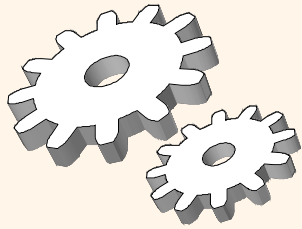
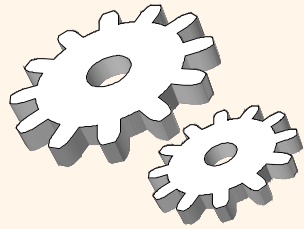


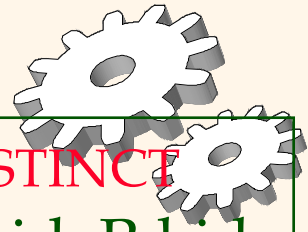
Evaluation of Relational Operations: Other Techniques

Simple Selections



- Select (R.attr op value) R
- No index, unsorted: must scan whole table
- With an index on selection attribute: use it

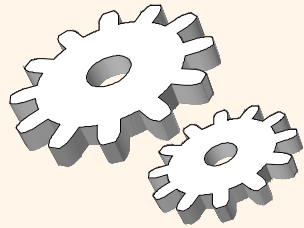
The Projection Operation



```
SELECT   DISTINCT
         R.sid, R.bid
FROM     Reserves R
```

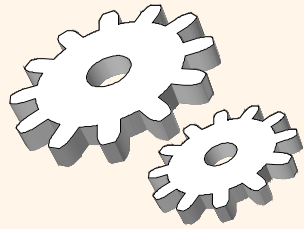
- An approach based on sorting:
  - Modify Pass 0 of external sort to eliminate unwanted fields.
  - Modify merging passes to eliminate duplicates.

Projection Based on Hashing



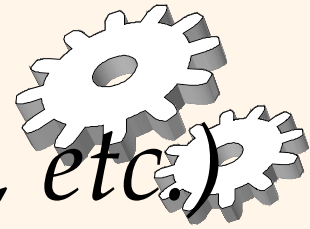
- *Partitioning phase*: Read R using one input buffer. For each tuple, discard unwanted fields, apply hash function *h1* to choose one of B-1 output buffers.
  - Result is B-1 partitions (of tuples with no unwanted fields). 2 tuples from different partitions guaranteed to be distinct.
- *Duplicate elimination phase*: For each partition, read it and build an in-memory hash table, using hash fn *h2* (<> *h1*) on all fields, while discarding duplicates.
  - If partition does not fit in memory, can apply hash-based projection algorithm recursively to this partition.

Set Operations

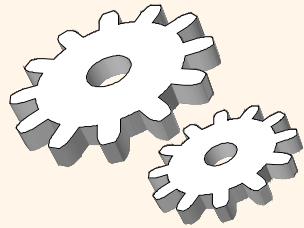


- Intersection and cross-product special cases of join.
- Union (Distinct) and Except similar; we'll do union.
- Sorting based approach to union:
  - Sort both relations (on combination of all attributes).
  - Scan sorted relations and merge them.
  - *Alternative*: Merge runs from Pass 0 for *both* relations.
- Hash based approach to union:
  - Partition R and S using hash function *h*.
  - For each S-partition, build in-memory hash table (using *h2*), scan corr. R-partition and add tuples to table while discarding duplicates.

Aggregate Operations (AVG, MIN, etc.)



- Without grouping:
  - In general, requires scanning the relation.
  - Given index whose search key includes all attributes in the SELECT or WHERE clauses, can do index-only scan.
- With grouping:
  - Sort on group-by attributes, then scan relation and compute aggregate for each group. (Can improve upon this by combining sorting and aggregate computation.)
  - Similar approach based on hashing on group-by attributes.
  - Given tree index whose search key includes all attributes in SELECT, WHERE and GROUP BY clauses, can do index-only scan; if group-by attributes form prefix of search key, can retrieve data entries/tuples in group-by order.



Summary

- A virtue of relational DBMSs: *queries are composed of a few basic operators*; the implementation of these operators can be carefully tuned (and it is important to do this!).
- Many alternative implementation techniques for each operator; no universally superior technique for most operators.
- Must consider available alternatives for each operation in a query and choose best one based on system statistics, etc. This is part of the broader task of optimizing a query composed of several ops.