Using a DBMS

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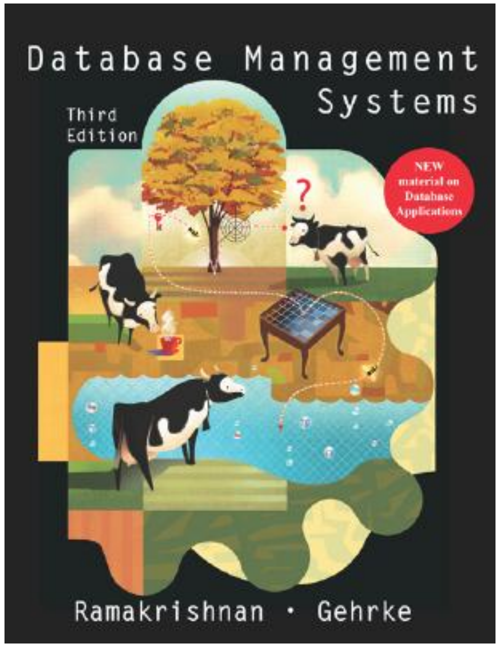
CS, NTHU

Assigned Reading

- Java concurrency
- "Database Management Systems," 3ed, by Ramakrishnan


Database Management Systems
Third Edition
NEW material on Database Applications
Ramakrishnan • Gehrke

Coverage

- Java concurrency
- Chaps 2 and 3 on how to store your data into a DBMS
  - ER model and relational model
- Chaps 4 and 5 on queries
  - SQL language (DDL and DML)
  - Relational algebra
- Chap 19* on how to store your data ***well***
  - Easy maintenance
  - Answering most queries fast

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Staring a New Thread

```
public class HelloRunnable implements Runnable {
    @Override
    public void run() {
        System.out.println("Hello from a thread!");
    }

    public static void main(String args[]) {
        (new Thread(new HelloRunnable())).start();
    }
}
```

or

```
public class HelloThread extends Thread {
    @Override
    public void run() {
        System.out.println("Hello from a thread!");
    }

    public static void main(String args[]) {
        (new HelloThread()).start();
    }
}
```

What Happened?

```
public class HelloRunnable implements Runnable {
    @Override
    public void run() {
        System.out.println("Hello from a thread!");
    }

    public static void main(String args[]) {
        (new Thread(new HelloRunnable())).start();
    }
}
```

- A new stack is allocated for `run()`, in addition to that of `main()`
- Your CPU spends time on executing `run()` ***in parallel with*** `main()`

Multiple Stacks, Single Heap

- The heap in memory scheme?
  - Stores objects
  - ***Shared by all threads***
- Can two threads access the same object? Yes
- How? Passing the same object to their constructors

```
public static void main(String args[]) {
    Counter counter = ...;
    (new Thread(new HelloRunnableA(counter))).start(); // thread A
    (new Thread(new HelloRunnableB(counter))).start(); // thread B
}
```

Concurrent Access

- Given the same object `counter`
- Suppose both threads execute in `run()`:

```
...
int c = counter.get();
c++; // c--;
counter.set(c);
```

```
class Counter {
    private int c = 0;
    public void set(int c) {
        this.c = c;
    }
    public int get () {
        return c;
    }
}
```

- Thread A's result will be lost if
  1. Thread A: Get c
  2. Thread B: Get c
  3. Thread A: Increment retrieved value; result is 1
  4. Thread B: Decrement retrieved value; result is -1
  5. Thread A: Set result in c; c is now 1.
  6. Thread B: Set result in c; c is now -1.

Synchronization

```
public class SynchronizedCounter {
   private int c = 0;
   public synchronized void set(int c) {
      this.c = c;
   }
   public synchronized int get() {
      return c;
   }
}
```

- Same as…

```
public class SynchronizedCounter {
   private int c = 0;
   public void set(int c) {
       synchronized(this){ this.c = c; }
   }
   public int get() {
       synchronized(this){ return c; }
   }
}
```

- Only one thread can enter sync. block of an obj. at a time
- Problem solved?

Still Wrong!

- Two threads in `run()`:

```
... // counter is a SynchronizedCounter instance
int c = counter.get();
c++; // c--;
counter.set(c);
```

- Thread A's result will still be lost if
  1. Thread A: Get c
  2. Thread B: Get c
  3. Thread A: Increment retrieved value; result is 1
  4. Thread B: Decrement retrieved value; result is -1
  5. Thread A: Set result in c; c is now 1.
  6. Thread B: Set result in c; c is now -1.

Synchronization at Right Place

- Solution1: callers lock `counter` during the entire increment/decrement period:

```
synchronized(counter){
   int c = counter.get();
   c++; // or c--;
   counter.set(c);
}
```

- Solution2: callee provides atomic methods

```
public class SynchronizedCounter {
   private int c = 0;
   public void synchronized increment() {
       c++;
   }
   public int get() {
       return c;
   }
}
```

Blocking and Waiting States

- Threads are ***blocked*** outside a critical section if someone is in
- Thread *A* in a critical section of `o` can stop and enter the ***waiting*** state by calling `o.wait()`
  - Gives up the lock, so some other blocking thread *B* can enter the critical section
  - If *B* calls `o.notifyAll()`, *A* competes for the lock again and resume

Wrap `wait()` in a Loop

- It’s a good practice to warp `wait()` in a loop to prevent bugs
- Queue length: 10

Threads A, B:

```
// enqueue
synchronized(queue) {
    while(queue.size() == 10) {
        queue.wait();
    }
    queue.add(...);
    queue.notifyAll();
}
```

Threads C, D:

```
// dequeue
synchronized(queue) {
    while (queue.size() == 0) {
        queue.wait();
    }
    ... = queue.remove();
    queue.notifyAll();
}
```

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DBMS ≠ Database

- A database is a collection of your data stored in a computer
- A DBMS (DataBase Management System) is a software that manages databases

Storing Data

- Let’s say, you have data in memory to store
- How does data in memory (heap) look like?
  - Objects
  - References to objects
- Objects formatted by classes you defined
- Could we store these objects and references directly?

Data Model

- Definition: A ***data model*** is a framework for describing the structure of databases in a DBMS
- Common data models: ***ER model*** and ***relational model***
- A DBMS supporting the relational model is called the relational DBMS

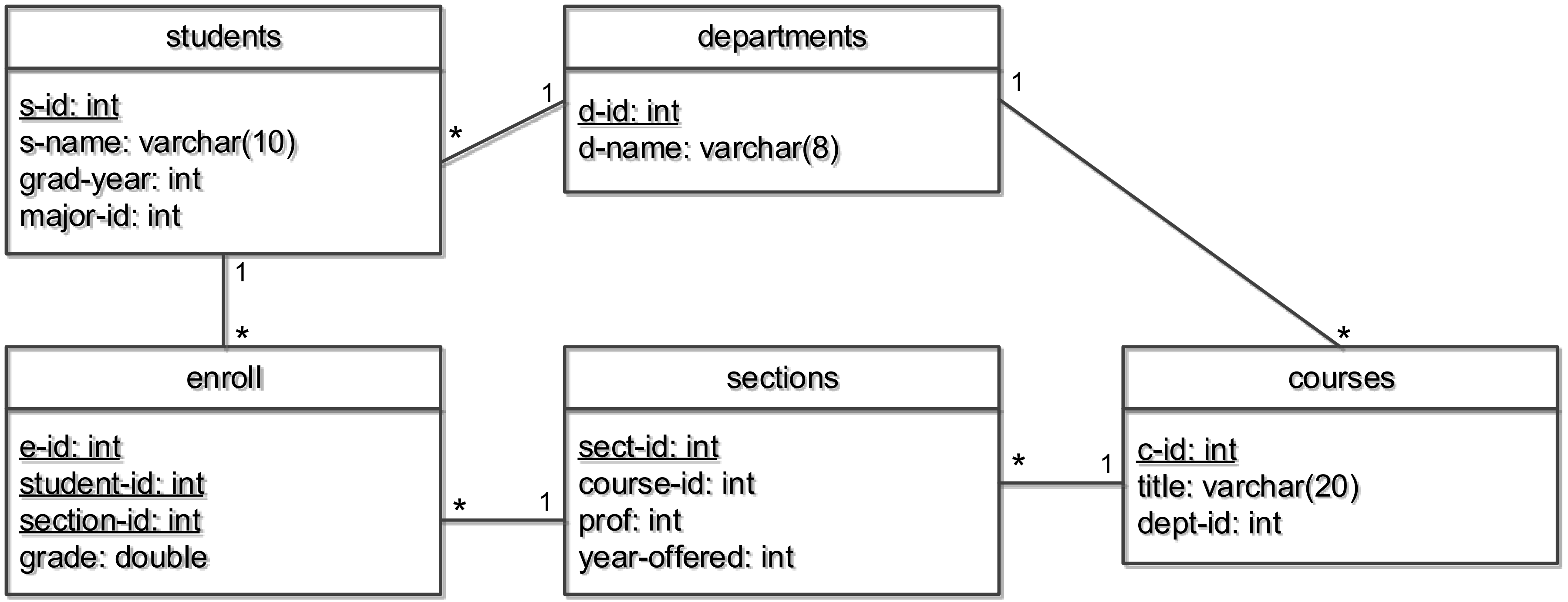
Why ER Model?

- Allows thinking your data in OOP way
- ***Entity***
  - An object (or instance of a class)
  - With attributes
- ***Entity group***
  - A class
  - Must define the ID attribute for each entity
- ***Relationship*** between entities
  - References ("has-a" relationship)
  - Could be 1-1, 1-many, and many-many

Why Relational Model?

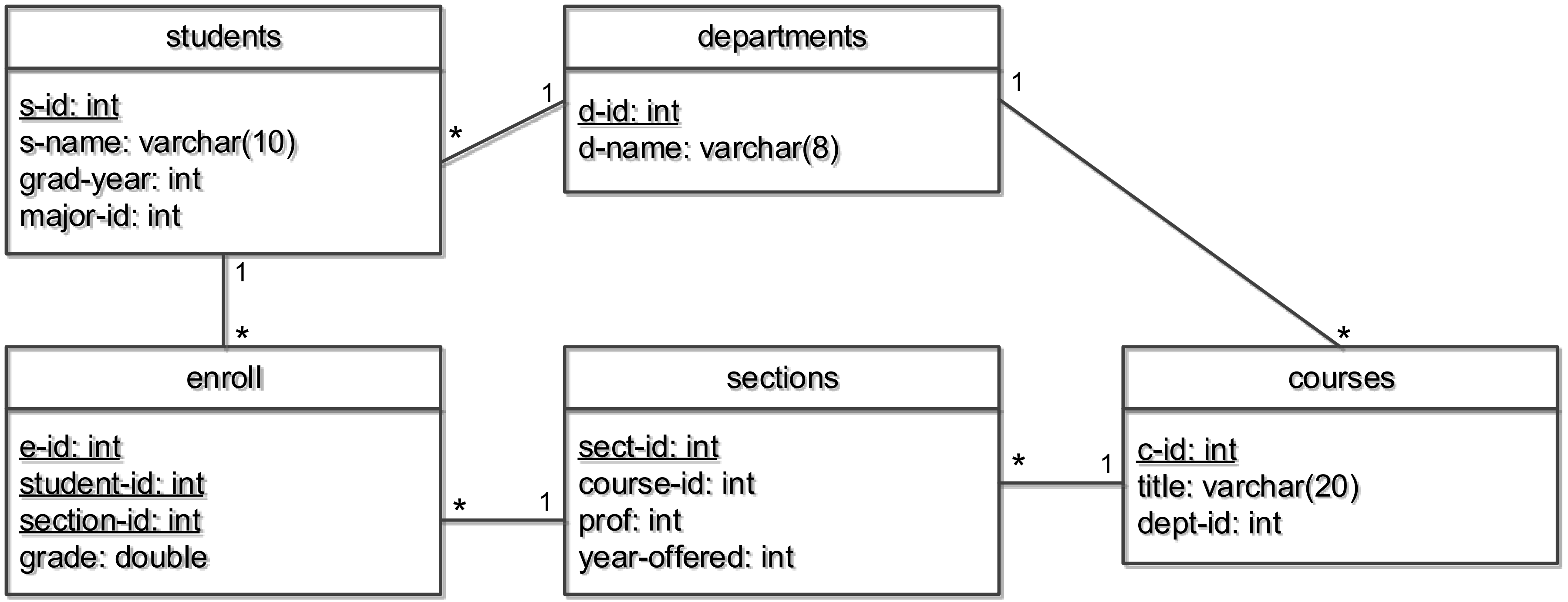
- To realize an ER model using a collocation of tables/***relations***
  - Simplifies data management and query processing
- Still logic (not how your data stored physically)

Example: Student DB



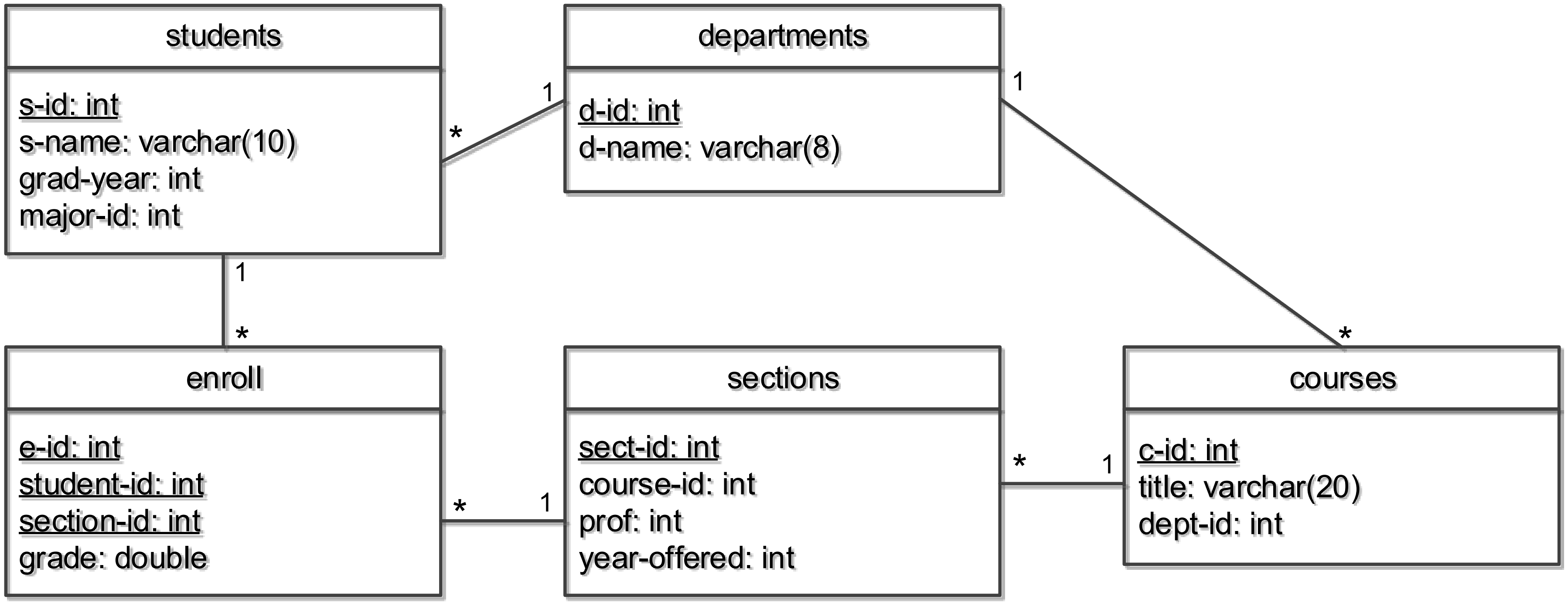
- Relation (table)
  - Realization of 1) an entity group via table; or 2) a relationship
  - ***Fields/attributes*** as columns
  - ***Records/tuples*** as rows

Example: A student DB



- ***Primary Key***
  – Realization of ID via a group of fields

Example: A student DB



- ***Foreign key***
  - Realization of relationship
  - A record can point to the primary key of the other record
  - Only 1-1 and 1-many
  - Intermediate relation is needed for many-many

Schema

- Definition: A ***schema*** is the structure of a particular database
- The schema of a relation/table is its fields and field types

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Queries

- Data Definition Language (DDL) on schema
  - CREATE TABLE …
  - ALTER TABLE …
  - DROP TABLE …
- Data Manipulation Language (DML) on records
  - INSERT INTO … VALUES …
  - SELECT … FROM … WHERE …
  - UPDATE … SET … WHERE …
  - DELETE FROM … WHERE …

Data Model and Queries (1/3)

Q1: among a set of blog pages, find those pages written by Steven Sinofsky after 2011

Step1: structure your data by following the ***relational data model***

– Identify ***records*** (e.g., web pages, authors, etc.) with the same ***fields*** in your data and place them into respective ***tables***

blog_pages

blog_id	url	created	author_id
33981	ms.com/…	2012/10/31	729
33982	apache.org/…	2012/11/15	4412

← record

field ↓

users

user_id	name	balance
729	Steven Sinofsky	10,235
730	Picachu	NULL

Data Model and Queries (2/3)

Q1: among a set of blog pages, find those pages written by Steven Sinofsky after 2011

```
CREATE TABLE blog_pages (
    blog_id INT NOT NULL AUTO_INCREMENT,
    url VARCHAR(60),
    created DATETIME,
    author_id INT);

INSERT INTO blog_pages (url, created, author_id)
    VALUES ('ms.com/...', 2012/09/18, 729);
```

blog_pages

blog_id	url	created	author_id
33981	ms.com/…	2012/10/31	729
33982	apache.org/…	2012/11/15	4412

Data Model and Queries (3/3)

Q1: among a set of blog pages, find those pages written by Steven Sinofsky after 2011

Step2: issue queries

```
SELECT b.blog_id
    FROM blog_pages b, users u
    WHERE b.author_id=u.user_id
        AND u.name='Steven Sinofsky'
        AND b.created >= 2011/1/1;
```

How Is a Query Answered?

```
SELECT b.blog_id
    FROM blog_pages b, users u
    WHERE b.author_id=u.user_id
        AND u.name='Steven Sinofsky'
        AND b.created >= 2011/1/1;
```

product(b, u)

blog_id	url	created	author_id	user_id	name	balance
33981	…	2009/10/31	729	729	Steven Sinofsky	10,235
33981	…	2009/10/31	729	730	Picachu	NULL
33982	…	2012/11/15	4412	729	Steven Sinofsky	10,235
33982	…	2012/11/15	4412	730	Picachu	NULL
41770	…	2012/10/20	729	729	Steven Sinofsky	10,235
41770	…	2012/10/20	729	730	Picachu	NULL

b

blog_id	url	created	author_id
33981	…	2009/10/31	729
33982	…	2012/11/15	4412
41770	…	2012/10/20	729

u

user_id	name	balance
729	Steven Sinofsky	10,235
730	Picachu	NULL

How Is a Query Answered?

```
SELECT b.blog_id
    FROM blog_pages b, users u
    WHERE b.author_id=u.user_id
        AND u.name='Steven Sinofsky'
        AND b.created >= 2011/1/1;
```

select(p, where…)

blog_id	url	created	author_id	user_id	name	balance
41770	…	2012/10/20	729	729	Steven Sinofsky	10,235

p = product(b, u)

blog_id	url	created	author_id	user_id	name	balance
33981	…	2009/10/31	729	729	Steven Sinofsky	10,235
33981	…	2009/10/31	729	730	Picachu	NULL
33982	…	2012/11/15	4412	729	Steven Sinofsky	10,235
33982	…	2012/11/15	4412	730	Picachu	NULL
41770	…	2012/10/20	729	729	Steven Sinofsky	10,235
41770	…	2012/10/20	729	730	Picachu	NULL

How Is a Query Answered?

```
SELECT b.blog_id
    FROM blog_pages b, users u
    WHERE b.author_id=u.user_id
        AND u.name='Steven Sinofsky'
        AND b.created >= 2011/1/1;
```

project(s, select…)

blog_id
41770

s = select(p, where…)

blog_id	url	created	author_id	user_id	name	balance
41770	…	2012/10/20	729	729	Steven Sinofsky	10,235

Query Algebra

- Operators
  - Product, select, project, join, group-by, etc.
- Operands
  - Tables, output of other operators, predicates, etc.

$$\begin{tikzcd}
 & \text{project(s, select…)} & \\
 & \text{s = select(p, where…)} \arrow[u] & \\
 & \text{p = product(b, u)} \arrow[u] & \\
\text{b} \arrow[ur] & & \text{u} \arrow[ul]
\end{tikzcd}$$

Query Plan

- A tree that answers a query

$$\begin{tikzcd}
& \text{project(s, select…)} & \\
& \text{s = select(p, where…)} \arrow[u] & \\
& \text{p = product(b, u)} \arrow[u] & \\
\text{b} \arrow[ur] & & \text{u} \arrow[ul]
\end{tikzcd}$$

- ***Not unique!***
- A DBMS automatically seeks for the best query plan

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How Good are Your Data?

- Let’s say, if you want to track the topics of a blog page
- Is this a good table?

blog_pages

blog_id	url	created	author_id	topic	topic_admin
33981	ms.com/…	2012/10/31	729	programming	5638
33981	ms.com/…	2012/10/31	729	databases	5649
33982	apache.org/…	2012/11/15	4412	programming	5638
33982	apache.org/…	2012/11/15	4412	os	7423

Insertion Anomaly

blog_pages

blog_id	url	created	author_id	topic	topic_admin
33981	ms.com/…	2012/10/31	729	programming	5638
33981	ms.com/…	2012/10/31	729	databases	5649
33982	apache.org/…	2012/11/15	4412	programming	5638
33982	apache.org/…	2012/11/15	4412	os	7423

33983	apache.org/…	2013/02/15	7412

?

- A blog cannot be inserted without knowing all fields of topics (except setting them to null)

Update Anomaly

blog_pages

blog_id	url	created	author_id	topic	topic_admin
33981	ms.com/…	2012/10/31	729	***win prog.***	5638
33981	ms.com/…	2012/10/31	729	databases	5649
33982	apache.org/…	2012/11/15	4412	programming	5638
33982	apache.org/…	2012/11/15	4412	os	7423

- If you forget to update all duplicated cells, you get inconsistent data

Deletion Anomaly

blog_pages

blog_id	url	created	author_id	topic	topic_admin
33981	ms.com/…	2012/10/31	729	***programming***	***5638*** X
33981	ms.com/…	2012/10/31	729	databases	5649
33982	apache.org/…	2012/11/15	4412	programming	5638
33982	apache.org/…	2012/11/15	4412	os	7423

- Deleting topics force you to delete the blog fields too

Normalization

- Avoids these anomaly through schema normalization
  - 3rd normal form
  - BCNF normal form
- Idea: break your one, big table into multiple small, modular tables
  - Reuse tables
  - Avoid bias towards any particular pattern of querying