Geographic Decision Making in Urban Management

A SOLAP Tool for the Analysis and the Management of Public Lighting in the City of Oran

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Abstract— **Approaches to business intelligence provide data mining techniques offering a new vision in multidimensional information analysis. This is particularly true when it comes to information with spatial reference. The procedures leading to the creation of Data Warehouses (DW) are inefficient when it comes to integrating the spatial dimension. Indeed, deriving a Spatial Data Warehouse (SDW) suggests the use of methods able to process complex geographical information, taking several aspects into account. If the archive character of the data is relatively easy to identify for each aspect, it is not obvious to detect this criterion in a global view of the geographic entity. We present in this paper an experiment showing a Geo-Decisional methodology of SDW construction, integrated in the functionalities of a Geographic Information System (GIS), to have a general procedure providing an information database and the specific tools to initiate spatial Data mining operations. An experimentation of this methodology to manage public lighting in the city of Oran is presented.**

Keywords - Data Warehouse; Data mining; SOLAP; GIS.

I. INTRODUCTION

Any activity on a territory generates data and information with spatial reference. The abundance of information on the space that we occupy shows the great interest various actors of territorial administration have on geographic information. New information technology has produced an exponential increase of data and information in almost all organizations. This has led to an improvement in management and better accuracy in the decisions made. In the field of economic activity, data processing proposes decision making approaches (Business Intelligence - BI) able to analyze non-volatile archived data over a fixed time period. Emanating from business intelligence, this approach is intelligent and produces particular inductions, unsuspected and undetected by traditional methods. Properties, trends and findings not revealed by classical approaches are updated and contribute greatly to making a more judicious decision. These tools are structured around the DW concept. They allow an exploratory search of data (Data mining). However, when the geographic information is concerned, these approaches are helpless and sometimes not well adapted.

Geographic information, the base of any characterization of territory, is complex and has multidimensional aspects in its definition. The geometric and topological aspect expresses metric characteristics like localization, shape, surface, and also all spatial relations between objects. It is coupled with attributive aspects describing intrinsic information of its theme. This duality in definition of geographic information is not taken into account by these new approaches. The GIS are excellent tools to characterize information with spatial reference. They offer a range of solutions to manage geographic information and to make deterministic spatial analysis. However, these systems do not make a spatio-temporal and oriented-subject analysis of the archived data. That represents the predominant constraint over their ability to provide an analysis using data mining.

Our study aims to present a methodology by enriching and adapting DW and Data mining approaches in the spatial context for the management of public lighting in the city of Oran. A Spatial On Line Analytical Processing (SOLAP) is developed. The specificity of this tool is dictated by the complexity of geographical information and especially its diversity. It is unrealistic at current state of research to claim to develop universal tools SDW or SOLAP. Each geographical theme is specific. Hydrology, agriculture, transport, waste management or public lighting are not treated in the same manner. Objects have different geometric and topological aspects. For this reason, the few SOLAP experiments identified in the world are all specific and target a defined theme. The application we have developed here is integrated into the GIS environment to allow visualization and mapping of the results.

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II. THE PROBLEM OF THE SPATIAL ANALYSIS

A. *DW and Spatial DW:*

A DW is a derivation of existing data structures such as databases to produce a structure containing archived data not subject to change.

Bill Inmon [7], considered as the founding father of DW, defines them as follows: "*A Data Warehouse is a collection of subject-oriented, integrated, not volatile, historical and organized data for decision-making*." (Figure 1)

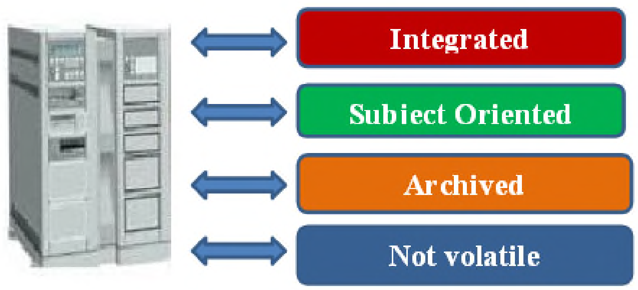

Figure 1. Data Warehouse

This definition assumes that data is stored in its most elementary level for basic and flexible use, making it easy and fast to analyze the information.

Accessing and processing the DW data are done by using a set of tools called Data Warehousing (Figure 2). In Data Warehousing, data is modeled as a data-cube, when the number of data does not exceed three dimensions. Each dimension is represented by one table. If the cube exceeds three dimensions, it is called hyper-cube.

By integrating the spatial dimension, Spatial DW is defined (SDW).

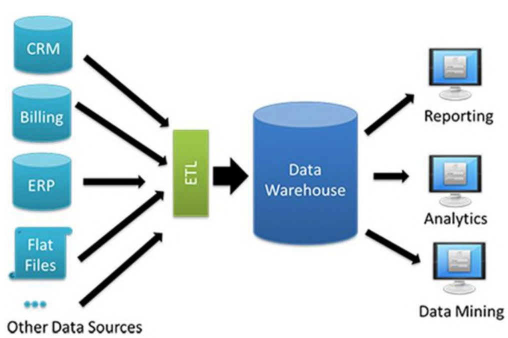

Figure 2. Manipulating tools of DW: The DWing

It is recognized that analytical processes do not use the full potential of data when they do not integrate the spatial component. However, this spatial dimension is mostly present in territory information defining, location, address, postal code, GPS location, region or country, position, territorial reference, etc.

It is currently estimated that 80% of data stored in corporate databases have spatial reference [5]. Sometimes, the spatial component comes in several elements in addition to position, like a shape, an orientation and a size. Simple visualization of spatial components allows providing first understanding of phenomenon in relation to its space (Figure 3). So, the simple fact of displaying spatial data gives an idea of their location in territory, their extent, their distribution (concentrated, dispersed, grouped, random, regular, etc.). This visualization action makes it possible to discover information not available by traditional OLAP tools.

Figure 3. Spatial distribution of phenomenon

B. *Data mining – OLAP - SOLAP:*

The set of methods requiring analysis using DW is grouped into the concept called OLAP [6]. It opposes to transactional analytical approaches offered by DBMS tools. If we are interested in the spatial component of information, we are in the presence of a Spatial OLAP approach (Figure 4). Distinction between the two concepts is fundamental. The introduction of spatial component as dimension in analysis requires a method combining a geometric approach with a more classical, literal and attributive process in relation to the reference theme.

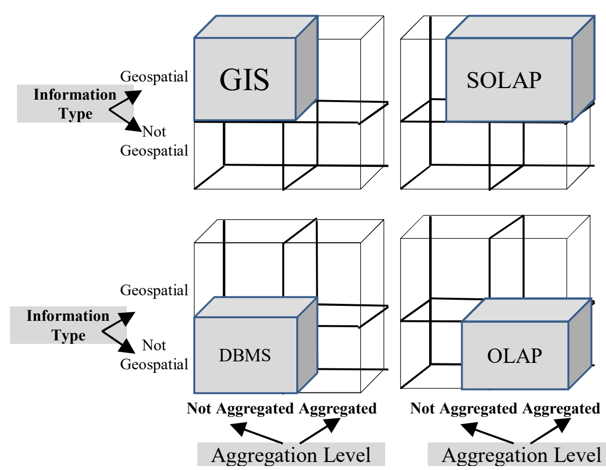

Figure 4. Type of Spatial Analysis

Any spatial Data mining is dependent on the existence of updated, stable and coherent SDW. This results from need to process space data in order to extract knowledge by exploratory means (Statistical, excavation, visualization, etc.).

SOLAP application is presented as "*A type of software that allows fast and easy navigation in spatial databases and offers several levels of granularity of information, several themes, several epochs and several modes of synchronized or non-synchronized display: Maps, charts and diagrams* "[3].

A SOLAP technology suggests new decision support functions, not available in traditional GIS tools or OLAP tools. This technology allows cartographic visualization of data, cartographic navigation on the map itself or in symbols displayed on the map, according to different types of drilling. In SOLAP technology, the creation of the results maps is dynamic, unlike some OLAP visualization software (e.g., Cognos Visualizer) where each spatial navigation operation (e.g., drilling) has to be predefined in application and associated with a map. This limitation of OLAP makes it more complex to update geometric data, by distributing information on several maps. The SOLAP tool manages adequately the mapping rules for analysis results on maps [4].

According to its definition, SOLAP does not require an expert person for its use. The user can create a multitude of different maps by some clicks. In presentation of results, SOLAP uses same semiological rules (e.g., color, frame, contour) for all displays. This makes it possible to have a visual synchronization between various modes of presentation and to have homogeneous panorama. Graphical semiology used for various types of display (i.e. tables, graphs and maps) remains synchronized during drilling or other operations, preserving perceptual continuity, necessary for discovery of correlations [9].

Three possible architectures exist for a SOLAP tool [1] (Figure 5).

- Predominant OLAP: This kind of solution proposes all features of an OLAP tool. It is implicit that such solution uses capacities of OLAP server. On the other hand this solution will integrate few functions of GIS, generally the functions of displaying, cartographic navigation and selection of geometric elements. The functions of space analysis, space synchronization, etc., are not available. Sometimes some minimal functions of space drilling can be offered and then make it possible to develop interesting SOLAP applications.

- Predominant GIS: OLAP server can be simulated inside a relational database by means of star model. When volumes of data are relatively low, this solution can be very advantageous. The requests can be adapted according to the needs of a particular project. For example, this action can be done while avoiding calculating, some non-significant aggregations or while making it possible to join tables implied in the requests in a way more flexible than OLAP servers allow it usually. On the other hand, this solution must include, in database, elements making it possible realization of OLAP operations such as drilling and the reassembly. The predominant GIS solutions offer all the features of GIS functions, but only one small subset of OLAP tool. This solution couples relational database simulating OLAP server with a GIS software or any tool for visualization of space data. The graphic interface for user and functions of semantic and spatial drilling must be programmed.

- Hybrid or Mixed Solution: This type of solution, integrate GIS functionalities and OLAP tools with the same proportions. It could be described as a centric-geospatial application, where spatial reference of objects is used constantly in the exploration and analysis of data. This type of solution is useful when the application must be integrated in Geomatic environment with a high data flow. It offers an OLAP server and a GIS tool. Then, it is possible to develop an OLAP extension to integrate in the GIS software. A SOLAP technology allows to group or to enrich both functionalities OLAP and GIS. The graphical interface provides the user with both spatial and semantic drilling functions, spatial analysis functions, mapping functions and so on. Tools of map navigation allow you to drill into maps according a synchronized manner with other types of displays (e.g. tables and diagrams).

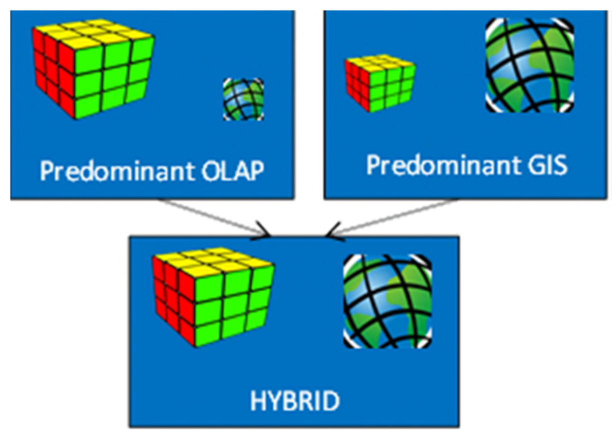

Figure 5. Architectures of SOLAP Solutions

Finally, SOLAP applications must be distinguished from SOLAP technologies. A SOLAP technology is a generic technology specially built to offer basic or more advanced SOLAP functions without the need of programming. A SOLAP application is a business application that provides the user with a number of SOLAP features and can be constructed with SOLAP technology or with combinations of non-SOLAP technologies (eg. GIS and OLAP and a self-programing code, or with other technologies) [2].

Our work is the development of a SOLAP application named "public lighting" integrated into GIS environment with software ArcGis in the city of Oran.

III. The Problem of Public lighting in Oran

A. Current situation of public lighting in Oran :

Oran is defined as a medium-sized city of Mediterranean territory (Figure 6). It is located in north-west of Algeria, and is considered the second largest city of the country. It has a population of 1.5 million. It is spread over an area of about 105 km² and incorporates a set of buildings combining several architectural types ranging from Arabic-Moorish to Haussmannian and Modern.

Figure 6. The City of Oran

Public lighting for city of Oran is a common problem and at center of many economic, social and political stakes. There is today a strong expectation, expressed by the populations in terms of urban lighting. These challenges of urban lighting especially security of properties and people, security of movement, valorization of city and economic development are well understood by elected officials and their citizens. A well illuminated city will be more pleasant to live in, more attractive to its visitors and more marked in its night identity. Today, the image and the living environment are essential conditions of attractive business for the city.

B. The statistics of public lighting in ORAN :

Oran has a significant public lighting network. It consists of:

- more than 42,000 luminaires,
- more than 3,600 switch cabinets,
- more than 916 control stations,
- Beyond 1,956 Km of cable,

Several companies, public and private, manage the network of lighting. The main operator remains ERMESSO which governs more than 60% of network of territory of Oran, and all control on the town of Oran. This operator has recently introduced mapping and modern technological tools in network management (GIS, GPS, etc.).

Frequent breakdowns are announced on the network generating a growing dissatisfaction of the population because of the deficiency of lighting generated by these incidents.

The potential causes of these incidents are not always identified. Operators in charge of management of network operate according to a policy of event-driven maintenance. Indeed, the teams of maintenance, they have the role of mitigating incidents which have occurred on the territory following the request of security services, communal services or of citizens. The only actions undertaken in this situation is replacement of defective devices (lamp, lighting, cupboard, cable, etc.). This situation is one of the main causes which motivate us to implement a SOLAP application to analyze the network, to diagnose nonobvious causes of incidents and to decide on a policy of adequate maintenance.

C. Elaborating the SDW "Public lighting Oran":

The SDW is generated from an existing database at ERMESSO. It is a collection of geographic data organized in specific system (GIS), dealing with public lighting on territory of city of Oran. The different components of the Database are layers of information structured around the territory and reference entities relating to the topic of study. The main ones are:

- Luminaires: A set of lighting post with their technical characteristics.
- Cabinets: The energy distribution cabinets to which the luminaires are connected,
- Lines : Connection Cables between the luminaires and the Cabinets,
- Road Network: The streets of Oran organized in categories, type, flow, road surface type, etc.
- Administrative Division: The different boundaries identifying territory of municipalities, urban areas and neighborhoods.
- A satellite image (SPOT 6) with resolution of 1,5 meters, taken in March 2015.

D. Different components of the SDW:

All referred entities in the database of the GIS will be represented in our SDW. However, light versions of entities will be produced to achieve efficient and coherent SDW. The problem lies in the choice of the entities components, candidate for the SDW. We target in our approach, the relevance, simplicity and stability of the information for the elements making up the SDW. The elaborated procedure aims precisely discrimination of the fields of objects and to keep only those that meet these criteria.

- *Stability:*

The SDW concentrates stable and nonvolatile data. This supposes data which undergo the least possible updates and modifications. The measurement of stability is ensured by installation of a flag for each entity in GIS database, and counting the number of updates with date of the last update over one given period (3 months, 6 months, or a year). A standardized classification is operated on the entities to calculate rate of update. The rate of update reflects for us the variability of information and its temporal stability. Consider the case of the entity distribution cabinet (Figure 7).

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Fields, like daily consumption, agent code and electric charge are volatile entities when variability is daily. They cannot claim to integrate the SDW.

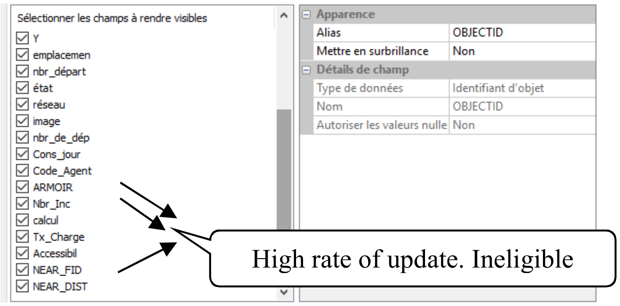

Figure 7. Energy Distribution cabinets

Below, we present the procedure for the calculation of functional stability.

```
Procedure Stability
Begin
    Fmj [] : intger Variable = number of update
    Tmj[] : Normalized rate of update
    Candidate : logical variable
    /* Calculation the number of update
    For each coverage of entity
        do
            For each entity Ei of the coverage in
        the period time
                do
                 If Update
                        then
                        Fmj[Ei]=Fmj[Ei]
                 +1
                        Stamp the date
                 Endif
                End
        End
    /* Calculation of the stability of the update rate
    For each coverage of information do
        For each entity Ei of the referenced coverage
        do  Calculate Tmj[Ei]
          if Tmj[Ei] < critical value
           then Candidate = "true" /* field eéligible for
    SDW
            Else
              Candidate ="false" /*   Non   éligible,   à
        exclure
          Endif
          End
```

With the execution of this operation, we will have eligible information and other non-eligible ones to join the SDW. For the user, non-eligible fields will not be displayed. He will have leisure to choose among eligible components those which he decides to put in SDW.

- *Spatial Relevance:*

The objective of this property is to identify among all the information eligible for the SDW, those that will be relevant for future spatial analysis. It is a very complex operation. Indeed, the component that does not influence a phenomenon today; can be preponderant in its variability in the future. It is developed to determine the potential correlations existing between objects. Generally it is the result of analysis that can lead to suspect the effect of component on the phenomenon. Our approach focuses initially only on the spatial relations. The spatial junctions like crossing type, connection, proximity and inclusion are detected and their significant advent is assessed. If the relationship is robust, then the entity is judged able to integrate with SDW.

This procedure is dynamic in our choice. Inclusion or exclusion in SDW is not fixed. The user is given the opportunity to reintegrate into the SDW a component that may fail in the Relevance procedure. This is generally observed when execution of SOLAP does not lead to significant results.

```
Procedure Spatial Relevance
Objects = {Set of the stable objects}
Begin
        For each entity Ei ∈ Objects
                Do
                Compute spatial relationship in Objects
                If ∃ relation robuste
                        Then
                                Accept for SDW
                Endif
                End
End
```

- *Space Coherence:*

We understand by space coherence an expression of the reality compared to its space modeling. It means determination geometrical and semantic and spatial constraints of objects. If an object is regarded as a zone, we must make sure that it is well represented by a closed polygon generating a surface, a boundary, an interior and an outside. For a linear object, it will not contain a priori surface but only one length, as well as the point object which will not derive other information except its position.

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```
Procedure Space Coherence
Objects = {Set of stable and relevant objects}
Begin
        For each Object Oi ∈ Objetcs
        do /* Geometric and topologic constraint
                Case : point
                Verift (position)
                Case : linear
                Verify (Length, non-overlap)
                Case : surface
                Verify  (surface, non-degenerative)

                End
                End
End
```

E. SDW Generating:

The procedures established above make it possible to purify the data coming from database and to keep only those that will feed the SDW. Since we have opted for a GIS-predominant solution, we will assimilate the SDW to a particular geodatabase that will be injected into GIS tool.

F. SOLAP Operations: Definition:

There is a panoply of OLAP operations allowing Data mining. We can gather them in two groups [10]:

1. Operators of drilling:
   - Aggregation (or Roll-Up): this operation concerns calculation for one or more dimensions. It makes it possible to climb in hierarchies by incorporating measurements.
   - To drill (or Roll-down or drill-Down): drill-down is operation of zoom down. It makes it possible to obtain information on a level of finer detail by disaggregating measurements.
2. Slice operators:
   - Slicing: A slice is a section or a subset of a multidimensional array. It allows you to focus on a particular area of event.
   - Dicing: dice is the selection of certain values of dimension. It makes it possible to restrict dimension of the hypercube.
   - Rotating: this operation makes it possible to change orientation of the cube, for example by inter-changing rows and columns of result.

In case of SOLAP, these same operations will require, in addition to informational search, a cartographic representation showing the result. It is the transcription of this action into the GIS functionality that determines the specificity of the SOLAP tool.

IV. EXPERIMENTATION

A. Data mining and diagnosis of publicl lighting:

A first aggregation operation shows that the mapping of the number of incidents per district over a period of one quarter, displays a certain disparity between certain districts deemed stable and others very disturbed. The districts "Hai Hamri" and "Hai Ghoualem" are considered to be very degraded (over 80 incidents). The maintenance budgets are precisely calculated on incident thresholds and distributed equitably between districts of the same class (Figure 8).

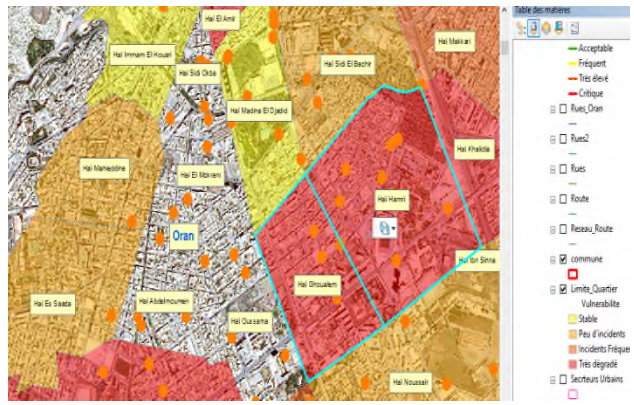

Figure 8. Mapping the districts by incidents number

At the executing of our application SOLAP, we can see that in the "Hai Hamri" district, only two cabinets are problematic with a high frequency of incidents (Figure 9) [8]. The other cabinets are relatively stable. Conversely, district "Hai Ghoualem" is degraded. The majority of its distribution cabinets have frequent incidents (Figure 10).

Figure 9. Situation of cabinet of district Hai Hamri

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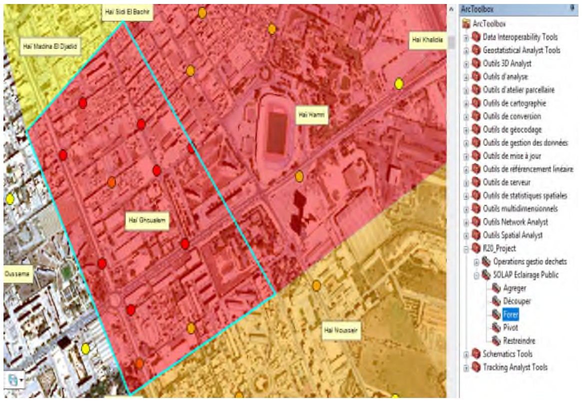

Figure 10. Situation cabinet of Hai Ghoualem

This shows that classification of districts, performed by usual functionalities of GIS is erroneous, and suffers from inaccuracy in actual diagnosis of the state of the lighting. This observation cannot be detected by classical tools of spatial analysis. The advantage of SOLAP is that it can navigate through archived data in several dimensions and views, to arrive at non-obvious findings by deterministic analysis.

B. *Synthesis:*

Visualization of the results of Data mining of public lighting showed the limits of diagnoses already stopped by the company in charge of the network. The exploitation of observations carried out by operations of SOLAP tool makes it possible to contribute effectively to a precise and rational management of network and especially to refine and better specify the different decisions.

V. CONCLUSION

The contribution of spatial Data mining like a technique, like a discipline and especially like a methodology, confers a better apprehension of phenomena having an anchoring on territory. Deductive inductions resulting from their procedure often inform about states and trends, unsuspected and not detected by usual techniques of space analysis, too restrictive and too deterministic.

The SOLAP approach developed in this experiment highlighted a true and capital knowledge for effective management of a lighting network. The notable fact is that this tool is quickly adopted by the persons responsible for management of public lighting, due to the fact that it does not require any special prerequisites for its use or significant training. With the contribution of other information characterizing the territory, the SDW can produce an informational base even more useful for the Data mining process.

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