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A Efficient Indexing Maintenance Method for Grouping Moving Objects with Grid

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Abstract

When we take cognizance of the regular track of moving objects within a limited area, we put forward an indexing method for grouping the moving objects with Grid based on Time-Parameterized R-tree (GG TPR-tree). With the GG TPR-tree, we can use the grouped moving objects which are neighbors and will run to the same direction in the future to improve the efficiency for indexing. So, we put forward the grouping algorithm and clustering algorithm based on grid, and moving objects indexing maintenance algorithm and moving objects indexing update algorithm based on grouping. Experimental results show that the performance of GG TPR-tree's indexing maintenance method is better than the other indexing structure on managing a great capacity of moving objects within a limited area.

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Keywords: moving objects; grid technique; GG TPR-tree; indexing maintenance method

1.Introduction

Conventional index method of moving objects was put forward aiming at the movement uncertainty of the moving objects. It believes that the movement of the moving objects is like that of the molecule, stochastic and irregular. But in practice, because the moving objects are manual-controlled, the actual movement of the mobile devices reflects the user's requirements, and even the devices exercise along with the user. Therefore, most of the movements are not without purpose and inevitably reflect the features of group and collaboration. The efficiency of the index will be improved greatly when these features are dig deeply and are taken good use of to control the moving objects by group.

Through observation we find that whether the mobilization of personnel and equipment in military field or the supervision and navigation of the vehicles in civil field, the moving objects finish their movements in the man-defined spatial grid lines with certain binding character in most of the time. The spatial grid lines are not only the highways at all levels, but also include the new roads temporarily opened for some missions, the existing lines of airplanes and ships and so on. Even if the moving objects have to bypass and

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leave the current route for some reason, including road construction, roads damaged by the enemy and so on, this behavior is still in group and the routes they choose can still be regarded as spatial grid lines. [1, 2]

To this end, we put forward the grouping algorithm and clustering algorithm based on grid, and moving objects indexing maintenance algorithm and moving objects indexing update algorithm based on grouping.

2.Grouping algorithm based on grid classification

For convenience, we use road network to represent the spatial grid lines in order to illustrate our thoughts in the following presentation. Grouping decision procedure based on road network:

2.1.Analysis of the Moving Objects' Mode of Motion

According to the motion characteristics of the moving objects, we can regard them as the points whose spatial locations change over time. In the database, we can use<Loc, Vec, A_1, A_2, ⋯, A_n> to state, Loc representing the spatial location of the moving objects in the reference time, Vec representing the velocity vector of the moving objects in the reference time and A_1, A_2, ⋯, A_n representing the non-spatial attribute of the moving objects. [3, 4] Based on the analysis above, we know that regardless of whether a group of moving objects logically belong to the same group, as long as they exercise on the same group, they must bear the similar motion attribute due to mutual constraints. That is to say, they have the similar character like Loc and Vec. Therefore, we can abstract their common attributes by grouping to do the overall index and maintenance, which will reduce the cost of indexing and maintaining the moving objects.

The relationship among the grouping moving objects can be divided into two categories: one discusses the relationship among the moving objects within the same group, while the other discusses the relationship among the moving objects within several groups.

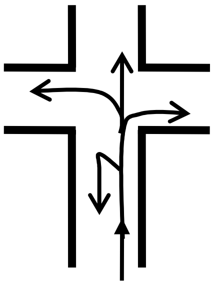


Figure 1. The moving kinds of a group of moving objects.

- Analysis of the Moving Objects' Moving kinds within the Same Group

  When a group of moving objects move in the road network, the regularity for change of Vec can be discussed in the following four situations:

  (1) The constant linear motion of which the moving direction of Vec does not change, as well as its motion speed (or base on certain average speed, on which a little rise and fall is allowed);

  (2) The speed-change linear motion of which the moving direction of Vec does not change, but its motion speed has a wider scale of acceleration or deceleration. It mainly happens on intersections or other situations which an emergent avoidance is needed;

  (3) All moving objects change the motion direction of Vec according to a common rule, and this way of motion mainly happens on situations like carrying out on curves or turning around;

  (4) All moving objects change the motion direction of Vec according to different rules, and this way of motion mainly happens on road sections like crosswise or retro- gradation roads;

From the analysis above we may know that under the second way of motion, this group of moving objects will restore to the former moving state after passing the crossroads. The relative relation between them does not change, which is same to the first way of motion, but the average speed under the second way of motion is lower than it under the first way of motion. Consequently it has no influence on the grouping of moving objects. While in the same way, if the moving objects all turn around with the same speed under the third way of motion, and keep moving forward in the speed before turning around, it also has no influence on the grouping of moving objects. While since all moving objects in a group are arranged according to certain sequence, so the moving object in the behind has certain delay no matter on the change of speed or the change of direction compared with the former one. Therefore when the former moving object slows down, the lower speed of the boundary rectangle begins to go down, but the upper speed still need to accord with the speed of the delayed moving object, so the area of the boundary rectangle is enlarged, and the index efficiency of retrieval is reduced. Since the moving objects under the fourth way move in detaching motion toward different directions, so objectively the nodes in which the moving objects lie need to be divided in a further way, thanks to which problems like the area enlargement of boundary rectangle and the reduce of index can be avoided.

- Analysis of the Moving Objects' Moving Kinds within Several Groups

The interaction of several groups can be seen as that of two moving objects within one group, so here is the case discussing the interaction between two groups. Two groups of the moving objects exercise in the road network and their moving kinds can be divided into two situations:

- Two groups of the moving objects are going around a turn. Because of the same and similar Vec, we can combine the two groups and index in order to improve the index efficiency. (2-a)
- (2) The Vec of the moving objects is in the opposite direction. In this case, it is not appropriate to combine the two because the combination will cause the rapid expansion of MBR and index efficiency will fall down. (2-b)

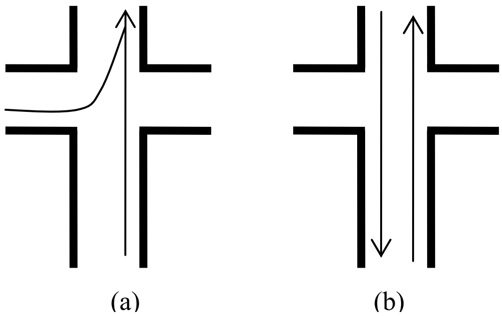


Figure 2. The moving kinds of several groups of moving objects.

2.2.Index of the Moving Objects Based on Grid Grouping

Through the analysis above, the existence of the grid represented by road network will achieve batch management of the moving objects on the whole and reduce the intermediate links of the index maintenance, thereby increasing the index efficiency. Therefore, we put forward GG TPR-tree based on Grid Grouping. This method groups the moving objects on the basis of their grid field, such as the road network, achieving high efficient index and management.

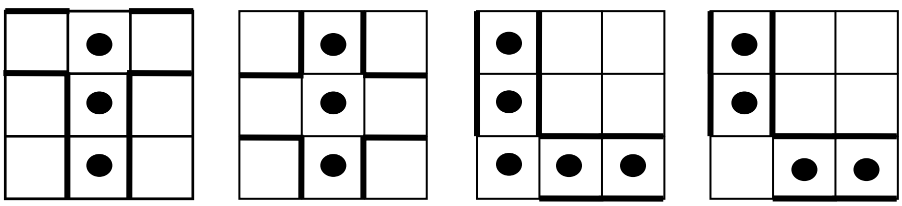
To better illustrate the grouping algorithm based on road network, we conduct the following definition:

Definition: confluent nodes: when a moving object is similar to another one in movement direction, transitional speed and transitional direction, and meanwhile their distance is not beyond the index structure's maximum distance, we say that these two moving objects are compatible. By extension, if any two nodes (leaf nodes or intermediate nodes) meet the requirements above, we say that these two are compatible.

Algorithm 1: Grouping with Gird (GG)
Input: old group node
Output: new group nodes
BEGIN

- Devise the original MBR respectively horizontal and vertical into 9 blocks.
- For all moving objects Do
- Insert the blocks into the corresponding location： $G_1,\cdots,G_9$
- Calculate the distance d of the grid object to the MBR center.
- Calculate the average distance from the point to the MBR Center： $\overline{d_n} = \left(\overline{d_{n-1}} \times (n-1)\right) / n$
- End For
- If Average distance $\overline{d_n} \geq 1$ Then
- Delete old group node from GG TPR-tree
- nodestack $\leftarrow G_1,\cdots,G_9$
- For all g $\in G_1,\cdots,G_9$ Do
- If $\overrightarrow{v_{g_1}} = \overrightarrow{v_{g_2}}$ Then
- Delete g_1, g_2 from nodestack
- nodestack $\leftarrow g = g_1 \cup g_2$
- End If
- End For
- End If
- For all node $\in$ nodestack Do
- insert node into GG TPR-tree
- End For

END



（a） （b） （c） （d）

Figure 3. The process to separate a group of moving objects.

In GG algorithm, one to six steps project the moving objects to the Grids which divide the original MBR in three equal parts horizontally and vertically; seven to sixteen steps delete the groups that meet the conditions and do the re-grouping according to the classification structure of the moving objects in various Grid; seventeen to nineteen steps insert TPR-tree of new grouping standard to the algorithm and insert into a sub-tree with top-down searching algorithm, starting from the root node and thus finish the index maintenance.

2.3.Clustering Algorithm Based on Grid Classification

When the overlapping phenomenon happens, because the location and the motion regularity are similar among two groups of moving objects, in order to increase the index efficiency, we need to take the way of merging by group to maintain the index. Therefore, we put forward CG algorithm. The idea of this algorithm is that when two groups of moving objects gradually increase their compatibility to the extent that the gravity spacing d< ε , merging index can increase the future efficiency.

Algorithm 2: clustering with Gird (CG)
Input: old group nodes
Output: new group node
BEGIN

- Devise the original MBR of group1 and group2 respectively horizontal and vertical into 9 blocks.
- Calculate the average distance from group1 and group2 to the MBR Center respectively： $\overline{d_{group_1}}$ 和 $\overline{d_{group_2}}$
- If $\left|\overline{d_{group_1}} - \overline{d_{group_2}}\right| < \varepsilon$ Then
- For all node $\in$ $\text{group}_1 \cup \text{group}_2$ Do
- Insert node into new group
- End For
- Insert new node into GG TPR-tree
- End If

END

In CG algorithm, the first step divides the overlapping MBR of the original two groups in three equal parts horizontally and vertically; the second step is to calculate the distance from two grouping objects to the overlapping MBR center; the third to the eight steps show that if two groups meet the merging condition, concentrate all the moving objects on a new group and delete the original two groups. The new group will use the standard TPR-tree insertion algorithm, inserting into a sub-tree with the top-down search algorithm from the root node and then index maintenance is completed.

GG and CG algorithms only do the index maintenance when necessary and they will use the grouping method when maintaining. Compared to traditional TPR-tree index maintenance algorithm which deals with every moving object, the former two algorithms greatly reduce the times of insertion and deletion of TPR-tree index, thus improving the system's maintenance efficiency.

3.Index Maintenance and Updating Algorithm

CG TPR-tree index preserves the basic idea of TPR-tree index design. It builds index for all the moving objects on the basis of R-tree and adds the relative information of corresponding sub-tree to the middle node and the information includes the integral value of the rate's maximum value and minimum value within a group from the reference moment and the pointer to the parent node and so on, thus forming the extended TPR-tree. Its record form is five-group < MBR， $\overrightarrow{\text{Vector}_{\max}}$ ， $\overrightarrow{\text{Vector}_{\min}}$ ， ptr_{parent} ， ptr_{child} >, separately representing the node's boundary rectangle, the rate's maximum integral value and minimum integral value from the reference time, the pointer point to the parent node and the child node. As the time goes by, every node groups automatically through moving and generates all kinds of attribute information in five-group, preparing for future index maintenance and updating. Initially, the index structure built through the way of R-tree causes the extension of MBR in every node due to bearing the moving objects with all kinds of motion characteristics. To ensure the index efficiency, we put forward GMOM and GMOU o the basis of GG TPR-tree index method.

3.1.Description of GMOM Algorithm

GMOM algorithm maintains GG TPR-tree nodes at all levels by grouping and its idea is as follows: all the grouping moving objects are not possible to move with the same rate and direction which will inevitably lead to the extension of MBR as time goes by and the index efficiency will be lowered. When TPR-tree's MBR is on a certain layer overlap, the GMOM algorithm starts to eliminate the overlapping field.

In GMOM algorithm, one to five steps achieve the root node's child nodes from GG TPR-tree, not including the child nodes that belong to the leaf nodes themselves; six to fourteen steps are the recursive search for non-leaf nodes of all levels that cause the overlapping of MBR; fifteen to nineteen steps delete all the sub-nodes that have nothing to do with the overlapping of MBR and cut and contract the rest nodes MBR as the analysis above.

Algorithm 1：GMOM

Input: GG TPR-tree root

Output: maintained GG TPR-tree MBR

BEGIN

- If root.children $\neq$ NULL Then
- For all child $\in$ root.children Do
- If child.children $\neq$ NULL
- Then childstack $\leftarrow$ child
- End For
- End If
- For all node1 $\in$ childstack Do
- For all node2 $\in$ childstack Do
- If node1.MBR $\cap$ node2.MBR $\neq$ NULL
- Then
- For all child $\in$ node2.children Do
- If child.children $\neq$ NULL
- Then childstack $\leftarrow$ child
- End For
- End If
- End For
- End For
- For all node1, node2 $\in$ childstack Do
- If node1.MBR $\cap$ node2.MBR = NULL Then
- Delete node from childstack
- Else
- cut out the node.MBR
- End If
- End For

END

3.2.Discription of GMOU algorithm

GMOM algorithm groups and updates the nodes of GG TPR-tree and its idea is as follows:

When MBRs at a certain layer of GG TPR-tree overlap as time goes by and GMOM algorithm can not eliminate the overlapping field, we should consider using GMOM algorithm to re-group the relative nodes of GG TPR-tree.

In GMOM algorithm, the second step calls that GG algorithm carries out the grouping operation to the overlapping nodes of MBR; the third step calls that CG algorithm carries out the merging operation within the group to the overlapping nodes of MBR.

Algorithm 2：GMOU

Input: childstack of GMOM

Output: updated GG TPR-tree indexing

BEGIN

- For all childstacks Do
- GG (childstack)
- CG (childstack)
- End For

END

4.Conclusion

By grouping the moving objects which are similar in location and movement with making use of the grids to realize the whole maintenance and control in the groups, reducing the intermediate links of index maintenance, hereby increasing the maintaining and updating efficiency of tree index. Meanwhile, we bring forth the GG algorithm and the CG algorithm both based on the grid technology, as well as the CG algorithm and the GMOU algorithm both based on grouping. Backed by the index structure based on GG TPR-tree, times of index insertion and deletion dramatically reduce by means of the algorithms above when maintaining and updating the index of mass data within the limited range, lessening the access frequency of disk pages. Therefore, with adopting the above-mentioned algorithms, the GG TPR-tree performs better at the indexing aspect than the existing indexing method for moving objects

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