IST Computer Science and Engineering Doctoral Degree Information Management System (DD-IMS)

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Abstract

As a result of the development of modern Information and Communication Technologies (ICT), the academic world has entered the information society era. Nowadays, many operations regarding Higher Education data management are handled by ICT Systems. At Instituto Superior Técnico (IST), the Fenix system, an Academic Information Management System capable of managing data and supporting all processes related to the university degrees, was developed. However, the Fenix system has limitations in terms of managing data regarding Doctoral Degrees. We designed and implemented a Doctoral Degree Information Management System (DD-IMS) that manages data concerning the IST Computer and Science Engineering (CSE) Department PhD students. The architecture for the DD-IMS is a client-server architecture composed of three tiers that are physically separated (three-tier architecture): (i) a database to store the relevant data about PhD processes, (ii) a web server to contain the business logic, and (iii) a client, whose functionality is accessible via a web browser. DD-IMS communicates with the Fenix system to take advantage of the data that is already stored there. We conducted an experimental validation to evaluate the DD-IMS at three levels: functionality, usability, and performance. Users showed a high level of satisfaction with the DD-IMS usability. Regarding performance, the results obtained show that, with the increase of concurrent users, the DD-IMS had a sustained growth in terms of error rate and average response time, maintaining an acceptable performance with a large number of concurrent users.
Keywords: Information Management System; PhD Students Management; Higher Education Management Systems; Software Engineering

1. Introduction

As a result of the development of modern Information and Communication Technologies, the academic world has entered the information society era. Nowadays, many operations regarding data management in Higher Education institutions (e.g., enrolling in courses or exams, publishing grades, etc.) that were not performed via IT Systems in the past, are now handled by these systems. The basic idea behind all these systems is to enable entering the relevant data, storing it, and then displaying it as required by different types of users, namely students, teachers, coordinators, and administrative staff.

Instituto Superior Técnico[1] (IST) offers a broad set of degrees that cover the most important scientific areas related to Engineering, Science, Technology, and Architecture. Information systems are required to manage data that supports all processes related to those degrees. Thus, the Fenix[2] system was developed to be a comprehensive academic Information Management System. Regarding Bachelor and Master degrees, it provides several functionalities that enable students, teachers, degree coordinators, and administrative staff to effectively manage data. In what concerns data about PhD processes regarding courses and students, Fenix also gives support but in a limited way.

1.1. Main Processes of an IST Doctoral Program

Doctoral Programs involve a set of milestones that must be achieved by the students. There are four main candidate/student stages of the CSE Doctoral Program: (i) Applying to the Doctoral Program; (ii) Completing 30 ECTS credits of courses (the courses are chosen by the student when she defines her study plan); (iii) Setting up the Thesis Advisory Committee (CAT from the Portuguese *Comissão de Acompanhamento de Tese*) and defending a *Thesis*

[1] https://tecnico.ulisboa.pt/

[2] https://fenix.tecnico.ulisboa.pt/

Proposal evaluated by that committee (corresponds to the PhD Thesis Proposal course, 30 ECTS); and (iv) Setting up the jury and passing a *thesis defense* (PhD Thesis, 180 ECTS). The result is a considerable amount of data exchanged between students, coordinators, supervisors, and administrative staff. Currently, the Fenix system gives support to the management of IST Doctoral processes for students, coordinators, supervisors, departments administrative staff, Post-Graduation Area[3] (PGA) administrative staff, members of the Computer Science and Engineering[4] (CSE) Department Coordinating Committee for the 3rd cycle (CC3C), and members of the CSE *Pedagogical/Scientific Council* (CCP from the Portuguese *Conselho Científico-Pedagógico*)[5].

Figure 1 shows the main data flows involved in IST Doctoral Programs. Departments[6] send the original version of PDF documents (in paper format) and forms (e.g., study plan, jury proposals, etc.) related to Doctoral Programs processes to the PGA for its validation and approval (it is the responsibility of the PGA coordinator to submit PhD documents to the IST Scientific Council for approval). The approved documents are digitally stored in PDF format in the Fenix system, to be further visualized by coordinators, supervisors, students, or members of the administrative staff when requested. For example, when a student chooses her study plan (i.e., the courses she wants to enroll), it must be analyzed and approved (signed) by the student's supervisor(s), by the department coordinator, and then sent to the PGA that submits it to the Scientific Council. This process is not automatically supported, as it is done by hand. After this sequence of approvals, the document is stored in the Fenix system. Another example is the thesis defense process, where the documents submitted by the students (e.g., thesis dissertation, student's CV, thesis submission form, etc.) and the thesis defense jury proposal go through the coordinator, supervisor(s), PGA, and Scientific Council, to be validated and approved. The Fenix system has the capability of sending alerts to the CSE Doctoral Degree actors. Moreover, the CSE department administrative staff uses several spreadsheets, as a complement to the Fenix system, to store data regarding the PhD students.

[3]https://posgraduacao.tecnico.ulisboa.pt/en/o-nucleo-de-pos-graduacao/

[4]https://fenix.tecnico.ulisboa.pt/departamentos/dei/o-dei

[5]https://fenix.tecnico.ulisboa.pt/departamentos/dei/organizacao

[6]In the figure, we only illustrate the CSE department but it is valid for all the other IST departments

1.2. Fenix Limitations

As mentioned before, the Fenix system has limitations in terms of managing data regarding Doctoral Degrees. First, the existence of multiple views available to the coordinator, administrative staff, CC3C and CCP members, and students makes it very hard to manage and visualize data due to the existence of multiple points of access to students' data. Moreover, it is very difficult and sometimes impossible to obtain statistics about the degree (e.g., how many students are enrolled, how many have defended their Thesis Proposal in a given period, etc.). In particular, this feature is critical for coordinators that are responsible for periodically producing reports with statistics regarding the Doctoral Degree activity. In some cases, the results retrieved through the various views may even be inconsistent. For example, when PGA administrative staff access the Fenix Academic Services and Academic Administration views, different results may be retrieved regarding the list of active PhD students (the number of listed students differs in these two views). Furthermore, there are some types of data that are not accessible for certain user types (e.g., a supervisor does not have access to her students' curricular plan, which contains the courses in which the students have enrolled in and the grades obtained in those courses; students do not know how much time is left for important deadlines such as the thesis proposal submission).

Second, at the level of the CSE Doctoral Degree, there is an emergent need to have an information management system that has the capability of providing answers to a set of questions that are typically posed by students, supervisors, coordinator, CC3C and CCP members, and department administrative staff that, currently, cannot be answered (e.g., how much time, in average, do students take to conclude their Doctoral Program; for a given supervisor, who are her students, etc.).

1.3. Contributions

In order to understand the users' needs, which is important when defining the solution for implementing the new information management system, we gathered the requirements [10] that it should meet through a set of interviews so that we could understand the limitations of the current solution (Fenix system) and the requirements of the new system. Having in mind the requirements gathered, the main contributions of this work are:

1. **Design and implementation of a relational database** that stores all the relevant data concerning active[7] CSE PhD students in

[7]A student is considered to be active since the moment she is admitted in the Doctoral Degree until the moment when her thesis is defended and approved.

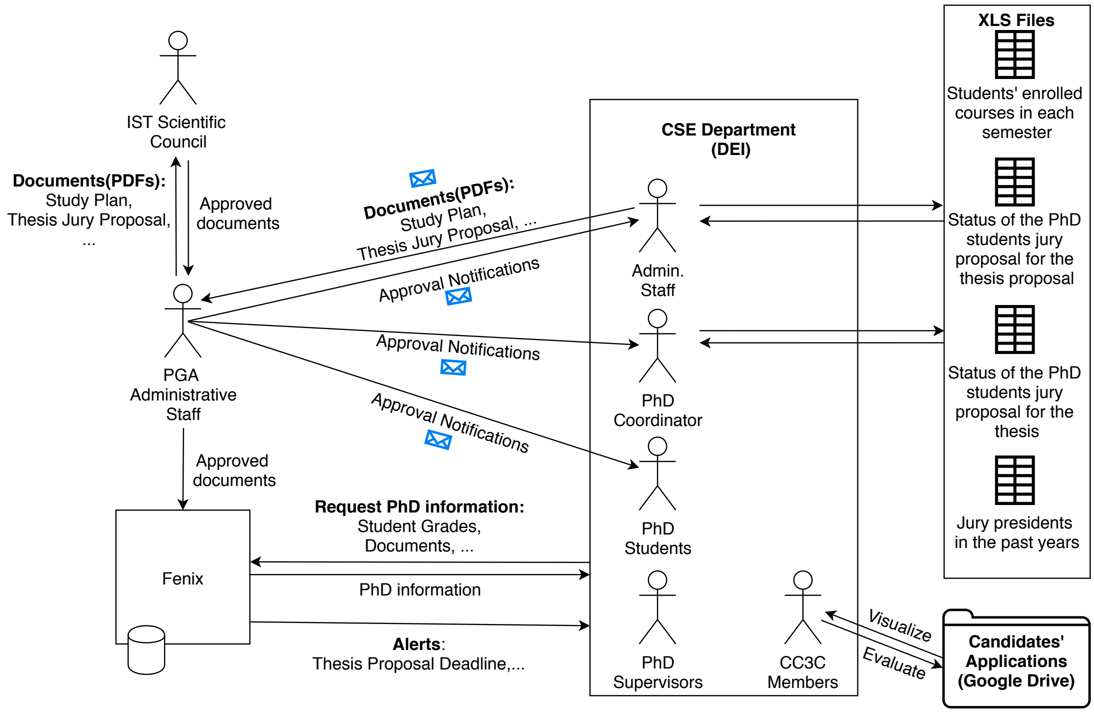

Figure 1: Main data flows involved in the IST Doctoral Program.

a structured way, thus enabling to monitor each student's progress and to obtain statistics about the behavior of the PhD Doctoral program.

2. **Design and implementation of the DD-IMS**, a system that manages the information regarding CSE PhD students. The DD-IMS is composed of the following modules: (i) *Evaluation of Applications*, that supports the evaluation of the candidates' applications; (ii) *Registration*, supporting the students' registration; (iii) *Study Plan*, that supports the students' study plan management; (iv) *Supervision*, that supports the students' supervision team management; (v) *Curricular Plan*, that supports the students' data regarding their enrolled courses and the courses that they have taken; (vi) *Thesis Proposal*, supporting the Thesis Proposal management; (vii) *Thesis*, supporting the thesis defense management; (viii) *Statistics*, that supports the statistics regarding CSE PhD students; and (iv) *Doctoral Program Management*, that supports the management of the Doctoral Program Faculty members, CC3C, CCP and Scientific Committee members, staff members, and coordinator. DD-IMS has a web application, accessible to IST users, which provides a user interface so that users can visualize and manage the data regarding the CSE PhD students' processes. Each of the system's actors has access to a specific set of views so that they can use the functionalities of the modules described above.

1.4. Outline

This paper is organized as follows. Section 2 summarizes the study carried out about similar systems that already exist, analyzing their characteristics. Section 3 presents the design and implementation details of the new IST CSE Doctoral Degree Information Management System (DD-IMS). Section 4 describes the experimental validation that we conducted and the results obtained. Finally, Section 5 presents the conclusions about the DD-IMS and its results.

2. Related Work

We analyzed software systems with a similar purpose to the Information System that we want to develop. These systems can be divided into two types of systems: (i) Enterprise Resource Planning (ERP) systems that can be adapted and extended to create adequate software for an organization-specific goal; and (ii) software systems built from scratch to satisfy the needs of a specific organization. In Higher Education institutions, the services typically supported by information systems are the following ones [5]: Student Lifecycle Management (SLM), Learning Management Systems (LMS), Human Resources (HR), Finance, Library services, Student Information, Content Management System (CMS), and the University Portal. In which concerns our project, the services we want to provide are PhD SLM and Student Information. At IST, most of the other services are supported by the Fenix system or other software products (e.g., SAP [8] for Finance).

We analyzed the following software systems built from scratch: FenixEdu [2], Manipal University Jaipur - Online Faculty Information System (MUJ-OFIS) [3], University Study-Oriented System (USOS) [9], and HISinOne [4][7]. Regarding ERP systems that have a general-purpose and are configurable for Higher Education, we analyzed the following systems: Fedena [8], Salesforce for Education[9], and Banner by Ellucian[10]. A summary of the systems analyzed in this section is presented in Tables 1 and 2.

Table 1: Comparison of Information Management Systems that were built from scratch for Higher Education institutions.

Systems/ Characteristics	FenixEdu	MUJ-OFIS	USOS	HISinOne
Open Source?	Yes (LGPL 3.0)	No	No	No
Development Team	IST	Manipal University	MUCI Consortium	HIS
Compatible Databases	MySQL Maria DB	MySQL	Oracle Database	Postgres
API?	Yes	No	Yes	No
Extensible?	Yes	No	Yes	Yes
Browser Client Application?	Yes	Yes[1]	Yes	Yes
Programming Language	Java	PHP (Laravel)	Python (Django)	Java (J2EE)
Supports PhD Degree?	Limited	Unknown	Unknown	In Development

[1] Compatible with Google Chrome, Opera, and Safari but has certain compatibility issues with Mozilla and Internet Explorer.

Table 2: Comparison of ERPs for Higher Education institutions.

Systems/ Characteristics	Fedena	Salesforce for Education	Banner by Ellucian
Open Source?	Yes[1] (LGPL 2.1)	No	No
Development Team	Foradian Technologies	Salesforce	Ellucian
Compatible Databases	MySQL	—[2]	Oracle Database
Extensible?	Yes	Yes	Yes
Browser Client Application?	Yes	Yes	Yes
Programming Language	Ruby (Ruby on Rails)	Apex	Java

[1] Only the base version is open source.
[2] Unknown

After analyzing these systems, we concluded that there were two possible solutions to implement the DD-IMS: to use an already existent ERP system available in the market or to build a new system from scratch. Another possibility was to improve the Fenix, as its software is extensible and open source, but was not considered due to IT resources limitations in the FenixEdu team.

[8] https://www.sap.com/index.html
[9] https://www.salesforce.org/
[10] https://www.ellucian.com/

Using an already existing ERP system has the advantage of being possible to use the available functionalities of that system. On the other hand, this may not be easy if we need to change or extend the functionality of the system. Adapting the system architecture to the requirements and modules specified for the project may be difficult if the architecture is not the most appropriate one for the implementation of one or more functionalities. Besides, using an ERP system implies its acquisition, which has a financial cost associated. With this in mind, only an open source system can be considered for use in our system implementation and Project Fedena is the only system that meets this requirement.

Concerning the solution of building a new system from scratch, the big advantage is that it is possible to create a solution that is tailored to the system requirements and whose architecture is adapted to all functionalities of the system. In contrast, it is not possible to use the functionalities already implemented in existing systems. However, the cost of implementing all the functionalities can be mitigated by using web application frameworks or libraries that facilitate the development.

After analyzing the advantages and disadvantages of both solutions, it was decided to build a new system from scratch. Despite not using any of the systems described, the Fenix API, a component referred to in this section, was used for the benefit of the new system. With this API, it is possible to communicate with the Fenix system, thus avoiding the storage of data that is already stored in the Fenix system.

3. CSE DD-IMS

DD-IMS is a software application developed to manage the data regarding the CSE Doctoral Degree in a way that simplifies the job of the users involved (students, supervisors, coordinator, CSE department administrative staff, CSE Scientific Committee, CC3C and CCP members), and facilitates the collection of data used to obtain statistics related to the degree. The system communicates with the FenixEdu API, taking advantage of the data that is already stored in the Fenix system.

Figure 2 shows how the DD-IMS can be integrated into the current processes and data flows involved in the CSE Doctoral Degree. This figure can be seen as an evolution of Figure 1, presented in Section 1. The differences between these two figures are the following: (i) with the DD-IMS, the CSE department users only need to communicate with this system, instead of sending information to the PGA administrative staff by e-mail and interact with the Fenix system; (ii) the new system accesses the Fenix system to retrieve data that is stored there; and (iii) to satisfy the PGA needs, the new system is capable of generating documents in PDF format (e.g., study plan form, thesis defense jury proposal, etc.) and sending them to the PGA by e-mail.

3.1. Architecture

The architecture for the DD-IMS is a client-server architecture composed of three tiers that are physically separated (three-tier architecture): (i) a client that allows the user to access the application through a web browser; (ii) a web server that encloses the application logic; (iii) a relational database that stores the data about PhD students and their progress. The architecture of the developed system is represented in Figure 3.

The web server component contains the business logic of the system. DD-IMS modules follow the Model-View-Template (MVT) pattern. The **Model** layer is the interface that contains everything related to the database access. The **View** layer is the middle layer between the Model layer and the Template layer that contains the business logic. Finally, the **Template** layer is responsible for presenting the data that comes from the View layer. This layer controls what should be displayed and how it should be displayed to the users. Regarding its functionality, the web server can be divided into nine distinct modules:

1. Evaluation of Applications - supports the evaluation of the candidates' applications;
2. Registration - supports the students' registration in the DD-IMS, allowing them to insert their personal and academic data;
3. Study Plan - supports the students' study plan management;
4. Supervision - supports the students' supervision team management;
5. Curricular Plan - supports the students' data regarding their enrolled courses and the courses that they have taken;
6. Thesis Proposal (CAT) - supports the Thesis Proposal management, i.e., Thesis Proposal jury proposal and Thesis Proposal defense minutes;
7. Thesis - supports the thesis defense management, i.e., jury proposal;
8. Statistics - that supports the statistics regarding CSE PhD students;
9. Doctoral Program Management - supports the management of the Doctoral Program Faculty members, CC3C and CCP members, the Scientific Committee members, staff members, and coordinator.

3.2. User Roles and Permissions

The DD-IMS is accessed by users with three types of roles: Student, Staff, and Faculty. These roles must have different permissions in the system. To handle this issue, user roles permission groups (each permission group gives access to a set of actions). In DD-IMS, each one of the three types of user roles is associated with one or more permission groups, as shown in Table 3.

Table 3: Association between user roles and permission groups.

User Role	Permission Groups
Student	**Student Required** - all students belong to this permission group (e.g. allows students to edit supervision, study plan, etc.)
Staff	**Staff Required** - assigned to administrative staff members (e.g. allows to change the Doctoral Program coordinator, CC3C and CCP members, etc.)
Faculty	**Supervisor Required** - assigned to all faculty members (e.g. allows supervisors to visualize their students' processes) **Coordinator Required** - assigned to the faculty member who is the coordinator of a Doctoral Program (e.g. allows a Doctoral Program coordinator to visualize the processes of all students enrolled in that Doctoral Program) **CC3C Required** - assigned to faculty members that are members of the CSE CC3C (e.g. allows a CC3C member to give feedback about applications, as well as to give feedback about thesis proposal and thesis juries) **CCP Required** - assigned to faculty members that are members of the CSE CCP (e.g. allows a CCP member to give feedback about thesis proposal and thesis juries) **Scientific Committee Required** - assigned to faculty members that are members of the CSE Scientific Committee (e.g. allows a Scientific Committee member to visualize a thesis jury)

Each permission group gives access to specific functionalities of the DD-IMS. The **Student Required** permission group gives access to functionalities related to the academic path of a student in her Doctoral Program: Registration, Study Plan, Supervision, Thesis Proposal, and Thesis. The **Supervisor Required** permission group gives access to the user's supervised students. Both **Coordinator Required** and **Staff Required** permission groups give access to all Doctoral Program students processes and statistics related to Doctoral Program students and candidates. With one of these permissions, users can also visualize and manage information regarding the Doctoral Program faculty members, CC3C members, coordinator, and courses. Also, with the **Coordinator Required**, **Staff Required**, and **CC3C Required** permissions, users can manage the data regarding the evaluation of the applications to the Doctoral Program. The functionalities related to the evaluation of juries, i.e., being able to evaluate both thesis proposal and thesis jury proposals, require one of the following permissions: **Staff Required**, **Coordinator Required**, **CC3C Required**, or **CCP Required**.

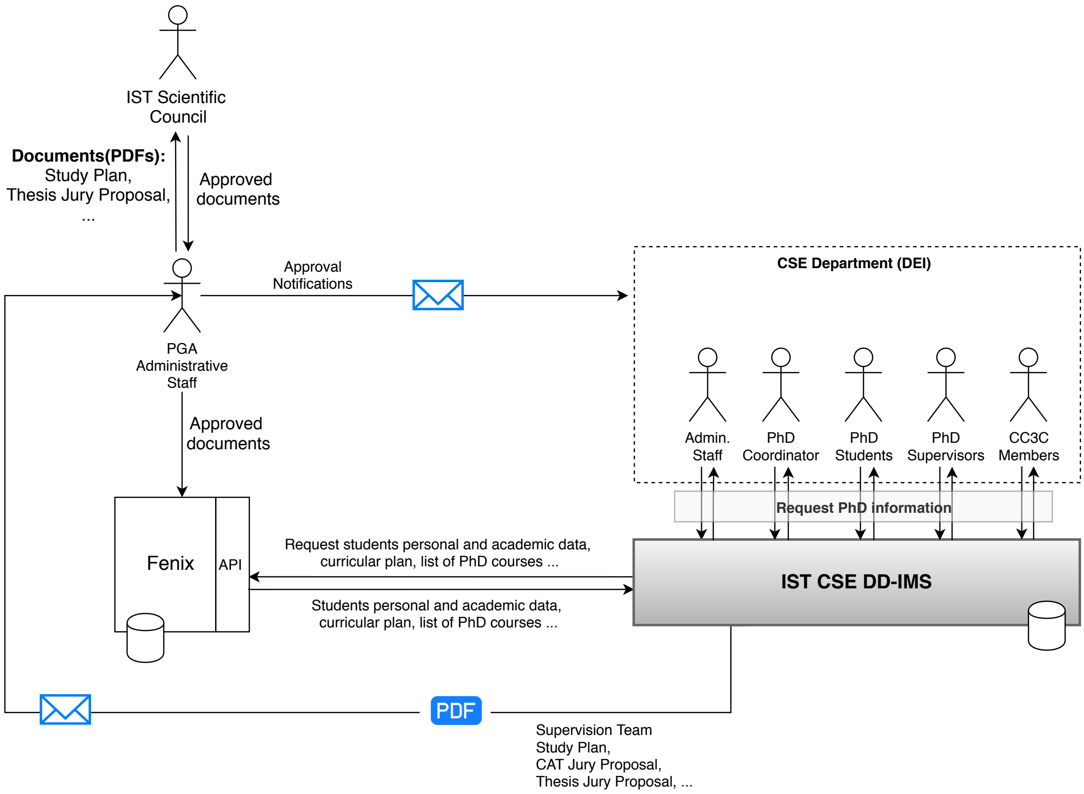

Figure 2: Integration of the DD-IMS with the main data flows involved in the CSE Doctoral Degree.

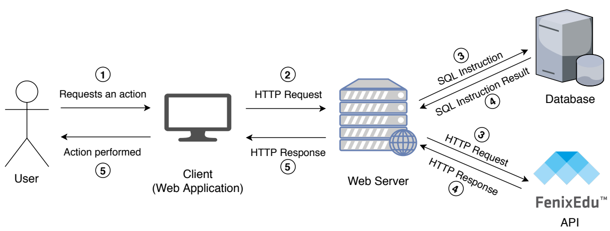

Figure 3: Architecture of the System.

In addition to these functionalities, all types of users are informed about the pending actions (Alerts) that they must perform in the application.

3.3. User Interface

The DD-IMS user interface was designed to be as similar as possible to the Fenix user interface, to facilitate the users' adaptation to the new system. As it happens in Fenix, the DD-IMS user interface presents a set of tabs on top of the webpage. Depending on their role and permissions, users have access to a set of tabs. Figure 4 shows a screenshot of the DD-IMS user interface. The screenshot displays the study plan of a PhD student, which can be consulted by the coordinator and the administrative staff via the "All Students" tab (the supervisors can visualize it inside of the "My Students" tab). On this page, not only the information regarding the student's study plan is available to users but also the student's personal and academic information, supervision team, thesis proposal information, and thesis information. Users can change the type of information displayed by clicking on one of the left side menu options presented (i.e. Personal Information, Previous Degrees, Academic Information, Study Plan, Supervision, Thesis Proposal, or Thesis).

3.4. Implementation

The DD-IMS user interface was developed using the most known technologies for producing web content, supported by most of the browsers, namely HTML, CSS, and JavaScript. Regarding the web server, Django[11] was the web framework used for implementing this system. Regarding the database component, we opted to use the PostgreSQL Relational DBMS[12] for setting up and hosting the database as it is considered by the Django documentation as the most capable database management system in terms of schema support. Regarding authentication, the IST Central Authentication Service[13] (CAS) is used to authenticate IST users in the DD-IMS. The IST CAS allows any user with a TecnicoID to authenticate in the system.

[11] https://www.djangoproject.com/
[12] https://www.postgresql.org/
[13] https://id.tecnico.ulisboa.pt

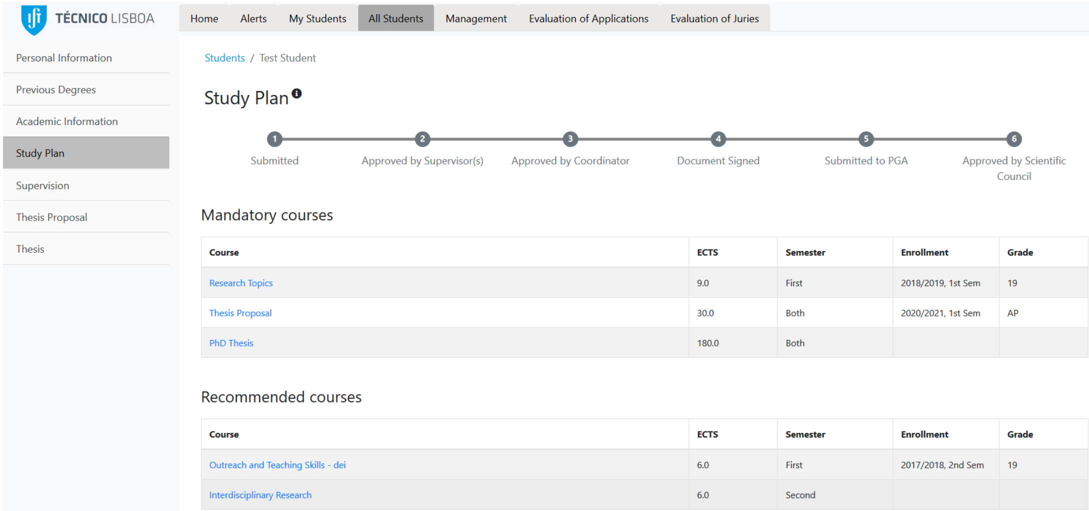

Figure 4: Screenshot of the Study Plan left side menu option, inside of the "All Students" tab.

4. Experimental Validation

We conducted an experimental validation to evaluate the DD-IMS at three levels: functionality, performance, and usability.

4.1. Performance Evaluation

We performed load tests to analyze the system response when used by a large number of users simultaneously. The tool used for performance testing was JMeter[14]. The load tests were executed on a virtual machine with the following specifications:

- Operating System: Debian stable
- RAM: 1 GB
- Processor: Intel Core (4 MB Cache, 2.4 GHz)
- Number of CPU Cores: 1
- Disk Space: 10GB

The load tests were divided into 9 scenarios, which made it possible to evaluate the system behavior variation from two different perspectives:

1. Testing the system behavior with a **variable number of users** performing a set of actions (50 actions were performed by 25, 50, 100, 200, 400, and 800 users)
2. Testing the system behavior with a **variable number of actions** performed by each user (50 users performed 25, 50, 100, 200, 400, and 800 actions)

To simulate users behavior more realistically, we added a delay (Think Time) of 2 seconds between each user's action. During the execution of these tests, the system performance was evaluated by the following three measures: (i) **error rate** measures (in percentage) how frequently are internal server errors (or HTTP 5xx codes[15]) returned to clients; (ii) **response time** measures (in ms) how much time, on average, do clients wait for system response since they send their request; and (iii) **throughput** measures (in requests per second) how many requests the system can handle simultaneously.

The graphic shown in Figure 5 presents the results obtained regarding the error rate measure. With the increase in the number of actions, the error rate maintains a constant percentage of 0 percent. Regarding the number of concurrent users, the error rate remains equal or very close to zero, until the number of users is 100. Starting from there, there is linear growth which means that the system has a sustained increase in the error rate. With 800 users, the error rate reaches 4 percent.

The graphic shown in Figure 6 presents the results obtained regarding the average response time measure. With the increase in the number of actions, there is little variation over the average response time. Regarding the number of concurrent users, the average response time grows linearly with the number of concurrent users.

The graphic shown in Figure 7 presents the results obtained regarding the throughput measure. Regarding the number of actions, the throughput has a significant growth between 25 and 100 users and then stabilizes with values between 18,5 and 20 requests per second. With the increase of concurrent users, the throughput increases logarithmically from less than 10 requests per second (with 25 users) to approximately 27 requests per second

[14] https://jmeter.apache.org/

[15] https://developer.mozilla.org/pt-PT/docs/Web/HTTP/Status

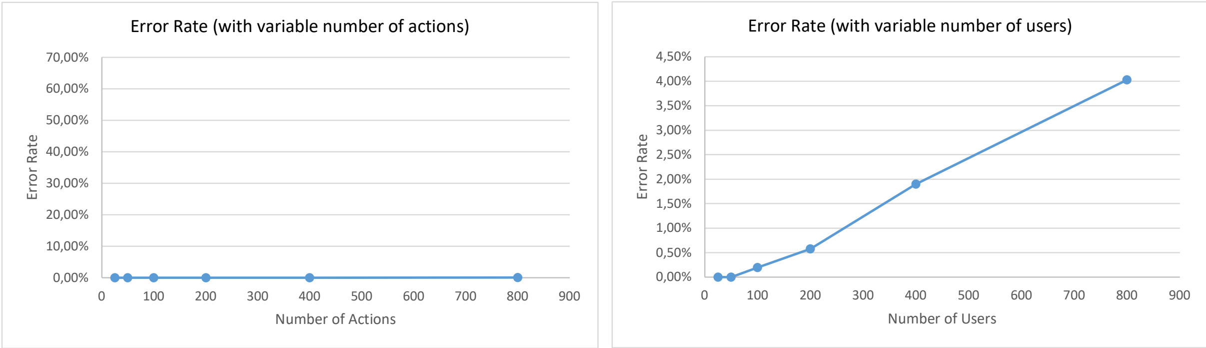

Figure 5: Error rate with variable number of actions and users.

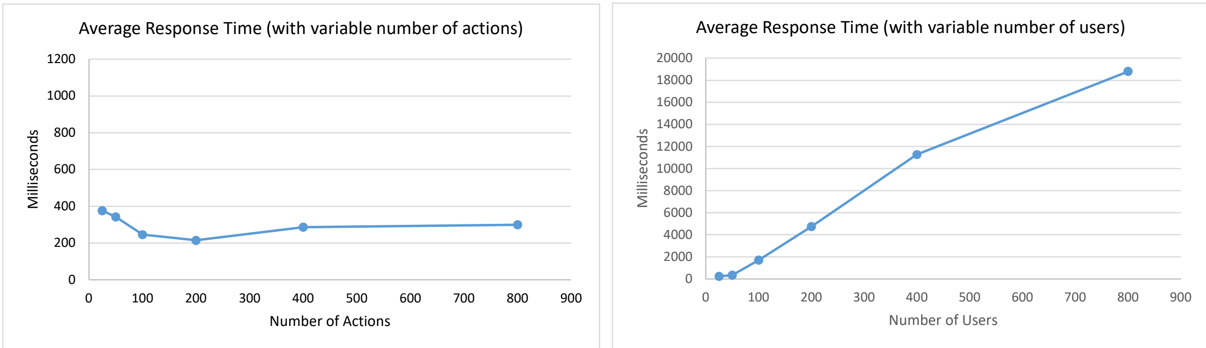

Figure 6: Average response time with variable number of actions and users.

(with 800 users). This is due to the fact that with only 25 users sending requests with a think time of 2 seconds, the system is not handling as many requests as it can handle.

The results obtained show that the DD-IMS had a sustained growth in terms of error rate and average response time, maintaining an acceptable performance with a large number of concurrent users. After observing the behavior of the DD-IMS in response to a significant number of concurrent users (considerably larger than the potential number of active users involved in the CSE Doctoral Degree which is around 200/300 users), we can conclude that the DD-IMS meets the performance and reliability needs of an Information Management System for the CSE Doctoral Degree.

4.2. Usability Evaluation

We performed tests with the future users of the system, namely: PhD students, supervisors, coordinator, members of the CSE administrative staff, members of the CC3C, and members of the CCP. The goal of these tests was to validate the DD-IMS graphical user interface, namely in what concerns the performance of the users when using the system as well as their satisfaction. This evaluation was divided into two phases: formative evaluation and summative evaluation.

The formative evaluation was performed iteratively during the implementation phase, to identify aspects that cause usability problems. The modules developed were tested in order to: (i) find bugs; ii) find improvements to be applied to the UI; and (iii) confirm the functionalities implemented. The following modules were tested during this evaluation phase: Evaluation of Applications, Registration, Supervision, Study Plan, Thesis Proposal, Thesis, and Management.

The summative evaluation was performed after the conclusion of the DD-IMS implementation, to evaluate the success of the final product. For this evaluation, we selected a set of users that did not have any experience with DD-IMS before the evaluation but, at the same time, have familiarity with the context and vocabulary of the tasks. A total of 29 users participated in the DD-IMS usability evaluation, more specifically, 10 students, 10 supervisors, 2 administrative staff members, 3 coordinators, 2 CC3C members, and 2 CCP members. We evaluated the system quantitatively and qualitatively. First, the quantitative evaluation focused on how the users performed a set of tasks assigned to them. As the system has multiple user groups, six types of tasks were defined: Student tasks, Supervisor tasks, Staff tasks, Coordinator tasks, CC3C member tasks, and CCP member tasks. The following measures were taken during the execution of the tasks: (i) "Did the user complete her task?";

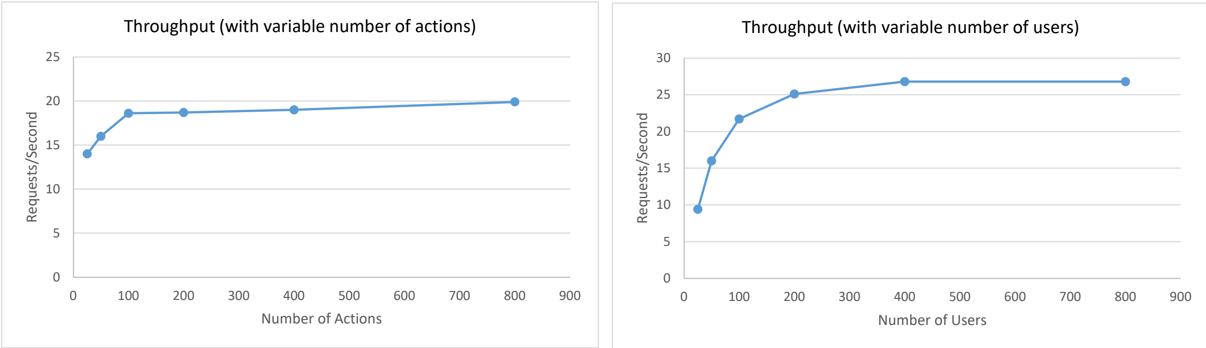

Figure 7: Throughput with variable number of actions and users.

(ii) "How much time was taken to conclude the task?"; and (iii) "How many errors were made by the user?". The results showed that a large majority of the users concluded all the tasks assigned to them and, in general, the users did not find any major difficulties while executing the tasks.

After finishing the execution of tasks, users gave their feedback about the DD-IMS, by answering a questionnaire[16]. This questionnaire was used to qualitatively measure the system usability, as it contains a group of 10 questions with five response options for users (from Strongly agree to Strongly disagree). With the users' answers, it was possible to calculate the System Usability Scale (SUS) score, a number, between 0 and 100, that represents a measure of the system usability. To calculate this number, each item score must be multiplied by 2.5 to convert the original scores from 0-40 to 0-100. Based on the questionnaire answers given by the 29 users that participated in the DD-IMS usability evaluation, we converted each user's answers in a score from 0 to 100 (SUS score). After analyzing this data, we obtained an average SUS score of 88.19, with a standard deviation of 10.54 and a median of 90. This is interpreted as a very good evaluation result, which means that users are quite satisfied with the DD-IMS usability. Analyzing the SUS scale percentile ranking [1], which tells how well a system SUS score compares to other systems, we can conclude that the DD-IMS is well above the average (68), receiving an 'A' grade, and its SUS score (88.19) is close to the 100th percentile. Figure 8 presents the distribution of the SUS scores given by the users. During the evaluation sessions, users also suggested some modifications to improve DD-IMS usability.

5. Conclusions

We developed the DD-IMS, a system that manages the information regarding CSE PhD students. DD-IMS relational database stores all the relevant data

[16]Available at: `https://tinyurl.com/DD-IMS-Evaluation`

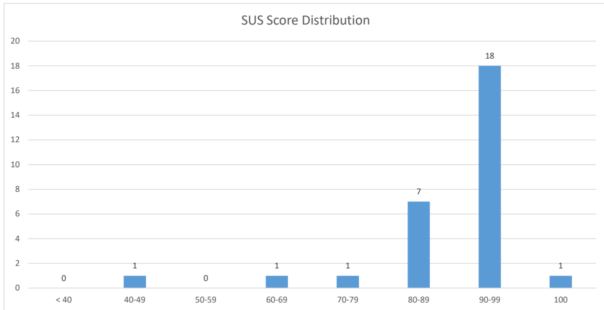

Figure 8: SUS scores distribution.

concerning CSE PhD students in a structured way, thus enabling to monitor each student's progress and to obtain statistics about the behavior of the PhD Doctoral program. DD-IMS web server encloses a web application, accessible to IST users, which provides a user interface so that users can visualize and manage the data regarding the CSE PhD students' processes.

We conducted an experimental validation for the DD-IMS, at three levels: functionality, usability, and performance. With the results obtained, we can conclude that the DD-IMS meets the usability, performance, and reliability requirements of the Information Management System for the CSE Doctoral Degree.

The DD-IMS has already entered into production and is already being used within the CSE department. At this time, 78 CSE Doctoral Degree students had registered in DD-IMS, among the 89 students listed in the Fenix system as being registered (*matriculados*, in Portuguese) and active. If the decision is to adopt it as the official tool within the department to manage the CSE doctoral program data, it must be maintained, fixing problems detected by its users. Besides, some aspects should be improved. These aspects can be divided into two main groups: (i) modifications to be integrated into the DD-IMS current functionality (lower implementation time); (ii) new functionalities (higher implementation time). The complete list of modifications and new functionalities to be implemented on the DD-IMS are presented on [6].

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