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A meta-language for MDX queries in eLog Business Solution

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Abstract—**The adoption of business intelligence technology in industries is growing rapidly. Business managers are not satisfied with ad hoc and static reports and they ask for more flexible and easy to use data analysis tools. Recently, application interfaces that expand the range of operations available to the user, hiding the underlying complexity, have been developed. The paper presents eLog, a business intelligence solution designed and developed in collaboration between the database group of the University of Modena and Reggio Emilia and eBilling, an Italian SME supplier of solutions for the design, production and automation of documentary processes for top Italian companies.**

eLog enables business managers to define OLAP reports by means of a web interface and to customize analysis indicators adopting a simple meta-language. The framework translates the user's reports into MDX queries and is able to automatically select the data cube suitable for each query.

Over 140 medium and large companies have exploited the technological services of eBilling S.p.A. to manage their documents flows. In particular, eLog services have been used by the major media and telecommunications Italian companies and their foreign annex, such as Sky, Mediaset, H3G, Tim Brazil etc. The largest customer can provide up to 30 millions mail pieces within 6 months (about 200 GB of data in the relational DBMS). In a period of 18 months, eLog could reach 150 millions mail pieces (1 TB of data) to handle.

I. Introduction

During the last decade Data Warehousing and Business Intelligence become key technologies for storing, analyzing and navigating business processes, providing managers and decision makers with OLAP [9] tools. OLAP is the most popular way to exploit information in a data warehouse, and it gives to end-users the opportunity to analyze and explore data interactively on the basis of the multidimensional model. Many commercial OLAP tools use languages, such as MDX (MultiDimensional eXpressions) [11]. An MDX expression returns a multidimensional result set that the user can navigate according to different viewpoints and at different levels of detail. MDX is very powerful and effective for IT managers, but it is unfeasible for unskilled users. On the other side, static predefined reports are easy to understand for business managers but are not flexible.

The approach we follow in eLog is intermediate between static reporting and OLAP, it is called *semi-static reporting*. In a semi-static report, users can follow a limited set of navigation paths. This approach provides some unquestionable advantages: (1) users need less skills to use data models and analysis tools than the ones needed for OLAP systems; (2) it is avoided the risk of achieving inconsistent or incorrect analysis results because of any misuse of aggregation operators; (3) posing constraints on the allowed analysis makes it possible to prevent users from unwillingly slowing down the system whenever they formulate heavy-demanding queries [7].

eLog is a Decision Support System (DSS) provided as a Software as a Service (SaaS) specifically developed for the document management traceability, optimization and analysis. The first version of eLog allowed business managers to select the required report starting from a predefined list, and, in case, to export the result in spreadsheet format. This paper outlines the improvements reached by the eLog new version, which allows to move from a transactional system to a multidimensional approach. With the new version, the user can dynamically create, save and share with other users his own reports. The MDXGenerator component acts as the middle layer between the framework and the OLAP engine, converting the reports requested by the business manager through a GUI, into MDX queries executed on the OLAP engine. In addition, eLog provides a simple and intuitive meta-language that defines new indicators or new aggregate functions for custom queries. Another functionality implemented in eLog is the selection, among all the cubes available in the data warehouse, of the optimal cube for the execution of the query. Using eLog, the decision maker is autonomous in the process of creating and managing new analysis, based on the entire set of measures and dimensions available in the underneath fact tables.

The paper is structured as follow. Section II presents a general overview of eLog, Section III contains the eLog case study we designed to explain how our system works. Section IV describes the Data Analysis service of eLog and Section

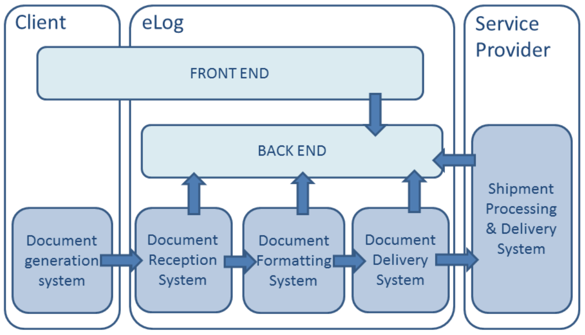

Client
eLog
Service Provider
FRONT END
BACK END
Document generation system
Document Reception System
Document Formatting System
Document Delivery System
Shipment Processing & Delivery System

Fig. 1. eLog documents flow

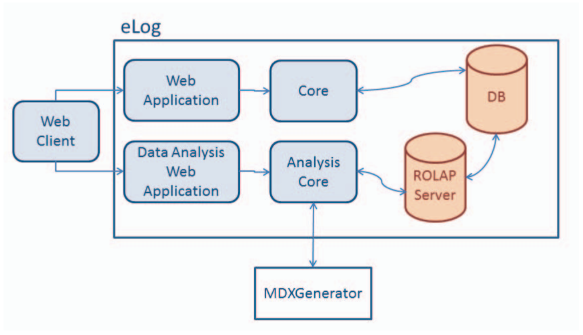


Fig. 2. eLog architecture

V depicts the conceptualization of schemas and queries we designed in order to decouple the GUI and the back-end. Section VI describes the MDXGenerator. Section VII gives the meta-language definition, Section VIII presents the algorithm modelled for the optimal cube selection and Section IX shows some tests we performed on the system. Section X depicts some related work, whereas conclusion and possible future evolvements of eLog are depicted in Section XI.

II. Overview of the eLog System

eBilling is a company that handles the entire life cycle of the document delivery process, from the generation of files starting from the raw data supplied by the client, until the electronic or hard copy delivery of the documents to the end user.

The eLog application is one of the modules embedded within the BCPortal®[1] developed by eBilling to meet the demands of the production process and document generation traceability.

eLog controls the production of spools and documents, the sending of emails or faxes, the communication to the printing providers and the delivery of printed documents. The framework stores low level granularity information related to operative production processes, i.e. documents transfer between servers and enterprises, in order to calculate the Key Performance Indicators (KPIs).

KPIs make possible to assess the adequacy of the expected and contractually specified services with respect to the Service Level Agreement (SLA). eLog traces the evolution and generates table reports and statistical graphics per type of flow, thus making it possible to keep track of the business communication process performance.

As shown in Figure1, data coming from the client's document generation system is traced during three stages of the document production process: receiving, formatting and sending of documents. Through eLog, customers have vision of both the internal and external document production processes, and all the estimated and actual events (pdf file generation, printing, delivery etc.).

[1]http://www.ebilling.it/framework.asp?m=0

The new version of eLog has been developed to meet the emerging needs of customer companies' business managers. The requirements that the new application had to meet can be summarized as follows:

1) *Simple GUI* - users can easily and effectively formulate multidimensional queries since all the complexities are masked by the underlying system.
2) *Personalization* - personalization for eLog customers is a key issue, as different companies would like to define their own indicators. The meta-language has been specifically designed for users that lacks of technical knowledge on query languages in order to facilitate the definition of even complex expressions.

Further improvements introduced by the eLog's new version are:

1) *Technological improvement* - the previous version was a web application developed in Apache Struts which allows users to extract static reports from the database by a web form. The database system was queried through SQL or OQL statements and the result sets were exported as excel files and therefore analyzed locally. The new version, instead, offers to customers an on-line service with an easy-to-use interface implemented in Adobe Flex. Users can take advantage of a portable (it requires just a browser with Flash player) and efficient (all the data is maintained remotely, hence issues such as occasionally data loss are avoided) tool.
2) *Data conceptualization* - in order to conceptualise the description of data and queries and to decouple the GUI and the OLAP server, a set of XSD schema has been defined for the description of cubes, attributes and user generated queries. The XSD schema also provides the ability to share or exchange custom attributes or queries among users.
3) *Modular and reusable software architecture* - MDXGenerator is a stand-alone java library, OLAP engine independent. Beside being used in the context of eLog, MDXGenerator can be plugged into any other frameworks compliant with the data conceptualization implemented in the XSDs.

Figure 2 summarizes the architecture of eLog. The Core component provides general services related to eLog project setup, search services and monitoring. The Web Application component communicates with the Core component and provides high level services to the user. The Analysis Core component communicates with the ROLAP server and manipulates the results returned from multidimensional queries, in order to improve the data rendering operations of the Data Analysis Web Application component. The Analysis Core component permits to analyze reports expressed through the GUI and converts them into multidimensional queries. To accomplish this task, it is supported by the MDXGenerator: a standalone library that provides functionalities for automatic multidimensional queries generation starting from user inserted configurations. The Data Analysis Web Application component is responsible for presenting and validating the analysis reports. The DB component is responsible for processing and maintaining large amounts of data acquired from the outside world, applying rules of extraction, transformation, loading and data aggregation in order to satisfy the Data Analysis features requirements. For the ETL process, we take advantage from our previous work on semantic ETL [1].

III. eLog Case Study

In order to explain in detail the features provided by the MDXGenerator and the meta-language, firstly it is useful to introduce a simple explicative Dimensional Fact Model (DFM [7]); we will use this fact model to design our examples appearing in the next sections. The model has been taken from the real data warehouse model of eLog. In particular we took out 5 dimensions over 25 and 3 measures over 19.

Our example represents the monitoring activity of the SLA related to some mail pieces, called missives. The conceptual representation of our example has been depicted in Figure 3. The measures we took into consideration are the total number of missives in SLA (*SumMsvINSLA*), and the total and average number of missives for which the SLA has been expired (respectively *SumMsvOUTSLA* and *AvgMsvOUTSLA*). The fact has been modeled using five different dimensions, namely: *Time*, *Geographic*, *Business Process*, *Society* and *Client*. The last three dimensions are simple as they contain just one element in the hierarchy, while, in the *Time* dimension we represented the *day* of interest, the *month*, the *quarter*, the *semester* and the *year*. Similarly, the *Geographic* dimension has been divided in *city*, *county*, *region* and *state*. Two descriptive attributes, *cod* and *type*, have been, respectively, inserted in the *Client* and *Business Process* dimensions, in order to specify a property upon the related hierarchy.

IV. eLog Data Analysis

The eLog Data Analysis provides trend analysis functionalities. The web application interface (see Figure 4) contains the list of the already created reports on the left part. In the middle it is visualized the pivot table, which is rendered once the query result is available. The right part of the interface contains on the top all the attributes (predefined and custom)

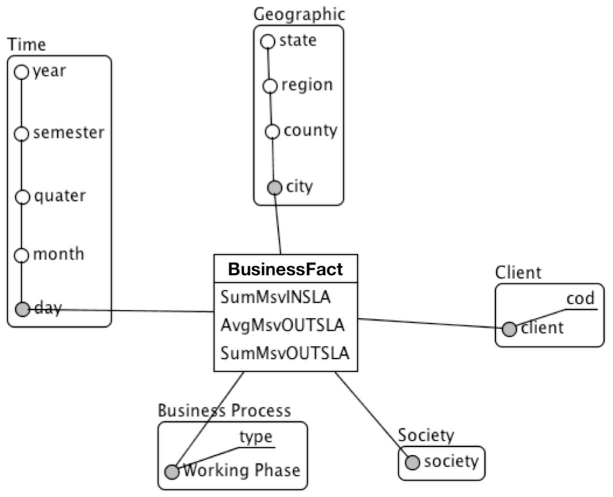


Fig. 3. Fact schema of the cube we used to model our examples

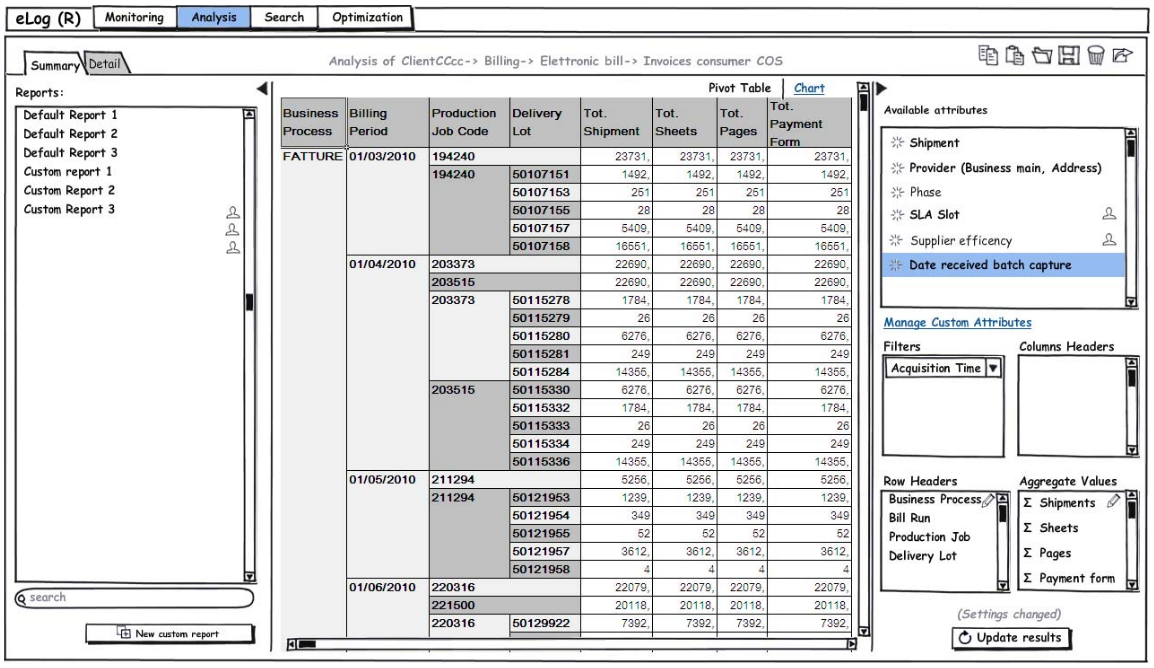
that are available for selection, and, on the bottom, the four quadrants the user can fills with attributes in order to create the desired query.

The user can create his own reports starting from a list of attributes. Attributes can be moved on one of the four quadrants: filters, columns, rows and values. Attributes disposed on the values quadrant will be aggregated using one of the available aggregate functions. Each attribute placed on the rows defines the level of aggregation and it can also define specific properties. For example the attribute *Client* contains the property *cod* (see Figure 3) that can be selected by the user if he decides to visualize this information.

Some predefined KPIs are provided by eLog; the user has the opportunity to adopt these predefined attributes or to define new indicators, called *custom attributes*. A custom attribute is the result of a meta-language expression and its operands are attributes already present in the analysis domain or alphanumeric constants.

In order to highlight the occurrence of certain events, the user may define formatting rules over the cells in the values area. The user can specify a boolean expression and the action to be taken if the expression is evaluated true. For example, a cell background can be changed in red if the contained number is below a certain threshold. Moreover, the web interface provides advanced querying features, e.g. to select the top-k values or to filter results by measure values.

The Data Analysis provides also save and load functionalities which allow to store the created custom attributes, the formatting settings, and the entire pivot table configuration if desired. We define *pivot table configuration* as the output query resulting from the user interaction with the data analysis interface, i.e. the selected attributes for each of the four quadrants and the list of predifined and custom attributes.



Business Process	Billing Period	Production Job Code	Delivery Lot	Tot. Shipment	Tot. Sheets	Tot. Pages	Tot. Payment Form
FATTURE	01/03/2010	194240		23731,	23731,	23731,	23731,
		194240	50107151	1492,	1492,	1492,	1492,
			50107153	251	251	251	251
			50107155	28	28	28	28
			50107157	5409,	5409,	5409,	5409,
			50107158	16551,	16551,	16551,	16551,
	01/04/2010	203373		22690,	22690,	22690,	22690,
		203515		22690,	22690,	22690,	22690,
		203373	50115278	1784,	1784,	1784,	1784,
			50115279	26	26	26	26
			50115280	6276,	6276,	6276,	6276,
			50115281	249	249	249	249
			50115284	14355,	14355,	14355,	14355,
		203515	50115330	6276,	6276,	6276,	6276,
			50115332	1784,	1784,	1784,	1784,
			50115333	26	26	26	26
			50115334	249	249	249	249
			50115336	14355,	14355,	14355,	14355,
	01/05/2010	211294		5256,	5256,	5256,	5256,
		211294	50121953	1239,	1239,	1239,	1239,
			50121954	349	349	349	349
			50121955	52	52	52	52
			50121957	3612,	3612,	3612,	3612,
			50121958	4	4	4	4
	01/06/2010	220316		22079,	22079,	22079,	22079,
		221500		20118,	20118,	20118,	20118,
		220316	50129922	7392,	7392,	7392,	7392,

Fig. 4. eLog Data Analysis web interface

V. XSDs for High Level Conceptualization

Each pivot configuration is codified in a set of XML files that will be the input of the MDXGenerator component. Each XML configuration conforms to an high level conceptualization implemented in XML Schema (XSD) [15]. This approach allows us to maintain a logical separation between the interface used to define pivot configurations and the system that actually performs the queries on the data warehouse. On one side, all the information of the data warehouse schema are not encoded directly in the business logic (i.e. the web interface is not tight to a particular data model), on the other side, the back-end system is lightly coupled with the web interface, since the only communication means are the pivot configurations that are compliant with the XSDs. For these reasons, the MDXGenerator together with the XSDs' conceptualizations, can be seen as a bridge between the user interface and the OLAP server. Moreover, since the MDXGenerator receives as input just pivot configurations in XML, it can be considered not only in the context of eLog, but also as an external library that can be used from other applications.

A generic pivot configuration can be described by means of nine XSD schemas, each of which models a particular part of the pivot configuration. *eLogPivot* is the root element and it contains the general structure of every pivot configuration. This general structure contains six subsections: *eLogCube* specifies the cubes upon which the analysis should be executed; *eLogData* contains all the attributes that can be used inside the configuration; *eLogFilters*, *eLogColumns*, *eLogRows* and *eLogAggreagateValues* describe specific properties for attributes placed on quadrants. Inside *eLogData* two types of attributes can be specified: predefined attributes and custom attribute, respectively described by *eLogPredefinedAttribute* and *eLogCustomAttribute*.

VI. MDX Generator

MDXGenerator is the java library able to generate a MDX query starting from a XML pivot configuration. MDXGenerator is also responsable for the **syntactic verification** of the pivot configuration and the **semantic correctness** of the MDX expression.

The syntactic verification examines the input pivot configuration so that it contains all the attributes and the information needed for the correct creation of the query, and that, in addition, the information conforms to the XSD schemas described in Section V.

Once the input has been verified to be syntactically well-formed, it is divided in subsections of interest and parsed. During the parsing phase, six different structures are filled with the elements extracted from the pivot configuration. The first structure, called *Data Cube*, contains all the cubes that should be taken into consideration for the query execution, and hence contained in the *eLogCube* section of the input configuration. Section VIII describes in details how the Data Analysis component chooses the more suitable cube for execution on the OLAP server among the provided list. Another structure, namely *Data Attributes*, is allocated for the attributes - predefined or custom - directly involved in the query. The system is therefore able to work just on a subset of all the attributes contained in the *eLogData* section of the configuration.

For every custom attribute instantiated, the system performs on-the-fly translation of the meta-language expression into MDX. After that, the semantic correctness of the MDX expression is checked. The MDXGenerator verifies that the elements contained in the configuration can be mapped into the data schema on the OLAP server.

During the meta-language translation, we need to define a solve order sequence for all the selected custom attributes. This sequence is automatically computed by using the position in the quadrant chosen by the user. For instance, if the column quadrant contains two custom attributes, the attribute that has been firstly selected by the user, will be solved as first, meanwhile the second attribute will be solved after the first attribute. The other structures are used to store the elements contained in the quadrant, hence one structure for each quadrant.

```
<Pivot PivotId="123456" PivotName="TestPivot"
xsi:schemaLocation="eLogNamespace eLogPivot.xsd"
      xmlns="eLogNamespace" xmlns:xsi="http://www.w3.
      org/2001/XMLSchema-instance"> <
      PivotConfiguration>
    <PivotCubes>
      <CubeName Name="CUBE_1"/>
    </PivotCubes>
    <FiltersQuadrant>
      <PredefinedAttributeFilterList AttributeName="
            Time_Semester">
        <Filter>1</Filter>
      </PredefinedAttributeFilterList>
      <PredefinedAttributeFilterList AttributeName="
            Time_Year">
        <Filter>2010</Filter>
      </PredefinedAttributeFilterList>
    </FiltersQuadrant>
    <ColumnHeadingQuadrant>
    <PredefinedAttribute AttributeName="Business
          Process"/>
    </ColumnHeadingQuadrant>
    <RowHeadingQuadrant>
      <PredefinedAttribute AttributeName="Society">
        <Filter>Red Bull</Filter>
      </PredefinedAttributeFilterList>
    </RowHeadingQuadrant>
    <AggregateValuesQuadrant>
      <AggregateValue AttributeName="SumMsvINSLA"
            AggregateFunction="Sum">
        <Condition Operator=">" Value="1000">
          <Format FontColor="Black" BackgroundColor=
                "Red"/>
        </Condition>
      </AggregateValue>
    </AggregateValuesQuadrant>
  </PivotConfiguration>
  <PivotData>
    <PredefinedAttributeData AttributeName="
          Time_Year" DimensionName="Acq_Time"
          LevelName="Year"/>
    <PredefinedAttributeData AttributeName="
          Time_Semester" DimensionName="Acq_Time"
          LevelName="Semester"/>
    <PredefinedAttributeData AttributeName="Society"
          DimensionName="Society" LevelName="
          L_DES_SOCIETY">
      <AttributeMeasures>
        <Measure AggregateFunction="Count"/>
      </AttributeMeasures>
    </PredefinedAttributeData>
    <PredefinedAttributeData AttributeName="Business
          Process" DimensionName="Process" LevelName=
          "L_DES_PROCESS">
      <AttributeMeasures>
        <Measure AggregateFunction="Count"/>
      </AttributeMeasures>
      <AttributeDetails>
        <Detail Name="type" LevelPropertyName="TYPE"
              />
      </AttributeDetails>
    </PredefinedAttributeData>
    <PredefinedAttributeData AttributeName="
          SumMsvINSLA" DimensionName="Measures">
      <AttributeMeasures>
        <Measure Name="SumMsvINSLA"
              AggregateFunction="Sum"/>
      </AttributeMeasures>
    </PredefinedAttributeData>
  </PivotData>
</Pivot>
```

Listing 1. Pivot configuration example

Once the whole configuration has been parsed, MDXGenerator starts the composition of the final query: this is a java object containing three different strings, one for each section of a MDX query, namely `SELECT`, `FROM`, and `WHERE`. The `FROM` string contains a list of cubes; it is the Analysis Core's task to chose the best cube and consequently the reassembling of the query (see section VIII for a detailed description). The `SELECT` and `WHERE` strings are generated starting from the structures already filled, wrapping the attributes information with MDX language constructs.

Listing 1 shows a simple example of pivot configuration (with the omission of some specific details), while Listing 2 shows the MDX query generated by the library. As pointed out in Section 4, users can specify conditions and actions to be performed when conditions are verified.

In Listing 1, the condition "SumMsvINSLA>1000" on the aggregate value *SumMsvINSLA* has been set. The condition is verified on each single cell, once the condition occurs the format action is executed. In listing 1, this results in a red colored cell. Other similar features like for instance, the selection of top-k values, or the filtering by measure values, are managed directly by the web interface.

```
MEMBER [Process].[Total Business Process] AS Sum (
      Except ({[Process].[L_DES_PROCESS].Members }, [
      Process].[(All)].CurrentMember)), SOLVE_ORDER=1
SELECT NON EMPTY {UNION (Except ({[Process].[
      L_DES_PROCESS].Members }, [Process].[(All)].
      CurrentMember), [Process].[Total Total Business
      Process]) * {[Measures].[SumMsvINSLA]}} ON
      COLUMNS,
NON EMPTY {{[Society].[L_DES_SOCIETY].[Red Bull]}}
      ON ROWS
FROM CUBE_T1CATMS
WHERE [Acq_Time].[2010].[1]
```

Listing 2. MDX Query resulting from the pivot configuration of listing 1

A. MDX Generator Repository

Users can create a multitude of different reports using our system, however we expect that, once a new report is created, users continue to adopt it over time. Therefore not only the Data Analysis service supports the features of saving and loading reports, but also MDXGenerator implements a repository where already parsed configurations can be stored, thus decreasing the query generation time. The repository basically works as a cache memory: if a pivot configuration is stored in memory, there is no need to resolve the configuration, in fact the data can be retrieved directly from the cache. In order to maximize the reuse of cached information, we store each of the six data structures in the repository independently. If two pivot configurations differs just for a quadrant, we can use the already filled data structures for all the configuration sections that do not differ. MDXGenerator allows the reuse of the repository among different sessions thanks to its ability to save and load the cache in persistent memory. From the MDXGenerator configuration file, it can be specified if the repository must be made persistent, and how (so far, the repository can be saved on the file system or creating an entry on a database using JDBC).

VII. Metalanguage and Custom Attributes

The system allows users to combine predefined attributes in order to analyze some specific event, but the user may also create a **custom attribute**, specifying an expression which defines the new attribute. Since MDX can be considered too expressive and complex for the target users the application has been developed for, we designed a meta-language specifically tailored for our domain. This meta-language is a simplified version of the MDX language both in semantics and syntax.

In the next section we describe the meta-language, while in Section VII-B we briefly show how custom attributes can be created through a couple of examples.

A. Meta-language Description

The main features introduces by the meta-languages are:

(a) a list of functions to combine and manage attributes values;

(b) the hierarchy management: it is possible to create *new members* inside a hierarchy or *new hierarchies* embracing a subset of members of a hierarchy.

The following elements have been introduced: *Number*, *Constant*, *MDX Entity*, *Expression*. We define as *Number* any element containing just numbers, while *Constant* is an element containing any sequence of characters and (potentially) numbers. A *MDX Entity* is any member belonging to a dimension inside a cube: it is specified by using the MDX notation ([Entity] for example). An *Expression* can be of three types: *Arithmetic Expression*, composed by two arithmetic operands and one of the usual arithmetic operators ("+", "-", "*", "/"); *Comparison Expression* where the two operands are arithmetic and the permitted operators are the relational ones (" >", " <", " =", " >=", " <=" e " <>"); *Logic Expression*, described by two or more logic operands separated by one of the "AND", "OR", "XOR" and "NOT" operators. The strings "true", "false", and the `Search Function` are considered as logic operands.

The list of *Functions* we implemented in our meta-language in order to combine and manage values within the measures (and dimensions) is the following: `format`, `if`, `concat`, `contains`, `current`, `previous`, `following`.

1) Format Function: The `format` function accepts as parameters the element to be formatted and the formatting string, and returns as a result the string containing the element in the new format. The elements that can be passed as input are: an *MDX Entity*, an *Expression* or another *Function*. The formatting string is used to specify how the input element should be represented, and is composed by an optional value character followed by any sequence of numeric or alphabetic character. An example of `format` function and related MDX translation is reported in Listing 3 and 4.

```
FORMAT ([Price]; ‘‘$#,###.0”)
```

Listing 3. Example of Format Function

```
WITH MEMBER [Measures].[Price in Dollars] AS [
    Measures].[Price], FORMAT\_STRING=‘‘$#,###.0”
```

Listing 4. MDX translation of Listing 3

2) If Function: In the `if` function three parameters have to be specified: the condition that must be assessed, the value that has to be returned if the condition is true and the value that has to be returned otherwise. The accepted condition parameters are a *Comparison* or a *Logic Expression*. The permitted result elements are: *Constant*, *Arithmetic Operand*, *Expression* and *Function*. An example of `if` function and the related translation in MDX is reported in Listing 5 and 6.

```
IF ([SumMsvINSLA] >= 0; IF ([SumMsvINSLA] <= 100; ‘‘
    Low”; ‘‘High”); ‘‘Lost”)
```

Listing 5. Example of If Function

```
WITH MEMBER [Measures].[SumMsvINSLA Margin] AS IIF
    ([Measures].[SumMsvINSLA] >= 0; IIF ([Measures
    ].[SumMsvINSLA] <= 1; ‘‘Low”, ‘‘High”); ‘‘Lost”)
```

Listing 6. MDX translation of Listing 5

3) Concat Function: The `concat` function can be used to concatenate two input elements in one string. The elements allowed as input of the function are: *Constant*, *MDX Entity*, another `concat` function or `current`, `previous` and `following` functions. Listing 7 and 8 show an example of use of a `concat` function and its MDX translation.

```
CONCAT ([Time].[Month]; CONCAT (‘‘ ”; [Time].[Day]))
```

Listing 7. Example of Concat Function

```
WITH MEMBER [Time].[Complete Data] AS [Time].[Month]
     || ‘‘ ” || [Time].[Day]
```

Listing 8. MDX translation of Listing 7

4) Contain Function: The `contain` function searches into the first parameter the value of the second parameter: if the value is present the function returns "true", "false" otherwise. Therefore the `contain` function accepts two parameters: the element where the research must be accomplished and the value of interest. The input can be a *Constant*, an *MDX Entity*, `current`, `previous` or `following` functions. Listing 9 and 10 show an example and the related MDX translation of a `contain` function.

```
IF (CONTAIN ([File name]; ‘‘zip”); ‘‘Compressed”; ‘‘
    Not compressed”)
```

Listing 9. Example of Contain Function

```
WITH MEMBER [File].[Compression] AS IIF (Cbool (
    InStr (Str ([File].[File name]), ‘‘zip”)), ‘‘
    Compressed”, ‘‘Not compressed”)
```

Listing 10. MDX translation of Listing 9

5) Current, Previous and Following Functions: These functions are the equivalent of `CurrentMember`, `PrevMember` and `NextMember` in MDX. `current`/`previous`/`following` considers the current/previous/following member during the iteration inside a hierarchy or dimension. Listing 11 and 12 describe an example of a `previous` function.

```
PREVIOUS ([Sales].[2008])
```

Listing 11. Example of Previous Function

```
WITH MEMBER [Sales].[2007] AS [Sales].[2008].
    PrevMember
```

Listing 12. MDX translation of Listing 11

6) Create Hierarchy Function: To create and manage new hierarchies, a specific function has been introduced. This function creates a new hierarchy joining members from an existing hierarchy. The created hierarchy is therefore a subset of the original. The input parameters are a set of members belonging to the same hierarchy. An example of this function and related translation are reported in Listing 13 and 14.

```
CREATEHIERARCHY ([Coca−Cola]; [Red Bull]; [Pepsi])
```

Listing 13. Example of Create Hierarchy Function

```
WITH SET [Drink Companies] AS {[Society].[Coca−Cola
    ], [Society].[Red Bull], [Society].[Pepsi]}
```

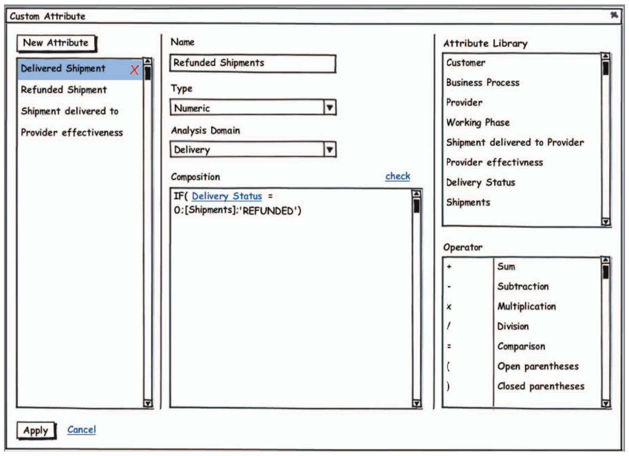
Listing 14. MDX translation of Listing 13

For a complete EBNF definition of the meta-language we developed, refer to the appendix.

B. Examples

Basically, the meta-language can be used to create two types of MDX elements: *new members* inside a hierarchy and *new hierarchies* embracing a subset of elements of a hierarchy already present in the cube. We introduce two simple examples.

In the first example, we want to compute for every client and for the cities of Naples and Rome, the number of missives in SLA and the total number of missives that are both in SLA and outside the SLA. This for the first and the second quarter of each year. Considering that the system does not contain an attribute specifying both the missive in SLA and out SLA, we have to define a new custom attribute expressing the sum between the predefined attributes SumMsvINSLA



Name: Refunded Shipments
Type: Numeric
Analysis Domain: Delivery
Composition:

```
IF( Delivery Status =
0;[Shipments];'REFUNDED')
```

Fig. 5. GUI for the creation of a new custom attribute

and SumMsvOUTSLA. To create the new custom member, starting from the GUI shown in Figure 5, the user enters in the field *Name*, the desired name for the new attribute (SumMsvIN/OUT), in *Type* the data type of the new attribute (Categorical Nominal, Categorical Ordinal, Numeric or Temporal), and in *Analysis Domain* the domain the new attribute belongs to.

```
<CustomAttributeData AttributeName=‘‘SumMsvIN/OUT”
    UserId=‘‘admin” AttributeType=‘‘N”
    AnalysisDomain=‘‘Production” SolveOrder=‘‘1”>
<Expression Definition=‘‘[SumMsvINSLA]+[SumMsvOUTSLA
    ]” Localization=‘‘en_US”/>
</CustomAttributeData>
```

Listing 15. Custom attribute definition for the first example

Further, the user is facilitate in the task of creating a meta-language expression defining the meaning of the custom attribute by the “Attribute Library” and the “Operator” lists that appear in the right part of the interface. The XML describing the new member SumMsvIN/OUT and compliant to the XSD depicted in Section V is reported in Listing 15.

For a custom attribute, the XML contains in *AttributeName* the name of the new member or hierarchy, in *UserId* the id of the user that creates it, in *AttributeType* the type of attribute (N for numeric, T for Temporal, CO for Categorical Ordinal and CN for Categorical Nominal), in *AnalysisDomain* the domain the new attribute belongs to, in *SolveOrder* the order in which the custom element must be solved by the OLAP server, and in *DimensionName* the dimension that contains the custom attribute (measures by default).

```
WITH
MEMBER Measures.[SumMsvIN/OUT] AS [Measures].[
    SumMsvINSLA]+[Measures].[SumMsvOUTSLA],
    SOLVE_ORDER=3
MEMBER [Client].[Total Client] AS Sum (EXCEPT({[
    Client].[L_DES_CLIENT].Members}, [Client].[(All)
    ].CurrentMember))
MEMBER [Geographic].[Total Geographic] AS Sum ({[
    Geographic].[City].[Rome], [Geographic].[City].[
    Naples]})
```

TABLE I
PIVOT CONFIGURATION OF THE FIRST EXAMPLE

Filters	Columns
Time.Quarter.1	SumMsvINSLA
Time.Quarter.2	SumMsvIN/OUT
Rows	**Aggregate Values**
Client	
Geographic.City.Rome	
Geographic.City.Naples	

TABLE II
PIVOT CONFIGURATION OF THE SECOND EXAMPLE

Filters	Columns
	SumMsvINSLA
	Paper Hierarchy
	Digital Hierarchy
Rows	**Aggregate Values**
Drink Companies	AvgMsvOUTSLA
Motor Companies	

```
SELECT NON EMPTY {Union ([Measures].[SumMsvINSLA],
      Measures.[SumMsvIN/OUT])} ON COLUMNS,
NON EMPTY {Union (Except ({[Client].[L_DES_CLIENT].
      Members}, [Client].[(All)].CurrentMember), [
      Client].[Total Client]) * {[Geographic].[City].[
      Rome], [Geographic].[City].[Naples], [Geographic
      ].[Total Geographic]}} ON ROWS
FROM CUBE_T1
WHERE {[Acq_Time].[Quarter].[1], [Acq_Time].[Quarter
      ].[2]}
```

Listing 16. MDX query generated from the pivot configuration of Table I

Since the meta-language has been developed in multiple localizations (Italian and English so far) in order to make users more familiar with it, each custom attribute contains one or more *Expression*, one for each localization. In each expression element, the attribute *Definition* contains the meta-language expression defining the new element, meanwhile *Localization* contains the localization (en_US for English, it_IT for Italian). The pivot configuration from which the query will be generated, is described in Table I. The MDX query produced by the MDXGenerator is shown in Listing 16.

The second example shows how new hierarchies can be created. Let us suppose we want to know the number of missives in SLA and the average number of missives out SLA. The results must be grouped by some particular business process and by certain society of interest.

The XML containing the definition of the new hierarchies is contained in Listing 17.

```
<CustomAttributeData AttributeName=‘‘Drink Companies
      ” UserId=‘‘admin” AttributeType=‘‘N”
      AnalysisDomain=‘‘Production” SolveOrder=‘‘1”
      DimensionName=‘‘Society”>
<Expression Definition=‘‘CREATEHIERARCHY([Coca−Cola
      ]; [Pepsi]; [Red Bull]; [7up])” Localization=‘‘
      en_US”/>
</CustomAttributeData>
<CustomAttributeData AttributeName=‘‘Motor Companies
      ” UserId=‘‘admin” AttributeType=‘‘N”
      AnalysisDomain=‘‘Production” SolveOrder=‘‘1”
      DimensionName=‘‘Society”>
<Expression Definition=‘‘CREATEHIERARCHY([BMW]; [
      Fiat]; [Audi]; [Mercedes]; [Renault])”
      Localization=‘‘en_US”/>
</CustomAttributeData>
<CustomAttributeData AttributeName=‘‘Paper Hierarchy
      ” UserId=‘‘admin” AttributeType=‘‘N”
      AnalysisDomain=‘‘Production” SolveOrder=‘‘1”
      DimensionName=‘‘Society”>
<Expression Definition=‘‘CREATEHIERARCHY([Business
      Process].[Contact].[Working Phases].[Paper])”
      Localization=‘‘en_US”/>
</CustomAttributeData>
<CustomAttributeData AttributeName=‘‘Digital
      Hierarchy” UserId=‘‘admin” AttributeType=‘‘N”
      AnalysisDomain=‘‘Production” SolveOrder=‘‘1”
      DimensionName=‘‘Society” TotalWithoutOverlapping
      =‘‘true”>
<Expression Definition=‘‘CREATEHIERARCHY([Business
      Process].[Contact].[Working Phases].[SMS]; [
      Business Process].[Contact].[Working Phases].[
      Email]; [Business Process].[Contact].[Working
      Phases].[Fax])” Localization=‘‘en_US”/>
</CustomAttributeData>
```

Listing 17. Custom hierarchies definition for the second example

As it can be noticed, in the `Digital hierarchy`, the property *TotalWithoutOverlapping* is true. This property (false by default) specifies how the repeated values must be treated in the total: if the property is set to true, the repeated values are counted just one time, in the other case the total considers also duplicated values. The pivot configuration is shown in Table II, meanwhile the related MDX query is contained in Listing 18.

```
WITH
SET [Paper Hierarchy] AS {[Business Process].[
      Contact].[Working Phases].[Paper]}
MEMBER [Procedure].[All Paper Hierarchy] AS Sum ([
      Paper Hierarchy]), SOLVE_ORDER=1
SET [Digital Hierarchy] AS {[Business Process].[
      Contact].[Working Phases].[SMS], [Business
      Process].[Contact].[Working Phases].[Email], [
      Business Process].[Contact].[Working Phases].[
      Fax]}
MEMBER [Business Process].[All Digital Hierarchy] AS
       Sum ([Digital Hierarchy]), SOLVE_ORDER=1
MEMBER [Business Process].[Total Business Process]
      AS Sum (Distinct ({[Paper Hierarchy], [Digital
      Hierarchy]})), SOLVE_ORDER=1
SET [Drink Companies] AS {[Society].[Coca−Cola], [
      Society].[Pepsi], [Society].[Red Bull], [Society
      ].[7up]}
MEMBER [Society].[All CustomHierarchy1] AS Sum ([
      Drink Companies]), SOLVE_ORDER=1
SET [Motor Companies] AS {[Society].[BMW], [Society
      ].[Fiat], [Society].[Audi], [Society].[Mercedes
      ], [Society].[Renault]}
MEMBER [Society].[All Motor Companies] AS Sum ([
      Motor Companies]), SOLVE_ORDER=1
MEMBER [Society].[Total Society] AS Sum ({[Drink
      Companies], [Motor Companies]}), SOLVE_ORDER=1
SELECT NON EMPTY {Union (Union (Union ([Business
      Process].[All Paper Hierarchy], [Paper Hierarchy
      ], ALL), Union ([Procedure].[All Digital
      Hierarchy], [Digital Hierarchy], ALL), ALL), [
      Business Process].[Total Business Process], ALL
      ) * {[Measures].[SumMsvINSLA], [Measures].[
      AvgMsvOUTSLA]}} ON COLUMNS,
NON EMPTY {Union (Union (Union ([Society].[All Drink
    Companies], [Drink Companies], ALL), Union ([
    Society].[All Motor Companies], [Motor Companies
    ], ALL), ALL), [Society].[Total Society], ALL)}
    ON ROWS
FROM CUBE_T1
```

Listing 18. MDX query generated from the pivot configuration of Table II

VIII. Cube Selection

The MDXGenerator only deals with the generation of the query. In case more that one cube is specified in the query, it does not investigate which cube is the more suitable for the query execution. For this reason, the query object created by the MDXGenerator contains in the FROM field all the cubes that might be used. In order to determine the cube that best fit the query, we developed an algorithm that chooses among all the cubes contained in the pivot configuration the optimal one for the execution of the query.

The algorithm has been designed to be as general as possible and completely independent on the input cubes. In such a way, it is not mandatory that the input cubes share the same semantic structure. In eLog each of the input cubes takes into consideration different portion of the schema and therefore it may contain data at different granularity. For example, the *phase-level* cube contains data at an higher granularity than the *contract-level* cube (since a contract collects more phases).

In our algorithm we consider a schema $\mathcal{S}(\mathcal{C},\mathcal{D})$, where $\mathcal{C}$ is the set containing all the cubes and $\mathcal{D}$ the set of all dimensions. Given a query $\mathcal{Q}$ derived from the pivot table configuration, we define $\mathcal{Q}_{\mathcal{L}'}$ as the query that involves the non empty set $\mathcal{L}'$ of hierarchical levels of dimensions, where $\mathcal{L}' \subseteq \mathcal{L}$ and $\mathcal{L}$ is the set of all the distinct levels belonging to at least one dimension contained in the set $\mathcal{D}$. We denote $\mathcal{C}_{\mathcal{L}}[l]$ as the not empty subset of $\mathcal{C}$ containing the cubes where the dimension of the level $l \in \mathcal{L}$ is used. We denote $|c|$ as the number of dimensions in the cube c. In addition, among all the cubes, we consider c^0 as the cube containing all the levels with lowest granularity.

```
Input: $\mathcal{C}$, $\mathcal{Q}_{\mathcal{L}'}$
Output $c \in \mathcal{C}$
begin
    $\mathcal{C}' = \cap_{l_i \in \mathcal{L}'} \mathcal{C}_{\mathcal{L}'}[l_i]$

    if $|\mathcal{C}'| = 0$ then $c = c^0$

    else
        if $|\mathcal{C}'| = 1$ then $c = c^1$

        else
            $c = c^*$ where $c^* \in \mathcal{C}', \nexists c' \in \mathcal{C}', c' \neq c^*, |c'| < |c^*|$
end
```

Listing 19. Algorithm for the selection of the cube starting from a pivot table configuration

Given the query $\mathcal{Q}_{\mathcal{L}'}$, we define as *optimal cube*, $c \in \mathcal{C}$, the one that contains all the dimensions of the levels $\mathcal{L}'$ involved in the query and has the minimal cardinality $|c|$ [2]. Listing 19 summarizes our algorithm.

[2]If more than one cube has the minimal cardinality and encloses all the dimensions of the levels $\mathcal{L}'$, the system executes the query $\mathcal{Q}$ on all the equivalent cubes.

TABLE III
DBMS Configuration

DBMS_Vendor	Oracle
DBMS_Distribution	Oracle 10g Standard Edition
DBMS_SGA	1,5Gb
DBMS_HostSO	Red Hat Enterprise Linux Server Release 5.3
DBMS_HostRAM	16Gb
DBMS_HostDisk	2 Disks SAS RAID1 10.000 rpm
DBMS_HostCPU	2 Processors 4 Core 3Ghz
DBMS_HostSwap	16Gb

TABLE IV
Application Server Configuration

AS_Vendor	JBOSS
AS_Version	JBOSS 4.2.0
AS_JDK	1,5 (32bit)
AS_HeapSize	2Gb
AS_HostRAM	16Gb
DBMS_HostDisk	2 Disks SAS RAID1 10.000 rpm
DBMS_HostCPU	2 Processors 4 Core 3Ghz
DBMS_HostSwap	16Gb

TABLE V
Client Configuration

Client_RAM	3Gb DDR2 400Mhz
Client_Disk	Dell SATA2 5400rpm
Client_CPU	Intel Core 2 Duo P9600@2,66 Ghz
Client_Network	Ethernet 1Gigabit

IX. Test

In order to evaluate the performance of the new version of eLog, we arranged preliminary tests on the systems. Analyzing real data gather from the first version of eLog a use case has been created. On this use case, we generated 15 typical queries, ordered by complexity, i.e. by the number of dimension involved (from a minimum of 3 to a maximum of 8 different dimensions). Table VI shows the queries summary, containing the number of dimensions used, the total amount of data returned for each query request and a brief description of the query. Even if our data warehouse consists of 25 dimensions, we did not adopt more than 8 dimensions per query, since it has been observed that a report containing such number of dimensions is enough complex for a typical pivot analysis. The number of facts we considered for our test are 8.974.662, and are related to 8 months of eLog's data production. We used Btree index for the foreign keys on the fact table. We simulated the concurrent access for up to 25 users. The software and hardware configurations we adopted for the DBMS, the Application Server and the Client are reported in Tables III, IV and V.

We made three different tests. In the first test, we measured

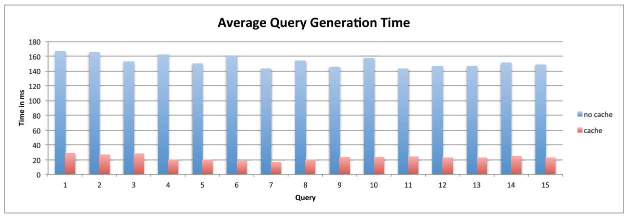


Fig. 6. Performance comparison between the MDX Generator with and without the cache functionality

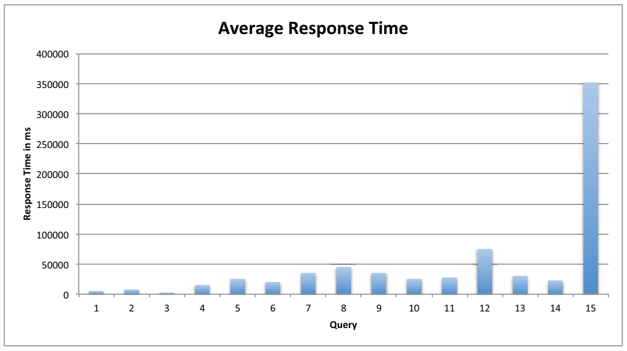


Fig. 7. Response time of the system

the time the MDXGenerator takes to elaborate each of the 15 queries without exploiting the caching functionality. In the second test, instead, we measured the performance of the MDXGenerator for the same set of queries but exploiting also the cache. Figure 6 represents the performance comparison between these two tests.As can be easily notice, exploiting the cache outperforms by 7 times the performance of the MDXGenerator.

In the third test, we measured the total response time of the system, starting from the time the user delivers the request, and ending when the client has completed the data loading from the server (hence taking into consideration also the MDXGenerator elaboration time using the cache). All the requests are submitted in parallel by all the 25 users and the response time, charted in Figure 7, is the average of the users response time. Each query has been executed without using the caching mechanism of the OLAP server.

X. Related Work

Nowadays, managers and decision makers wish to have a simple and powerful tool to perform data analysis. Many OLAP servers [4] allow the definition of queries among multidimensional databases by means of languages, such as MDX, that are very effective but hard to be used by business managers. On the other side, commercial tools for semi-static reporting provide a higher usability but lack in:

1) consistency with multidimensional operations,
2) proved theoretical foundations,
3) a middle layer implementing a conceptual view over the multidimensional element stored underneath and
4) analysis coherence [13].

Among the commercial tools landscape, Microsoft Excel PivotTable provides an expressive interface but does not support many dynamic analysis functionalities. Pivot tables are commonly criticized for disgraceful handling of large data sets and inefficiency in solving non-trivial analytical tasks, such as recognizing patterns, discovering trends, identifying outliers, etc.

State-of-the-art commercial OLAP tools, such as Business Objects, Cognos BI, Tableau and Targit, enhance the pivot table view by providing very flexible data manipulation capabilities, often as vendors proprietary visualizations. A most important system, called Polaris [14], extends the Pivot Table interface by offering a combination of a variety of displays and tools for visual specification of analysis tasks. Polaris is the predecessor of a commercial product called Tableau Software [2]. ProClarity was the first to enhance business intelligence with Decomposition Trees [12] for visual node-by-node disaggregation of data cubes. XMLA enriches the idea of hierarchical disaggregation by arranging the decomposed subtotals of each parent value into a nested chart (Bar- and Pie-Chart Trees) in its Report Portal OLAP client [16]. Visual Insights has developed a family of tools, called ADVIZOR, with an intuitive framework for parallel exploration of multiple measures [5]. Each of these systems adopt a proprietary data model and query language, while our framework uses the multidimensional model [7] and the MDX query language.

While most vendors tend to limit the scope of supported visual layouts to popular and proven ones, researchers propose to employ novel visualization techniques to take full advantage of multidimensional and hierarchical properties of data. [10] concentrates on the problem of loosing the aggregates computed at preceding query steps while changing the level of detail and propose to use hierarchical layouts for capturing the results of multiple decompositions within the same display using the Enhanced Decomposition Tree technique. An advanced exploration framework for OLAP based on coordinated views of dimension hierarchies is proposed in [3]. Each dimension hierarchy, with qualifying fact entries attached as the bottom- level nodes, is presented using a space-filling nested tree layout. Drilling-down and rolling-up is performed implicitly by zooming within each dimension view. A new visual interactive exploration technique for an analysis of multidimensional databases is proposed in [6]: users can gain both overviews and refine views on any particular region of interest of data cubes through the combination of interactive tools and navigational functions such as drilling down, rolling up, and slicing.

Our approach overcomes the limitations of conventional interfaces by abstracting various visualization options into a common presentation model and providing algorithms implemented into MDXGenerator for mapping user interactions (providing MDX database queries) as well as mapping query results to a specified visual layout.

TABLE VI
QUERIES INFORMATION

Query	Dim.	Ret. Data	Description
1	3	9758B	Number of completed, expected, unfinished missives, in SLA and out SLA missives, grouped by BILLING, OUTBOUND, RESEND ELIBRARY projects, for the customer MEDIASET and related to the acquisition time 1st quarter 2010
2	3	11136B	Number of completed, expected, unfinished missives, in SLA and out SLA missives, grouped by all projects related to the customer H3G, and to the acquisition time 1st and 2nd quarter 2010
3	5	29290B	Number of completed, expected, unfinished missives, in SLA and out SLA missives, grouped by EMISSION and ACQUISITION LOT, received in the fist quarter 2010, and belonging to the project BILLS POST CONSUMER of the customer H3G
4	5	81576B	Number of completed, expected, unfinished missives, in SLA and out SLA missives, grouped by PRICE DESTINATION and AREA, received in the 1st quarter 2010, belonging to the custom H3G
5	5	10710248B	Number of completed, expected, unfinished missives, in SLA and out SLA missives, grouped by PRICE DESTINATION and CAP, received in the 1st quarter 2010, belonging to the customer H3G
6	5	34240B	Number of completed missives, partitioned by SLA range, grouped by ACQUISITION LOT code, received in the 1st quarter 2010 and belonging to the customer H3G
7	7	57435B	Number of completed missives, partitioned by SLA range, grouped by EMISSION, ACQUISITION LOT and WORKFLOW, related to the acquisition time 2010 and belonging to the customer SKY
8	7	298874B	Number of missives, partitioned by SLA range, grouped by EMISSION, ACQUISITION LOT and WORKFLOW, related to the acquisition time June 2010 and belonging to the customer FASTWEB
9	6	189957B	Number of completed missives, partitioned by SLA range, grouped by EMISSION, ACQUISITION LOT and WORKFLOW, related to the acquisition time June 2010 and belonging to the customer FASTWEB
10	6	14467B	Number of completed missives, partitioned by delivery state, grouped by PRICE DESTINATION AM-CP-EU and weight range, related to the acquisition lots received in the 3rd quarter 2010 and belonging to the customer FASTWEB
11	6	2249665B	Number of completed missives, partitioned by delivery state, grouped by PRICE DESTINATION AM-CP-EU, related to the acquisition lots received in the 3rd quarter 2010 and belonging to the customer FASTWEB
12	7	2865182B	Number of completed missives, partitioned by delivery state, grouped by PRICE DESTINATION AM-CP-EU, AREA and CAP, related to the lots received in the 3rd quarter 2010 and belonging to the customer FASTWEB
13	6	17033B	Number of completed missives, partitioned by delivery state, grouped by PRICE DESTINATION AM-CP-EU and AREA, related to the lots received in the 2nd quarter 2010 and belonging to the customer MEDIASET
14	6	77427B	Number of completed missives, partitioned by delivery state and SLA range, grouped by PRICE DESTINATION AM-CP-EU and AREA, related to the acquisition lots received in the 1st quarter 2010 and belonging to the customer H3G
15	8	8375465B	Number of completed missives, partitioned by delivery state, grouped by PRICE DESTINATION AM-CP-EU, AREA and CAP, related to the lots received in the 3rd quarter 2010 and belonging to the customer FASTWEB

XI. Conclusion

We presented eLog: the business intelligence solution of eBilling for document management traceability, optimization and analysis. We outlined the improvements reached by the eLog new version, which allows to move from a transactional system to a multidimensional approach. eLog exploits the functionalities of the MDXGenerator library and the data model conceptualization provided by XSD schemas. MDX-Generator acts as the middle layer between the framework and the OLAP engine, converting the reports requested by the business manager through a GUI, into MDX queries executed on the OLAP engine. In order to customize data analysis indicators, eLog provides a simple and intuitive meta-language for unskilled users. Moreover, to optimize the MDX query execution on the OLAP server, we developed an algorithm for the optimal cube identification among all the cubes available in the data warehouse. The eLog architecture has been implemented in Adobe Flex for the web interface and in Java for the MDXGenerator. We plan to build a new version of MDXGenerator to extend the compliance of MDX language also for Microsoft SQL Server (so far, it is compliant with Mondrian technology).

The preliminary tests of eLog system produced promising results: the time needed to process even complex queries is acceptable. We plan more experiments on the applicative use of eLog system in the next future.

Starting from the assumption that MDX queries can be written in several ways maintaining the same semantics and obtaining the same result sets (e.g. operators like *except*, *sum*, *intersect* are interchangeable) we will investigate, in the future, how MDXGenerator can be enhanced in order to optimize the query generation process, following the approach presented in [8].

APPENDIX

```
(* TOKENS DECLARATION *)

(* CHAR TOKENS *)
letter = "ABCDEFGHIJKLMNOPQRSTUVWXYZ
    abcdefghijklmnopqrstuvwxyz_".
digit = "0123456789".
currency = "$ "
separator = ".,"

(* OPERATOR TOKENS *)
compOperator = "<" | ">" | "=" | "<=" | ">=" | "<>".
logicOperator = "AND" | "OR" | "XOR".
signOperator = "+" | "-".
mulOperator = "*" | "/".
not = "NOT".

(* BOOLEAN OPERATOR TOKENS *)
booleanValue = "true" | "false".

(* STRING AND NUMBERS TOKENS *)
string = {letter | digit} letter {letter | digit}.
constant = """ (" " | (string | number) {" " | (
    string | number)}) """.
mdxEntity = "[" string | number {" " string | number
    } "]".
number = digit {digit} [separator {digit}].

(* FUNCTION TOKENS *)
if = "IF".
format = "FORMAT".
current = "CURRENT".
concat = "CONCAT".
contain = "CONTAIN".
previous = "PREVIOUS".
following = "FOLLOWING".
createHierarchy = "CREATEHIERARCHY".

(* END TOKENS *)

(* META-LANGUAGE DEFINITION *)
GetMDX = Expression | Function | FormatFunction |
    AritmOperand | constant.

(* Expressions *)
Expression = AritmExpression | BoolExpression.

BoolExpression = CompExpression | LogicExpression |
    [not] InStrFunction.
CompExpression = ("(" AritmExpression ")" |
    aritmOperand) compOperator ("(" AritmExpression
    ")" | aritmOperand).
LogicExpression = [not] LogicFactor LogicOperator [
    not] LogicFactor {LogicOperator [not]
    LogicFactor}.
LogicFactor = LogicOperand | "(" CompExpression ")".
LogicOperand = booleanValues | InStrFunction.

AritmExpression = (AritmOperand | "("
    AritmExpression ")") AritmOperator (AritmOperand
    | "(" AritmExpression ")") {AritmOperator (
    AritmOperand | "(" AritmExpression ")")}.
AritmOperand = [signOperator] (number | mdxEntity).
AritmOperator = signOperator | mulOperator.

(* Format Function *)
FormatFunction = format "(" (Expression | Function |
    mdxEntity) ";" formatString ")".

(* Remaining Functions *)
Function = IfFunction | ConcatFunction |
    GetMemberFunction.

GetMemberFunction = CurrentFunction |
    PrevMemberFunction | NextMemberFunction.

IfFunction = if "(" BoolExpression ";" (Expression |
    Function | AritmOperand | constant) ";" (
    Expression | Function | AritmOperand | constant)
    ")".

CurrentFunction = current "(" mdxEntity ")".

ConcatFunction = concat "(" (mdxEntity | constant |
    ConcatFunction | GetMemberFunction) ";" (
    mdxEntity | constant | ConcatFunction |
    GetMemberFunction ")".

InStrFunction = contain "(" (mdxEntity | constant |
    GetMemberFunction) ";" (mdxEntity | constant |
    GetMemberFunction) ")".

PrevMemberFunction = previous "(" mdxEntity ")".
NextMemberFunction = following "(" mdxEntity ")".

CreateHierarchyFunction = createHierarchy "("
    mdxEntity ["." mdxEntity] {mdxEntity ["."
    mdxEntity]} ")"
```

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