An Improved Base State with Amendments Spatio-Temporal Data Model

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***Abstract*—The traditional base state with amendments model usually use the time sequence when choosing the base state to manipulate and it is usually use the extension of time point to represent the time-slot retrieval, which ignores the adjacent feature of the time point in a certain time-slot. The concept of operated base state and operation times is introduce in this paper, in which a base state with amendments spatio-temporal data model of dynamic selection base state is proposed, it resolves the problem of redundant operation caused by the false selection base state in the time sequence retrieval method. The concept of temporary base state is introduced in the time-slot retrieval, and it set the current moment as the temporary base state, and selects the fewer operands as the operation base state in the temporary base state and the fixed base state, which reduce a lot of duplicated operation and improve the retrieval efficiency.**

***Index Terms*—spatio-temporal data model; base state with amendments; data retrieval; temporary base state**

I. Introduction

Recently, temporal GIS become a research focus in the GIS field. The key problem of the temporal GIS is to create spatio-temporal data model, which is used to store, organize, manage and improve the property and the spatio-temporal semantic of the geographical objects that we can more accurately reproduce the history, track changes and predict the future. Although many spatio-temporal data model had been presented, such as sequent snapshots, base state with amendments, space-time composite, etc., the base state with amendments model is the most popular because of its advantage in less data storage [1]. Most of the traditional methods use the preset time-span to sample, and it stores the data state of a certain moment (which is call base state) and changes relative to the base state (which is call difference file), when retrieval a far away state, it almost reads all of the history data, which is lower efficiency. In order to improve the efficiency, the concept of operation base state and operand is introduce in this paper, in which a base state with amendments spatio-temporal data model of dynamic selection base state is proposed, it resolves the problem of redundant operation caused by the false selection base state in the time sequence retrieval method. The concept of temporary base state is introduced in the time-slot retrieval, and it set the current moment as the temporary base state, and selects the fewer operands as the operation base state in the temporary base state and the fixed base state, which reduce a lot of duplicated operation and improve the retrieval efficiency.

II. Related Works

In 1992, the publication of “Time in Geography Information System”, a doctor paper authored by Gail Langran, indicated the formal beginning of spatio-temporal data model in GIS. Although there are some spatio-temporal data models that have been brought forward up to now, but none is the optimal model in TGIS. See Fig. 1.

The traditional base state with amendments model is proposed by Longran, (see Fig.1 (a)), it made each of the history state as an amendment relative to current state. When the database recorded a more distant historical conditions, then update the base state of each time, we need to modify the entire difference file, which is unrealistic [2]. The methods shown in Fig.1 (b) solves the problem in the traditional method, but when retrieval a far away state, it is almost read all of the history state, and it is unrealistic too. The methods shown in Fig.1 (c) is proposed by Zhang Zu-xun, which is better then the first two methods, but it is also exist the problem occurs in the first two methods [3]. The method shown in Fig.1 (d) using Multi-level indexing, which is adding the multi-level index file in the entire history state, so it do not have to manipulate the difference file in certain moment retrieval, and it use a multi-level index points retrieval with span, effectively improving the method in Fig.1 (c). But when it is a long history state, it also has the problem occurred in Fig. 1(a) and Fig. 1(c). A dynamic multi-level retrieval method is proposed by CAO Zhiyue [4], see Fig.1 (e). Multiple base states were established dynamically throughout the history, the number of the difference file between the base states is called the base state distance. Compared with the Fig.1 (a) and Fig.1 (c), data access efficiency is improved and has no impact with the history. Dynamically created the base state and the difference file easing the problem of historical data retrieval efficiency, However, using the number of the difference files as the base state distance is not conducive to establish the index and update the difference files, due to the uneven distribution of the difference file data, resulting in the distribution of the base state is not the optimal location of the base state position. Multi-base state and single index is proposed by Zhang Baogang [12]; see Fig.1 (f). This model is largely made improvements on existing models, but because the base

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state is also under way from the threshold to, therefore, it does not solve the problem of long historical moment and difference file Increased, and the base state in the system is still occupying considerable space. The method of object change based on the critical index to optimize the base state is proposed by Li Yong, the base state distance is based on the Threshold and it is not based on the number of the difference files [5]; see Fig.1 (h). This method made great improvements, but it still selects the sequence of the base state as standards.

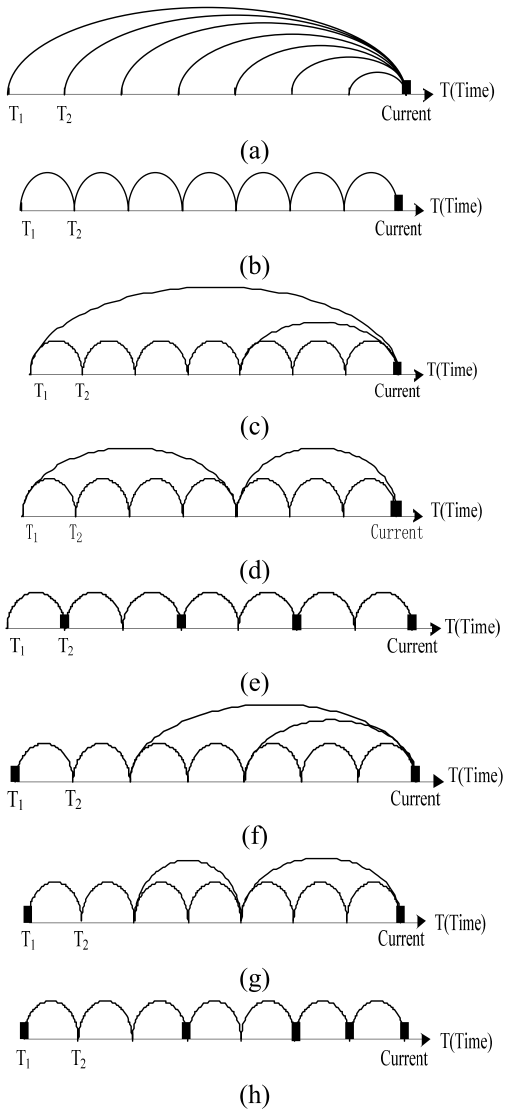

Fig. 1. The comparison of several improved base state amendments model

III. Temporal Characteristics of Spatial Objects and Time Sequence Retrieval Methods

A. Temporal characteristics of spatial objects

The process of the change of spatial object includes the deletion of the current objects, the adding of the new objects, the merge of the spatial objects, the split of the objects, the deformation of the objects, the changes of the attribute's information, the changes of topology and other conditions.

The deletion of objects and the adding of objects are all recorded in the areas of the temporal database [6]. The deletion of an object does not physically remove it from the database, but to put it into the historical database. For example, in the city model, the building *a* built in the year *A* need to delete for some reason, we don't remove it physically from the database but put it into the historical database corresponding to the moment *A*. The adding of a new object is to put the new object into the current version as the current data. For instance, a new building *b* in the year *B* is to put *b* into the current database. Therefore, actually, there are two cases to the temporal variable characteristics of spatial objects: the deletion of the old object (the changes of time T_i relative to T_{i+1}) and the adding of the new object (the changes of time T_{i+1} relative to T_i). In fact, the base state is the new data version when the changes of the spatial objects accumulate to a certain amount. Suppose the operand of the Q when creating the city model of non-base sate moment T_i, and when the Q is very big, then the operation times needed to save the moment T_i as base state is fewer, as a result, when the operation times needed in creating non-base state model is bigger then a certain threshold, a new base state is created. See Fig. 2.

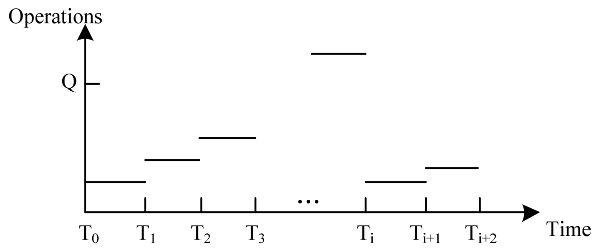

Fig. 2. New base state creating conditions

The moment T_0 is a base stat, the moment T_i and T_{i-1} is an adjacent moment flowing T_0, changes in accumulation of data is less than Q, it does not meet the requirements of building a new base state. When recoding the difference file of moment T_i, changes to the base state is more than the threshold Q, it is showed that load the base state T_0 to insert is too complex, saving the T_i as the base state, after that, load the moment T_i as base state, and the amount of difference file needed to record is reducing.

There are two components to complete a retrieval operation in the base state amendments model. One is to create the base state model according to the base state data; the other is to use the difference files, which are between the retrieval moment and the base state to operate on the base state in turn to create the model status of the retrieval objective moment. We can see that the decisive fundamental factors of the efficiency of the data retrieval are the data amount of the base state and the times of the change between the adjacent base state objects. The greater amount of the base state data, the longer time to create the base state; the more change times of the objects between the retrieval time and the operation base state, the more complex of the operation to embed the difference files into the base state.

B. Timing retrieval methods

To timing sequence as the standard model of base state with amendments, the moments between two adjacent base states will choose to load a fixed base state to operate. See Fig. 3.

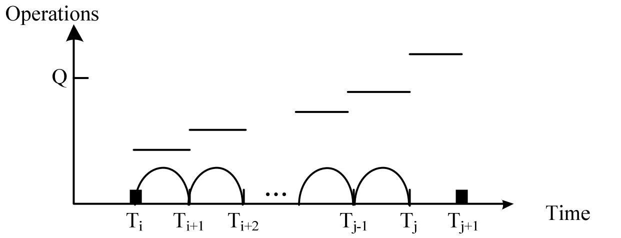

Fig. 3. The time sequence retrieval method of base state amendment model

For example, if T_i is set to be state A, then the momentsT_{i+1}, ..., T_j (T_{i+1}, ..., T_j do not meet the conditions to create a news base state) after base state A will choose to load base state A to operate. If the operand of the moment T_{j+1} reaches the threshold and T_{j+1} is set to be a new base state B, then it is very likely that the moment T_j, T_{j-1} ... T_k(i<k<j) it will need less operand if they choose base state B as the operation base state. So, in this paper we proposed a method which choosing to load the base state dynamically in multi-base state amendments models when we retrieve a time. This is to say, to use less operands as the standard when we choose operation base state, so as to reduce the number of the retrieval, reducing the complexity of the retrieval, improving the efficiency of the retrieval.

IV. CHOOSING THE OPERATED BASE STATE BY OPERATION TIMES SEQUENCE

According to the problem of the time sequence retrieval, a new retrieval method by sequence of operation times is proposed. This method is that it computes and compares the operation times needed in the adjacent base state from the retrieval moment, and selects base state with the smaller operation times as the operated base state to reduce the operating complexity and improve the retrieval efficiency, see Fig. 4. The moment T_1 and T_2 until to T_n stands for each history moment; the number n_1 and n_2 until to n_n stands for the data volume of a certain moment; the number B_1 and B_2 until to B_m stands for the data volume of each base state.

In order to explain the question more conveniently, now we give the following definitions:

Definition 1: The base state that is loaded in the retrieval moment T_i is called *operated base state*.

Definition 2: The total number of the operation which are needed to finishes the retrieval of moment T_i is called the *operation times* of moment T_i. The operation times of moment T_x relative to the base state B_y is represented by *f(x, y)*, it can be calculated by formula (1).

$$f(x,y)=\begin{cases} B_y+\sum\limits_{k=y+1}^{x} n_k & T_x > T_y \\ B_y+\sum\limits_{k=x}^{y-1} n_k & T_x < T_y \end{cases} \tag{1}$$

Definition 3: Compared with time sequence retrieval, the retrieval method based on the dynamical selection of base state is called *operation times sequence retrieval*.

Definition 4: During the cause of time-slot retrieval, the model and data which is created after the retrieval of two adjacent fix base state is called *temporary base state*, the temporary base state is relatively change with the change of retrieval moment.

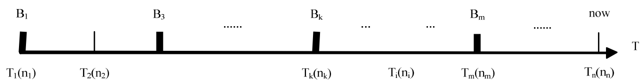

Fig. 4. Dynamic Selection for the Base State of the Base State with Amendments Spatio-temporal data model

At each moment T_i, we can choose one base state from the two adjacent base states B_k and B_m as an operated base state except moment T_1 and T_n, which requires a two-way retrieval chain. The records of the difference file are positive sequence, that is, the records are the changes of the moment T_i relative to T_{i-1}, and the changes include two types of data which is the destroy of the old objects and the creation of the new objects. The added parts from the moment T_i to T_{i+1} should be consistent with the deleted parts from the moment T_{i+1} to T_i; the deleted parts from the moment T_i to T_{i+1} shall be consistent with the added parts from the moment T_{i+1} to T_i. We can add a property *IsInsert* whose type is Boolean. If the value of property is *true*, it means that the records of the difference file have done the adding operations compared to the model of the previous moment, or the deletion operations. When we need the opposite retrieval, we may set *IsInsert* = *NOT IsInsert* so as to achieve two-way retrieval.

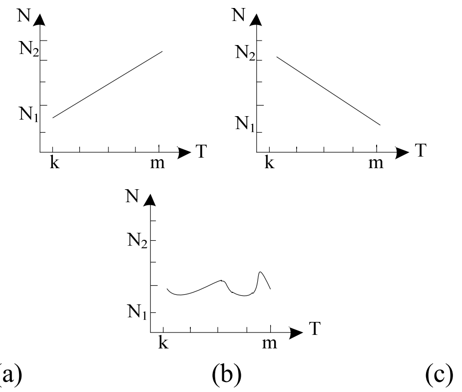

Fig. 5. The data volume relation between base states

The above analysis shows that except the first moment T_1 and current moment T_n, the base state $B_i(i \in (1,m))$ of other moments have two adjacent base states as candidates of the operated base state. Therefore, there are two results for the operation times of the moment T_i, and they're *f(i, k)* whose operated base state is B_k and *f(i, m)* whose operated base state is B_m.

The complexity of creating a model proportions to the data amount of the base state files and the difference files, thus we can use the amount of the operation required at this moment to represent the operation complexity of the moment. According to formula (1), the operation times of moment T_i can be calculated by formula (2) under positive sequence (T_i>T_k), and the operation times can be calculated by formula (3) under opposite sequence (T_i<T_m). The relationships between base state B_k and B_m have the following cases. See Fig. 5, N represents data volume, and T represents time.

$$f(i,k) = \sum_{j=k+1}^{i} n_j + B_k \tag{2}$$

$$f(i,m) = \sum_{j=i}^{m-1} n_j + B_m \tag{3}$$

If there are only added objects without deleted objects between base state B_k and B_m, then B_m can be calculated by formula (4) , see Fig.5 (a).

$$B_m = B_k + \sum_{j=k+1}^{m} n_j \tag{4}$$

If there are only deleted objects without added objects between base state B_k and B_m, then B_m can be calculated by formula (5), see Fig.5 (b).

$$B_m = B_k - \sum_{j=k+1}^{m} n_j \tag{5}$$

If there are both added objects and deleted objects between base state B_k and B_m, then B_m can be calculated by formula (6), see Fig.5 (c).

$$B_m = B_k - \sum_{j=k+1}^{m} \mu * n_j + \sum_{j=k+1}^{m} v * n_j \tag{6}$$

In formula (6), μ is the proportion of the deleted objects at the moment T_i, and v is the proportion of the added objects at the moment T_i. The operand of the moment T_i is *min(f(i, k), f(i, m))*. If *f(i, k)= min(f(i, k), f(i, m))*, The base state B_k should be selected as operate base state else B_m as operate base state. This is a method that the operated base state of the time T_i is determined.

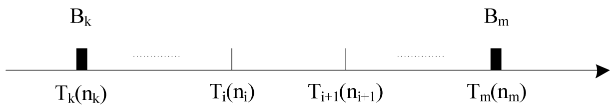

Fig. 6. Local model of the improved model

V. COMPARISON OF OPERATION TIMES RETRIEVAL AND TIME SEQUENCING RETRIEVAL

Generally, the time required to retrieve data is proportional to the number of the operands that the retrieval need. Next we will discuss the size of the operation times with the two types of retrieval about several cases in Fig. 5 with reference to Fig. 6.

The first situation is shown in Fig.5 (a). In this case, there are only added objects without deleted objects between the base state B_k and B_m. When T_k<T_i<T_m, we can derive formula (7) and (8) from formula (3) and (4).

$$f(i,m) = \sum_{j=i}^{m} n_j + B_k + \sum_{j=k+1}^{m} n_j \tag{7}$$

$$\sum_{j=k+1}^{i} n_j + B_k < \sum_{j=i}^{m} n_j + \sum_{j=k+1}^{m} n_j + B_k \tag{8}$$

Accordingly formula (9) can be derived from formula (2), (7) and (8). According to the principle of operation times minimization, the operation times of the moment T_i is *f(i, k)*. As a result, the base state B_k should be selected as operated base state.

$$f(i,k) < f(i,m) \tag{9}$$

The second situation is shown in Fig.5 (b). In this case, there are only deleted objects without added objects between the base state B_k and B_m. When T_k<T_i<T_m, we can derive formula (10) and (11) from formula (3) and (5).

$$f(i,m) = B_k - \sum_{j=k+1}^{i-1} n_j \tag{10}$$

$$B_k - \sum_{j=k+1}^{i-1} n_j < \sum_{j=k+1}^{i} n_j + B_k \tag{11}$$

Accordingly formula (12) can be derived from formula (2), (10) and (11). According to the principle of operation times minimization, the operation times of the moment T_i is *f(i, m)*. As a result, the base state B_m should be selected as operated base state.

$$f(i,k) < f(i,m) \tag{12}$$

The third situation is shown in Fig.5 (c). In this case, there are not only added objects but also deleted objects between the base state B_k and B_m. We can derive formula (13) from formula (3) and (6).

$$f(i,m) = \sum_{j=i}^{m-1} n_j + B_k + \sum_{j=k+1}^{i} (v-\mu) * n_j \tag{13}$$

There must be a moment $T_i(k \le i \le m)$ meeting formula (14). As a result, the base state B_k can be selected as the operated base state at the moment T_j (T_k<T_j<T_i) and the base state B_m as the operated base state at the moment T_j (T_i<T_j<T_m). If we select base state for retrieval by means of time sequencing, many redundant operations will be conducted when T_i<T_j<T_m.

$$\sum_{j=k+1}^{i} n_j = \sum_{j=i}^{m} n_j + \sum_{j=k+1}^{m} (v-\mu) * n_j \tag{14}$$

VI. TIME-SLOT RETRIEVAL ALGORITHM BASED ON TEMPORARY BASE STATE

A. The traditional approach

According to the different regions between the two event times, time-slot retrieval is divided into 4 situations [7-9], see Fig. 7.

When T_a = T_b, this is actually time-based retrieval, see Fig.7 (a). The T_a and T_b are between two adjacent base states but base state exists. Then load the first base state of B_i, and B_i on this basis with the difference file to the T_i, T_i is between T_a to T_b in a moment, see Fig.7 (b). Between the T_a and T_b the existence of a base state B_c, see Fig.7 (c). First load the base state B_i, calculating the moment base state of B_i and B_{i+1} and then load the base state B_{i+1}, calculating the base state and base state moments between B_{i+2}, and so on, that T_b up, see Fig.7 (d).

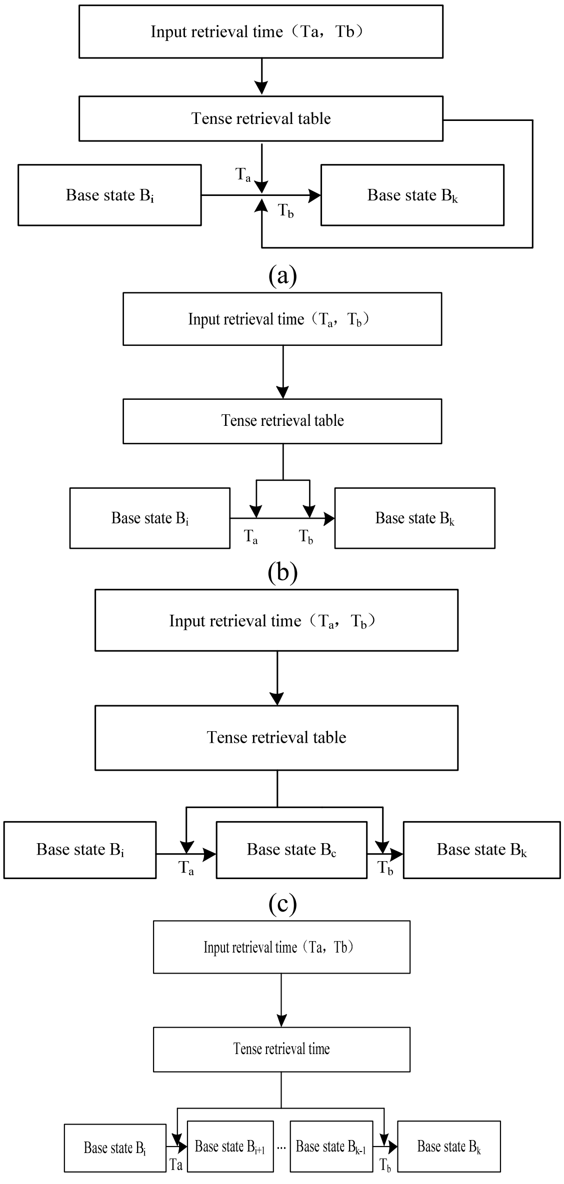

Fig. 7. Four types of Spatio-temporal data retrieval based on time-slot

Based on the above analysis, it can be found that the traditional model of base state with amendments to retrieve the processing time is relatively simple, but on the time period were independent of each other at each time of retrieval. The process according to point operation must be on the base state of each moment to load, but in time the moment of retrieval is similar, it is possible to load multiple times as the same base state, and also to repeat and retrieval of fixed points of the base state the difference between file operations, the inevitable large number of redundant operations are carried out.

B. Time-slot retrieval algorithm of temporary base-state

Retrieval model in the time period, in order to retrieve the adjoining time, and poor record of the file is in order, so you can use the relationship between times. Upon completion of the current search point generated model, the model data be retained as a temporary base state, the next retrieval time for the temporary base state as a candidate for operating the base state, in the interim the base state and the adjacent fixed base state between the calculated operand smaller base state as an operating base state.

Base state can be temporary period of time retrieval method in 3 steps

Step 1: According to the sequence number of search operations to retrieve the first time (T_a);

Step 2: After this retrieval model generated by the state as a temporary base state;

Step 3: turn sequence based on the number of search operations to retrieve the remaining moments T_i ($a < i <= b$).

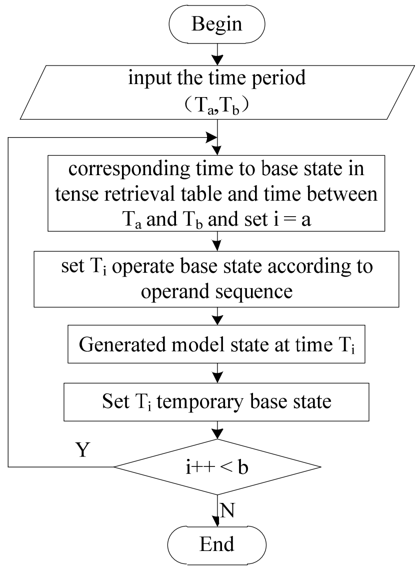

Fig. 8. time-slot retrieval algorithm of temporary base state

The implementation of *Step 1* is retrieval of the point. After completing *Step 1*, the model of time T_a is created, and set it as temporary base state, this base state can be a candidate operating base state in later. Because the model of time T_a is generated, so there is no need to reload it. When searching for T_{a+1}, according to the feature of the difference file, the difference file of time T_{a+1} relative to base state is the only thing which is needed to operate, it is not necessary to reloading the fixed base state ,and the difference file of the fixed the base state and T_{a+1} relative to fixed base state is need to operate at the same time, which is greatly reducing the operation complexity, with the same manner, until to retrieve to the end point of the time-slot, the realization is shown in Fig. 8.

VII. Experiments and Analysis

Table I is a difference file stemming from adding, delete, and modify data randomly in P4 2.8GHz CPU, 1GB Memory, Windows XP Operating System, and using Microsoft Visual C++ 6.0 development tools program specialized software program. The initial data amount is 10000. Each variation is set at around 2%. The variable critical of the objects between adjacent base states is set at 10%. Take the first adjacent base state to conduct the comparison.

TABLE I.
THE COMPARISON OF THE TIME SEQUENCE SELECTION OPERATE BASE STATE AND THE OPERAND SELECTION BASE STATE

comparison		Sequence		Operand sequence	
Moment	Data Volume	Operated Base State	Operand	Operated Base State	Operand
T_0(base state)	10000	T_0	10000	T_0	10000
T_1	187	T_0	10187	T_0	10187
T_2	242	T_0	10429	T_0	10429
T_3	168	T_0	10597	T_0	10597
T_4	206	T_0	10803	T_0	10803
T_5	174	T_0	10977	T_6	10862
T_6(base state)	176	T_6	10686	T_6	10686
aberration operand 125					

The moments $T_1T_2T_3T_4T_5$ between the adjacent base status T_0 and T_6 select the latest base state T_0 by pre-order as their operand base state by timing retrieval; (see Table I) .The time of retrieval need calculate and compare the operation times to T_0 and the operation times to T_6. It will take less operation times if $T_1T_2T_3T_4$ select to load base state T_0 rather than T_6 as their base state, so T_0 should be the operated base state and the result is the same with choosing base state by time sequence retrieval. However, it will take less operation times if T_5 choose to load T_6 rather T_0 as its base state, so we will choose T_6 as the operated base state, and it will reduce 125 operations compared with T_0 as the base state. So there will be less operation if we use operation times rather than time sequence as our standard when we make our choice of base state (the difference can even be the total number of a difference file's operation). What's more, with the increasing of u/v (the ratio of the delete operation and increment operation) between the adjacent base states, the operand retrieval will take more advantage than timing retrieval.

The comparison between the traditional method and the temporary base state time-slot method is shown in table II.

As shown, $T_0T_6T_{10}T_{15}$ are moment of the base state, in the case of coinciding of time endpoints ($T_a = T_b$), the two search methods about the time required the same number of operating. In the case of non-base state (T_1, T_6), the start point of two search methods, T_1, is needed to be loaded , so its operand data is the sum of the base state and the different file data. In traditional search mode, besides moment T_1, the other moments of operands are from the sum of current search point and different file data. But in the traditional base state of search mode, except for time T_1, other times only operated the different files from the current search time that relative to the temporary operation, so its operation is the current time data of different file data. The use of temporary base state to retrieve made the required operands more rarely. And with the time span increases, the number of fixed base state increases. The advantages are more obvious compared with the conventional retrieval method.

TABLE II.
COMPARISON BETWEEN THE TRADITIONAL METHOD AND THE METHOD IN THE PAPER

		T_a=T_b		T_a T_b no base state (T_1,T_4)		T_aT_b one base state (T_1,T_7)		T_aT_b more base state(T_1T_{16})	
time	date num	TdlRtl	TpyRtl	TdlRtl	TpyRtl	TdlRtl	TpyRtl	TdlRtl	TpyRtl
T_0 (B)	10000	10000	10000						
T_1	187	10187	10187	10187	10187	10187	10187	10187	10187
T_2	242	10429	10429	429	242	429	242	429	242
T_3	168	10597	10597	597	168	597	168	597	168
T_4	206	10803	10803	803	206	803	206	803	206
T_5	174	10862	10862			10174	174	10174	174
T_6 (B)	176	10686	10686			0	176	0	176
T_7	202	10888	10888			202	202	202	202
T_8	205	11093	11093					205	205
T_9	167	11029	11029					11029	167
T_{10} (B)	220	10862	10862					0	220
T_{11}	165	11024	11024					165	165
T_{12}	192	11219	11219					192	192
T_{13}	186	11405	11405					186	186
T_{14}	256	11248	11248					11248	256
T_{15} (B)	223	10992	10992					0	223
T_{16}	193	11185	11185					193	193
Total operand				12016	10803	22392	11355	45610	13162
deferent operand		0		1213		11037		32448	

VIII. CONCLUTIONS

This paper has discussed several common base states with amendments model, described their advantages and disadvantages, made a detailed analysis of the shortcomings about retrieval efficiency using timing retrieval to select operand base state so as to reduce the operation frequency to complete retrieval, lower the complexity of the retrieval and make a great progress on retrieval. Finally, the paper compared the timing retrieval with the operand retrieval to prove that the latter one has advantages over the former one on retrieval efficiency.

In the continuous retrieval circumstances, we can set the data model that is created by last time's retrieval as the temporary base state, and next time regard it as ordinary operation data to calculate when we retrieve .At the same time, we shall save the difference file in corresponding with the moment of temporary base state, delete the data of the temporary base state, and set the current retrieval as the temporary base state. We could use the result of last time in this way, and the efficiency of continuous retrieval in a specific period of time will be greatly improved.

The disadvantages in the retrieval efficiency of the base state amendments spatio-temporal data model based on time sequence selection operation base state is analyzed in this paper, the data retrieval method based on operand selection base state is proposed, in this method, the number of the needed operand is as a standard to select the base state, which is reducing the operations and retrieval complexity, improving the retrieval efficiency. Compared with the two methods, we can find that the operand selection operate based state has an obvious advantage in retrieval efficiency.

In the continuous retrieval circumstances, a time-slot retrieval based on temporary base state is advanced in this paper, we can set the data model that is created by last time's retrieval as the temporary base state, and next time regard it as ordinary operation data to calculate. At the same time, we shall save the difference file in corresponding with the moment of temporary base state, delete the data of the temporary base state, and set the current retrieval as the temporary base state. We could use the result of last time in this way, and the efficiency of continuous retrieval in a specific period of time will be greatly improved.

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REFERENCES

[1] YU Zhiwen, ZHANG Litian. The Extention of Spatio-temporal Data Model Based on Base State with Amendments[J]. Acta Scientiarum Naturalium Universitatis Sunyatseni, 2003, 42(1): 100-103.
[2] LANGRAN G.. Temporal GIS design trade-offs. In: Proceedings of GIS/LIS'88, San Antonio: ACSM, 1988.
[3] ZHANG Zu-xun, HUANG Ming-zhi. Temporal GIS Data Structure Discussion n. Bulletin of Surveying and Mapping, 1996, (1): 19-22.
[4] CAO Zhiyue, LIU Yue. An Object-oriented Spatio-temporal Data Model. Acta Geodaetica et Cartographica Sinica, 2002, 31(1): 87-92.
[5] Li Yong, Chen Shao-pei, Tan Jian-jun. The improved base state with amendments based on optimized base state intervals. Science of Surveying and Mapping, 2007, 32(1): 26-29.
[6] LIU Rui, ZHOU Xiao-guang, LI Xiao-lei. Base state with amendments spatio-temporal data model based on dynamic base state method. Science of Surveying and Mapping, 2009, 34(1): 130-132.
[7] ZHU Qing, HU Mingyuan ,ZHANG Yeting, DU Zhiqiang. Research and Practice in Three-Dimensional City Modeling. Geo-spatial Information Science, 2009, 12(1): 18-24.
[8] El-Hakim S.. Image-based 3D modelling. The Photogrammetric Record, 2006, 21(115): 269- 291.
[9] Mayer H.. Object extraction in photogrammetric computer vision. ISPRS Journal of Photogrammetry & Remote Sensing, 2008, 63(2): 213-222.
[10] Gruen A.. Reality-based generation of virtual environments for digital earth. International Journal of Digital Earth, 2008, 1(1): 88-106.
[11] SHE Jiang-feng, Feng Xue-Zhi, DU Jin-kang. A Review on Progress in Spatiotemporal Data Modeling. Journal of Nanjing University(Natural Sciences), 2005, 41(3): 259-267.
[12] ZHANG Bao-gang, AI Ting-hua. Research on General Spatio-temporal Data Model. Bulletin of Surveying and Mapping, 2007, (5): 14-15.
[13] Elias F., Kostas G., Nikos P.,et al. Nearest neighbor searchon moving object trajectories. Advances in Spatial and Temporal Databases. Berlin: Springer, 2005, 328-345.
[14] HUANG Yao-yi, CHEN Wen-cheng. The Application of Temporal GIS-Take the Fujian Province GDP Evolution as an Example. Geomatics & Spatial Information Technology, 2009, 32(3):121-127.
[15] Bin Jiang, Xiaobai Yao. Location-based services and GIS in perspective. Computers, Environment and Urban Systems, 2006, 30: 712-725.
[16] XIE Fu-qi, ZHU He-hua, LI Xiao-jun, SUN Xue-bing. Temporal GIS Models and Its Application in Tunneling. Chinese Journal of Underground Space and Engineering, 2009, 5(3): 546-552.
[17] Huiping Liu, Qiming Zhou. Developing urban growth predictions from spatial indicators based on multi-temporal images. Computers Environment and Urban Systems, 2005, 29(5): 580-594.
[18] Oksanen J., Sarjakoski T.. Uncovering the Statistical and Spatial Characteristics of Fine Toposcale DEM Error. International Journal of Geographical Information Science, 2006, 20(4): 345-369.
[19] Paul Martz. Open Scene Graph Quick Start Guide. Louis-ville: Skew Matrix Software LLC, 2007: 20.
[20] Zhu Qing, Gong Jianya, Zhang Yeting. An efficient 3D R-tree spatial index method for virtual geographic environments. ISPRS Journal of Photogrammetry and Remote Sensing, 2007, 62(3): 217-224.

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