Introduction to Database Systems

CSE 444

Lecture #9

Jan 29 2001

Announcements

- **Mid Term on Monday (in class)**
  - **Material in lectures**
  - **Textbook**
    - **Chapter 1.1, Chapter 2 (except 2.1 and ODL), Chapter 3 (except 3.2, 3.8), Chapter 4.1, 4.5, 4.6, Chapter 5 (except 5.10), Chapter 6.1, 6.2, 7.1, 7.3**
  - **Mid Term will be in class closed book exam**
- **Extra Office Hours**
  - **Surajit (Today) 4.50-5.50**
  - **Yana Thu 4.30-5.30**
- **Solution to HW#1 available**

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Decomposition: Schema Design using FD

Reading: Chapter 3.6, Chapter 6.1, Chapter 6.2

Review: Closure, Key, Superkey

- Given a set of attributes **M** over R(**A**), and a set of Fds on R, closure(**M**) is the set of all attributes L such that **M**->L
- If Closure(**M**) = **A**, then **M** is a superkey
- M is also a key if no proper subset **M'** of **M** satisfies closure(**M'**)=**A**
  - Superkey: A set of attributes containing key

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Review: BCNF

- A relation R(**A**) is in BCNF if for every nontrivial dependency **X**->Y on the relation R, **X** is a superkey
  - Every 2-column relation is in BCNF. Why?
  - Relation in BCNF does not have update or deletion anomalies
- If relation R(**A**) violates BCNF, decomposition is needed
  - How to find a FD that violates BCNF?
  - Check Closure(**X**) of every FD **X**->**Y** in the given set of dependency

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Decomposition Requires Care

Name	Category
Gizmo	Gadget
OneClick	Camera
DoubleClick	Camera

Price	Category
19.99	Gadget
24.99	Camera
29.99	Camera

When we put it back:

Cannot recover information

Name	Price	Category
Gizmo	19.99	Gadget
OneClick	24.99	Camera
OneClick	29.99	Camera
DoubleClick	24.99	Camera
DoubleClick	29.99	Camera

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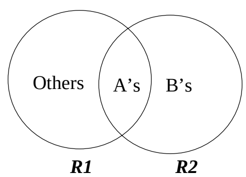
Decomposition Strategy for BCNF

Find a FD that violates the BCNF condition (RHS = all nontrivial attributes functionality determined by LHS):

$A_1, A_2, \ldots A_n \longrightarrow B_1, B_2, \ldots B_m$



Example

- Movie (title, year, studio,president, pres_addr)
  - S = {Title, year -> studio, studio -> president, president->pres_addr}
- Violating FD: studio -> president, pres_addr
- Decompose: Studio1(studio, president, pres_addr), Movie1(title, year, studio)
- Is Studio1 in BCNF?
  - What are applicable FD-s on Studio1?

Projecting FD

- Given F over R, what is the FD that must hold over R′, where R′ is obtained by decomposition?
- Compute closure(X) for each subset X of R′
- X-> B holds in S if
  - B in R′
  - B in closure(X)
  - B not in X
- See Examples 3.39 and 3.40 in text

Example: Projecting FD

- R(A,B,C,D,E) decomposed into S(A,B,C) and ..
- FD on R: A->B, B->E, DE->C
- Closure(A) =?
- Closure(B)=?
- Closure(C) = ?
- Closure({A,B}) =?

Decomposition Based on BCNF is Information Preserving

Attributes A, B, C. FD: A $\longrightarrow$ C

Relations R1[A,B] R2[A,C]

Tuples in R1: (a,b), (a,b′)

Tuples in R2: (a,c), (a,c′)

Tuples in the join of R1,R2: (a,b,c), (a,b,c′), (a,b′,c), (a,b′,c′)

Can (a,b,c′) be a bogus tuple? What about (a,b′,c′) ?

Decomposition into BCNF is Not Dependency Preserving

- Street, city -> zip, zip -> city
- Key: (street,city), (street,zip)
- Consider (Street,zip) and (zip,city)
  - How to check street, city -> zip?
  - Not dependency preserving!
- 3NF
  - Allow FD if LHS is part of a key (prime)

Problems with Decompositions

- There are three potential problems to consider:
  - Some queries become more expensive.
    - e.g., find employee and department names
  - Given instances of the decomposed relations, we may not be able to reconstruct the corresponding instance of the original relation!
  - Checking some dependencies may require joining the instances of the decomposed relations.
- Tradeoff: Must consider these issues vs. redundancy.

Summary of Schema Refinement

- If a relation is in BCNF, it is free of redundancies that can be detected using FDs.
- If a relation is not in BCNF, we can try to decompose it into a collection of BCNF relations:
  - Lossless-join decomposition into BCNF ***is*** always possible
  - Lossless-join, *dependency preserving* decomposition into BCNF is not always possible Lossless-join, dependency preserving decomposition into 3NF ***is*** always possible
  - Decompositions should be carried out and/or re-examined while keeping *performance requirements* in mind.
  - Various decompositions of a single schema are possible.

Constraints and Triggers

Reading: Section 6
(MidTerm: 6.1 and 6.2 only)

Constraints

- A constraint = an *assertion* about the database that must be true at all times
- Part of the database schema
- Correspond to *invariants* in programming languages

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Constraints

- CREATE TABLE movie_titles
  - (title CHARACTER(30) NOT NULL,..)
- CREATE TABLE distributor
  - (dist_name CHARACTER(30) UNIQUE,..)
  - May be NULL
- CREATE TABLE movie_titles
  - (title CHARACTER(30) PRIMARY KEY,..)
  - Unique and not null
- CREATE TABLE movie_stars
  - (movie_table CHARACTER(30) NOT NULL REFERENCES movie_titles,..)
  - Many-one (mapping must exist)

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SQL for Keys and Reference Keys

```
CREATE TABLE  Books (
   isbn  CHAR(11),
   title  CHAR(20),
   pubname CHAR(25),
   pubdate  DATE,
   PRIMARY KEY  (isbn),
   FOREIGN KEY (pubname) REFERENCES Publishers (name))
```

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Declaring Keys and Foreign Keys

- Composite Key Syntax
  - Primary Key (col1, col2)
  - Unique (col3)
- Foreign Key Syntax
  - Foreign Key <attributes> REFERENCES <table> (<attributes>)
  - Non-NULL value in Foreign Key must be present in the reference table

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Enforcing Constrainrts

- Key constraint
  - Check on update/insert
  - Use indexes for efficient validation
- Referential constraint
  - Default: Reject modifications that violate constraint
  - Cascade: Delete referencing rows
    - Delete movie => movie_stars deleted
  - Set Null: Set referencing column value to NULL

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Example

- CREATE TABLE Studio (
- ..
- presC# INT REFERENCES MovieExec(cert#)
  - ON DELETE SET NULL
  - ON UPDATE CASCADE)

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CHECK Constraint

- CHECK(search-condition)
- Like Where clause in Selection queries
- Value-based check
  - ..CHECK (movie_type IN ('Horror', 'Thriller',..))
- Simple check
  - .. CHECK (cost < 100 and cost > 0)
  - Use to verify min/max/set of intervals
- Complex
  - .. CHECK (cost < (select max(price) from Walmart_Store))

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ASSERTIONS

- Not attached to table declaration
- Specifies a multi-table constraint
- CREATE ASSERTION max_inventory
  - CHECK ((SELECT SUM(movie_cost) From Movies) + (SELECT SUM(music_cost) From Music) < 1000))
- Database must satisfy assertions at all times
  - Tuple constraint enforced only when table is not empty

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Deferrable Constraints

- By default, constraints are checked at the end of each SQL statement
- A DEFERRABLE constraint is checked only when the transaction is committed

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TRIGGERS

- Tells what followup actions to take after execution of a SQL
- CREATE TRIGGER NetWorthTrigger
  - AFTER UPDATE of networth ON MovieExec
  - REFERENCING OLD AS ot NEW AS nt
  - WHEN (ot.NetWorth > nt.NetWorth)
  - UPDATE MovieExec
  - SET NetWorth = ot. Networth
  - WHERE …
  - FOR EACH ROW .. Tuple vs. statement granularity

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Privileges, Users, Security

Reading: Chapter 7.4

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Granularity of AC

- GRANT privilege_list
- ON object
- TO user_list [WITH GRANT OPTION]
- Privilege_list
  - Select, Insert, Delete, Update, References, Usage
- Object
  - Table, Columns, Views, Domains, Transactions..

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Examples

- GRANT SELECT ON movie_titles TO PUBLIC
- GRANT REFERENCES (title) ON movie_titles TO USER1
- GRANT SELECT ON movie to kirk
- WITH GRANT OPTION
- GRANT SELECT ON movie to Rob

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REVOKE

- REVOKE <privilege list> ON <database element> FROM <user list>
  - CASCADE: All privileges granted based on revoked privileges are withdrawn
  - RESTRICT: Allows execution of REVOKE only if there is no implied CASCADE
- REVOKE GRANT OPTION FOR ….
- Follow examples 7.24-7.26

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Concurrency Control I: Transactions, Schedules, Anomalies

Why Have Concurrent Processes?

- Better throughput, response time
- Done via better utilization of resources:
  - While one process is doing a disk read, another can be using the CPU or reading another disk.
- DANGER DANGER! Concurrency could lead to incorrectness!
  - Must carefully manage concurrent data access.
  - There's (much!) more here than the usual OS tricks!

Transactions

- Basic concurrency/recovery concept: a *transaction (Xact).*
  - A sequence of many actions which are considered to be one atomic unit of work.
- DBMS "actions":
  - (disk) reads, (disk) writes
  - Special actions: commit, abort

The ACID Properties

- **A** tomicity: All actions in the Xact happen, or none happen.
- **C** onsistency: If each Xact is consistent, and the DB starts consistent, it ends up consistent.
- **I** solation: Execution of one Xact is isolated from that of other Xacts.
- **D**urability: If a Xact commits, its effects persist.

Passing the ACID Test

- Concurrency Control
  - Guarantees Consistency and Isolation, given Atomicity.
- Logging and Recovery
  - Guarantees Atomicity and Durability.
- We'll do C. C. first:
  - What problems could arise?
  - What is acceptable behavior?
  - How do we guarantee acceptable behavior?

Schedules

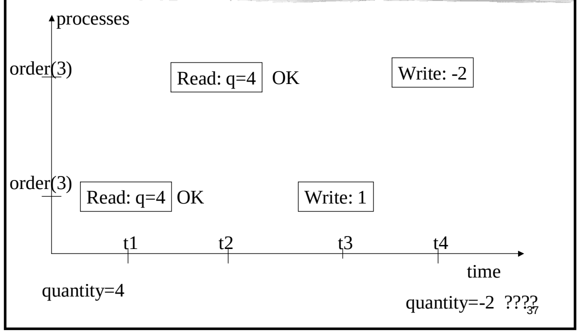
T1	*T2*
R(A)	
W(A)	
	R(B)
	W(B)
R(C)	
W(C)	

- Schedule: An interleaving of actions from a set of Xacts, where the actions of any 1 Xact are in the original order.
  - Represents some actual sequence of database actions.
  - Example: $R_1(A)$, $W_1(A)$, $R_2(B)$, $W_2(B)$, $R_1(C)$, $W_1(C)$
  - In a *complete* schedule, each Xact ends in commit or abort.
- Initial State + Schedule $\rightarrow$ Final State

Acceptable Schedules

- One sensible "isolated, consistent" schedule:
  - Run Xacts one at a time, in a series.
  - This is called a serial schedule.
  - NOTE: Different serial schedules can have different final states; all are "OK" -- DBMS makes no guarantees about the order in which concurrently submitted Xacts are executed.
- Serializable schedules:
  - Final state is what *some* serial schedule would have produced.
  - Aborted Xacts are not part of schedule; ignore them for now (they are made to `disappear' by using logging).

Transactions: Serializability



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Serializability Violations

⌘Two actions may <u>conflict</u> when 2 xacts access the same item:
- W-R conflict: T2 reads something T1 wrote; T1 *<u>still active</u>*
- R-W and W-W conflicts: Similar.

⌘WR conflict (dirty read):
- Result is not equal to any serial execution!
- T2 reads what T1 wrote, but it shouldn't have!!

transfer $100 from A to B	add 6% interest to A & B
T1	***T2***
R(A)	
W(A)	
	R(A)
	W(A)
	R(B)
	W(B)
	Commit
R(B)	
W(B)	
Commit	

Database is inconsistent!

More Conflicts

⌘RW Conflicts (Unrepeatable Read)
- T2 overwrites what T1 read.

T1:	R(A),		R(A), C
T2:		R(A), W(A), C	

- Again, not equivalent to a serial execution.

⌘WW Conflicts (Lost Update)
- T2 overwrites what T1 wrote.

T1:	W(A),		W(B), C
T2:		W(A), W(B), C	

- Usually occurs with RW or WR anomalies.
  - Unless you have "blind writes" (as here).

Now, Aborted Transactions

⌘<u>Serializable schedule</u>: Equivalent to a serial schedule of *committed* Xacts.
- as if aborted Xacts *never happened.*

⌘Two Issues:
- How does one undo the effects of a xact?
  - We'll cover this in logging/recovery
- What if another Xact sees these effects??
  - Must undo that Xact as well!

Cascading Aborts

T1	***T2***
R(A)	
W(A)	
	R(A)
	W(A)
abort	

⌘Abort of T1 requires abort of T2!
- <u>Cascading Abort</u>

⌘What about WW conflicts & aborts?
- T2 overwrites a value that T1 writes.
- T1 aborts: its "remembered" values are restored.
- Lose T2's write! We will see how to solve this, too.

⌘An <u>ACA (avoids cascading abort)</u> schedule is one in which cascading abort cannot arise:
- A Xact only reads data from committed Xacts.

Recoverable Schedules

T1	***T2***
R(A)	
W(A)	
	R(A)
	W(A)
	commit
abort	

⌘Abort of T1 requires abort of T2!
- But T2 has already committed!

⌘A <u>recoverable</u> schedule is one in which this cannot happen.
- i.e., a Xact commits only after all the Xacts it reads from commit.
- ACA implies Recoverable (but not vice-versa!).

⌘Real systems typically ensure that only recoverable schedules arise (through locking).

COMMIT and ROLLBACK

⌘Can end a database operation in two ways:

- EXEC SQL COMMIT;
- EXEC SQL ROLLBACK;