research center analysts and clients (i.e., companies). The set of analysts are compost by three stakeholders: managers (a department director), researchers (an electrical engineer) and general staff (a technician and a secretary). This survey is divided into three parts: (i) evaluation of general features, (ii) evaluation of information; and (iii) evaluation of the process. The results were aggregated through applying average.

Table 1 shows the results about general evaluation of the system. In this part, the participants answered questions about the system and its influences to the reality of the company, ease of access, interface and performance. It can be realized that the strongest feature of SILAB is the report generation, since this is important for managers, researchers and customers. On the other hand, some aspects of interface should be improved and a new project to evolve the system as a whole is starting.

Table 1: General evaluation.

	Poor (%)	Fair (%)	Satisfactory (%)	Excellent (%)
Reality	5	21	53	21
Accessibility	0	16	47	37
Interface	10	21	32	37
Performance	5	21	63	11
Reports	5	16	32	47

Table 2 shows the results about information evaluation. At this stage, the participants answered questions about availability of information, understandable format and relevance. As observed, the participants were satisfied with information provided by SILAB, especially considering its relevance to the management of the experiments. However, some aspects related to the format of information should be defined in a better way.

Table 2: Information evaluation.

	Poor (%)	Fair (%)	Satisfactory (%)	Excellent (%)
Relevance	0	11	37	53
Format	11	11	53	26
Availability	5	11	47	37

Finally, Table 3 shows the results related to the process standardization, productivity of employees and the transparency of processes executed in the system, considering the participants' point of view. Again, all participants mentioned that their tasks and activities are easier after the SILAB deployment, highlight productivity and transparency. Aspects related to standardization are being investigated since it is more complicated. One reason is the different types of customers and partners and an initial step for the SILAB evolution is to better identify business requirements.

Table 3: Process evaluation.

	Poor (%)	Fair (%)	Satisfactory (%)	Excellent (%)
Standardization	5	21	42	32
Productivity	11	5	37	47
Transparency	11	5	42	42

5 CONCLUSION

Since companies, research centers and universities are very close due to innovation demand and dynamic markets, IS-based solutions has been developed and deployed in order to support both the management and the engineering. Especially in experimentation domain in research laboratories, IS-supported empirical processes should be developed to control and manage the experiments lifecycle as well as their roles, activities and products. At CEPEL, this is happening through a partnership with a public university. The focus of this paper was to discuss an overview of SILAB, an IS that manages clients and laboratories' actions during processes of executing tests and certifying equipment. As shown, SILAB is responsible for real experiments based on industry demands and is composed by different modules that effectively control elements/aspects of experiments.

The development and deployment processes of SILAB involved eight stakeholders in three years: four developers, a project leader, a project coordinator and two domain experts (from the client). Some internal tests were accomplished during the development phase and professionals from the research center participated during the homologation tests. Three main difficulties can be highlighted: (1) the database migration from the legacy system to SILAB; (2) the automation of reports generation; and (3) the definition of the business rules to implement the Client cycle. On the other hand, three successful aspects should be considered: (1) the client was always available and very close to the development team in order to clarify the requirements; (2) the agile spirit of releasing small versions as soon as possible; and (3) the development team was composed by different professionals, i.e., a designer, two developers, a database administrator and an analysts.

As future work, according to survey results mentioned, a new partnership project related to data quality is ongoing and it will allow analyzing how SILAB can be used to improve the research center business model. In this case, our research group will use this real scenario to apply data quality techniques in order to reengineer SILAB and to better evolve its underlying workflow. The idea is to evolve SILAB from a system to a platform that should provide resources to create a software ecosystem based on the contributions from other companies related to the energy domain.

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