COP-VW: Cone-over-Projection Directional Model Viewer

Jefferson Amaral da Silva[1] and Karla Donato Fook[2]
[1]*State University of Maranhão (UEMA)*
São Luis-MA, Brazil
[2]*Department of Informatics, Federal Institute of Education, Science and Technology of Maranhão (IFMA),*
São Luís-MA, Brazil

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Abstract: An important feature for geographic systems is to identify directional relationships between objects stored in Spatial Database Management Systems (SDMS). This feature is used with other information type, such as Metric and Topological Relationships. This features group provides relative positioning between Geographical Objects in some direction, and supports decision makers job, such as to decide where setting up certain buildings, opening of access roads, and installation of transmission towers, for instance. Some approaches addresses to direction definition, but without implementation. Cone-Over-Projection Directional Model (COP Model) refines directions definition and enhances spatial queries accuracy in a significant form. The Model has a computational tool to support its application. This work presents the COP Model implementation through COP Viewer (COP-VW) application that uses Geometric Algorithms added to an SDMS located in a Web Server. Several users can access COP Model resources at different geographical locations, and different geodatabases can be available to environmental and urban planning decisions. This is a first step to migrate COP Model to mobile platform.

1 INTRODUCTION

The identification of Directional Relationships between objects stored in Spatial Database Management Systems (SDMS) can set a useful source of information. This feature combined with other, such as Metric and Topological Relationships supports urban planning job. Decision-makers use this features to decide where to make buildings, to open access roads, and to install transmission towers, for example. In these cases, is fundamental to know the relative positioning between Geographical Objects in a given direction.

Depending on the application domain, some spatial relations may be more significant than others (Papadias and Theodoridis, 1997). Topological relationships have a set of definitions and operations widely accepted (Egenhofer et al., 1991; Egenhofer and Franzosa, 1995). There's no unified Directional Relationships concept. This point is a problem and causes different approaches to define directions, each with its positive and negative points (Theodoridis et al., 1996).

As result, several models define the directional relationships, each one with their own characteristics. Researchers present Models in different implementation. Silva and Fook (2013) propose Cone-Over-Projection Directional Model (COP Model) to refine direction definitions. COP Model is a hybrid model that includes characteristics of the models based on Cone (Peuquet and Zhan, 1987) and Projection (Frank, 1992).

We highlight that the COP Model enhances spatial queries accuracy in a significant form, and aims to support decision makers in their resource management activities. This paper presents COP-VW, the computational tool that supports COP Model use. This software uses a Geodatabase hosted in a Web Server. This Geodatabase allows free access to information which supports decisions concerned to environmental and urban planning. In this case, makers' decisions can visualize several databases in different places around the world. There is a proposal to upgrade this Geodatabase to Mobile platform.

Next section presents directional relationships between objects approaches, and the COP Model

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adds. Section 3 presents COP Model and their characteristics. Section 4 presents COP Viewer specification, application, results and discuss about COP Model use. Finally, Section 5 presents some conclusions about the geographical application.

2 RELATED WORK

Authors propose directional relationships between objects approaches. There are two categories which include basic models for defining directional relationships: Cone-Based Models and Projection-Based Models (Xia et al., 2007).

The Cone-Based Models partition the space by using lines with an origin angle α (Figure 1). Typical models include the 4-direction Model, Figure 1(a), the 8-direction model, Figure 1(b), and the triangle model, Figure 1(c) (Tang et al., 2008). These Models provide an accurate identification of directional relationships for point geometries. However, misleading directional relations may be produced when reference objects are lines or polygons (Tang et al. 2008).

Figure 1: Cone-Based Model.

The Projection-Based Models divide space by using lines parallel to the axes (Spiros et al., 2007). The space around an object reference A is partitioned into nine areas:

- north (NA)
- northeast (NEA)
- east (EA)
- southeast (SEA)
- south (SA)
- southwest (SWA)
- west (WA)
- northwest (NWA)

These areas refer to the cardinal and ordinal directions. There is one extra region corresponding to the Minimum Bounding Rectangle (MBR) of the reference geometry (0A), as shown in Figure 2. In this category, the MBR Model is prominent (Tang et al., 2008).

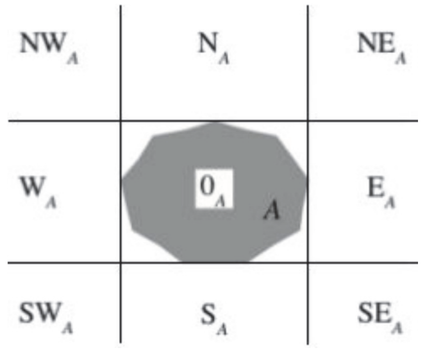

Figure 2: Projection-Based Model.

At first, Egenhofer et al. (2000) introduced a Minimum Bounding Rectangles (MBR) Model, which uses the 4-intersection matrix, projecting a grid over the concerned geometries (Egenhofer and Herring 1991). This Model expresses directional relationships between the MBR of the reference object A and the primary object B. It considers A (interior and boundary), and B (interior and boundary). Later, authors extended the model to 9-intersection matrix. Now the approach considers interior, boundary and exterior of A and B objects (Egenhofer and Herring 1991). Minimum Bounding Rectangles Model is not suitable for treating points, since they do not actually have MBR. Besides, Egenhofer work was theoretical, not presenting implementation.

Zhu et al. (2012) presents a model for defining directional relationships between geometries based on Geo-Ontologies. In this model, secondary queries made on Geo-Ontologies settle the directional relationships. The Zhu's model adds semantics to the research and enables tapping knowledge about the directionality in the objects represented in the ontology. However, this addition implies data arranged in the form of ontological basis on the studied area, and could result in spatial databases becoming incompatible with this model, if there is no ontology regarding their spatial context. Further, the ontological database is external to the SDMS, resulting in the need for two databases, one spatial and one ontological, separated to perform the search. Thus, integration with the existing SDMS resources becomes problematic and complex. In this work, the model is theoretical, and the implementation will be treated as a future work. Next presents COP-Model, which aims to improve the accuracy of spatial queries significantly.

3 COP-MODEL

Cone-Over-Projection Directional Model is a model for defining directional relationships between two geometries. For this, the model uses the union and adaptation of two models: 8 Directions Cone-Based Model and MBR Model (Projection-Based) introduced by Egenhofer et al. (2000).

COP Model simulates the human view angle, starting from a central point and grows as it moves away from the source with the ability to treat line and polygon geometries from Egenhofer model (2000).

The model developed core was overlapping the grid projection with the conical grid to identify areas where they differ. This feature reduces the gap between sizes of existing partitions on the projection model. The union of cone and projection models uses concepts and algorithms from computational geometry, and processes how objects relate to each other and with the regions defined by the designed model. COP Model improves significantly the accuracy of spatial queries. This feature is essential to support the territorial planning applications.

Da Slva and Fook (2013) developed a pseudo-implementation of COP Model. This pseudo implementation is generic and allows to be translated into various programming languages and in third-party application or database. These features were incorporated to SDMS. Developers can use this module as standalone software or as an extension of some existing Geographical Information System (GIS) as gvSIG, Kosmo GIS or QGIS. This implementation allows you to check the COP Model application and is a differential feature over others approaches.

Next section presents COP-VW, a Geographical Information System developed as a COP Model concept proof.

4 COP-VW

COP Viewer or COP-VW is software that allows COP Model application. Their architecture contains a Database Server. Several users in different geographical locations can access Geodatabase through Web to make spatial queries using COP-VW (Figure 3). The GIS allows that different decisions to be made for different territorial purposes more precisely. For example, select area to environmental protection or build factories or hospitals.

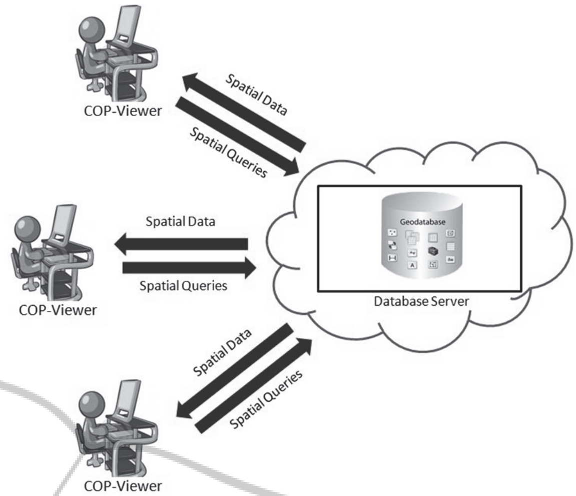

Figure 3: COP-VW Architecture.

We used the Java programming language, Sun Java Windowing (SWING) and Java 2D Graphics API (Java 2D) as follows:

- Java APIs such as Java Database Connectivity (JDBC) to connect with SDMS
- SWING to create the GUI
- Java 2D for graphic display of retrieved information from SDMS

There are several ways to implement new functionalities at Spatial Queries. We implement COP Model features as SDMS extensions from their source code. Geographical Information Systems only need to invoke operations aggregated to the database to use COP Model features (Figure 4). We stress this point as strong feature of work.

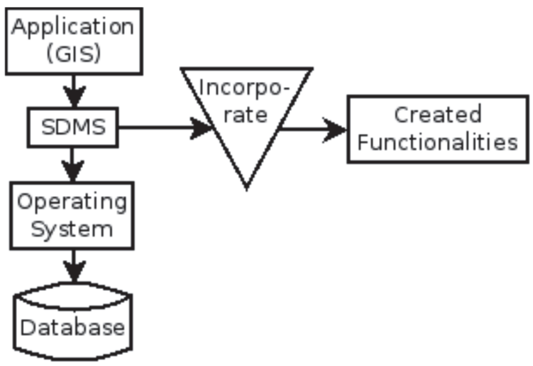

Figure 4: COP Model extensions insertion layer (Silva and Fook, 2013).

Spatial queries can unite topology and distance concepts with directionality concepts on the same database. COP-VW uses data structures of standardized SF-SQL hierarchy by OGC.

Figure 5: COP-VW main Form.

4.1 Specification

COP-VW works object concepts from COP Model. For this, we created classes to represent the information brought from SDMS. These classes were generated internally in the COP-VW. The model has two classes, and the spatial reasoning complexity was abstracted. We use standard Java programming language API and API provided by PostgreSQL/PostGIS.

The GIS includes resources to handle geospatial entities, objects and geometries, as well as a Descriptor Table. COP-VW uses SDMS and COP Model functionalities. There is not spatial processing functionality in it.

4.2 Implementation

COP-VW releases user to write SQL queries/SF-SQL directly. There are Forms to generate spatial queries visually. Figure 5 shows the main COP-VW Form. There are several parts in this Form: Figure 5 (a) displays information about the database connection and projection used by the geometries.

Figure 5(b) displays the spatial query produced by the tool. In Figure 5(c) there are creation and submit queries buttons. Figure 5(d) shows spatial layers presented in the open database. Figure 5(e) has graphical representation of the loaded geometries from database and results of spatial queries submitted. Finally, Figure 5(f) we see textual details recovered from spatial queries.

The display panel of the geometries shown in Figure 5(e) provides translational and scale features of the displayed geometry. This allows a better evaluation of the consultations results.

User can create Spatial Queries in a COP-VW Form (Figure 6). There are two different categories of queries available: “Test Target” and “Find Target”.

To perform “Test Target” type queries, user must inform: Reference Object, Target Object, and any direction of the COP Model. After that, COP Model implementation calculates the percentage of the area/length of Object Target in the direction informed towards the Reference Object.

Figures 6 and 7 show the Form for this query creation and its result, respectively.

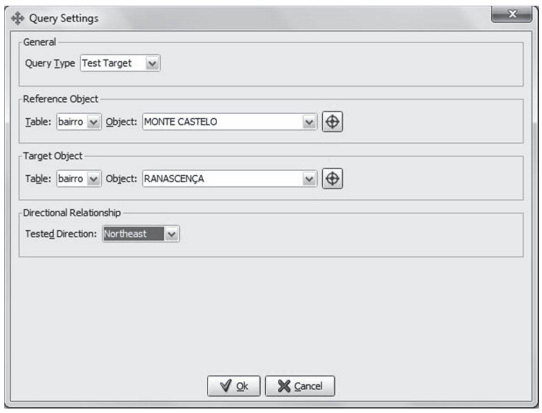

Figure 6: COP-VW “Test Target” query Form.

The COP-VW Query Text produced in Figure 6 is a SF-SQL: **`SELECT`**

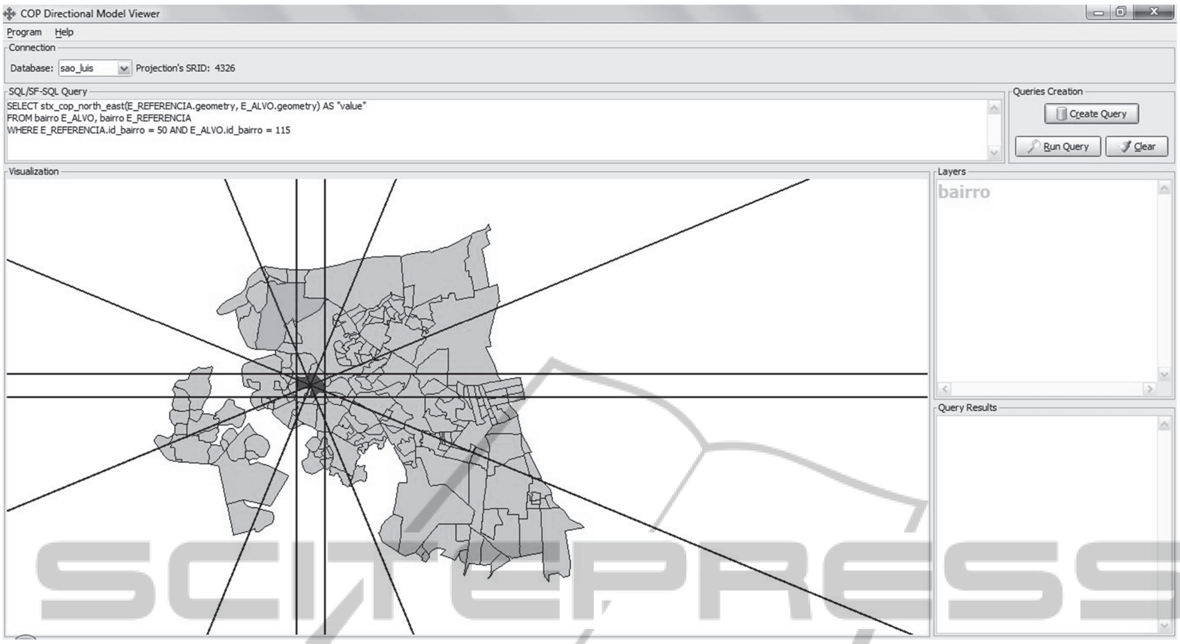

Figure 7: COP-VW result for "Test Target" query.

`stx_cop_north_east(E_REFERENCIA_geometry, E_ALVO.geometry)` **AS** `"value"` **FROM** `bairro E_ALVO, bairro E_REFERENCIA` **WHERE** `E_REFERENCIA.id_bairro = 50` **and** `E_ALVO.id_bairro = 115.`

Figure 7 shows output generated by query "Test Target". This query consists of a visual pointing Reference Object (magenta), Object Target (green) and grid lines Projection and cone.

User can make another category query using COP-VW: "Find Target". Figure 8 displays the Form to generate this query type.

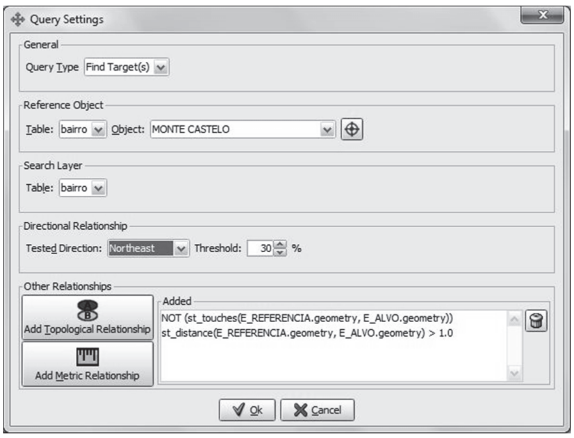

Figure 8: COP-VW "Test Target" query Form.

"Find Target(s)" queries need from user: object reference, a direction in which it will check for potential targets and the layer in which it will carry out the search. Application also requests a percent threshold for an object to be really considered valid target, because the percentage of area/length of the targets is considered.

Such consultations even offer the possibility of adding Topological and/or Metric Relationships tests. Thus, search results can be refined according to these characteristics of Spatial Objects. After that, COP-VW requests the SDMS to find Spatial Objects with requirements and limitations imposed.

An SF-SQL query example generated by this COP-VW Form is:

```
SELECT E_ALVO.texto AS "nome", E_ALVO.id_bairro AS "id",
stx_cop_north_east(E_REFERENCIA.geometry, E_ALVO.geometry) AS "porcentagem"
FROM bairro E_ALVO, bairro E_REFERENCIA
WHERE E_REFERENCIA.id_bairro = 50
AND
stx_cop_north_east(E_REFERENCIA.geometry, E_ALVO.geometry) >= 0.3
AND NOT
(st_touches(E_REFERENCIA.geometry,
E_ALVO.geometry))
AND st_distance(E_REFERENCIA.geometry,
E_ALVO.geometry) > 1.0.
```

Figure 9 presents the result of this query example.

The COP-VW also allows queries submission that relate different types and different Geometric tables, providing consultations involving the Polygon/Polygon, Polygon/Line, Polygon/Point,

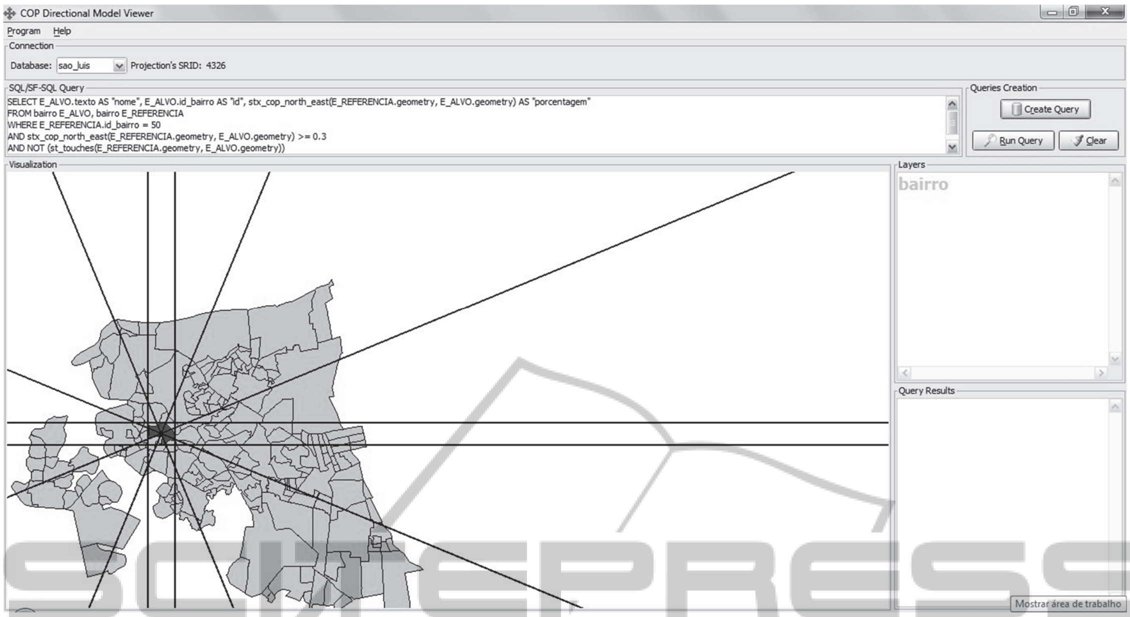

Figure 9: COP-VW result for “Find Target” query example.

Line/Polygon, Line/Line and Line/Point pairs. We carry out these cases in the SDMS extension and COP-VW only invoked them.

4.3 Discussion

Projection grid tends to partition the disproportionately space in that it moves away from the origin, favoring Side directions. The COP Model managed to minimize this by superimposing a conical grid. There were growth areas of the partitions to verify divisions generated by the COP Model. For this we used the same parameters used in the projection grating, or square with 1 unit MBR side and offset from 1 to 10 units away from the origin. Figure 10 shows the percentage distribution of space between the cardinals, side directions and added by COP.

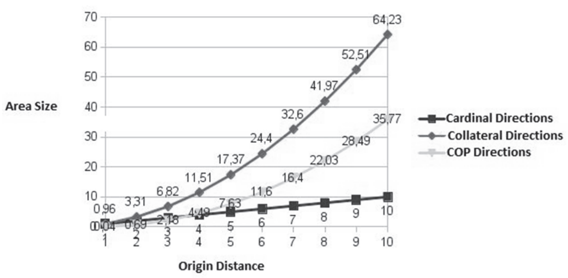

Figure 10: Growth Chart of directions in COP Model.

We show in Figure 10 an even exponential growth of the area presenting the Side directions and straight to the Cardinals directions. However directions added by COP Model also grow exponentially, which balances the growth of side directions, so this is not reaching the 59% of the partitioned area, as shown in Figure 11.

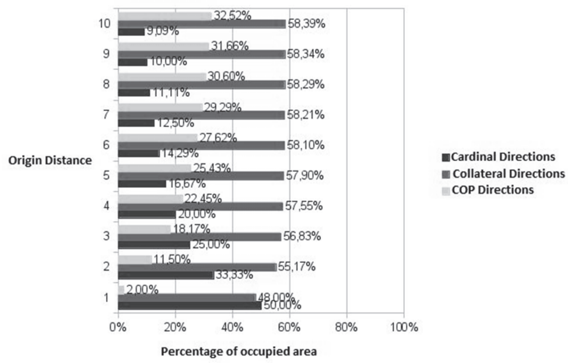

Figure 11: Percentage of space occupied by the COP Model directions.

According to user interpretation, areas of the cardinal directions with their respective COP directions can be added, and the COP directions are influenced by the cardinal directions. These considerations balance cardinals and collaterals. Figure 12 shows a comparison between the percentage areas occupied by cardinals and collaterals directions with the projection grid and the COP Model grid. We have the values related to cardinal directions and their respective influenced in the last one.

Figure 12 shows that with the COP Model grid, the growth of side areas is no longer exponential and

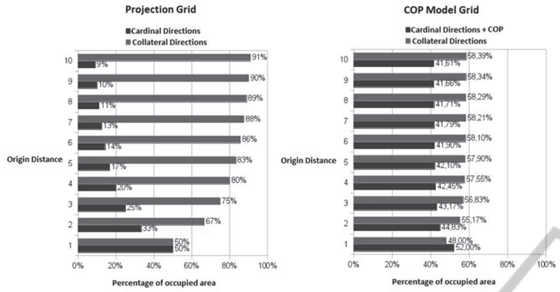

Figure 12: Comparison between Projection and COP Model partitions.

is replaced by closer linearity behaviour. Also be seen that as it moves away from the source, the gap in favour of the side direction continues to grow, but in smaller and smaller quantities. On the whole, the difference in areas that time had reached 82% in the Projection grid fell to 16.78% with the grid of the COP Model in this given situation. Thus, the model reduced the discrepancy between the areas by a significant way.

5 CONCLUSIONS

As a result of this work we granted some tangible artefacts: The mathematical definition of the COP Model, the COP ME (a suite of products that form the seamless deployment to SDMS), and COP-VW Geographical Information System.

The COP-VW allows to verify the COP Model implementation via Web, and to show that spatial processing functions carried out in the COP-ME are usable by a third-party software without needing redeployment or any specific suitability.

The presented GIS is the COP Model implementation from visual and friendly way. The implemented features could be tested individually and with existing features in SDMS, such as on the topological and metric relationships, so it was indeed found the implementation was faithful to the model definition. Further, the COP-VW can also be used as a graphic viewer geometries stored in any database that uses PostgreSQL/Postgis, regardless of whether or not using the COP-ME extension. COP-VW works with a Geodatabse located in a Web platform. This feature allows free access to information and supports decisions related to environmental and urban planning. Decision makers can visualize several databases in different geographical locations. This point is a strong feature of work.

As further work, we intend to develop the COP-VW in a Mobile platform. Finally, we stress that all procedures performed and created products were made using technologies free/opensource, which made the COP-VW free of the need to pay license fees, both for developers and for those using.

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