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SURVEY ON ETL PROCESSES

[1]AHMED KABIRI, [2]DALILA CHIADMI
Université Mohammed V-Agdal, EMI, SIR Laboratory Department of Computer science, Rabat Morocco
E-mail: [1]akabiri@emi.ac.ma, [2]chiadmi@emi.ac.ma

ABSTRACT

In Data Warehouse (DW) environment, Extraction-Transformation-Loading (ETL) processes constitute the integration layer which aims to pull data from data sources to targets, via a set of transformations. ETL is responsible for the extraction of data, their cleaning, conforming and loading into the target. ETL is a critical layer in DW setting. It is widely recognized that building ETL processes is expensive regarding time, money and effort. It consumes up to 70% of resources. By this work we intend to enrich the field of ETL processes, the backstage of data warehouse, by presenting a survey on these processes. Therefore, in current work, firstly (1) we review open source and commercial ETL tools, along with some ETL prototypes coming from academic world, secondly (2) we review the modeling and design works in ETL field. Also, (3) we approach ETL maintenance issue then (4) we review works in connection with optimization and incremental ETL. Finally, (5) we present and outline challenges and research opportunities around ETL processes.

Keywords: *ETL, Data warehouse, Data warehouse Population, Data warehouse Refreshment, ETL Modeling, ETL Maintenance.*

1. INTRODUCTION

In current international context where concurrency between entities is high, the need of decision support is a high priority. Conversely, the one can imagine how dramatic bad decision is.

Data Warehouse (DW) defined by Inmon [1] as “collection of integrated, subject-oriented databases designated to support the decision making process” aims to improve decision process by supplying unique access to several sources. In real world, enterprises as organizations invest in DW projects in order to enhance their activity and for measuring their performance.

In next section we propose to focus on this decision support system.

1.1 DW Layers

Figure 1 illustrates the architecture of DW system. In this figure the one can note that DW system has four levels:

- **Sources**: They encompass all types of data sources. They are data provider. The two famous types are databases and flat files. Finally let note that sources are autonomous or semi autonomous.
- **ETL**: stands for Extraction Transformation and Loading. It is the integration layer in DW environment. ETL tools pull data from several sources (databases tables, flat files, ERP, internet, and so on), apply complex transformation to them. Finally in the end, data are loaded into the target which is data warehouse store in DW environment.

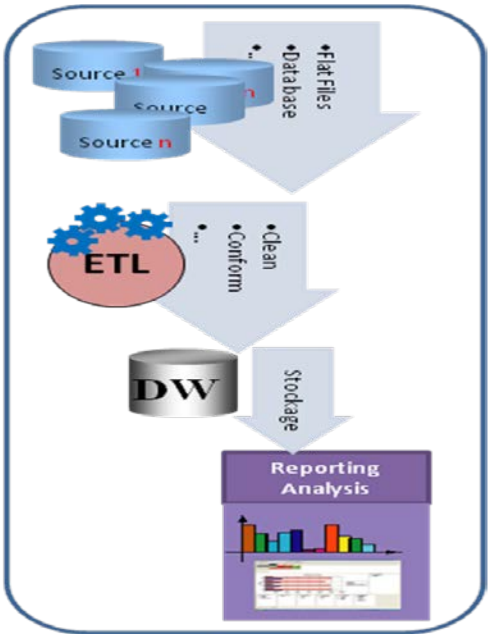

Figure 1: Data Warehouse Environment

- **DW:** is a central repository to save data produced by ETL layer. DW is a database including fact tables besides dimension tables. Together these tables are combined in a specific schema which may be star schema or snowflake schema.

- **Reporting and Analysis** layer has the mission to catch end-user request and translate it to DW. Collected data are served to end-users in several formats. For example data is formatted into reports, histograms, dashboard...etc

ETL is a critical component in DW environment. Indeed, it is widely recognized that building ETL processes, during DW project, are expensive regarding time and money. ETL consume up to 70% of resources [3], [5], [4], [2]. Interestingly [2] reports and analyses a set of studies proving this fact. In other side, it is well known too, that the accuracy and the correctness of data, which are parts of ETL responsibility, are key factors of the success or failure of DW projects.

Given the fact expressed above, about ETL importance, the next section presents ETL missions and its responsibility.

1.2 ETL Mission

As its name indicates, ETL performs three operations (called also steps) which are Extraction, Transformation and Loading. Upper part of figure 2 shows an example of ETL processes with Talend Open source tool. The second part of figure 2 shows the palette of Talend tool that is a set of components to build ETL processes. In what follows, we present each ETL step separately.

Extraction step has the problem of acquiring data from a set of sources which may be local or distant. Logically, data sources come from operational applications, but there is an option to use external data sources for enrichment. External data source means data coming from external entities. Thus during extraction step, ETL tries to access available sources, pull out the relevant data, and reformat such data in a specified format. Finally, this step comes with the cost of sources instability besides their diversity. Finally, according to figure 2, this step is performed over source.

Loading step conversely to previous step, has the problem of storing data to a set of targets. During this step, ETL loads data into targets which are fact tables and dimension in DW context. However, intermediate results will be written to temporary data stores. The main challenges of a loading step are to access available targets and to write the outcome data (transformed and integrated data) into the targets. This step can be a very time-consuming task due to indexing and partitioning techniques used in data warehouses [6]. Finally, according to figure 2, this step is performed over target.

Transformation step is the most laborious one where ETL adds value [3]. Indeed during this step, ETL carries out the logic of business process instanced as business rules (sometime called mapping rules) and deals with all types of conflicts (syntax, semantic conflicts … etc). This step is associated with two words: clean and conform. In one hand, cleaning data aims to fix erroneous data and to deliver clean data for end users (decisions makers). Dealing with missing data, rejecting bad data are examples of data cleaning operations. In other hand, conforming data aims to make data correct, in compatibility with other master data. Checking business rules, checking keys and lookup of referential data are example of conforming operations. At technical level and in order to perform this step, ETL should supplies a set of data transformations or operators like *filter, sort, inner join, outer joins*…etc. Finally this step involves flow schema management because the structure of processed data is changing and modified step by step, either by adding or removing attributes.

We refer interested readers to [3] and [5] for more details and explanation of each step.

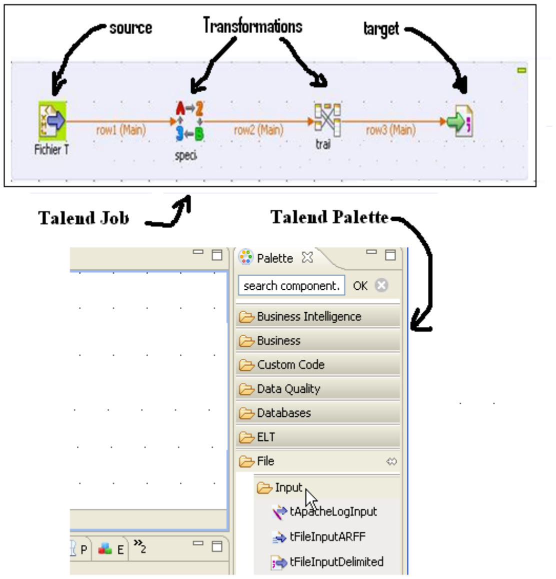

Figure 2: ETL Example and Environment with Talend Open source

The remaining of this paper is organized as follows. In section 2, we review some open source and some commercial ETL tools, along with some ETL prototypes coming from academic world. Section 3 deals with research works in the field of ETL modeling and design while section while section 4 approaches ETL maintenance issue. Finally, in section 4, we present and outline challenges and research opportunities around ETL processes. We conclude and present our future works in section 6.

2. ETL TOOLS AND RESEARCH PROTOTYPES

In Section 1, we present the technique of material views originally created to refresh the DW. In Section 2, we review ETL tools with examples of commercial tools as open source tools.

2.1 Commercial ETL Tools

A variety of commercial tools overwhelms the ETL market which is a promising market. A study [7] conducted by TDWI, identifies a list of indicators and criteria for their comparison and evaluation. Each commercial ETL tool adopts its own notation and its won formalism. Consequently, metadata between these tools are not exchangeable. In contrast, among their commonalities, they all offer a graphical language for the implementation of ETL processes.

We distinguish two subfamilies in the commercial ETL field. On the one hand, there is subfamily of payable ETL DataStage [8] and Informatica [9]. On the other hand, the second subfamily of commercial ETL comes with no charge. In fact, they are free under certain conditions. Indeed, despite the ETL licenses are expensive, major DBMS (Database Management System) editors like Oracle and Microsoft, offer there ETL solution freely for each DBMS license purchased. In other words, ETL solution is included in DBMS package license. In the following we present an example of each subfamily.

DataStage [8] is the ETL solution of IBM editor. Its basic element for data manipulation is called "stage." Thus, for this tool an ETL process is a combination of "stages." Thus we speak about transformation stages and stages for extracting and loading data (called connectors since release 8) which are interconnected via links. The IBM solution DataStage provides two other tools: Manager and Administrator. They are designed, respectively, for supervising the execution of ETL processes and for dealing with ETL project configuration. It should also be noted that IBM offers two versions in its ETL solution: DataSatge SERVER version and DataSatge PX version. This last version has the advantage to manage the partitioning in data processing. Finally, DataStage generates OSH code from ETL job built with stages placement.

SSIS stands for Sql Server Integration Services. This is the ETL solution of Microsoft editor [10]. As mentioned above, SSIS is free with any DBMS SQL SERVER license which includes two extra tools that are SSRS and SSAS (respectively for reporting and OLAP analysis). The atomic element or the basic element in SSIS is called a "*task*". Thus, for this tool an ETL process is a combination of *tasks*. More precisely, SSIS imposes two levels of *tasks* combination. The first level is called "*Flow Control*" and the second level controlled by the first, is called "*Data flow*." Indeed, the first level is dedicated to prepare the execution environment (deletion, control, moving files, etc ...) and supplies *tasks* for this purpose. The second level (data flow) which is a particular *task* of the first level performs classical ETL mission. Thus, the *Data-Flow* task offers various tasks for data extraction, transformation and loading.

In conclusion of this section, we have presented commercial ETL, along with some examples of theme. In next section, we present another category of ETL, open sources tools.

2.2 Open Source ETL

Some open source tools are leaders in their area of interest; for example, Linux in operating system area and Apache server in web servers' area. But the trend is not the same for open source business intelligence (BI) tools. They are less used in the industrial world [11].

To understand this restriction of use of open source BI tools, Thomsen and Pedersen study this fact in [11] work. In this perspective, the authors start by counting BI tools available in open source with illustration of features of each tool. Then the criteria adopted in this study were defined. Thus, in ETL scope the criteria taken into account are:

- ROLAP or MOLAP aspect of the tool that is whether the tool can load relational databases or multidimensional cubes.
- Incremental mode of the tool that is the features of loading modified data or newly created ones.
- The manner of using the tool; via graphical interface, via xml file configuration…etc.

- The richness of offered features.
- The parallelism or the partitioning useful for the treatment of massive data.

In summary, ten open source ETLs are presented and this study concludes that the most notables are *Talend* and *Kettle* because of their large users' community, their literature, their features and their inclusion in BI suites. Finally, let note that another version of this study is available in [12].

In the following we suggest to look closely at one of these tools. More precisely, we will limit to *Talend* tool.

Talend is an open source, offering a wide range of middleware solutions that meet the needs of data management and application integration [13]. Among these solutions there are two solutions for data integration: *Talend Open Studio for Data Integration* and *Talend Enterprise Data Integration*. Respectively, they are a free development open source tool and non free development tool that comes with advanced deployment and management features. *Talend* data integration solution is based on the main following modules:

1. *Modeler*, a tool for creating diagrams. To this end, it offers a range of components independent of any technology.
2. Metadata Manager that is a repository for storing and managing metadata.
3. *Job Designer*, graphical development environment for ETL jobs creation. This tool in turn provides a rich palette of components for data extraction, transformation and loading.

From the point of view of a developer, the implementation of a ETL process with *Talend Open Studio Data Integration* consists on the insertion of components from the palette offered by *Job Designer* (more than 400 components). From the point of view of a designer, the use of *Talend* consists on modeling with *Modeler* module. **But the relationship between these two levels is not available**. In other words, transition from ETL diagrams built with *Modeler* to ETL job written with *Job Designer* is not offered.

In next section, we see another type of ETL tools, those coming from research world.

2.3 Framework and Tools from Research

In this section, we will see some projects, from academic world, dealing with the problem of ETL. These projects are: SIRIUS, ARKTOS, DWPP and PYGRAMETL.

SIRIUS (Supporting the Incremental Refreshment of Information Warehouses) is a project developed at information technology department in Zurich University. SIRIUS, [14] looks at the refreshment of data warehouses. It develops an approach metadata oriented that allows the modeling and execution of ETL processes. It is based on SIRIUS Meta model component that represents metadata describing the necessary operators or features for implementing ETL processes. In other words, SIRIUS provides functions to describe the sources, targets description and the mapping between these two parts. At the end, this description leads to the generation of global schema. At execution level, SIRIUS generates Java code ready for execution after a successful compilation. Finally, SIRIUS includes techniques for detecting changes in the operational sources (databases exactly) besides supervision support, for the execution of defined ETL processes.

ARKTOS is another framework that focuses on the modeling and execution of ETL processes. Indeed, ARKTOS provides primitives to capture ETL tasks frequently used [15]. More exactly, to describe a certain ETL process, this framework offers three ways that are GUI and two languages XADL (XML variant) and SADL (SQL like language). An extension of this work is available in [16] where authors discuss the meta-model of their prototype. The basic element in ARKTOS is called an activity whose logic is described by a SQL query. At execution level, ARKTOS manages the execution of each activity and associate it with the action to take when an error occurs. Six types of errors are taken into account. Firstly, they are 1) violation of the primary key, 2) violation of the uniqueness and 3) violation of reference. These three types are special cases of integrity constraints violation. The other type of error is 4) NULL EXISTENCE for the elimination of missing values. Finally, the two remaining errors types are 5) FIELD MISMATCH and 6) FORMAT MISMATCH related respectively to domain errors and data format errors.

PYGRAMETL (Python based framework) is a programming framework for ETL processes [17]. In this work, the authors attempt to prove that ETL development based on a graphical tool are less efficient than conventional ETL developments (code editing). In other words, instead of using a graphical palette of components, and then proceed by inserting and personalize the elements of this palette, it is more appropriate to make codes and create scripts via a programming language. In this perspective, PYGRAMETL suggests coding with Python language. Also it offers a set of functions most commonly used in the context of populating data warehouses such as filtering data and feeding slowly changing dimensions. Finally, the authors of PYGRAMETL present, as illustration, a comparison between PYGRAMETL (their tool) and PENTAHOO, an open source ETL tool.

Another interesting work that touches the ETL is available in [18]. This work which focuses on ETL performance that is a fundamental aspect among others of ETL, presents **DWPP** (Data Warehouse Population Platform). DWPP is a set of modules designed to solve the typical problems that occur in any ETL project. DWPP is not a tool but it is a platform. Exactly, it is C functions library shared under UNIX operating system for the implementation of ETL processes. Consequently, DWPP provides a set of useful features for data manipulation. These features are structured in two levels. Indeed, the first level is based on the features of operating system and those of the Oracle DBMS (the chosen target for DWPP) while the second level regroups developed features which are specific and useful in ETL treatment. Finally, as this work comes from a feedback on the development and deployment of DWPP based large-scale ETL projects, it does not address the variety of sources nor targets. Indeed, DWPP is limited to flat files as source and Oracle DBMS as target. Another work associated to DWPP is available in [6] where authors give more details on the functional and technical architecture of their solutions. In addition, the authors discuss some of the factors impacting the performance of ETL processes. Thus, the authors address the physical implementation of the database with focus on data partitioning as well as pipelining and parallelism. These aspects are addresses using UNIX operating system functionalities.

During this section we have presented open source ETL tools as commercial tools, along with some prototype from academic world. In next section, we deal with ETL design and modeling. We present related works to these issues.

3. ETL MODELING AND DESIGN

Research in data warehouse field is dominated by the DW design and DW modeling. ETL field is not an exception to this rule. Indeed, in the literature one can note several research efforts that treat DW population performed by ETL processes. (ETL) are areas with high added value labeled costly and risky. In addition, software engineering requires that any project is doomed to switch to maintenance mode. For these reasons, it is essential to overcome the ETL modeling phase with elegance in order to produce simple models and understandable. Finally, as noted by Booch et al in [19], we model a system in order to:

- Express its structure and behavior.
- Understand the system.
- View and control the system.
- Manage the risk.

In the following we go through research works associated with ETL design.

3.1 Meta-models based Works on ETL Design

During DOLAP 2OO2 conference, Vassiliadis et al [20] present an attempt to conceptual modeling of ETL processes. The authors based their argument on the following two points. At the beginning of a BI project, the designer needs to:

1. Analyze the structure and the content of sources.
2. Define mapping rules between sources and targets.

The proposed model, based on meta-model, provides a graphical notation to meet this need. Also, a range of activities commonly used by the designer is introduced.

The model in question continues by defining two concepts: the *Concept* and *Relationship-Provider*. Respectively, it is a source or a target with their attributes and relationships between attributes (fields of source or target). Transformations are dissociated with mapping rules (*Relationship-Provider*). Indeed, in order to transform attributes such as removing spaces or concatenating attributes, *Provider Relationship* uses an extra node (element of the model). Ignoring which source to prioritize to extract data, the model introduces *candidate relationship* to designate all sources likely to participate in DW population. The selected source is denoted *active relationship*.

The authors complement their model via an extensive paper [21] by proposing a method for the design of ETL processes. Indeed, in this work, the authors expose a method to establish a mapping between the sources and targets of ETL process. This method is spread over four steps:

1. Identification of sources
2. Distinction between candidates' sources and active sources.
3. Attributes mapping.
4. Annotation of diagram (conceptual model) with execution constraints.

Works around this model are reinforced by an attempt to transition from conceptual model to logical model. This is the subject of [22] paper where authors define a list of steps to follow to insure this transition. In addition, this work proposes an algorithm that groups transformations and controls (at conceptual level) into *stages* that are logical activities. Finally, a semi-automatic method determining the order execution of logical activities is defined too.

Another work around ETL presents KANTARA, a framework for modeling and managing ETL processes [4]. This work exposes different participants that an ETL project involves particularly designer and developer. After the analysis of interaction between main participants, authors conclude that designer needs helpful tool, which will makes easy the design and maintenance of ETL processes. In response, authors introduce new graphical notation based on a meta-model. It consists mainly on three core components which are, *Extract, Transform and Load* components. These components are chosen according to ETL steps. Besides, each component manages a set of specific meta-data close to its associate step. This work is consolidated with another work presenting a method for modeling and organizing ETL processes [23]. Authors start by showing functional modules that should be distinguished in each ETL process. This leads to distinguish several modules, especially *Reject Management* module for which a set of metadata to manage are defined. The proposed approach takes five inputs (namely *mapping rules, conforming rules, cleaning rules, and specific rules*) and produces a conceptual model of an ETL processes using a graphical notation presented previously.

3.2 UML Based Works

In 2003 Trujillo [24] proposes a new approach, UML based for the design of ETL processes. Finding that the model of Vassiliadis [20] is based on ad-hoc method, the authors attempt to simplify their model and to base it on a standard tool. In this model, an ETL process is considered as class diagram. More precisely, a basic ETL activity which can be seen as a component is associated with a UML class and the interconnection between classes is defined by UML dependencies. Finally, the authors have decided to restrict their model to ten types of popular ETL activities such as *Aggregation, Conversion, Filter and Join*, which in turn are associated to graphical icons.

In 2009 (DOLAP 2009), Munoz et al modernize this model through a new publication [25] dealing with the automatic generation of code for ETL processes from their conceptual models. In fact, the authors have presented a solution oriented MDA. It is structured as follows:

- For PIM (Platform Independent Model) layer, which corresponds to conceptual level, ETL models are designed using UML formalism, more precisely the result of the previous effort.
- For PSM (Platform Specific Model) layer which corresponds to the logical level, the platform chosen is Oracle platform.
- For the Transformation layer that allows the transition from PIM model to PSM model is made with QVT (Query View Transformation) language. These transformations can bind PIM meta-model elements to PSM meta-model elements.

Another research team presents in [26] another research effort about ETL and UML based. But this work is restricted to extraction phase omitting transformations and loading phases. Thus, this work presents an approach object-oriented for modeling extraction phase of an ETL process using UML 2. To this end, authors present and illustrate the mechanism of this phase as three diagrams. These diagrams are class diagram, sequence diagram and use case diagram of extraction phase. Finally, six classes which are *data staging area, data sources, wrappers, monitors, integrator* and *source identifier* are shown. These classes are used and in above diagrams.

3.3 Web Technologies Based Works

The advent of the web has disrupted information systems. ETL in turn are affected by this wave. Indeed, semantic web technologies are used in the development of data warehouses refreshment processes. Thus, in 2006 Skoutas et al present an ontology based approach for the design of ETL processes [27]. Applied to a given domain whose concepts are identified, OWL (web ontology language) is used to construct the domain ontology in question. Then the OWL ontology constructed is exploited to annotate and mark schemas of both sources and DW (target). Finally, a reasoning technique is put into action to induce connections and conflicts between the two extremes (between source and DW). This approach is semi-automatic and allows getting a part of necessary elements for the design of ETL. Namely, they are mapping rules and transformations between sources and target attributes. However, this work suffers from two following drawbacks:

1. The scope of the data is limited to relational sources.
2. Ontology construction is not efficient.

Therefore, the same authors enhance their proposal in 2007 via an extension of their work [28]. The scope of data handled is expanded to include structured data and unstructured data. Finally, a prototype of the solution is implemented in Java.

It is clear that the contribution of this approach is relevant, but it is still insufficient. Indeed, a conceptual model is not limited to the mapping rules, but there is also (among other) the Data Flow to manage which consists on activities orchestration and arrangement. Finally, let note that results accuracy of applying this approach is closely related to the degree of matching between ontology and schemas of sources and DW. Furthermore, in reality, the schemas of sources are not expressive or non-existent [3].

Another approach based on web technologies, more precisely on marriage between BPMN (Business Process Modeling Notation) and BPEL (Business Process Execution Language) is presented in [29]. This work aims to align to MDA standard. Indeed, it proposes to use BPMN for the PIM layer and to use BPEL for PSM layer. Nevertheless transformation layer is not well developed in spite of the transition from BPMN to BPEL is mentioned. In fact, this work considers that the mapping between BPMN and BPEL is acquired and provided by multiple tools. Finally, this effort provides an extensible palette of useful features for the ETL design using BPMN notation.

Another interesting work related to the design of ETL based on RDF (Resource Description Framework) and OWL, two web technologies, is detailed in [30]. This work has the advantage of presenting a method over several steps ranging from the creation of models for ROLAP cubes until the creation of the ETL layer. The basic idea behind this work is to convert the data source to a RDF file format that is consistent with OLAP ontology which is constructed in turn. Then target tables are populated with data extracted via queries generated over OLAP ontology.

The scientific community has enriched the field of modeling ETL with different approaches presented above. These proposals differ in the formalism and the technology used. But they have the same drawback that is the lack of support and approaches to change management in ETL. In next section, we cover this issue.

4. MAINTENANCE OF ETL PROCESSES

ETL process can be subject of changes for several reasons. For instance, data sources changes, new requirements, fixing bugs…etc. When changes happen, analyzing the impact of change is mandatory to avoid errors and mitigate the risk of breaking existent treatments.

Generally, change is neglected although it is a fundamental aspect of information systems and database [31]. Often, the focus is on building and running systems. Less attention is paid to the way of making easy the management of change in systems [32]. As a consequence, without a helpful tool and an effective approach for change management, the cost of maintenance task will be high. Particularly for ETL processes, previously judged expensive and costly.

Research community catches this need and supplies, in response, few solutions. The one can starts with a general entry point to change issue in [31] that is a report on evolutions and data changes management. Indeed, authors summarize the problems associated with this issue as well as a categorization of these problems. Finally, the authors discuss the change issue according to six aspects which are: What, Why, Where, When, Who and How.

Regarding data warehouse layer, change can occur at two levels, either in schemas or in data stored from the first load of data warehouse. Managing data evolution, contrarily to schema evolution, over time is a basic mission of DW. Consequently, research efforts in DW evolution and changes are oriented to schema versioning. In this perspective, authors present in [33] an approach to schema versioning in DW. Based on graph formalism; they represent schema parts as a graph and define an algebra to derive new schemas of DW, given a change event. The formulation of queries invoking multiple schema versions is sketched. Same authors rework their proposal in [34] by investigating more data migration. Finally, X-Time [35] is a prototype resulting from these efforts.

Using ETL terminology, above previous research efforts focus on the target unlike the proposal of [36] which focuses on changes in the sources. In this work, the authors consider the ETL process as a set of activities (a kind of component). Thus, they represent the ETL parts as graphs which are annotated (by the designer) with actions to perform when a change event occurs. An algorithm to rehabilitate the graph, given a change event in sources is provided too. *However, this approach is difficult to implement, because of enormous amount of additional information required in nontrivial cases* [37]. The authors extend their work in [38] by detailing the above algorithm for graph adaptation. The architecture of prototype solution has been introduced too. It has a modular architecture centralized around the component Evolution Manager. This prototype is called HECACTUS [39] and aims to enable the regulation of schema evolution of relational database. In other words, this approach is does not take in account other kinds of data stores or sources like flat files.

Another approach dealing with change management in ETL is available in [32].In this paper, authors present a matrices based approach for handling impact of change analysis in ETL processes. Indeed, ETL parts are represented as matrices and a new matrix called K matrix is derived by applying multiplication operations. Also authors expose how this K matrix summarizes the relationship between the input fields and the output fields and how it synthesizes the attributes dependency. Particularly, the K matrix makes possible to know "*which attributes are involved in the population of a certain attribute*" and which attributes are the "customers" of a given one. In addition, an algorithm to detect affected part of ETL process when a change deletion event occurs, either in sources or targets or inside ETL, have been presented. Finally, this matrices based approach constitutes a sub module of whole solution that is a framework called KANTARA.

These proposals dealing with change management in ETL are interesting and offer a solution to detect changes impact on ETL processes. However change absorption is not addressed. In next section, we present research works taking in account performance aspect.

5. OPTIMIZATION AND INCREMENTAL ETL

ETL feeds DW with data. In this mechanism and depending on the context, ETL performance will be critical fact. For example, [2] reports a study for mobile network traffic data where a tight time window is allowed for ETL to perform its missions (4 hours to processes about 2 TB of data where the main target fact table contains about 3 billion records).

In situations like one described above, ETL optimization is much appreciated. Concerning this issue at research level, unfortunately, works and proposals are little. The first work dealing with this issue treats the logical optimization of ETL processes [40]. In this proposal, authors model the problem of ETL optimization at logical level, as state space search problem. In particular an ETL process is conceived as a state and a state space is generated via a set of defined transitions. The approach is independent of any model cost. However the discrimination criterion for choosing the optimal state is based on total cost. The total cost of a state is obtained by summarizing the costs of all its activities.

Another solution to achieve performance consists of extracting and processing only modified or new data. This is called incremental mode of ETL processes. More precisely, this style of ETL is suitable to contexts where the request of fresh data, from end users, is very pressing.

By definition incremental ETL has two challenges. They are:

1. To detect modified data or new data at sources level.
2. Integrate data of previous step.

Incremental ETL is associated to near real time ETL. In one hand, the historical and business contexts of this category of ETL are sketched in [3] where authors motivate and explain *why* this new category of ETL. In other hand, authors of [41] formalize the problem of incremental ETL under the following assumption: for a given target, there are two types of ETL jobs feeding this target. Namely: initial ETL job, for first load and second ETL job for, recurrent load in incremental mode. Thus, this work presents an approach to derive incremental ETL jobs (second type) from the first one (initial load) based on equational reasoning. Transformation rules for this purpose are defined too. As input, they take an ETL job as an expression E described according to a defined grammar G. In output, four ETL expression E_{ins}, E_{del}, E_{un} and E_{uo}, are produced dealing with change events occurring at sources (insertion, deletion, update…etc). Another work dealing with incremental ETL is available in [42] where authors present an approach based on existing method of incremental maintenance of materialized views to get automatically incremental ETL processes from existing ones.

Approaches presented above, both require the existence of the initial ETL processes to transform them into incremental mode. Therefore they are suitable for existing ETL projects wishing to migrate and take profit from incremental mode. Thus they are not suitable for new ETL projects starting from scratch.

All previous sections review the literature in ETL field. In next section we present main research opportunities in ETL processes.

6. RESEARCH OPPORTUNITIES

In our opinion, research opportunities and challenges around ETL exist and are promising. As in other research fields, design and modeling still dominate others research issues. Obviously all issues reviewed previously are open. Out of these challenges, we summarize in what follows main pressing issues:

- **Standardizing models**: many conceptual models enrich the ETL design field. However no proposal becomes a standard neither widely accepted by research community like multi dimensional modeling in data warehouse area. Therefore proposals and works in this perspective are desirable and hopeful.
- **Mapping Language**: mapping rules are an important delivery in ETL design. We consider that in order to use efficiently this delivery, it is desirable to express these rules in a standard language compatible with ETL constrains and aspects.
- **Big Data and ETL**: Big data technologies arrive with exciting research opportunities. Particularly, performance issue seems solvable with this novelty. Thus, works and proposals using these technologies and taking in account ETL specificities; like partitioning, data transformation operations, orchestration…etc; are desirable.
- **Testing**: Tests are fundamentals aspects of software engineering. In spite of this importance, and regarding ETL, they are neglected. Thus, an automatic or even a semi automatic approach for validating or getting data for tests is very hopeful.
- **Unstructured data and Meta data**: theses two topics are not specific to ETL processes. They are common issues to data integration area. Thus, they are open challenges which can be addressed in ETL context.
- **Change absorption**: As we said in previous sections, only few approaches handling changes impacts on ETL exist. But it is more challenging to automatically or semi automatically absorbing changes once they are detected. In other words, an approach is needed to adapt running ETL jobs according to changes occurring either in sources, targets or in business rule (transformation rule).

7. CONCLUSION

ETL (Extraction-Transformation-Loading) is the integration layer in data warehouse (DW) system. ETL is known with two tags: complexity and cost. Indeed, it is widely recognized that building ETL processes is expensive regarding time, money and effort. It consumes up to 70% of resources.

Due its importance, this paper focused on ETL, the backstage of DW, and presents the research efforts and opportunities in connection with these processes. Therefore, in current survey, firstly we give a review on open source and commercial ETL tools, along with some ETL prototypes coming from academic world. Namely SIRIUS, ARKTOS, PYGMATEL, DWPP. Also, *Talend Open Studio* and Microsoft ETL solution (SSIS), respectively an open source and commercial tool, were taken as examples for explanation and illustration. Secondly we cover modeling and design works in ETL field. Thus several works using different formalism or technologies like UML and web technologies, are reviewed. Then this survey continues by approaching ETL maintenance issue. Namely, after problem definition, we review works dealing with changes in ETL processes using either graph formalism or matrices formalism. Before conclusion, we have given an illustration of performance issue along review of some works dealing with this issue, particularly, ETL optimization and incremental ETL. Finally, this surveys ends with presentation of main challenges and research opportunities around ETL processes.

At the end of this survey and as a conclusion, we believe that research in ETL area is not dead but it is alive. Each issue addressed above is open to review and investigation.

REFRENCES:

[1] W. Inmon D. Strauss and G.Neushloss, “DW 2.0 The Architecture for the next generation of data warehousing”, *Morgan Kaufman*, 2007.

[2] A. Simitisis, P. Vassiliadis, S.Skiadopoulos and T.Sellis, “DataWarehouse Refreshment”, *Data Warehouses and OLAP: Concepts, Architectures and Solutions, IRM Press*, 2007, pp 111-134.

[3] R. Kimball and J. Caserta. “The Data Warehouse ETL Toolkit: Practical Techniques for Extracting, Cleaning, Conforming, and Delivering Data”, *Wiley Publishing, Inc*, 2004.

[4] A. Kabiri, F. Wadjinny and D. Chiadmi, "Towards a Framework for Conceptual Modelling of ETL Processes ", *Proceedings of The first international conference on Innovative Computing Technology (INCT 2011)*, Communications in Computer and Information Science Volume 241, pp 146-160.

[5] P. Vassiliadis and A. Simitsis, “EXTRACTION, TRANSFORMATION, AND LOADING“, *http://www.cs.uoi.gr/~pvassil/publications/2009_DB_encyclopedia/Extract-Transform-Load.pdf*

[6] J. Adzic, V. Fiore and L. Sisto, “Extraction, Transformation, and Loading Processes”, *Data Warehouses and OLAP: Concepts, Architectures and Solutions, IRM Press*, 2007, pp 88-110.

[7] W. Eckerson and C. White, “Evaluating ETL and Data Integration Platforms”, *TDWI REPORT SERIES, 101communications LLC*, 2003.

[8] IBM InfoSphere DataStage, *http://www-01.ibm.com/software/data/infosphere/datastage/*

[9] Informatica, *http://www.informatica.com*

[10] Microsoft SSIS, *http://msdn.microsoft.com/en-us/library/ms169917.aspx*.

[11] C. Thomsen and T,B Pedersen, "A Survey of Open Source Tools for Business Intelligence", *DB Tech Reports September* 2008. homepage: www.cs.aau.dk/DBTR.

[12] C. Thomsen and T,B Pedersen, "A Survey of Open Source Tools for Business Intelligence".*International Journal of Data Warehousing and Mining.Volume 5, Issue 3,* 2009.

[13] Talend Open Studio, *www.talend.com*

[14] A.VAVOURAS,"A Metadata-Driven Approach for DataWarehouse Refreshment", *Phd Thesis, DER UNIVERSITÄT ZÜRICH,ZÜRICH*, 2002.

[15] P. Vassiliadis, Z.Vagena, S. Skiadopoulos, and N.Karayannidis, "ARKTOS: A Tool For Data Cleaning and Transformation in DataWarehouse Environments", *Bulletin of the Technical Committee on Data Engineering, 23(4)*, 2000.

[16] P.Vassiliadis, Z.Vagena, S.Skiadopoulos, ,N. Karayannidis.N and T.Sellis, "ARKTOS: towards the modeling, design, control and execution of ETL processes" *Information Systems, Vol. 26*, 2001, pp 537-561.

[17] C.Thomsen and T,B Pedersen, "pygrametl: A Powerful Programming Framework for Extract–Transform–Load Programmers". *Proceeding DOLAP*09, 2009.

[18] Adzic.J and Fiore.V, "Data warehouse population platform", *Proceedings of the International Workshop on Design and Management of Data Warehouses (DMDW03), 2003*

[19] G.Booch, J.Rumbaugh and I.Jacobson, *"The unified modeling language user guide", Addison-Wesley*, 1998.

[20] P. Vassiliadis, A. Simitsis and S. Skiadopoulos. “Conceptual modeling for ETL processes”, *Proceedings of the 5th ACM Int Workshop on Data Warehousing and OLAP*, DOLAP02, 2002.

[21] A. Simitsis and P. Vassiliadis. “A methodology for the conceptual modelling of ETL processes”, Proceedings *of DSE*, 2003.

[22] A. Simitsis. “Mapping conceptual to logical models for ETL processes”, *Proceeding of the 8th ACM International Workshop on Data Warehousing and OLAP*, DOLAP'05, 2005.

[23] A. Kabiri and D. Chiadmi, "A Method for Modelling and Organazing ETL Processes".

Proceedings of The second international conference on Innovative Computing Technology (INTECH 2012). Communications in IEEE Volume 241, 2012, pp 146-160.

[24] J. Trujillo and S. Lujan-Mora, "A UML Based Approach for Modeling ETL Processes in Data Warehouses", *In I.-Y. Song, S. W. Liddle, T. W. Ling,and P. Scheuermann, editors, ER, volume 2813 of Lecture Notes in Computer science, Springer*, 2003.

[25] L.Muñoz, J.Mazón and J.Trujillo. "Automatic Generation of ETL processes from Conceptual Models". *Proceedings of ACM International. Workshop on Data Warehousing and OLAP*, DOLAP'09, 2009.

[26] Mrunalini M., Suresh Kumar T.V, Evangelin D, Geetha and Rajanikanth K, "Modelling of Data Extraction in ETL Processes Using UML 2.0". *DESIDOC Bulletin of Information Technology, Vol. 26, No. 5*, 2006, pp 3-9.

[27] D. Skoutas and A. Simitsis. "Designing ETL processes using semantic web technologies". *Proceedings of DOLAP06*, 2006.

[28] D. Skoutas and A. Simitsis. "Ontology-based conceptual design of ETL processes for both structured and semi-structured data", *International Journal on Semantic Web and Information Systems*, 2007.

[29] Z, ElAkkaoui and E.Zimanyi, "Defining ETL Workflows using BPMN and BPEL". *Proceedings of DOLAP09*, 2009, pp 41-48.

[30] Marko Niinimaki, Tapio Niemi, "An ETL Process for OLAP Using RDF/OWL Ontologies", *Journal on semantic web and information Systems, Vol 3, No 4*, 2007.

[31] J.F. Roddick et al, "Evolution and Change in Data Management - Issues and Directions", *SIGMOD Record 29, Vol. 29*, 2000, pp 21-25.

[32] A. Kabiri, F. Wadjinny and D. Chiadmi, "Towards a Matrix Based Approach for Analyzing the Impact of Change on ETL Processes", *IJCSI international journal, Volume 8, issue 4, July 2011.*

[33] M. Golfarelli, J. Lechtenborger, S. Rizzi and G. Vossen, "Schema Versioning in Data Warehouses", *ER Workshops, LNCS 3289*, 2004, pp 415–428.

[34] M. Golfarelli, J. Lechtenborger, S. Rizzi and G. Vossen, "Schema versioning in data warehouses: Enabling cross version querying via schema augmentation", *Data and Knowledge Engineering*, 2006, pp 435–459.

[35] S. Rizzi and M Golfarelli, "X-time: Schema versioning and cross-version querying in data warehouses", *International Conference on Data Engineering (ICDE)*, 2007, pp.1471–1472.

[36] G. Papastefanatos, P. Vassiliadis, A. Simitsis and Y. Vassiliou, "What-If Analysis for Data Warehouse Evolution", *Proceedings of DaWaK conference*, LNCS 4654, 2007, pp 23–33.

[37] Dolnik A. (2009). "ETL evolution from data sources to data warehouse using mediator data storage", *MANAGING EVOLUTION OF DATA WAREHOUSES MEDWa Workshop*, 2009

[38] G. Papastefanatos, P. Vassiliadis, A. Simitsis and Y. Vassiliou, "Policy-Regulated Management of ETL Evolution", *Journal on Data Semantics XIII, LNCS 5530*, 2009, pp 146–176.

[39] G. Papastefanatos, P. Vassiliadis, A. Simitsis and Y. Vassiliou, " HECATAEUS: Regulating Schema Evolution. Data Engineering", *International Conference on Data Engineering (ICDE)*, 2010, pp 1181-1184

[40] A. Simitsis, P. Vassiliadis, and T. Sellis. "Logical optimization of ETL workflows", *Proceedings of International Conference on Data Engineering (ICDE)*, 2010, pp 1181-1184.

[41] T. Jorg and S. Debloch. "Formalizing ETL Jobs for Incremental Loading of Data Warehouses", *Proceedings of der 12*, 2009.

[42] X. Zhang, W. Sun, W. Wang, Y. Feng, and B. Shi, "Generating Incremental ETL Processes Automatically", *Proceedings of the First International Multi-Symposiums on Computer and Computational Sciences (IMSCCS'06)*, 2006.