MISTRAL

Processing Relational Queries Using a Multidimensional Access Method

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FORWISS

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MISTRAL Project Management

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Overview

1. Concept of the UB-Tree: Z-Regions
2. Insertion
3. Range Query Algorithm
4. Tetris Algorithm
5. Kernel Integration
6. Performance Overview
Relations and MD Space

- Decision Support Relation (similar to TPC-D)
  - Fact(customer, product, time, Sales)
  - defines a three dimensional cube

- Point Query
  - All sales for one customer for one specific product on a certain day

- Partial Match Query
  - All sales for product X

- Range Query
  - All sales for year 1999 for a specific product group for a specific customer group
Design Goals

- clustering tuples on disk pages while preserving spatial proximity
- efficient incremental organization
- logarithmic worst-case guarantees for insertion, deletion and point queries
- efficient handling of range queries
- good average memory utilization
Z-Ordering

\[ Z(x) = \sum_{i=0}^{s-1} \sum_{j=1}^{d} x_{j,i} \cdot 2^{i \cdot d + j - 1} \]
A Z-region \([\alpha : \beta]\) is the space covered by an interval on the Z-curve and is defined by two Z-addresses \(\alpha\) and \(\beta\).

**Z-region [4 : 20]**

**UB-Tree partitioning:**

\([0 : 3],[4 : 20], [21 : 35],[36 : 47], [48 : 63]\)

**Point data creating the UB-Tree on the left for a page capacity of 2 points**
UB-Tree Insertion 1/2/3/4
UB-Tree Insertion 18/19
Multidimensional Range Query

SELECT * FROM table
WHERE (A_1 BETWEEN a_1 AND b_1) AND
(A_2 BETWEEN a_2 AND b_2) AND
.....
(A_n BETWEEN a_n AND b_n)
Theoretical Comparison of the Rangequery Performance

<table>
<thead>
<tr>
<th>composite key clustering B-Tree</th>
<th>multiple B-Trees, bitmap indexes</th>
<th>multidimensional index</th>
<th>ideal case</th>
</tr>
</thead>
<tbody>
<tr>
<td>$s_1 \times P$</td>
<td>$s_1 \times I_1 + s_2 \times I_2 + s_1 \times s_2 \times T$</td>
<td>$s_1 \uparrow \times s_2 \uparrow \times P$</td>
<td>$s_1 \times s_2 \times P$</td>
</tr>
</tbody>
</table>
rangeQuery(Tuple ql, Tuple qh)
{
    Zaddress start = Z(ql);
    Zaddress cur = start;
    Zaddress end = Z(qh);
    Page page = {};

    while (1)
    {
        cur = getRegionSeparator(cur);
        page = getPage(cur);
        outputMatchingTuples(page, ql, qh);
        if (cur >= end) break;
        cur = getNextZAddress(cur, start, end);
    }
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        if (cur >= end) break;
        cur = getNextZAddress(cur, start, end);
    }
}
rangeQuery(Tuple q_l, Tuple q_h)
{
    Zaddress start = Z(q_l);
    Zaddress cur = start;
    Zaddress end = Z(q_h);
    Page page = {};

    while (1)
    {
        cur = getRegionSeparator(cur);
        page = getPage(cur);
        outputMatchingTuples(page, q_l, q_h);
        if ( cur >= end ) break;
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    }
}
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{
    Zaddress start = Z(ql);
    Zaddress cur = start;
    Zaddress end = Z(qh);
    Page page = {};

    while (1)
    {
        cur = getRegionSeparator(cur);
        page = getPage(cur);
        outputMatchingTuples(page, ql, qh);
        if (cur >= end) break;
        cur = getNextZAddress(cur, start, end);
    }
}
rangeQuery(Tuple $ql$, Tuple $qh$)
{
    Zaddress $start = Z(ql)$;
    Zaddress $cur = start$;
    Zaddress $end = Z(qh)$;
    Page $page = {}$;

    while (1)
    {
        $cur = $getRegionSeparator($cur$);
        $page = $getPage($cur$);
        outputMatchingTuples($page$, $ql$, $qh$);
        if ($cur >= end$) break;
        $cur = $getNextZAddress($cur$, $start$, $end$);
    }
}
rangeQuery(Tuple qI, Tuple qH)
{
    Zaddress start = Z(qI);
    Zaddress cur = start;
    Zaddress end = Z(qH);
    Page page = {};

    while (1)
    {
        cur = getRegionSeparator(cur);
        page = getPage(cur);
        outputMatchingTuples(page, qI, qH);
        if (cur >= end) break;
        cur = getNextZAddress(cur, start, end);
    }
}
rangeQuery(Tuple ql, Tupleqh)
{
    Zaddress start = Z(ql);
    Zaddress cur = start;
    Zaddress end = Z(qh);
    Page page = {};

    while (1)
    {
        cur = getRegionSeparator(cur);
        page = getPage(cur);
        outputMatchingTuples(page, ql, qh);
        if ( cur >= end ) break;
            cur = getNextZAddress(cur, start, end);
    }
}
rangeQuery(Tuple q1, Tuple qh)
{
    Zaddress start = Z(q1);
    Zaddress cur = start;
    Zaddress end = Z(qh);
    Page page = {};

    while (1)
    {
        cur = getRegionSeparator(cur);
        page = getPage(cur);
        outputMatchingTuples(page, q1, qh);
        if (cur >= end) break;
        cur = getNextZAddress(cur, start, end);
    }
}
rangeQuery(Tuple ql, Tuple qh)
{
    Zaddress start = Z(ql);
    Zaddress cur   = start;
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    Page page = {};

    while (1)
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        outputMatchingTuples(page, ql, qh);
        if (cur >= end) break;
        cur = getNextZAddress(cur, start, end);
    }
}
rangeQuery(Tuple \(ql\), Tuple \(qh\))
{
    Zaddress \(start\) = \(Z(ql)\);
    Zaddress \(cur\) = \(start\);
    Zaddress \(end\) = \(Z(qh)\);
    Page \(page\) = {};
    
    while (1)
    {
        \(cur\) = getRegionSeparator(\(cur\));
        \(page\) = getPage(\(cur\));
        outputMatchingTuples(\(page\), \(ql\), \(qh\));
        if ( \(cur >= end\) ) break;
        \(cur\) = getNextZAddress(\(cur\), \(start\), \(end\));
    }
}
```java
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Range Queries and Data Distributions
Growing Databases

1000 tuples

50 000 tuples
Summary UB-Trees

- 50% storage utilization, dynamic updates
- Efficient Z-address calculation (bit-interleaving)
- Logarithmic performance for the basic operations
- Efficient range query algorithm (bit-operations)
- Prototype UB/API above RDBMS (Oracle 8, Informix, DB2 UDB, TransBase, MS SQL 7.0) using ESQL/C

 Patent application
Standard Query Pattern

SELECT * FROM table
WHERE (A_1 BETWEEN a_1 AND b_1) AND
    (A_2 BETWEEN a_2 AND b_2) AND
    ...
    (A_n BETWEEN a_n AND b_n)
ORDER BY A_i, A_j, A_k, ...
(GROUP BY A_i, A_j, A_k, ...)
Z-Order/Tetris Order

\[ T_j(x) = x_j \circ Z(x_1, \ldots, x_{j-1}, x_{j+1}, \ldots, x_d) \]
The Tetris Algorithm

sort
direction
Summary Tetris

- Combines sort process and evaluation of multi-attribute restrictions in one processing step
- I/O-time linear w.r. to result set size
- Temporary storage sublinear w.r. to result set size
- Sorting no longer a “blocking operation”

.patent application
Integration Issues

● Starting point with TransBase:
  – clustering B*-Tree
  – appropriate data type for Z-values: variable bit strings

● Modifications to B*-Tree in TransBase:
  – support for computed keys:
    » Z-values are only stored in the index, not together with the tuples
    » tuples are stored in Z-order
  – generalization of splitting algorithm:
    » computed page separators for improved space partitioning
- **Minor extensions:**
  - DML
  - Multi-user support, i.e., locking, logging facilities → handled by underlying B*-Tree

- **Major extensions:**

- **New modules:**

- **NO changes for:**
Summary Integration

- Integration of the UB-Tree has been achieved within one year

- TransBase HyperCube is shipping since Systems 1999 and was awarded the 2001 IT-Prize by EUROCASE and the European Commission

- UB-Trees speed up relational DBMS for multidimensional applications like Geo-DB and data warehouse up to two orders of magnitude

- Speedup is even more dramatic for CD-ROM databases (archives)
Application Fields of the UB-Tree

● Data Warehouses
  – Measurements with SAP BW Data
    » UB-Tree/API for Oracle
    » UB-Tree *on top of* Oracle outperforms conventional B-Tree and Bitmap indexes *in* Oracle!
  – Measurements with the GfK Data Warehouse
    » UB-Tree in TransBase HyperCube
    » significant performance increases (Factor of 10)

● Geographic Databases

● „Multidimensional Problems“
  – Archiving Systems, Lifecycle-Management, Data Mining, OLAP, OLTP, etc.
The UB-Tree
Further Information

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