

XIS-Reverse: A Model-Driven Reverse Engineering Approach for Legacy Information Systems

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Keywords: Model-Driven Engineering, Model-Driven Reverse Engineering, Model-Driven Reengineering, Database, Legacy System

Abstract: Due to the development of new technologies companies face high costs managing and maintaining their legacy applications, thus upgrading those systems became a complex challenge. This paper describes a model-driven reverse engineering approach that aims to support the mentioned challenge. This approach takes as input the legacy relational database schema, but also user preferences to better guide the reverse engineering process. From these artefacts it is possible to extract models of the legacy application through model-to-model transformations based on a set of well defined rules and heuristics. The main contributions of this proposal (compared with the state of the art) are the semi-automatic identification of generalizations and aggregations and the possibility to automatically extract attribute values to enrich the produced models. The paper also includes an evaluation and a discussion of the proposal based on two real-world applications.

1 INTRODUCTION

Enterprises have to manage legacy software applications which were built in the past and are still being used since then. In the long term the maintenance of such applications become rather complex, mainly due to outdated or poor documentation and reduced flexibility of the original software technologies (De Lucia et al., 2008). To overcome these problems software reengineering approaches can be used (Arnold, 1993). Reengineering supports evolutionary maintenance of legacy applications by analysing and modifying such applications rebuilding them in a new form (Chikofsky and Cross, 1990).

A model-driven engineering (MDE) approach can be seen as a chain of model transformations that produces the target software artefacts from more abstract models (Ruiz et al., 2016). Using this kind of approach, the most common model transformations are: Model-to-Model (M2M) and Model-to-Text (M2T) (da Silva, 2015). M2M transformations generate a target model from a source model. M2T transformations produce a textual representation from a source model.

Model-driven reengineering is the application of MDE principles and techniques to reengineer an application. As illustrated in Figure 1, a complete model-driven reengineering process is composed of three main stages (Chikofsky and Cross, 1990): (i) re-

verse engineering, (ii) restructuring and (iii) forward engineering. First, the reverse engineering stage aims to extract knowledge defined in low abstraction representations through introspection and analysis of the initial source artefacts (initial models); this process collects valuable information that makes it easier to define current legacy application requirements. Second, the system restructuring stage involves establishing a mapping between the source and the target systems. Third, the forward engineering stage produces the artefacts to the new target system. Each of these stages is a transformational process that can be implemented by means of a model transformation chain whose initial set of models is injected. This model injection is performed with a T2M transformation applied to textual software artefacts, such as SQL data definition language (DDL) scripts (Ruiz et al., 2016).

Model-Driven Reverse Engineering (MDRE) uses MDE principles and techniques to reverse engineering, producing relevant (model-based) views from legacy systems, thus facilitating their understanding and subsequent manipulation (Bruneliere et al., 2014). A MDRE process is a part of the model-driven reengineering process merely focused in the reverse engineering stage.

This paper proposes a MDRE approach to produce high-level specifications of legacy information systems in a human-controlled way. These specifications

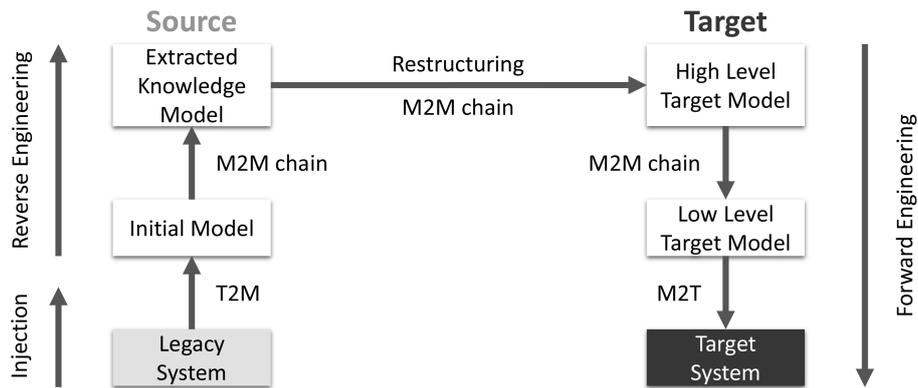


Figure 1: Model-driven reengineering process (extracted from (Ruiz et al., 2016)).

are defined according to domain specific languages, and produced from the injection and the reverse engineering stages.

The remainder of the paper is organized as follows. Section 2 gives a brief introduction of the context of this research. Section 3 describes the proposed MDRE approach and associated tool. Section 4 discuss the main results after using two real-world applications. Section 5 analyses and compares this proposal with the related work. Finally section 6 presents the conclusion and future work.

2 BACKGROUND

This research has been developed at the Instituto Superior Técnico, Universidade de Lisboa, in the area of MDE, namely within the MDDLingo¹ initiative.

MDDLingo is an umbrella researching initiative that aggregates several projects around MDE topics, namely involving the definition of a family of languages, also known as XIS*. This set of modelling languages derives from XIS-UML profile (da Silva, 2003), involving namely XIS-Mobile (Ribeiro and da Silva, 2014b; Ribeiro and da Silva, 2014a), XIS-CMS (Filipe et al., 2016) or XIS-Web (Seixas, 2016). XIS-UML is a set of coherent constructs defined as a UML profile that allows a high-level and visual modeling way to design business information systems. In general these languages include the following views: Entities (which includes Domain and Business Entities views), UseCases (containing Actors and Use Cases views), Architectural and User-Interfaces (composed by Interaction Space and Navigation Space views).

¹<https://github.com/MDDLingo>

Figure 2 illustrates a very simple XIS* Domain view which aggregates domain classes (XisEntity), their attributes (XisEntityAttribute) and relationships (XisEntityAssociation/XisEntityInheritance).

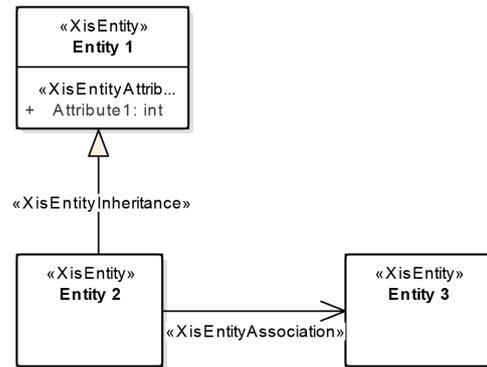


Figure 2: XIS* Domain view.

In addition, Figure 3 shows the BusinessEntities view which allows to define higher-level entities (Xis-BusinessEntity), that aggregate XisEntities and that in the context of a given use case are easily manipulated.

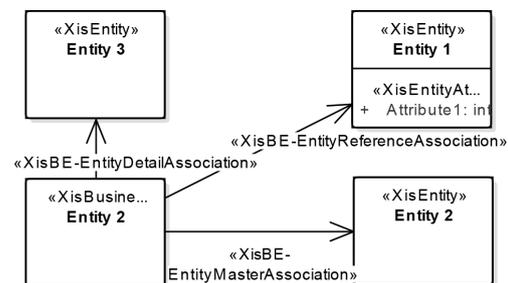


Figure 3: XIS* BusinessEntities view.

Finally, Figure 4 shows the UseCases View. This details the operations an actor can perform when interacting with the application in the context of a business entity (Ribeiro and da Silva, 2014b).

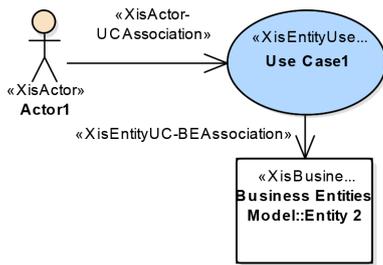


Figure 4: XIS* UseCases view.

XIS* languages are very alike in terms of the Entities view, however there are some discrepancies on their Use Cases, Architectural and User-Interfaces views due to each platform target application. For example, XIS-CMS does not have an Architectural view.

It is to point out that all of them are able to generate their User-Interfaces, using a smart approach based on M2M transformations given the set of Domain, Business Entities, (Architectural,) Actors and Use Cases views.

3 XIS-REVERSE APPROACH

The MDRE approach proposed in this paper is named “XIS-Reverse”. This approach focus only in the first two stages of the reengineering process (Figure 1), namely Injection and Reverse Engineering stages. XIS-Reverse (Reis and da Silva, 2017) is generically represented in Figure 5. It starts by extracting the application database schema from an existent data source (through injection). Thereafter the Application data model is generated. Secondly, the user is able to define his own preferences by tweaking some heuristic’s parameters, producing the XIS-Reverse configuration. The reverse engineering stage takes as input these two artefacts, and generates XIS* models. Then, the designer can analyse the produced artefacts and introduce some refinements, such as changing automatically identified relationships into different ones in the Entities view, enhancing the Use-Cases views, etc.

3.1 Tools Support

Since Sparx Systems Enterprise Architect (EA)² is the tool used to design business information systems in the other XIS* projects, in order to reduce dependencies for future work and learning curve for the user, we decided to also implement XIS-Reverse on

²<http://www.sparxsystems.com/products/ea>

top of this tool. Moreover, from this tool we used a set of provided technologies, namely the Automation Interface and the Model Driven Generation³.

Both reverse engineering configuration and execution steps (Figure 5) are supported by the XIS-Reverse tool. Moreover, in terms of the application database access and the profiler log file injection, for now this tool only supports SQL Server connections and profiler log files generated from the Microsoft SQL Server Management Studio Profiler Tool. Regarding the produced specifications, this tool is able to produce XIS* models but also RSLingo’s RSL⁴ (da Silva, 2017) specifications. However, due to space constraints, only XIS*/XIS-Web models are considered. Furthermore, this tool can be extended to support different representations.

3.2 Running Example

For better understanding and simplicity of the explanation, we introduce a simple but practical example: the Social Security legacy application (SS-App).

The SS-App is a simple application that manages beneficiaries, dependents and tutors, associated documents and user accounts.

This domain is modelled as 8 tables: *Beneficiary* and *Dependent* which primary keys are foreign keys to a *Person* table. *Dependents* table represents the relationship between a *Beneficiary* and a *Dependent* (through its foreign keys linked to each of those tables). A *Dependent* may have a *Tutor*, which are linked by a foreign key. Each *Beneficiary* has a set of documents (since a *Document* has a foreign key to a *Beneficiary* table) and a unique *UserAccount* (due to the unique constraint that the *UserAccount* table has over its *BenIdNumber* foreign key). Furthermore, several documents not linked to any *Beneficiary* may exist as an *UnknownDocument*.

Each of those tables, columns, constraints and number of rows in the database are represented in Figure 6.

3.3 Data Schema Extraction

Following the aforementioned process of Figure 5, during the Data Schema Extraction step, in order to extract the application data model our approach depends on the EA native capability⁵ to reverse engi-

³http://www.sparxsystems.com/resources/mdg_tech

⁴<https://github.com/RSLingo/RSL>

⁵http://www.sparxsystems.com/enterprise_architect_user_guide/13.0/model_domains/importdatabaseschemafromod.html

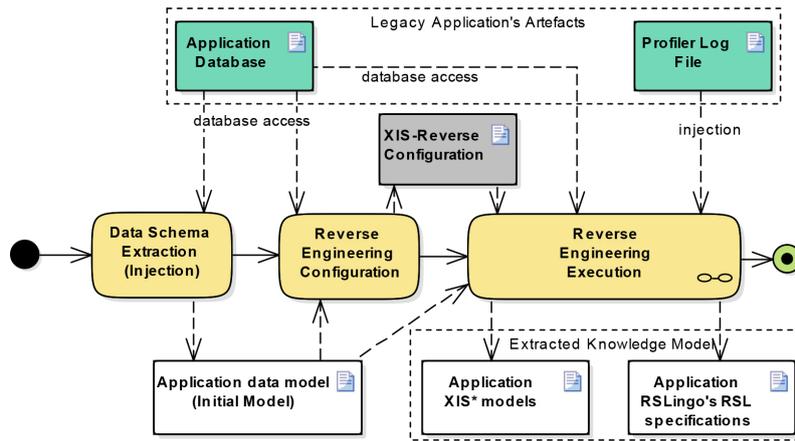


Figure 5: Overview of the XIS-Reverse approach.

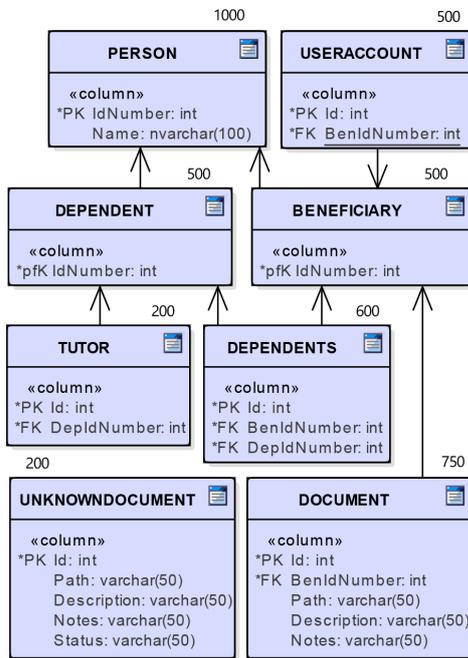


Figure 6: Case Study SS-App data model.

neer a database model through an ODBC connection. Moreover, EA supports several ODBC data sources⁶.

3.4 Reverse Engineering Configuration

The configuration panel of the tool has four main areas: input, output, transformation rules guidance and appearance.

The Input area allows to specify the root node to where the application data model was extracted, to in-

⁶http://www.sparxsystems.com/enterprise_architect_user_guide/13.0/model_domains/supported_databases.html

roduce the database name and to choose how to enhance the output specifications.

In the Output area the user can select additional output representations, namely XIS-Web or RSLingo's RSL representations.

The Transformation Rules Guidance area allows the user to contribute with his knowledge to enhance the Reverse Engineering process. This configuration can be split into three areas: (i) Simple Principal Tables (ii) Attribute Values Extraction and (iii) Generalization discovery. The user can select which tables are Simple Principal Entities (which we consider as entities without many relationships, such as configuration entities or "kind of" entities). Moreover, the user can enhance the produced specifications by extracting attribute values from a selected column of a certain table. Furthermore, in both cases the user can also filter the list of tables by specifying the maximum number of rows per table, which allows the user to find more easily "kind of" tables, since usually they have few number of instances (rows). Finally, the user can activate generalization discovery and add some knowledge, such as a list of XisEntityAttribute names to ignore, the minimum number of shared XisEntity-Attributes (e.g. 5 or 10), and to choose how to aggregate those entities (e.g. by the higher number of shared attributes or by the higher number of aggregated entities).

The Appearance configuration area allows to improve readability of the produced specifications, by arranging models into smaller views and changing the name of the tables to a clearer one.

3.5 Reverse Engineering Execution

Taking as input (i) the application data model, (ii) the XIS-Reverse configuration and (iii) the profiler log

file or the database connection, the reverse engineering process is composed by a set of transformation tasks, that will be applied. Those include a chain of M2M transformations which are used to specify the application as a set of XIS* views.

3.5.1 Initialization

Before M2M transformations take place, the profiler log file or the database connection, if provided, are used to extract more detailed information about the legacy application, that may enhance the produced specifications.

From the profiler log file it is possible to extract SQL statements (INSERT, SELECT, UPDATE and DELETE), and from those statements the set of used tables. Moreover, from that we generate 4 different lists, one for each type of statement, where each one of them holds for each table the number of occurrences for the corresponding kind of statement.

A database connection can be used to collect for each table in the initial application model, the current number of rows in the actual application database.

3.5.2 Transformations to XIS models

The following transformations are broken down into the different set of produced elements.

XisEntities transformation rules

For each table of the extracted application data model, the following XIS Entities (XE-i) rules are applied:

(XE 1) If a table has exactly 2 foreign keys, each one to a distinct table, does not contain more attributes (excluding its foreign keys and primary keys), and one of the two things (1) the primary key is composed of exactly two primary keys which are also the foreign keys (two pfK) or (2) both foreign keys are not primary keys. Following that, this table will be translated into a XisEntityAssociation between the two referenced tables, using a many-to-many cardinality, ie. *:~ cardinality (e.g. *Dependents* in the running example).

(XE 2) Otherwise the table will map a XisEntity (e.g. *Beneficiary* in the running example).

XisEntityAttributes transformation rules

Regarding table columns, the following XIS Entity Attributes (XEA-j) rules are applied:

Let A, B be two tables related by a foreign key constraint from B (referencing table) to A (referenced table):

(XEA 1) For the complete Primary Key:

a) If all the foreign key columns in B are also its complete primary key, in other words B and A have a 1:1 relationship since B primary key references A primary key. Then B foreign keys will be translated into a XisEntityInheritance relationship, where the class equivalent to A will be the superclass and the equivalent class to B will be the subclass (e.g. *Person* (A) and *Beneficiary* (B) in the running example).

b) Otherwise, the complete Primary Key will not be represented (e.g. *UnknownDocument* in the running example). Due to XIS* Domain View similarity to a Class Diagram, each XisEntity can be seen as a Class, which can have objects, and each object is different by definition, so there is no need for a unique identifier for each XisEntity.

(XEA 2) For the remaining columns with Foreign Key constraints:

a) If the foreign key in B constitute a unique index the XisEntityAssociation will have a 1:1 cardinality, preserving the relationship direction (e.g. *BenIdNumber* of *UserAccount* in the running example).

b) If A was not selected as Simple Principal Entity by the user (configuration stage), and one of the following options is also true: 1) the profiler log file was provided, both A and B tables were referenced in that file, and table B had the same or higher amount of INSERT operations as A did, or 2) the database connection was provided and table B had the same or higher amount of rows as A did (if B foreign key column allows NULL values, only rows with NOT NULL values on that column will be taken into account). Then we assume that there is an aggregation relationship between entity A and B (A aggregates B), that is translated into a XisEntityAssociation, preserving the foreign key cardinality and represented with a bidirectional arrow (e.g. *Beneficiary* with 500 rows (A) and *Document* with 1000 rows (B) in the running example).

This reasoning made sense for us since that, assuming that A and B are respectively strong and weak entities, A is the one which aggregates B, it is fair to assume that if that foreign key was made for that purpose, then there must be at least the same amount of B instances created compared with A.

c) Otherwise, the XisEntityAssociation will have a 1:* cardinality between table B and A, preserving the relationship direction (e.g. *Dependent* (A) and *Tutor* (B) in the running example).

(XEA 3) Otherwise the column will be translated into a `XisEntityAttribute` with a corresponding `XIS*` attribute type following a predefined mapping (e.g. *Name* from table *Person* in the running example). Moreover, if previously configured, the user can explicitly select if values from a certain `XisEntityAttribute` from a particular `XisEntity` should be extracted and written as an annotation, which will be linked to the `XisEntity`. This feature is a significant contribution since the produced specifications are enhanced with those values, allowing a better understanding of the `XisEntities` captured from the legacy domain.

Note: in both b) and c) cases, from XEA-2, when the Not Null option is not set for that column (in other words, that column can be NULL), the `XisEntityAssociation` target's cardinality is the concatenation of 0.. with the original target cardinality. (e.g. 1 was the original target cardinality and the column allowed NULL values, then it becomes 0..1)

Implicit XisEntityInheritance transformation rule

For each `XisEntity`, after the previously mentioned `XisEntities` and `XisEntityAttributes` rules are applied and if the corresponding feature was configured, the following `XIS Entity Inheritance (XEI)` rule is applied:

(XEI) A `XisEntityInheritance` identification is performed comparing every `XisEntity` and their `XisEntityAttributes` with each other. We assume that two `XisEntityAttributes` are the same if they share the same name and type. During this comparison, if previously defined, some `XisEntityAttributes` can be excluded by their name. Moreover, we cluster 2 or more `XisEntities` if they share at least the same or more predefined number of shared `XisEntityAttributes`. Furthermore during this comparison only `XisEntities` without inheritance relationship will be taken into account.

After this clustering procedure, there are two ways of finding inheritance, depending on the configuration, the list can be ordered by the descending number of entities or ordered by the descending number of shared `XisEntityAttributes` in each cluster. While this list has clusters of `XisEntities` a Superclass is created for each cluster. This Superclass will have the identified `XisEntityAttributes`, each of the `XisEntities` in that cluster will be linked to the superclass using a `XisEntityInheritance` and will not own the `XisEntityAttributes` that their Superclass has (e.g. *UnknownDocument* and *Document* share 3 identical columns (Path, Description and Notes) in the running example).

In order to implement the first phase of this algorithm, given the complexity that is comparing every `XisEntity` with each other taking into account all their `XisEntityAttributes`, in domains that can easily be compound by hundreds or thousands of elements, we based our approach in the MapReduce (Dean and Ghemawat, 2008) programming model which allows to handle large data sets.

XisBusinessEntities transformation rules

For each `XisEntity`, the following `XIS Business Entities (XBE-k)` rules are applied:

(XBE 1) If the current `XisEntity` aggregates other `XisEntities` or is not aggregated by another `XisEntity` (i.e. we do not consider weak entities as Business Entities), then a corresponding `XisBusinessEntity` will be created, followed by the creation of a `XisBE-EntityMasterAssociation` that will link that `XisBusinessEntity` with its `XisEntity` from the Domain view, and for each `XisEntityAssociation`:

- a) If the `XisEntityAssociation` is an aggregation then it will be translated into a `XisBE-EntityDetailAssociation` between that `XisBusinessEntity` and the target `XisEntity` of the `XisEntityAssociation`. Moreover, if the corresponding target `XisBusinessEntity` exists, there will be a `XisBE-EntityReferenceAssociation` between the target `XisBusinessEntity` and the source `XisEntity`.
- b) Otherwise it will be translated into a `XisBE-EntityReferenceAssociation` between that `XisBusinessEntity` and the target `XisEntity` of the `XisEntityAssociation`.

(XBE 2) Otherwise there is no mapping.

XisEntityUseCases transformation rules

For each `XisBusinessEntity`, the following `XIS Entity Use Case (XEUC)` rule is applied:

(XEUC) There will be a corresponding elementary `XisEntityUseCase` that is named "Manage" followed by the `XisBusinessEntity` master `XisEntity` name, associated to the `XisBusinessEntity` by a `XisEntityUC-BEAssociation`. And a default `XisActor` will be linked to the `XisEntityUseCase` using a `XisActor-UCAssociation` (e.g. *Beneficiary* in the running example). Additionally, each `XisEntityUseCase` has boolean tagged values representing the CRUD operations for the master, detail and reference entities (e.g. *CreateMaster*, *ReadDetail*). And in our approach, all of them will be set to true.

4 EVALUATION

The XIS-Reverse approach to reverse legacy information systems, is able to extract high-level specifications from a legacy application. This approach benefits from a flexible set of configuration points and new features not found in the related work, producing more detailed results, that overall will help the user to get a better understanding of each entity in the domain.

In order to evaluate the contributions of the XIS-Reverse approach, we use two real-world legacy applications. In first case, we use the available specifications for that application and compare the obtain results of the XIS-Reverse with those specifications. In the second case, since there is no updated documentation about the system, to perform the evaluation we use the knowledge that we got after working in the development of that application for 12 months.

In terms of aggregations detection, at least when using a system with a good amount of data (usage), our heuristics are able to correctly identify those relationships and help the user to get better results by specifying Simple Principal Entities (with and without domain knowledge).

Regarding implicit generalizations discovery, our approach proved that can extract accurate results. However this feature does not benefit much from user domain knowledge, since several experiments with different configurations scenarios must be executed to find the best results. Yet, in the extreme scenario, if the user has a good knowledge of each attribute of each entity, this feature should be disabled, since the identification of generalizations can be easily done manually.

Although not evaluated, we assume that extraction of attribute values, independently of the user domain knowledge level, can benefit the user if values from certain entity attributes can be extracted, giving him a better understanding of the entity role in the domain.

Additionally, an analysis of the XIS-Reverse interoperability with a XIS* framework is performed, in order to access how well both tools can work together. We used the XIS-Web technology (Seixas, 2016), since it is the most recent XIS* technology. Despite two XIS-Web limitations, that can be easily bypassed, overall, the produced XIS-Web specifications with the XIS-Reverse tool, are suitable to be used with the XIS-Web framework.

5 RELATED WORK

Reverse engineering of software applications have been extensively studied in the last decades, and their main contributions have been crucial to produce better results in this complex activity, and furthermore to stimulate the development of reverse engineering tools. More recently, MDE started to be applied to reverse engineering (MDRE), promoting a more systematic and flexible process. Moreover, MDRE approaches have been extended in order to completely reengineer a source application into a new target application through model-driven reengineering techniques.

This section overviews the most relevant research studies, covering data schema extraction and reverse engineering of databases. Moreover, those contributions are also compared with our approach.

5.1 Data Schema Extraction

Gra2MoL (Izquierdo et al., 2008) Text-to-Model (T2M) language and MoDisco (Bruneliere et al., 2014) framework have been specially tailored for data schema extraction (model injection). Gra2MoL is a Domain Specific Language (DSL) to write transformations between any textual artefact which conforms to a grammar (e.g. source code) and a model which conforms to a target metamodel. On the other hand, MoDisco is a Java framework intended to facilitate the implementation of MDRE approaches. Regarding to data schema extraction, MoDisco facilitates the implementation of discoverers (model injectors), and it currently provides discoverers for Java, JSP and XML. A drawback for both approaches is that they would require the definition of such transformations and discoverers, respectively, to extract the database schema.

Schemol (Díaz et al., 2013) is another tool for injecting models. However, this tool allows injecting data stored into database by specifying transformations that express the correspondence between the source database schema and the target metamodel.

Furthermore, in terms of database model injection (to ease this T2M transformation) it is possible to transform a database schema into a graphical representation using a variety of commercial and academic tools. DB-MAIN (Hainaut et al., 1994) and SQL2XMI (Alalfi et al., 2008) are two examples of such academic tools. Firstly, DB-MAIN is a toolbox that supports database reverse engineering, and includes legacy database schemas extractors, through several sources such as ODBC drivers or SQL files. Secondly, SQL2XMI is entitled as a lightweight

transformation of data models from SQL Schemas to UML-ER expressed in XMI. To our knowledge, this tool is still limited compared with DB-MAIN since it does not infer entity types or cardinalities, and for now it is only compatible with the MySQL implementation of the SQL DDL.

To sum up, given that a set of existing tools already support data schema extraction from several sources, without additional specification of transformations, we took advantage of such tools, more precisely we used EA.

5.2 Reverse Engineering

A reverse engineering approach can be classified in several ways. Table 1 gives a properties summary of the thereafter analysed research works. These properties include: kind of analysis, output, the existence of tools for automating the approach, automation level of those tools in regards to the reverse engineering stage, if the tool allows extension and main contributions (A - Aggregations Extraction, G - Implicit Generalization Extraction and V - Attribute Values Extraction).

Regarding reverse engineering techniques, several approaches have been proposed, which are usually distinguished by the particular application artefact used as main information source. The most relevant research works, following such distinction, are described below.

Schema analysis (Premerlani and Blaha, 1993) is mainly focused on spotting similarities in names, value domains and representative patterns. This technique may help identify missing constructs (e.g. foreign keys). Moreover, (Premerlani and Blaha, 1993) specification of a manual process was adapted in our approach to semi-automatically and automatically identify generalizations and many-to-many associations, respectively.

Data analysis (Chiang et al., 1994; Pannurat et al., 2010) uses content mined from a database. Firstly it can be used to analyse the database normalisation and secondly to verify hypothetical constructs suggested by other techniques. Given the combinatorial explosion that can affect the first approach, data analysis technique is mainly used with the purpose of the second approach. In addition, our approach uses this technique in a similar way, however it is applied to classify associations.

Screen analysis (Ramdoyal et al., 2010) state that user interfaces can also be sources of useful information. These user-oriented views over a database may display spatial structures, meaningful names and, at run time data population and errors combined with data-flow analysis may provide information about

data structures and schema properties. Moreover, our approach did not consider this kind of analysis.

Static (Petit et al., 1994; Di Lucca et al., 2000) and Dynamic (Cleve et al., 2011a; Cleve et al., 2011b) program analysis can easily give valuable information about field structure and meaningful names, or identifying complex constraint checking and foreign keys after a complex analysis. A main challenge of dynamic program analysis is the extraction of highly dynamic interactions between a program and a database. Moreover, the analysis of SQL statements is one of the most powerful variant of source code analysis. Furthermore, our approach uses static program analysis in the profiler log file, aiming to classify associations.

Additionally, a set of approaches, concerning the application of MDE, are also taken into account. Our analysis focused on their injection and reverse engineering stages.

As previously introduced, MoDisco MDRE framework (Bruneliere et al., 2014) has a huge potential in order to support reverse engineering activities, due to its generic and extensible properties. Besides its legacy application discoverers (model injectors), MoDisco also allows the definition of transformations and generators, responsible for restructuring and forward engineering tasks over the system models, respectively. Our approach could be implemented extending this framework, however that would require the definition from scratch of all the three stages (discoverers, transformations and generators) needed to produce the desired artefacts.

Polo et al. propose a method and a tool, called Relational Web (Polo et al., 2007) specially designed for database reengineering. The starting point is a relational database, whose physical schema is reverse engineered into a class diagram representing its conceptual schema. In the restructuring stage, the class diagram is manipulated by the user and then passed as input to the forward engineering step. Moreover, this tool supports the definition of new database managers to be used as input and the implementation of new code generators. Furthermore, on the one hand this approach only uses as input the physical schema, and user knowledge, and its tool does not take advantage of the existing MDE techniques nor technologies. However, this approach defined foreign key's semantic extraction techniques, to identify inheritance relationships and associations, that were adapted and extended by our approach, in order to identify aggregations.

As previously stated, DB-MAIN (Hainaut et al., 1994) is a toolbox that offers a complete functionality with which to apply database reverse engineer-

Table 1: Classification of some works on reverse engineering.

| Approach | Analysis | Output | Tools | Auto. | Extension | Contributions |
|------------------------------------|-----------------------------|-------------------------------|-------|-------|-----------|---------------|
| (Premerlani and Blaha, 1993) | schema | OMT class diagram | no | n.a | n.a. | G |
| (Chiang et al., 1994) | data | Extended ER | no | n.a | n.a. | n.a. |
| NoWARs (Pannurat et al., 2010) | data | Conceptual schema | yes | Semi | n.a. | n.a. |
| RAINBOW (Ramdoyal et al., 2010) | screen | ER model | yes | n.a. | n.a. | n.a. |
| (Petit et al., 1994) | program (static) | Extended ER | no | n.a | n.a. | n.a. |
| (Di Lucca et al., 2000) | program (static) | Object-Oriented class diagram | no | n.a | n.a. | n.a. |
| (Cleve et al., 2011a) | program (dynamic) | n.a. | yes | n.a. | n.a. | n.a. |
| (Cleve et al., 2011b) | program (dynamic) | n.a. | yes | n.a. | n.a. | n.a. |
| Modisco (Bruneliere et al., 2014) | schema and program (static) | KDM or UML | yes | Auto. | yes | n.a. |
| Relational Web (Polo et al., 2007) | schema | UML | yes | Auto. | yes | n.a. |
| DB-MAIN (Hainaut et al., 1994) | schema and program (static) | GER | yes | Semi | yes | G |
| XIS-Reverse (our approach) | schema, data and program | XIS* and RSLingo's RSL | yes | Semi | yes | A;G;V |

ing. Regarding to reverse engineering DB-MAIN includes features such as extractors of legacy database schemas, transformations between schemas, data and code analysis tools, among others. This tool is one of the most mature ones, in regard to database reverse engineering, meaning that it includes several features that have been the result of a great number of research contributions from Namur University. DB-MAIN supports a lot of common transformations and extraction tools thus, a user with such tools can handle almost any needed transformation to create a good conceptual schema. However, this tool will require the user to apply all the needed transformations, thus the degree of automation achieved in our approach is higher. Furthermore, DB-MAIN supports generalization representation, but once again it must be identified by the user.

Regarding to the main contributions of this paper, we do not find any other approach that specializes associations (e.g. distinguishing between associations and aggregations), nor any approach that allows to extract attribute values and their representation into the target conceptual schema.

6 CONCLUSION AND FUTURE WORK

This paper presented a model-driven reverse engineering approach, named XIS-Reverse, applied to legacy information systems. This approach provides the opportunity to maintain and extend a given application, even in cases that the related documentation is outdated or missing. Moreover, XIS-Reverse is able to specify an application both as XIS* models and as RSLingo's RSL specifications. The main contributions of this paper in terms of reverse engineering, are focused in the implementation of semi-automatic heuristics that can identify certain relationships between entities, namely aggregations and generalizations, and also the possibility to extract attribute values from the source databases to enrich the target models or specifications. Those contributions have proved to be accurate, by extracting good results when used with two real-world applications.

Furthermore, we also concluded that the XIS-Reverse tool is capable to generate models suitable to be used with a XIS* framework, in order to generate a new application.

Regarding future work, in terms of extensibility of the process we would like to evaluate the similarity between the combined results of XIS-Reverse and XIS-Web (new application) with the original legacy application. Additionally, we would like to extend the XIS-Reverse approach in order to support new input and output technologies, and include more reverse engineering approaches.

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