Historical Civil Registration Record Transcription Using an eXtreme Model Driven Approach

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***Abstract*—Modelling is considered as a universal approach to define and simplify real-world applications through appropriate abstraction. Model-driven system engineering identifies and integrates appropriate concepts, techniques, and tools which provide important artefacts for interdisciplinary activities. In this paper, we show how we used a model-driven approach to design and improve a Digital Humanities dynamic web application within an interdisciplinary project that enables history students and volunteers of history associations to transcribe a large corpus of image-based data from the General Register Office (GRO) records. Our model-driven approach generates the software application from data, workflow and GUI abstract models, ready for deployment.**

***Index Terms*—Software and System Engineering, Model-Driven Development, Web Application, Historical Civil Record, Digital Humanities, XMDD, DIME.**

I. Introduction

Historical data concerning individual life events, combined with wider socio-economic records provide excellent sources for analysis and reflection. Accordingly, the digitalisation of corpora of historical data concerning various aspects of the life and activities of individuals and communities is an essential precondition for the ease of analysis, for example using modern data analytics and AI techniques. The Digital Humanities Manifesto 2.0 (DH) [1] presents DH as a discipline which studies the intersection of the disciplines of computing and humanities. DH currently combines methods, tools, and technologies provided by the computing sciences (such as data visualization, information retrieval, text mining etc.) with the perspectives and methodologies stemming from the humanities disciplines (such as history, trend analysis etc). One of the increasingly popular means of using digitally available data foots on the concept of a Digital Twin (DT) [2]. A Digital Twin is a virtual and abstract model of a physical entity (an engine, a patient, a student, a plant or a city) that serves as the enabler means for simulation, analysis, prediction, and real-time analysis of the system it represents. It has gained enormous relevance and popularity in recent years as it provides a handy virtual model of a physical process or service. In the Industry 4.0 context, it often leverages technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), Cyber-Physical Systems (CPS) and Big Data for digitization. By definition, digital twins refer to a "live" model that continuously updates and changes as its physical counterpart changes [3]. In the Humanities, the DT concept unfold a massive potential to transform the landscape of how DH methods can assist in the representation, analysis and understanding of our past, which in turn can provide useful learnings for the present and future. It promises a tremendous innovation potential, and most of the current research on digital twins is focusing on specific implementations for concrete use cases and the generalization towards reusable abstract models [4]. Developing a mirror of a traditional Digital Humanities record system through the digital twin lens is time-consuming, complicated and requires deep interdisciplinary knowledge in the humanities domain and model creation and software development. Too often, this induces a knowledge gap, giving rise to fundamental research questions on how to connect the two disciplines in such a way that a "lingua franca" can bridge the concepts and the means of expression and analysis of both disciplines.

We use a specific kind of Model-Driven Design, called XMDD for (eXtreme Model-Driven Design) [5] to bridge this gap. Model-Driven Development (MDD) specifically focuses on supporting the collaborative (software) development process by using abstract representations of data and processes. Using these models, we combine computing knowledge with the formal descriptions of the historian's knowledge, and this way succeed in reducing complexity and improve productivity, as described by [6].

To reduce the discipline-specific knowledge gap between humanities and technology, the project "DBDIrl[1] - Death and Burial Data: Ireland 1864-1922 [7]" adopts a data-driven public-history and digital-humanities research methodology which uses advanced MDD for application development. DBDIrl is an interdisciplinary project that combines historians' understanding of Big old data with computer analysts' tools and methodologies. Its objective is to build an extensible and reusable Big Data interoperability and analysis framework that supports flexible Big Data integration between different historical data sources and provides a web-based platform for the analysis of its underlying corpora. The corpora stem from various sources of national records, like the civil registration records of the General Register Office, the individual level census returns of 1901 and 1911, and various coroner's court records within the period 1864 to 1922, i.e., from the intro-

"Death and Burial Data: Ireland 1864-1922" is a project funded by Irish Research Council Laureate Award IRCLA/2017/32 to Dr. Ciara Breathnach (Department of History - DH), in cooperation with Prof. Tiziana Margaria (Software Systems, Dept of Computer Science and Information Systems - CSIS) at the University of Limerick.

[1]https://www.dbdirl.com/

duction of civil registration records in 1864 to 1922, when the Irish Free State was established. This Digital Humanities platform needs to be robust and easily evolvable, able to integrate different data and interpreted terms, able to manage and analyze various data representations and enrichments, all in a transparent and FAIR (i.e., Findability, Accessibility, Interoperability, and Reuse of digital assets) [8] data context.

This paper focuses on developing an efficient and flexible data access mechanism to make the heterogeneous sources of historical data available to a wider range of researchers through adequate user interfaces.

DBDIrl applies the eXtreme Model-Driven Approach for complete design, development and execution of a Big Data interoperability framework. The first component of that framework is a Web application that supports efficient and correct data entry. We refer to it as the *Historian DIME app* or *Historian app* in short, and it is completely developed following a model-driven approach.

Key contributions of this work are:

- A model-driven Web application for input and storage of Irish Civil Registration data, specifically death registration data, from 1864 to1922, introducing a database for subsequent digital data analysis.
- Producing a systematic and clean data source for (relevant subsets of) the death records. Massive information regarding the death records was previously collected as images of the original registers stored as TIFF files, plus an excel index summary. The page-by-page images of the handwritten records were digital, but it was impossible to analyze them. The database of systematic and clean data can now be processed for further research, concerning the discovery of information, its evolution, trends over time, and finding insightful patterns about individuals and families.
- Illustrating the impact of the MDD approach on the adaptation and evolution of the Historian App, from its first version to the current one, including the re-usability of components and the refinement of its organization, to support increasing levels of error prevention and embedded error checking. It is essential if we want to gradually build a platform, where such applications and data analytics applications can be quickly and correctly assembled from a service-oriented Domain Specific Language that covers the functionalities and the data occurring in a history research context.
- Showcasing the use of DIME [9], a specific low-code application design framework, where stakeholders can develop their specific application without any coding knowledge.

To our knowledge, this is the first attempt to work with Historians as customers using a model-driven approach.

The paper is organized as follows: Section II presents the project background and motivation. Section III describes related work in the fields of MDD and Big data analysis. Section IV discusses the co-development methodology and its life-cycle along with an explanation of the abstract architecture and workflow of the proposed XMDD based application. Section V illustrates the model types of the XMDD technology and the concrete design of the Historian App. Section VI describes some major challenges with corresponding proposed solutions. Finally, Section VII concludes the paper and highlights some future work.

II. DBDIrl Project Background

The General Register Office (GRO) is responsible for recording Irish civil information of birth, marriage and death. In 2016 it placed historical data online for free on irishgenealogy.ie. To initiate a search at the site, some basic personal information is required, but it has limited functionalities. This site holds civil data sets regarding individuals, but for the fundamental objectives of DBDIrl, a centralized data storage containing complete and correct data is needed for future research and exploration. As the primary data, DBDIrl uses the Death Registration Data (DRD) from 1864 to 1922 directly shared by from the GRO. We received approximately 4.3 million individual Civil Register records of death registration in two different formats. Over 1 TB were images produced through high-resolution scans of the original register pages and provided as .TIFF files. We also received .csv files with group id, name, age, superintendent's district and .TIFF file path of all individual death records. Fig. 1 shows a page from the death register. Each scan captures a full register page, including up to 10 individual records, each recording an individual death.

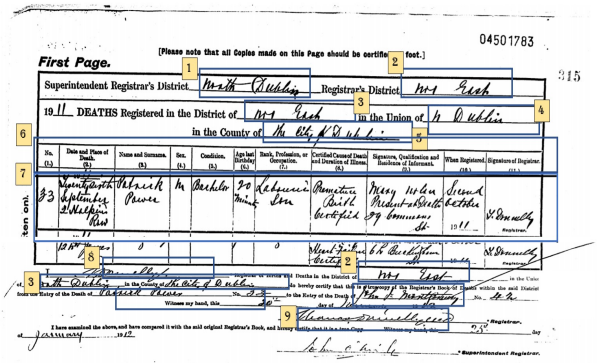


Fig. 1: Death record of Irish civil registration: the GRO original register page (TIFF file available at irishgenealogy.ie) with properties highlighted.

In the absence of complete metadata and a fully digital version of the image's contents, the .TIFF file is de facto just a picture, i.e., an unstructured analog image of the page, and useless for the purpose of automatic analysis of the contained information. A human eye sees easily that every record has 11 index properties (identified and numbered in Fig. 1) describing the death event and its circumstances. This set of complex

properties collectively represents the individual's death event along with its essential information. Their complete digitization, meaning the transformation of the TIFF images into a curated repository of clean and faithful data that is fully automatically searchable and analyzable, is the aim of the current phase of DBDIrl.

For essential quality guarantee, the historical digital data collection must maintain with certainty the overall integrity of the original historical data. Additionally, the technology needs to enable domain experts, like historians and archivists, to handle the maintenance of the data collection and the evolution of the applications. These experts are mostly not programmers, and most certainly not experienced in all of web development, databases, software architectures, UI design and development, privacy and security, testing and deployment. So we adopted a programming-less low code approach based on an Integrated Modelling Environment (IME) that subsumes most of these characteristics in the development platform of choice.

The goal consists of three main tasks:

1) transform the TIFF files into a digital curated repository;
2) achieve this transformation in a low-code environment that is easily maintainable and evolvable, effectively building a new generation data entry, storage and management platform for digital humanities;
3) make historical data from heterogeneous sources available to a wider range of researchers through adequate user interfaces and easy-to-use analysis tools.

Currently we are working on tasks 1 and 2.

A. Automated Digitization Attempt

DBDIrl started with attempts to transcribe the .TIFF files to an operable, structured data format. A widespread approach would use OCR or Natural Language Processing (NLP) tools to extract the text from each .TIFF file. While the state of the art tools work quite well for printed texts, they severely failed in our case. In fact well-known language processing tools could not produce any useful results. There are many reasons for this failure: (1) death records are handwritten texts, which is a difficult problem; (2) they were written by different registrars and their superintendents, with considerable variation of handwriting pattern; (3) tools have difficulty handling the data variety, (4) for some writers the corpus of records is very small and insufficient for a good training set; (5) very few existing tools extract the text as individual properties, thus even in case of success a significant manual post-processing would be needed; (6) accurate text extraction needs a well-trained model with a huge and precisely labelled data sets for training, which is not available here; (7) there should be reliable methods to combine all the individual property texts into correct death record entries, which is difficult when most properties are not correctly recognized; and (8) there is a scalability issue when uploading millions of records into a server.

B. Supported Digitization

As a consequence, we abandoned an automated recognition approach for the time being, in favour of a manual, but highly assisted and supported data enrichment through a web based application. In this sense, the first and second task now align much more closely: We have now an XMDD based web application for the historians' data entry, where application developers and historians work side by side in application design and development within a model-driven, low-code environment. This application development approach helps the historians to further develop and maintain their own application at the model level, without the need of any programming knowledge.

III. Related Work

Since the emergence of UML and its predecessors, several MDD approaches have been proposed in the literature to address the generation of code from models representing various aspects of the system [10], including for telecommunications [11], web and client applications [12]–[15]. MDD techniques are mainly used for decreasing the effort needed for application development and maintenance and increase the portability to new platforms. The eXtreme Model-Driven Development (XMDD) [5] approach is a low-code approach that combines several software designs and programming paradigms such as agility, model-driven development, service orientation, domain-specific languages, data management, data flow and control flow design, Formal models and methods, generative programming, eXtreme programming, aspect orientation and full code generation [5], [16]. According to [17],

> "Models allow sharing a common vision and knowledge among technical and non-technical stakeholders, facilitating and promoting the communication among them."

In terms of specific MDD approaches and applications, [18] proposed automated extraction, analysis, and visualization of data and metrics on model-driven artifacts. In cyber-physical systems, [19] and [20] demonstrate the use of MDD in robotics. [21] proposed a DSL for service customization for telecommunications sytems. [22] proposed a Domain-Specific Modelling Language for smart home applications with two transformation templates that generate code from instances of SmartHomeML for SmartThings and Alexa. They designed the transformation using an MDD approach in a platform-specific model-to-code implementation artefact.

In e-learning, [23] propose a course management system that stores a course model as machine-readable components that generates a final course in different platform-specific target models. In web applications, modern Single-Page Applications (SPA) use MDE to connect between client and server of a web application, and [24] present a model-driven approach for the consumption of RESTful Web services in SPA.

Ref [25] defines a Machine Learning based MDE approach that analyzes Big Data for probabilistic modelling by defining a domain-specific modelling language. In Big Data, [26] introduced SkyViz, a model-driven approach for automating the translation of user objectives to visualize the Big Data Analytics' results into a set of most suitable and concrete

visualizations. [27] proposed a design method to specify, deploy, and monitor Big Data Analytics solutions using MDD.

While all this shows that MDD is applied in a variety of relevant areas for the DBDIrl project, as per our study there are no MDD based context-aware web applications that work with real-world big data archiving, management and analysis.

IV. The Historian App as a MDD Application

The Historian App we developed and evolved in a number of iterations is the DBDIrl solution to data entry, storage and management for the historical civil registration (i.e., death) data of Ireland from 1864 to 1922.We adopt the eXtreme Model-Driven Development (XMDD) paradigm [28], which provides a fast turnaround of easily modifiable prototypes understandable to the non-IT experts. In this way, a more collaborative approach between domain experts (here the historians as central stakeholders) and developers establishes itself along the entire project life cycle.

The agile model-based approach helps repeat the feedback and co-design cycles with the historians in a continuous refinement process. In addition, using models also helped the developer team when reflecting, presenting and explaining the work progress to the historians and the historians when understanding and monitoring the development.

We chose the DIME Integrated Modelling Environment [9], [29], based on Domain-Specific Libraries (DSLs), as the XMDD framework for our project. DIME provides reusable features, and functionalities [20], [30] where developers can develop web applications within a low-code environment without having any programming knowledge. DIME supports model types for processes, services, data, and the UI that are integrated and kept consistent to a reasonable extent by the platform. Many domain-specific libraries (DSLs) are already available, for example, for the GUI design of the web applications. New services as well as entire new DSLs can be introduced in an easy way. These characteristics help the IT specialists and the domain specialists to better understand and monitor the development throughout the project life cycle on the basis of the domain knowledge.

A. The IME-based co-development lifecycle

The application development life cycle of the Historian App is illustrated in Fig. 2.

The project development life cycle involves in each phase both the computer scientists and historians, in different roles. The historians become successively more skilled in dealing with the models and application design. At project completion the historians may be able to modify and evolve, or even design and implement, their own web applications on the basis of the existing DSLs, without any coding knowledge.

1) Phase 1 - Application Modelling:
As illustrated in Fig. 2, the project life cycle starts by collecting and collaboratively analyzing the historians' requirements. They are materialized as abstract workflow models with the corresponding (unique and coherent) data model. Data and processes go hand in hand in DIME, so they are typically co-developed and co-evolved in an XMDD approach. In this phase, the historians used their expert knowledge about handling historical data and the correctness of the data and the records. The historians collected the data and analysed their characteristics. While historians were finalizing the data properties that they need for their further analysis, the computer scientists started designing the data models including entities, attributes and relations. Then the historians specified how they want the data to be stored, explaining what is already there and usable, what else needs to be added, and how. Next, the CS team designed the corresponding data and workflow models, expressing the high-level application logic and the elementary operations required for application development. Gathering this expert knowledge in terms of workflows and properties or conditions (on the individual data item, the record, the workflows) corresponds to gathering the historian data entry application's static and behavioral requirements. At this phase, the historians also validated the models and helped in finalizing them.

2) Phase 2 - Model Completion and Compilation:
The second phase includes all the XMDD: model refinement, followed by DSL extension and implementation of new functionalities. Here the historians participated as stakeholders for detailed questions, the CS team as fine granular designers and developers. The CS team extended the DSLs where functionalities were missing, implemented them in a reusable, service-oriented way and modelled the Web application GUI. A growing hierarchy of nested workflows structure the application logic in behavioural features. For the business logic they acted as application configurators on the basis of these models and services. We reuse existing DIME process models such as *RetrieveEnumLiteralSIB* that gets a field status (illustrated in Fig. 4) but also designed new processes for further required operations such as *GetPrePopulated* to load in the application a predefined set of data from a file. This phase also includes the models-to-code generation phase from the collection of validated models, and the deployment on a standard web stack. It produces a deployed, running application, that is further examined, updated, recompiled and redeployed.

3) Phase 3 - Application Execution and Testing:
In this phase, the Historians and other end users (like history students and volunteers in the transcribathons for the data entry) test and use the application, as shown in Fig. 3. Small adjustments and optimizations may be carried out as a consequence of live testing. This is the validation and use phase of the current version of the application. It includes live debugging, error handling and fixing, as well as the definition of new features and changes for the next development phase.

The whole cycle follows an agile software development procedure.

B. Modeling the Historian Web Application: The Full Workflow

We describe now the application workflow along with the explanation of the main processes and GUI models developed

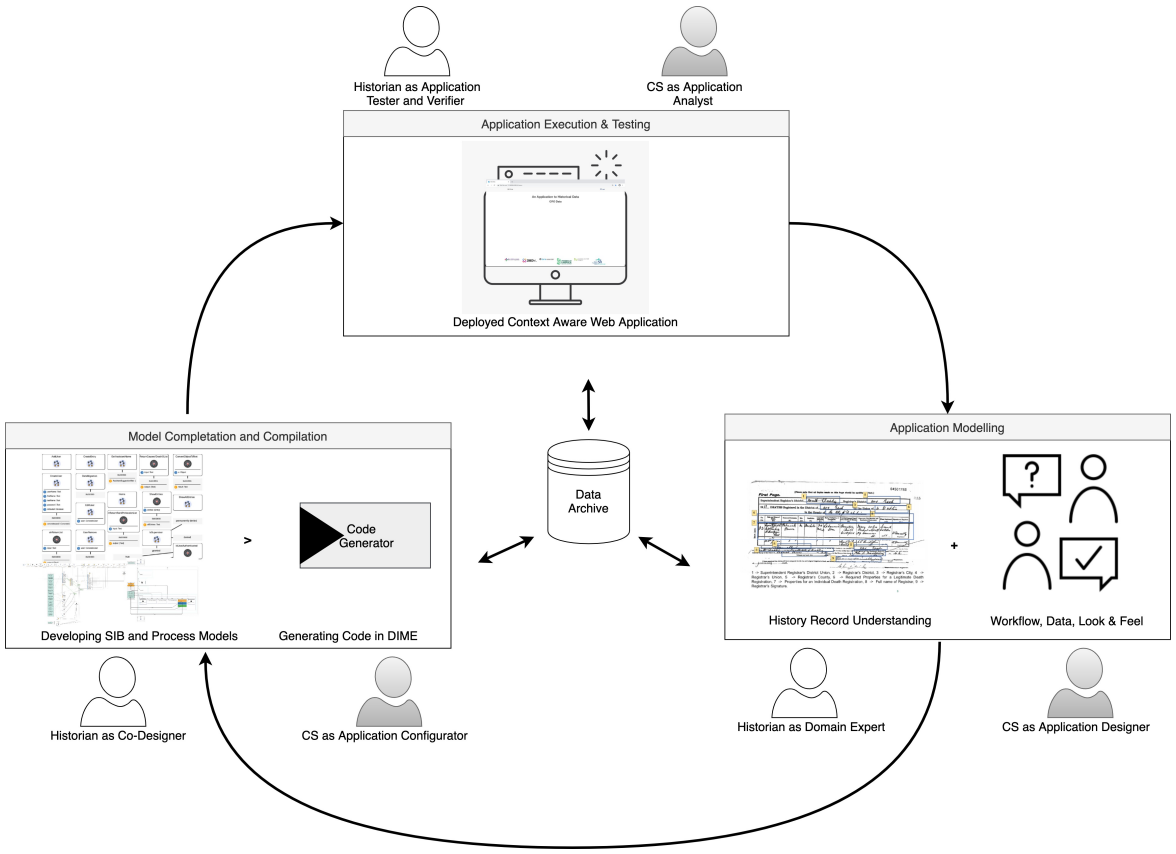


Fig. 2: Collaborative development lifecycle in an IME: agile iterative phases, roles of Historians and Computer Scientists (CS).

for the application. The Model-Driven Development (MDD) of DBDIrl starts with listing and developing process models, the data model and identifying user roles. Fig. 3 illustrates the feature-level abstract architecture of DBDIrl's data entry web application in terms of *Processes*, *GUIs*, *Actions* and *Event Handlers* (as indicated by the respective stereotypes `<<Process>>`, `<<Action>>` etc.) along with the connections among them.

The application homepage[2] is a GUI model where users can login. Its action Login calls the process IsSupervisorGuard, that checks the login credentials and establishes the user role: Supervisor or Student.

In the **Student** role, a successful login directly links to the *EntryTable* page, a GUI model where the student sees all the entries recorded by him/her. Action *AddNewEntry* leads the user to the *EntryForm* page, a GUI model which calls the *CreateEntry* process shown in Fig. 4.

On the *EntryForm* page, users enter the data of all the records from the .TIFF file of the death record register page, by filling up field by field the record's properties in the corresponding fields on the web page.

[2]The Historian App is available at https://civilreg.dbdirl.com/home, it is accessible to predefined, verified users.

CreateEntry is a big process: it receives the data entered by the user and to do so in an error-free way it calls other processes that provide support functions. For example, it uses the *GetPrePopulation* process for reading pre-populated data from a file, *GetSuggestions* to provide pre-populated options in the Web form as drop-down menu for certain data attributes, *CreateAddress* to create a new (complex) address object with the individual attributes city, county, district and street. Similarly, *CreateTimeDuration* creates a duration object from various time properties. The *GetPrePopulation* process receives the group id of a death record provided by the user, and it reads name, age, superintendent's district and .TIFF file path from the .csv files we received from the GRO. It also auto-fills the corresponding fields of the *EntryForm*. The *GetSuggestions* process reads large lists of pre-populated, validated values for a number of properties. It displays those options as a drop-down menu in the form, to ease the input of attributes like cause of death, registrar name, assistant name, rank profession and street names of Ireland from 1864 to 1922. These data collections are pre-validated, as the Historians collected them from 18's Ireland records. *CreateEntry* performs all the individual operations needed to successfully save an entry with all its values entered by the user (either by hand or by selecting pre-populated fields), property by property. Event

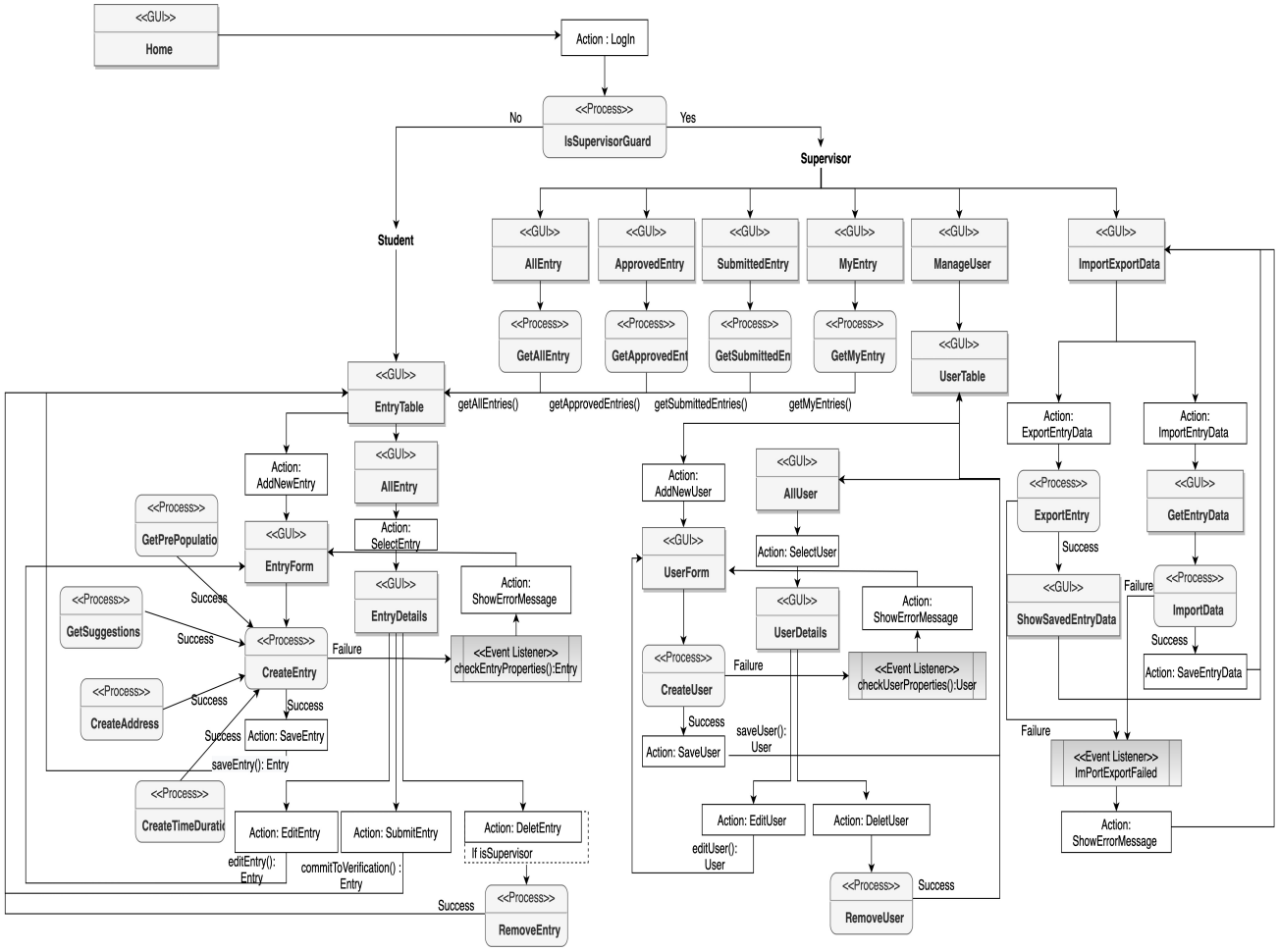


Fig. 3: Model-driven abstract architecture of DBDIrl's data entry web application - Feature level

listeners on *CreateEntry* process help check data validity and show alert messages in case of a wrong entry (incorrect value or format). Finally, the action *SaveEntry* from the *EntryForm* successfully saves an entry and sends the user back to the *EntryTable*, to process the next record.

Fig. 5 shows the entry table as it is displayed on the Historian App web page, with the corresponding GUI model in DIME. We see here that the structure and look and feel are very recognizable. The data flow is explicitly modelled, and we recognize buttons (like the *CreateEntry button*) and other elements like fields filled from the database and status indicators that are color coded (orange, green and blue).

From the *EntryTable*, selecting an entry leads the users to the *EntryDetails* GUI: there they can (re)view the entered entry details and choose to edit the entry (this brings them back to the *EntryForm*, filled with all the previously entered data), or submit the entry for review. The *Entry Delete* option is only available to the Supervisor role, who can delete an entry from the database.

In the **Supervisor** role, a successful login directly links to the *EntryTable* GUI. The supervisor is displayed the user's entries and also has other options, like seeing all submitted and approved entries individually. The Supervisors have a validation and approval function: they can see the details of all the entries stored by Student users, and have actions to perform edits, approve, as well as remove each entry.

Fig. 6 shows the *ShowEntry* process, with flows for the *Approve*, *Submit for Review*, *Edit*, *Remove*, *Close* entry operations. Selecting *ManageUser* leads the supervisor to a *UserTable* page that includes the *AllUser* GUI (displaying all the users) and the *AddNewUser* action. *AddNewUser* calls the *UserForm* GUI, containing all the fields required to creating an user.

Similar to *CreateEntry*, the *CreateUser* process performs all the operations necessary to create a user. It also includes an event listener that alerts the supervisor in case wrong or ill-formatted information is provided. After saving a user, the action *EditUser* calls the *UserForm* again with the previously provided data to edit, while *DeleteUser* calls the *RemoveUser* process to delete the user. Supervisor can also import and export data to and from the application. An event listener is used to check issues regarding import/export operations, together with the processes *ExportEntry* and *ImportData* that

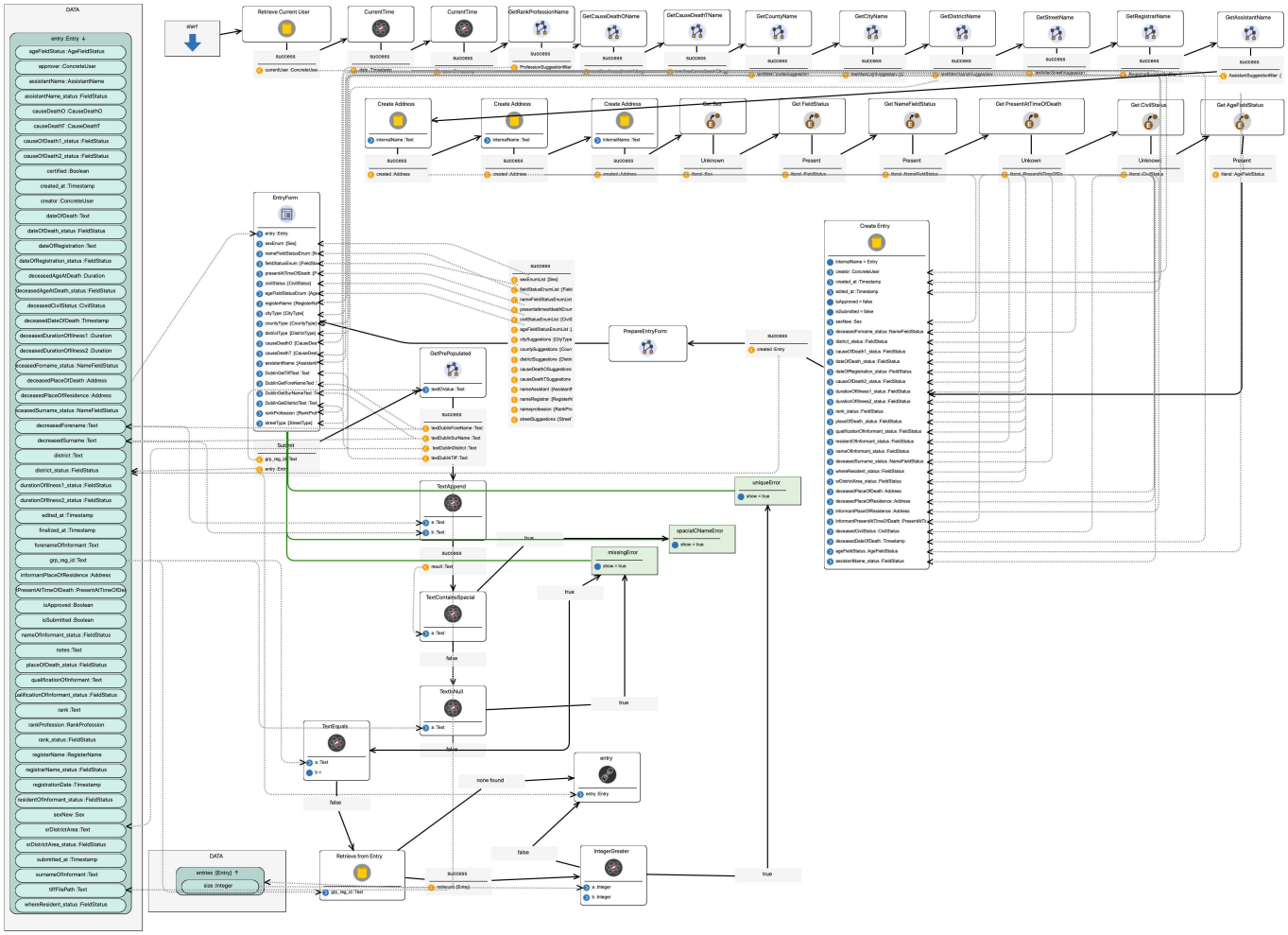


Fig. 4: Create Entry process of Historian DIME app including all other processes that successfully stores a death record with all its attributes and event listeners.

export and import data, respectively.

Altogether, Fig. 3 presents an overview of how the Historian App is organized, and shows the interplay among all the Processes, GUIs, (GUI)Actions and Event Handlers.

V. Model Types and Concrete Models

We describe now the main model types, model elements and models of the Historian App.

A. Data Model

Fig. 7 shows the data model of the application, representing both the concrete and abstract data. It contains both unidirectional and bidirectional relations such as association and inheritance. In our finer granular representation of a record, every Entry has 27 individual properties. Some properties like Sex, Address, Age include sub properties, which are at the elementary granularity needed for data analysis. The decision of moving to these 27 properties from the original 11 properties of Fig 1 is an example of the design choices for the Historian App stemming from the co-design practice. As shown in Fig. 7, every concrete user can have base user who as act as creator (only students) or approver of an entry. The Entry itself is a concrete type data at DIME (green data objects at Fig. 7). Most of the attributes of entry are stored as text or number i.e. primitive attributes of DIME (small yellow components at Fig. 7). Some are Enum type attributes e.g. Civil Status with some optional values (brown data objects at Fig. 7). Some properties may not be present in the original record: the corresponding cases are captured by the FieldStatus. Some attributes e.g. Registrar Name are created as concrete type object so that they can receive list of data options and presented as drop-down menu to the application and user can choose the correct information from provides options. Duration and Address are also concrete type objects with required values.

B. Graphical User Interface Models

In DIME, the GUI model type represents the structure (layout and contents) of the Historian app's individual web

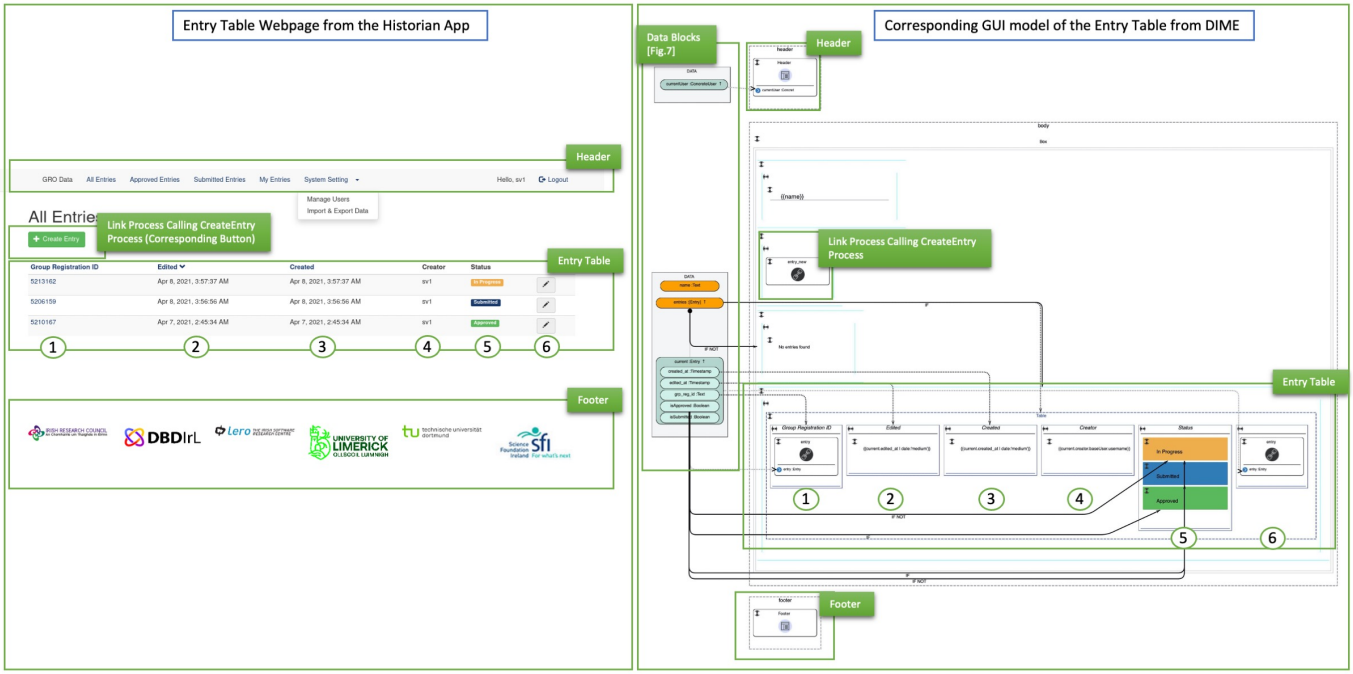


Fig. 5: The Entry Table of the Historian App: Web page (Left) and its corresponding GUI model (Right).

pages. A collection of GUI models defined, therefore the abstract and concrete "look" of the presentation layer of a DIME application. We see in Fig. 3 that the created GUI models connect the GUI and Process Models. Every GUI models of Historian DIME app is created using components from DIME palette. The GUI models call process models to execute an operation. These GUI models are also reusable, for example we use EntryForm at Fig. 3 for both create and update operation of each entry.

C. Native DSLs

In DIME, the actions and services are collected in domain specific palettes that are basically a service or component oriented DSL. The DSL elements correspond to (calls to) individual functionalities that are either directly implemented or provided by an external service provider, like e.g. the database. The individual functionalities are modelled as special native types called SIBs, for service-independent building blocks, where service-independent means that they are widely reusable across applications. These Native SIBs enable interoperability on a structural level. Within the Historian app, besides the pre-existing DIME SIBs we create Native SIBs for different operations such as data pre-population, CSV file import and export and to get field suggestions etc.

D. Data-flow

In DIME data flow is explicitly modelled within the process models. The input/output ports of SIBs can either be connected directly with each other or used to read and write from/to variables placed in a dedicated container representing the data context [9]. Fig. 3 shows the data flow connections of the proposed application using arrows. All other figures of the Historian DIME app shows data flow connection.

E. Process models

Process models express the business logic in a fashion roughly similar to Activity Diagrams, but with a clean formal semantics. There are several process types: basic, interactable and interaction processes. Each process type follows certain rules regarding which kind of SIBs they contain and the kind of tasks they express. The graphical syntax and general handling are the same for all the types of SIBs and processes. Fig. 3 shows the process models that are created for the Historian application. The collection of process models together with the connected GUI, actions and data flow expresses the behaviour of the application in terms of its operation. Fig. 4 shows the actual process model CreateEntry of Historian app (also presented in Fig. 3) that performs all necessary operations and successfully stores an entry to the database.

Process models can also be of different type such as

a) Basic Processes: : Basic Processes consist of native SIBs and built-in SIBs, and express the smallest processes of the application's business logic. In the Historian app, basic processes models are the CRUD (i.e., create, read, update, and delete) operations and data operations. In Fig. 3 CreateUser and RemoveEntry are two examples of basic processes.

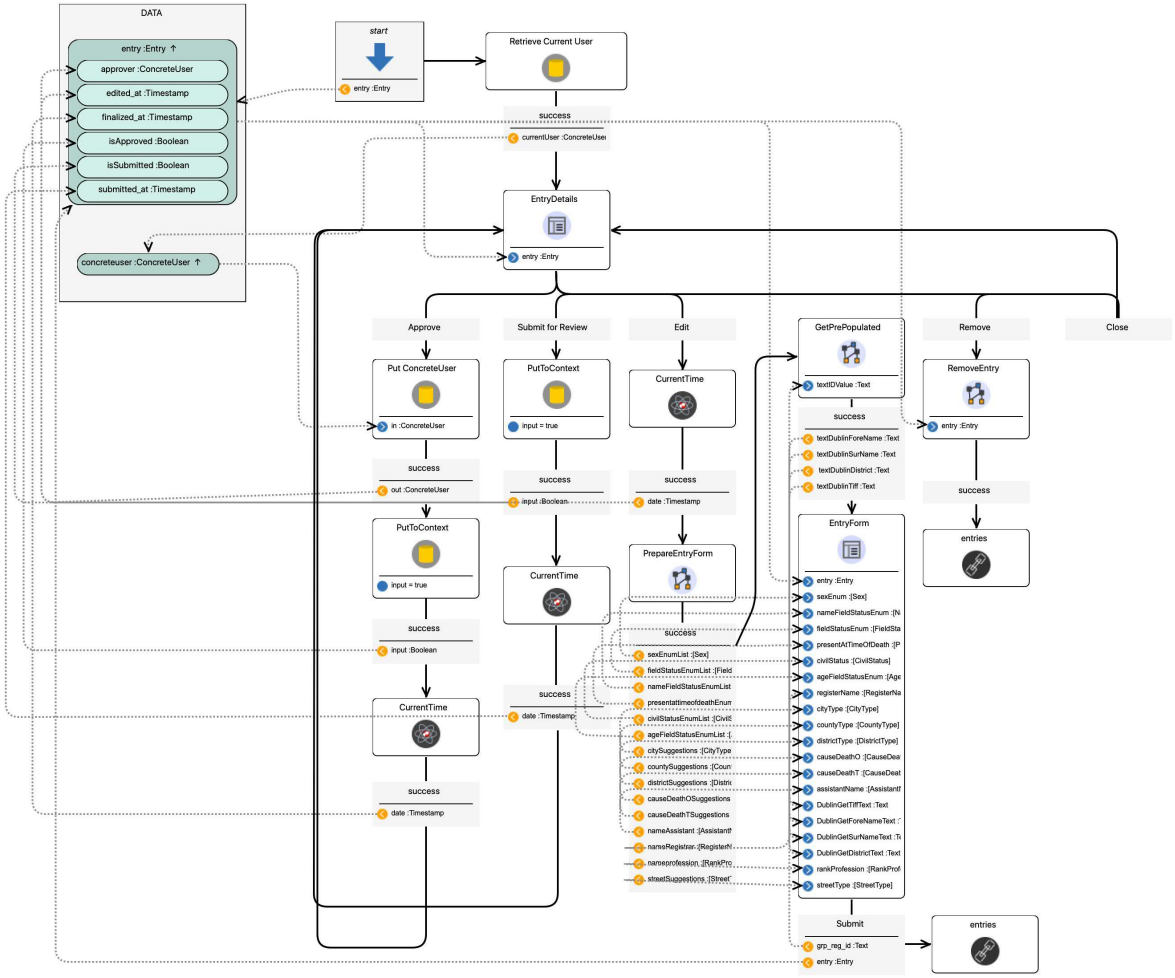


Fig. 6: Entry table management process of Historian app, with flows for the Approve, Submit for Review, Edit, Remove, Close entry operations.

b) Interactable Processes: : Interactable Processes work as interfaces between the front-end layer and the backend of the application. They are similar to Basic processes, but are restricted to non-native type. The StartUp process is the only interactable process in the Historian app. This process includes operation of successful login of user with different role.

c) Interaction Processes: : Interaction Processes are used to define the immediate interaction between user and application, accordingly they can be seen as a sitemap [9]. Where interactable SIBs communicate with the backend, interaction SIBs establish a new hierarchy level with the frontend. As the Historian app is essentially a sophisticated daTa entry app, most of its processes are developed as interaction process, like GetPrePopulation, GetSuggestions, CreateAddress etc.

d) Security Processes: : Security Processes realize the (role based) access control with a predefined interface. The IsSupervisorGuard and ExportFileGuard processes are two examples of security processes in the Historian application. In IsSupervisorGuard the start node must include the currently signed-in user (i.e., the Supervisor) as an input, and all following nodes are restricted to be labelled with "granted".

VI. Challenges and Solutions

A. Defining the major context parameters

In a context-dependent application, a DSL should enable modelling the different context situations that may occur during user interface usage. This DSL will eventually help developers to separately specify context-specific services to monitor various parameters and react accordingly. For example, the application's abstract GUI rules cover various adaptation dimensions: layout, navigation, reusability. Accordingly, modelling, adaptation, transformation and execution of processes and GUIs take into consideration the context management and the corresponding adaptation. In particular, the processes and functionalities are associated with responsive GUIs.

B. User interface adaptation at runtime

To achieve a responsive web application, the integrated execution environment must be equipped to generate adaptation services in dependence of the context. For this, the generated

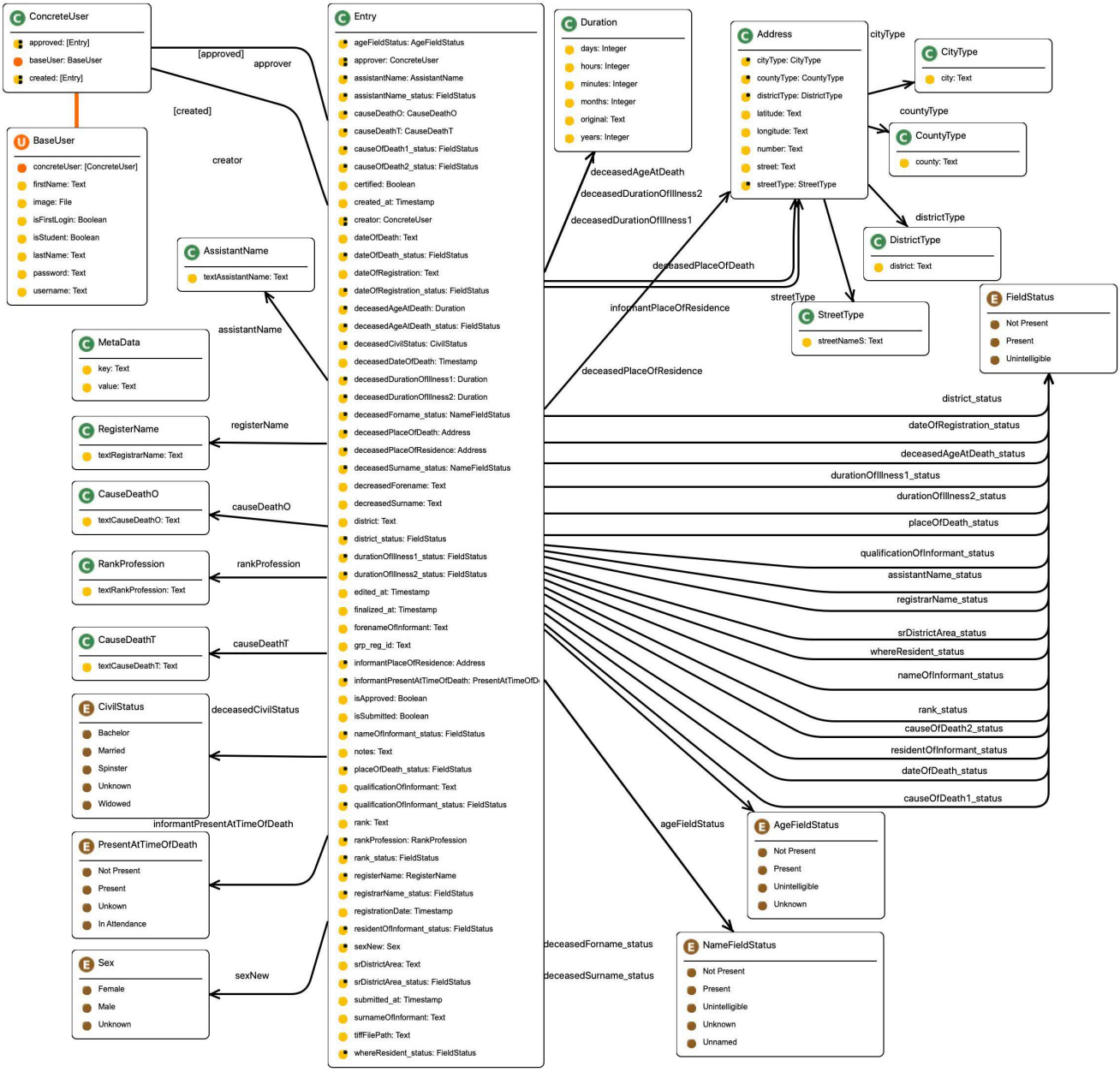
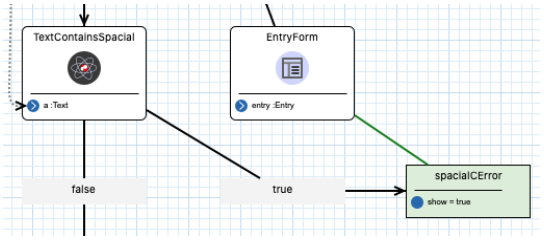
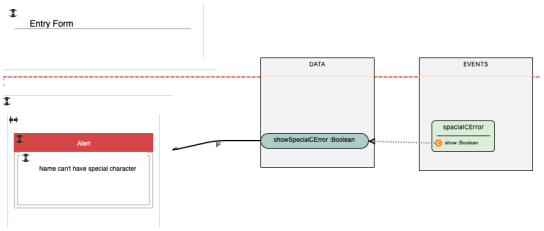


Fig. 7: Data model of Irish civil registration in DIME.

adaptation processes need to be coupled with generated code that enables an automatic dynamic reaction of the runtime UI to the context-of-use. In the Historian App, the data entered by the user is the predominant part of the dynamic context to which the app reacts. The reaction manifests itself in a validation of the entry or an error message if problems are detected. To address various run-time errors, we introduced 'Alert' models with the event handler. To this aim, we introduced native SIBs for several condition checks, detecting e.g., whether an unintentional special character is entered, or a date entered in an incorrect format, a required field is left unattended, the ID not unique etc. Process events are connected with those detections, and respective event-listeners are introduced at the corresponding GUI models, enabling this was a run time error handling. Fig. 8(a) shows an event and corresponding event listener model connected with respective alert that warns the user that 'Name can't have special character' (Fig. 8(b)). We also proposed a rule-based classifier [31] for overall data monitoring and error detection. The integration of the classifier with the DIME application is currently ongoing.



(a) Detection: Event Listener in the CreateEntry Process.



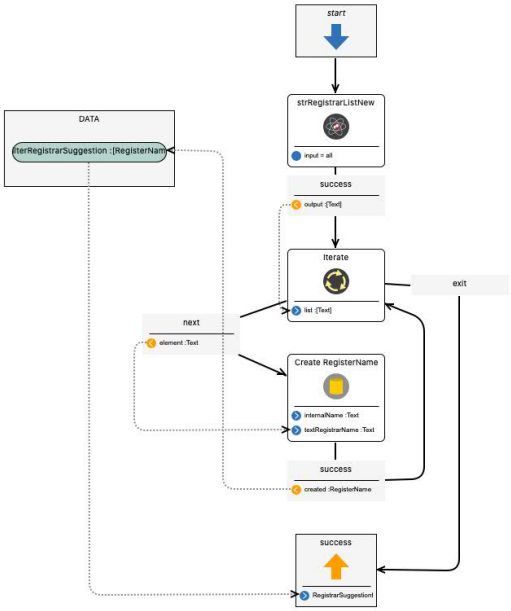
(b) Handling: Event with corresponding alert in the EntryForm GUI.

Fig. 8: Handling a run-time error in DIME: unexpected special character in the name field.

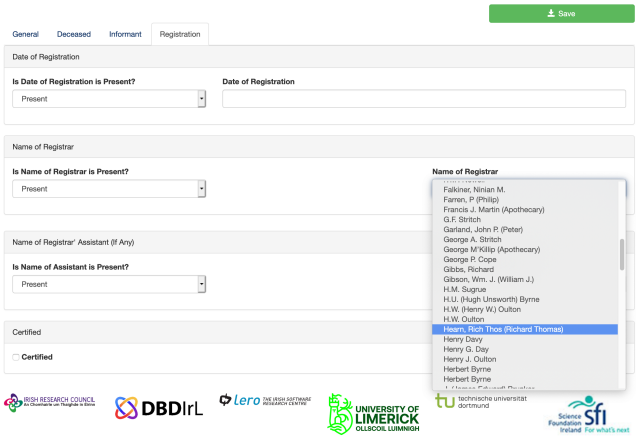
C. Data Entry with minimum error

In 2020 we conducted a pilot Transcribathon using the Historian application version 1, which was not a responsive application with built-in data checks. Examining the resulting data entry, it emerged that most of the wrong entries occurred at the fields Cause of death, Address, Age/Duration and at the Registrar names. The date format also posed problems.

As a solution, we worked together to create drop-down lists of cause of death, registrar name and street name which can be used to provide a predefined list of suggestions, thereby eliminating the free text entry, and reducing error rate. For registrar name prediction, it is possible to create a registrar names list for the period and location of interest. Using the method employed by 18 we ordered the geographical data like street, city and county names of Ireland, which occur in various address fields. All these lists are added to the application, by augmenting it with native SIBs and adequate GUI and process elements. Fig. 9 shows an example. The Web page screenshot of Fig. 9b shows the Registrar data entry page, and in particular the pre-populated data field for the registrar name of a death record. This drop-down menu or combo-box lists all the registrar names collected from the early 1900s Dublin Street Directory. Once the historians found and verified the names of the registrars who registered the death records relevant to this specific time and place, the IT specialists created the GetSuggestion process shown in Fig. 9a. This process shows the list as a drop-down menu in the right location of the application page. Thus, instead of inputting a free string that needs to be validated, in version 2 for this field users can select the correct option from this menu, avoiding errors instead of repairing them.



(a) GetSuggestions process.



(b) Registrar name field with suggestions.

Fig. 9: Data entry error handling in the Historian App by providing suggestions.

VII. Conclusions

In this paper, we presented the first MDD based application developed in the DBDIrl project to support the correct and reliable data entry of Civil registration records. As this project deals with a large dataset, we need a reliable application that prevents as much as possible errors. To this aim, we co-developed with the Historians a model-driven application using XMDD as an agile version of MDD and the DIME integrated modelling environment. We briefly introduced the various model types and showed how they are used in conjunction to create a coherent data, process, GUI and role-based access model. The main advantage of these choices is the ability to quickly react to the findings, exemplified here by the evolution from the V1 to V2 of the App. In

particular, the V2 greatly improves the achieved data quality by making the Application reactive to context-specific events, and equipping most of the data entry fields with pre-populated lists of plausible options, as for addresses causes of death and registrar names, and with context-specific rule checks, as for date and age formats. The main lesson learned is that such an application is necessarily long lived, due to the sheer enormous amount of data to be digitized over time, by many groups of volunteers, and never really "finished". In such a context of continuous improvement, the ability to collaborate with the Historians on the basis of models rather than code is an essential asset, producing successive versions of the app that improve or customise specific aspects of the functionality and the presentation.

The work currently in progress concerns on the one side the inclusion of rule-based classifiers in the application, and on the other side the development in the same paradigm of a data analytics application. The Analysis App needs to be as flexible and customizable as this one, because it will serve the certainly diverse and specialized analysis needs of a growing community of researchers working on big data archival systems in the digital humanities.

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