CS525: Advanced Database Organization

Notes 6: Query Processing
Part II: Parsing and pre-processing

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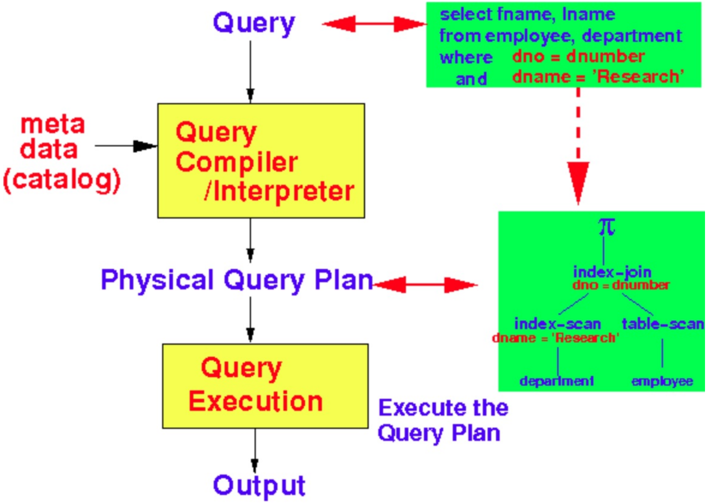
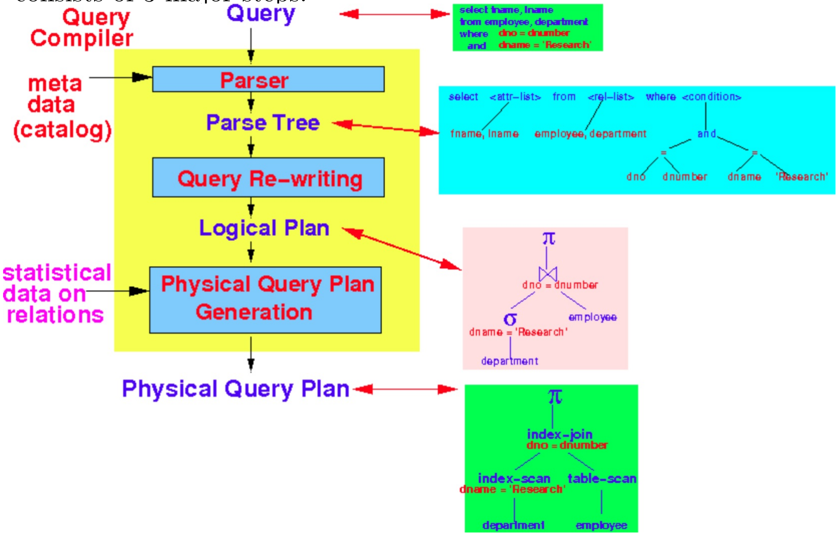
March 6^{th} 2024

Slides: adapted from a course taught by Shun Yan Cheung, Emory University

Steps needed to process a query (SQL command)

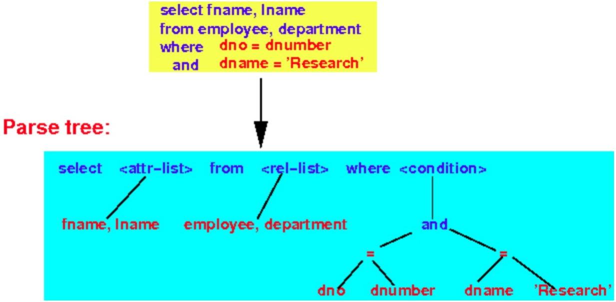


- consists of 3 major steps:



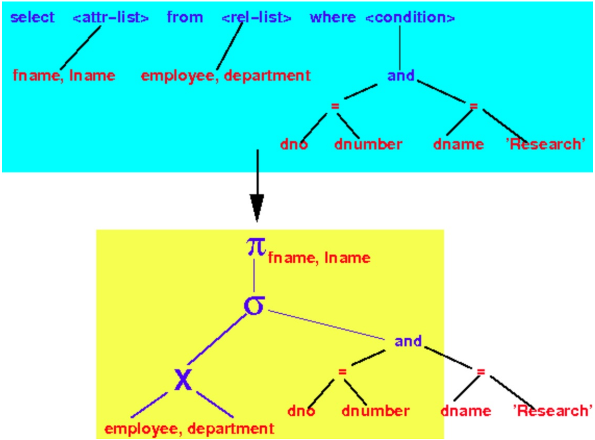
Parser

- Parses the `SQL command` and constructs a query parse tree that represents the syntax elements in the `SQL command` (Queries need to be translated to an internal form)
  - Queries posed in a declarative DB language (“what should be returned”, not “where is it found”)
  - Queries can be evaluated in different ways



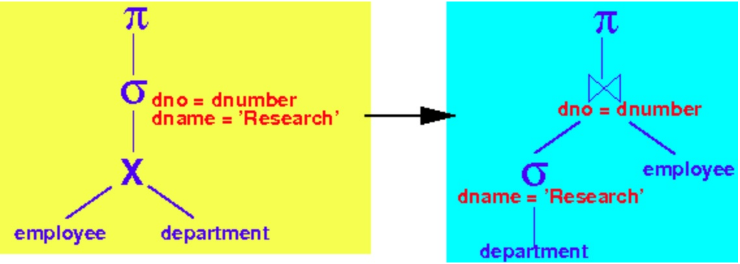
Query Re-writing

1. converts a query parse tree into an un-optimized logical query plan
   - A logical query plan consists of relational algebra operators



Query Re-writing

2. converts the un-optimized logical query plan into an optimized logical query plan



- The optimized logical query plan is a.k.a. the logical query plan
- *The cost measure used to decide on which query plan is better is the size (# tuples) of all the intermediate result relations generated by the logical query plan.*

Logical Query Plan/Physical Query Plan

- Logical Query Plan

  The optimal sequence of ***relational algebra operations*** to perform the query
- Physical Query Plan

  The optimal sequence of ***relational algebra algorithms*** to perform the query
  - Consists of
    - Physical Operators (algorithms used to execute some relational algebra operation, e.g., one-pass join, index-join, etc)
    - The order in which the physical operations are performed (a tree)
    - Way to obtain the input for each physical operator

      - Pipeline (using iterator)

      - Materialization

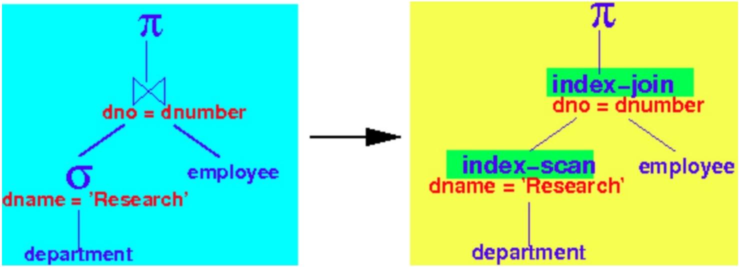
Physical Query Plan Generation

- Select the best algorithms to execute the logical query plan
  - Usually, there are multiple algorithms available to implement one **`relational algebra operation`**
  - We select the best algorithm depending on
    - Availability of indexes
    - How much main memory is available (# of available buffers) for the algorithm (Fast algorithms require more memory)

- *The cost measure used to decide on which physical query plan is better is the # disk I/O operations used by the physical operator (algorithm).*

Physical Query Plan Generation

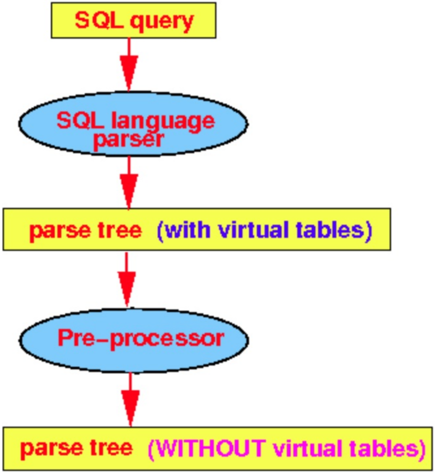
- Select the Physical query operator (algorithm) for each relational algebra operator in the optimal query plan.



SQL Query Parser

- The SQL query parser consists of 2 parts
  - The SQL language parser
    - Parses an `SQL command` into a `parse tree`
  - The SQL pre-processor
    - Checks for some semantic consistencies
    - Replaces `virtual tables (views)` by the corresponding `SQL query` used to obtain the `virtual tables (views)`

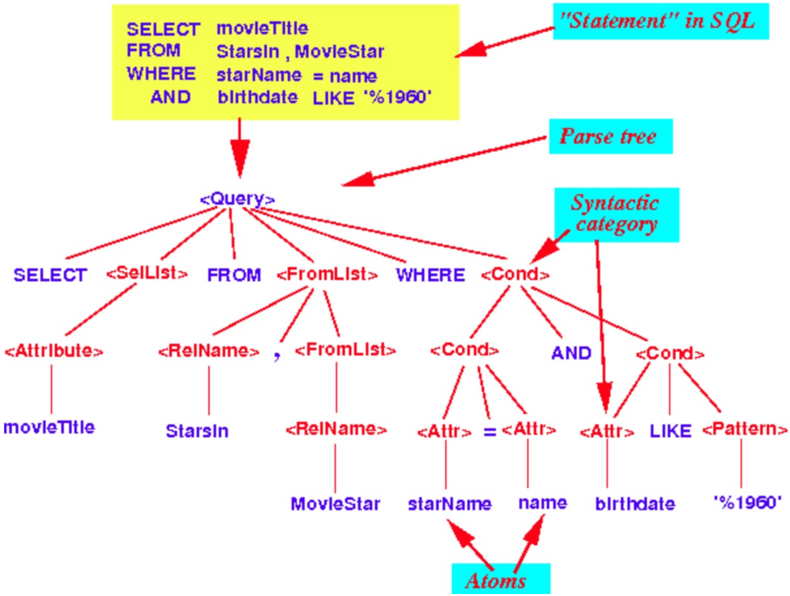
SQL query parser



Parser and parse tree

- *Parsing: Converting an (SQL) query into a query parse tree.*
- Parser
  - a computer program that translate statements ("sentences") in a programming language (e.g., SQL) into a parse tree or syntax tree.
- Parse tree
  - Tree represents the hierarchical structure of the SQL command and its components.
  - Each node in the tree corresponds to a specific part of the SQL command, like tables, conditions, and selected columns.
  - Provides a structured way to understand the syntax of the query.
  - Parse tree: a tree whose nodes corresponds to
    - `atoms` of the programming language (like identifiers, keywords, literals, etc.) or
    - `syntactic categories` of the programming language (like expressions, statements, declarations, etc.)

Example


SELECT movieTitle
FROM StarsIn , MovieStar
WHERE starName = name
AND birthdate LIKE '%1960'
"Statement" in SQL
Parse tree
Syntactic category
<Query>
SELECT
<SelList>
FROM
<FromList>
WHERE
<Cond>
<Attribute>
<RelName>
,
<FromList>
<Cond>
AND
<Cond>
movieTitle
StarsIn
<RelName>
<Attr>
=
<Attr>
<Attr>
LIKE
<Pattern>
MovieStar
starName
name
birthdate
'%1960'
Atoms

Atoms and Syntactic Categories

- Atom
  - Lexical element in a (programming) language that cannot be expressed in more elementary lexical elements
  - *Atoms can not be divided any further*
- Atoms is a.k.a. terminals in a compiler course
- Examples
  - **keywords**: `SELECT, FROM, WHERE, etc`
  - **identifiers**: `employee, name, ...`
  - **Constants**: `3`, 3.14, `'April', ...`
  - **Operators**: `+,` >= `, LIKE, ...`
  - **Tokens**: `(`, `;` , `,` , ...

Syntactic category

- Lexical construct in a (programming) language that is built up with other lexical elements following some syntactic rules[1].
  - Syntactic categories can be divided further
- A syntactic category is denoted as follows:
  - < `Name-of-a-Syntactic-category` >
- Syntactic categories is a.k.a. non-terminals in a compiler course
- Examples of syntactic categories
  - < `Query` >
  - < `Arithmetic expression` >
  - < `Condition`> `(or Boolean expression)`

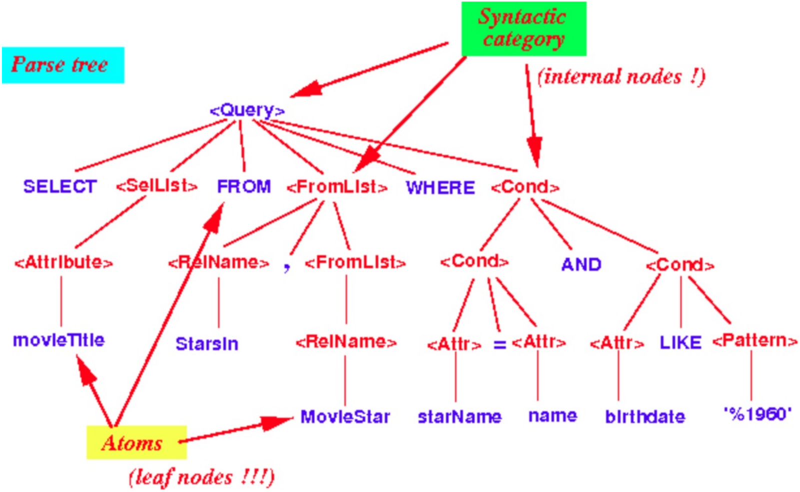
- *In natural language, a syntactic category refers to the classification of words or phrases based on their grammatical roles and how they can be ordered to create meaningful sentences.*

[1] *The rules of how to order words help the language parts make sense.*

Properties of a parse tree

- A node in the parse tree is either an atom or syntactic category
- If a node is an atom, then
  - that node does not have any children (i.e.: atoms are always leaf nodes)
- If a node is a syntactic category, then
  - the `subtree` of the node is the instantiation of one of the syntax rules of the grammar

Properties of a parse tree: Example



Grammar of programming languages

- A grammar is a formal system that describes the syntax (structure) of a language. It defines the rules for constructing valid sentences or programs in that language.
- A grammar is defined by a set of re-writing rules
- Re-writing rules are the fundamental elements of a grammar. They specify how symbols can be replaced or re-written in the language.
- A re-writing rule has the following form:

```
<A> ::= Re-write_Rule
```

- Meaning:

  <A> can be expressed (replaced by) the right-hand-side (re-write rule)

- Example: re-writing rules

```
<expr>   ::= <term>     | <expr> + <term>   | <expr> - <term>
<term>   ::= <factor>   | <term> * <factor> | <term> / <factor>
<factor> ::= <constant> | ( <expr> )
```

A simplified SQL grammar

- To illustrate the translation process from `SQL query` to logical query plan, we use a `simplified SQL grammar`

```
<Query>      ::=  SELECT <SelList>
                  FROM   <FromList>
                  WHERE  <Condition>

<SelList>    ::=  <Attribute> |
                  <Attribute> , <SelList>

<FromList>   ::=  <Relation>  |
                  <Relation>  , <FromList>

<Condition> ::=  <Condition> AND <Condition>   |
                  <Attribute> IN ( <Query> )    |
                  <Attribute> = <Attribute>     |
                  <Attribute> LIKE <Pattern>
```

- Note: This is the `grammar` used by the textbook. It is brief, but incomplete.

Simplified SQL Grammar

$$
\begin{aligned}
\langle \text{sql\_query} \rangle &::= \text{SELECT } \langle \text{select\_list} \rangle \text{ FROM } \langle \text{table\_name} \rangle \langle \text{where\_clause} \rangle \langle \text{group\_by\_clause} \rangle \langle \text{having\_clause} \rangle \langle \text{ord} \\
\langle \text{select\_list} \rangle &::= * | \langle \text{column\_list} \rangle ; \\
\langle \text{column\_list} \rangle &::= \langle \text{column\_name} \rangle | \langle \text{column\_name} \rangle , \langle \text{column\_list} \rangle ; \\
\langle \text{table\_name} \rangle &::= \langle \text{identifier} \rangle ; \\
\langle \text{where\_clause} \rangle &::= \text{WHERE } \langle \text{condition} \rangle ; \\
\langle \text{group\_by\_clause} \rangle &::= \text{GROUP BY } \langle \text{column\_name} \rangle ; \\
\langle \text{having\_clause} \rangle &::= \text{HAVING } \langle \text{condition} \rangle ; \\
\langle \text{order\_by\_clause} \rangle &::= \text{ORDER BY } \langle \text{column\_name} \rangle ; \\
\langle \text{condition} \rangle &::= \langle \text{comparison\_condition} \rangle | \langle \text{logical\_condition} \rangle ; \\
\langle \text{comparison\_condition} \rangle &::= \langle \text{column\_name} \rangle \langle \text{comparison\_operator} \rangle \langle \text{value} \rangle ; \\
\langle \text{logical\_condition} \rangle &::= \langle \text{condition} \rangle \text{ AND } \langle \text{condition} \rangle \\
&\quad | \langle \text{condition} \rangle \text{ OR } \langle \text{condition} \rangle \\
&\quad | \text{NOT } \langle \text{condition} \rangle ; \\
\langle \text{comparison\_operator} \rangle &::== \mid < \mid > \mid \leq \mid \geq \mid \neq \mid \neq ; \\
\langle \text{column\_name} \rangle &::= \langle \text{identifier} \rangle ; \\
\langle \text{value} \rangle &::= \langle \text{numeric\_literal} \rangle |' \langle \text{string\_literal} \rangle ' ; \\
\langle \text{identifier} \rangle &::= [a - zA - Z][a - zA - Z0 - 9]* ; \\
\langle \text{numeric\_literal} \rangle &::= [0 - 9]+ ; \\
\langle \text{string\_literal} \rangle &::=' \langle \text{characters} \rangle ' ; \\
\langle \text{characters} \rangle &::= \langle \text{character} \rangle | \langle \text{character} \rangle \langle \text{characters} \rangle ; \\
\langle \text{character} \rangle &::= \text{any valid character.}
\end{aligned}
$$

“Base” syntactic categories

- Base syntactic categories, a.k.a terminal symbols or tokens, are fundamental building blocks in any programming language.
- In SQL, these base syntactic categories are predefined and represent the basic elements from which SQL statements are constructed.
- There are a number of special syntactic categories in any programming language.
- In `SQL`, these are
    - `<Relation>`
    - `<Attribute>`
    - `<Pattern>`
    - `<Identifier>`
    - `<Constant>`

“Base” syntactic categories: Properties

- They are not defined using explicit grammar rules, as they are treated as atomic elements.
- Instead, their properties and usage are defined by rules and conventions provided by the SQL language specification.
- These categories are essential for building meaningful SQL statements, as they identify tables, columns, patterns, and specific values.
- Example
    - <`Identifier`> must start with a letter or _ and followed by letters, digits or _
    - <`Relation`> must start with a letter or _ and followed by letters, digits or _ And it must identify a `relation` in the database

Example of parse trees

- `Relations` used in the example
  - The movie **movieTitle** made in **movieYear** features movie star **starName**

```
StarsIn(movieTitle, movieYear, startName)
-- links a movie's title and release year with the
    name of a star who acted in that movie.
```

  - The movie star **name** has the specified **address**, **gender** and **birthdate**

```
-- stores details about individual movie stars.
MovieStar(name, address, gender, birthdate)
```

- `SQL Query`

```
-- list of movieTitle values for movies in which the
    stars with birthdates ending in '1960' appeared
SELECT  movieTitle
FROM    StarsIn, MovieStar
WHERE   starName = name AND birthdate LIKE '%1960'
```

Example of parse trees

- The `parse tree`
  - We re-write a `Query` using this rule:

```
<Query>::=  SELECT <SelList>
            FROM   <FromList>
            WHERE  <Condition>
```

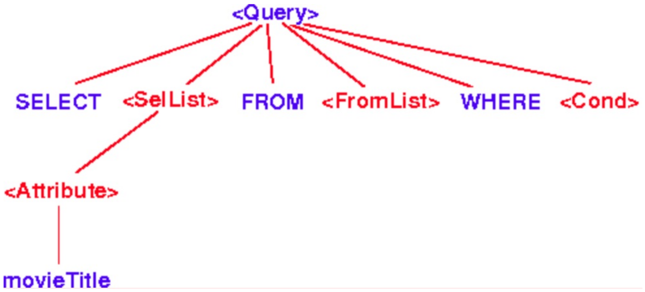
  - The `parse tree` is now

Example of parse trees

- Then we re-write `SelList` using

```
<SelList> ::= <Attribute>
          ::= movieTitle
```

- The `parse tree` is now

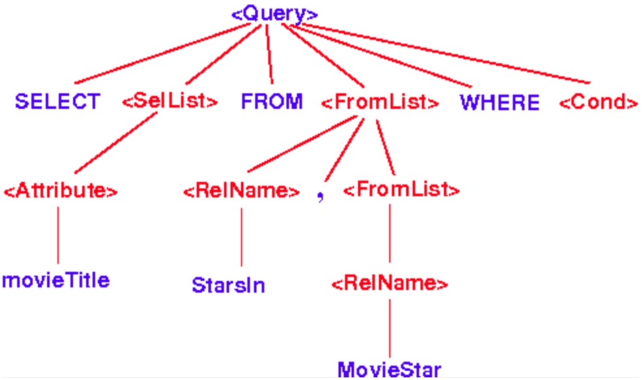


Example of parse trees

- Then we re-write `FromList` using

```
<FromList>  ::=  <Relation> , <FromList>
            ::=  <Relation> , <Relation>
            ::=   StarsIn , <Relation>
            ::=   StarsIn , MovieStar
```

- The `parse tree` is now



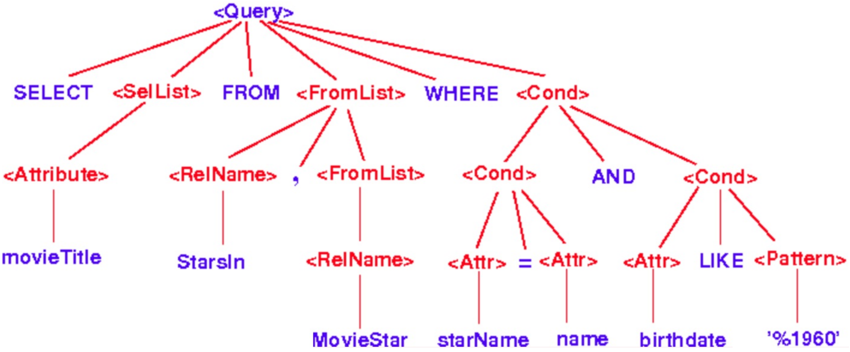
Example of parse trees

- Then we re-write `Condition` using

```
<Condition> ::= <Condition> AND <Condition>
            ::= <Attribute> = <Attribute>  AND  <Condition>
            ::= <Attribute> = <Attribute>  AND  <Attribute>
                                                LIKE <Pattern>
            ::= starName = name AND birthdate LIKE '%1960'
```

Example of parse trees

- The `parse tree` is



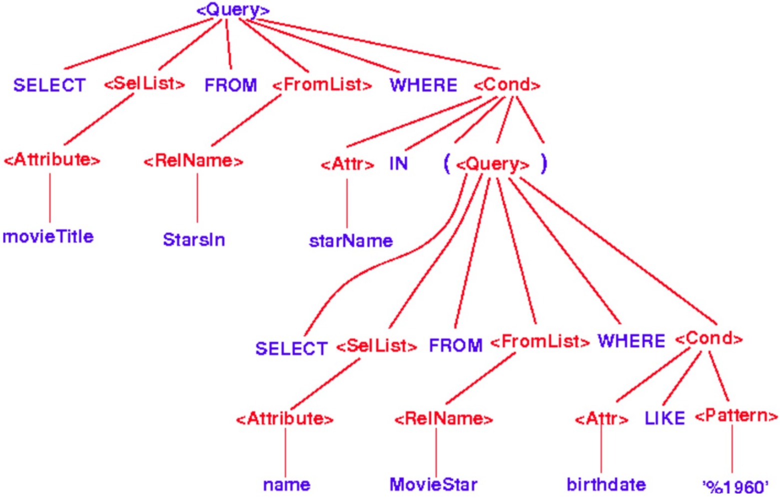
Example 2

- SQL query

```
SELECT movieTitle
FROM   StarsIn
WHERE  starName IN (SELECT name
                    FROM   MovieStar
                    WHERE  birthdate LIKE '%1960')
```

Example 2

- The `parse tree` is



Pre-processing an SQL query

- Example of a `query`:

```sql
SELECT   fname, dno
FROM     employee, department
WHERE    dnumber = dno
```

- Looks correct.
- Query can have `semantical errors`:
  - Does the database contain the relation `employee` (or `department`)?
  - Does the attribute `dno` (or `fname`) exist in the specified relations (`employee` and `department`)?
    - If it does, which relation does `dno` belong to?
  - And so on

Tasks in Pre-processing an SQL Query

- Check whether the `relations` used in the `FROM` clause exist in the database
- Check and resolve each `attributes` used in the `query`
  - Which `relation` does the `attribute` belong to? (Scope checks)
- Check the `data types` and correct usage of the `attributes`
  - Can some operations be applied to the `attribute`?
    e.g., `+` operation requires a `number` type
- Replace the `virtual relations (views)` by their corresponding `SQL query`

Semantic checks: Example

```
SELECT *
FROM R
WHERE R.a + 3 > 5
```

- `Relation R` exists?
- Expand `*`: which attributes in `R`?
- `R.a` is a column?
- Type of constants `3`, `5`?
- `Operator +` for types of `R.a` and `3` exists?
- `Operator` > for types of result of `+` and `5` exists?

Example: virtual relation pre-processing

- `Virtual table` definition

```sql
CREATE VIEW Paramount_Movies AS
     (SELECT title, year
      FROM   Movies
      WHERE  StudioName = 'Paramount')
```

  - The SELECT query is **equivalent** to the following **logical query plan**

$$\pi_{title,year}$$

$$\sigma_{StudioName='Paramount'}$$

Movies

Example: virtual relation pre-processing

- Consider the following query on the virtual table `Paramount_Movies`:

```sql
SELECT    title
FROM      Paramount_Movies
WHERE     year = 1979
```

  - The `Query Processor` will first `parse the query` and create the following `logical query plan`

$$\pi_{title}$$
$$|$$
$$\sigma_{year=1979}$$
$$|$$
$$\texttt{Paramount\_Movies}$$

Example: virtual relation pre-processing

- Then, the `virtual table` is replaced by the corresponding `logical query plan`

$$\pi_{title}$$

$$\sigma_{year=1979}$$

$$\pi_{title,year}$$

$$\sigma_{StudioName='Paramount'}$$

`Movies`

- Next: Convert Parse Tree into initial L.Q.P