

THE IRRAD DATA MANAGER (IDM)*

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Abstract

The Proton Irradiation Facility (IRRAD) is a reference facility at CERN for characterizing detectors and other accelerator components against radiation. To ensure reliable facility operations and smooth experimental data handling, a new IRRAD Data Manager (IDM) web application has been developed and first used during the last facility run before the CERN Long Shutdown 2. Following best practices in User Experience design, IDM provides a user-friendly interface that allows both users to handle their samples' data and the facility operators to manage and coordinate the experiments more efficiently. Based on the latest web technologies such as Django, JQuery and Semantic UI, IDM is characterized by its minimalistic design and functional robustness. In this paper, we present the key features of IDM, our design choices and its overall software architecture. Moreover, we discuss scalability and portability opportunities for IDM in order to cope with the requirements of other irradiation facilities.

INTRODUCTION

The Proton Irradiation Facility (IRRAD), located in the East Area of the Proton Synchrotron (PS) accelerator complex at CERN, is an infrastructure dedicated to the qualification of materials, electronic systems and detector components for High-Energy Physics (HEP) experiments. A beam of protons with a momentum of 24 GeV/c accelerated by the PS is delivered to IRRAD, in pulses, and used for the irradiation experiments. IRRAD started its operations in 1999 [1]; it went through a major upgrade in 2014 to deal with the increasing demand for irradiation experiments by the HEP community, linked to the development of the High-Luminosity LHC [2]. Every year in IRRAD, hundreds of electronic and detector components, called "samples", are tested and qualified. Dosimetry is an important part of the operation; thus, during the irradiation experiments, aluminum dosimeters are placed together with the samples for defining the actual accumulated fluence [3] through gamma spectrometry. As a result, the registration, planning and follow-up of these experiments require the management of a considerable amount of data.

In the early years of IRRAD, a software application called Sample Manager was developed and used on a local computer for the registration of the samples to be irradiated. For the upgraded IRRAD facility, this system was outdated,

running only on local computers with specific drivers, and could not be upgraded. Thus, these facts called for the development of a new web-based system with specific software requirements. These requirements were that the new system should be in line with the new IRRAD facility software needs, integrate into the modern software infrastructure of CERN, and provide better User Experience (UX). Since this application would be online, security was also a crucial issue to be considered. Moreover, after the irradiation experiments, the samples are radioactive and therefore this system had to be also compliant with the CERN traceability procedures and able to send/receive data from the official system used by CERN for the traceability of potential radioactive equipment (TREC) [4]. Last but not least, the scalability and portability of the system were also important aspects taken into consideration for future developments.

In this paper, we describe the overall development of IDM, the new IRRAD Data Manager web application [5], and its key functionalities. More specifically, in the second section, the design life cycle of IDM is described. In the third section, the software choices, the architecture and the deployment methods are presented. In the fourth section, we focus on the functionalities of IDM. Finally, in the fifth section, we conclude by providing some statistics regarding IDM operations during the IRRAD run of 2018, and presenting, as future work, our ideas on extending and adapting the IDM functionalities to other irradiation facilities.

DESIGN LIFE CYCLE

As stated in the previous section, User Experience was an important aspect for the new web application IDM. In particular, IDM should provide an intuitive interface targeting different user groups, such as physicists, engineers and technicians. Therefore, IDM design was based on UX universal principles in order to be intuitive and user-friendly [6]. In particular, we applied a User-Centered Design (UCD) approach, which allows for a better understanding and identification of the users' requirements and goals [7].

Research and Exploration

The first phase of a UCD focuses on the users' needs and tasks. For this reason, we used the CERN Irradiation Facilities online database developed in previous work in order to find information and details about existing irradiation facilities at CERN and worldwide [8]. Then, we interviewed coordinators, operators and users of IRRAD and of some of the irradiation facilities found. This allowed for a better understanding of the current state of the art regarding the used software tools. We thus gained a better insight of the users'

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needs, reaching the conclusion that there was no existing tool that could already fulfill these requirements.

Insight Synthesis

The second phase of a UCD requires taking into consideration the previously acquired user insights and defining specific user requirements and use cases. In this step, roles, permissions and tasks for each role were described in detail [9]. For instance, one specification included in the document is that an administrator is authorized to view all the experimental data of the facility, whereas standard users can only access the data of the experiments they are participating in.

UI Prototyping

After several iterations of this requirement and use case definition process, the next step is the design of (possibly many) User Interface (UI) prototypes. For producing such a UI prototype but without implementing any actual functionality, the use of a wireframe software such as Balsamiq was deemed necessary. Balsamiq is a graphical user interface application that allows developers to build and test easily UI prototypes [10]. Figure 1 provides some examples of such early UI design prototypes.

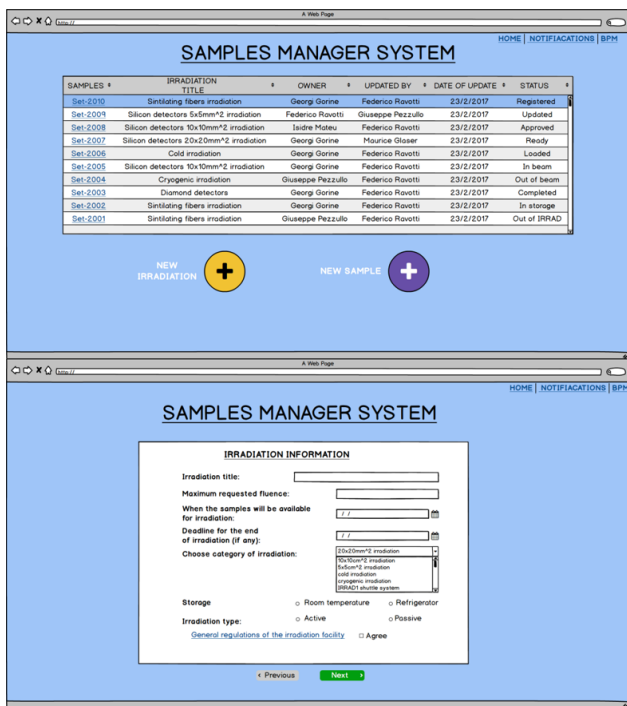


Figure 1: Balsamiq prototypes.

Evaluation

The final step of a UCD, before actual software implementation, is the evaluation of the projected designs. The already built prototypes were tested and evaluated by the facility operation team, and the most suitable prototype was chosen for

implementation. This final UCD phase may, in practice, require to return to the UI prototyping if none of the proposed UI designs end up fitting the evaluators' expectations.

DEVELOPMENT

The four main concerns guiding our software design and development decisions were the compliance with the CERN software infrastructure, security, scalability and portability specifications. We address these questions while detailing below our software choices, the IDM architecture and its deployment facets.

Software Choices

To face these main concerns, we decided to use the state-of-the-art web technologies described below.

Django IDM has been developed using Django, an open-source high-level Python web framework [11]. Django is a modern web technology that insures better security, for example via cross-site request forgery (CSRF) protection, quick development and less code, avoiding redundancy.

Oracle Database Oracle was chosen as the default database for storing the IDM data. The choice of the Oracle database is based on the fact that Oracle is broadly used in other CERN software infrastructures and is also well supported by CERN, thus allowing for better database maintenance and backup opportunities [12].

JavaScript and JQuery For the purpose of making IDM more user-friendly, some interactive components were implemented. JavaScript and JQuery, a JavaScript library that helps with the high-level manipulation of HTML and other web-related data structures, were chosen for the implementation of the IDM front end in order to simplify the development of these interactive features [13].

Semantic UI The IDM front end aims for a minimalist design, focusing only on the components necessary to be compliant with the UX principles [6]. For this reason, the layout of IDM was implemented via the Semantic UI development framework, which provides enough aestheticism and responsiveness to user interfaces [14].

Architecture

The IDM software architecture is mainly based on the Django architecture (see Fig. 2), which abides by an alternative to the traditional Model-View-Controller (MVC) architecture, the Model-View-Template (MVT) architecture. More specifically, the Django architecture contains three layers of development: the Model, View, and Template layers.

The Model layer provides the structure and primitives for the manipulation of user data. As shown in Fig. 2, this layer is, in our case, directly mapped to an Oracle database, which means that each Model class is represented by a database table. In addition to the IDM data, the Oracle database stores also operational information related to the irradiation

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facility such as the particle flux, read by IDM and used for the real-time computation of estimated accumulated proton fluences.

The View layer provides the logic for user request processing and response. In this layer, the Infor-provided [15] suite of web services for Enterprise Asset Management (EAM) [16] is integrated in order to allow for a transparent communication between IDM and TREC [4]. These web services implement the requests for the create, read, update and delete operations (CRUD) in the Infor EAM system used in the back end of TREC [16].

Finally, the Template layer provides a specific syntax used for rendering the information and presenting it to users. As shown in Fig. 2, the Semantic UI framework, JavaScript and the JQuery library were integrated in these templates in order to provide an intuitive and interactive user interface for IDM.

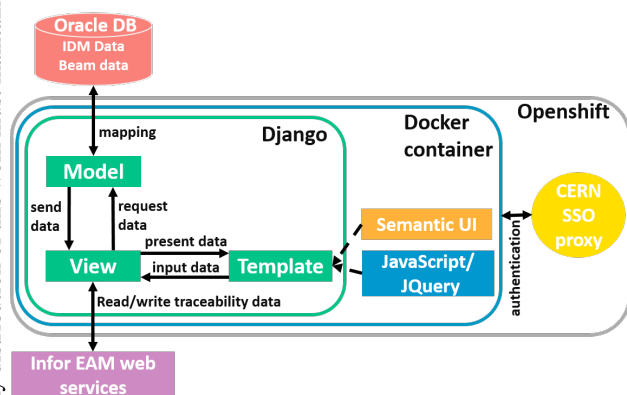


Figure 2: IDM architecture.

Deployment

DevOps technologies allow for the Continuous Integration and Continuous Delivery (CI/CD) of software. Thus, a Docker container [17] is used for the containerization of the IDM software in order to deal with potential dependency issues. Leveraging the software services provided by CERN, this Docker image is built on the CERN Platform-as-a-service (PaaS) infrastructure, based on RedHat OpenShift, which facilitates the automatic process of building Docker images [18]. OpenShift is based on Kubernetes, an open-source system for automating deployment for containerized applications [19].

In line with our focus on security issues, IDM uses the CERN Single Sign-On (SSO) system for user authentication, ensuring in this way a level of security for IDM comparable to other CERN services. For this purpose, a basic Apache server was deployed that acts as a SSO authenticating proxy for the application.

FUNCTIONALITIES

IDM provides the key functionalities needed for the data management of the IRRAD facility, the follow-up of irradiation

experiments and the traceability of the IRRAD samples and other potentially radioactive components (see Fig. 3).

Registration

All the data related to an irradiation experiment are registered in IDM. Users first register into the dedicated mailing list (e-group) of IRRAD users; this provides the permission to the users to log into IDM. Once logged in, they can request to perform an irradiation experiment by providing details such as information about the samples to be irradiated, the type of irradiation experiment requested and the availability of the components to be tested. Moreover, for reasons of data privacy, users can only see and modify the experiments to which they are associated and take part in. Thus, when a user registers an experiment, he/she also needs to assign access permissions to the specific users that this experiment will be visible to.

On the IRRAD side, the facility coordinators who have access to the IDM "administrator" view can approve the experiment requests if the experiment complies with the planning of the facility and the irradiation procedures. Once the irradiation experiment is approved, the users are then allowed to register the samples corresponding to their experiments; they can also provide additional details such as the quantity, dimensions and physical composition of the samples necessary for computing the parameters related to the operation.

Planning

In IRRAD, there are nine remotely-controlled, movable stages (IRRAD tables) along the path of the proton beam; they are used to place the samples for irradiation [20]. This setting introduces some complexity when planning the irradiation experiments. IDM enables a better planning of the experiments' sequence by providing an overview of the registered experiments and samples, and of their availability, to the facility coordinators and operators. Through IDM, the coordinators can assign the samples to a suitable support and keep track of their position. Moreover, they can associate dosimeters to the relevant samples; those will be used for assessing after irradiation, through spectrometry, the accumulated fluence.

Furthermore, the fact that the samples are positioned in parallel along the beam line causes another challenge in the planning of the irradiation experiments. Even though a high-energy beam does not degrade completely after interaction with a thin layer of matter, however, it interacts and produces secondary particles, if a significant amount of matter with considerable density (e.g. interaction length) is put into the beam. For mitigating this phenomenon, users are asked to register the material composition of their samples. This information is then used for the computation of experiment-specific proton interaction lengths, which provide the necessary information to the coordinators on the amount of samples that can be irradiated at the same time.

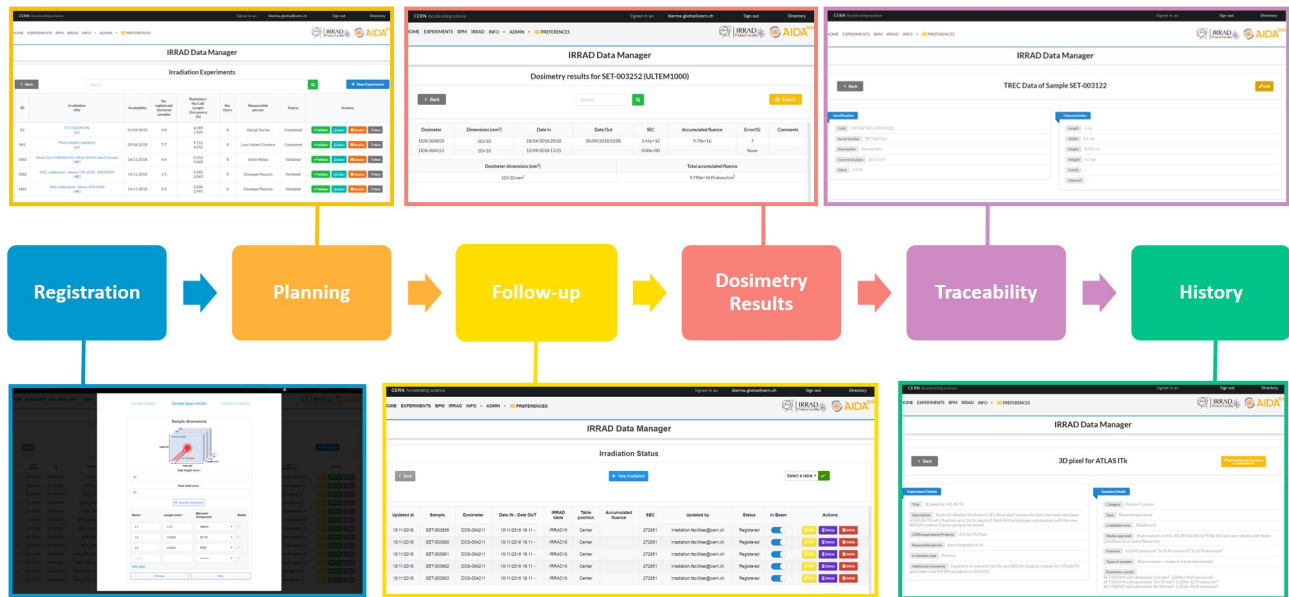


Figure 3: Typical screen shots illustrating IDM key functionalities.

Follow-up

Once an irradiation experiment is launched, IDM provides a status panel for the follow-up of the experiment; it is refreshed every five seconds. The start of an experiment triggers the corresponding functions for reading the beam flux values and providing an estimate of the accumulated fluence. When the IDM-estimated accumulated fluence reaches the user-requested fluence, the irradiation experiment is considered as complete and a notification is sent to the coordinators.

Dosimetry

As previously mentioned, dosimeters are used in order to assess the accumulated fluence actually received by the samples; to get an accurate value, a gamma spectrometry analysis of these devices is thus performed once an irradiation experiment is completed [3]. These data are registered and provided to the users as the final dosimetry results, necessary for further physics data analysis.

Traceability

CERN uses a dedicated system for ensuring the proper traceability of potentially radioactive equipment [4]. In order for IDM to be compliant with these traceability procedures, naming conventions compatible with TREC are used in IDM when labeling the samples and dosimeters used in the facility. Moreover, through IDM, the relevant labels can be printed and then attached to the corresponding samples and dosimeters.

When samples have to be transported outside the IRRAD facility to a CERN area or shipped to another location out-

side CERN, the users need to perform a transport request and transfer the relevant data to the CERN radiation protection service, through TREC. Similarly to IDM, TREC requires the registration of certain characteristics of the samples such as the dimensions or the material type. Since these data are already registered in IDM, the need of integrating these data into the TREC system is obvious so that the users do not have to perform the same registration in both systems. Moreover, the facility operators need to collect the samples after irradiation into containers; those must be also registered in TREC. This requires creating associations among samples and containers and registering them directly in TREC through IDM. To implement these functionalities, IDM uses the Infor EAM web services for data exchange [16].

History

For minimizing the amount of radioactive waste, which has an important environmental impact, but also for reducing the cost of an irradiation experiment, facility operators and users should be attentive to not repeating similar irradiation experiments and to keeping the materials set in the beam to a minimum. To help in these matters, IDM implements functionalities that allow for knowledge sharing among IRRAD users by keeping the history of the previously performed experiments. Users can choose to make their experiment details visible to other IRRAD users. This way, the latter can learn from past experiments, in particular, the procedures that need to be followed and the expected results.

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UI Customization

One important principle of good user experience design is the idea that there is no "one size fits all". Therefore, IDM needs to be easily customizable and appealing to the various users' taste. Thus, IDM provides functionalities that allow users to customize their interfaces. For example, they can change certain display configurations such as background color or font size.

CONCLUSION AND FUTURE WORK

In this paper, IDM, a new software tool for the management of the data from the CERN Proton Irradiation Facility, IRRAD, is presented. After following a user-centered design approach, key functionalities were implemented based on modern technologies such as the Django framework, JavaScript, JQuery and Semantic UI. IDM runs in a Docker container and was deployed on OpenShift.

IDM was first used for the IRRAD run of 2018, handling the data of 81 irradiation experiments involving 97 users, 787 samples and 405 dosimeter entries; 2056 dosimetry results were registered and handled by the system during that year. Feedback from facility users, operators and coordinators was received during the whole run and used for improving the functionalities and user experience of IDM.

In the coming years, new functionalities will be added to IDM in order to satisfy the users' requirements and follow the facility upgrades. Moreover, we will investigate the possibility to customize IDM for other irradiation facility infrastructures with different characteristics and needs. In certain cases, IDM may in fact be already functional, with small modifications and specific configurations, for other irradiation facilities.

Finally, the development of IDM was also the motivation for working at a more abstract level, identifying the key concepts related to the data management of irradiation experiments; this led to the creation of a standardized model, the Irradiation Experiment Data Management ontology (IEDM) [21]. A by-product of this formalization effort is that, from this ontology, a web application similar to IDM can be automatically generated and used as a starting point for the development of a data manager system for other irradiation facilities [22].

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