Intelligent selection technique for database indexing to augment the speed performance of query processing on mobile device

*Samir Khemaies Boucetta, Daut Daman, Shabbeer Shaik

Faculty of Computing and Information Technology Rabigh, King Abdulaziz University, Rabigh 21911, Kingdom of Saudi Arabia
sBoucetta@kau.edu.sa

Abstract: Mobile device has been used widely in every aspects of human life such as: business, personal and even in government organization. Meanwhile, Mobile device such as hand-phone required fast internet connection such as 3G or even 4G. However, this network evolution stills not enough to solve the data load between server and hand-phone. In this paper, we proposed a new algorithm on indexing database to speed up the performance of information retrieval on spatial database. The intelligent selection techniques named as mRTree which is a hybrid between Quadtree and R-Tree indexing technique. The mRtree is an intelligent technique which is able to choose whether system will execute R-Tree or Quadtree based on data behavior and network condition like an expert system. The decision rules is designed through specific parameter of spatial data such as: size of data, number of query, number of record and etc. Based on testing that we have performed, the mRTree is able to increase the speed of communication between server and hand-phone around 30% on 3G network and even 45% on 4G Network. This result is able to bring research perspective about the ability of indexing technique system on mobile device and used for many applications such as GIS, or other client-server application.
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1. Introduction

Lately mobile application has been used in every aspect of people life. On the other hand, GIS application has been received great support from the emergence internet technology. GIS which is previously used on desktop, local or even in server, lately this trend has changed into GIS mobile application. This GIS mobile application can be displayed on such small device like hand-phone, smart-phone or ipad or another tablet pc(Rajinder, S.N, 2004). A lot of innovation has been invented that give Mobile GIS technology capability to be run on small bandwidth, limitation of application capability, color resolution and even small screen display[2]. Furthermore, Mobile GIS technology also enable process of spatial data transferring, data collection, processing and dissemination with huge amount of geographical data[2]. In database technology, indexing is one of database technique which can be created using one or more database table columns to give rapid searching and efficient access of ordered records. Spatial indexing has become an efficient methodology for managing spatial data records. A part of the records are strongly linked to a place. Like other structures of indexing, geographical indexing may be combined with other indices. The dissimilarity is that spatial index has particular access process to retrieve spatial data from data-store and to optimize spatial queries on spatial databases. This research attempts to enhance the processing of information retrieves time of spatial data from server on Mobile GIS technology, and it attempts to provide a tuning method for spatial data indexing. The last stage is developing a system that run on windows mobile platform that connected to server through 3G and 4G.

2. Related Works

Spatial database that consist of spatial network which is able to control moving objects. This spatial network constrained moving objects, monitoring free-moving objects[3]. The existing approach of mobile GIS is designed to share a computation between mobile clients and server. In addition, Spatial-temporal databases is providing a way to process queries efficiently so that user can obtain answer quickly[4]. Spatial database cluster and storage will cause slowly transaction and long recovery time that is way it need fast indexing search[5]. Furthermore, slow query and cryptic data structures are give another challenge on SOLAP (Spatial OLAP). Geographic Knowledge Discovery (GKD) need systems that support interactive exploration of data without being slowed down by the intricacies of a SQL (Structured Query Language) such as type query language and cryptic data structures. This problem has been solved by using a Hypermedia SOLAP method. GKD require maps comparison of different phenomena or epochs, crawling information from these maps is need to roll-up data for more worldwide information and to synchronize maps with tables and charts. Whilst such developments will improve the experience of the user with the system, important questions remain with respect to the competing objectives of providing documents to fulfill the requirements of specific users and concurrently respecting privacy concerns. According to NSERC (Natural Sciences and Engineering Research Council), Industrial Research Chair will take concern into an account and will address some technological and legal issues raised by the distribution and the sharing of Hypermedia and SOLAP information through wireless networks. As it has designed and developed the SOLAP technology used for the project on multi field[6]. This will continue on improving this technology, including its enrichment with other types of data such as hypermedia or multimedia[7]. That's why, indexing technique for Historical Spatio-Temporal Point Data RDBMS is supported for spatio-temporal data is limited, and most existing spatio-temporal indices cannot be readily integrated into existing RDBMSs. The increasing number of indexed temporal ranges and number of records in the database are an practical index for spatio-temporal (PIST) data[8]. The other researcher, Tian G. et al. also proposed an idea to enhance the performance of mobile query by using r-tree indexing. He also implement the method to spatial data on mobile GIS that load into mobile device[9]. On the other hand, spatial query such as Bounded Spatial Datasets (BSDs) query also raise a challenge that need to be solved. A BSD has two main elements: 1. objects with identified locations, and 2. unknown regions. The method of BSD query: site-based approach and area-based approach, for range and kNN query processing has shown more efficiency on cost compare to previous and baseline method[10]. The other method that contributes to enhance GIS data loading beside data indexing for query is dynamic display cache model. The dynamic display cache model is constructed based on intelligent agent, structure of web GIS dynamic cache and model for cache data. This model is able to enhance GIS application on web by performing fast graphics loading and response efficiency when loading large data, and manage the load of network[11]. Moreover, The remote spatial database has problem on handling large number of database and limitation of interfacing when access the system. That is why researcher tends to utilize series of k-NN queries to find estimated cumulative range of query results [12].

The limitation of memory and a low computational capacity in the mobile devices are some of the problems in the spatial index and hashing methods. The volume of spatial data and the computational cost of spatial operations are very large; however the mobile devices still stuck on limited memory and a low computational capacity compared to the Personal Computer (PC). Therefore, a spatial indexing for the mobile devices should be able to achieve good filtering efficiency as well. Some of the problem has been solved using a spatial indexing which is called MHF (Multilevel Hashing File) method for the mobile map service. The storage utilization of MHF is using the simple hashing technique to improve the searching speed process. Therefore, designing a density scheme of MBR (Minimum Bounding Rectangle) called HMBR (Hybrid MBR). Future research is expected to be useful for mobile map service, ITS (Intelligent Transportation System), LBS (Location Based Service) that have been increasingly studied recently is still needed in this area [9]. R-tree and Quadtree indexes that use wide framework are the best spatial data indexing methods among any other existing spatial indexing methods for low-dimensional spatial data [13]. In queries processing, R-tree method may be more efficient due to better maintenance of spatial immediacy, but it might slow down in updating or index creating and implementation of own concurrency protocols on top of table-level concurrency mechanisms, since R-tree is built logically as a tree and physically using tables inside the database and search involves recursive SQL for traversing tree from root to relevant leaves. Linear Quad- tree results in simpler index creation, faster update and inherit configuration in B-tree concurrency control protocols, because those indexes calculate tile estimation for geometries and use existing Btree indexes for performing spatial search and other DML operations[13].

Chen et al, 2003 and Francis et al., 2008 that delivers parallel methodology and contributes on development to this research is called mRTree spatial data indexing method. QR-tree presenting a quick speed spatial indexing structure based on Quadtree and R-tree[14-15]. It carries out data space with the space level partition strategy of Quadtree multistage partition and uses different R-tree index space object for each partition subspace. The research indicates that although mRTree always required more storage space than R-tree, it increased better performance in insertion, deletion, and especially searching. The result has showed that the more amounts of spatial data, the less cost and the better performance of mRTree. In the other word, for a large spatial database, mRTree obtained more superiority compared to R-tree [16]. Another similar methodology is a scalable constraint-based Q-hash indexing for moving objects [15]. All previous researches have mixed the algorithm of R-tree and Quadtree to create a new structure of spatial data indexing method. However, all previous researches have faced problems on storage consumption, while it is only better in some ranges of data as well as moving object environment.

2.1 R-Tree database Indexing

R-tree is tree data structures which is originally come from B-tree. R-Tree is used for demonstrating multidimensional points of data, such as indexing for spatial processing methods on multi-dimensional information. Each node in the tree interacts until the smallest d-dimensional rectangle that surrounds its child nodes. The leaf nodes comprise cursor to the real geometric entity in the database, as an alternative of child. The entity are symbolized by the tiny elements associated with rectangle in which they are enclosed [16]. Commonly, the nodes will communicate with leaf, thus the tree is selected so that a small amount of nodes is selected during a spatial query. Spatial query might require a number of nodes to be called before recognize the existence or absence of specific rectangle.

If we talk about Mobile GIS technology, we suggest choosing R-tree, due to R-Tree able to handle data containing and several overlap like "whole Earth objects" (object of full earth without requirement or detail), bounding-box based methods will not work properly. Overlapping data band is answered by turning the splits that decrease the exposure, using the splits that decrease border of bouncing boxes when creating nodes. As well, Mobile GIS will store, retrieve and process spatial data; spatial data in Geographical Information System is a compulsory element that needs to be solved for all of the problems that might occur in the future. In order to bring better understanding of R-Tree algorithm we have put detail explanation as follow. R1 and R2 are the root nodes. R1 is an instance, include child nodes R3 and R4, and include them with minimum bounding rectangle. The property of R-tree is described below [16] (Refer to Figure.1 and Figure.2):

- All of the leaf node include with x and X index records excluding root. The root could have less access than x.
- Every index record within a leaf node, indicate tuple represent the minimum rectangle. It holds the m-dimension spatial data object.
- All of the un-leaf node excluding the root has around x and X child
- Every access in un-leaf node has smallest rectangle which grasp rectangles in every child node.
- If the root is not a leaf, it has at least two child nodes.
- If the tree is stable and all leaves will be on the same level.

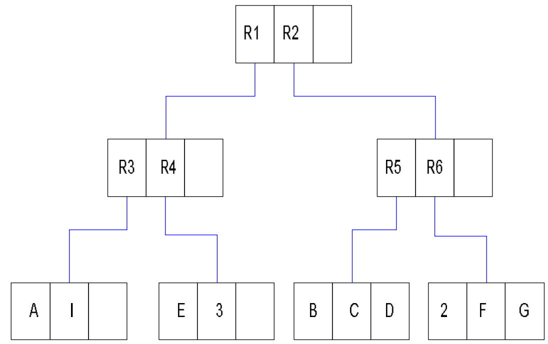

Figure 1. Tree Structure of R-Tree [16]

A lot of Scholars have explored R-tree spatial indexing since it is one of the finest spatial indexing. It is also recommended in Oracle spatial database.

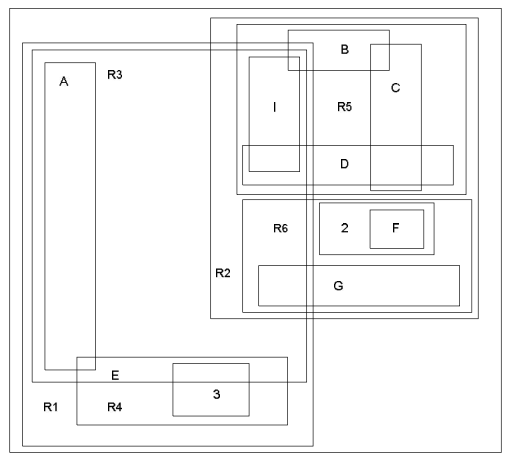

Figure 2. Tree Structure of R-Tree - 2[16]

Now, a lot of innovative spatial cluster grouping algorithm and R-tree insertion algorithm has been planned to speed up query processing. Those algorithm such as : k-means clustering method and employs the 3D overlap volume, 3D coverage volume and the minimum bounding box shape value of nodes as an integrated grouping criteria [17]. A scalable technique which is called Seeded Clustering will allows us to maintain R-tree indices by bulk insertion while keeping speed with high data arrival rates has also been proposed by Lee et.al. (2006). This bottom-up update policy on R-trees will generalizes existing update techniques and aims to augment update performance[18]. An original bulk insertion technique for R-Trees using Oracle 10g that is fast and does not decreased the quality of the result is also already presented[19]. A generalization for the relatives of R-trees which is called the Multi-scale R-tree, that allows efficient retrieval of geometric objects at different levels of detail has also been proposed [20]. An efficient Content-Based Image Retrieval (CBIR) system using R-tree spatial indexing which utilized shape information of images in order to assist the retrieval process is also created by database researcher[21].

On the other hand, another scholar has describe the problem on real-time mobile GIS based on the HBR-tree to control massive of location data efficiently have been used by other researcher[22]. A Technique combining existing Q + R-tree and QuadTree in terms of range query completing time by a high order of magnitude has also been proposed[23]. An efficient protocol for the kNN search on a broadcast R-tree, which is a popular on multi-dimensional index tree, in a wireless broadcast environment in terms of latency and tuning time as well as memory utilization also become concern on R-Tree Research[24-25].

2.2 Quad-Tree database Indexing

Quadtree is a tree data composition used to develop a set of hierarchical data compositions. The general property is based on the principle of recursive decomposition where internal node has up to four children. Basically, Quadtree is dividing two dimension spaces then divides it into four sub-parts or regions. The part could be in rectangular, arbitrary or square shape. Finkel and Bentley gave a name for Quadtree on data structure in 1974. This spatial data indexing has similar partitioning method with Q-tree. Quadtree has general decomposition methods where it crumbles the space into flexible cell which has maximum capacity. The region will be divided, then directory tree pursue Quadtree spatial decomposition when meet the optimum capacity [28]. Figure.3 shows Quadtree process.

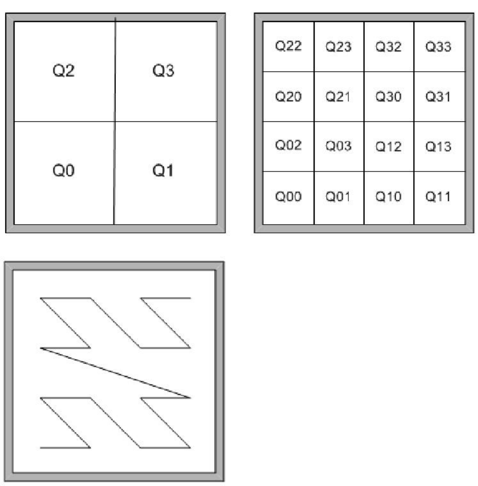

Figure. 3. Tree Structure of QUAD-Tree [28]

At this time, Quadtree is used for point data, curves, surfaces, areas and volumes. It will be divided to the same parts on each level, or may be managed by the input. This process, in image processing, is often expressed in terms of image space hierarchy against object space tree. The decomposition resolution can be repaired, or may be arranged by some materials of input data. In some applications the origin of data formation whether they state the restrictions of sections can also be distinguished. Although it is not recommended for particular spatial indexing, there are many advantages of using Quadtree spatial indexing on special circumstances. An algorithm based on applying eigenspace methods has been presented to a Quadtree of related set images to solve estimation problem in the occurrence of occlusion or background clutter. The inability to locate desired object and apply the appropriate normalizations effortlessly, are efficiently overcome by the recursive Quadtree procedure[26]. Furthermore, the new structure of Multi version Linear Quadtree (MVLQ) has been introduced based on spatio-temporal access method. This indexing structure can be used as an index mechanism for storing and accessing evolving raster images[27].

3. Material and Method to build intelligent selection technique

There are advantages and disadvantages of combining the indexes and build a selection engine. The intelligent selection technique named as mRTree has disadvantages on required more storage compared to regular index, but the difference storage is not too significant and combination of the indexes are not flexible (only better in some ranges of data). In contrast, mRTree method has advantages on flexibility, which depends on the condition of the data; it also can choose which index is most suitable with the current condition. This benefit gives significant improvement if we use the suitable spatial data indexing. This section we describe how Hybrid Quadtree and R-tree spatial data indexing method are used to create mRTree. The proposed fusion of Quadtree and R-tree spatial data indexing method is based on the weakness and strength of each those spatial data indexing methods. mRTree is used to combine those spatial data indexing techniques. In implementation part, some of the tables used Quadtree spatial data indexing, while the others use R-tree spatial data indexing method. One or two spatial data indexing method will be implemented in a single spatial database. The use of R-tree and Quadtree spatial data indexing method in different tables is based on the condition of data and requirement of applications which will augment the speed of spatial data query processing.

This research intends to explore the behaviour of R-tree and Quadtree spatial data indexing method. Each of those methods has different strength and weakness according to application requirements and type of data. Our aim is to select a suitable spatial data indexing method. If Quadtree and R-tree are used together for data indexing, it can contribute on improving spatial data transferring speed. Consequently, the process of transferring and retrieving spatial data using wireless broandband network will be more efficient and effective. As we have explained earlier, mRTree indexing is composed from Quad Tree and R-Tree indexing database which is controlled by rule base system based on particular condition. These conditions will act as a classifier to choose QuadTree or R-tree indexing technique. The methodology is shown in Figure.4.

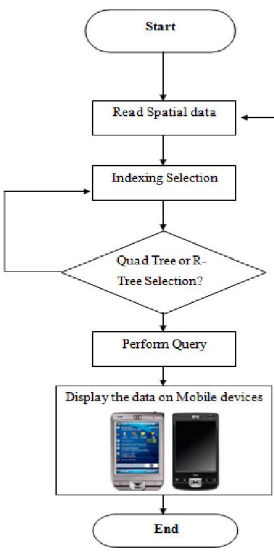

Figure 4. Architecture of Intelligent selection technique

Table 1. mRtree System specification

Web Server and Database Server	**Processor**	**Intel Pentium i5**
	RAM	3GHZ
	Web Server	IIS
	GIS Server	Oracle Application Server,Map Viewer and MapGuide Open Source
	Database	Oracle 10g Spatial
Mobile Devices:	HTC Touch Pro2	Smartphone
	OS	Windows Mobile 6.5
	Web Browser	Personal Internet Explorer

The process of selecting indexing method is requiring particular condition such as:

- Number of spatial record
- The available bandwidth
- The speed of mobile device performance (memory and processor)

The detail specification of our server and client can be viewed in Table 1.

4. Experimental Result to build intelligent selection technique

The intelligent indexing technique is formulated through equation 1.

$$DA(q)=\sum_{j=1}^{N}\left\{\prod_{i=1}^{n}\left(S_{j,i}+q_i\right)\right\} \quad (1)$$

DA is represent number of disk accessed in n-dimensional R-Tree index which accessed by query window q=(q1,…,qn) and side (sj,n,…,sj,n) of each tree nodes sj(j=1,…,N). The formula above is to calculate the current effect of node size and R-Tree query performance. On the other hand, Quadtree has strong partition efficiency by dividing block into several regions. By defining F (X,Y,W) which is expressed number of fragments that obtained from block width (W) and X and Y is shifted units parallel to x and y axis. W is positive integer while X and Y is absolute position (refer to equation 2 and 3).

$$F(X,Y,W)=F(C_1\bullet 2^x, C_2\bullet 2^y, 2^i)=(2^x,2^y,2^i) \quad (2)$$

Where x,y,I,C1 and C2 are positive integers

$$F(X,Y,W)=F(x,y,i) \quad (3)$$

During the testing Pasir Gudang map is used as spatial data source that acquired from our university. In this case study we have tried to load particular data from small number of records until large number of records (we obtained peak record on: 256000 records). It has shown a good result in order to load various numbers of records that give appreciation to the MRTree algorithm. Figure.5 shows the result on zooming process when searching on particular location.

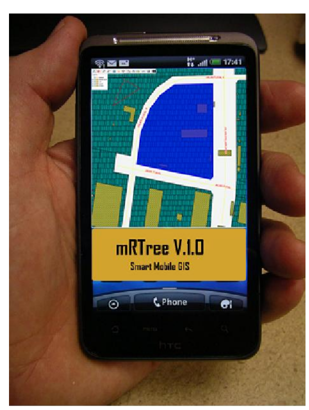

Figure 5. Result of mTRee run on HTC smartphone-1

We have conducted three kinds of testing's (refer to Fig.6, 7 and 8):

- Loading data through mobile device using 3G connections
- Loading data through mobile device using 4G connections
- Loading the spatial data using web browser on server (LOCAL).

Figure.6. has loaded full map of Pasir Gudang spatial data. The data is quite clear and easy to interact. The resolution of spatial data needs to be reduced in order to increase the performance of data load. We have succeed on perform mTRee query to load full data of Pasir Gudang map. This process required 3.5 second for 2000 records until 35 second for 256000 records.

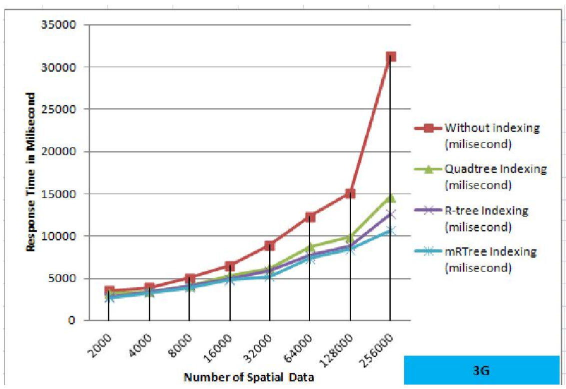

Figure 6. Response time of various indexing technique compared to mRTree- Using HTC mobile 3G connection

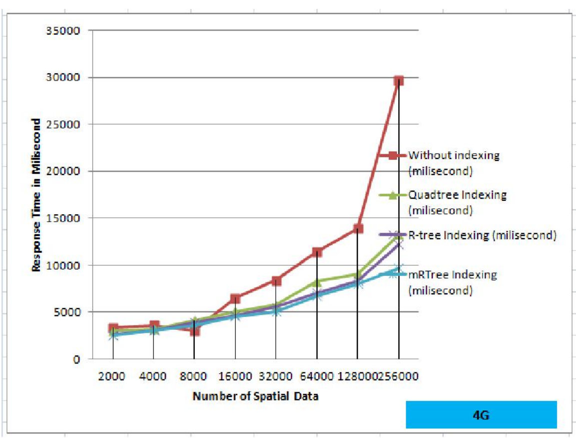

Figure 7. Response time of various indexing technique compared to mRTree- Using HTC mobile 4G connection

Figure. 6 and 7 has shown promising result on mRTree with small response times even on large quantity of data processing. This result has been tested on wireless broadband 3G and 4G connection. There are 6.13% faster if we use 4G connection to load Pasir Gudang map as spatial data. If the wireless connection speed is below 3G speed, the response time of query will increase rapidly (speed decrease).

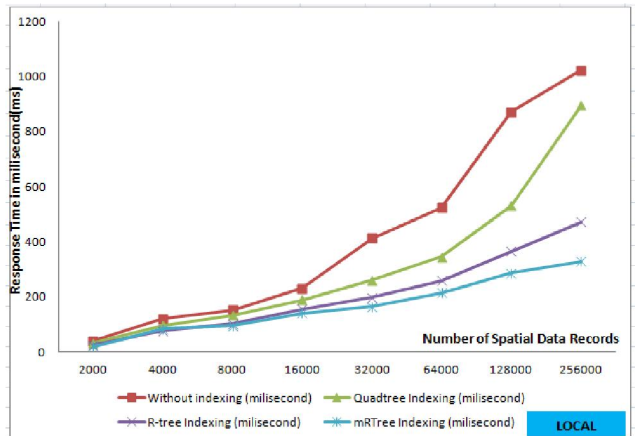

Figure 8. Response time of various indexing technique compared to mRTree- on Server using web Browser (LOCAL ACCESS)

Figure.8 is local processing which is executed through web browser on server. Even though processing on server, the speed of mRTree is much faster compared to other algorithm like QuadTree or R-tree or even without any indexing. This performance is believed to bring great change on mobile GIS technology, because with strong support of network architecture and mRTree technique, it will be possible to process large data and displayed on mobile devices like HTC or other Smartphone.

5. Discussion and Conclusion

The results on this study have shown the capability of mRTree to increase the performance of query processing on mobile device through wireless broadband connection. The intelligent selection technique holds important roles to make the best selection when to use R-tree or Quadtree indexing. This choice can save the time consumption for communication between server and mobile client. The proposed technique is able to reduce processing delay time until 65.11% compared to without indexing. Hence, the mRTree is able to handle complex query and large amount data that has become an obstacle for mobile GIS development. Even tough, the broadband wireless network give 6.13% contribution on increasing the speed of query processing, the spatial data indexing algorithm like mRTree still obtained greater contribution on this case. The future work on this re-search is how to reduce storage and memory consumption of mRTree processing as side effect of complex calculation.

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