# ER Diagram

### Many to Many

A can have multiple B and B can have multiple A



### One to Many

A can have multiple B but B can only have one A



### One to One

A can have only one B and B can have only one B



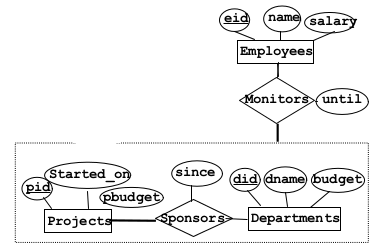
### At least one

Bold arrow specify there is at least one element.

|  |  |
| --- | --- |
|  | A have at least one |
|  | A have exactly one |

### Aggregation

Allows us to treat a reltionship set R as an entity set so that R can participate in other relationships



# Relational algebra

|  |  |
| --- | --- |
| Selection |  |
| Projection |  |
| Renaming |  |
| Cross product |  |
| Join |  |
| Division |  |
| Intersection |  |
| Union |  |
| Set different |  |

* Condition/Theta Join
* Equi Join: in2 Condition join where condition contains ONLY equalities
* Natural Join: Equijoin on all common attribute

# Sql

## Datatype

|  |  |
| --- | --- |
| Char(n) | A character string of fixed length n |
| VarChar(n) | Denotes a string of up to n charaters |
| INT or INTEGER | An integer |
| SHORTINT | Smaller integer |
| FLOAT or REAL | Float number |
| DOUBLE PRECISION | Double |
| DATE | Date format YYYY-MM-DD |
| TIME | Time format: hh:mm:ss |

## Table operations

|  |
| --- |
| --Create table  CREATE TABLE Students  (  id INT NOT NULL,  name VARCHAR(20),  login CHAR(10),  major VARCHAR(20) DEFAULT 'undefined',  school\_id INT,  PRIMARY KEY(id),  FOREIGN KEY(school\_id) REFERENCES School(id)  )  --Drop table  DROP TABLE Students  --Alter table  ALTER TABLE Students ADD COLUMN firstyear:integer |

## Row operation

|  |
| --- |
| --INSERT  INSERT INTO Students (id, name, faculty) VALUES (8908998, 'Dupont', 'Science')  --Delete  DELETE FROM Students WHERE id = 0894984  --Update  UPDATE Students SET faculty = 'Arts' WHERE id = 9849849 |

## Trigger

|  |
| --- |
| CREATE TRIGGER updateSkater  AFTER DELETE ON Skaters  REFERENCING OLD TABLE AS DeletedSkaters  FOR EACH STATEMENT  INSERT  INTO StatisticsTable(ModTable, ModType, Count)  SELECT ‘Skaters’, ‘delete’, COUNT(\*)  FROM DeletedSkaters |
| Use begin/end to encapsulate more than one  action  FOR EACH ROW/STATEMENT  WHEN …  BEGIN ATOMIC  do 1thing;  do 2nd thing;  END |

# XML

WHAT DAFUQ?!!@#!@#!?

## DTD

|  |  |
| --- | --- |
| <!DOCTYPE DiscoverTheWorld [  <!ELEMENT DiscoverTheWorld (tour\*,reservation\*)>  <!ELEMENT tour (type, start-date, duration, price) >  <!ELEMENT reservation (cname, caddress, cost, special\*)>  <!ATTLIST tour TourId **ID** **#REQUIRED** >  <!ATTLIST reservation ResID **ID** **#REQUIRED**  TourID **IDREF** **#REQUIRED**>  <!ELEMENT type (**#PCDATA**) >  <!ELEMENT start-date (**#PCDATA**) >  <!ELEMENT duration (**#PCDATA**) >  <!ELEMENT price (**#PCDATA**) >  <!ELEMENT cname (**#PCDATA**) >  <!ELEMENT caddress (**#PCDATA**) >  <!ELEMENT cost (**#PCDATA**) >  <!ELEMENT special (**#PCDATA**) >  <!ATTLIST special price **CDATA** **#REQUIRED**>  ]> | <!DOCTYPE Politics [ <!ELEMENT Politics (Politician\*, Province\*)>  <!ELEMENT Politician ((CurrentMayor | CurrentMop)?, address?)>  <!ELEMENT CurrentMayor (since?)>  <!ELEMENT CurrentMoP (since?)>  <!ELEMENT Province (City+, Riding+, population?)>  <!ELEMENT City (population?)>  <!ELEMENT Riding (population?)>  <!ELEMENT address (**#PCDATA**) >  <!ELEMENT since (**#PCDATA**) >  <!ELEMENT population (**#PCDATA**) >  <!ATTLIST Politician pname **ID** REQUIRED  website **CDATA** IMPLIED  friends **IDREFS** IMPLIED>  <!ATTLIST CurrentMayor cityID **IDREF** REQUIRED>  <!ATTLIST CurrentMoP rname **IDREF** REQUIRED>  <!ATTLIST Province pname **ID** REQUIRED>  <!ATTLIST City cityID **ID** REQUIRED  cname **CDATA** REQUIRED>  <!ATTLIST Riding rname **CDATA** REQUIRED>  ]> |
| **<bibliography>**  **<books>**  **<book** ISBN="23456" year="1995"**>**  **<title>** Foundations ... **</title>**  **<author>** Hull **</author>**  **<author>** Abiteboul **</author>**  **<publ>** Addison Wesley **</publ>**  **</book>**  **<book>** ...**</book>**  **</books>**  **<journals>**  **<journal>**  **<title>** ... **</title>**  **<article>** ... **</article>**  ...  **</journal>**  **<journal>** ... **</journal>**  **</journal>**  **</bibliography>** | **<DiscoverTheWorld>**  **<tour** TourId="1"**>**  **<type>** Brazil junge **</type>**  **<start-date>** 16-April **</start-date>**  **<duration>** 14 **</duration>**  **<price>** 2229 **</price>**  **</tour>**  **<tour** TourId="2"**>**  **<type>** Brazil junge **</type>**  **<start-date>** 30-April **</start-date>**  **<duration>** 21 **</duration>**  **<price>** 2999 **</price>**  **</tour>**  **<tour** TourId="3"**>**  **<type>** Kenia safari **</type>**  **<start-date>** 30-April **</start-date>**  **<duration>** 21 **</duration>**  **<price>** 3229 **</price>**  **</tour>**  **<reservation** ResId="541" TourId="1"**>**  **<cname>** Bettina Kemme **</cname>**  **<caddress>** Montreal **</caddress>**  **<cost>** 2579 **</cost>**  **<special** price="5"**>** vegetarian **</special>**  **<special** price="20"**>** single **</special>**  **</reservation>**  **<reservation** ResId="542" TourId="2"**>**  **<cname>** Your Name **</cname>**  **<caddress>** Your Address **</caddress>**  **<cost>** 3105 **</cost>**  **<special** price="5"**>** vegetarian **</special>**  **</reservation>**  **</DiscoverTheWorld>** |

|  |
| --- |
| <!DOCTYPE people[  <!ELEMENT people(person\*)>  <!ELEEMNT person(name\*, (lastname|familyname)?)>  <!ATTLIST person PID ID #REQUIRED  age CDATA #IMPLIED  children IDREFS #IMPLIED  mother IDREF #IMPLIED  >  <!ELEMENT name(#PCDATA)>  <!ELEMENT lastname(#PCDATA)>  <!ELEMENT familyname (#PCDATA)>  ]> |

Data types: PCDATA (parsed character data) or CDATA (unparsed)

Attributes

* ID unique identifier (similar to primary key)
* IDREF: reference to single ID
* IDREFS: space-seperated list of references

Values

* can give a default value
* #REQUIRED must exist
* #IMPLIED optional

Specified in an XML file with <!DOCTYPE name SYSTEM "path/to/thing.dtd">

Can use regex style things too. \* is 0 or more. + is 1 or more, (a | b)? is one or the other

## XPATH

## /bibliography/book/author all author elements by root navigating through those elements

## /bibliography/book/@ISBN All ISBN attributes

## //title all title elements anywhere in the document

## /bibliography/\*/title titles of bibliography entries assuming that there could be books, journals, reports, etc...

## /bibliography/book[@year>1995] returns books where the year > 1995

## /bibliography/book[author='FooBar']/@Year returns the years of books written by FooBar

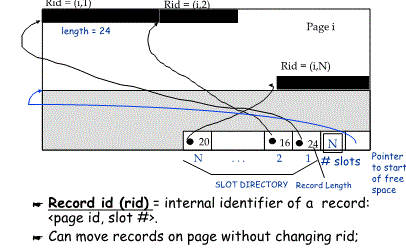
## /bibliography/book[count(author) <2]

* /bibliography/book/author[position()=1]/name position is the location of the node in the node set

## XQuery

|  |  |
| --- | --- |
| For | Let |
| for $b in document("bib.xml")/bib/book  return <result> $b</result> | let $b in document("bib.xml")/bib/book  return <result> $b</result> |
| <result><book>…</book></result>  <result><book>…</book></result>  <result><book>…</book></result>  …  <result><book>…</book></result> | <result>  <book>…</book>  <book>…</book>  ..  <book>…</book>  </result> |

|  |  |
| --- | --- |
| -Basic Queries: **'/'**  to navigate one path at a time  Example:/Bookstore/Book/Title  **'//'** all paths following this  Example://Title  When wanting to access an attribute of an element use @  Example:/Bookstore/Book/data(@ISBN)  **'|'** **OR** operator ONLY USED INSIDE CONDITIONS  Example:/Bookstore/Book|Magazine/Title  **'='** can act like == like in Self-Join Queries below  Navigation accesses:  Example: parent::\* \*::child following-silbling::\*  **-Queries involving CONDITIONS**  **1condition:**  Example:/Bookstore/Book[@Price<30]  Example:/Bookstore/Book/Authors/Author[2] the 2nd author of each element  **2conditions:**  To write a condition, it needs to be inside '[...]' then followed by the output that we are looking for  Example:/Bookstore/Book[@Price<30]/Title  **Condition to find elements that contain other elements:**  Example:/Bookstore/Book[Remark]/Title  **Conditions && Conditions + Some output:**  Example: Looking for a title that has one last name =Ullman and price<90  /Bookstore/Book[@Price<90 and Authors/Author/Last\_Name="Ullman"]/Title  **Conditions Inside Conditions + Some output:**  Example:Looking for a title with author ="Jeffrey Ullman" and price<90  /Bookstore/Book[@Price<90 and Authors/Author/[Last\_Name="Ullman" and First\_Name="Jeffrey"]]/Title  **Conditions && !Conditions + Some output:**  Example:Looking for a title with author ="Ullman" and NOT author="Widom"  /Bookstore/Book[/Authors/Author/Last\_Name="Ullman" and count(/Authors/Last\_Name="Widom"=0]/Title  **The condtion 'contains':**  /Bookstore/Book[contains(Remark, "great")]/Title | **Self-Join Query**  Quering two instances of the database at one and joining them together.Trying to find the magazines wheres theres a book with the same title. Example: doc("BookstoreQ.xml")/Bookstore/Magazine[Title=doc("BookstoreQ.xml")/Bookstore/Book/Title]  **Navigation Accesses**  The name() function returns the name of a tag or element  To find all elements whose parent is not "Bookstore" or "Book"  **/Bookstore/\*[name(parent::\*)!="Bookstore" and name(parent::\*)!="Book"]** |



## XML in DB@^%$^$#

|  |
| --- |
| INSERT INTO MyXML(id, INFO) VALUES (1000,  '<customerinfo cid="1000">  <name>Kathy Jones</name>  <addr country =Canada">  <street>123 fake</street>  <city>Ottawa</city>  <prov-state>Ontario</prov-state>  <pcode-zip>H0H 0H0</pcode-zip>  </addr>  </customerinfo>') |

# Buffer

|  |  |  |
| --- | --- | --- |
| DBMS stores information persistently on (“hard”) disks.  ❑ Unit of transfer main-memory/disk: disk blocks or pages.  ❑ Timing:  ✩ 2- 20 msec for random data block (bad seek time)  ✩ If blocks are sequentially on disk, only +1ms per block  ✩ Compare main memory access: in nanoseconds  ❑ Basic operations (READ/WRITE from/to disk)  ❑ Why disks?  ✩ Cheaper than Main Memory  ✩ Higher Capacity  ✩ Main Memory is volatile | When loading a page from disk:  ✩ Replacement frame must have “pin counter” of 0  ❑ When requesting a page that is in the buffer  ✩ Increment pin counter  ❑ After operation has finished  ✩ Decrement pin counter  ✩ Set dirty bit if page has been modified:  ❑ Frame is chosen for replacement by a replacement policy:  ✩ Only unpinned page can be chosen (pin count = 0)  ✩ Least-recently-used (LRU), Clock, MRU etc. | If requested is not in pool:  ✩ If there is an empty frame, use it  ✩ Else choose an empty frame for replacement. If the frame is dirty (page was modified), write it to disk  ✩ Read requested page into chosen frame  Buffer management in DBMS requires ability to:  ✩ **pin a page** in buffer pool, **force a page to disk** (important for  implementing CC & recovery),  ✩ adjust **replacement policy**, and **pre-fetch pages** based on  access patterns in typical DB operations. |

# Indexing

|  |  |  |
| --- | --- | --- |
| **COST MODEL**  Measure performances by simplifying the parameters (IO focused):  ✩ only consider disk reads (ignore writes)  ✩ only consider number of I/Os and not the individual time for each read (ignores page pre-fetch)  ✩ Average-case analysis; based on several simplistic assumptions. ● delete/update ▲ depends on where | **HEAP FILES**  ✩ Linked, unordered list of all pages of the file  ✩ Is it good for:  ● scan retrieving all records (SELECT \*)?  ▲ yes, you have to retrieve all pages anyway  ● equality search on primary key  ▲ not great: have to read on avg half the pages for 1 record  ● range search or equality search on non-primary key  ▲ not great, all pages need to be read  ● insert  ▲ yes, can insert anywhere  ● delete/update  ▲ depends on where | **SORTED FILES**  ✩ Records are ordered according to one or more attributes of the relation  ✩ Is it good for:  ● scan retrieving all records (SELECT \*)?  ▲ yes, you have to retrieve all pages anyway  ● equality search on sort attribute  ▲ good: find first qualifying page with binary search (log2)  ● range search on sort attribute  ▲ good: find first qualifying page with binary search (log2):  adjacent pages might have additional matching records |

Let suppose we have a relation R (A, B, C, D, F) such that:

* A and B are int (6 byte)
* C-F are char [40] (10 byte per char).
* Tuple = 172 bytes. 200,000 tuples
* Each data page has 4000 bytes and is around 80% full
* B values are uniformly distributed
* Rid = 10 bytes
* Size of pointer in intermediate page = 8 bytes
* Index pages are 4K and between 50%-100% full

|  |  |  |
| --- | --- | --- |
| Goal | Formula | With this example |
| Number of pages |  |  |
| Index entry size in root and intermediate pages |  |  |
| Average number of rids per data entry |  |  |
| Average length per data entry |  |  |
| Average number of data entries per leaf page |  |  |
| Estimate number of leaf page |  |  |
| Number of entries in intermediate pages |  |  |
| Height of tree |  | 3 |

Non-clustered index B-tree with <k, list of rid>

Height of tree = Number of leaf pages / (min | max)? number of entries in intermediate pages

Give the pids of all projects within department D2 that started in 2014.

Give the pids of all projects that have at least one excellent evaluation

|  |  |  |
| --- | --- | --- |
| **Force Flush strategy**   * All changes are flush to disk BEFORE commit | * Completed transaction need not action * Active transaction might have partial changes on disk(Need undone) | * Append to log file log record before flushing * At commit/abort append to log file commit/abort log record * When recovering from crash: Scan log backward for each record if commited ignore otherwise install Before-Image of the record |
| **No force flush strategy**   * Changes might be flushed at any time(BEFORE/AFTER commit) | * Done transaction might have missing changes (must be redone) * Active/Aborted transaction might have been flushed before crash(Must be undone) | * For each write(x) of a transaction T with x being on page P: Log record with before AND after image of x(Before so you can undo changes, After so you can redo changes) * Flush before-image to disk before flushing the P * Flush after-image to disk before commit of T * At commit/abort append commit/abort record to log file and flush |

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| * **Unrepeatable read:** If T1 read twice the same data item but T2 change its value between the first and the second * **Dirty read:** If T2 read from T1 before T1 commit. * **Lost update:** If T2 modify a data item modified by T1 without taking in account the value modified by T1. |  |

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| --- | --- |
| Schedule   * Serial schedule: All transaction one after the other * Non-serial schedule: Transaction overlap * Serializable: Dependency graph has no cycle(T1 always does action before T2) * Recoverable schedule: If transaction reads a value written by transaction then commit only after committed * Avoiding cascading aborts: A transaction reads only values written by committed transactions. * Strict: A transaction only read or overwrite value written by committed transaction | Schedule examples:   * Strict and serializable * Avoids cascading aborts, non-strict, serializable * Recoverable, not avoiding cascade aborts, serializable * Not recoverable, serializable * Not recoverable, Not-serializable |

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| --- | --- | --- | --- | --- | --- | --- |
| **Unrecoverable** | **Recoverable schedule with cascading abort** | **Recoverable schedule with commit** | **Avoids cascading** | **Non strict** | **Strict** | **Strict and serializable** |
| |  |  | | --- | --- | | T1 | T2 | | R(A) |  | | W(A) |  | |  | R(A) | |  | commit | | commit |  | | |  |  | | --- | --- | | T1 | T2 | | R(A) |  | | W(A) |  | |  | R(A) | | abort |  | |  | abort | | |  |  | | --- | --- | | T1 | T2 | | R(A) |  | | W(A) |  | |  | R(A) | | commit |  | |  | commit | | |  |  | | --- | --- | | T1 | T2 | | R(A) |  | | W(A) |  | | abort |  | |  | R(A) | |  | commit | | |  |  | | --- | --- | | T1 | T2 | | W(A) |  | |  | W(A) | | abort |  | |  | commit | | |  |  | | --- | --- | | T1 | T2 | | W(A) |  | | abort |  | |  | W(A) | |  | commit | | |  |  | | --- | --- | | T1 | T2 | | R(x) |  | |  | W(x) | |  | commit | | W(x) |  | | commit |  | |

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| **Lock request:**   * If lock is S, no X lock is active and the request queue is empty: * Add the lock to the granted lock queue and set the lock type to S * If lock is X and no lock active(request queue is also empty): * Add the lock to the granted lock queue and set the lock type to X * Otherwise * Add the lock to the request lock queue | **Lock release:**   * Remove the lock from the granted lock queue * If this was the only lock granted on this object: * Grant one X lock(If the first of the request is a X lock) * Grant n S lock(If the first n element are S lock) |
| **Deadlocks:**   * Make the wait-for graph() * If cycle then we have a deadlock (Noooooooooooooo…) | **Solve Deadlock:**   * Add a timeout for each transaction and abort if transaction timeout. Problem on what timeout value to choose * Request all the lock at the beginning of the transcation |

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| --- | --- |
| **Predicate locking:**   * Grant lock on all records that satisfies logical predicates(e.g. depid>5, age > 2\*salary) * More bullshit | **Predicate looking example:**   * Assume 2 tranascrtions: * Assume: T1 execute first then it has a X-lock on Skaters with sid=123 * Assume: T2 has to scan the entire table to get skater with rating=5 * For each tuple   - set S-lock on tuple  - Check condition  - If condition TRUE keep lock and return value  - If condition FALSE release lock   * It need to read the tuple where sid=123 and rating= 5 but block has T1 has a lock on it. * T2 is block by T1 although there is no conflict |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Problems of strict 2PL locking:**   * Very restrictive, low concurrency, problem with long query * More and more exception   **In order to allow for more concurrency, SQL2 defines various levels of isolation**   * Assumed to be implemented by different forms of locking * Avoid different levels of anomalies * Used for non-critical transactions or read-only transactions * Lower levels of isolation do NOT provide serializability   **Problem**   * Definitions are no more appropriate if systems do not use locking but other forms of concurrency control * For instance, Oracle’s “serializable” level does not provide serializable schedule as defined in the literature | Isolation level:   * In principle isolation levels are independent of concurrency control mechanics * In reality they were defined with locking in mind  |  |  |  |  | | --- | --- | --- | --- | | Isolation level/Anomaly | Dirty read | Unrepeatable read | Phantom | | Read uncommitted | Maybe | Maybe | Maybe | | Read committed | No | Maybe | Maybe | | Repeated reads | No | No | Maybe | | Serializable | No | No | No |  * **Read uncommitted:** * Read op. do not set locks; can read not-committed updates * **Read committed:** * Read op. set short S locks; have to wait for X locks to be released * release lock immediately after execution of op * **Repeated reads:** * Read operations set standard lock S locks; standard 2PL * **Serializable:** * Read op. must set S locks that cover all objects that are read * predicate locks or coarse locks (e.g., lock on entire relation) |

# Big data

|  |  |
| --- | --- |
| Some bullshit info:   * Hardware * CPU does not increase * Instead muticode * Usage * Astronomy: high-resolution, high-frequency sky surveys * Medicine: digital records, MRI, ultrasound * Biology: sequencing data * User behavior data: click streams, search logs | Parallel Query Evaluation:   * Inter-query parallelism * Different queries run in parallel on different processors; each query is executed sequentially * Inter-operator parallelism * Different operator within the same execution tree run on different processors * Intra-operator parallelism * A single operator(JOIN, GROUP, …) runs on many processor |
| **Horizontal data Partitioning:**   * Data * Large table * Key value store * Goal * Partition into chunks of records stored at N nodes * Range partition * Equal size of each chunk * Hash partitioned on attribute X * Record r goes to chunk i, according to hash function * xample: hash function H(r.X) mod P+1 * Range partitioned on attribute X * Partition range of X into: * Record r goes to chunk i, if | Vertical Partitioning:   * Column stores * Data: relation * Partition into , , * Query: * SELECT A FROM R * Query only needs to access partition RA * Much less IO |
| **Execution steps:**   * User indicates m (number of map tasks), r (number of reduce tasks), key/value set = document Set DS * System creates m map tasks and splits input set of 1key/value pairs into m partitions and gives each map task one partition as input * Each Map task executes user written map function * WordCountMap: * For each input key/value pair (dkey, dtext)   For each word w of dtext  Output key-value pair (w, 1)   * Next step only completes once all map tasks have completed * System sorts map outputs by key and transforms all key/value pairs with same key k to one key/value-list pair * For Word count: all (‘and’, 1), (‘and’, 1), (‘and’, 1) … are transformed into one (‘and’, (1,1,1,….)) * System partitions output by key into r partitions and assigns these partitions as inputs to the r reduce tasks * Each reduce task executes user written reduce function * WordCountReduce: * For each input key/value-list pair   Output (k, n) | --------------------------------------------------------------------------------------------------------- |

# Map reduce

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| --- | --- |
| **Relational Operators with Map/ reduce**   * Assume R(A, B, C) relation (no duplicates) * **Selection with condition c on R** * for each tuple t of R for which condition c holds, output * Reduce: identity, that is output * **Projection on A, B, of R** * Map: transform each tuple of R into tuple of R, and output * There might now be duplicates, that is several tuples, the group function will aggregate them to * Reduce: for each tuple output | * **Grouping: SELECT a, sum(b) GROUP by (a)** * Map: for each tuple (a, b,c) of R output (a,b) * Group and shuffle will create for each value a key/value-list ( * Reduce: for each perform aggregation |
| * **Natural Join R(A,B,C) with Q(C,D,E) via hash-join(SELECT FROM R1,R2)** * Map:   For each tuple of R, output  For each tuple of Q, output   * Group and shuffle will aggregate all key/value pairs with same c-value * Reduce:   For each tuple (c, value-list), example:    Rt = Qt = empty;  for each v=(rel,tuple) in value-list  if v.rel = R: insert tuple into Rt else insert tuple into Qt for v1 in Rt, for v2 in Qt, output(c,v1,v2)  Basically produces all combinations (c, ai,bi,dj,ej) | Pig latin:   * Users = **LOAD** ‘users’ **AS** (name,age); * Filtered = **FILTER** Users **BY** age >= 18 **AND** age <= 25; * Pages = **LOAD** ‘pages’ **AS** (uname, url); * Joined = **JOIN** Fltrd **BY** name, Pages **BY** uname; * Grouped = **GROUP** Jnd **BY** url; * Smmd = **FOREACH** Grpd **GENERATE** ($0), COUNT($1) **AS** clicks; * Srtd = **ORDER** Smmd **BY** clicks desc; * Top5 = **LIMIT** Srtd 5; * **STORE** Top5 **INTO** ‘top5sites’   http://images.clipartof.com/small/1122642-Cartoon-Of-A-Grinning-Pig-Smoking-A-Cigar-And-Wearing-A-Cowboy-Hat-Royalty-Free-Vector-Clipart.jpg |

# Query evaluation

|  |  |
| --- | --- |
| **Examples for flowing problems:**   * Participates * 100 000 tuples * 1000 pages * 100 tuples per page * Skaters * 40 000 tuples * 500 pages * 80 tuples per page * Index on sid has 170 leaf page * Index on names has 300 leaf page | * **Reduction factor of a condition defined as** * **If not known, DBMS makes simple assumptions** * **Result size:** * How to know the number of different values, max, min, * through indices, heuristics, separate statistics (histograms) |
| **Simple selection:**   * No index: * Search on arbitrary attributes: scan the entire relation   e.g.   * Search on primary key attributes: scan on average half of S   e.g.   * Index on selection attribute * Use index to find qualifying data entries, then retrieve corresponding data records. | **Clustered B+tree**   * Costs: * Example 1 * SELECT \* FROM Skaters WHERE name sid = 5 * 1 tuple match * Example 2 * SELECT \* FROM Skaters WHERE name LIKE ‘Z%’ * System estimate the number of matching tuples(Around 100 match on 2 data page as its clustered) * Example 3 * SELECT \* FROM Skaters WHERE name < ‘F%’ * Assume around 10 000 tuples match(On 125 datapage) |
| **Unclustered B+tree**   * Costs: * Example 1 * SELECT \* FROM Skaters WHERE name sid = 5 * Same * Example 2 * SELECT \* FROM Skaters WHERE name LIKE ‘Z%’ * Assume around 100 match on 80 data page but we need to retrieve some data page twice * Example 3 * SELECT \* FROM Skaters WHERE name < ‘F%’ * Assume around 10 000 tuples match | **Unclustered B+tree with sorting:**   * Sort matching data entries (rid=pid,slot-id) in leaf-pages by page-id * Only fast if the the 75 leaf pages with matching entries fit in main memory * Retrieve each page only once and get all matching tuples * #data pages = #data pages that have at least one matching tuple; * worst case is total # of data pages * Example 1 * SELECT \* FROM Skaters WHERE name sid = 5 * Same * Example 2 * SELECT \* FROM Skaters WHERE name LIKE ‘Z%’ * Assume around 100 match on 80 data page * Example 3 * SELECT \* FROM Skaters WHERE name < ‘F%’ * Assume around 10 000 tuples match(assume thataround 490 data pages) * Note: sorting expensive if leaf-pages do not fit in main-memory |
| **Sort:**   * Sometimes a pass 2 is needed * Pass 0 created more runs than there are main memory buffers * Therefore Pass 1 produces more than one run * Pass 2 takes the runs of Pass 1 and merges them * Cost * SELECT sname, age FROM Skaters ORDER BY age * If everything fits into main memory (Only pass 0 needed):   Read number of data pages sort and pipeline result into next operator (project)   * Pass 0 + pass 1 needed Pass 0: read # pages, write # pages (have to write temp. results!)   Pass 1: read # pages, sort and pipeline result into next operator  3 \* #pages   * Pass 0 + pass1 + pass2 needed   5 \* #pages | **Join cost estimation:**   * Join attribute is primary key for Skaters * Each Participates tuple matches exactly with one Skaters tuple * Cross product is always the product of individual relation sizes * For other joins more difficult to estimate (Continues in next episode…) |

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| **Nested loop joins:**   * Simple nested loop join: For each tuple in the outer relation P, we scan the entire inner relation S * Page-oriented Nested Loops join: For each page of P, get each page of S, and write out matching pairs of tuples <p, s>, where p is in P-page and s is in S-page. | **Join cost on relation R1(outer) and R2(inner):**  **Block oriented nested loop join:**   * Smaller relation fits in main memory+2extra buffer page: * No relation fits in main memory(B join frame):   **Index nested loop join**   * Index on the join column of one of the relation(R2): * If the join attribute is primary key in inner relation   **Sort merge join**   * Sort P and S on the join column, then scan them to do a ``merge’’ (on join col.), and output result tuples * Advance scan of P until current P-tuple >= current S tuple, then advance scan of S until current S-tuple >= current P tuple; do this until current P tuple = current S tuple. * At this point, all P tuples with same value in Pi (current P group) and all S tuples with same value in Sj (current S group) match; output <p, s> for all pairs of such tuple 1s. * P is scanned once; each S group is scanned once per matching P tuple. (Multiple scans of an S group are likely to find needed pages in buffer.) |