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ER Diagram

- ## Many to Many

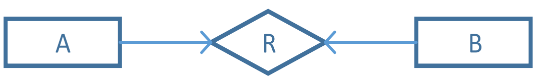
A can have multiple B and B can have multiple A

- ## One to Many

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

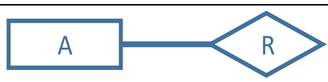
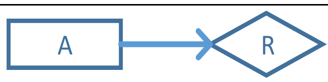
- ## One to One

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



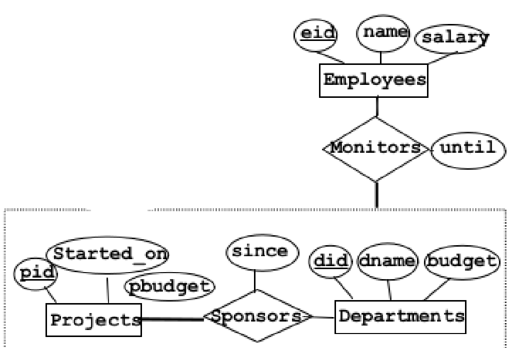
- ## At least one

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	$\sigma_{condition}(Element)$
Projection	$\pi_{attributes}(Element)$
Renaming	$\rho(R(A_1,..,A_n),R_{alias}(B_1,..,B_n))$
Cross product	$\times$
Join	$\bowtie$
Division	$\backslash$

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Intersection	∩
Union	∪
Set different	−

- Condition/Theta Join $Rout = Rin1 \bowtie cRin2 = \sigma c(Rin1 \times Rin2)$
- Equi Join: $Rout = Rin1 \bowtie Rin1a1 = Rin2b1, \ldots, Rin1an = Rin2bnR$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
```

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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

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- 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

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

<table>
<tr><td>-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::*
<u>-Queries involving CONDITIONS</u>
<u>1condition:</u>
Example:/Bookstore/Book[@Price<30]
Example:/Bookstore/Book/Authors/Author[2] the 2nd author of each element
<u>2conditions:</u>
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
<u>Condition to find elements that contain other elements:</u>
Example:/Bookstore/Book[Remark]/Title
<u>Conditions && Conditions + Some output:</u>
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
<u>Conditions Inside Conditions + Some output:</u>
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
<u>Conditions && !Conditions + Some output:</u>
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
<u>The condtion 'contains':</u></td><td><u>Self-Join Query</u>
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]
<u>Navigation Accesses</u>
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"]</td></tr>
</table>

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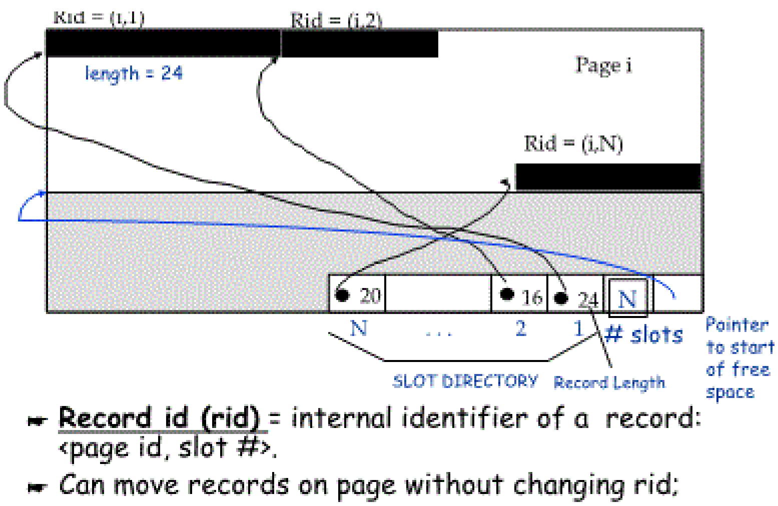
/Bookstore/Book[contains(Remark, "great")]/Title	



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	HEAP FILES	SORTED FILES
Measure performances by simplifying the	☆ Linked, unordered list of all pages of the	☆ Records are ordered according to one or more

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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	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	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	$\frac{number\ of\ tuples\ *\ tuple\ size}{fill\ rate\ *\ page\ size}$	$\frac{172 * 200000}{40000 * 0.80} = 10750$
Index entry size in root and intermediate pages	$size\ of\ key + size\ of\ pointer$	$6 + 8 = 14\ bytes$
Average number of rids per data entry	$\frac{\text{number of tuples}}{\text{different values (if uniform)}}$	$\frac{200{,}000}{20{,}000} = 10$
Average length per data entry	$\text{size of key} + (\text{number of rids} * \text{size of rid})$	$6 + 10 * 10 = 106$
Average number of data entries per leaf page	$\frac{\text{fillrate} * \text{page size}}{\text{length of data entry}}$	$\frac{0.75 * 4000}{106} = 28\ entries\ per\ page$
Estimate number of leaf page	$\frac{\text{number of different values}}{\text{number of entrier per page}}$	$\frac{20{,}000}{28} = 715$
Number of entries in intermediate pages	$\frac{\text{fillrate} * \text{page size}}{\text{lenght of index enty}}$	$min = \frac{0.5 * 4000}{14} = 143, \max = \frac{1 * 4000}{14} = 285$
Height of tree	Number of leaf pages	

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.

$$\pi_{pid}\left(\sigma_{dep_{id}=D2 \wedge start_{date}=2014}(Project)\right)$$

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

$$\pi_{Project.pid}\left(\sigma_{Evaluation.grade='execlent'}(Project \bowtie Evaluation)\right)$$

	Join cost on relation R1 and R2: • **Block oriented nested loop join:** - Smaller relation fits in main memory+2extra buffer page: $cost = page(R1) + page(R2)$ - No relation fits in main memory(B join frame): $cost = page(R1) + \frac{page(R2) * page(R1)}{B-2}$ • **Index nested loop join** - Index on the join column of one of the relation(R2): $cost = page(R1) + card(R1) * cost\_finding\_index(R2)$

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

• **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.	

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)	Schedule examples: • Strict and serializable $r1(x), w2(x), c2, w1(x), c1$ • Avoids cascading aborts, non-strict, serializable • Recoverable, not avoiding cascade aborts, serializable $r1(x), w2(y), w2(x), r1(y), c2, c1$

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- Recoverable schedule: If transaction T_i reads a value written by transaction T_j then T_i commit only after T_j 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

- Not recoverable, serializable
  $$r1(x), w2(y), r1(x), c1, c2$$
- Not recoverable, Not-serializable

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

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(T_i *need ressource lock by* T_j)
- If cycle then we have a deadlock (Nooooooooooooo…)

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

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:
  - $UPDATE\ Skaters\ set\ rating\ =\ 7\ WHERE\ sid\ =\ 123$
  - $SELECT\ max(age)\ FROM\ Skaters\ WHERE\ rating\ =\ 5$
- 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

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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 $R(K, A, B, C)$
  - Key value store $KV(K, V)$
- Goal
  - Partition into chunks $c_1, \dots c_n$ 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: $-\infty = v_0 < v_1 < \cdots < v_p = \infty$
  - Record r goes to chunk i, if $v_{i-1} < t.X < v_i$

Vertical Partitioning:

- Column stores
- Data: relation $R(K, A, B, C)$
- Partition into $RA(K, A)$, $RB(K, B)$, $RC(K, C)$
- Query:
  - SELECT A FROM R
- Query only needs to access partition RA
- Much less IO

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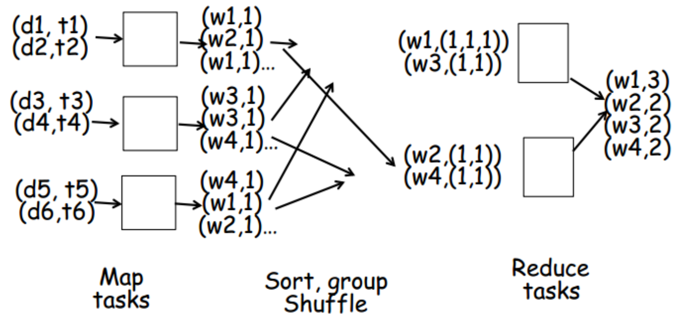
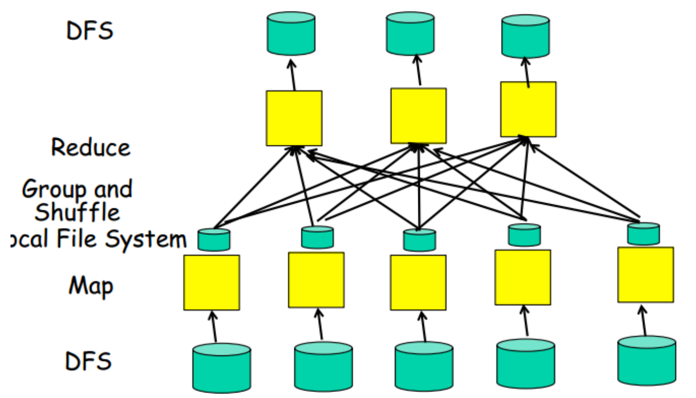
Execution steps:

- 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 $(k, v1), (k, v2), \dots (k, vn)$ with same key k to one key/value-list pair $(k, (v1, v2, \dots vn))$
  - 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 $(k, (v1, v2, \dots\ vn)$
    - Output (k, n)





Map reduce

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 (t, t)
  - Reduce: identity, that is output (t, t)
- **Projection on A, B, of R**
  - Map: transform each tuple $t = (a, b, c)$ of R into tuple $t' = (a, b)$ of R, and output (t', t')
  - There might now be duplicates, that is several (t', t') tuples, the group function will aggregate them to $(t', (t', \dots, t'))$
  - Reduce: for each tuple $(t', (t', \dots, t'))$ output (t', t')

- **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 a key/value-list $(a, (b1, b2, \dots)$
  - Reduce: for each $(a, (b1, b2, \dots))$ perform aggregation $(e.g., b1 + b2, \dots)$

- **Natural Join R(A,B,C) with Q(C,D,E) via hash-join(SELECT FROM R1,R2)**
  - Map:
    - For each tuple (a, b, c) of R, output $(c, (R, (a, b)))$
    - For each tuple (c, d, e) of Q, output $(c, (Q, (d, e)))$
  - Group and shuffle will aggregate all key/value pairs with same c-value
  - Reduce:
    - For each tuple (c, value-list), example:
    - $(value - list\ = (R, (a1, b1)), (R, (a2, b2)), \dots (Q, (d1, e1)), \dots))$
      - 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'