Research on Template Computing Mode of Remote Sensing Image Based on Partition Model

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***Abstract*— As the amount of data rises and application needs expand, the efficient organization and management of remote sensing data has become a bottleneck restricting the application of remote sensing technology. The Global Partition Theory (GPT) and high performance computing provide an approach to solve the above mentioned problems. GPT studies how the Earth's surface is split into different levels of thickness seamless mesh and how to organize and manage it. Thus, rapid integration of mass remote sensing data of different sources, different types and different resolution can be achieved. Meanwhile, there is a natural segmentation of regional location and distributed storage features in spatial data in the partition organization framework, which makes remote sensing images computing model based on partition inherently parallel attributes. Combing a partition model of the Extended Model Based on Mapping Division (EMD), the researchers study the partition facet of remote sensing image, and propose the conceptual model and data model of partition facet template. Combing with parallel processing framework in high-performance computing of remote sensing image, the researchers design the template-based computing mode of partition facet and the partition process of spatial data. Through analyzing spatial relationship of partition facets, such as containment relationship, neighboring relationship and direction relationship, the researchers propose the basic calculation modes of partition template. There are aggregation, division in longitudinal and extend, conversion in transverse. This research paper is of great significance for expanding the application of GPT, improving the remote sensing technology speed, accelerating spatial information visualization analyzing and decision making speed. It also provides valuable guidance for studying high-performance remote sensing image processing in the future.**

***Index Terms*— Remote Sensing, EMD Partition Model, Partition Facet, Template Data Model, Computing Mode**

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I. INTRODUCTION

Remote Sensing refers to the technology to measure, analyze and determine the nature of the target through certain sensor device in the distance, but not in direct contact the target [1]. Data obtained by remote sensing technique has the following advantages, such as high real-time, covering-widely and rich information-. So it has been widely used in many military and civilian fields like aviation, aerospace, military reconnaissance, disaster forecasting and environmental monitoring. With the development of sensors, remote sensing platforms, data communications technology, spatial data obtained by remote sensing is expanding rapidly, which results into the situation of “the production and transmission capacity of spatial data is far greater than its analysis capabilities” (Deren LI). At the same time, many applications have increasingly higher requirements of timeliness, accuracy and reliability of remote sensing images. The efficient organization and management of spatial data and its processing speed have become a bottleneck affecting the quick application of remote sensing images. These questions result in high-performance processing methods and technology developing of remote sensing images.

As remote sensing applications research and theoretical exploration deepens, especially after “Digital Earth” proposed, remote sensing image processing is faced with some new questions of global continuous, multi-level and dynamic environment resources and social information. The traditional grid system gradually exposed limitations of projection complex, lacking of multi-scale data integration and management. The Global Partition Theory (GPT) is put forward in this circumstance. Division in earth science refers to the partitioning method of geospatial location. The GPT is based on spatial partition organizational framework, which divides the earth into discrete facets with similar shapes ,rules and clear levels. It can realize massive global data storage, extraction and analysis, and ensure

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spatial data application services in global harmonization organization, sphere-plane integrated expression and rapid integration of multi-source spatial data [2, 3]. So it can solve a series of bottlenecks that restrict quickly retrieval, efficient integration and sharing of geospatial information. It achieves that the multi-source, multi-scale, multi-temporal spatial information can be integrated into organizations, open-sharing, interoperability and rapid distribution and so on.

The paper will introduce GPT and a partition model of the Extended Model Based on Mapping Division (EMD), and study the partition facet of remote sensing image. Besides, the conceptual model and data model of partition facet template will be proposed, and subdividing process of spatial data will be designed. And we propose a kind of facet computing model of partition template. Through analyzing spatial relationship of partition facets, such as containment relationship, neighboring relationship and direction relationship, we propose basic calculation modes of partition template. There are aggregation, division in longitudinal and extend, conversion in transverse. This research will provide the possibility and a base for remote sensing templates parallel processing.

II. Global Partition Theory

Global Partition Theory (GPT) is a kind of multi-levels, multi-scale data organization. It is based on global grid division, and has unique advantages in expression and management of spatial information [4-6]. It studies on how to divide the Earth into levels of facets with regular shape and small deformation. It has equal spatial distribution and fusion spatial indexing mechanism, which can support multi-resolution and multi-scale transformation. So it is considered as a new seamless open hierarchical spatial data management framework. It can achieve to store, extract and analyze massive data in global scale. It can solve the existing limitations of traditional data models that manage multi-scale, hierarchical global data. It’s ensuring that the global spatial data will be expressed in a global, continuous, hierarchical and dynamic model [7-9].

Partition model is the key of GPT, it researches on how to subdivide the Earth, what shape of subdivided facets is and how to code the facets. At present, there are three kinds of partition models in China and abroad. They are latitude and longitude grid model, equal regular polyhedron grid model and adaptive grid model [10]. The partition methods can be classified into polyhedral division, experience division and wavelet division. Typical partition models include QTM [11], STQIE [12], SIMG [13] and so on. The partition model generally adopts quadtree structure and partition code to organize facets, and achieve interrelated global remote sensing system in different levels and different facets at the same level. But some partition models have questions of computing complex and facets reshape, so it can’t adapt to high efficient requirements of spatial information processing.

Based on integrating advantages of various partition models, Professor Cheng Chengqi in Peking University proposed a new partition model of the Extended Model Based on Mapping Division (EMD) [14-16]. The main idea of EMD is using regular polyhedral triangles partition method in high latitudes, while using equal latitude and longitude grid basing mapping division in low and middle latitudes [14]. The EMD model is the subset of mapping division system, and its development. It can realize unified organization and management of remote sensing, survey and map data. Except the similar advantages of other partition model, the EMD model has simple and clear correspondence with existing space data and coordinate system. Through integrating basic survey technology, present space data can be easily merge into this organization system. So it has strong practicability. At the same time, the system of EMD has unified record baseline, data association method and efficient data organization method of calculating for spatial data. So it can reflect the spatial characteristics of the data to the maximum extent. It can achieve unified organization and management of multi-type, multi-scale and large amount of spatial data, and support multi-scale transformation, centralized services and distributed services across the region [17, 18].

In the EMD model, partition is done according to topographic maps division from four to six levels. The forth level partition facets are gotten by dividing the third level facet into four equal parts, their size is 3°×2°.

Divide the forth level facet into four equal parts, the fifth level facets will be gotten, and each one is 1°30'×1°. The sixth level equal part facets are gotten by dividing the fifth level facet into nine equal parts, its size is 30'×20'. The three levels facets are corresponding with division maps range of 1:500000, 1:250000 and 1:100000 scale.

From the seventh level in the EMD model, partition is recursively done by quadtree partition with equal latitude and longitude difference. The seven to ten facets are corresponding with 1:50000, 1:25000, 1:10000, 1:5000 division map ranges. The other levels partition and the polar partition method are shown in Ref. [16].

The facet coding model in the EMD model includes middle-low and high latitude coding method. The middle-low latitude (0°-88°) coding is using sequence encoding from the first to sixth level, and using Hilbert curve for seventh and above level. The high latitude (88°-90°) coding is using QTM encoding. The coding structure and code generation method are also shown in Ref. [16].

III. Partition Facet Template of Remote Sensing Image

A. Partition Facet Template Conceptual Model

Partition facet is a multi-scale segmentation unit with regular shape and small deformation, which is divided by certain partition model. Each partition facet has accurate geospatial position range, regular geometric shape, distinct hierarchical structure, and a unique identification code. The main parameters of partition facet are code, dividing level, corner coordinates, location coordinates, area, length, position, curvature, projection area and conversion accuracy. The code is a globally unique mark, and it can be converted into other common coordinate system easily.

Partition facet template of remote sensing image (called partition facet template) is a spatial feature set of partition facets. It may be extracted from high resolution remote sensing image. It may also be other spatial data related to partition facet. Actually, partition facet template is a data sample of remote sensing image that corresponded with certain range of partition facet. Usually, the data is orthophoto remote sensing with obvious features. It contains spatial feature set, geographical features set and control point data of partition facet. So it inherits all the advantages of partition facet, and can establish association between abstract partition model and specific remote sensing images. Using partition facet template, an unknown remote sensing image can be quickly identified which one belongs to which partition facet. According to different data processing requirement, many kinds of templates can exist for different applications. Each template is corresponding to a specific algorithm of partition data processing.

B. Partition Facet Template Data Model

Partition facet templates consist of facet information, template type and template data. Facet information includes code, level, shape, area, geographic location and projection transformation of partition facet. Template type corresponds to specific partition processing algorithms, which can be created by template management module, and use to manage template metadata information. Template data refers to basic sensing image information corresponding to certain partition facet. It includes resolution, coordinate, pixel information, and color, texture, shape feature of spatial entities. Template metadata includes data format, data type, data files algorithm interface, data processing algorithm interface. Here, the data files algorithm is responsible for generating and parsing data files. the data processing algorithm is responsible for spatial data processing using template data.

Operation Defination Layer	Registration	Projection Transformation	Image Mosaic	Object Retrieval	Landform Analysis
Data Model Layer	Referenced Image Data	Control Points Data	Features Data	Altimetric Data	
Concept Model Layer	Template Code	Altimetric Data Partition	Features Recombination	Control Points Measure	

Figure 1. Data model of partition facet template

The data model of partition facet template is shown in Figure 1.

The conceptual model layer describes uniform interface and abstract model of partition facet template. It is the basis for designing various template types. The data model includes reference remote sensing image data and all kinds of template data. The operation definition layer consists of specific algorithms of various types of templates in data layer. It can customize operations according to the data type in data layer.

C. Rapid Generation Process of Partition Facet Template

Figure 2 shows the subdivided generation processing flow for geospatial data.

When geospatial data goes into partition system, preprocessing is the first work to do. Then it needs to determine the partition level according to resolution or scale of the metadata in spatial data. And determine the location of partition facet according to the data center of latitude and longitude coordinates. After that, spatial data partition processing will be done according to it's upper-left and lower-right latitude and longitude coordinates and the size of the facet. This step can determine the facets range of data and decide whether the data is in one partition unit. If so, partition code will be obtained and reorganize the spatial data basing partition facet. And if not, overlay and analyze the image data and facet set. Then, analyze the contain relationship between partition facet and trimmed image data. Through encoding the partition facet according the theory of GPT, organize image data according to facet codes, and geospatial data organized by partition facet will be gotten at last [19].

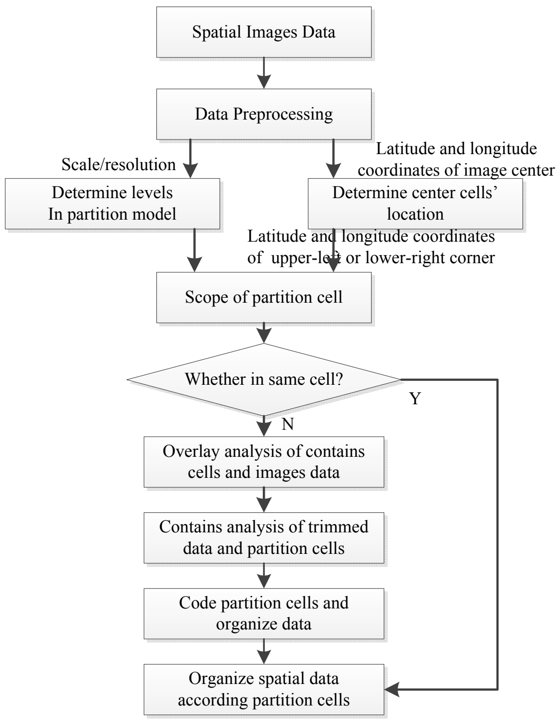

Figure 2. Partition processing flow of spatial data

IV. Template-Based Computing Mode for Remote Sensing Images Partition Facet

In the organized framework of the earth partition, arbitrary geospatial data becomes part of the partition data after higher accurate registration with the reference data. For each precision reference image of partition facets, extracting the control points and other spatial characteristics, it can be made templates. Then we can make parallel processing on the multiple facets of a large area image using partition templates. With the frame and storage cluster of partition, we can achieve high-performance parallel processing of template.

Template-based parallel processing is using the advantages of partition facet template to achieve parallel processing for massive remote sensing image data. The overall framework of it can be shown in Figure 3.

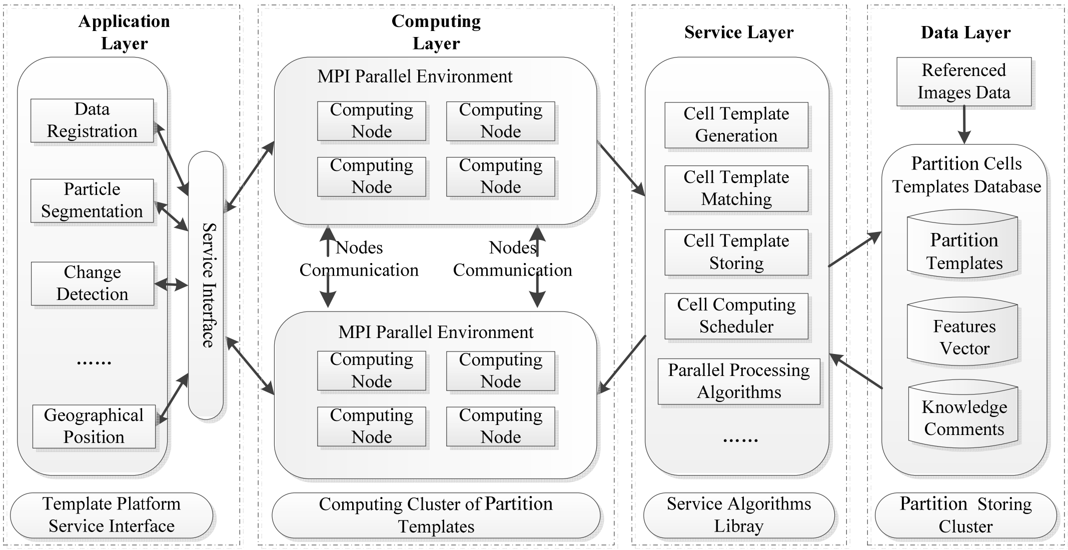

Figure 3. Overall framework of template-based parallel processing for partition data

A..Advantages of Templates Parallel Processing Mechanism

Currently, template parallel processing mechanism has already become one of the most effective ways to improve the speed and efficiency of remote sensing processing. High-performance cluster processing mechanism, which is based on parallel processing and cell processing mechanism and mass distribution processing, is the main method adopted by high-performance remote sensing processing [20, 21]. At the same time, high-performance cluster, distributed computing system and specialized hardware devices are widely adopted in the field of high-performance remote sensing processing. People rely high-performance cluster processing mechanism on the platform and use parallel processing to improve speed [22, 23].

Partition facet template of remote sensing image has many distinct advantages in parallel processing.

- Facilitate to realize multi-source remote sensing images quickly match. The global multi-source remote sensing images are unified organized according to regions of partition facets. So all remote sensing images of the same region can be quickly obtained just by facet codes. Using distributed storage can directly parallel process remote sensing image, and greatly save overhead and improve overall efficiency.
- Favor to multi-scale freedom granular partition spatial image data. Since there are nested hierarchies among levels of partition facets in partition organization, the remote sensing images can partition into different levels of sub-data corresponding to partition facet. So remote sensing images' multi-scale freedom granular dividing is completed.
- Realize efficient geographical location and access of partition data. The partition data is stored according to a certain level and sequence. You can quickly access any location partition data blocks using the association of code, storage location and actual region. And if using distributed parallel storage, retrieval efficiency will be greatly improved.

B. Template-Based Partition Facets Parallel Processing Mechanism

Template-based partition facets parallel processing mechanism is backed by the lower-facet data model, thus it is suitable for efficiently processing mass data. The geographical segmentation feature of the partition data supports parallel data processing. Partition template provides the global spatial data with efficient storage and organization methods. After parallel processing, people can attain geographical division of the spatial data of different regions and provide guarantee for multi-regional parallel calculation. Template-based partition facets parallel processing mechanism not only improves the processing speed by parallel model, but also conducts regional storage and parallel calculation according to the geographical attributes of the spatial data. Thus, it is able to realize multi-facet data processing. Partition data storage model provides support for efficiently accessing and processing the distributed data. People can use uniform partition data form to obtain the data of different sizes within the documents, thus realizing parallel processing of the single data document.

C. Computing Mode of Partition Facet

The main idea of template-based computing mode of partition facet is: consider template as basic unit of partition facet computing, establish baseline image with the unit of partition facet in an appropriate level and range, create partition template according to facet information, image information and special application. When processing the data in any zone, the partition image facet template will be extracted from template database for computing. Thus, remote sensing image fast partition parallel processing is achieved. It can provide support for relevant application.

The EMD partition model has nature of point and surface relationship, and each partition level is relatively uniform in local area. Because of space continuity and distributed storage of spatial data, the partition facets can easily implement concurrent execution in many parallel compute nodes. Because partition data has record storage and internal organization format, the parallel processing within one computer node can be easily achieved.

The architecture of partition template computing is shown in Figure 4.

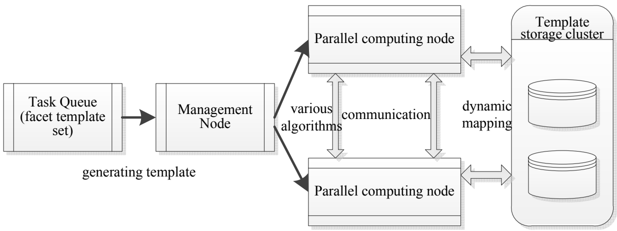

Figure 4. Architecture of partition template computing

Partition facet based on the template parallel processing mode is shown in Figure 5.

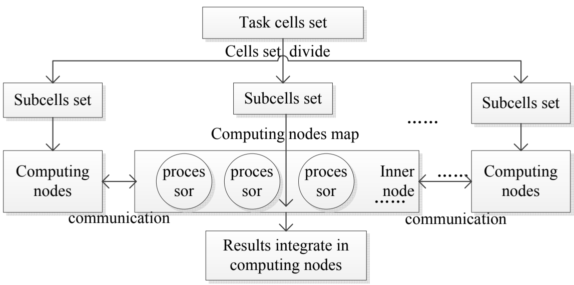

Figure 5. Template-based partition facets parallel processing mode

Structural model of partition images is a key and base of partition facet computing. Remote sensing image data is organized by GPT, so the image data block, pixel and partition facet have certain relationship. Using partition framework of structure facet, the remote sensing image can be expressed as structure partition data set. Because of multi-scale partition facet and global uniqueness of partition code, the data unit can directly index and compute combining pyramid image and space filling curves. Constructing partition image structure model mainly considers layering and partitioning strategies. Hierarchical strategy can be flexible depending on the data source. There is greater flexibility in choosing multi-source data for pyramid image, which can ensure image accuracy and reduce data calculation. Block strategy is to improve I/O access efficiency of image data. Generally, choose $2^n \times 2^n$ pixels as the standard data block of image. And at the same time, record the block code and geographic coordinate range for each image block [15].

Template-based partition facet computing mode comprises two directions calculated in the longitudinal direction of the facet polymerization, splitting and other operations, and in the transverse direction of the facet extension, shrinkage and other operations. Wherein the polymerization represents a number of same level facets gathered to get a high-level facet, mainly involving the combination of positional relationship of same level facets, facet data structure adjustment, etc. Split represents a high-level facet split into several low-level facets, mainly related to facets split, control point adjustment, high precision image selection and so on. Extended operation represents the same level of adjacent facets directly spliced, mosaic, composed of large temporary view.

VI. TEMPLATE-BASED PARTITION FACET COMPUTING EXAMPLES

A. Spatial Relationship of Partition Facet

The spatial relation of partition facet is caused by its pure geometry location. It is the basis and premise for parallel processing of partition facet. There are three primary spatial relationships among partition facets. They are measure relation, location relation and topological relation [16]. The measure relation is used to describe the distances and sizes among facets, and it mainly contains space distance model and measurement accuracy. The location relation is used to express orientation relationship among facets, such as front or back, up or down, left or right, corner angle. The topological relation refers to some invariants under topological transformation, and it is the key feature information for partition template storing and computing. In EMD model, the topological relationship among facets is the base of quick transforming and adjusting images in several levels. The facets in the same level have relations of apart, neighbor, and equal, and the facets in different levels have relations of inclusion.

1) Inclusion Relation

Using partition code, the inclusion relation in different levels can be described as follows. Suppose M_A and M_B are the binary code of codes of facet *A* and *B*, and their lengths are L_A and L_B respectively. If $L_A<L_B$, and the L_A front bits of M_B are consistent with M_A, we say *A* contains *B*. That is:

$$A \supset B \Leftrightarrow \{L_A < L_B, M_A \otimes M_B(0, L_A) = 0\} \tag{1}$$

In this format, the mark ⊗ expresses XOR operation, the expression $M_B(0,L_A)$ means that the code bit from *0* to L_A of M_B.

2) Neighborhood Relation

Since the facet code is the globally unique identifier of partition facet, it also corresponds to a geographical area in real world. The continuity of geographical area can be reflected by neighborhood relations of partition facets in same level. The neighborhood relationship also can be computed by their codes' binary operations. For example, the partition facets *A* and *B* have four kinds of neighborhood relationships, they are described as:

$$Neighboring-\mathrm{Re}lationship(A,B)\Leftrightarrow\begin{pmatrix}L_A=L_B,|M_A-M_B|=1\\L_A>L_B,\&M_A(i)=0,M_A(1,L_B)-M_B=1\\L_A>L_B,\&M_A(i)=1,M_B-M_A(1,L_B)=1\\L_A<L_B,\&M_B(i)=0,M_B(1,L_A)-M_A=1\\L_A<L_B,\&M_B(i)=1,M_A-M_B(1,L_A)=1\end{pmatrix} \quad (2)$$

Here, $M_A(i)$ represents the bit *i* in code M_A of facet *A*, $M_A(i,j)$ represents the bit *i* to *j* of M_A, "-" represents binary subtraction, "&" represents binary union operation of bit.

3) Separation Relation

Using the previous method to discriminate on the two facets, if they are neither inclusion nor neighborhood relations, then the two facets will be for the separation relationship.

4) Experiments

Aiming at the above computing mode of remote sensing images, we carried out a verification experiment. Four facets aggregation results are shown in Figure 6.

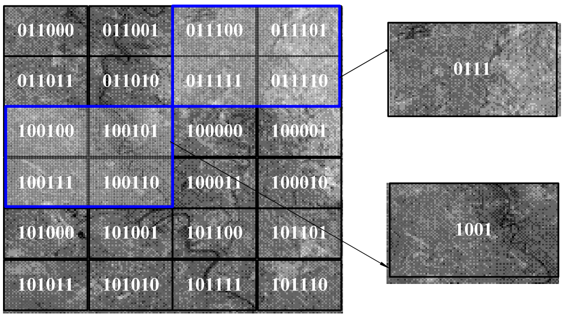

Figure 6. Four facets aggregation results

The results show that the proposed method can make use of partition facet template and achieve quick processing of remote sensing image. It will simplify computing task of remote sensing images, and easy to express and recognize the typical objects in remote sensing images. The computing mode is not dependent on vector structure, and it can directly analyze spatial relations using uniform partition codes. So it can improve the speed of browsing or displaying remote sensing images. But present experiment was done in single computer with four cores; we will focus on its efficiency in parallel processing computing cluster environment in further study.

B. Remote Sensing Template-based Partition Facet Computing

Partition template has characteristics and advantages of partition facet, and also has basic information of original remote sensing images. According to the applied requirements of EMD model and remote sensing images in different regions, many kinds of templates can be designed, such as control point templates for matching and feature templates for target retrieval.

The computing mode for images data is defined by partition facet template. It is based on basic spatial relations of inclusion, neighboring, apart, distance and corner-angle. It refers to some operations of remote sensing images in unit of facet, such as moving, changing, resizing, rotating, and restructuring and so on. It mainly includes operations in two directions; they are aggregation or split in longitude and extension or conversion in transverse.

1) Longitude computing mode

Aggregation operation means several facets in the same level gathered into a high-level facet. It mainly involves facets' position recombination and data structure adjustment. Splitting operation means a high-level facet is splitted into several facets of low-level. It mainly involves facet's segmentation, sub-facets rearrangement, high-precision images selection.

Suppose the number of facets is *N*, the number of facets' code will have bits of *logN*. So, the facets of A_1, A_2, ..., A_i $(i<=N)$ aggregate into one facet *B*, it can be described as:

$$\begin{aligned}L_B&=Min\ (L_A(i))-\log(N)\\M_{Bi}&=\&M_B,M_A(i)\oplus(j)\end{aligned} \quad (3)$$

Here, the mark ⊕ represents EXOR operation in binary. This formula can be repeated recursively by bit. The operation of one facet *B* split into A_1 , A_2, ..., A_i can be looked as reverse operation of it.

2) Transverse computing mode

Transverse computing mode is mainly among facet in the same level. It provides browsing and retrieval operations for remote sensing images. Extension operation represents facets directly stitching or mosaic and is composed of large temporary views. Conversion operation is corresponding to the specific operation of remote sensing images for moving, rotating, cropping.

3) Application Examples

Template-based partition facet parallel processing technology is based on the following typical technologies: partition processing of remote sensing data; forming partition facet set; forming corresponding template according to partition facet; storing template; satisfying specialized needs. The typical applications include image retrieval, image real-time processing, and information fast compilation.

The application flow is shown in Figure 7.

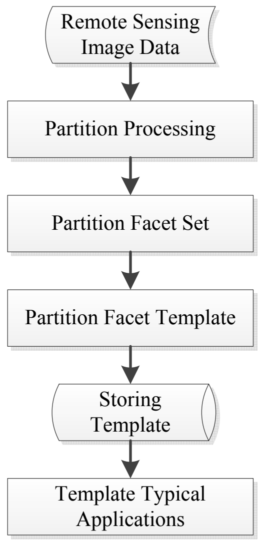

Figure 7. Partition template computing mode application flow

Based on the above information, people attempt to research the remote sensing data of the tourist sites by the template-based partition facet processing mechanism. They propose some typical applications. In the Ubuntu 12.04 server environment, people can use 5 DELL machines of quad cores to build small-scale parallel processing platform. People can select the remote sensing image of 2.5M, 5M, 10M as the original image data. People can process the remote images by partition and feature extraction, then forming partition-based template database. They can attain user interface design by VC++. Compared with other remote sensing image processing system, this small-scale application system has the advantages of fast image display and intuitive feature information. Meanwhile, it can be used for retrieving and presenting the original template in the regional images of different areas.

V. CONCLUSION

Remote sensing image data has been widely applied in many military and civilian fields. As the amount of data rises and application needs expand, the efficient organization and management of remote sensing data has become a bottleneck restricting the application of remote sensing technology. In this paper, we discussed GPT and EMD partition model, and proposed the conceptual model and data model of partition facet template. In addition, the template-based parallel processing flow was introduced and computing mode of partition facet was designed. We also emphasized how to realize special computing mode of remote sensing images basing basic spatial relation of subdivision facets. These operations are aggregation, split, extension and conversion. They provide underlying computing foundation and implementation premise for parallel computing of remote sensing image. This research paper plays an important role in speeding up visualization expressing, and target detecting, identifying and decision-making, and can reduce preparation time for spatial information. And it has some demonstration in the application of GPT.

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