

Prism Geometry: Simple and Efficient 3-D Spatial Model

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1. INTRODUCTION

With the recent increase of demands for 3D information, we need a robust data model of 3D spatial objects to meet the requirements from diverse applications. For this reason, several studies have been done out by ISO/TC211 and OGC, among which the data model of ISO 19107[2] and the data model for KML[6] are the most important ones. The data model of ISO 19107 provides a strong expressive power of 3D spatial information with a sophisticated model for full 3D solid object. And GML[4] is based on the spatial data model of ISO 19107. However this data model has a serious drawback that the size of data in GML is large and the implementation of ISO 19107 is difficult and heavy, due to the complicated structure of this data model.

On the contrary, the data model employed by KML, which has been developed for the use of Google Earth, includes a simple 3D spatial data model to offer visualization services of 2D and 2.5D spatial objects. Compared with GML, the size of data in KML is smaller than GML and most of systems supporting KML are lighter than those for GML. However the expressive power in KML is limited due to its simple spatial data model and COLLADA, which is another data format for 3D spatial objects, must to be used if the 3D information is complex.

In this paper, we propose an alternative 3D data model, called *prism model*, to provide an enough expressive power and achieve a satisfactory efficiency at the same time. Note that the prism means not only the *triangular prism* but also *polygonal prism*. Our model is based on the extrusion technique to represent 3D objects from 2D footprint spatial objects like the model in KML. But we generalized it to handle more diverse shapes with upper and lower geometries as shown in figure 1.

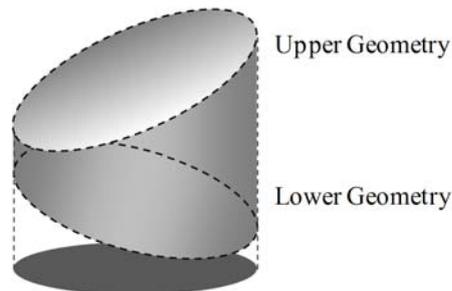


Figure 1: An example of prism geometry

The rest of this paper is organized as follows; in section 2, we introduce the basic concepts of the prism data model. We give a brief comparative study of our model with other 3D spatial data models in section 3 and conclude this paper in section 4.

2. SCHEMA OF PRISM MODEL

The geometry schema of the prism model is based on the simple feature geometry[5] model of OGC. Figure 2 shows the diagram of basic prism model. It contains three types of extrusive geometry, *extrusive point*, *extrusive curve*, and *extrusive surface*, which are a subclass of curve, surface, and solid respectively. Each extrusive geometry is bounded by one lower and one upper geometries, which have the same 2D footprint geometry. The vertices of an upper geometry have higher z-values than lower geometry. These properties are described as follows.

Property 1: Footprints of lower and upper geometries

$$\forall p \in G_{upper}, \forall q \in G_{lower} \rightarrow p.x = q.x \wedge p.y = q.y \wedge p.z \geq q.z$$

Property 2: the height values of lower and upper geometries

$$G_E = \{(x, y, z) \mid z_{lower} \leq z \leq z_{upper}, (x, y, z_{lower}) \in G_{lower}, (x, y, z_{upper}) \in G_{upper}\}$$

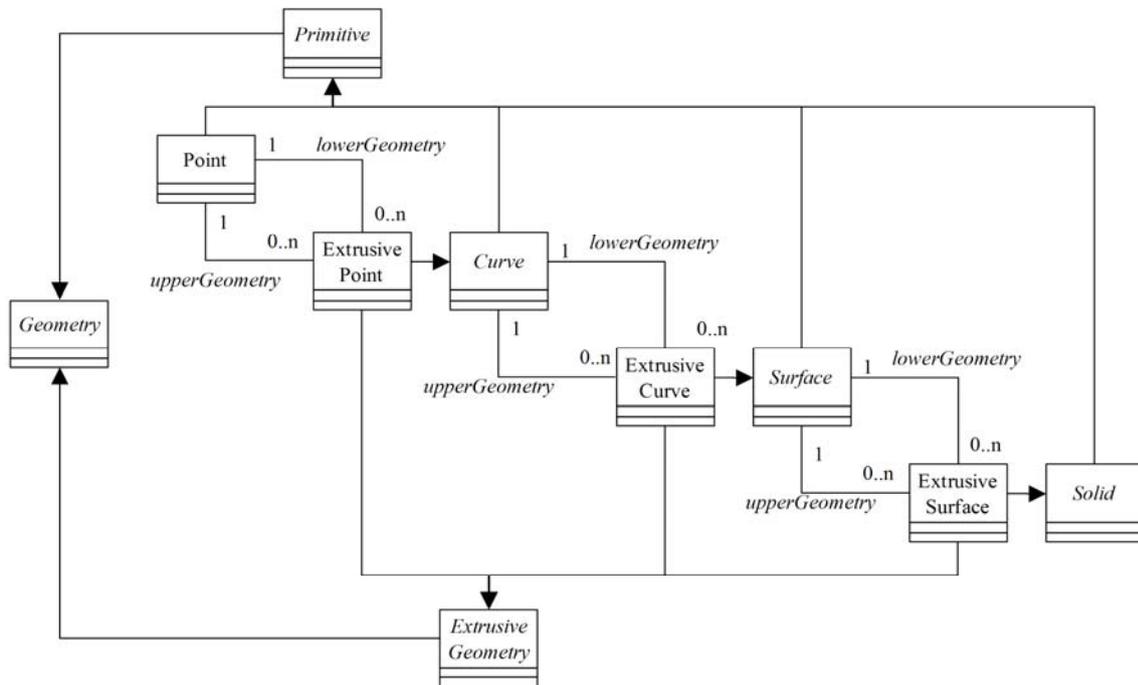


Figure 2: The diagram of extrusive geometries

For example, a solid is represented by an extrusive polygon with a lower and an upper polygon, which are in fact a subset of surface as depicted by figure 3 and 4.

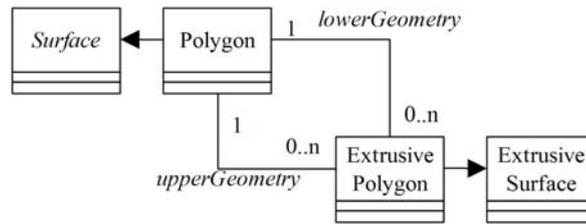


Figure 3: Diagram of data model for extrusive polygon

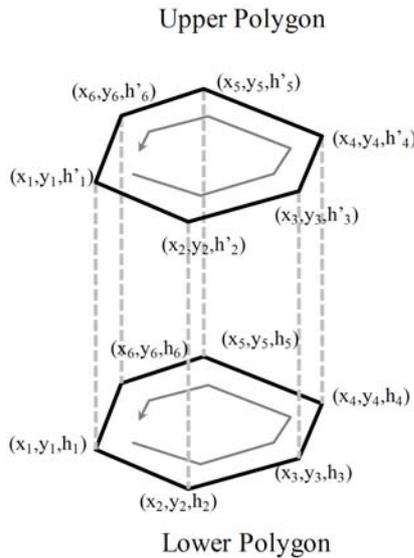


Figure 4: An example of extrusive polygon

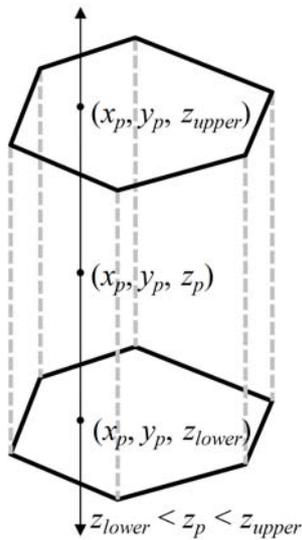
3. COMPARISON OF PRISM MODEL WITH OTHER 3D MODELS

The prism model has several advantages as follows. First the prism model is simpler and contains less geometric component than the ISO 19107 and consequently the size of data by our model is smaller than GML. For example, a cube is composed of 8 vertices, 12 lines and 6 faces by the model of ISO 19107, while it is described by 8 vertices, 8 lines, and 2 faces. It means that the storage, data transfer, and geometric computation efficiency by the prism model is better than the ISO 19107 because of the smaller size of data.

Second, we apply the 2D filtering technique to process 3D spatial queries, which is a common query processing policy for 2D spatial databases. For example, given a 3D range query, we first filter only the spatial objects contained by the 2D footprint of the query region and then refine the small number of candidates obtained from the filtering step to check if they are really in the given 3D range. It is possible and efficient since most 3D objects such as buildings and facilities are placed on the terrain.

Third, the 3D geometric computation by the prism model is more efficient than full 3D geometric computation. For example, in order to compute the point-in polyhedron, we first check if the point is lower than the upper geometry and upper than the lower geometry and second if the point is contained by the footprint polygon as shown

by figure 5. This algorithm is much simpler than the geometric computation with full 3D.[1]



Algorithm 1 Point in extrusive polygon

```

PointInExtrusivePolygon( p, g_upper, g_lower )
1  if ( PointIn2DPolygon( p, g_upper ) ) then
2    if ( g_upper.z ≤ p.z ≤ g_lower.z ) then
3      return true
4    endif
5  endif
6  return false

```

Figure 5: A query example of point in extrusive polygon

Fourth, most 3D geometries can be described by the prism model. If a 3D geometry, for example an arbitrary polyhedron, is complex, then we can decompose it into a set of prisms and represent the geometry by the set of decomposed prism. However the 3D objects with curved surfaces can not be represented by the prism model.

Figure 6 shows the relationship between the expressive power of the 3D spatial data models. The model of ISO 19107 or GML contains most of 3D geometries, while the model of TEN(TETrahedronized irregular Network)[7][8] includes only polyhedron. The expressive power of prism model is almost equivalent with that of TEN model except that it may include not only plain face but also curved face for upper and lower geometries. It means that the expressive power of the prism model is slightly stronger than TEN.

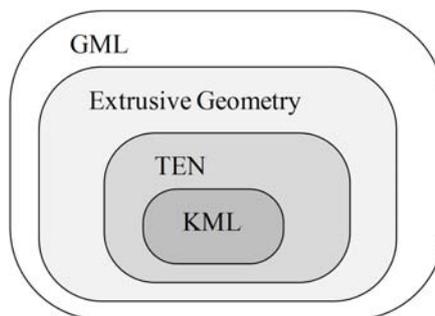


Figure 6: Relationship between 3D solid models

4. CONCLUSION

In this paper, we proposed the prism model which is an alternative 3D data model. The characteristic of our model are summarized as follows;

- The model represents 3D geometry using a pair of lower and upper geometries.
- The model is simple because of redundancy removal of data.
- The model is able to do efficient query processing using 2D spatial properties.

In this paper, we validated that 3D geometric computation by the prism model is efficient. Therefore we will develop efficient algorithms of processing of 3D geometric operations such as intersections between polyhedrons by the model and verify by experiments for the future.

5. ACKNOWLEDGEMENTS

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