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Modified R-tree Model

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Abstract: ***In this paper, the modified model of the R-tree structure was suggested. The main difference between classic R-tree structure and the modified model is rejection of the restriction for amount of descendants for each tree node. In addition, the proposed model supports three types of the relations between objects. Two types of the relations implemented based on hierarchy tree structure and one as reference connection at the same level of the tree hierarchy. The created model is very suitable for CAD systems development, especially for construction field.***

Keywords: R-tree, building object, hierarchy structure, objects relations types, BVH-tree.

1. Introduction

The 2D graphics subsystems, which are used in complex CAD systems, must satisfied at least two conditions: rapid objects display and rapid objects access. For the most cases, all objects in CAD systems have topological relations and combine in some hierarchy with arbitrary depth.

The best structure for the graphics object indexing is the R-tree [1]. The tree automatically supports hierarchy, thus we can use this feature for the objects topological relations storing. Besides, we can create a system of classes based on R-tree, which could be suitable not only for the objects hierarchy but all others aspects of the objects processing – creation, modification and destruction.

2. The Model

2.1 Basic Modification

We need make some improvement of R-tree to create such kind class system. Firstly, restrictions for minimal and maximal amount of descendants for each tree node must be removed. Suggested modified R-tree can contain arbitrary number of the descendants for any tree node. We get unbalanced tree structure but flexibility and simplicity much more important in this case.

The modified R-tree can be used for direct description of the hierarchy of the graphics objects, which are used for building objects modeling. For example, we can consider a floor plan of any building. Object “floor” is the root pf the tree and all others building elements of the floor are nodes of this tree. The floor can be divided into sections and the sections can by divided into zones. The zones consist of walls, beams, columns, slabs etc. The walls can consist of windows and doors, Windows and doors can consist of small elements: slopes, windowsills, frames etc. (Fig. 1).

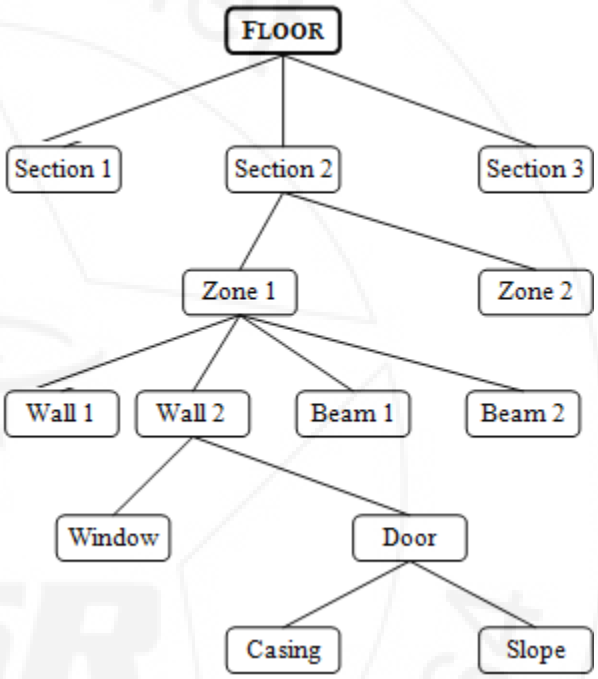

Figure 1: An example of the modified R-tree, which is describes a floor plan of a dwelling house

2.2 Modification with Relations

Another important modification of R-tree is the thing that the modified R-tree in contradistinction to classic R-tree allows cases when the same object is present in several different branches. It is necessary to full coverage of three possible kinds of the topological relations: “including”, “grouping” and “linking” [2]. Especially it is important for the “linking” relation. In the example at Fig. 1 this kind of the relation is possible for the objects “zone” and “wall”, because the same wall can be linked to several zones so far as it boundary between them. The same thinking we can apply for all other building elements.

Based on the previous thinking about the “linking” relation, the tree at Fig. 1 should be modified to obtain all possible links (Fig. 2).

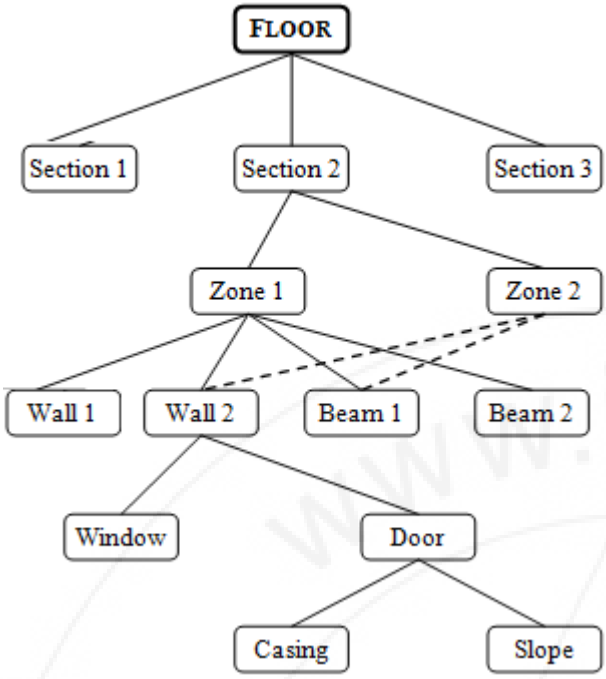

Figure 2: An example of the modified R-tree with the "linking" relation addition

After the "linking" relation addition, we obtain the new structure, which is not tree in classic meaning. In fact, it is some graph with hierarchy elements and such kind of structure is very difficult and muddle. For the sake of removing the negative consequences, which are inherent to tree structure at Fig. 2, it is suggested to use relations "including" and "grouping" as basis for the modified R-tree construction. In this case, the trees will have distinct hierarchy and will not have nodes with multiple parents. The "linking" relation should be used at the same level of hierarchy only (Fig. 3).

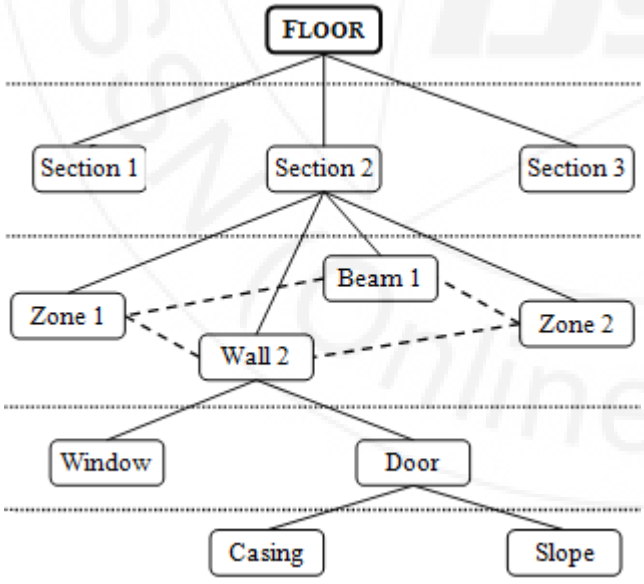

Figure 3: An example of the modified R-tree with the "linking" relation at the same level of hierarchy

Software implementation of such kind of the relations is very simple – it is enough to have three lists for each kind of the relations in every object. However, the relations "including" and "grouping" must be mutually excluded, thus they can be put into one list with additional flag, but it is not substantial and depends on implementation.

2.3 Extension to 3D

Extension of the classic R-tree to 3D is BVH-tree (Bounding Volume Hierarchy). All signs of the classic R-tree are kept here and different bounding volumes are used as the bounding boxes. For the most cases, it is an axis-aligned minimal bounding box but it can be arbitrary solid body (prism, sphere, pyramid and etc.) [3].

The modified R-tree extension to 3D keeps all characteristics were described above and use an axis-aligned minimal bounding box as bounding volume. From the implementation point of view, it is the simplest solid body, which allows making efficient search in 3D space.

As for 2D case, the 3D modified R-tree has all three types of the relations between objects: "including", "grouping" and "linking". In fact, the 3D tree structure is the same to the 2D tree structure, the differences only in the boundary shapes, the object representations and the searching algorithms.

In addition, one important thing – usually 3D representation of the objects consists of several geometric primitives, but the leaf node of the tree is always full building object. For example, 3D representation of the building object "column" consists of several polygons (quadrangle or triangle for the most cases), but the leaf node of the tree is the building object "column" and not it geometric parts.

3. Conclusions

The modified R-tree model considered in this paper allows creating efficient data structures for the hierarchical objects and in particular for 2D and 3D modeling of the building objects.

As the future work, it would be great to describe more accurate and detailed method of implementation the suggested model into software application.

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