COMP163

Database Management Systems

Query Processing: Chapter 19

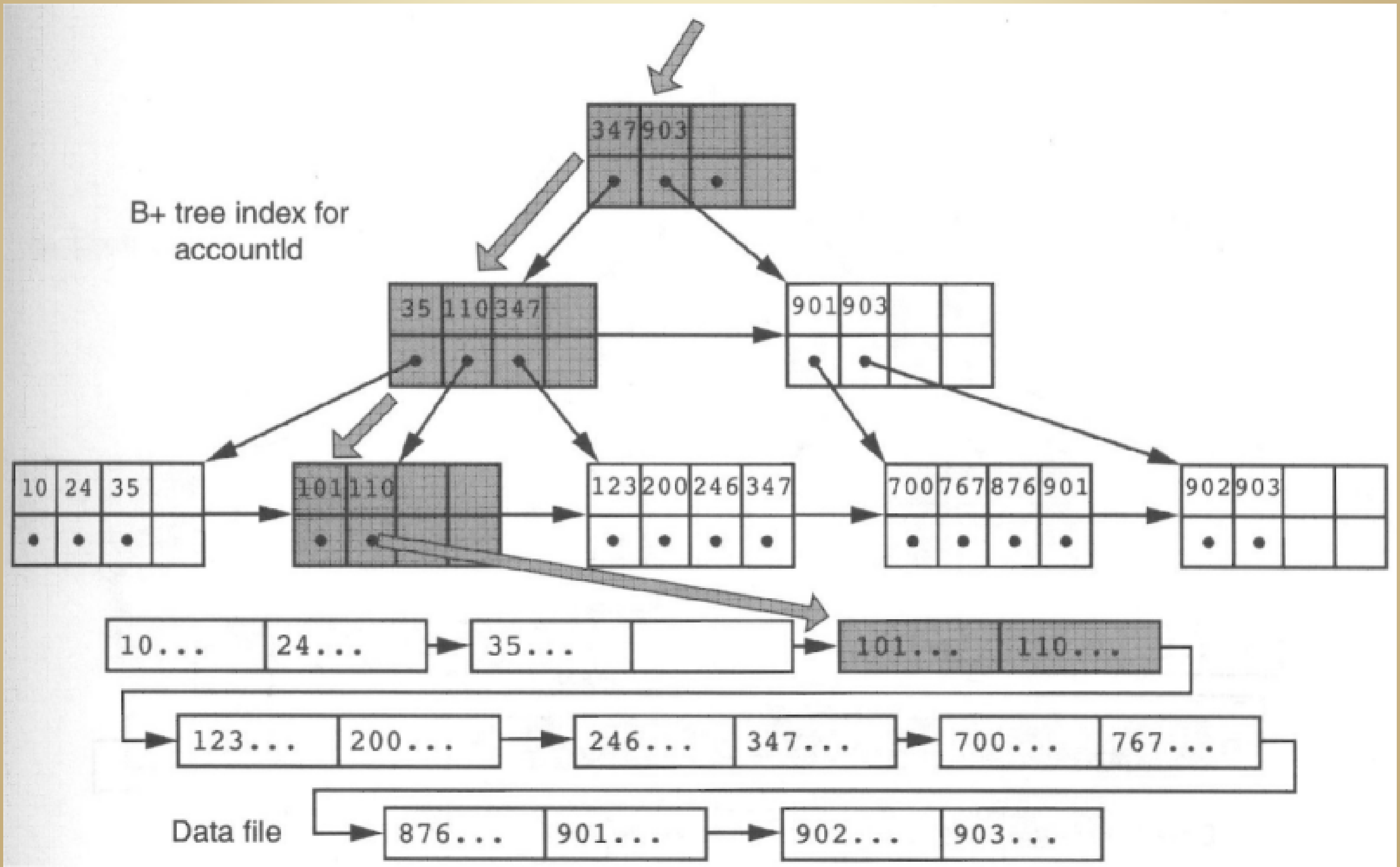
Using Indexes for Queries

Database Instance and Available Indexes:

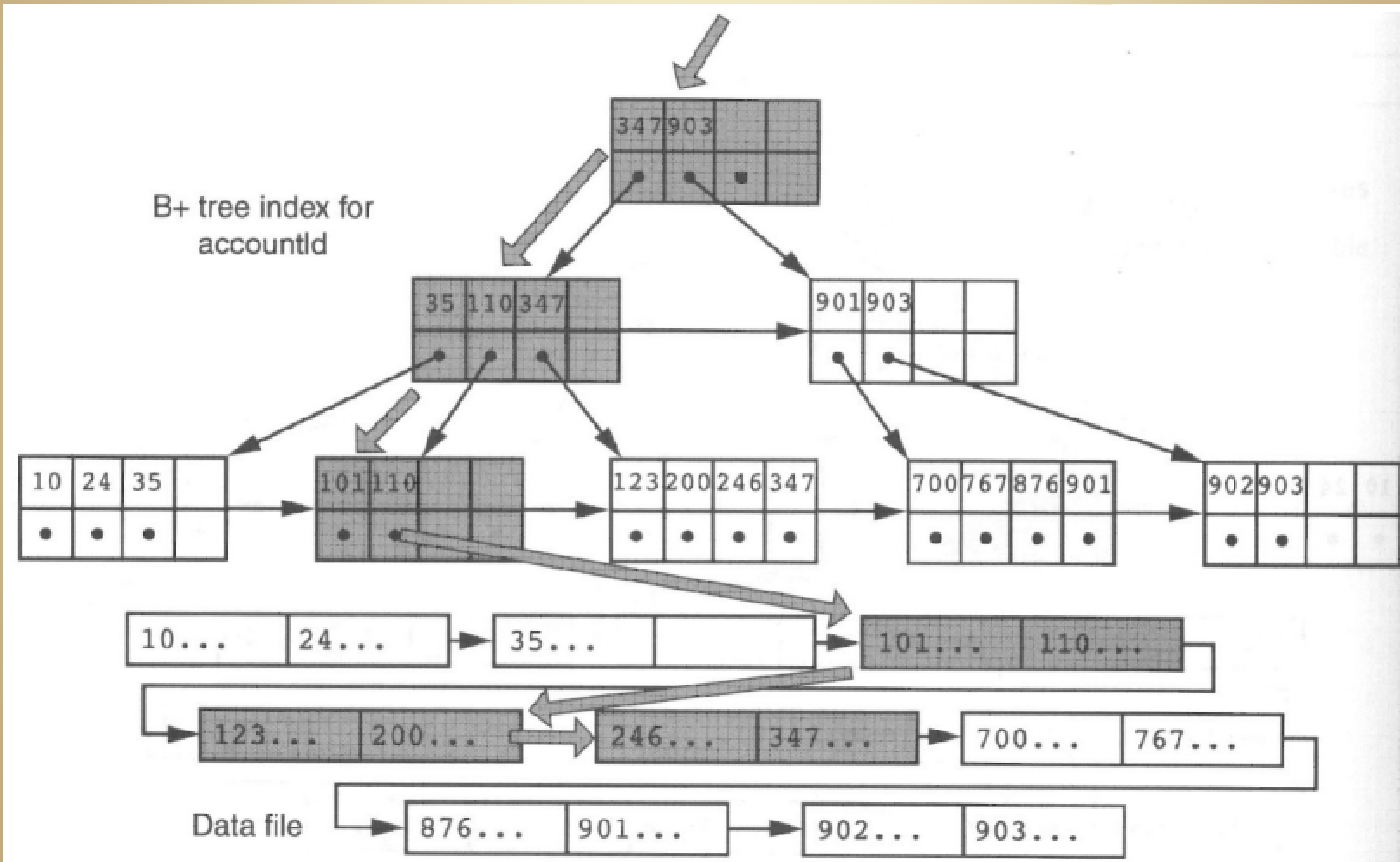
Table	Entries	Number of Entries per Block	Number of Blocks	Index Fields	Index Type	Keys per Node	Depth of B+ Tree
Customer	10,000	10	1,000	accountId	B+ tree and ordered sequential file	100	3
				lastName	B+ tree	50	3
				zipcode	hash	100	
Rental	1,000,000	100	10,000	accountId	B+ tree	100	3
				movieId	B+ tree	100	3
				date	B+ tree	100	2
Movie	10,000	20	500	movieId	B+ tree and ordered sequential file	100	3
				title	B tree	20	4
				genre	Hash	100	

Examples from: *Principles of Database Systems* by Greg Riccardi, Addison Wesley, 2001

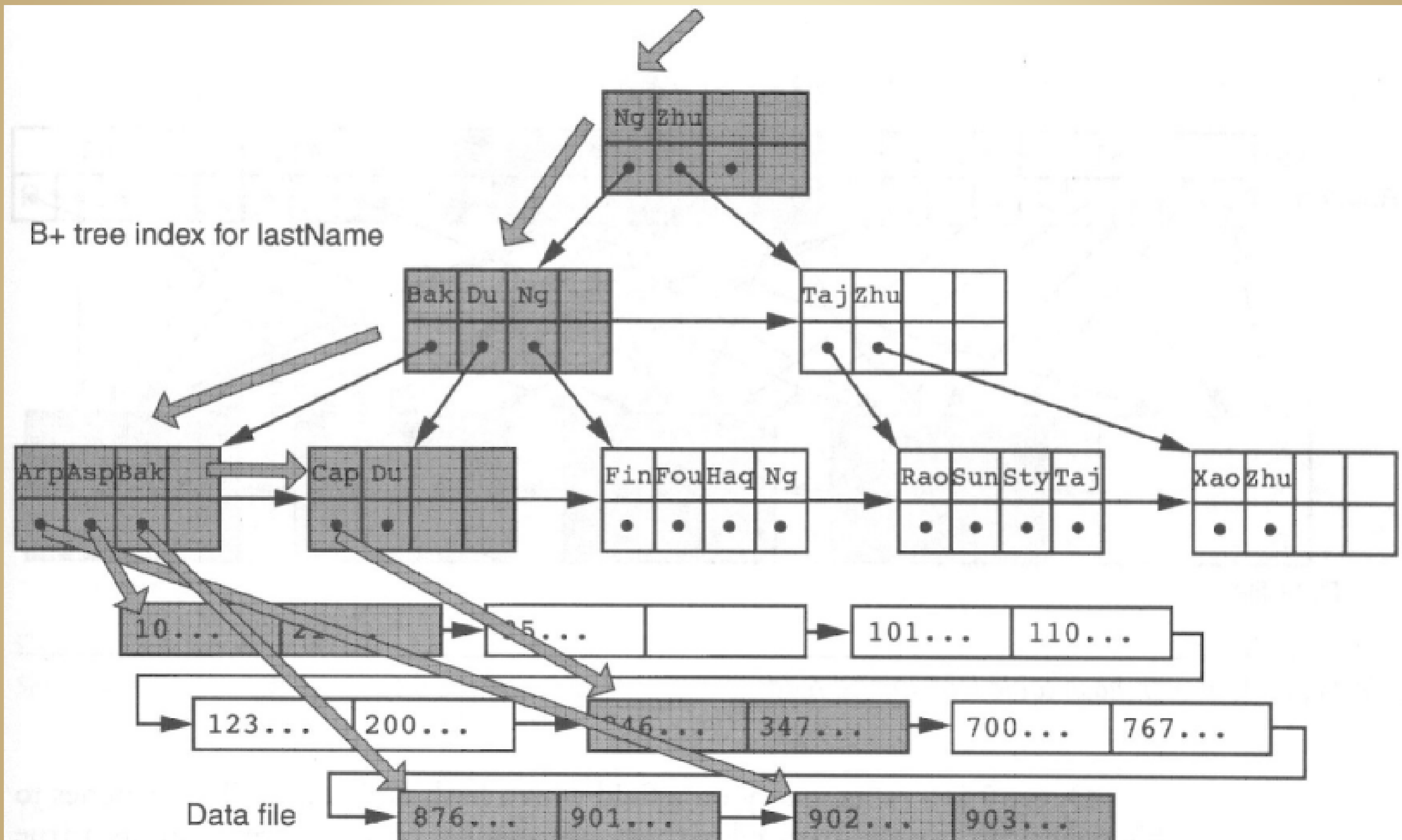
```
select * from Customer
where accountId = 101
```



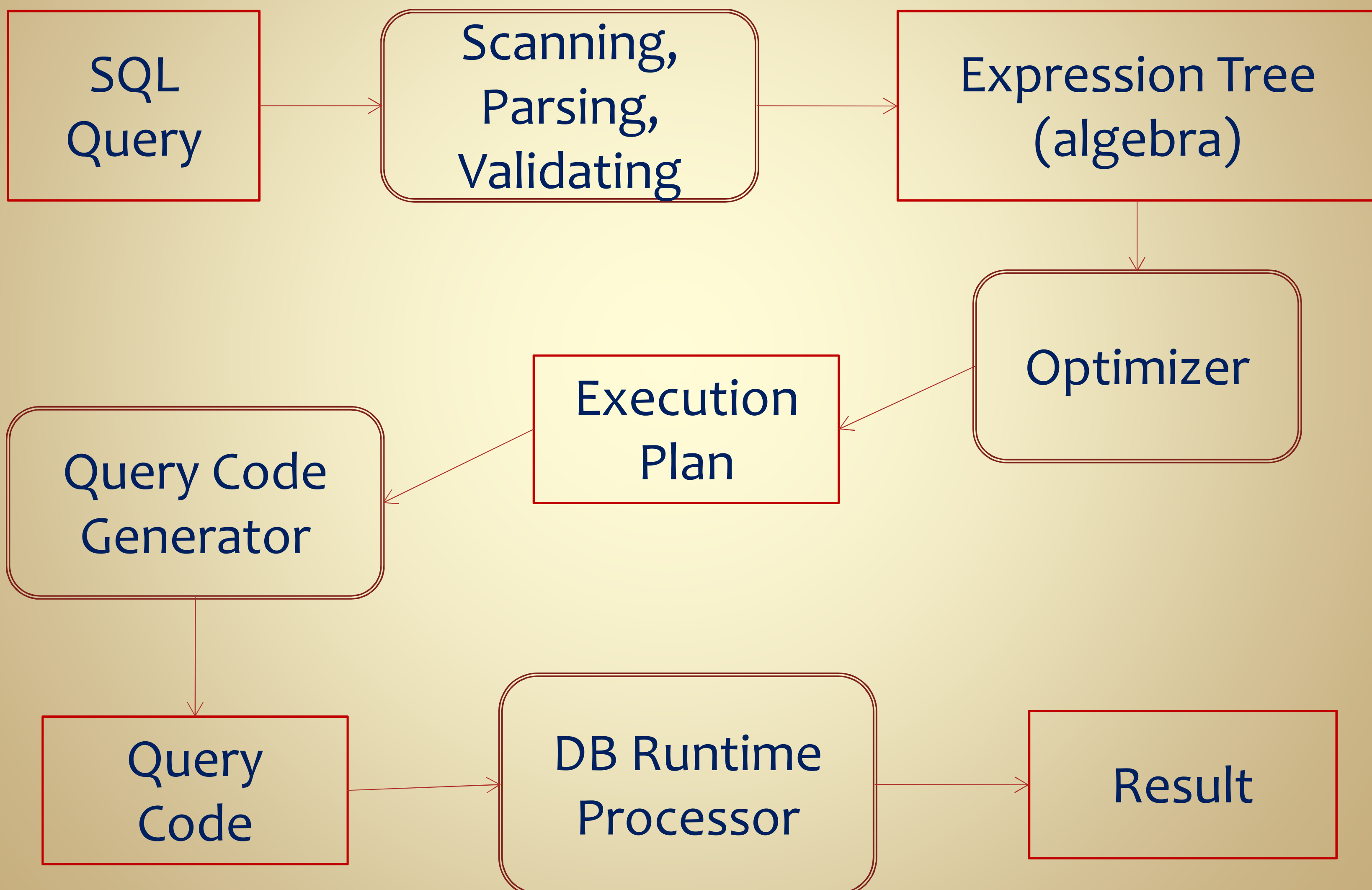
select * from Customer
where accountId >= 101 and accountId < 300



select * from Customer where lastName < 'D'



Query Processing



Query Optimization

- Query optimization determines
  the most efficient (or sufficiently efficient)
  process for executing the query

- Optimization reorganizes
  an expression tree for a query
  using algebraic transformation rules

- Information used:
  - implementation techniques for algebra operators
  - algebraic transformation rules
  - heuristic rules
  - cost estimates

Algebraic Transformations

- Commutative: $\sigma \quad \bowtie \quad \text{x} \quad \cup \quad \cap$
- Associative: $\bowtie \quad \text{x} \quad \cup \quad \cap$

- Cascades of select:
  - $\sigma_{\text{c1 AND c2 AND … AND cn}}(R) \equiv \sigma_{c1}(\sigma_{c2}(\ldots \sigma_{cn}(R))\ldots))$
  - selects can then be commuted

- Cascades of project:
  - $\pi_{L1}(\pi_{L2}(\ldots \pi_{Ln}(R))\ldots)) \equiv \pi_{L1}(R)$
  - projects cannot be commuted

Algebraic Transformations

- Commuting select and project:
  - $\pi_{A1,A2,\ldots,An}(\sigma_c(R)) \equiv \sigma_c(\pi_{A1,A2,\ldots,An}(R))$

    valid when selection condition only involves attributes in projection list
- Converting select/cross-product into join:
  - $\sigma_c(R \times S) \equiv R \bowtie_c S$

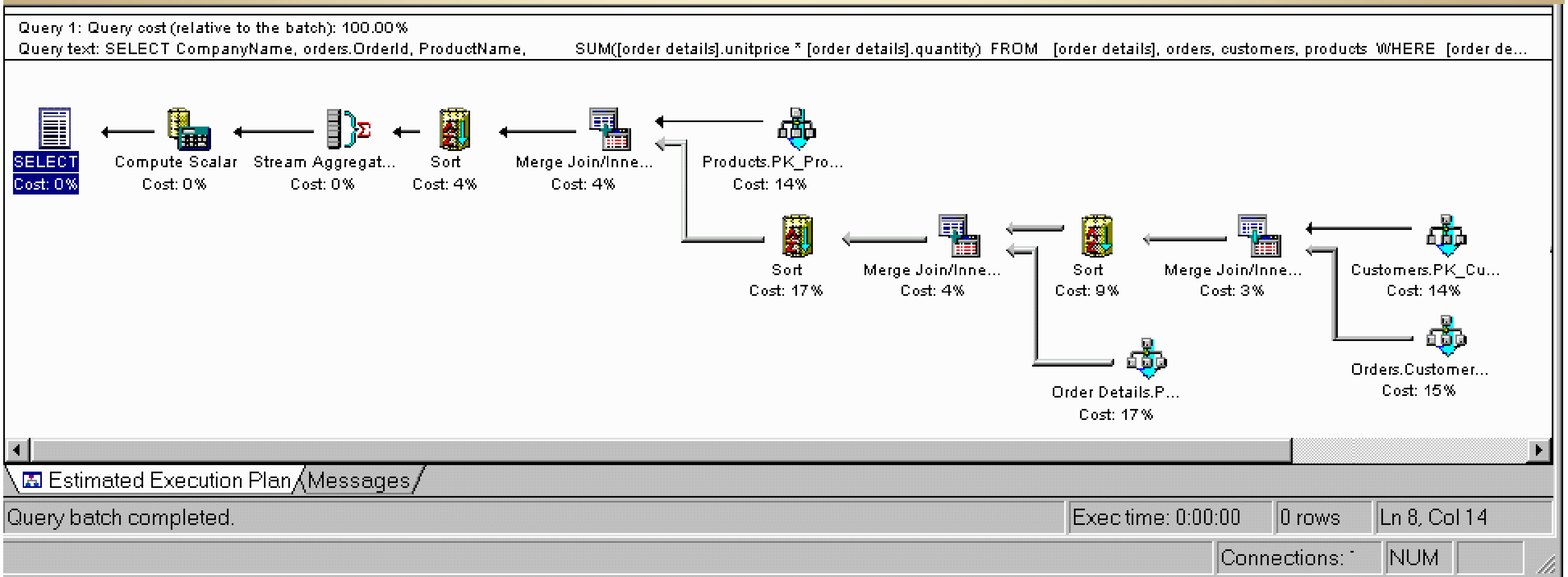
Algebraic Transformations

- Commuting select and join or cross-product:
  - $\sigma_c(R \bowtie S) \equiv \sigma_c(R) \bowtie S$
    valid when selection condition involves only attributes in R
- Commuting project with join or cross-product:
  - $\pi_L(R \bowtie_c S) \equiv (\pi_{A1,A2,\ldots,An}(R)) \bowtie_c (\pi_{B1,B2,\ldots,Bn}(S))$
    where $A1,\ldots,An \subseteq L$ are attributes of R,
    and $B1,\ldots,Bn \subseteq L$ are attributes of S,
    and A1,…,An, B1,…,Bn are involved in C
    (slightly more complicated if C contains attributes not in L)

Optimization Heuristics

- **Break up conjunctive select conditions**
  into a cascade of selects
  - more flexibility in moving selects
- **Push selects as early as possible,**
  using commutativity of select with other operators
- **Reorder sub-expressions such that most restrictive selects are done first**
- **Combine select/cross-product into join**
- **Push projects as early as possible**
  - keep only necessary attributes

Example Query Plan



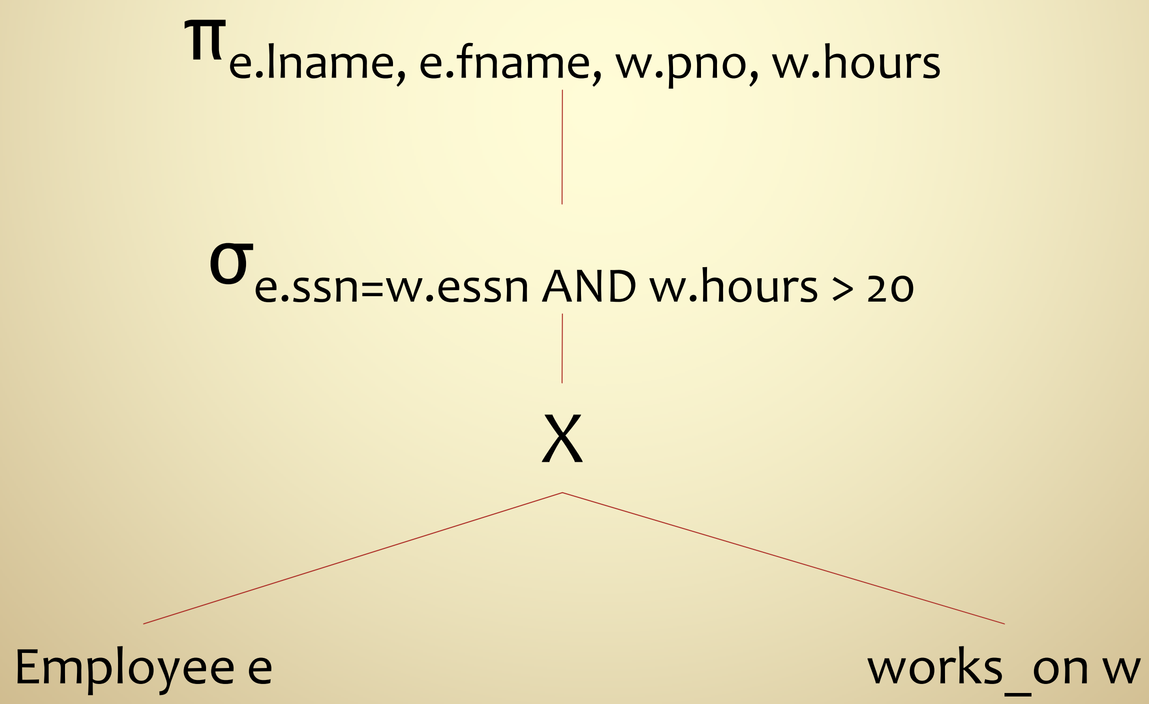
Microsoft SQL Server

Optimization Processor

- Enumerate the query plans
  - Apply algebraic transformations & heuristics to get all reasonable trees
- Estimate the cost of each plan
  - Account for size of relations, available indexes, information about file layout, info about value distributions …
- Choose the best (fastest) plan

Example Query

```
select e.lname, e.fname, w.pno, w.hours
from employee e, works_on w
where e.ssn = w.essn and w.hours > 20;
```



Example Query

$\pi_{e.lname,\ e.fname,\ w.pno,\ w.hours}$

$\sigma_{w.hours > 20}$

$\sigma_{e.ssn=w.essn}$

X

Employee e

works_on w

Heuristic: Conjunctive select → cascade of selects

Note: selects could commute

Example Query

$\pi_{e.lname,\ e.fname,\ w.pno,\ w.hours}$

$\sigma_{w.hours > 20}$

$\bowtie_{e.ssn=w.essn}$

Employee e   works_on w

Heuristic:
Combine select
and cross → join

Example Query

Heuristic:
Push selects as early as possible

$\pi_{e.lname,\ e.fname,\ w.pno,\ w.hours}$

$\bowtie_{e.ssn=w.essn}$

Employee e

$\sigma_{w.hours\ >\ 20}$

works_on w

Example Query

$\pi_{e.lname,\ e.fname,\ w.pno,\ w.hours}$

$\pi_{e.ssn,\ e.lname,\ e.fname,\ w.essn,\ w.pno,\ w.hours}$

Heuristic:
Push projects as early as possible

$\bowtie_{e.ssn=w.essn}$

First cascade projects to get attributes needed to push through join

Employee e

$\sigma_{w.hours\ >\ 20}$

works_on w

Example Query

$\pi_{e.lname,\ e.fname,\ w.pno,\ w.hours}$

$\bowtie_{e.ssn=w.essn}$

Heuristic:
Push projects as early as possible

Push project through join

$\pi_{e.ssn,\ e.lname,\ e.fname}$

Employee e

$\pi_{w.essn,\ w.pno,\ w.hours}$

$\sigma_{w.hours > 20}$

works_on w

Example Query

$\pi_{e.lname,\ e.fname,\ w.pno,\ w.hours}$

$\bowtie_{e.ssn=w.essn}$

Heuristic:
Push projects as
early as possible

Push project
through select

$\pi_{e.ssn,\ e.lname,\ e.fname}$

$\sigma_{w.hours\ >\ 20}$

Employee e

$\pi_{w.essn,\ w.pno,\ w.hours}$

works_on w

Example Query

- At this point we've generated seven different query plans for the same query
- Adding strategies/algorithms for implementing individual operations would add even more potential plans
- Next Step: Estimate the cost of executing each plan