Towards a General Object-Relational Spatial-Temporal Data Model (ORSTD Model)

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ABSTRACT
Temporal-spatial applications need data modeling to show the complex behavior of objects with the change of time and place. This requires arguing the ability of object-relational model to provide a structure of storage, indexing, and organization to represent multiple dimensions for spatial-temporal systems and identify the behavior happening to them according to the conceptual framework (what/where/when) in order to make it a logical structure close to human cognition. This paper proposes a general Object-Relational Spatial-Temporal Data Model (ORSTD). The idea behind ORSTD model is to collect all spatial-temporal information in only one object using the concept of Nested Tables. ORSTD model can support and integrate that information efficiently within a dynamic environment. This model can also capture different attributes and behaviors of a location and time and reflect them in nested tables in a way that it can be expanded to different spatial-temporal applications. The proposed model, ORSTD, has been verified for different spatial temporal scenarios, and results show that the proposed model can represent spatial temporal efficiently and effectively.

Keywords: Object-Relational, Nested Table, Pyramid Framework, Third Structure, Space and Time Applications.

1. INTRODUCTION
In the real world, there are many applications required to support time and spatial such as natural phenomena control, computing traffic network, land parcels traffic volume at different times, biological systems, and Geographical (GIS) [6, 8, 10].

In fact, traditional database systems cannot store and manage a complex data such as spatial-temporal data [2, 7]. Despite the ease of spatial-temporal data gathering, the operation of storage and management of this data has imposed another challenge, which is the modeling of spatial and temporal data. This modeling will facilitate of data analysis and show multiple dimensions of spatial-temporal behavior logically as closer as to human understanding [5, 7, 8, 17].

Modeling spatial-temporal data requires that the spatial and temporal attributes should be integrated together [8, 10, 16]. In addition, the modeling also needs to the discrete representation of continuous phenomena so that all changing states of the objects should be continuously modeled [8, 10, 17].

Many researches conducted in this area show that the researchers were always willing to provide different models to meet the requirements mentioned above; however these models were related to specific applications. Few studies addressed an overall framework that can be extended to various temporal-spatial applications [3, 5, 8, 10, 18]. A contribution of this paper is providing a model capable of achieving all requirements mentioned above.

As mentioned earlier in this section, there is a challenge that arises from the traditional database systems. This challenge is the difficulty to store and manage a complex data such as spatial-temporal data. Thus, object-relational database management systems become the new standard for addressing the growing data management and analysis [2, 6, 7, 19, 20].

Object-relational database management systems provide an infrastructure that can create a multi-structure representation that can incorporate concepts closer to humans' perception. This can be achieved by using Abstract Data Types (ADT) and associated functions such as adjacent () and SDO_GEOMETRY. These functions are used to create and manipulate geometries [2, 6, 7, 14, 15, 20].

This paper aims at developing a novel model called ORSTD that tries to integrate space and time using object-
relational approach. ORSTD can describe Multiple-dimensions based on the conceptual framework (what/where/when). In addition, it can represent both spatial and temporal attributes together and model the continuously changing objects. It also can show multiple dimensions of spatial-temporal behavior logically closer to human understanding and finally, it can be extended to various temporal-spatial applications.

2. RELATED WORK
This section reviews the most important studies related to this research.

Authors in [8], proposed a general object-oriented spatial-temporal data model, Restructuring of this model consists of three class store them theme, space and time attributes, and show the behavior for Spatial-Temporal applications, The results showed a partial solutions to some problems such as the separation of space and time, application driven, and continuous spatial change. However, the proposed model does not support temporal spatial query language well.

Authors in [9], proposed spatial-temporal data model based on business process of resource management according to the theory of the object-relation model. The branching spatial data model based on point sets, the location-based branching spatial data model, the branching temporal data model and the relations among these sets. However, the proposed model does not support temporal spatial query language and did not give the scenarios to model work.

Authors in [10], proposed a spatial-temporal data model for biodiversity using the object-relation approach Based on Donna J. Peuquet’s pyramid framework [3]. However, the proposed model does not give details about the geometric Attributes, behavior and how to manipulation them.

Authors in [11], aim at extending object relational database management system to support spatial-temporal data. The authors proposed A Spatial-temporal data model for biodiversity. However, the study does not focus on temporal query language and spatial-temporal topology.

Authors in [12], proposed a sound basis for the development of spatial-temporal conceptual models, based on the orthogonality principle in adding space and time to data structures. However, the study does not focus on spatial-temporal query language.

3. THE DATA MODELING APPROACH
This paper proposes modeling of data across database with efficient and effective, and has a logical structure clear and understandable, and easy to maintenance and expansion. This section presents over proposed model ORSTD

3.1. The Mechanism of Data Modeling Approach
The idea behind the proposed model ORSTD depends on the three-dimension of the spatial-temporal objects, that each object have theme, space, and time attributes as shown in Figure 1.

![Figure 1: The three-dimensions of the spatial-temporal object](image1)

Extending object-relational spatial temporal data model from Pyramid Framework (what/where/when triad structure) as shown in Figure 2.

![Figure 2: The Pyramid Framework (what/where/when triad structure)](image2)

Object-relation model ORSTD takes the quality from object-oriented model and takes the flexibility from the relation-oriented model, which provides structure solution, through the use of Abstract Data Types (ADT) , from these types can create the nested table, which can be structured that support is represented in a Pyramid Framework (triad structure), and this is what we will discuss in the next section.
3.2. Nested Tables Structure

Structure of the proposed model ORSTD has been implemented in only one object (Nested Tables), which can take the information easily because all the information is stored in only one object, Figure 3 illustrates the structural components of the proposed model.

![Nested Tables Structure](image)

Figure (3): The Nested Tables Structure

Modeling the three-dimensional data for the spatial-temporal systems via nested tables consists of a triad structure, representing the spatial-temporal attributes and defines the input data and processes that are the types of behavior in spatial-temporal systems, and that the model supports various relationships between objects as shown in Figure 4.

![Nested tables consist of a triad structure](image)

Figure (4): Nested tables consist of a triad structure

3.2.1 Attributes

The first column in the table represents the theme Attributes (the first dimension), which enters the information for each object “What is this object” and other related property information, can define different types of attributes, and also inherited (Figure 5).

![Different Types of Theme Attributes, and also inherited](image)

Figure (5): Different Types of Theme Attributes, and also inherited

The second column of the table used to support spatial-temporal columns containing multivalued attributes, Represents one column in the nested table, the Attributes of the space (the second dimension), which enters the information for geometry, also can rely to object data type (MDSYS.SDO_GEOMETRY) to create set of primitive spatial data types (point, line, area), complex spatial data types and operations on these data types like intersection and distance, and also inherited as shown in Figure 6.

![Complex spatial data types and operations, and also inherited](image)

Figure (6): Complex spatial data types and operations, and also inherited
The other column in the nested table represents the attributes of the Temporal (the third dimension), which will enter the information for timestamps, also can rely to object data type (datetime, interval datatypes, time zone) to support store consistent information about the time of events and transactions. The time information stored will represent timestamps. Figure 7 illustrates that each timestamps is the instant and the time between two timestamps is the Interval.

<table>
<thead>
<tr>
<th>Theme Attributes</th>
<th>Spatial-Time Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID</td>
<td>NAME</td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Fig (7): The time information stored will represent timestamps

### 3.2.2 Behaviors

ORSTD model defines different types of object behavior such as relationships among a set of spatial objects (topological, network and metric), temporal relationship with other objects.

- **Stay-in**: object stay-in one status during period of time.
- **Transform-between**: object transform from one status to another during period of time.
- **Appear/disappear**: object attributes values appear or disappear during period of time.
- **Increase/decrease**: object Attributes values Increase or decrease during period of time.
- **Splitting**: object splitting to two or more objects during period of time.
- **Moving**: object moving from location to another location.

### 3.2.3 Relationship

ORSTD model supports relationships among the components of the object.

- **One to many** relationship: one theme attribute may be related to more spatial attributes and many timestamps (theme attribute doesn’t change during this interval while the spatial or/and Temporal attributes changed)

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**Figure 8** illustrates some cases of behavior that are supported by the model.

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**Figure 9**: Model supports different types relationships
4. EXPERIMENTAL STUDY

This Section presents the experimental results and evaluation of our approach ORSTD that has been implemented Oracle 11.2.0.3 by using tools Toad9, and the experimental study by three stages.

4.1. Collection and Preparation the spatial-temporal data

In this stage collection the historical spatial-temporal data set, Taking the lake Spatial-Temporal data from GeoCommunity site " http://data.geocomm.com ", The site interested in the Geographic Information Systems (GIS), CAD, Mapping. and the prepared of the lake Spatial-Temporal data has been cancel some Spatial attributes such as Bathymetric and others attributes, and maintain only the attributes of the border, and the lake Spatial-Temporal data set covering the changes of 12 years.

4.2. Develop the ORSTD model.

In this stage it build the physical ORSTD model by using the object-relational database management system, and the lake Spatial-Temporal data imported to manipulation by oracle object-relational database management system. Figure 10 shown the lake Temporal-spatial data set during the 12 years.

4.3. Analyze the Results.

In this stage it analysis how the ORSTD model supports various spatial-temporal phenomena, and how the ORSTD model explains the spatial-temporal changes inside an object or among objects.

Figure 11 shows the graphical representation of the spatial-temporal data to the lake that store in the nested tables, which explains some of the temporal spatial phenomena inside the object or among objects.

- **Stay-in**: stay the lake at it is from the beginning of the first year to the end of the first year.
- **Transform-between**: from the beginning of the second year to the end of the lake transform to a new status.
- **Increase**: Increase the lake volume during the period from the beginning of the third year to the end.
- **Decrease**: Decrease the lake volume during the period from the beginning of the fifth year to the end.
- **Splitting**: During the period from the beginning of the seventh year to the end of the lake Splitting into two lakes
- **Appear/disappear**: the appearance and disappearance of the new lake during the period from the beginning of the seventh year to the end of the twelfth year
From Figure 11 we note that the model can support different Spatial-temporal phenomena, and to give different interpretations of the changes taking place within the object or between objects such as stay-in, transform-between, Increase/ decrease, appear/disappear, splitting, etc, and show the temporal changes in different time events (linear, cycle, or branching).

4. CONCLUSIONS

This paper presents our proposed model ORSTD based on extending object-relational database to support spatial-temporal, the purpose of this study to provide a general object-relational spatial-temporal data model, Capable of supporting and integrating spatial-temporal information efficiently, understand more complex geometric data types like points, lines, and polygons, and explain the different types of object behavior such as relationships among a set of spatial objects (topological, network and metric), and temporal relationship with other objects.

As a future work, the proposed model can be improved and extended to deal efficiently with different types of the spatial-temporal applications and phenomena especially GIS applications. This can be achieved by appropriate adjustments to the structure of the nested table so that it can adapt to various restrictions. An extensive work can be addressed to improve spatial-temporal query language.

6. REFERENCES