Lecture 08
Relational Databases – SQL
(Structured Query Language)

Administrivia

BEFORE lab, please read and highlight
• Assignment 8
• Database Design (on learn.uwaterloo.ca)
  Adapted from Access Database Design & Programming by Steven Roman
• The SQL tutorial notes (on learn.uwaterloo.ca)
• Slides for this lecture

START the lab this week by doing the SQL tutorial

Topics for today
• relational database design
• when you need another table, and why
• SQL (Structured Query Language)
• a model for relational databases

Please ask questions!
Assumptions for Today’s Lecture

You’ve seen a two-table relational database
  • you’ve been exposed to
    forms, reports, queries, sorting, & data validation
  • you’re familiar with the terms
    database
    table
    record (aka row)
    field (aka column)

If this wasn’t true at the beginning of the term,
  • by now you’ve completed the Filemaker Intro

Things to Think about

How does a DBMS differ from a spreadsheet?
Why would I choose to use a DBMS?
How does SQL differ from FileMaker?
What are the reasons for needing more than one database table?
Why SQL?

It’s an excellent MODEL for how relational DBMS’s work

Modern “big” DBMS’s are SQL-based

Many PC databases are not
  • but can often be used as “front-ends” to mainframe SQL systems
  • though FileMaker Pro 11–16 and MS Access are based on SQL

OS X actually comes with two SQLs!
  • “SQL Lite,” which is designed to be embedded in programs (including the O/S)
  • “My SQL,” a (very) popular open source SQL server (used for the Math Faculty’s inventory database)

Often you can
  import data from an SQL database into software with a nice GUI (eg FileMaker)
  by crafting an appropriate “SQL select statement”

Databases – Structured Data

Why use a database at all?

Structuring data allows us to do things we can’t do efficiently, or can’t feasibly do, with unstructured data
  • The added power & flexibility aren’t free
    it takes time and effort to create (and maintain) the structure
  • You have to decide if that effort is worthwhile

Obvious questions:
  • What do I mean by “structure” in a database?
  • What’s the payoff?
“Structure”

The visa worksheet in the Excel assignment

• is an example of a 1–table database, although we built it in Excel, not with a DBMS
• each ROW ("record") holds data for a particular transaction
• each COLUMN holds a particular piece of data about that transaction (a "field")
• we could have used FileMaker

though for what we wanted to do, it wouldn’t have been worth the effort of learning FileMaker
• indeed, we could have placed the data in a Word table or even in a text processor (e.g., BBEdit)... separate fields by tabs, separate records by ¶

but working with the data would have been MUCH harder
— think about implementing the Actual Balance and Statement Balance columns!

The Excel Assignment — Keeping Track of VISA Charges
**Key DBMS Functionality**

Data entry *“validation”*

Sophisticated searching (aka “queries”)

Sophisticated summarizing and reporting

Safe simultaneous updates by multiple users

The REAL power of a relational database

• appears when you have multiple related tables
  • what does “related” mean?
  • why have multiple tables?

---

**A Music Library**

The goal — to refine our understanding of why/when multiple tables are necessary

Suppose you want to keep track of your music

• Album Title
  • Artist
  • Medium (CD, Tape, LP record, ...)
  • Category (Jazz, Classical, Hard Rock, ...)
  • Price
  • Purchase Date
  • Copyright
  • Label

Well, you could do it with a word processor

• but ... how to find all the recordings by Led Zeppelin?
• & ... what’s the value of your Charlie Parker albums?
• & ... how to avoid entry of a bogus Medium, Category, etc.
• & ...

How well would Excel work?

Consider how we might manage our music in FileMaker
Filemaker

- requires datatypes — Text, Number, Date, etc — why?
- provides data entry options for data validation (default values, value lists, range checks, etc)

Aside: looks a lot like a spreadsheet, eh?

But as you know, FileMaker has a lot more layout flexibility than Excel.
Also, FileMaker restricts the way you can inter-connect fields via computation (= formulas) ["structure"]...
SQL – Structured Query Language

Here’s a simple language that lets us describe matching between (database) tables

\[ \text{select field_list from table_list where conditions} \]

EG

\[ \text{select Title, Artist, Price from Albums} \]

Another Example of an SQL Select Statement

\[ \text{select Album_ID, Mins, Secs, Title from Songs} \]
Asking for albums below a certain price

```
select Title, Artist, Price
from Albums
where Price < 10.00
```

Asking for albums with a particular album title

```
select Title, Artist, Medium, Category, Price
from Albums
where Title = 'North Country'
```
Asking for albums by a particular artist

```sql
select Title, Artist, Medium, Category, Price from Albums where Artist = 'The Rankin Family'
```

### Results

<table>
<thead>
<tr>
<th>Title</th>
<th>Artist</th>
<th>Medium</th>
<th>Category</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Country</td>
<td>The Rankin Family</td>
<td>CD</td>
<td>Folk</td>
<td>19.54000</td>
</tr>
<tr>
<td>Fare Thee Well</td>
<td>The Rankin Family</td>
<td>CD</td>
<td>Folk</td>
<td>25.29000</td>
</tr>
</tbody>
</table>

Suppose you want songs too?

### Containing such data as

- Title
- Side
- Track
- Playing Time

### Maybe you're the librarian for a radio station...

### Can we just add Song fields to the Albums Table?

- It's a lot of work (145 additional fields!)
- And how to find a song?
- Or list all the songs that are more than 3 minutes long?
- Or make an alphabetical list of the songs!

### How many songs should you set the table up for?

If too few ... you run out
If too many ... you waste effort & space
The Songs for each album ... as a list

<table>
<thead>
<tr>
<th>Album Title &amp; Artist</th>
<th>Med</th>
<th>Category</th>
<th>Price</th>
<th>Per-Date</th>
<th>Copyright</th>
<th>Label</th>
</tr>
</thead>
</table>

Macintosh

<table>
<thead>
<tr>
<th>S-T</th>
<th>M-S</th>
<th>Song Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>A Heart Full of Love</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>At the End of the Day</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>I Dreamed a Dream</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>Lovely Ladders</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>Who Am I?</td>
</tr>
<tr>
<td>1</td>
<td>5</td>
<td>Comes To Me</td>
</tr>
<tr>
<td>1</td>
<td>6</td>
<td>Contention</td>
</tr>
<tr>
<td>1</td>
<td>7</td>
<td>Castilla on a Cloud</td>
</tr>
<tr>
<td>1</td>
<td>8</td>
<td>Master of the House</td>
</tr>
<tr>
<td>1</td>
<td>9</td>
<td>The Therapeutic Web</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>Lock Down</td>
</tr>
<tr>
<td>1</td>
<td>11</td>
<td>56 Stairs</td>
</tr>
<tr>
<td>1</td>
<td>12</td>
<td>Red and Black</td>
</tr>
<tr>
<td>1</td>
<td>13</td>
<td>Do You Know How the People Sing?</td>
</tr>
<tr>
<td>1</td>
<td>14</td>
<td>It's My Life</td>
</tr>
</tbody>
</table>

This looks pretty good...

... though it's also laborious to set up...

... but try another record, ...
As a Form (2)

...and we can see there are a lot of empty fields

The General Problem Just Illustrated

We want to have multiple copies of some field(s) and we can’t know in advance how many copies — especially difficult if there’s no limit!

Replicating fields is bad because

* it’s a lot of work to set up
* it makes searching difficult
* you waste a lot of space
* you must modify the database structure to add more copies if you run out
Now it's easy to find a song, but ... look at all that space wasted in repetitive album info! (See next slide.)

And consider changing the Category for an album...
Be careful
* to get ALL the songs for that album
One Table, One Song/Record – The Data (2)

Notice that Album Title, Artist, Medium, Category, ... & Label are completely determined by the Album ID.

That is,

If you know the Album ID, you know what the Album Title, Group, Medium, Category, ... & Label are,

ie they're always the same for a given Album ID.

So why store the Album Title, Group, Medium, ... & Label repeatedly?

Why not store them once somewhere else, and keep just the Album ID with each song?

One Table, One Song/Record – The Data (3)

So the idea is to keep (just) the songs in a separate table:

- With just an Album ID field for each song record to locate the album information for each song; it’s just an integer, so it doesn’t take much space.
- From the Album Table: use Album ID to find Songs in the Song Table. DBMS’s do this for you automatically.
- From the Song Table: use Album ID to find album info in the Album Table. DBMS’s do this for you automatically.
- Avoids wasted space.
- Searching is straightforward.
- Adapts automatically and efficiently to ANY number of songs / album.

Important!

Don’t be confused by album data shown in the Song Table — it’s temporarily copied from the Album Table just for...
The Song Table in FileMaker

as a list, showing all the songs on an album

as a form, showing one song & info for the album on which it appears

The Song Table as a list, showing all the songs on an album

as a form, showing one song & info for the album on which it appears

The Album info is temporarily copied from the Album table.

The Album Table in FileMaker

as a list, showing album information only

as a form, showing info about one album and a list of all the songs on that album in the Songs table

The Songs info is temporarily copied from the Songs table.
Terminology

**Album ID**
- is a “primary key” for the Album Table
  because it uniquely identifies an album
- is a “foreign key” of the Songs Table
  because it contains a primary key of the Album Table
  and thus links a Song record to a unique Album record

“One-to-many” and “many-to-one”
- wrt Album ID
  - Albums is the “one table”
  - Songs is the “many table” because for a given Album ID
    - there is only ONE Album record
    - but are (usually) MANY Song records
  - “many-to-many” can happen, too
    - though not by matching a primary key in each of two tables!
    - it is often useful
  - we’ll see an example next week

---

The Albums & Songs Database

<table>
<thead>
<tr>
<th>Albums</th>
<th>Songs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Album_ID</td>
<td>Song_ID</td>
</tr>
<tr>
<td>(a primary key)</td>
<td></td>
</tr>
<tr>
<td>Title</td>
<td>Side</td>
</tr>
<tr>
<td>Group</td>
<td>Track</td>
</tr>
<tr>
<td>Medium</td>
<td>Title</td>
</tr>
<tr>
<td>Category</td>
<td>Mins</td>
</tr>
<tr>
<td>Price</td>
<td>Secs</td>
</tr>
<tr>
<td>Purchase Date</td>
<td>Album_ID</td>
</tr>
<tr>
<td>Copyright</td>
<td>(a foreign key)</td>
</tr>
<tr>
<td>Label</td>
<td></td>
</tr>
<tr>
<td>Sample</td>
<td></td>
</tr>
</tbody>
</table>

the relationship from Albums to Songs on Album_ID is one-to-many
the relationship from Songs to Albums on Album_ID is many-to-one
Summary

Relational databases
• keep data in multiple tables
• each of which has a primary key
• and link those tables
• by matching field values (though not necessarily via a foreign key)

This works in both directions
• given a song, get the album info
• given an album, list the songs on that album
  — just by matching field values (a “relationship”)

Criteria for when you need another table...

(1) You have more than one “entity” (eg cars and drivers); fields for one are empty for the other (& vice-versa)

(2) You can have multiple values of some field, ESPECIALLY when you can’t predict how many (such as having multiple songs on each album)

(3) Given the value of one field A ...

eg in a Course Offerings table:
Listing the songs on an album ("dot notation") . . . and matching songs to a particular album

```
select Side, Track, Songs.Title from Albums, Songs
where (Albums.Title = 'North Country') and
(Albums.Album_ID = Songs.Album_ID)
```

```sql
Listing the songs in alphabetical order ("order by")

select Side, Track, Songs.Title from Albums, Songs
where (Albums.Title = 'North Country') and
(Albums.Album_ID = Songs.Album_ID)
order by Songs.Title
```
More on Matching (1)

Here’s the precise syntax of a select statement

```sql
select  field_listA
from    table_list
[where  conditions]
[order by field_listB]
[group by field_listC]
```

You must type each clause in the order shown

just as “The red bounces ball.” is incorrect English

[ • • • ] means that • • • is optional

Fields in the various field_lists must exist in a table of table_list

you can use “*” as field_listA to mean “all the fields”

If two tables use the same field name, you must write TableName.FieldName
to indicate which field you mean

they aren’t necessarily a (foreignKey, primaryKey) matchup

More on Matching (2)

Repeated from the previous slide...

```sql
select  field_listA
from    table_list
[where  conditions]
[order by field_listB ]
[group by field_listC]
```

The ordering specified by “order by” is

• first by the leftmost field in field_listB
• then by the second leftmost field in field_listB
• etc, from left to right

The “where” clause can accomplish two things

• extract only specific records
  eg where (Albums.Title = ‘North Country’)
• specify a connection between two tables
  eg where (Albums.AlbumID = Songs.AlbumID)

Actually, these two actions aren’t really different . . .
A model for how the where clause works (1)

Consider the two tables

<table>
<thead>
<tr>
<th>Students</th>
<th>Register</th>
</tr>
</thead>
<tbody>
<tr>
<td>IDN</td>
<td>IDN</td>
</tr>
<tr>
<td>Name</td>
<td>Course</td>
</tr>
<tr>
<td></td>
<td>Term</td>
</tr>
<tr>
<td></td>
<td>Mark</td>
</tr>
</tbody>
</table>

with Students data

<table>
<thead>
<tr>
<th>IDN</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Aaron</td>
</tr>
<tr>
<td>11</td>
<td>Sarah</td>
</tr>
<tr>
<td>12</td>
<td>Jose</td>
</tr>
<tr>
<td>13</td>
<td>Marie</td>
</tr>
</tbody>
</table>

and Register data

<table>
<thead>
<tr>
<th>IDN</th>
<th>Course</th>
<th>Term</th>
<th>Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>CS200</td>
<td>9701</td>
<td>89</td>
</tr>
<tr>
<td>10</td>
<td>Biol458</td>
<td>9701</td>
<td>75</td>
</tr>
<tr>
<td>11</td>
<td>CS200</td>
<td>9701</td>
<td>81</td>
</tr>
<tr>
<td>11</td>
<td>Econ335</td>
<td>9701</td>
<td>94</td>
</tr>
</tbody>
</table>

(What are the primary keys for these tables? The foreign keys?)

A model for how the where clause works (2)

Suppose you said

```sql
select * from Students as S, Register as R
```

Here’s what that produces —

<table>
<thead>
<tr>
<th>S.IDN</th>
<th>S.Name</th>
<th>R.IDN</th>
<th>R.Course</th>
<th>R.Term</th>
<th>R.Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Aaron</td>
<td>10</td>
<td>CS200</td>
<td>9701</td>
<td>89</td>
</tr>
<tr>
<td>10</td>
<td>Aaron</td>
<td>11</td>
<td>CS200</td>
<td>9701</td>
<td>81</td>
</tr>
<tr>
<td>10</td>
<td>Sarah</td>
<td>11</td>
<td>Econ335</td>
<td>9701</td>
<td>94</td>
</tr>
<tr>
<td>11</td>
<td>Sarah</td>
<td>10</td>
<td>CS200</td>
<td>9701</td>
<td>89</td>
</tr>
<tr>
<td>11</td>
<td>Sarah</td>
<td>10</td>
<td>Biol458</td>
<td>9701</td>
<td>75</td>
</tr>
<tr>
<td>11</td>
<td>Sarah</td>
<td>11</td>
<td>CS200</td>
<td>9701</td>
<td>81</td>
</tr>
<tr>
<td>11</td>
<td>Sarah</td>
<td>11</td>
<td>Econ335</td>
<td>9701</td>
<td>94</td>
</tr>
<tr>
<td>12</td>
<td>Jose</td>
<td>10</td>
<td>CS200</td>
<td>9701</td>
<td>89</td>
</tr>
<tr>
<td>12</td>
<td>Jose</td>
<td>11</td>
<td>CS200</td>
<td>9701</td>
<td>81</td>
</tr>
<tr>
<td>12</td>
<td>Jose</td>
<td>11</td>
<td>Econ335</td>
<td>9701</td>
<td>94</td>
</tr>
<tr>
<td>13</td>
<td>Marie</td>
<td>10</td>
<td>CS200</td>
<td>9701</td>
<td>89</td>
</tr>
<tr>
<td>13</td>
<td>Marie</td>
<td>10</td>
<td>Biol458</td>
<td>9701</td>
<td>75</td>
</tr>
<tr>
<td>13</td>
<td>Marie</td>
<td>11</td>
<td>CS200</td>
<td>9701</td>
<td>81</td>
</tr>
<tr>
<td>13</td>
<td>Marie</td>
<td>11</td>
<td>Econ335</td>
<td>9701</td>
<td>94</td>
</tr>
</tbody>
</table>

(What are the primary keys for these tables? The foreign keys?)

(Note the convention for defining the "table aliases" S and R.)
More likely what you want is something like

```sql
select * from Students as S, Register as R
where S.IDN = R.IDN
```

which produces

<table>
<thead>
<tr>
<th>S.IDN</th>
<th>S.Name</th>
<th>R.IDN</th>
<th>R.Cours</th>
<th>R.Term</th>
<th>R.Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Aaron</td>
<td>10</td>
<td>CS200</td>
<td>9701</td>
<td>89</td>
</tr>
<tr>
<td>10</td>
<td>Aaron</td>
<td>10</td>
<td>Biol458</td>
<td>9701</td>
<td>75</td>
</tr>
<tr>
<td>11</td>
<td>Sarah</td>
<td>11</td>
<td>CS200</td>
<td>9701</td>
<td>81</td>
</tr>
<tr>
<td>11</td>
<td>Sarah</td>
<td>11</td>
<td>Econ33</td>
<td>9701</td>
<td>94</td>
</tr>
</tbody>
</table>

by constructing the previous table
and then throwing out rows that don't satisfy the where clause

Or more elegantly,

```sql
select S.IDN, Name, Course from Students as S, Register as R
where S.IDN = R.IDN
```

which produces

<table>
<thead>
<tr>
<th>S.IDN</th>
<th>S.Name</th>
<th>R.Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Aaron</td>
<td>CS200</td>
</tr>
<tr>
<td>10</td>
<td>Aaron</td>
<td>Biol458</td>
</tr>
<tr>
<td>11</td>
<td>Sarah</td>
<td>CS200</td>
</tr>
<tr>
<td>11</td>
<td>Sarah</td>
<td>Econ33</td>
</tr>
</tbody>
</table>
Just the courses for Aaron

```sql
select S.IDN, Name, Course from Students as S, Register as R
where (Name = 'Aaron') and (S.IDN = R.IDN)
```

which produces

<table>
<thead>
<tr>
<th>S.IDN</th>
<th>S.Name</th>
<th>R.Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Aaron</td>
<td>CS200</td>
</tr>
<tr>
<td>10</td>
<td>Aaron</td>
<td>Bio458</td>
</tr>
</tbody>
</table>

List the students taking CS 200

```sql
select Course, R.IDN, Name
from Students as S, Register as R
where (Course = 'CS200') and (R.IDN = S.IDN)
```

which produces

<table>
<thead>
<tr>
<th>R.Course</th>
<th>R.IDN</th>
<th>S.Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS200</td>
<td>10</td>
<td>Aaron</td>
</tr>
<tr>
<td>CS200</td>
<td>11</td>
<td>Sarah</td>
</tr>
</tbody>
</table>
Suppose we add a third table

<table>
<thead>
<tr>
<th>Students</th>
<th>Register</th>
<th>Courses</th>
</tr>
</thead>
<tbody>
<tr>
<td>IDN</td>
<td>IDN</td>
<td>Name</td>
</tr>
<tr>
<td>Name</td>
<td>Course</td>
<td>Room</td>
</tr>
<tr>
<td>Term</td>
<td>Time</td>
<td>Description</td>
</tr>
</tbody>
</table>

**NB:** Students.Name and Courses.Name hold different things

Here's some data for Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Room</th>
<th>Time</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS100</td>
<td>DC1351</td>
<td>M 1230</td>
<td>Introduction to Computer Usage</td>
</tr>
<tr>
<td>CS200</td>
<td>MC4060</td>
<td>M 1230</td>
<td>Advanced Concepts for Computer Usage</td>
</tr>
<tr>
<td>Biol458</td>
<td>B2 350</td>
<td>MWF 830</td>
<td>Behavioural Ecology</td>
</tr>
<tr>
<td>Econ335</td>
<td>ML212</td>
<td>TR 1000</td>
<td>Economic Development</td>
</tr>
</tbody>
</table>

What's the primary key for Courses?

A list of the courses for Aaron, with description

```
select S.Name, Course, Description
from Students as S, Register as R, Courses as C
where (S.Name = 'Aaron')
and (S.IDN = R.IDN)
and (R.Course = C.Name)
```

which produces

<table>
<thead>
<tr>
<th>S.Name</th>
<th>R.Course</th>
<th>C.Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aaron</td>
<td>CS200</td>
<td>Advanced Concepts for Computer Usage</td>
</tr>
<tr>
<td>Aaron</td>
<td>Biol458</td>
<td>Behavioural Ecology</td>
</tr>
</tbody>
</table>

Incidentally,

it would be better to use Aaron's IDN than his name (why?)

if it makes sense, you can use <, ≤, >, ≥ or <> instead of =

you can use as many tables as you want
Adding New Records – Insert

**Insert Into** *table_name* ( *list_of_fields* ) **Values** ( *list_of_values* )

**EG**

```sql
insert into Students ( IDN, Name ) **values** ( 14, 'Barbara' )
```

Altering Existing Data – Update

**Update** *table_name* **Set** *field* = *value* **Where** *condition*

**EG**

```sql
update Students **set** Name = 'Mike' **where** IDN = 10
update Register **set** Mark = 100 **where** Course = 'CS200'
update Register **set** Mark = 0
```
Removing Records – Delete

\[ \text{Delete From } \text{table\_name} \text{ Where } \text{condition} \]

EG

\[ \text{delete from Students where IDN = 14} \]
\[ \text{delete from Students} \]

---

Creating Tables and Fields (1)

CREATE TABLE Students
(
    IDN integer NOT NULL,
    Name varchar(10) NOT NULL,

    PRIMARY KEY (IDN),

    CHECK (IDN between 10 and 99),
);

CREATE TABLE Courses
(
    Name varchar(10) NOT NULL,
    Room varchar(10) NOT NULL,
    Thyme varchar(10) NOT NULL,
    Description varchar(40) NOT NULL,

    PRIMARY KEY (Name),
);

Each field has a type (Integer, Char, ...)
allocate storage
know how to manipulate (eg compare)

"NOT NULL"
you must supply a value

PRIMARY KEYs are identified
Creating Tables (2)

CREATE TABLE Register
(
    IDN integer NOT NULL,
    Course varchar(10) NOT NULL,
    Term integer NOT NULL,
    Mark integer,
    PRIMARY KEY (IDN, Course, Term),
    FOREIGN KEY (IDN) REFERENCES Students (IDN) ON DELETE CASCADE,
    FOREIGN KEY (Course) REFERENCES Courses (Name) ON DELETE CASCADE,
    CHECK (IDN between 10 and 99),
    CHECK (Term between 5800 and 9999),
    CHECK (Mark between 0 and 100),
);

FOREIGN KEY

identify the target table
what happens on deletion or updates?

Indices (1)

Consider
• select Name, IDN from Students where Name = 'Marie'

How long does it take to find the right record?
• suppose you have 15,000 students
• examine the records one-by-one?
• is that how you look up somebody's phone number?

No!
• if the records were sorted by Name
  it would be much faster

Can we assume records are sorted in the order we want?
• not if we might look things up on any of two or more fields!
• also, we don’t want to have to enter data in sorted order,
  or have to sort all the data before looking something up
The solution: create indices
  • and update them whenever a record is added
  • or a name is changed

Indices are “auxiliary tables” you can’t (directly) manipulate
  • the DBMS updates them when you change an indexed table

For our example database
  • Create Index ByName On Students( Name )
  • Create Index ByIDN On Students( IDN )
  • Create Index ByCourse On Register( Course )
  • etc.

If an index exists and would be useful
  • SQL will use it automatically

SQL won’t create an index for you, however
  • except for primary keys

EG
  • delete a table
  • delete an index
  • add a field
  • delete a field

We won’t worry about them because it’s easier to use the Sybase Central
Sybase Central — Creating a New Field

Sybase Central — Utilities (Creating a New Database, Backups, etc)
Selects albums whose purchase price is equal to the purchase price of the album “Led Zeppelin.”

Selects albums whose purchase price is greater than the average purchase price of all albums.
### Sub-Selects (3)

**SQL Statements**

```sql
SELECT Albums.Album_ID, Albums.Title FROM Albums
WHERE
  EXISTS (SELECT * FROM Songs
            WHERE Songs.Album_id = Albums.Album_ID
            AND Songs.Title = Albums.Title)
ORDER BY Albums.Title;
```

**Results**

<table>
<thead>
<tr>
<th>Album_ID</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bad</td>
</tr>
<tr>
<td>2</td>
<td>Childhood Dreams</td>
</tr>
<tr>
<td>3</td>
<td>Fare Thee Well Love</td>
</tr>
<tr>
<td>4</td>
<td>Get A Grip</td>
</tr>
<tr>
<td>5</td>
<td>God Shuffled His Feet</td>
</tr>
<tr>
<td>6</td>
<td>Keep the Faith</td>
</tr>
<tr>
<td>7</td>
<td>North Country</td>
</tr>
<tr>
<td>8</td>
<td>The Phantom of the Opera</td>
</tr>
</tbody>
</table>

Selects albums for which there’s at least one whose title is identical to the album’s title.

### Sub-Selects (4)

**SQL Statements**

```sql
SELECT Albums.Album_ID, Albums.Title FROM Albums
WHERE
  NOT EXISTS (SELECT * FROM Songs
               WHERE Songs.Album_id = Albums.Album_ID
               AND Songs.Title = Albums.Title)
ORDER BY Albums.Title;
```

**Results**

<table>
<thead>
<tr>
<th>Album_ID</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bad</td>
</tr>
<tr>
<td>2</td>
<td>The Way You Make Me Feel</td>
</tr>
<tr>
<td>3</td>
<td>Speed Demon</td>
</tr>
<tr>
<td>4</td>
<td>Librarian Girl</td>
</tr>
<tr>
<td>5</td>
<td>Just Good Friends</td>
</tr>
<tr>
<td>6</td>
<td>Another Part of Me</td>
</tr>
<tr>
<td>7</td>
<td>Man in the Mirror</td>
</tr>
<tr>
<td>8</td>
<td>I Just Can’t Stop Loving You</td>
</tr>
<tr>
<td>9</td>
<td>Dirty Diana</td>
</tr>
<tr>
<td>10</td>
<td>Smooth Criminal</td>
</tr>
</tbody>
</table>

Selects albums for which there’s no song whose title is identical to the album’s title.

There are other variations...
What’s Next?

Comparing FileMaker and SQL

Remember to read

* “Database Design” on learn.uwaterloo.ca