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RETRIEVAL OPERATORS OF REMOTE SENSING APPLICATIONS

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A set of operators of remote sensing applications have been proposed to fulfill most of the Functional Requirements (FR). These operators capture the functions of the applications, which can be considered as the services provided by the applications. In general, a good application meets maximum FR from user. In this paper, we have defined a remote sensing application by a set, having all images created at dissimilar time instances, and each image is categorized into set of different layers.

Keywords: Remote sensing applications, Retrieval operators, Functional requirements, Satellite images, Geographical information system.

1. Introduction

Remote Sensing can be in critical domains like, social-sciences, disaster-management, security-surveillance and military. Remote Sensing (RS) applications are data intensive and data driven, consisting of multitude of information used for short term/long term decision making [1]. The heterogeneous (temporal and spatial diverse) nature of this domain, adds the intricacy of development and successful implementation of such systems [2]. The traditional Software Engineering (SE) approaches using linear life cycle models are unsuitable for developing such systems [1], owning to their peculiar nature (data diversity, temporal instability, voluminous and broader context etc.) and needs. These peculiar characteristics dictate to adopt specialized systems for the development of RS information systems. The prime system development challenge is due to evolutionary or dynamic character of RS domain [3]. Such evolutionary or dynamic domains demand an extremely iterative analysis or development process. Although, many approaches have been used for developing agile systems but they do not outfit all FR of developing evolutionary or dynamic systems [1]. These systems have charisma for historical information recording or tracing back changes which adds to the system development, a temporal nature. Since, information evolves as the time passes in dynamic domains, and is not attractive to dump the elderly information. For example, in scientific domains, the experiments used in some specific research projects, different methodologies (procedures) may be adopted to attain a specific goal, so that the best one can be selected at the end. Hence, it is vital to associate temporal information, to the phases of agile development methodologies [4].

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2. Related Work

In literature, a Temporal Object System (TOS) has been proposed [5] which maintains the structure and state changes of an object in a temporal manner. In TOS, objects are permitted to progress over time known as *temporal objects (TO)*. A group of TOs are placed into a family, sharing the common properties. A TO, referred to as an *offstage object* [5], is defined by using the classified knowledge of a family. He also explained the renovations of both offstage objects and temporal complex objects in [6, 7, 8].

This work was an extension to the work reported [8] and a report on the TOS operators and their implementation. Shah has proposed TOS operators which are grouped into modules of three, based on their pertinent functions.

i. Object Manager (OM) (or Object Module).

ii. Family Module (FM).

iii. Root of TOS (RTOS) Module.

OM is a vital module, consisting of fundamental operators. It provides an ability for a simple TO, to be defined and afterward add a stage in the TO. The remaining operators are grouped into; RTOS and FM.

Mainly, the existing Relational Database (RD) systems [4], data objects are stored in a non_ temporal manner (don't store time varying data and has no capability to manipulate it). The previous values are replaced by the new values as the attribute changes its value [5]. Hence, the only state available in the database is the last one. However, for database applications like Core Architecture Data Model (CADM), which is used for systems development, interoperability and resource planning whereas Computer Advisory Committee

(CAC) it is not appropriate to dispose of previous information. In these cases, it is required to associate a time dimensions with the data to identify the time at which the data is pertinent. A time dimension is associated at the attribute level or tuple level for history management about a data object. This type of database is known as a *temporal database* [5].

Time in a Temporal Relational System (TRS) is modeled as a time interval/time point. Time value is associated with a data object and is determined by the system/ assigned by the user. When a time value is associated by the system, it is known as a *physical time like* transaction time and if user assigns it, it is known as a *logical time/*user defined time [9].

In our paper we have proposed retrieval operators of functional requirements for remote sensing applications.

3. Proposed Retrieval Operators and Their Implementation

In this paper, set of retrieval operators have been proposed to represent main FR of RSA. These operators detain the functions/behaviors of RSA. A set of images of RSA have been defined and are created at dissimilar time-instances. A set of different layers are included in each image.

Let us assume that a total number of M images are there in a RSA, defined in Equation (1).

$$RSA = \{(Im_i,t_i) \mid 1\leq i \leq M\} \quad (1)$$

In Equation (1), (Im_i,t_i) is defined as the i^{th} component/image of remote sensing application, created at time instance t_i, which satisfies the inequality, $1\leq i \leq M$.

An image Im_i, can further be categorized in term of its layer as in Equation (2).

$$Im_i= \{L_{i,j} \mid 1\leq j \leq m_j \leq 5 \} \quad (2)$$

Assuming that we have considered total five (5) layers in the image Im_i but it can have more than five.

Now we define layers of same type in different images of a remote sensing application. Let L_m, is a layers set of the m^{th} type, created at time instances, t_{1m}, $t_{2m},\ldots\ldots t_{Nm}$, in diverse images of the remote sensing application.

We physically represent these layers as vegetation, soil, railway line, water body and urban.

The set *LY* of layers in RSAs be written in Equation (3).

$$LY = \{L_{j,m} \mid 1\leq j \leq M , 1\leq m \leq 5\} \quad (3)$$

The subscript, *j*, in Equation (3), represents Total Number (TN) of images in the RSA and *m* represents the layer type. As we have defined formally a RSA and its images, now we define the retrieval operators for remote sensing application.

In this paper, a time-instance, t_i lies between interval $[t_1, now]$, where *now* represents the current time instance.

3.1 Distance Operator

The operator (DT) defined in Equation (4), computes distance within two given locations (points) at the t_i, the time-instance.

$$DT_{ti} = (d(p_j,p_k), t_i) \quad (4)$$

In Equation (4), p_j and p_k represents two different points/locations, belonging to two different layers of any image Im_i. The distance between two points can be computed with the help of Euclidean distance formula.

3.2 Area Operators

A set of operators is defined in this section, to find areas of layers of different types, in an image, Im_i (see Equation (2)). We name such type of area as a *temporal area*. Area operator can be useful in some important decisions making, for example in forest estimation, resource management, over the time era.

We compute the area *a* by using Equation (5).

$$a = d * \sum_{i=1}^{m} y_i \quad (5)$$

In Equation (5), *d*, represent the distances between *offset lines* and y_i, the lengths of *offset lines*.

3.2.1 Maximum (Max) and Minimum (Min) Areas Operators

Two operators have been proposed in section to find Max. area and Min. area layers in an image. We identify the following two cases of maximum and minimum area operators.

Case 1: To find out a layer having Max area and Min area amongst all layers in an image Im_i, created at t_i,(time instance).

Case 2: Find Max area and Min area amongst all layers of any particular type in all images of an application, which were created at different time instances, t_1, $t_2,\ldots.t_m$.

3.2.1.1 Case 1

We define two operators to find a Max. area layer and Min. area amongst all layers in an image I_i.

The Max area operator over a set of layers is defined in Expression (i).

$Max_{ti}(\{(L_{i,j},j)\} \mid 1 \le j \le m_j)$ (i)

The operator in Expression (i), represents two step working:

i. First step computes *temporal areas*

iv. Second step computes Max area layer among all layers of an image.

The operator's output is: a) Max area b) relevant layer type. It can be helpful in image categorization.

The operator in Expression (ii) traces a layer having Min area amongst all layers in an image *Imi*.

$Min_{ti}(\{(L_{i,j},j)\} \mid 1 \le j \le m_j)$ (ii)

The term $(L_{i,j},j)$, $L_{i,j}$ denotes the j^{th} layer type in the image, created at t_i.

3.2.1.2 Case II

Let $L_{i,m}$ is a *m-th* layer type of the i^{th} image as given in Equation (iii), created at the time instance t_i.

Two operators have been defined in Expression (iii) and (iv).

$Max\_m(\{(Im_i,m)\} \mid 1 \le i \le M \le now \text{ and } 1 \le m \le 5)$ (iii)

The first term Im_i, of Tuple (Im_i,m) in Expression (iii), denotes the images set, and the second term, *m*, represents the layer type. Two steps working of this operator is i) *temporal areas* are computed, of each m^{th} layer type belonging to all images. ii) Max areas among all computed areas of m^{th} type layers corresponding to each image. The operator returns Max area of a given layer type.

Similarly, the operator has been defined to compute Min area in Expression (iv).

$Min\text{-}m(\{(Im_i,m)\} \mid 1 \le i \le M \le now \text{ and } 1 \le m \le 5)$ (iv)

The working of this operator is same as discussed above. This operator is helpful in predicting the *depletion* r*ate* of a specific layer in the future.

These operators assist management activities and for future planning of the land helpful in maintaining harmony sustainable resources belonging to a specific region.

3.3 Change Tracing Operators

In this section, we have defined operators for tracing three (3) types of changes:

a. Data Change

b. Structural Change

c. Combination of data and structural change

3.3.1 Operator for Data Change Tracing

Let us assume that two images, Im_i and Im_j, of RSA, taken at two time instances, t_i and t_j, respectively. The *temporal areas* of any particular layer type (m^{th} type) in two images are: $A_{i,m}$ and $A_{j,m}$, respectively. The subscripts *m* $(1 \le m \le 5)$ represents the layer type (i.e. *vegetation, urban area, soil, water body or railway line*).

The operator *DC* have been defined for data change tracing in the areas $A_{i,m}$ and $A_{j,m}$ of m^{th} type layer, corresponding to two images as given in Expression (v).

$DC(A_{i,m}, A_{j,m})$ (v)

The operator give in Expression (v), computes the difference $(A_{i,m} - A_{j,m})$, and traces a data change that during a time_interval $[t_i, t_j]$ $(t_i < t_j)$, in same type of layer. This operator returns one of the following three results:

i. When $DC(A_{i,m}, A_{j,m}) = Zero$. This represents *no change* in the *temporal area* of the m^{th} layer type in two different images.

ii. When *DC* $(A_{i,m}, A_{j,m})$ *is negative or<0)*, it represents that growth has been occurred in the temporal area of the *m-th* layer type.

iii. When *DC* $(A_{i,m}, A_{j,m})$ *is positive or >0)*, it means depletion in the *temporal area* has occurred in the m-th layer type.

3.3.2 Structural Change (STC) Tracing Operator

The structural change tracing operator has been defined in Expression (vi). Two images, Im_i and Im_j have been taken during time instances t_i and t_j, respectively, of the RSA.

$STC(A_{i,m}, A_{j,m})$ (vi)

The difference $(A_{i,m} - A_{j,m})$, between two area have been computed and traces a *structural change* during $[t_i, t_j]$, the time interval (where $t_i < t_j$),

A *structural change* occurs, if any of the following conditions exists:

i) $STC(A_{i,m}, A_{j,m}) = |A_{i,m}|$

ii) $STC(A_{i,m}, A_{j,m}) = |A_{j,m}| \quad \forall \; (1 \le m \le 5)$

3.3.3 Data Change and Structural Change (Combined) Tracing Operator

The operators have been defined to trace back data change and structural change combined, in two different images of the RSA. This change can have following five cases (Case 1- Case 5), listed in Table 3.

Table 3. Case extraction (Case 1- Case 5), from different combination of changes

Type of Change	Case 1	Case 2	Case 3	Case 4	Case 5
Depletion of Layer (s) *(data change)*	Y	Y	Y	N	Y
Growth in Layer (s) *(data change)*	N	Y	Y	Y	Y
Deletion of Layer (s) *(structural change)*	N	N	Y	Y	Y
Addition of Layer (s) *(structural change)*	Y	Y	N	N	Y

Legends used: Y->Yes, N->No

Table 3 shows that deletion and addition of layer(s) falls in Case 1 while in Case 2, there is growth, depletion and addition of layer(s). Similarly other cases can be extracted in the same way.

3.3.4 Operator for tracing Type IV Change

We define operator, to trace back Type IV, in this section. i.e., data change and structural change (combined). Expression (vii) represents fourth type of change and derivation of its five cases discussed earlier.

$$DC\ (A_{i\,m}, A_{j\,m}) \wedge (STC\ (A_{i\,m}, A_{j\,m}), \text{ if } \exists\ (A_{i\,m} \wedge A_{j\,m} = 0))\ \forall\ (1 \leq m \leq 5) \qquad \text{(vii)}$$

In Expression (vii), the first part of the operator($DC\ (A_{i\,m}, A_{j\,m})$), handles the change in data(if it exists), and if ($DC\ (A_{i\,m}, A_{j\,m} = 0)$. It means no change has been occurred.

The 2nd part of the operator, i.e., $SC\ (A_{i\,m}, A_{j\,m})$ *if* $\exists\ A_{i\,m} \wedge A_{j\,m} = 0)$, computes the difference(*i.e.*, $A_{i\,m} - A_{j\,m}$) between the *temporal areas*. The second part term of the Expression (vii), finds a structural change (if it exists), during the time interval $[t_i, t_j]$, (where $t_i < t_j$), in a particular layer type corresponding to diverse images.

This paragraph explains the way one can trace Type I change (data change) and Type II change(structural change),from Expression (vii).

If ($DC\ (A_{i\,m}, A_{j\,m}) > 0)$) for same type layers(say *m-th*), belonging to two different images(Im_i and Im_j). Resulting, a depletion (data change) in the *temporal areas* of two layers of type(say *m-th* type) has occurred, corresponding to two diverse images during $[t_i, t_j]$, and if $\exists\ (A_{i\,m} \wedge A_{j\,m} \neq 0)$, means structural change(Type II) has occurred.

Similarly, if $DC\ (A_{i\,m}, A_{j\,m} = o)$, of Expression (vii), it means that no Type I(data change) has occurred and $SC\ (A_{i\,m}, A_{j\,m}) = Abs(A_{j\,m})$, it means a new layer $A_{j\,m}$, has been added to the RSA during $[t_i, t_j]$. This is the case of structural change (Type II change).

4. Case Study

We present a case study in this section, for change tracing besides Islamabad Highway using SPOT satellite images. The growth in urban area and population has badly affected the area under observation. Particularly, the area around highway has rapidly changed into urban area due to the transportation facility. We have studied and analyzed three years satellite images (1992, 2000 and 2009) for change tracing along Islamabad highway so that it helps in improving decision making and for better supervision (services).

Following are three satellite images and the area covered by each image is 201Sq.km.

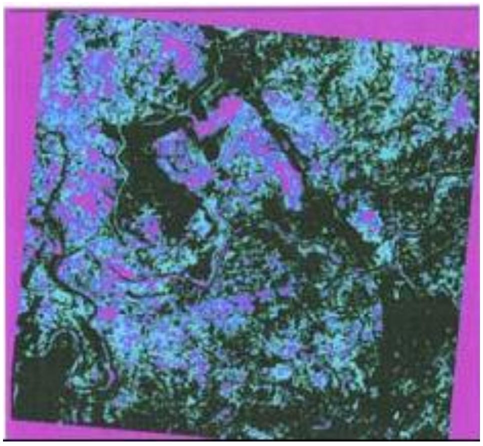

Figure 4a. SPOT satellite image taken in 1992, along Islamabad Highway.

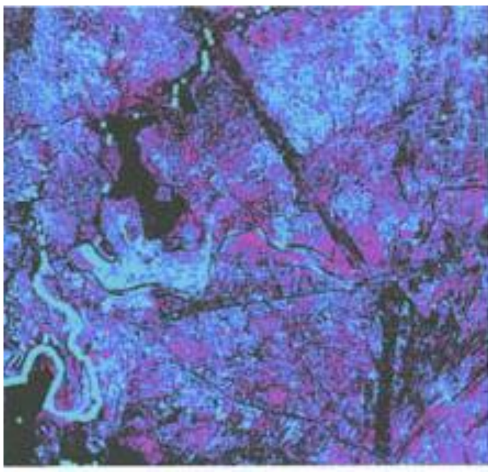

Figure 4b. SPOT satellite image taken in 2000, along Islamabad Highway.

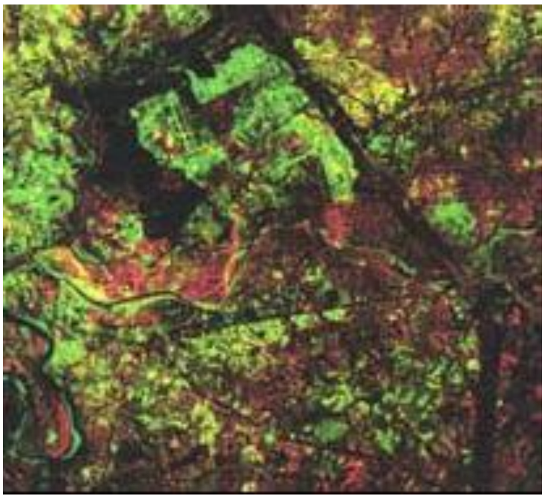

Figure 4c. SPOT satellite image taken in 2009, along Islamabad Highway.

Table 4. Area covered by each layer in satellite images of three years.

Image Taken (Year)	Layer Name	Area covered by Each Layer (Sq.km)	Number of Pixels (Layer)	Pixel %age of Each Layer in the Image
1992	water body	24.5778	253030	12
	Soil	90.1724	915556	45
	vegetation	66.4021	676552	33
	railway line	20.3245	206085	10
2000	water body	23.2225	233258	12
	Soil	94.4123	957664	46
	vegetation	54.3243	558924	27
	railway line	20.3245	233258	10
	Urban	10.4876	109262	5
2009	water body	20.3245	209975	10
	Soil	97.2134	982280	48
	vegetation	41.8376	424839	21
	railway line	20.3245	208465	10
	Urban	22.1432	226265	11

The area operator defined in Equation (v) can be used to find out the area covered by each layer in an image taken at any time instance t_i.

Table 4 represents the area covered by each layer in all three year images.

Maximum and minimum area layers within image and within same type of layers of different images can also be evaluated by applying operators given in Expressions (i-iv). Data change, structural change and combination of both are evaluated by using Expressions (v), (vi) and (vii), respectively.

5. Results and Analysis

Our proposed retrieval operators work well for the case study taken in the previous section. Operator to find out maximum area layer within image taken in 1992, return *soil layer* as it covers almost 45 % of total area covered by that image and it can be shown in Table 4. Similarly minimum area operator returns *railway line* *layer*, covering 10% of total area of image taken in 1992. To find out a layer (say *vegetation*), having maximum area, within images of three years, returns *vegetation* in year 1992 as it covers an area of 66 Sq. Km. as compared to 54 (year 2000) and 41 Sq. Km. (year 2009), shown in Table 4. Operators for change detection, return data and structural change during (1992-2000). Data change is there in *vegetation* and *soil* layers and structural change is due to new layer addition i.e. *urban* in the year 2000. Similarly, only data change is observed during (2000-2009).

6. Conclusion

In this paper we have proposed retrieval operators of RS. We have considered maximum of five layers in an image but an image can have more than five layers and their types may be different, depending upon FR from the user. Each operator is associated with a time stamp to realize FR form the user for better decision making and history management. These operators can be used to find out the area of a specific layer, Maximum area layer and at the same time three different types of changes are captured with the passage of time to better track for history management.

7. Future Work

We intend to further extend the list of operators and their implementation to enhance capabilities to fulfill maximum FR from user. We have considered some of the functional requirements from user. Other functional requirements can be explored and their operators and implementation might benefits the users of remote sensing applications.

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