Odds and Ends of SQL

CPS 216

Advanced Database Systems

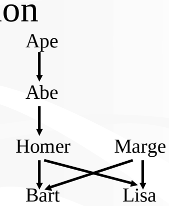
Outline

- Recursion
- Triggers
- Application programming

Recursion

ParentChild(parent, child)

parent	child
Homer	Bart
Homer	Lisa
Marge	Bart
Marge	Lisa
Abe	Homer
Ape	Abe



- Example: find Bart's ancestors
- "Ancestor" has a recursive definition
  - X is Y's ancestor if
    - X is Y's parent, or
    - X is Z's ancestor and Z is Y's ancestor

Recursion in SQL

- SQL2 has no recursion
  - You can find Bart's parents, grandparents, great grandparents, etc.
  - But you cannot find all his ancestors in a single query
- SQL3 proposal has recursion
  - WITH RECURSIVE statements
  - Implemented by DB2

Ancestor query in SQL3

```
WITH
  RECURSIVE Ancestor(ancestor, descendent) AS      -- Define ancestor-descendent relationship
    (SELECT * FROM ParentChild)                    -- Base case
    UNION
    (SELECT a1.ancestor, a2.descendent             -- Recursion
     FROM Ancestor AS a1, Ancestor AS a2
     WHERE a1.descendent = a2.ancestor)
SELECT ancestor
FROM Ancestor
WHERE descendent = 'Bart';                         -- Find Bart's ancestors
```


Linear recursion

- Technically, SQL3 only requires support of linear recursion: each RECURSIVE definition has at most one reference to a recursively-defined table
- Can we make the ancestor query linear?

```
WITH
  RECURSIVE Ancestor(ancestor, descendent) AS
    (SELECT * FROM ParentChild)
    UNION
    (SELECT parent, descendent
     FROM ParentChild, Ancestor
     WHERE child = ancestor)
  SELECT ancestor FROM Ancestor
  WHERE descendent = 'Bart';
```

Fixed point of a function

- If $f: T \rightarrow T$ is a function from a type T to itself, a fixed point of f is a value x such that $f(x) = x$
- Example: What is the fixed point of $f(x) = x / 2$?
  - 0, because $f(0) = 0 / 2 = 0$
- To compute a fixed point of f
  - Start with a "seed": $x \leftarrow x_0$
  - Compute $f(x)$
    - If $f(x) = x$, stop; x is fixed point of f
    - Otherwise, $x \leftarrow f(x)$; repeat
- Example: compute the fixed point of $f(x) = x / 2$
  - With seed 1: 1, 1/2, 1/4, 1/8, 1/16, … $\rightarrow 0$

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Fixed point of a query

- A query q is just a function that maps an input table to an output table, so a fixed point of q is a table T such that $q(T) = T$
- To compute fixed point of q
  - Start with an empty table: $T \leftarrow \varnothing$
  - Evaluate q over T
    - If the result is identical to T, stop; T is a fixed point
    - Otherwise, let T be the new result; repeat
  - ➢Starting from $\varnothing$ produces the unique minimal fixed point (assuming q is monotonic)

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Finding ancestors

```
RECURSIVE Ancestor(ancestor, descendent) AS
  (SELECT * FROM ParentChild)
   UNION
  (SELECT parent, descendent
   FROM ParentChild, Ancestor
   WHERE child = ancestor)
```

parent	*child*
Homer	Bart
Homer	Lisa
Marge	Bart
Marge	Lisa
Abe	Homer
Ape	Abe

ancestor	*descendent*

↓

ancestor	*descendent*
Homer	Bart
Homer	Lisa
Marge	Bart
Marge	Lisa
Abe	Homer
Ape	Abe

→

ancestor	*descendent*
Homer	Bart
Homer	Lisa
Marge	Bart
Marge	Lisa
Abe	Homer
Ape	Abe
Abe	Bart
Abe	Lisa
Ape	Homer

→

ancestor	*descendent*
Homer	Bart
Homer	Lisa
Marge	Bart
Marge	Lisa
Abe	Homer
Ape	Abe
Abe	Bart
Abe	Lisa
Ape	Homer
Ape	Bart
Ape	Lisa

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Intuition behind fixed-point iteration

- Initially, we know nothing about ancestor-descendent relationships
- In the first step, we deduce that parents and children form ancestor-descendent relationships
- In each subsequent steps, we use the facts deduced in previous steps to get more ancestor-descendent relationships
- We stop when no new facts can be proven

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Mixing negation with recursion

- If q is non-monotonic
  - The fixed-point iteration may flip-flop and never converge
  - There could be multiple minimal fixed points—so which one is the right answer?
- Want to know more?
  - Maybe another, more theoretical database course
  - Or take an AI course
  - Or read the two-volume Ullman book, Database and Knowledge-Base Systems

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Trigger

- A trigger is an event-condition-action rule
  - When event occurs, test condition; if condition is satisfied, execute action
  - An "active database" feature
- Example:
  - Event: whenever there comes a new student…
  - Condition: with GPA higher than 3.0…
  - Action: then make him/her take CPS 216!

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Trigger example

```
CREATE TRIGGER CPS216AutoRecruit
  AFTER INSERT ON Student              → Event
  REFERENCING NEW AS newStudent
  FOR EACH ROW
  WHEN (newStudent.GPA > 3.0)          → Condition
  INSERT INTO Enroll
    VALUES(newStudent.SID, 'CPS 216');  → Action
```


Trigger options

- Possible events include:
  - INSERT ON table
  - DELETE ON table
  - UPDATE [OF column] ON table
- Trigger can be activated:
  - FOR EACH ROW modified
  - FOR EACH STATEMENT that performs modification
- Action can be executed:
  - AFTER or BEFORE the triggering event

Transition variables

- OLD: the modified row before the triggering event
- NEW: the modified row after the triggering event
- OLD_TABLE: a hypothetical read-only table containing all modified rows before the triggering event
- NEW_TABLE: a hypothetical table containing all modified rows after the triggering event
- Not all of them make sense all the time, e.g.
  - AFTER INSERT statement triggers
    - Can use only NEW_TABLE
  - BEFORE DELETE row triggers
    - Can use only OLD
  - etc.

Statement trigger example

```
CREATE TRIGGER CPS216AutoRecruit
  AFTER INSERT ON Student
  REFERENCING NEW_TABLE AS newStudents
  FOR EACH STATEMENT
  INSERT INTO Enroll
    SELECT SID, 'CPS 216'
    FROM newStudents
    WHERE GPA > 3.0
    AND SID NOT IN
      (SELECT SID FROM Enroll
       WHERE CID = 'CPS 216');
```


Another trigger example

Give faculty a raise if all GPAs increase (in one update)

```
CREATE TRIGGER AutoRaise
  AFTER UPDATE OF GPA ON Student
  REFERENCING OLD_TABLE AS o
              NEW_TABLE AS n
  FOR EACH STATEMENT
  WHEN (NOT EXISTS(SELECT * FROM o, n
                   WHERE o.SID = n.SID
                   AND o.GPA >= n.GPA))
  UPDATE Faculty SET salary = salary + 1000;
```

- A row trigger would be hard to write and inefficient

Yet another trigger example

Never give faculty more than 50% raise in one update

```
CREATE TRIGGER NotTooGreedy
  BEFORE UPDATE OF salary ON Faculty
  REFERENCING OLD AS o NEW AS n
  FOR EACH ROW
  WHEN (n.salary > 1.5 * o.salary)
  SET n.salary = 1.5 * o.salary;
```

- BEFORE triggers are often used to "condition" data

Implementation issues

- Recursive firing of triggers
  - Action of one trigger causes another trigger to fire
  - Can get into an infinite loop
    - Some DBMS restrict trigger actions
    - Most DBMS set a maximum level of recursion (16 in DB2)
- Interaction with constraints (very tricky to get right!)
  - When do we check if a triggering event violates constraints?
    - After a BEFORE trigger (so the trigger can fix a potential violation)
    - Before an AFTER trigger
  - AFTER triggers also see the effects of, say, cascaded deletes caused by referential integrity constraint violations

(Based on DB2; no two DBMS implement the same policy!)

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Programming in SQL

- Idea: Instead of making SQL do more, just use it together with a general-purpose programming language

➢ Embedded SQL

➢ JDBC (and ODBC, Perl DBI, etc.)

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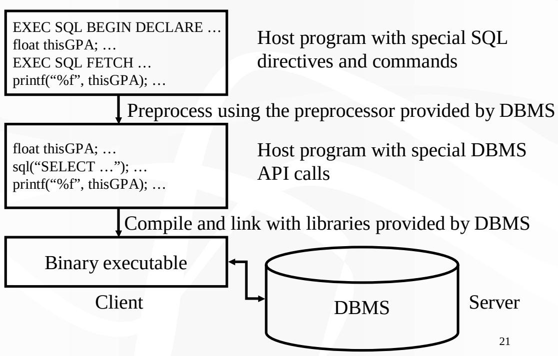
Embedded SQL



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Issues when embedding SQL

- Which statements are SQL?
  - A special preprocessor directive EXEC SQL
- How are the values passed from the host program into SQL commands?
  - Explicitly declared shared variables that are accessible to both SQL and the host program (preprocessor will insert conversion code if necessary)
- How are the results of SQL queries returned into program variables?
  - For a query returns a scalar, use SELECT INTO
  - For a query returns a set, use a cursor

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Embedded SQL example

```
EXEC SQL BEGIN DECLARE SECTION;
int thisSID; float thisGPA;
EXEC SQL END DECLARE SECTION;
```

→ Shared variable declarations

Declaration of a cursor, used to loop over a set of results

```
EXEC SQL DECLARE CPS216Student CURSOR FOR
  SELECT SID, GPA FROM Student
  WHERE SID IN (SELECT SID FROM Enroll
                WHERE CID = 'CPS 216')
  FOR UPDATE;
```

FOR UPDATE; → You can update through the cursor if it is clear how to map a result row to a real row in a database table

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More embedded SQL

```
EXEC SQL OPEN CPS216Student;                -> Open result set
EXEC WHENEVER NOT FOUND DO break;           -> Exit condition
while (1) {          Read through the cursor          Loop
  EXEC SQL FETCH CPS216Student INTO :thisSID, :thisGPA;
  printf("SID %d: current GPA is %f\n", thisSID, thisGPA);
  printf("Enter new GPA: ");
  scanf("%f", &thisGPA);
  EXEC SQL UPDATE Student SET GPA = :thisGPA
    WHERE CURRENT OF CPS216Student;
}                    Update through the cursor
EXEC SQL CLOSE CPS216Student;               -> Close result set
```

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Dynamic SQL

- Embedded SQL is fine for “canned” queries, but how do we write a generic query interface?
- Two special statements to make it dynamic

```
EXEC SQL BEGIN DECLARE SECTION;
char query[MAX_Q_LEN];
EXEC SQL END DECLAR SECTION;
while (1) {
   /* issue SQL> prompt */
   /* read user input into query */
   EXEC SQL PREPARE q FROM :query;
   EXEC SQL EXECUTE q;
}
```

Ship query to DBMS and get it compiled; return a handle q

Use handle to execute query

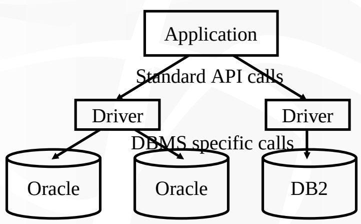
Limitations of embedded SQL

- Not very portable
- Cannot talk to different DBMS at the same time

➢ Need to compile the application for each DBMS because different DBMS use different preprocessors and different libraries

JDBC

- Solution: one more level of indirection through drivers
  - Same idea as ODBC, Perl DBI, etc.



JDBC example

Connecting to the database can easily take the longest time! Connection pooling!

```
Connection conn =
   DrvierManager.getConnection(url, uid, password);
```

```
Statement stmt = conn.createStatement( );
ResultSet rs = stmt.executeQuery(“SELECT * FROM Student”);
while (rs.next( )) {
   int sid = rs.getInt(1);
   String name = rs.getString(2);
   System.out.println(“SID: ” + sid + “ name: ” + name);
}
stmt.close( );
```

Executing query and looping through result set

More JDBC example

```
conn.setTransactionIsolation(TRANSACTION_SERIALIZABLE);
conn.setAutoCommit(false);
```

Getting ready for transactions

```
PreparedStatement pstmt =
   conn.prepareStatement
   (“INSERT INTO Student(SID, name) VALUES(?, ?)”);
// read sid and name from input
pstmt.setInt(1, sid);
pstmt.setString(2, name);
pstmt.execute();
pstmt.close();
conn.commit();
```

Performing an insert

Review of introductory materials

- Relational model and relational algebra
- Relational design theory
  - FD, MVD, BCNF…
- SQL
  - Query: SFWGHO, subqueries, NULL, recursion
  - Constraints and triggers
- Transaction processing
  - Concurrency control and recovery
- Programming with SQL
  - Embedded SQL
  - JDBC