CONTENT-BASED SPATIAL QUERY RETRIEVAL

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Abstract **- Information acquisition with the availability of modern information technology has become easier. We rely on various information systems in our daily lives. Geographical information system and spatial query retrieval become more and more important in vehicle navigation, robot automation, and satellite signal processing. Spatial query is made easy with the handheld technology like PDA and sketching device. However powerful query methodology needs powerful retrieval techniques to produce the desired output. Content based spatial query retrieval is one of the best resorts for spatial query retrieval. Structural spatial query retrieval is in content based retrieval family that is also an active research area in spatial databases. Structural spatial query retrieval assesses similarity by its structural arrangement, known as configuration similarity. This research developed an enhanced structural spatial query retrieval model for spatial databases.**

Keywords: **Content based retrieval, structural spatial query, configuration similarity, and spatial retrieval.**

1. RESEARCH RATIONALE

This research developed a Structural Spatial Query Retrieval Model for spatial databases by Spiral Web representation. The Spiral Web representation model is able to represent the unique relations among query objects in a structural spatial query like neighborhood relation, relative distance, and direction and object geometry. The Spiral Web representation has also eliminated the conventional multi measures used in structural similarity assessment and replaced it with single measure. On top of this, it proposed an improved way of associating objects in a query and eliminated the object approximations used in existing models. In short, the model was proven to be more effective than existing models in three main areas that are single similarity measure, improved reduced object association, and object approximation free. This research has been successful in proving the proposed model as a feasible and practical model for structural spatial query and retrieval of spatial information from spatial databases. The representation and similarity assessment proposed in the model has been tested and compared with the two main streams in structural spatial query that are the generic and Blaser(2000) model. The testing results have proven the applicability and practicability of the model. Furthermore the model produced better results in overall situations. On top of these, the proposed model and its prototype have laid a platform for many other researches in the domain of structural spatial similarity.

2. FRAMEWORK OF THE MODEL

Blaser (2000) constructed a structural similarity model with multi measures consists of topology, direction and metrics. Papadias and Delis (1997) dealt with the structural similarity with multi relations as well. Papadias et. al. (1998b) also constructed a model for structural similarity with multi constraints. Papadias et. al. (1998a) proposed spatial query retrieval with multi fuzzy relations structural similarity like direction, distance and topology. These researches have one common concept that is multi spatial relations like direction, distance and topology are essential for structural similarity assessment.

It is clear that there is no single measure that can substitute these multi relations as to date of this research. The invention of a single similarity measure is essential as it reduces processing time, effort and complexity. Furthermore the issues of integration and calibration of multi measures can be resolved. However the single measure structural similarity must be able to substitute the existing multi measures without sacrificing or trading off the efficiency of spatial query retrieval.

In order to obtain such a structural similarity model, this research proposed a framework in Table 1. The generic framework for configuration similarity includes all major types of spatial relations and also handles the fuzziness of the spatial relations in a query. It consists of multi relations defined in binary strings for topology, direction and distance, encoding of binary relations using conceptual neighborhood and algorithm to compute similarity for the binary relations. The claimed advantages of the generic framework are the expressiveness of the binary string encoding when given a binary string, a spatial configuration can be easily inferred, and vice versa; the efficient automatic calculation of neighborhoods and relation distance, and the uniform representation of all three types of relations (topological, directional, distance) in various resolution levels.

Components of Generic Framework	Components of Proposed Framework
Definition of multi measures/relations like cardinal direction, distance and topology.	Definition of single measure
Determine conceptual neighborhoods and encoding of query object into binary string of multi measures	Definition of Spiral Web structure with encoding of query objects into object values (OV)
Algorithm to assess structural similarity with multi relations	Algorithm to assess structural similarity with single measure
Problems	**Solutions**
Multi measures lack of integration and increase similarity processing complexity	Introduces single measure that does not require integration and reduces similarity processing complexity
Conceptual neighborhood of objects in query increase processing time, effort and complexity	Introduces Spiral Web that has improved object association computation
Object approximation with bounding box cannot support concave objects	Introduces Spiral Web structure that is object approximation free

Table 1 : Comparisons of Frameworks of Generic and Proposed Single Measure Structural Similarity Model

Though the generic structural similarity models use multi spatial similarity measures like topology, cardinal direction and distance for spatial query retrieval by structural similarity retrieval in spatial databases (Papadias et. al. 1998b, Blaser, 2000,), but the multi measures lack of proper integration mechanisms causing high inexactness in retrieved spatial configurations, increased computation time and processing efforts as the number of measures used increases. The number of objects to be searched in a spatial database, N for n number of objects in a query is [N!/(N-n)!]. If N>n, the candidate is N^n where retrieval of structural queries is exponential to the query size. Structural query processing becomes more expensive if inexact matches are to be retrieved in common practical applications.

In the encoding of binary relations and similarity assessment, the generic models associate the query objects for forming object pairs with either complete or reduced association relations. In fact, both the complete and reduced object association relation computation still have rooms for improvement on how to determine and define the most meaningful association computation that can improve the exactness of retrieved spatial configurations (Blaser, 2000). Hence this can reduce the number of associations for encoding and similarity assessment complexity of spatial query retrieval by structural similarity. On top of that, the objects in a spatial query are approximated into bounding boxes where those that are unlikely to satisfy the query are eliminated and a set of potential candidates are selected in the filtering step of spatial query retrieval. Since bounding rectangles are only the approximations, they cause some potential objects being eliminated at the early stage of spatial query retrieval. This is crude approximation that often leads to incorrect matching when concave region objects are involved (Goyal and Egenhofer, 2001).

Consequently, the research hypothesis is to establish novel spatial query retrieval by structural similarity that defines a spatial structure, Spiral Web that supports single similarity measure; introduces an improved reduced association relation computation; and eliminates object approximation in assessing structural similarity that can resolve the problems in the generic structural retrieval model.

Framework of the proposed SMSS covers definitions of spatial query, spatial structure for query representation, encoding mechanism of structural similarity and algorithm of assessing structural similarity for retrieved configurations. The Spiral Web structure is the foundation component of the proposed model that can overcome the shortcomings in the existing spatial query retrieval by structural similarity. The single similarity measure is developed to enhance the multi measures used in existing structural similarity assessment as multi measures grows exponentially complicated when number of query objects grows. Furthermore, the multi measures require higher processing effort and lack of proper integration. The improved reduced association relation technique improves on the number of association relations that needs to be assessed to further reduce redundancy in encoding of query similarity.

3. SPIRAL WEB REPRESENTATION

This research proposes a unique structure, Spiral Web that caters the object arrangement need of a spatial query. It produces single measure for spatial query retrieval by structural similarity and eliminates object approximations. The single measure reduces the processing time, efforts and complexity in structural similarity assessment.

3.1 Significance of spiral web

The existing structural similarity models utilize the bounding rectangles to approximate a query. Approximation filters and speeds up the searching of similar configurations from spatial databases. However there are situations where approximation causes incorrect filtering. Bounding rectangles are only the approximations; they cause some potential objects being eliminated at the early stage of spatial query retrieval. The approximated query loses their original positioning when the topology, direction, distance and other metrical refinements between bounding boxes do not necessarily coincide with the topological relation between the actual objects. This crude approximation often leads to incorrect matching when concave region objects are involved.

Spiral Web structure does not have this problem, as it is object approximation free. It eliminates the use of approximation and bounding boxes and uses actual geometric structure in representing a spatial query. It is a unique way of spatial query representation. It provides single similarity measures to represent all targeted objects. Hence it is more sensitive to the relative positions of query objects in a query. Figure 1 shows a query and its Spiral Web. In Figure 2, the relative distances and geometry among the objects in the query change slightly, therefore the Spiral Web created for representing that query also changes. These two samples show that the Spiral Web is sensitive to the changes of relative settings in a query with the distinguishable values in Table 2.

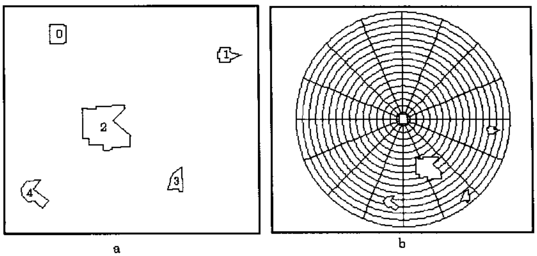

Figure 1 : Sample 1 (a) Spatial Query (b) Spiral Web

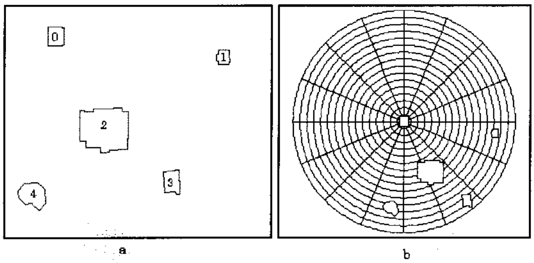

Figure 2 : Sample 2 (a) Spatial Query (b) Spiral Web

Object	OV(ZN, RN) for Query 1	OV(ZN, RN) for Query 2
0	8.556370, 15.99990	8.556370, 15.99990
1	5.000010, 3.239480	5.000010, 3.116270
2	7.264850, 8.230100	7.311050, 8.290780
3	7.000010, 1.915820	7.000000, 1.693650
4	9.000000, 3.952420	8.999990, 3.842360

Table 2 : Distinctive Measured Value for Query 1 and Query 2

Every query is represented in a Spiral Web with multi cells, $SW_i = \{C_1, C_2, \ldots, C_{n-1}\}$ and a single similarity value is computed for each object in the query, SOVi $= \{OV_1, OV_2, \ldots, OV_{n-1}\}$ where every Spiral Web built would have a set of single similarity measures associated to it. A cell is identified by an index consists of zone and ring identity numbers, $C_i(Z_i, R_i)$. The height and partitions depend solely on the number of objects in a spatial query. An OV for each object in the spatial query has a zone value and ring value, OV (ZN, RN) encoded from the Spiral Web. The encoded OV is compared with the objects in the spatial database through similarity assessment. The Spiral Web simplified the encoding and similarity assessment of query as it eliminates the multi measures that are used in the generic models. A Spiral Web has a few components that play the important roles, {Q, RO, Ctr, D, Di, C, H, P}. Firstly, a spatial query, Q is taken in for processing, reference object, RO, center, Ctr, diameter, D and maximum distance, Di are extracted from the query. Then a Spiral Web consists of core, C that has height, H and partitions, P is created for each structural query.

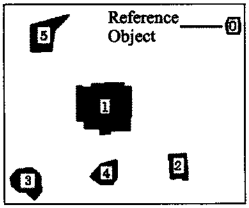

Figure 3 : Identify Reference Object

3.2 Core

A spatial query, Si has multiple, n targeted objects, Tn, therefore $S_i = \{T_1, T_2, \ldots, T_n\}$. Once a query input is accepted, identifying the reference object from the query is the initial task. The reference object (RO) is identified from the first drawn object in a query. This is because the first object is the initial or starting location when a user sketches or draws a spatial query for structural similarity assessment. It has no reference to base on when it is drawn while the rest of the objects are drawn relatively base on its location. For instance, Object 0 shown in

Figure 3 is selected as the reference object for the Spiral Web based on this criterion, as it is the first sketched object for that query. The rationale of assigning a reference object in each query is to allow comparison of center and off-center objects in the query to preserve their relative direction, distance and topology details. The main idea of creating the Spiral Web is to represent a query with single measure that is meaningful for structural similarity assessment. Hence the core is important for determining that single measure. The extracted reference object is required for determining the center, diameter and maximum distance in constructing a Spiral Web as shown in Figure 4 where the reference object is the core the Spiral Web.

A center (Ctr) is determined from the centroid of reference object. It consists of a pair of coordinates, Ctr(x, y). Ctr is important for constructing a Spiral Web for a query where it is the center of a Spiral Web. Once a reference object and its centroid and diameter are determined, the core of the Spiral Web can be constructed. The core determines the width and height of the whole Spiral Web; hence it determines the object values of a query. From the identified RO and Ctr, the diameter, D of a reference object is measured. The diameter is one of the components used to determine the height of a Spiral Web. The obtained diameter is used to determine the core of the Spiral Web.

The second component to determine the height of the Spiral Web is the maximum distance from the reference object to the furthest object. In a query, there is a set of distances from reference object to targeted objects, $D_i=\{d_1, d_2, \ldots, d_{n-1}\}$. Di is the highest measured distance value from the reference object to all the targeted objects in a query. The distance is measured with Euclidean Distance. The object pair is determined with the improved reduced association relation that is (N-1) where N is the number of object in a query.

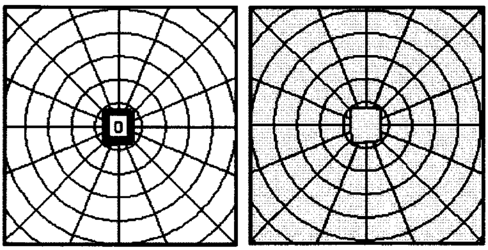

Figure 4 : (a) Spiral Web with the Reference Object, 0 (b) Core of Spiral Web

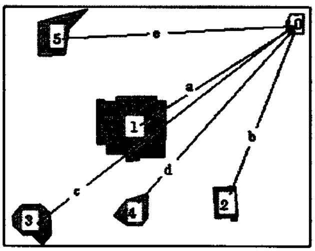

Figure 5 : Compute Maximum Distance

3.3 Height

Height is the number of rings of a Spiral Web. It is determined with the diameter and maximum distance obtained from the query. H=Di/D where H is the height, Di is the maximum distance and D is the diameter. From the H value obtained, a Spiral Web with rings is built. The height of each Spiral Web differs as the diameter and maximum distance vary in each spatial query. A ring is a circular structure derived specifically for a Spiral Web. The rationale for creation of ring for a Spiral Web is to complement the zone to describe a query. With the partitions with zone alone is insufficient to describe a query that has objects falling on more than a zone. Figure 6 shows a sample ring structure used for a Spiral Web consists of 6 objects in which the 6 rings are in dissected view.

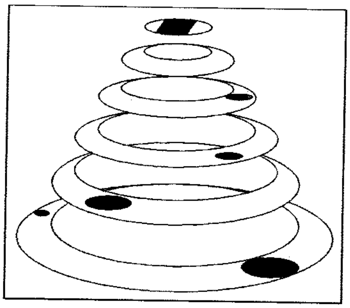

Figure 6 : A Sample Consists of 6 Rings for a Structural Query with 6 Query Objects

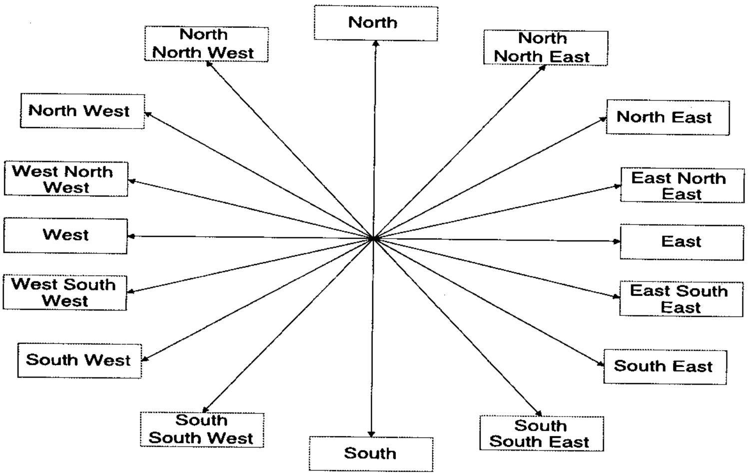

Figure 7 : Directional Zones

3.4 Partition

People manipulate concrete relations rather than continuous quantitative direction that is angles to express and reason about directions. Most previous work defines qualitative directions using either object projections or centroids. Each approach has its advantages and shortcomings. In this research, a centroid-based method is applied where the direction between two objects is determined by the angle between their centroids since projections are more complicated. This is because the Spiral Web aims to encode the query by its relative relations between query objects that do not use any projections. The set of relative direction relations defined is shown in Figure 7, they are north, north northeast, northeast, east northeast, east, east southeast, southeast, south southeast, south, south southwest, southwest, west southwest, west, west northwest, northwest, and north northwest. The directions are used to formulate the zone in the Spiral Web.

The zone is divided according to the direction model that is 4 zones consist of north, east, south and west. The 8 zones model consists of additional directions like northeast, southeast, northwest, and southwest. The 16 zones consist of north, northeast, north northeast, east northeast, south, southeast, south southeast, east southeast, east, northwest, north northwest, west northwest, south southwest, southwest, west southwest and west. The criterion used to derive zones is the number of objects exists in a structural query. The rationale for various numbers of zones is: The lesser number of partitions, lesser details can be provided; but the more number of partitions, the higher the processing effort is required. It is desirable to have more detailed partitions, but it is mandatory to minimize the processing effort required. Hence only an optimized number of partitions is used. Initially a Spiral Web with 4 zones is built for every query. Then computation of single measure value follows. The conditional checking continues for "IF two objects fall into same zone" and "IF two objects have same object values". These are the deterministic criteria for the number of zones to be created in a Spiral Web. The rationale for adopting these criteria is to ensure all objects in a query are represented with distinguishable values. If a Spiral Web fail to meet the criteria, then it will be recreated with more zones at an exponential factor of 4^n as the directional categories are also subdivided with 4^n where n is the number of times the Spiral Web is recreated and it starts with the value of 1. If there are only five objects exist in a structural query, the number of zones is computed accordingly from 4, 8 to 16 zones. The created Spiral Web consists only 8 zones as it is sufficient to determine a single measure value for the structural query where Object B falls in Zone 8, Object C falls in Zone 1 and Object D falls in Zone 2 and 3 and Object E falls in Zone 4 where no object fall into similar zone, and no similar single measure value for any object in the query.

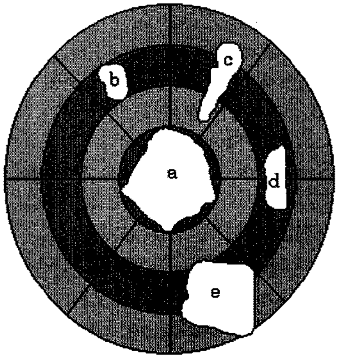

Figure 8 : A Spiral Web consist of 8 Zones and 4 Rings

3.5 Association

An association relation is a link between two or more objects. It is formed with complete or reduced association methods. A standard relation includes a pair of objects. Multi relations are involved when a group of objects is brought into relation with single object like a house is related to a park in the housing estate. Association can be made with the most commonly used spatial relations in structural similarity assessment like topology, relative direction and relative distance (Papadias et. al. 1998a, Papadias et. al. 1998b, Blaser 2000, Goyal and Egenhofer, 2001).

With the complete association technique, the number of possible association relations in a spatial scene is R = (N*(N-1)) for N number of object exists in every query. A query consists of four objects; the complete association approach has 12 association relations, the reduced association with R = ([N*(N-1)]/2) reduces the association relations to 6 whereby the proposed improved approach assesses only 3 associations. The reduced association computation still allows room of improvement to further remove redundancies though it has reduced by half of the number as compared to complete association computation.

With the proposed computation, (N-1) is sufficient to assess the structural similarity of a query hence the reduced association, [(N-2)*(N-1)]/2 is further reduced. The number of redundant relations increases by the number of similarity measures, P used that is (((N-2)*(N-1))/2*P). For a query consists of 8 objects processed with multi measures consist of topology, direction and distance, there are 63 associations. However the number of association reduces from ((N*(N-1))/2) to (N-1) for a single similarity measure with the improved reduced association relation

The proposed structural similarity assessment uses the improved reduced object association technique. It has been improved in term of the number of association relations that needs to be assessed to further reduce redundancy. Instead of evaluating all the relations, the improved object association only considers the relation from reference object to all targeted objects in a query with $\alpha = \beta - 1$ where α is the number of relations to be created or assessed, β is the number of objects in a query.

This research aims to prove that this neighborhood relation arrangement is effective to represent a structural query and reduces complexity in processing as it reduces number of associations. The cyclometric complexity determination used in Software Engineering is applied to show the complexities in each object association relation to prove that the proposed improved object association is less complicated as compared to the complete and reduced approaches where C is Cyclometric Complexity, E is number of edges or links and N is number of nodes. The proposed approach has the cyclometric complexity of "1" in all queries despite the number of objects exist in them.

3.6 Area

Area is one of the components in Spiral Web structure (Ballard and Brown, 1984). It is required to compute the single measure for a query. Area is one important descriptor of 2-D geometric structure (Ballard and Brown, 1984). Area of Occupied Zone (refer as A_Z) means the area of a zone being touched by an object and (refer as A_T) is the size of the object. Area of Occupied Ring (refer as A_R) means the area of a ring being touched by an object.

Figure 9 shows five objects obtained from a spatial query where Object 2 touches on ten rings and two zones, the area of occupied zone is the area of the object that falls on the two zones and the area of occupied ring is the area of the object that falls on the ten rings.

4. SINGLE MEASURE

This research proposed single measure structural similarity for spatial query retrieval. The single measure structural similarity is made possible with a structure for mapping a spatial query, Spiral Web. It provides a significant single object value, OV to represent each spatial query and objects. The single measure considers the importance of direction, distance and topology in structural similarity assessment, so it covers these details with the zone and ring concepts in the Spiral Web.

4.1 Single Measure for Multi Zones Single Ring (MZSR)

The OV for a query object that falls into multi zones single ring is modeled as in Equation 1. As there are more than a zone involve, Σ(Zone) is computed by summing up all the zones being touched by the object. Since it involves only single ring, Σ(Ring) is computed by the only ring being touched by the object.

$$OV = (ZV_n, RV_n)$$
$$ZV = \sum_{n=1} [[ZN_1 + ZN_2 + ... + ZN_n]] \pm tol_z$$
$$RV = \sum_{n=1} [[RN_1]] \pm tol_R$$

Equation 1 Single Measure for MZSR Object

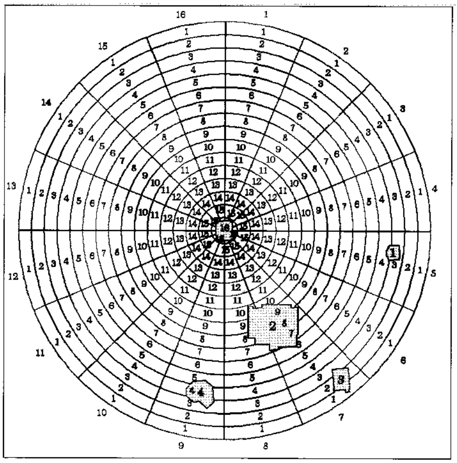

Figure 9 : A Spiral Web for a Structural Query

4.2 Single Measure for Multi Zones Multi Rings (MZMR)

The OV for an object that falls into multi zones single ring is modeled in Equation 2. Since the computation concerns on computing the OV for an object that falls into more than one zone and more than one ring, the number of zones and rings touched by the target object is crucial to determine the OV. For more than one zones involve, Σ(Zone) is the sum of all the zones being touched by the object. On the other hand, it also involves more than one ring, Σ(Ring) is computed by summing all the rings being touched by the object.

$$OV = (ZV_n, RV_n)$$
$$ZV = \sum_{n=1} [[ZN_1 + ZN_2 + ... + ZN_n]] \pm tol_z$$
$$RV = \sum_{n=1} [[RN_1 + RN_2 + ... + RN_n]] \pm tol_R$$

Equation 2 Single Measure for a MZMR Object

4.3 Single Measure for Single Zone Single Ring (SZSR)

Equation 3 shows the designed computation of OV for an object that falls into single zone single ring. Consequently both the number of zone and the number of ring touched by the target object are used to determine the OV. Since there is one zone involve, therefore Σ(Zone) is modeled by the only one zone being touched by the object and Σ(Ring) is computed by the only ring being touched by the object.

$$\begin{aligned} OV &= (ZV_n, RV_n) \\ ZV &= \sum_{n=1} [ZN_1] \pm tol_z \\ RV &= \sum_{n=1} [RN_1] \pm tol_R \end{aligned}$$

Equation 3 Single Measure for a SZSR Object

4.4 Single Measure for Single Zone Multi Rings (SZMR)

Equation 4 is designed to compute OV for an object that falls into multi zones single ring. The equation mainly concerns on computing the OV for an object that falls into single zone and multi rings. Due to only one zone involve, therefore Σ(Zone) is computed by the only one zone being touched by the object. It involves more than one ring, so Σ(Ring) is computed by summing up all the rings being touched by the object.

$$\begin{aligned} OV &= (ZV_n, RV_n) \\ ZV &= \sum_{n=1} [ZN_1] \pm tol_z \\ RV &= \sum_{n=1} [[RN_1 + RN_2 + \ldots + RN_n]] \pm tol \end{aligned}$$

Equation 4 Single Measure for a SZMR Object

5. STRUCTURAL SIMILARITY ASSESSMENT

The structural similarity assessment is based on the proposed similarity measure in Section 4. The similarity assessment is straightforward and simple as compared to the multi measures similarity assessment, this help to reduce the complexity, time, and effort. Furthermore it eliminates the multi measure integration in similarity assessment. The most important one is it still preserves the essential direction, distance and topology contents of a query in the structural similarity assessment. The Objects in the database do not have any prefixed OV, it is case by case basis. The linear searching starts by selecting first object in the spatial database for comparison, all its surrounding objects that fall within the spiral web would have an OV, then comparison can be made for the OV from query object to OV from spatial object. A difference can be counted then ranked the retrieved objects with the least to the most difference with Equation 10. The hits are prioritized by Equation 11 and being presented to user.

5.1 Significance of assessment

Generic structural similarity assessment employs a multi-step strategy that makes use of the dependencies among the different types of spatial relations like coarse topology, detailed topology, metrical refinements, cardinal directions and relative distances in the interpretation of a query. With the single measure structural similarity made available with the Spiral Web, the structural similarity assessment procedures are simplified. Instead of assessing the similarities from multi measures, the similarity is assessed with single measure only. A spatial query is obtained from the Spiral Web representation. Linear searching starts after a spatial query is formulated, then the single similarity measure is compared. The false hits are eliminated while the remaining hits are prioritized and being presented to user.

Furthermore it eliminates the integration problem of multi measures while preserving the importance of topology, direction and distance details obtained from a spatial query. This proposed model emphasizes on preserving the importance of topology, direction, and distance details in a spatial query with a single measure structural similarity. Consequently, this section discusses on how topology, direction and distance affects the single measure structural similarity by looking into how the OVs change as these parameters change as in Equation 5. The change of OV is determined by the change in ZV, the Zone Value and RV, the Ring Value. ΔZ is the change of ZN, the Zone ID; ΔR is the change of Ring ID, RN, A_Z means the area of a zone being touched by an object, A_R is the area of a ring being touched by an object and TA is the size of the object. TZ is the total number of zone and TR is the total number of ring in a Spiral Web. Δt_Z is the change in tolerance value for a zone value and Δt_R is the change in tolerance value for a ring value.

$$OV_{new} = (ZV_{new}, RV_{new})$$

where :

$$ZV_{new} = ZV_{org} + \Delta Z \pm \Delta t_Z$$

$$RV_{new} = RV_{org} + \Delta R \pm \Delta t_R$$

$$\Delta t_Z = \left[\frac{1}{TZ_{new}} - t_{Z_{old}} \right]$$

$$\Delta t_R = \left[\frac{1}{TR_{new}} - t_{R_{old}} \right]$$

Equation 5 Changes of OV

The topology defined in this research is illustrated in Figure 10. The object in circle is the reference object and the rectangle is the target object. For instance, the target object overlaps the reference object in case A; both reference and target objects are apart from each other in case B; both the reference and target objects meet one another in case C; the target object falls in the reference object in case D; the target object contains the reference object in case E.

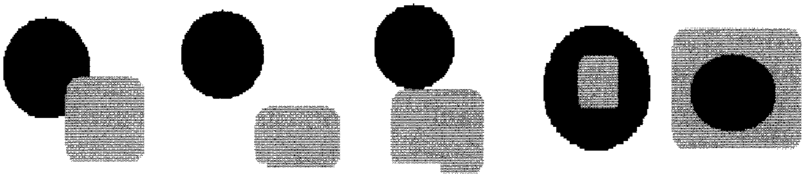

Figure 10 : Topological Relations: (a) Overlaps, (b) Disjoins, (c) Meets, (d) Contained by and (e) Contains to be Evaluated in a Spatial Query

Equation 6 is the change of OV for an object that is affected by a change in topology relation with the reference object in a query. From the various changes of topological relation in the above queries, the changes of OV are obtained. The topological relation changes the OV because of the change in relative distance from the reference object to each object in a query. The change in relative distance also causes the change in maximum distance in a query. The maximum distance is the distance of the reference to the furthest object in a query. When maximum distance and relative distance change, the number of ring and zone in a Spiral Web also changes. Then the OV changes as a result of these changes. For object that falls into single zone single ring, multi zones multi rings, single zone multi rings or multi zone single ring, the change in OVs is different.

For MZSR and MZMR object, ΔZ is computed by adding the changes in all the zones being touched by an object. ΔZ is computed according to the proportion of each zone being touched. However as MZSR only involves single ring, ΔR is the change computed by the single ring being touched by the object. For MZMR that involves more than a ring, ΔR is the change computed by all the rings being touched by an object according to the proportion of each ring being touched. For SZMR and SZSR object, ΔZ is computed by adding the change in only single zone being touched by an object. For SZMR, the ΔR is computed according to the proportion of each ring being touched since it involves more than a ring. On the other hand, ΔR for SZSR is the value change computed by the single ring being touched by the object.

$$\Delta Z = \sum_{n=1} [[ZN_1 + ZN_2 + ... + ZN_n]]$$
$$\Delta R = \sum_{n=1} [[RN_1 + RN_2 + ... + RN_n]]$$
$$ZN_n = (ZN_{new} - ZN_{old}) * [A_Z / TA]$$
$$RN_n = (RN_{new} - RN_{old}) * [A_R / TA]$$

Equation 6 Change of OV When Topology Relation Changes

Equation 7 shows the change of OV as a consequence of changes in relative directions between object pair. This computation is applicable for all MZMR, MZSR, SZSR and SZMR object.

$$\Delta Z = \sum_{n=1} [ZN_1 + ZN_2 + ... + ZN_n]$$
$$\Delta R = \sum_{n=1} [RN_1 + RN_2 + ... + RN_n]$$

$$ZN_n = [ZN_{old} + ((RD_{old} - RD_{new}) / (360 / TZ_{old}))] * [A_Z / TA]$$
$$RN_n = (RN_{new} - RN_{old}) * [A_R / TA]$$

Equation 7 Change of OV When Relative Direction Changes

Equation 8 shows the change of OV when relative distance changes. The OV changes because the relative distance changes the maximum distance and the number of ring and zone in a Spiral Web. If the relative distance increases the maximum distance, it also increases the number of zone and ring. However if the relative distance reduces the maximum distance, it will reduce the number of zone and ring as well. Therefore the OV changes because the ZV, the Zone Value and RV, the Ring Value changes when relative distance changes.

$$\Delta Z = \sum_{n=1} [[ZN_1 + ZN_2 + ... + ZN_n]]$$
$$\Delta R = \sum_{n=1} [[RN_1 + RN_2 + ... + RN_n]]$$
$$ZN_n = (ZN_{new} - ZN_{old}) * [A_Z / TA]$$
$$RN_n = (RN_{new} - RN_{old}) * [A_R / TA]$$

Equation 8 Change of OV When Relative Distance Changes

Equation 9 shows that the OV is influenced by the relative size of the object in a Spiral Web applicable to all MZMR, SZSR, MZSR and SZMR object. As the relative size changes, the A_Z that is the area of a zone being touched by an object, A_R, the area of a ring being touched by an object and TA, the size of the object also change. Hence it affects ZV, the Zone Value and RV, the Ring Value.

$$\Delta Z = \sum_{n=1}[[ZN_1 + ZN_2 + ... + ZN_n]]$$
$$\Delta R = \sum_{n=1}[[RN_1 + RN_2 + ... + RN_n]]$$
$$ZN_n = (ZN_{new} - ZN_{old}) * [(A_{Z_{new}} / TA_{new}) - (A_{Z_{old}} / TA_{old})]$$
$$RN_n = (RN_{new} - RN_{old}) * [(A_{R_{new}} / TA_{new}) - (A_{R_{old}} / TA_{old})]$$

Equation 9 Change of OV When Relative Size and Geometry Changes

On top of these, a Spiral Web representation is object approximation free, it makes the configuration retrievals more intuitive to the query. A Spiral Web representation computes less object association relations with the proposed improved reduced object association also reduces the number of assessment on objects in a spatial query.

For each query consists of a set of query objects with OV, $S=(S_1, S_2, \ldots, S_n)$, there are zero to many sets of retrieved configurations that is $R=\{R_1, R_2, \ldots, R_n\}$. For each retrieved configuration, R_n there is at least more than one retrieved object, $Rn=\{r_1, r_2, \ldots, r_n\}$. The structural similarity of a retrieved configuration to a query, S_Q is made up of a list of assessed structural similarity for individual object pair, S_{OB} where S_n is the OV of the query object, R_n is the OV of the retrieved object, N is total number of associated object pairs, SX_n is the zone value for the query object, SY_n is the ring value for the query object, RX_n is the zone value for the retrieved object, RY_n is the ring value for the retrieved object, T_z is the total number of zone exists and T_r is the total number of ring exists in a Spiral Web. SOBJ determines the similarity of each object in a query to a matched object from a database; hence the similarity of a query is determined by averaging the similarity values of the matched objects from database.

Equation 10 computes the structural similarity of an object in query to a retrieved object in a database. It computes the differences with $[\frac{(SX_i - RX_j)^2}{T_Z} + \frac{(SY_i - RY_j)^2}{T_r}]$ where $(SX_i - RX_j)^2$ is the difference of zone value and $(SY_i - RY_j)^2$ is the difference of ring value. There are four types of single measure, therefore the structural similarity of query object also differed depending on whether it falls on multi zones multi rings, single zone single ring, multi zones single ring or single zone multi rings. The details are discussed in the following sections. Equation 11 is the structural similarity for a query. It is derived from the structural similarity of query object. Since there are four types of structural similarity of query object, the structural similarity of query is a summation of all of them that is $S_{OB_{MZSR}}(S_i, R_j)$, $S_{OB_{MZMR}}(S_i, R_j)$, $S_{OB_{SZSR}}(S_i, R_j)$ and $S_{OB_{SZMR}}(S_i, R_j)$.

$$S_{OB}(S_i, R_j) = 1 - [\frac{(SX_i - RX_j)^2}{T_Z} + \frac{(SY_i - RY_j)^2}{T_r}]$$
$$where\ S_i \leftarrow OV_i, R_j \leftarrow OV_j$$

Equation 10 Single Measure Structural Similarity of Query Objects

$$S_Q = \sum_{\forall ij, i \supseteq 2, j \supseteq 0} \frac{S_{OB}(S_i, R_j)}{n-1}$$
$$where\ S_i \leftarrow OV_i, R_j \leftarrow OV_j$$

Equation 11 Single Measure Structural Similarity

5.2 Assessment for query object in MZSR

The structural similarity assessment of query object falls on multi zones single ring is shown in Equation 12. The computation obtains the multi zone values of query by $\sum_{n=1}^{n}[ZN_n \pm tol_z]$ and the single ring value by $(RN_1 \pm tol_r)$. RX is the zone value and RY is the ring value of the retrieved spatial object. For each object from the database that is taken into comparison with the query has a pair of zone and ring value.

$$S_{OB_{MZSR}}(S_i, R_j) = 1 - [\frac{((\sum_{n=1}^{n}[ZN_n \pm tol_z])_i - RX_j)^2}{T_Z} + \frac{((RN_1 \pm tol_r)_i - RY_j)^2}{T_r}]$$

Equation 12 Structural Similarity of Query Object that Falls into Multi Zones Single Ring

5.3 Assessment for query object in MZMR

Equation 13 shows the assessment of structural similarity of query object that falls into multi zone multi rings in a Spiral Web. Since there are multi zones and multi rings involved, the computation of zone value is $\sum_{n=1}^{n}[ZN_n \pm tol_z]$ and ring value is $\sum_{n=1}^{n}[RN_n \pm tol_r])$. The zone and ring values from spatial database remain as RX and RY.

$$S_{OB_{MZMR}}(S_i, R_j) = 1 - [\frac{((\sum_{n=1}^{n}[ZN_n \pm tol_z])_i - RX_j)^2}{T_Z} + \frac{((\sum_{n=1}^{n}[RN_n \pm tol_r])_i - RY_j)^2}{T_r}]$$

Equation 13 Structural Similarity of Query Object that Falls into Multi Zones Multi Rings

5.4 Assessment for query object in SZSR

Equation 14 is the computation for similarity assessment for query object in single zone single ring. Since there is one zone and one ring involved, the zone value, $(ZN_1 \pm tol_z)$ is compared with RX and the ring value, $(RN_1 \pm tol_r)$ is compared with RY.

$$S_{OB_{SZSR}}(S_i, R_j) = 1 - [\frac{((ZN_1 \pm tol_z)_i - RX_j)^2}{T_Z} + \frac{((RN_1 \pm tol_r)_i - RY_j)^2}{T_r}]$$

Equation 14 Structural Similarity of Query Object that Falls into Single Zone Single Ring

5.5 Assessment for query object in SZMR

Equation 15 shows the similarity assessment for query object that falls into single zone multi rings. There are more than a ring involved; hence the ring value is assessed by $\sum_{n=1}^{n}[RN_n \pm tol_r])$ and the zone value is assessed with $(ZN_n \pm tol_z)$. The spatial object from the spatial database determines RX and RY.

$$S_{OB_{SZMR}}(S_i, R_j) = 1 - [\frac{((ZN_1 \pm tol_z)_i - RX_j)^2}{T_Z} + \frac{((\sum_{n=1}^{n}[RN_n \pm tol_r])_i - RY_j)^2}{T_r}]$$

Equation 15 Structural Similarity of Query Object that Falls into Single Zone Multi Rings

6. MODEL EVALUATION TOOLS

The outcome of a similarity assessment between a query and a spatial database is a set of retrieved results and a list of similarity values. Different models used affect the similarity values and rankings of retrieved objects. For instance, the reduced association relation model (Blaser, 2000) claimed to be better that complete object association technique as it reduces the number of binary relations assessed in a query. Consequently the performance evaluation of the proposed model is conducted by evaluating the ranking of the retrieved results using the proposed model compared with the complete association model and reduced association model (Blaser, 2000). There are three commonly used statistical measurements for comparing the retrieved results. The statistical analysis of the correlated similarity assessment between the proposed model with Blaser's model (2000), and between the proposed model with conventional model are compared separately by using the well known Spearman Rank Correlation Test, Wilcoxon Signed Rank Test and, Mean and Standard Deviation Test.

7. TESTING AND RESULTS

This section shows the results from the testing. This research use two benchmarks i.e. Blaser's (2000) and the Conventional Models. The three statistical testing tools used are Wilcoxon Ranks, Spearman Ranks, Adjusted Average and Standard Deviation. The results are allocated into 6 tables. Table 1 to Table 4 consists of two categories of results. The first category is the first 10% of ranks from similarity retrieval and the second category covers the results from the entire ranked results. The average for the first category is the adjusted average whereby the MaxAvg in the second category represents the highest deviation from zero being observed between the first and the last ranks. Table 1 is the summary of the statistical tests of rank differences where conventional model is compared with the proposed model. Table 2 is the summary of the statistical tests of rank differences where reduced association with multi measures is compared with the proposed model. The summary of the normalized statistical tests for complete association with multi measures verses proposed model is shown in Table 3. Table 4 compares the normalized statistical tests for reduced association with multi measures against the proposed model. Finally, the summary of the normalized values for scene similarity for reduced association with multi measures is compared with proposed model is shown in Table 5 and Table 6. The listed findings are the evidence proving the functionality of the proposed model in representation and similarity assessment of structural queries in comparison with the conventional and Blaser's model: 1. All the rankings have significant correlation. 2. The first few positions of the two ranking lists show an excellent correspondence. 3. Databases containing spatial scenes that are similar to the structural spatial query resulted in a high correspondence of the ranking lists. 4. The Proposed, Conventional and Blaser models sort the spatial scenes in the spatial databases into similar and dissimilar scenes. 5. The two ranking methods (Blaser and Proposed) agree for the most similar and the most dissimilar spatial scenes. 6. The proposed approach assesses rotated scenes with a consistently higher similarity value than using Conventional and Blaser approach. 7. The proposed approach produces higher scene similarity values than Blaser and Conventional approach. 8. The trend for the rank differences within the first part of the ranking lists is negative. 9. The Proposed approach shows lower differences of scene similarity values.

Database	**First 10%**		**Entire Databases**			
	Average	***StdDev***	***MaxAvg***	***StdDev***	***Spearman***	***Wilcoxon***
1	-0.130	1.470	-1.570	4.950	0.980	0.080
2	0.000	1.130	-4.430	11.300	0.830	0.165
3	-2.800	2.990	-4.500	13.120	0.780	0.2[illegible]
4	-61.300	82.100	-90.000	193.600	0.800	1.125
5	-50.500	68.100	-73.600	204.800	0.766	1.[illegible]
Average	**-22.946**	**31.158**	**-34.820**	**85.554**	**0.831**	**0.724**

Table 1 : Statistical Tests of Rank Differences – Conventional Verses Proposed Model

Database	First 10%		Entire Databases			
	Average	*StdDev*	*MaxAvg*	*StdDev*	*Spearman*	*Wilcoxon*
1	-0.135	1.490	-1.670	5.000	0.979	0.071
2	0.000	1.200	-4.470	11.980	0.828	0.152
3	-2.500	3.100	-5.000	14.000	0.765	0.255
4	-61.500	82.140	-93.260	194.100	0.780	1.124
5	-50.850	68.410	-76.590	204.920	0.755	1.986
Average	**-22.997**	**31.268**	**-36.200**	**86.000**	**0.821**	**0.718**

Table 2 : Statistical Tests of Rank Differences – Blaser Verses Proposed Model

Database	First 10%		Entire Databases			
	Average	*StdDev*	*MaxAvg*	*StdDev*	*Spearman*	*Wilcoxon*
1	-0.150%	2.000%	-2.000%	7.100%	100.000%	95.780%
2	0.000%	1.200%	-6.100%	16.500%	100.000%	89.950%
3	-3.300%	3.900%	-6.900%	19.000%	100.000%	81.300%
4	-6.000%	7.900%	-8.800%	18.200%	100.000%	27.880%
5	-5.000%	6.500%	-7.100%	18.600%	100.000%	6.500%
Average	**-2.890%**	**4.300%**	**-6.180%**	**15.880%**	**100.000%**	**60.282%**

Table 3 : Normalized Statistical Tests – Conventional Verses Proposed Model

Database	First 10%		Entire Databases			
	Average	*StdDev*	*MaxAvg*	*StdDev*	*Spearman*	*Wilcoxon*
1	-0.140%	2.200%	-2.100%	7.500%	100.000%	95.000%
2	0.000%	1.500%	-6.100%	17.000%	100.000%	89.400%
3	-3.100%	4.200%	-7.000%	20.000%	100.000%	82.000%
4	-5.800%	8.000%	-9.000%	18.300%	100.000%	27.000%
5	-4.900%	6.500%	-7.100%	18.700%	100.000%	5.700%
Average	**-2.788%**	**4.480%**	**-6.260%**	**16.300%**	**100.000%**	**59.820%**

Table 4 : Normalized Statistical Tests – Blaser Verses Proposed Model

Database	Conventional		Blaser		Proposed	
	Average	*StdDev*	*Average*	*StdDev*	*Average*	*StdDev*
1	0.600	1.080	0.600	1.020	0.480	1.000
2	-1.150	1.580	-1.140	1.530	-0.990	1.450
3	4.910	1.690	4.890	1.690	4.300	1.650
4	2.830	2.920	2.810	2.900	2.500	2.600
5	3.030	2.000	3.010	1.980	2.780	1.780
Average	**2.044**	**1.854**	**2.034**	**1.824**	**1.814**	**1.696**

Table 5 : Normalized Values for Scene Similarity Using Individual Data Files

Database	Conventional		Blaser		Proposed	
	Average	StdDev	Average	StdDev	Average	StdDev
1	3.980	2.150	3.900	2.05	3.000	1.950
2	5.010	2.600	4.500	2.530	4.100	2.300
3	5.300	2.750	5.200	2.610	4.800	2.500
Average	4.763	2.500	4.533	2.397	3.967	2.250

Table 6 : Normalized Values for Scene Similarity Using Multilayer Databases

8. KNOWLEDGE GENERATION

In general, the reviewed structural spatial query similarity assessments use multiple spatial similarity measures like topology, cardinal direction and relative distance (or metrics) for structural spatial query retrieval from spatial databases. These multiple measures increase computation complexity, time and processing on similarity assessment. In contrast, the proposed model created the Spiral Web and single similarity measure. The difference of computation complexity is ((N*2)* R) where N is number of objects and R is the number of similarity measure for every additional object exists in a query. Consequently, the proposed approach reduces the complexity of structural similarity assessment. On top of that, the proposed approach is verified and validated to be able to produce the similar rankings of retrieved spatial scene though it requires less processing computation. The new knowledge generated is the Spiral Web and single similarity measure can counterfeit the multi measures in the existing structural spatial query similarity. It is clear that a single similarity measure can represent a meaningful subset of details of the structural spatial query that makes the retrieval as good as the existing models.

Besides, the proposed model introduces an improved reduced object association relation computation for associating spatial objects in a structural spatial query. The computation of linking between spatial objects has been further reduced as compared to existing models. In short, the performance and contributions of the improved reduced object association relation in structural spatial query retrieval is significant because it created a new way to assess associate relations among query objects that requires less time of computation yet produces the similar outcomes as the complete and reduced models.

On the other hand, the proposed model does not approximate the spatial objects in a structural spatial query into bounding rectangles. Bounding rectangles are only the approximations that cause some potential objects being filtered out at early stage of spatial query retrieval. The bounding box is a crude approximation that often leads to incorrect matching when concave region objects are involved (Goyal and Egenhofer, 2001) in which some query objects are eliminated and only a set of potential candidates are selected in the filtering step of spatial query retrieval. The knowledge generated is the Spiral Web technique that is object approximation free can solve the problem of concave objects where structural spatial queries are not approximated into bounding boxes. The three main areas of contribution of the proposed model that are structural spatial query representation, similarity assessment and retrieval are detailed below.

8.1 Spiral web representation

Structural spatial query has been an active area of research for spatial databases. However majority of the researches are on how to improve the searching by using various artificial intelligences and how to improve the query representation by incorporating various parameters like shape, topology, direction, distance and other metric refinements. In general the researchers have the same aim that is to use structural spatial query more efficiently in querying and retrieving spatial information from spatial database using spatial configurations as spatial query input. Consequently, this research probes into a new way of representing and assessing similarity of structural spatial query that consists of spatial configurations with the creation of Spiral Web. The Spiral Web is an effective technique in representing a spatial scene that consists of spatial configurations namely a structural spatial query. The effectiveness includes the ability to represent various spatial scenes distinctively, where each spatial object in a spatial scene and the spatial scene itself is given a set of distinguishable object values (OV). The distinguishable values are used in the similarity assessment later. This OV is found to be able to substitute the multiple values used in conventional and Blaser's models. The knowledge obtained is the Spiral Web is a structure that is able to represent a structural spatial query and provide meaningful single similarity measure value that is OV where the similarity of the structural spatial query can be obtained.

8.2 Single measure structural similarity assessment

The structural spatial query similarity assessment is the assessment of how similar a structural spatial query is as compared to a set of spatial objects from the spatial database. The existing approaches highlight on using multi measures like topology, metric, cardinal direction and relative distance for assessing how similar a query as compared to the spatial objects from the spatial databases. Multi measures require greater resources for processing and the result subjects to proper integration issues.

The existing approaches approximate a structural spatial query by using bounding rectangle where the approximation causes inaccuracy for queries with concave objects. On top of these, the existing approaches use the complete and reduced association relation for associating object pairs in a structural spatial query. This causes redundancy in relation computation. The proposed model eliminated object approximation in the structural spatial query processing. Furthermore the proposed model has created a better set of association relation computation to cut down on the resources need to associate object pairs and assess each relation in a structural spatial query. Based on the testing results, Spearman Correlations show that the retrieval ranks of the proposed model is 83.1% whereby Blaser approach is 81.3% similar to conventional approach, the Wilcoxon tests also show that proposed approach (72.4%) retrieved more similar results than Blaser approach (70.9%) as compared to conventional approach. On top of these, the standard deviation of proposed approach is lower than Blaser approach in rank differences as compared to conventional approach that is 85.554 verses 86.73.

8.3 Single verses multi measures

A single similarity measure is established as the solution to multi measures for structural spatial query similarity assessment in this research. The single measure compares similarity by using single object value established from the Spiral Web built for a structural spatial query. The single similarity measure is tested and validated to be able to assess and rank the same set of spatial objects retrieved from spatial databases with lower standard deviation and average values in comparison with multi measures. Consequently, the single similarity measure is proven to be applicable and practical for assessing similarity of spatial objects from spatial databases. A single similarity measure is a new approach for similarity assessment and multi similarity measures are not indispensable but it can be substituted by the single similarity measure in structural similarity assessment.

8.4 Object approximation verses actual spatial object geometry

The research investigated the possibility of object approximation free. The actual boundary of a spatial object is used in the proposed model. It is evaluated in Testing and Evaluation that the proposed model that used actual boundary of spatial object in similarity assessment produces the same set and rankings of retrieval from the spatial databases. The integration of spatial object's boundary into structural similarity assessment can overcome concave object's topology, metrical refinements, relative distance and relative direction determinations.

Consequently the object approximation free is tested and proven to be more effective in producing better results of retrieval.

8.5 Complete/reduced verses improved association relation

The improved reduced association technique can retrieve and rank the spatial configurations from spatial databases better than the existing association methods as it uses less number of associations in structural similarity assessment. The improved reduced association is a good technique for structural spatial query retrieval since it can cover the sufficient details required for processing.

9. SPATIAL QUERY RETRIEVAL

The structural spatial query retrieval is enhanced with the Spiral Web representation and similarity assessment with single similarity measure, object approximation free and improved reduced association relation. The proposed structural spatial query retrieval works better than existing models as it has lower standard deviation (2.25) and average differences (3.967) in spatial scene similarity differences using multilayer databases. It also has lower standard deviation (1.184) and average differences (1.7) in spatial scene similarity differences using individual data files as compared to Blaser (2.034 and 1.82) and conventional (2.044 and 1.854) approaches. Furthermore the retrieval rankings of spatial configurations from spatial databases are highly correlated with lower standard deviation and difference averages. It is clear that the proposed model has established a more effective structural spatial query retrieval technique.

10. FUTURE RESEARCH

The compiled areas of future research are probable for contributions in the spatial database management system for structural query and retrieval of spatial configurations. The extensions on structural spatial query model include the integration of metadata, multimedia data, temporal change, implicit spatial objects, multi-modal user input, and multidimensional data. Some future directives like enhancement of structural similarity assessment, similarity retrieval and human computer interaction are also proposed.

10.1 Integration of Metadata for Retrieval from Spatial Database Management Systems.

The proposed model is tested for individual data files and multilayer maps. The individual data file is tested for performance comparison with the existing models whereas the multilayer maps are tested for applicability of the model in real world databases. However the applicability and practicability of the proposed model in real world spatial database system like a GIS can be extended. As in GIS, there are more potential matches for a structural query in large real world spatial database system. In order to support real world spatial database system, the search engine can utilize the metadata that focuses on smaller portion of all potential matches.

10.2 Integration with Other Multimedia Data for Retrieval from Spatial Database Management Systems.

The existing work is conducted by translating analog models of instances in reality like images or paper maps into digital form. The multimedia data type includes digital model of reality like digital images and digital maps. The various translators convert the analog data models at different resolution. Some translators add in analysis of analog information as Spatial-Query-By-Sketch (Blaser, 2000) and SNEPS (Srihari and Rapaport, 1989). Besides these horizontal translators, there are vertical translators that translate between the digital models like a digital image into a digital map. In order to portray the real world entities in to a computationally accessible form, it is essential to provide a combinational translator that can translate voices, written texts, and images into meaning structural spatial query statements that are ready for query and retrieval for spatial information from spatial databases.

10.3 Integration of Temporal Changes for Retrieval from Spatial Database Management Systems.

As to date of this research, all the models inclusive of the proposed model for structural similarity retrieval only work for static structural spatial query. The proposed model can be extended for querying dynamic structural spatial query where spatial objects in the query are allowed to change their state, locality, existence and spatial relations over time. In order to achieve this, research needs to be conducted to study how the change in the state of a spatial object relates to the change in the spatial relations.

10.4 Integration of Implicit Spatial Objects for Retrieval from Spatial Database Management Systems.

A structural spatial query contains both explicit and implicit spatial objects where explicit objects are taken into processing for query and retrieval. However, implicit objects are often hidden and ignored like the relevance of road intersections in a query. If these intersections are taken into detail consideration, it might lead to more accurate matching. Therefore research exploration into this area can help to find out rules of thumb that can be incorporated into the proposed model to better support structural spatial query for spatial database management systems.

10.5 Integration of Multi-Modal User Input for Retrieval from Spatial Database Management Systems.

The proposed model does not support multi-modal user input. However multi modal user input is a better way of communicating a structural spatial query. For instance, Blaser (2000) uses sketching to obtain the structural spatial query, and additional modals like writing and talking help to get more detailed query. In order to integrate these multi modals into the proposed model, interpretation, representation and integration of these modals need to be investigated in great details.

10.6 Integration of Multidimensional Spatial Objects for Retrieval from Spatial Database Management Systems.

The proposed model does not support multidimensional spatial object. Hence the proposed model only focuses on region or polygon objects where line objects like roads and rivers seen in the testing are transformed into polygon before processing, Multidimensional objects are difficult to interpret for they might be point or region objects in reality but user queries them as polygons or points that causes multi dimensional problem that requires an in-depth investigation. Consequently research can be conducted in incorporating multidimensional data into the proposed model.

10.7 Other Enhancements.

Firstly, the proposed model investigated and explored into a new structural similarity assessment technique. This lays a foundation on structural similarity assessment research not only in spatial database management systems, but also in multimedia retrieval system, image query and retrieval systems, and medical database management system. New researches can focus on how to integrate the query representation and similarity assessment methods into their individual area of interest wherever dealing with structural spatial query retrieval.

Secondly, the proposed model is proven to be applicable for spatial databases. It can also be applicable for spatial configuration similarity retrieval from image databases. Hence research can be conducted to adapt and adopt the proposed model into structural similarity retrieval from image databases from the dimensions of how the data is stored, managed and retrieved.

Lastly, this research has proposed a structural spatial query model that takes in human sketches in digital forms as query. This model allows human to express their request for spatial information from spatial databases. Furthermore the researches into spatial databases are in great demand as the users of computers no longer request for textual information but with geographical information as well in marketing, business management, and image retrieval. This proposed model is a good foundation for human computer interaction for structural spatial query retrieval researches. This research gives guidelines and standards on how to develop a structural spatial query retrieval system for query and retrieval with spatial configurations. Therefore the future researches that investigate human computer and multi modal interaction in structural spatial query may utilize the design and outcomes of this research as the framework by adding in other modals.

11. CONCLUSION

Due to the writing space constraint, most of the parts of the research cannot be discussed here, but they are documented in the dissertation. In short, this research has been successful in proving the proposed model as a feasible and practical model for structural spatial query and retrieval of spatial information from spatial databases. It derived the query representation and similarity assessment for 4 types of query that is SRMZ, SZSR, MZMR and MZSR. The similarity assessment uses a linear search through the all the objects in the database, by comparing and selecting each object one by one assuming they are the candidates in the first only by using the OV alone, no shape, color or size comparisons at all. In future, AI may be added to speed up the linear search and so on. Currently it is the most basic using spiral web to produce OV to compare with objects in the spatial database.

The representation and similarity assessment proposed in the model has been tested and compared with the two main streams in structural spatial query that are Conventional and Blaser models. The testing results have proven the applicability and practicability of the model. Furthermore the model produced better results in overall situations. On top of these, the proposed model has laid a platform for future researches in this domain.

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