A First Framework for Mutually Enhancing Chorem and Spatial OLAP Systems

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Abstract: Spatial OLAP systems aim to interactively analyze huge volumes of geo-referenced data. They allow decision-makers to on-line explore and visualize warehoused spatial using pivot tables, graphical displays and interactive maps. On the other hand, it has been recently shown that chorem maps represent an excellent geovisualzation technique to summarize spatial phenomena. Therefore, in this paper we introduce a framework being capable to merge the interactive analysis capability of SOLAP systems and the potentiality of a chorem-based visual notation in terms of visual summary. We also propose a general architecture based on standards to automatically extract and visualize chorems from SDWs according to our framework.

1 INTRODUCTION

Spatial On-Line Analytical Processing (SOLAP) systems allow on-line analyzing huge volume of spatial data to provide numerical indicators according to some analysis axes (Bédard et al., 2006). SOLAP has been sucessufylly applied in several application domains such as health, agriculture, etc. SOLAP systems integrate Geographic Information Systems (GIS) functionalities with OLAP systems to provide a cartographic visualization of these indicators (Bédard et al., 2006). Decision-makers trigger SOLAP operators by the simple interaction with visual components of SOLAP clients (pivot tables, graphical and cartographic displays). Therefore, they can easily and interactively explore geo-referenced data set looking for unknown and/or unexpected patterns and/or confirm their decisional hypothesis on some spatial phenomena. The success of SOLAP rests on the visual analytic paradigm “Analyze First - Show the Important - Zoom, Filter, Analyze Further - Details on Demand” (Keim et al., 2006), and its adaptation to geographic information, the so called Geovisualization. Geovisualization integrates the techniques of scientific visualization, cartography, image analysis, and data mining to provide a theory of methods and tools for the representation and discovery of spatial knowledge (MacEachren et al., 2004). Geovisualization analytics tasks are performed using SOLAP operators (Slice and Dice, Roll-up and Drill-down) whose results are displayed in interactive thematic maps. However, a part from thematic maps, SOLAP systems lack of advanced Geovisualization techniques as described in (Bimonte, 2014). In particular, summarizing information (i.e. Zoom visual analytic task) is reduced to aggregation of measures values using SQL aggregation functions of Roll-Up operator (e.g. SUM, MIN, MAX), but no additional visual summary is provided.

Consequently, sometimes SOLAP cartographic displays are not well adapted to complex spatial phenomena, which need several or temporal indicators leading to useless and/or clutterd maps (Silva et al., 2012).

Per contra, recent results have demonstrated that chorems can be used to both catch a thematic global view of a territory and its phenomena (De Chiara et al., 2011) (Del Fatto et al., 2008), and investigate complex spatial phenomena by accessing data characterizing them. A chorem is a schematized spatial representation, which eliminates any detail unnecessary to the map comprehension (Brunet, 1986). The main limitation of these approaches is that chorem map extraction cannot be done on-demand according to spatial decision-makers needs. This limits the potentiality of the spatial decision-making process, since, as stated in (MacEachren et al., 2004), high interactivity exploration and analysis

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are mandatory when dealing with complex and unknown datasets.

In this paper we carry out our aim of supporting users' tasks through advanced solutions and systems, and describe how chorems can be used to perform on-line analysis through a simple and immediate approach that exploits analysis capabilities of SOLAP systems. On this basis, in this paper we propose a *unique framework, called ChoremOLAP*, that, starting from warehoused spatial datasets, is able to on-line produce and visualize chorem maps exploiting the functionalities of SOLAP systems.

The paper is organized as follows. Section 2 recalls some basic notions about SOLAP systems and chorems, detailing related work. Section 3 present a real case study. The ChoremOLAP system is described in Section 4. Section 5 presents a discussion of our proposal. Conclusions and future work are drawn in Section 6.

2 RELATED WORK

Data warehouses (DW) and OLAP systems are Business Intelligence technologies aim to support on-line analysis of huge amounts of data. Warehoused data are structured according the so-called multidimensional model, which represents data according to different analysis axes (dimensions) and facts (Inmon, 1992). Dimensions are composed of hierarchies, which define groups for data (members) used as analysis axes. Facts represent the subjects of analysis, and they are described by numerical measures, which are analysed at different granularities associated to the levels of hierarchies. Decision-makers can aggregate measures at coarser hierarchy levels using classical SQL aggregation functions (AVG, SUM, MIN, MAX, COUNT). OLAP operators are defined to explore warehoused data. Classical OLAP operator are: Slice which selects of a part of the data warehouse, Dice which projects a dimension, RollUp which aggregates measures climbing on a dimension hierarchy, and DrillDown, which is the reverse of RollUp.

Since OLAP systems do not allow to integrate spatial data into the analysis and exploration process, Spatial OLAP (SOLAP) systems have been introduced (Bédard et al., 2006). SOLAP systems integrate OLAP and Geographic Information System functionalities in a unique framework to take advantage from the analysis capabilities associated to spatial data. SOLAP redefines main OLAP concepts. In particular, the integration of spatial data in OLAP dimensions brings to the definition of spatial dimension: non geometric dimension, spatial geometric dimension (i.e. members with a cartographic representation) or mixed spatial dimension (i.e. combine cartographic and textual members). When the studied subject of the decision process is the spatial information itself, then the concept of *spatial measures* are introduced. A SOLAP system allows visualizing results of SOLAP queries using interactive tabular and map displays.

Few works investigate using advanced geovisualization methods (such as Space-Time cubes, geobrowser) for SOLAP (a survey can be found in (Bimonte, 2014)). Indeed, existing SOLAP tools are limited to classical GIS visualization maps such as chloropleth and thematic maps.

In the last few years, much work has been done on the chorem concept and on its exploitation as an appealing visual notation to convey information about phenomena occurring in specific application domains, such as land use and territorial management. The term chorem derives from the Old Greek word χώρα (read chora). According to the definition of the French geographer Roger Brunet (Brunet, 1986), a chorem is a schematized spatial representation, which eliminates any unnecessary details to the map comprehension. A chorem is a synthetic global view of data of interest which emphasizes salient aspects. Figure 1 shows an example of a chorem map, which contains chorems referring to the environmental dynamics of the area around the city of Poitiers, France.

This map results from a participatory process with agents of DREAL Poitou-Charentes (regional office of the environment) (Lebourg M-N, et al., 2014). They handy draw all the information needed using a Geographic Information System. Then, they simplify the geometries of the map using the GIS functionalities according an adapted semiotic. This chorem map shows the predominance of transport corridors in the organization of the territory, the urban continuity and the expansion of the cities. Moreover, chorems show the interaction between these dynamics and the environmental issues of this area.

The evolution of chorems both in terms of applications and semantics is extensively discussed in (Del Fatto, 2009) where the author provides a review about the history of chorem, from its definition (Brunet, 1986) to recent applications (Kilppel et al., 2005).

A more recent application of the chorem concept has been illustrated in (Del Fatto et al., 2008) where the authors show how chorems can be used to

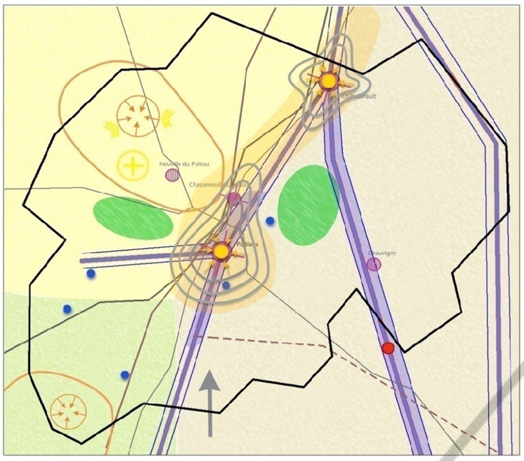


Figure 1: Chorems example.

visually summarize database content. To this aim they provide for a definition and a classification of chorems meant both to homogenize chorem construction and usage, along with a usable framework for computer systems. In particular, this work emphasizes the role that chorems may play in supporting decision-makers when analyzing scenarios, by acquiring syntactic information (what, where and when), as well as semantic aspects (why and what if), useful to human activity of modelling, interpreting and analyzing the reality of interest. A prototype is also described, targeted to generate chorems from a spatial dataset through a uniform approach that takes into account both their structure and meaning.

Finally, in (De Chiara et al., 2011) the authors enhance the role that a chorem map may play in geographic domains, by extending the semantics associated with it through a more expressive visual notation. In particular, by adopting the revisited Shneiderman's mantra, namely "Overview, zoom and filter, details on demand" (Keim et al., 2006), they allow users to acquire information about a single phenomenon by accessing data characterizing it from the underlying database. Each task of interaction assumes a context-sensitive meaning and invokes a proper function among the ones specified in agreement with the mantra. As an example, when a zoom / filter combination is applied on a chorem, users are provided with data from spatial dataset which initially contributed to its definition.

The main limitation of previously described approaches is that chorem map extraction cannot be done on-demand according to spatial decision-makers needs. This limits the analysis of decision-making process since as stated in (MacEachren et al., 2004), a high interactivity exploration and analysis is mandatory when dealing with complex and unknown datasets.

To be useful for decision-makers, some authors define classes of chorems in order to help decision-makers to choice the right visual representation for a particular phenomenon. Therefore, from the initial chorematic grid of Brunet (1986), JP Deffontaines et al. (1990) have formalized spatial models to represent agricultural phenomena. S Lardon and P-L Osty (2000) have shown an application of spatial modelling on bushes expansion in farming lands. Lardon and Piveteau (2005) have revised and adapted the chorem grid for territory management purposes. They distinguished structures (considered space objects) and dynamics (spatial processes in which these objects are identified). However, decision-makers have hand-extract and hand-draw their chorems from data sources.

Thus, *the framework presented in the paper enhances chorems systems since it allows the online extraction and visualization of chorems using SOLAP operators. At the same time, adding chorems visualization to SOLAP improves its geovisualization analysis capabilities* (c.f. Section 5).

3 FAO CASE STUDY

An example of a Spatial DW (SDW), which will be used all along the paper to describe our proposal, is depicted in Figure 2 using the UML profile presented in (Boulil et al., 2015). Here, several stereotypes have been defined, one for each element of the SDW. For example a spatial dimension presents the <<SpatialDimension>> stereotype, a spatial level is identified with <<SpatialAggLevel>> stereotype. The <<Fact>> stereotype designs facts and numerical and spatial measures have the stereotypes <<NumericalMeasure>> and <<SpatialMeasure>>.

The SDW is loaded using open-data of FAO (FAO2015). It allows analysis of agricultural cultivated surface and production per year, country and crop. It presents a spatial hierarchy grouping countries in areas, and years by decade. Using this SDW it is possible to answer queries like: "What is the total surface and production of wheat per country and year?". More complex analysis could be performed using this SDW. In particular to evaluate national agricultural policies, it is possible to compare agricultural production and surface over time, for example using the query: "*What are differences of total surface and production per*

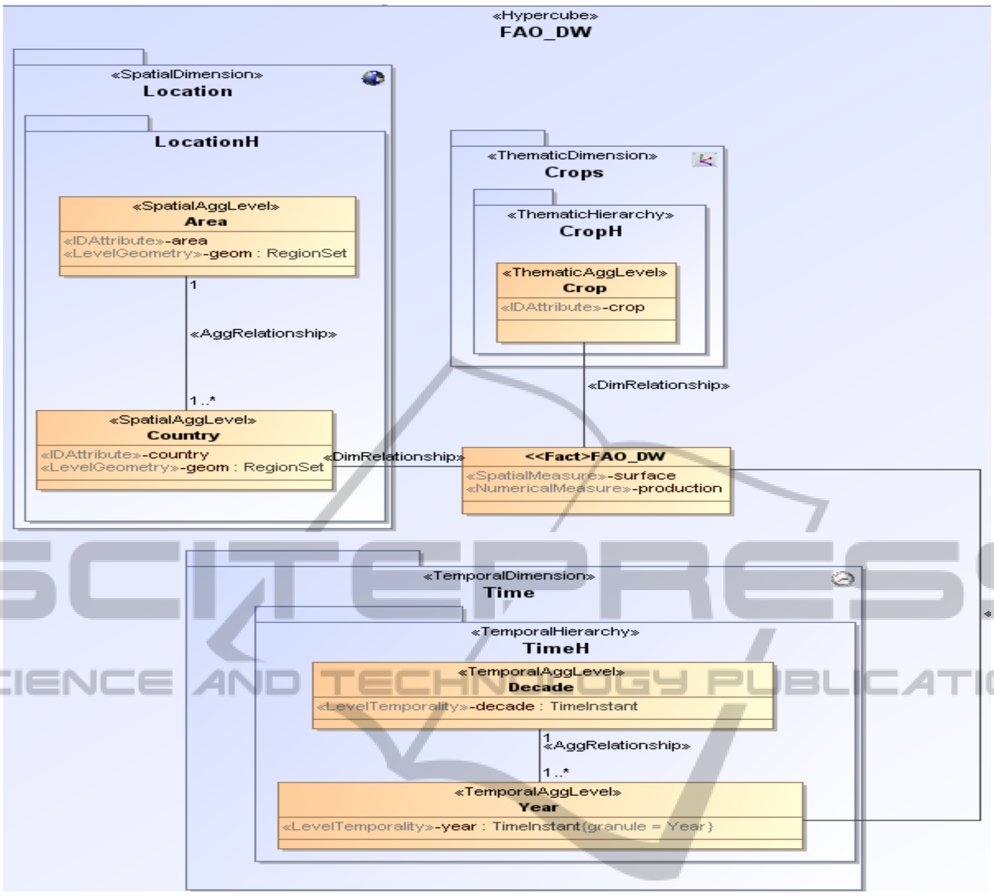


Figure 2: FAO Spatial Data Warehouse.

country on the last 5 years. In our case study, we work using national wheat production and national wheat area harvested of European countries between 1991 and 2011. These data allow us to analysing not only the variations of production and acreage but also variation of crop yields and productivity. The range of the period studied lets us to do several analysis in different temporal scales.

4 CHOREMOLAP

In this section, we present the theoretical framework for integration of SOLAP and chorems (Sec 4.2), and its implementation in a SOLAP tool (Sec 4.1).

4.1 Architecture

ChoremOLAP architecture is described in Figure 3. It is based on a Relational SOLAP architecture composed of three tiers: SDW, SOLAP server and SOLAP client.

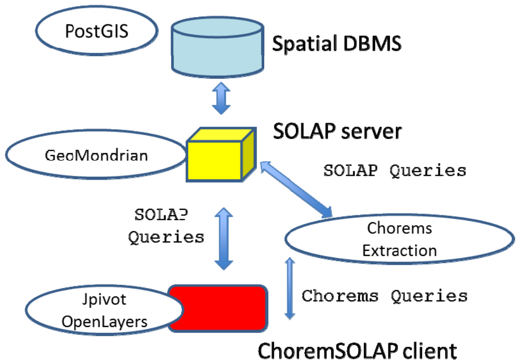


Figure 3: ChoremOLAP architecture.

The Spatial Data Warehouse tier is implemented using the Spatial DBMS PostGIS (PostGIS, 2015). PostGIS is an extension of Postgres providing a native support for spatial data and spatial analysis functions. This tier is used for storing alphanumeric and spatial multidimensional data. Warehoused spatial data is stored using the star-schema (Kimball, 1996), where levels of the denormalized spatial dimension present geometric attributes.

Example. The logical model of our case study is shown on Figure 4, where a table for each dimension is defined, and one table for the fact.

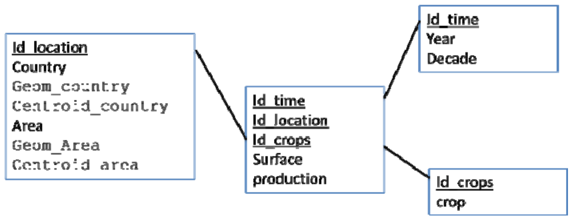


Figure 4: Star-schema of the FAO SDW.

The spatial dimension presents a geometry column for each spatial level (Geom_country and Geom_area). We also note that two additional geometries representing the centroid of the countries and the areas have been defined since, as detailed in the next sections, they are used for the chorems visualization.

The SOLAP server used is GeoMondrian (GeoMondrian, 2015). GeoMondrian is an open-source SOLAP Server supporting GeoMDX. GeoMondrian represents dimensions and measures using an XML file, which defines a mapping on the logical schema. GeoMondrian supports SOLAP queries on the top of Postgis.

The SOLAP client is a web-based client composed of the OLAP client JPivot and the GIS client OpenLayers. In particular, JPivot is an open-source web-based OLAP client implementing all OLAP operators by the simple interaction with the pivot table. JPivot supports MDX. Cartographic visualization of SOLAP queries is provided by the cartographic web client OpenLayers. Openlayers is an open source JavaScript library for displaying map data in web browsers.

The architecture presented in (Bimonte, 2014) has been extended in two ways to support chorems extraction and visualization as described in Section 4.3. We have used this SOLAP system since it provides an open and customizable visual interface. Indeed, the main idea for implementing customizable cartographic visual displays in the SOLAP client is the usage of SLD and GML standards, which are used by standard mapping web services (e.g., WMS). A Styled Layer Descriptor (SLD) is an XML schema specified by the Open Geospatial Consortium (OGC) for describing the appearance of map layers. Moreover, the Geography Markup Language (GML), defined by the Open Geospatial Consortium, allows expressing geographical features. We use GML to represent spatial data and the SLD for its appearance.

The original geovisualization proposed method in (Bimonte, 2014) consists of chloropleth maps (e.g. coloured geometries) implemented using GML and SLD. Here, we have added the visualization of icons representing chorems as described in the Sec 4.2.

In the SOLAP server, we have implemented a component that translates a chorem query in a classical SOLAP GeoMDX query. In this way, chorem queries are transparently handled by any SOLAP server. The proposed extensions are detailed in the rest of this section.

4.2 Principles

Our geovisualization methods are based on two main groups:

- Chorem-based geovisualization methods, which are based on chorems, and
- Non chorem-based geovisualization methods, which are classical geovisualization methods.

4.2.1 Chorem-based Geovisualization Methods Principles

The chorems used in our approach are a subset of chorems identified by S Lardon and P-L Osty (2000) that can be extracted from spatial warehoused data, as shown on Figure 5. Here, 5 main groups of chorems are described.

Chorem Group			Extraction
Type	Icon	Goal	SOLAP elements
Characteristics	Grid	How is the territory divided?	Spatial level
	Network	How is the territory drained and supplied?	Spatial Network level
	Hierarchy	What organises the territory?	Spatial level and measure
Dynamics	Territorial dynamics	How is it altered? How is the territory transformed?	Spatial level and spatial measure

Figure 5: Chorems and extraction mapping of the ChoremOLAP framework.

In particular, *Grid* represents how the territory is divided by actors (for example, municipalities). *Network* designs the presence of network structures such as roads, rivers, but also informational networks drained and supplied the territory. *Hierarchy* specifies the different entities and how they organize the territory.

The dynamic chorems result from the temporal evolution of these structures. The *Territorial Dynamic* transforms differentiated spaces, even by continuous expansion or by discrete allocation.

Example. In Figure 6 an example of instance for each group of chorems is also presented using our case study.

Let us now describe what elements of the spatio-multidimensional model are used to extract chorems (Figure 5).

Grid chorems group concerns only the geometries of spatial levels.

Example. In our case study the chorem "Area limits" is simply defined using the spatial level "Area" of the SDW.

In the same way, *Network* chorems group is also only associated to spatial levels defined as spatial network levels in (Bimonte et al., 2013).

Hierarchy chorems group refers to spatial members and their numerical properties, which can change along non-spatial dimensions.

Example. In our example, "Production increase" chorem is defined using the spatial level "Country" and the measure "Production".

Finally, *Territorial Dynamics* chorems group is similar to *Hierarchy*, but here the properties are strictly related to the geometries of the spatial level (spatial measures).

Example. The "surface" measure is a spatial measure, and so the "Surface Reduction" chorem is calculated using the spatial level "City" and "surface" measure.

4.2.2 Non Chorem-based Geovisualization Methods Principles

The system proposed in (Bimonte, 2014) allows to displays results of SOLAP queries using chloropeth maps. Here we extended them by using the simplified geometries of the *Grid* chorems group.

Moreover, it allows visualizing nominal measures using an iconic representation. For example, in order to visualize production evolution, we define three icons:  if there is an augmentation,  if there is a diminution, and  otherwise.

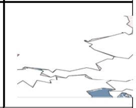
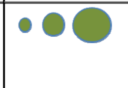
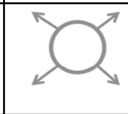
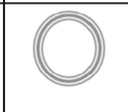
Group	Instance	
	Name	Icon
Grid	Area limits	
Hierarchy	Production value	
Territorial dynamics	Surface Expansion	
	Surface Stagnation	
	Surface Reduction	

Figure 6: Chorems of the FAO SDW.

4.3 Extraction and Visualization

In this section, we detail how chorems of Figure 5 are extracted (Section 4.3.1) and visualized (Section 4.3.2) on the top of the SOLAP architecture of Figure 3

4.3.1 Extraction

In order to extract chorems on the top of a classical SOLAP server, we use MDX. MDX is de-facto standard query language of OLAP servers. MDX allows defining calculated measures (i.e. measures calculated using measures values stored in the SDW tier).

The template MDX formula for the Territorial Dynamics chorem is presented in Figure 7. The chorem is represented by the calculated measure `[Measures].[ChoremE]` that assumes the values:

- "-1" the phenomenon reduces
- "0": the phenomenon does not change
- "+1" the phenomenon expands

where:

- *Phenomena* is the measure used for the chorem definition. For example *Phenomena = "Surface"* allows the extraction of *Surface Reduction, Surface Stagnation and Surface Expansion* chorems respectively (Figure 7);
- *TimeRange* represents the interval between two dates (*Date*) (for example *TimeRange =5* allows comparing *Phenomena* values of each year with 5 years ago values).

```
with member [Measures].[Y-1] as
'IIf(((ParallelPeriod([Time].[year], TimeRange,
[Time].CurrentMember) IS NULL) OR
(ParallelPeriod([Time].[Date], 1.0, [Time].CurrentMember) =
0.0)), (- 1.0), ParallelPeriod([Time].[Date], 1.0,
[Time].CurrentMember))'
 //check for existing previous dates

  member [Measures].[diff] as 'IIf(([Measures].[Y-1] > (-
1.0)), ([Measures].[Phenomena] - [Measures].[Y-1]), (-
1.0))'
 //calculate the difference with previous date

  member [Measures].[TauxVariation] as 'IIf(([Measures].[Y-
1] > (- 1.0)), ([Measures].[diff] / [Measures].[Y-1]), (-
1.0))', format_string = "Percent"
 //transform the difference in a percentage value

  member [Measures].[Choreme] as 'IIf(([Measures].[Y-1] <
0.0), "-2", IIf(([Measures].[TauxVariation] < 0.0), "-1",
IIf(([Measures].[TauxVariation] > 0.0), "+1", "0")))'
 //calculate the chorem values
```

Figure 7: Territorial Dynamics chorem MDX template.

4.3.2 Visualization

The visualization of the *Grid* chorems group is simply achieved by the visualization of simplified geometries of the spatial levels members stored in the SDW tier (Figure 5).

Example. An example of Grid visualization is shown on Figure 8.

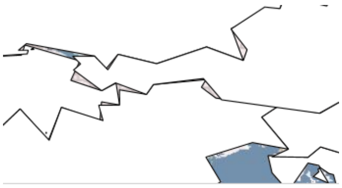


Figure 8: Visualization of the Grid chorem.

The visualization of the *Territorial Dynamics* chorems group is implemented using a simple SLD template (Figure 9).

```
<Rule>
    <ogc:Filter>
        <ogc:PropertyIsEqualTo>
            <ogc:PropertyName>NonSpatialDimensionsMembersChorem</ogc:Property
        Name>
            <ogc:Literal>ChoremValue</ogc:Literal>
        </ogc:PropertyIsEqualTo>
    </ogc:Filter>
    <PointSymbolizer>
        <Graphic>
            <ExternalGraphic>
                <OnlineResource xlink:href="ChoremImage" xlink:type="simple"/>
                <Format>image/gif</Format>
            </ExternalGraphic>
            <Size>ChoremImageSize</Size>
    </Graphic>
    </PointSymbolizer>
    <PolygonSymbolizer>
        <Fill>
        <CssParameter name="fill-opacity">0.0</CssParameter>
        </Fill>
    </PolygonSymbolizer>
</Rule>
```

Figure 9: Territorial Dynamics chorem SLD template.

An SLD template is generated for each combination of non spatial members (*NonSpatialDimensionsMembersChorem*) present in the pivot table result (for example "2000"). It also defines a rule for each chorem value *ChoremValue* corresponding to the calculated measure `[Measures].[ChoremE]` (-1, 0, +1). For each rule, an image associate to the chorem value is visualized (*ChoremImage)*. The location where this image is displayed is represented using GML. We use the centroid of the spatial member, when it is a polygon stored in the spatial dimension table (Figure 4).

Example. Figure 10 shows an example of the chorems *Surface Stagnation, Surface Reduction, and Surface Expansion* for each country in 2000. Decision-makers rapidly "see" that Italy presents a surface reduction, while France has a surface expansion.

Figure 10: Surface Stagnation, Surface Reduction, and Surface Expasion.

The *Hierarchy* chorems group is implemented in the same way, but here we present only an example of visualization.

Example. An example of Hierarchy chorem visualization of the production on 2000 is shown on Figure 11 (Italy and Switzerland are in the same category, while France production is higher).

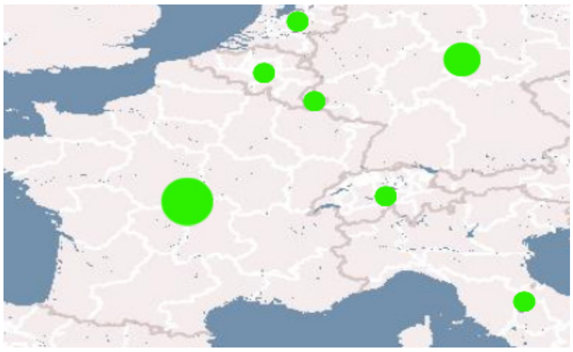


Figure 11: Production value.

An example of non-chorem based geovisualization (Sec. 4.2.2) showing a chloropleth map for the value of the surface on 2000 and the production evolution per country is shown on Figure 12.

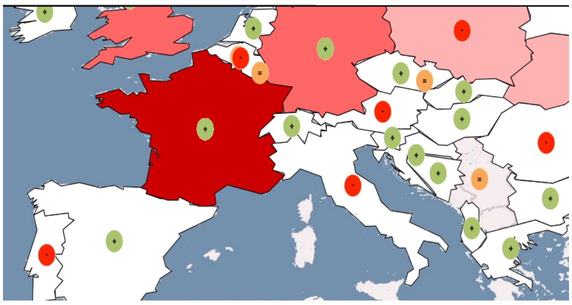


Figure 12: Non chorem-based geovisualization.

5 DISCUSSION

In this section, we analyse how our approach mutually improves SOLAP and chorems systems.

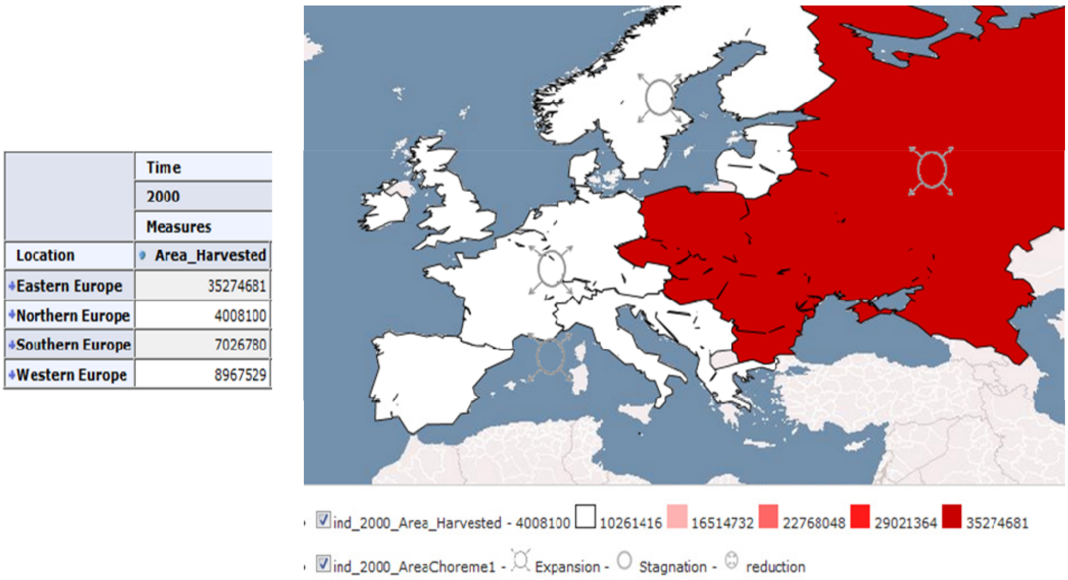
5.1 Chorems Improved by SOLAP

As we state in the previous section, ChoremOLAP allows to interactively creating chorems. This is achieved by simply triggering SOLAP queries, as described in the following.
SOLAP operators allow to explore the warehoused data on-line aggregating measures values, and in our tool also chorem values. For example, decision-makers can move from the "Area" spatial level to the "Country" spatial level by the simply interaction with the pivot table of our web-client (i.e. DrillDown operation on the spatial dimension) (Figure 13). As shown on Figure 13a, the surface chorem is visualized at the "Area" spatial level. When the decision-maker DrillDowns to the "Country" spatial level, the chorem map is instantaneously re-calculated for each country (Figure 13b).
In the same way, the decision-maker can dynamically change other dimensions. For example starting from the chorem map of figure 13a, he change the year, for example moving from 2000 to 1995, and the chorem map is online calculated.
Thus, we can conclude that SOLAP system allows the online creation and visualization of chorem maps.

5.2 SOLAP Improved by Chorems

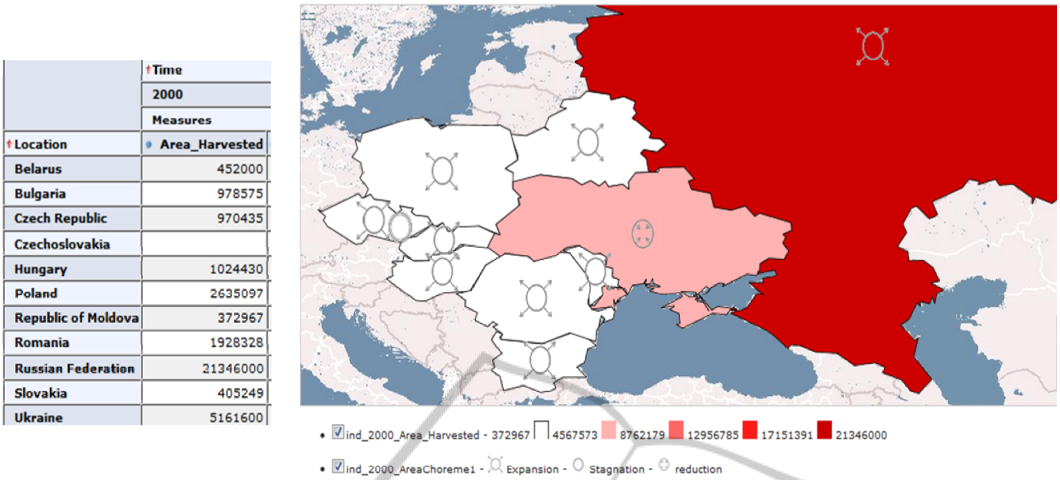
Let us now describe how SOLAP maps are improved by chorems visualization.

In order to evaluate the new analysis capabilities offered by our framework from a visualization point of view, we performed a comparative study of ChoremOLAP against one of the most advanced commercial SOLAP clients. We compare our proposal to classical SOLAP visualization methods and we analyze the ability to represent different kind of SOLAP queries.
In table 1 we present what and how many measures can be visualized with govisualization methods for SOLAP including our chorem maps.



(a)

Figure 13: Drill Down for automatic chorem extraction and visualization.



	Time
	2000
	Measures
Location	Area_Harvested
Belarus	452000
Bulgaria	978575
Czech Republic	970435
Czechoslovakia	
Hungary	1024430
Poland	2635097
Republic of Moldova	372967
Romania	1928328
Russian Federation	21346000
Slovakia	405249
Ukraine	5161600

(b)

Figure 13: Drill Down for automatic chorem extraction and visualization (cont.).

Table 1: Geovisualization methods for SOLAP.

SOLAP Geovisualization methods		Measure type	
		Number	Type
Thematic map (map using diagram displays such as bar charts, pie charts)		More than 1	Quantitive
Cloropeth map (map using only one colour per geographic objects)		1	Ordinal
			Nominal
Cloropeth Multimaps (set of cloropeth maps displayed in the same screen)		More than 1	Ordinal
			Nominal (one per map)
Thematic Multimaps (set of thematic maps displayed in the same screen)		More than 1	Quantitive
Chorem map	Hierarchy	1	Ordinal
	Territorial dynamics	1	Nominal

Table 2: Evaluation of geovisualization methods.

Query	Measures	Measures type	SOLAP geovisualization	Our Framework
Q1"What is the total surface and production of wheat per country and year?"	two classical SOLAP measures	2 quantitative	Thematic map	
Q2: "What is difference of total production per country on the last 5 years on 2000?"	One chorem (production evolution)	ordinal	Cloropeth map	Hierarchy chorem map
Q3: "What is difference of total surface per country on the last 5 years on 2000?"	One chorem (surface evolution)	nominal	Cloropeth map	Territorial dynamics chorem map
Q4: "What is difference of total surface per country on the last 5 years on 2000, and the production on 2000?"	One chorem (surface evolution)	nominal	Cloropeth map	Territorial dynamics chorem map
	Classical SOLAP measure	quantitative	Thematic map	Thematic map
Q5: "What is difference of total production per country on the last 5 years on 2000, and the production on 2000?"	One chorem (production evolution)	ordinal	Cloropeth map	Hierarchy chorem map
	Classical SOLAP measure	quantitative	Thematic map	Thematic map
Q6: "What are differences of total surface and production per country on the last 5 years on 2000?"	One chorem (surface evolution)	nominal	Cloropeth Multimaps	Hierarchy chorem map
	One chorem (production evolution)	ordinal		Territorial dynamics chorem map

In table 2 we evaluate these geovisualization methods on 6 SOLAP queries. These queries represent all possible combinations of possible measures involved in a SOLAP query.

Query Q1 is a classical SOLAP query, therefore there is no need to use chorems.

Query Q3 concerns one chorem (surface evolution). Here using chorem visualization is very satisfying for the decision-maker since to each nominal value of the chorem (stagnation, etc.) a particular icon is used. Chloropleth map can be also used, but decision-maker is forced to mentally associate a colour to a surface evolution.

Thus, *chorem maps should be preferable to chloropleth maps for nominal measures*.

For the query Q2 chorem maps and chloropleth maps have the same expression power.

For the Queries Q4 and Q5, our framework presents the same advantage of Query 3.

Query Q6 concerns 2 chorems (surface and production evolution). Therefore, chloropleth multimaps (one chloropleth map per measure) can be used, but the main limitation is that the decision-maker has mentally to overlay the maps to compare the two measures country by country. *Thus our approach seems perform chloropleth multimaps*.

To conclude, our geovisualization methods based on chorems do not always replace classical geovisualization methods of SOLAP tools, but they appear useful when dealing with phenomena that can be represented as chorems.

However, usability test should be provided to quantify the advantage of using chorem maps instead of SOLAP maps. They represent our future work.

6 CONCLUSIONS AND FUTURE WORK

SOLAP systems allow decision-makers to on-line explore warehoused spatial data by means of SOLAP operators, which aggregate numerical indicators, to produce reports composed of pivot tables, graphical displays and thematic maps. However, when the analysed spatial phenomena are complex, advanced geovisualization techniques are need. On the other hand, it has been recently shown that chorem maps represent an excellent geovisualzation technique to summarize and reveal hidden spatial phenomena. However, chorem systems are based on pre-defined maps, which limit potentiality of spatial decision-making process.

Thus, the goal of this paper is to introduce a framework being capable to merge the interactive analysis capability of SOLAP systems and the potentiality of a chorem-based visual notation in terms of visual summary.

In detail, we propose a set of methods to on-line extract and visualize chorems on the top of a SDW. We also propose an implementation of our framework using a general architecture based on standards.

As future work, we plan to investigate other chorems as defined in (Lardon et al., 2005). We also plan to define a usability study to evaluate in a quantitative way the pro and cons of the usage of chorems instead of classical SOLAP geovisualization methods from a visualization point of view.

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