1 INTRODUCTION

A Data Warehouse (DW) is a special database storing a huge volume of data dedicated to decisional systems. Its design methodology must take into account several things, among them the heterogeneity of data sources, the correspondence between data source models and multidimensional models as well as the manipulation of data structures. In a DW context, the data structure manipulation becomes really a crucial subject of research; especially in the design phase of DWs or Data Marts (DM) (Kimball, 1996) (Tryfona and al, 1999) (Moody and al, 2000) (Bonifati and al, 2001).

DMs are extracted from the DW; they are characterized by their multidimensional schemes (MDS). These MDS are represented as diagrams generally in respect to the Golfarelli formalism (Golfarelli and al, 1998).

Our team researches are in the context of designing a semi-automatic DW hybrid methodology summarized by the following steps:

1) Acquisition of the OLAP requirements expressed as tabular sheets (Feki, 2004),
2) Derivation of the DM schema on the basis of the OLAP requirements (Soussi and al, 2005),
3) Generation of the DW schema by integrating DM schemes (Majdoubi and al, 2005).

Our contribution in this paper consists in the visualization and the graphical manipulation of DM schemes. Actually, these schemes are described in XML and resulted from a generation module (i.e., step 2 above). More accurately, it is to develop a GUI assuring two main tasks: i) the visualization of the DM schema and ii) the alteration of the DM schema.

This paper is organized as follows: section 2 gives an overview of our context of study. Section 3 defines the multidimensional basic concepts. Section 4 defines our alteration operations: addition, deletion, and rename of multidimensional elements. Section 5 deals with the prototype of the interface whereas section 6 summarizes the presented work and introduces its perspectives.
The alteration consists in modifying these schemes through suitable operations listed in Table 1. This manipulation aims to adapt and refine the generated MDS in respect to the user requirements.

### Table 1: Categories of operations on a MDS.

<table>
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<tr>
<th>Operations</th>
<th>Inputs</th>
<th>Outputs</th>
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<td>Display MDS</td>
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<td>- Rename</td>
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### 3 BASIC CONCEPTS

To clarify our operations for MDS alteration, we find necessary to define the multidimensional concepts as presented in (Nabli and al, 2005).

**- Fact definition**

A fact $F$ is defined as $(\text{Name}_F, \mathcal{M}_F)$ where:

- $\text{Name}_F$ is the name of the fact which represents the analysis subject,
- $\mathcal{M}_F = \{\mathcal{M}_1, \mathcal{M}_2, \ldots, \mathcal{M}_N\}$; is the set of all measures of $F$.

**- Measure definition**

A measure $\mathcal{M}_i$ of a fact $F_i$ is defined by the couple $(\text{Name}\mathcal{M}_i,\text{Func}\mathcal{M}_i)$ where:

- $\text{Name}\mathcal{M}_i$ is the name of the measure,
- $\text{Func}\mathcal{M}_i$ is the compatible aggregation function with every measure, with $\text{Func}\mathcal{M}_i \subseteq \{\text{Min}, \text{Max}, \text{Sum}, \text{Average}, \text{Count}\}$.

**- Dimension definition**

A dimension $D$, representing an analysis perspective, is defined by the triplet $(\text{Name}_D, \mathcal{A}_D, H_D)$ where:

- $\text{Name}_D$ is the name of the dimension,
- $\mathcal{A}_D = \{\mathcal{A}_1, \mathcal{A}_2, \ldots, \mathcal{A}_N\}$; is the set of all attributes composing a dimension $D$,
- $H_D = \{H_1, H_2, \ldots, H_N\}$; is the set of all hierarchies associated with the dimension $D$.

**- Hierarchy definition**

A hierarchy is an acyclic graph defined by the couple $(\text{Name}_H, \mathcal{P}_H)$ where:

- $\text{Name}_H$ is the name of the hierarchy,
- $\mathcal{P}_H = \langle p_1, p_2, \ldots, p_N \rangle$; is an organization of the strong attributes of the hierarchy $H_D$ of $D$ such as $p_i \rightarrow p_j$ means that the parameter $p_i$ has a granularity strictly finer than $p_j$.

**- Multidimensional schema**

A multidimensional schema $S$ is constituted of measured facts associated to analysis dimensions. It is defined by $(\text{Name}_S, \mathcal{D}_S, \mathcal{F}_S, \text{Func}_S)$ where:

- $\text{Name}_S$ is the name of multidimensional schema,
- $\mathcal{D}_S$ is the name of analysis domain of $S$,
- $\mathcal{F}_S = \{F_1, F_2, \ldots, F_N\}$; is the set of all facts of $S$,
- $\mathcal{D}_S = \{D_1, D_2, \ldots, D_N\}$; is the set of all dimensions of $S$,
- $\text{Func}_S$ is a function that associates to every fact $F_i$ a set $D_S$ of dimensions.

### 4 SCHEMA ALTERATION

This section defines a set of operations useful to alter a DM schema (star or constellation). These operations are the addition, the deletion, and the rename of multidimensional elements. They are those defined in (Nabli and al, 2005), and extended with display and rename operations. We present them in the following sub-sections.

#### 4.1 Addition Operations

The addition operations insert new multidimensional elements into a MDS. We define five operations depending on whether we add a hierarchy, a measure, a dimension, an attribute or a fact.
- **Hierarchy addition**
The hierarchy addition inserts a new hierarchy into an existing dimension of a MDS.

**Definition**
The hierarchy addition operation AddH adds a hierarchy to a dimension. Its syntax is:

$$\text{AddH} (S, D, H) = S'$$

**Inputs:**
- $S = (\text{Name}_S, \text{Dom}_S, \text{FS}, \text{DS}, \text{Func}_S)$ is a MDS,
- $D = (\text{Name}_D, \text{AD}, \text{HD})$ is a dimension of $S$,
- $H = (\text{Name}_H, \text{PH})$ is the hierarchy to be added to $D$, where $\text{PH} = \{p_1, p_2, \ldots, p_N\}$.

**Conditions:**
- $D \in S.\text{DS}$ and $H \notin D.\text{HD}$

**Outputs:**
- $S'$ is the MDS $S$ enriched by the hierarchy $H$ where:
  - $S' = (\text{Name}_S, \text{Dom}_S, \text{FS}, \text{DS}', \text{Func}_S)$
  - $\text{DS}' = \{D_1, D_2, \ldots, D', \ldots, D_N\}$;
  - $D' = (\text{Name}_D, \text{AD'}, \text{HD'})$
  - $\text{AD'} = \text{AD} \cup \{p_1\} \cup \{p_2\} \cup \ldots \cup \{p_N\}$;
  - $\text{HD'} = \text{HD} \cup \{H\}$.

- **Measure addition**
The operation adds a measure to a fact.

**Definition**
The measure addition operation AddM inserts a new measure into a fact in a MDS. Its syntax is:

$$\text{AddM} (S, F, M) = S'$$

**Inputs:**
- $S = (\text{Name}_S, \text{Dom}_S, \text{FS}, \text{DS}, \text{Func}_S)$ is a MDS,
- $F = (\text{Name}_F, \text{MF})$ is a fact of $S$ where $\text{MF} = \{\text{MF}_1, \text{MF}_2, \ldots, \text{MF}_N\}$ is the set of all measures constituting $F$,
- $M = (\text{Name}_{MF_i}, \text{Func}_{MF_i})$ is the measure to be inserted into $F$.

**Conditions:**
- $F \in S.\text{FS}$; $M \notin F.\text{MF}$

**Outputs:**
- $S'$ is the MDS $S$ whose $F$ fact is enriched by the measure $M$ where:
  - $S' = (\text{Name}_S, \text{Dom}_S, \text{FS}', \text{DS}, \text{Func}'_S)$
  - $\text{FS}' = \{F_1, F_2, \ldots, F', \ldots, F_N\}$;
  - $F' = (\text{Name}_F, \text{MF'})$
  - $\text{MF'} = \text{MF} \cup \{M\}$.

- **Dimension addition**
This operation inserts a new dimension into a MDS and preserves its nature (star or constellation).

**Definition**
The dimension addition operation AddD adds a dimension to a set of facts in a MDS. Its syntax is:

$$\text{AddD} (S, F, D) = S'$$

**Inputs:**
- $S = (\text{Name}_S, \text{Dom}_S, \text{FS}, \text{D}, \text{Func}_S)$ is a MDS,
- $F = (\text{Name}_F, \text{MF})$ is the fact to which a new dimension will be associated,
- $D = (\text{Name}_D, \text{AD}, \text{HD})$ is the dimension to be added to $F$.

**Conditions:**
- $F \in S.\text{FS}$; $D \notin S.\text{DS}$; $\text{AD} \in S.\text{AD} \cup \text{D}$ and $\text{HD} \notin S.\text{HD}$

**Outputs:**
- $S'$ is the MDS enriched by the dimension $D$ where:
  - $S' = (\text{Name}_S, \text{Dom}_S, \text{FS}', \text{DS}, \text{Func}'_S)$
  - $\text{D} = (\text{Name}_D, \text{AD'}, \text{HD'})$
  - $\forall f \in F.\text{FS}$; $\text{Func}'_S(f) = \text{Func}_S(f) \cup D$.

- **Attribute addition**
The attribute addition operation inserts a parameter into a hierarchy of a dimension.

**Definition**
The attribute addition operation AddA inserts a new attribute into a hierarchy of a dimension. Its syntax is:

$$\text{AddA} (S, D, H, L, A) = S'$$

**Inputs:**
- $S = (\text{Name}_S, \text{Dom}_S, \text{FS}, \text{DS}, \text{Func}_S)$ is a MDS,
- $D = (\text{Name}_D, \text{AD}, \text{HD})$ is a dimension,
- $H = (\text{Name}_H, \text{PH})$ is a hierarchy of $D$ where $A$ will be added,
- $L$: is the insertion level of $A$ in $H$,
- $A$: is the attribute to be added.

**Conditions:**
- $D \in S.\text{DS}$; $H \notin D.\text{HD}$

**Outputs:**
- $S'$ is a MDS whose one of its dimensions is enriched by a new attribute $A$.
  - $S' = (\text{Name}_S, \text{Dom}_S, \text{FS}, \text{D}', \text{Func}_S)$
  - $\text{D}' = (\text{Name}_D, \text{AD'}, \text{HD'})$
  - $\text{AD'} = \text{AD} \cup \{A\}$;
  - $\text{HD'} = \text{HD} \cup \{A\}$.

- **Fact addition**
The addition of a fact $F$ to a star schema having common dimension(s) with $F$ transforms the star into constellation.

**Definition**
The fact addition operation AddF inserts a new fact into a MDS. Its syntax is:

$$\text{AddF} (S, F, \text{Dim}) = S'$$

**Inputs:**
- $S = (\text{Name}_S, \text{Dom}_S, \text{FS}, \text{D}, \text{Func}_S)$ is a MDS,
- $F = (\text{Name}_F, \text{MF})$ is the fact to be inserted into $S$,
- $\text{Dim} = \{d_{F_1}, d_{F_2}, \ldots, d_{F_N}\}$ is a set of dimensions to which $F$ can be associated.

**Conditions:**
- $F \not\in S.\text{FS}$; $\text{Dim} \subseteq S.\text{DS}$ and $\text{Dim} \neq \emptyset$

**Outputs:**
- $S'$ is the MDS $S$ enriched by $F$ where:
  - $S' = (\text{Name}_S, \text{Dom}_S, \text{FS}', \text{DS}, \text{Func}'_S)$,
4.2 Deletion Operations

This category of operations deletes multidimensional elements without correspondent in the data source. We distinguish the deletion of a hierarchy, a measure, a dimension, an attribute or a fact.

- **Hierarchy deletion**
  This operation deletes a hierarchy of a dimension from a MDS and maintains the schema nature.

**Definition**

The hierarchy deletion operation DelH deletes a hierarchy from a dimension. Its syntax is:

\[
\text{DelH}(S, D, H) = S'
\]

- **Inputs**:
  - \( S = (\text{Name}_S, \text{Dom}_S, F^S, D^S, \text{Func}_S) \) is a MDS,
  - \( D = (\text{Name}_D, A^D, \text{HD}) \) is a dimension of \( S \),
  - \( H = (\text{Name}_H, \text{PH}) \) is the hierarchy to be deleted from \( S \), with \( \text{PH} = \{p_1, p_2, ..., p_N\} \).

- **Conditions**:
  - \( D \in S.DS \);
  - \( H \in D.HD \);
  - \( |HD| \geq 2 \); and
  - \( \forall a \in A^D, \forall H \in D.HD, a \notin H.\text{PH} \).

- **Outputs**:
  - \( S' \) is the MDS \( S \) not having the hierarchy \( H \) where:
    - \( S' = (\text{Name}_S, \text{Dom}_S, F^S, D^S', \text{Func}_S) \),
    - \( D^S' = \{D_1, D_2, ..., D'_M, ..., D_N\} \),
    - \( \forall f \in F^S; \quad \text{Func}_S'(f) = \text{Func}_S(f) \setminus D \).

- **Measure deletion**
  Measure to be deleted must not be the single one in its fact.

**Definition**

The measure deletion operation DelM deletes a measure from a fact. Its syntax is:

\[
\text{DelM}(S, F, M) = S'
\]

- **Inputs**:
  - \( S = (\text{Name}_S, \text{Dom}_S, F^S, D^S, \text{Func}_S) \) is a MDS,
  - \( F = (\text{Name}_F, M^F) \) is a fact of \( S \) where \( M^F = \{M^F_1, M^F_2, ..., M^F_N\} \) is the set of all measures belonging to \( F \),
  - \( M = (\text{Name}_M^F, \text{Func}_M^F) \) is the measure to be deleted.

- **Conditions**:
  - \( F \in S.F^S; \quad |M^F| \geq 2 \).

- **Outputs**:
  - \( S' \) is the MDS where the measure \( M \) is removed from the fact \( F \) where:
    - \( S' = (\text{Name}_S, \text{Dom}_S, F^{S'}, D^S, \text{Func}_S^{'}) \),
    - \( F^{S'} = \{F_1, F_2, ..., F'_M, ..., F_N\}; \quad F' = (\text{Name}_F^{'}, M^{'}) \),
    - \( M^{'_F} = M^F \setminus \{M\} \).

- **Dimension deletion**
  A dimension could be deleted if and only if it is not the single one in its MDS.

**Definition**

The dimension deletion operation DelD deletes a dimension from a fact in a MDS. Its syntax is:

\[
\text{DelD}(S, F, D) = S'
\]

- **Inputs**:
  - \( S = (\text{Name}_S, \text{Dom}_S, F^S, D^S, \text{Func}_S) \) is a MDS,
  - \( F = (\text{Name}_F, M^F) \) is a fact from which a dimension \( D \) will be removed,
  - \( D = (\text{Name}_D^{'}, A^{D{'}, H^{D{'}}} \) is the dimension to be deleted.

- **Conditions**:
  - \( F \in S.F^S; \quad D \in S.D^S \); and \( |D^{'_S}| \geq 2 \).

- **Outputs**:
  - \( S' \) is the MDS from which the dimension \( D \) is removed where:
    - \( S' = (\text{Name}_S, \text{Dom}_S, F^{S'}, D^S \setminus \{D\}) \),
    - \( \forall f \in F^S; \quad \text{Func}_S^{'}(f) = \text{Func}_S(f) \setminus D \).

- **Attribute deletion**
  This operation deletes a strong or a weak attribute from a hierarchy and removes it from the dimension. The hierarchy identifier is the only attribute that cannot be deleted.

**Definition**

The attribute deletion operation DelA deletes a dimension attribute from a MDS. Its syntax is:

\[
\text{DelA}(S, H^D_i, A) = S'
\]

- **Inputs**:
  - \( S = (\text{Name}_S, \text{Dom}_S, F^S, D^S, \text{Func}_S) \) is a MDS,
  - \( H^D_i = (\text{Name}_H^D, \text{PH}) \) is a hierarchy not having the attribute \( A \),
  - \( A \) is the attribute to be removed.

- **Conditions**:
  - \( A \in H^D_i; \quad A \notin \text{PH} \), and \( A \neq H^D_{i,p1} \).

- **Outputs**:
  - \( S' \) is the MDS from which the attribute \( A \) is deleted.
    - \( S' = (\text{Name}_S, \text{Dom}_S, F^S, D^S \setminus \{A\}, \text{Func}_S^{'}) \),
    - \( D^S' = \{D_1, D_2, ..., D'_{M'}, ..., D_N\} \);
    - \( H^D' = \text{Nom}_D^{'}, A^{D{'}, H^D{'}} \),
    - \( A^{D{'}} = A^D \setminus \{A\} \),
    - \( H^D' = \text{Nom}_D(\text{PH}) \); and \( \text{PH} = \text{PH}^{'_D} \setminus \{A\} \).

- **Fact deletion**
  This operation deletes a fact \( F \), its measures and its specific (not shared) dimensions from a constellation schema.
Definition
The fact deletion operation $\text{DelF}$ deletes a fact from a MDS. Its syntax is:
$$\text{DelF}(S, F, \text{Dim}) = S'$$

Inputs:
- $S = (\text{Name}^S, \text{Dom}^S, F^S, D^S, \text{Func}^S)$ is a MDS,
- $F = (\text{Name}^F, M^F)$ is the fact to be deleted,
- $\text{Dim} = \{d_1, d_2, \ldots, d_N\}$ is a set of dimensions to which $F$ can be associated.

Conditions:
- $F \in S. F^S; | F^S | \geq 2$ and $\text{Func}(F) = \text{Dim}_F$

Outputs:
- $S'$ is the MDS from which we deleted the fact $F$ where:
  - $S' = (\text{Name}^{S'}, \text{Dom}^{S'}, F^{S'}, D^{S'}, \text{Func}^{S'})$,
  - $F^{S'} = F^S \setminus \{F\}$,
  - $D^{S'} = D^S \setminus \text{Dim}$,
  - $\text{Func}^{S'}(F) = \emptyset$

4.3 Rename Operations
This operation renames a multidimensional element by a meaningful name supplied by the user. It preserves the established correspondence of the renamed element with the data source and the uniqueness of names constraint:
$$\text{Nom}_1 = \text{Nom}_2 = \text{Nom}_3 = \text{Nom}_4 = \emptyset.$$
To illustrate the use of our operations, we apply those of Table 2 on the star schema S1.

Table 2: Examples of graphical operations on S1.

<table>
<thead>
<tr>
<th>Operation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DelA (S1, Supplier, Region)</td>
<td>Deletes the attribute Region of the Supplier dimension.</td>
</tr>
<tr>
<td>AddF (S1, Sale, Time)</td>
<td>Inserts a new fact (SALE, AmountSale, Qtity_soldSale, MinSale) into S1. This fact shares the Time dimension with the fact PURCHASE.</td>
</tr>
<tr>
<td>AddD (S1, Sale, Client)</td>
<td>Adds the dimension (Client, IdCClient, CityClient, DepartmentClient, RegionClient) to the fact SALE.</td>
</tr>
<tr>
<td>AddA (S1, Client, IdClient, AgeClient, SliceClient)</td>
<td>Inserts new attributes into S1. This results in the creation of a new hierarchy as the following steps show.</td>
</tr>
<tr>
<td>AddH (S1, Client, HClient2)</td>
<td>Adds the hierarchy H2Client =&lt;IdCClient, AgeClient, SliceClient&gt; to the Client dimension.</td>
</tr>
<tr>
<td>DelM (S1, Sale, Min)</td>
<td>Deletes Min measure from SALE fact.</td>
</tr>
</tbody>
</table>

Figure 5 describes the results of the applied operations on S1.

Figure 5: S2 graphical representation.

The addition of the fact SALE transforms S1 into a constellation model since we obtain two facts (PURCHASE and SALE) that share the common dimension Time. It is the only operation that changes the multidimensional model nature transforming a star into a constellation.

6 CONCLUSION

In this paper, we defined a set of operations necessary to MDS alteration. In order to validate our proposals, we have implemented a GUI that integrates these operations. The interface, currently under finishing, allows the designer to visualize the MDS as a tree by the DM schema explorer or as a multidimensional diagram. Our operations can be useful to the evolution of a DM schema.

REFERENCES


