Translating Entity-Relationship to Relational Tables
Fall 2017

School of Computer Science
University of Waterloo

Databases CS348
Outline

1. ER to Relational Mapping
2. Data Definition in SQL (DDL)
3. Views and View Management
4. Data Security/Control (DCL)
Main ideas:

- Each entity set maps to a new table
- Each attribute maps to a new table column
- Each relationship set maps to either new table columns or to a new table
Representing Strong Entity Sets

Entity set \( E \) with attributes \( a_1, \ldots, a_n \) translates to table \( E \) with attributes \( a_1, \ldots, a_n \)

Entity of type \( E \leftrightarrow \) row in table \( E \)
Primary key of entity set \( \rightarrow \) primary key of table

Example:

```
<table>
<thead>
<tr>
<th>StudentNum</th>
<th>StudentName</th>
<th>Major</th>
</tr>
</thead>
</table>
```

(University of Waterloo)
Representing Weak Entity Sets

Weak entity set $E$ translates to table $E$

Columns of table $E$ should include
- Attributes of the weak entity set
- Attributes of the identifying relationship set
- Primary key attributes of entity set for dominating entities

Primary key of weak entity set $\rightarrow$ primary key of table
Example:

![ER Diagram](image)

- **Account**
  - **AccNum**
  - **Balance**

- **Transaction**
  - **TransNum**
  - **AccNum**
  - **Date**
  - **Amount**

<table>
<thead>
<tr>
<th>Account</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>AccNum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balance</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Transaction</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>TransNum</td>
<td>AccNum</td>
<td>Date</td>
<td>Amount</td>
<td></td>
</tr>
</tbody>
</table>
Representing Relationship Sets

- If the relationship set is an identifying relationship set for a weak entity set then no action needed

- If we can deduce the general cardinality constraint \((1,1)\) for a component entity set \(E\) then add following columns to table \(E\)
  - Attributes of the relationship set
  - Primary key attributes of remaining component entity sets

- Otherwise: relationship set \(R \rightarrow \text{table } R\)
Columns of table $R$ should include
- Attributes of the relationship set
- Primary key attributes of each component entity set

Primary key of table $R$ determined as follows
- If we can deduce the general cardinality constraint $(0,1)$ for a component entity set $E$, then take the primary key attributes for $E$
- Otherwise, choose primary key attributes of each component entity
Representing Relationship Sets (cont.)

Example:

Note that the role name of a component entity set should be prepended to its primary key attributes, if supplied.
Representing Aggregation

Tabular representation of aggregation of $R$

$= \text{tabular representation for relationship set } R$

To represent relationship set involving aggregation of $R$, treat the aggregation like an entity set whose primary key is the \textbf{primary key} of the table for $R$
Representing Aggregation (cont.)

Example:

- **Student**: StudentNum
- **Course**: CourseNum
- **EnrolledIn**: StudentNum, CourseNum
- **CourseAccount**: UserId, StudentNum, CourseNum, ExpirationDate
- **Account**: UserId

Diagram:

- Student (StudentNum) connected to EnrolledIn (StudentNum, CourseNum)
- EnrolledIn (StudentNum, CourseNum) connected to CourseAccount (UserId, StudentNum, CourseNum, ExpirationDate)
- CourseAccount (UserId, StudentNum, CourseNum, ExpirationDate) connected to Account (UserId)

(University of Waterloo) ER to Relational 11 / 39
Representing Specialization

Create table for higher-level entity set, and treat specialized entity subsets like weak entity sets (without discriminators)

Example:

```
Student
  StudentNumber
  StudentName

Graduate
  StudentNumber
  ProfessorName

Degrees

Professor
  ProfessorName
```

Table:

<table>
<thead>
<tr>
<th>Student</th>
<th>Graduate</th>
<th>Degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>StudentNumber</td>
<td>ProfessorName</td>
<td>Degree</td>
</tr>
</tbody>
</table>

(University of Waterloo)
Representing Generalization (Approach #1)

Create a table for each lower-level entity set only

Columns of new tables should include
- Attributes of lower level entity set
- Attributes of the superset

The higher-level entity set can be defined as a view on the tables for the lower-level entity sets
Representing Generalization (Approach #1)

Example:

```
<table>
<thead>
<tr>
<th>LicenceNum</th>
<th>MakeAndModel</th>
<th>Price</th>
<th>Tonnage</th>
<th>AxelCount</th>
</tr>
</thead>
<tbody>
<tr>
<td>LicenceNum</td>
<td>MakeAndModel</td>
<td>Price</td>
<td>MaxSpeed</td>
<td>PassengerCount</td>
</tr>
</tbody>
</table>
```

(University of Waterloo)
Representing Generalization (Approach #2)

Treat generalization the same as specialization.

Example:

```
LicenceNum    MaxSpeed    PassengerCount
Car
LicenceNum    MakeAndModel    Price
LicenceNum    Tonnage     AxelCount
Truck
Vehicle
MakeAndModel

COVERS

Vehicle
LicenceNum    MakeAndModel    Price

Truck
LicenceNum    Tonnage     AxelCount

Car
LicenceNum    MaxSpeed    PassengerCount
```

(Topology of the vehicle relationship: LicenceNum, MakeAndModel, Price, Tonnage, AxelCount, MaxSpeed, PassengerCount)
Example Translation: ER Diagram

ER Diagram:

- **CourseNum** → **Course** → **CourseName**
  - (0, N)
- **SectionOf**
  - (1, 1)
- **Term**
  - (1, 1)
- **Section**
  - (1, 1)
- **TaughtBy**
  - **Professor** → **ProfName** → **ProfNum**
- **EnrolledIn**
  - **Student** → **StudentNum** → **StudentName**
- **SectionNum**
  - (6, 50)
- **Mark**
  - **GPA**
- **Off-Site Section**

(University of Waterloo)
Example Translation: Relational Diagram

- **Course**
  - CourseNum
  - CourseName

- **Student**
  - StudentNum
  - StudentName
  - GPA

- **Section**
  - CourseNum
  - SectionNum
  - Term
  - ProfNum

- **EnrolledIn**
  - CourseNum
  - SectionNum
  - StudentNum
  - Term
  - Mark

- **Off-Site Section**
  - CourseNum
  - SectionNum
  - Term
  - Location

- **Professor**
  - ProfNum
  - ProfName
Outline

1. ER to Relational Mapping
2. Data Definition in SQL (DDL)
3. Views and View Management
4. Data Security/Control (DCL)
Defining Relations and Integrity Constraints in SQL

- connected with a table (definition)
  - Primary Keys
  - Foreign Keys
  - CHECK constraints

- separate ECA rules (triggers)
Tebles with a Primary Key

- specifies a *attributes* of a table (w/types)
- specifies a *primary key* in a table
- syntax:

  ```sql
  CREATE TABLE <name>
  (
    ... <attributes>,
    PRIMARY KEY ( <list of attr> )
  )
  ```

- also creates an unique index on the key
Example

create table DEPT
  ( ID integer not NULL,
    DeptName char(20),
    MgrNO char(3),
    PRIMARY KEY (ID)
  )
Example (cont.)

sql => insert into DEPT values \\
sql (cont.) => ( 1 , 'Computer Science' , 000100)
DB20000I The SQL command completed successfully.

sql => insert into DEPT values \\
sql (cont.) => ( 1 , 'Computer Science' , 000100)
SQL0803N One or more values in the INSERT or UPDATE statement are not valid because they would produce duplicate rows for a table with a unique index.
SQLSTATE=23505
Foreign Key

- specifies an *referential constraint*
- syntax:

```
CREATE TABLE <name>
(
    ... <attributes>,
    FOREIGN KEY ( <attrs> )
    REFERENCES <ref-table>( <attrs> )
    ON DELETE <delete-action>
    ON UPDATE <update action>
)
```

- the actions can be:

  * **RESTRICT** – produce an error
  * **CASCADE**  – propagate the delete
  * **SET NULL** – set to “unknown”
create table EMP
( SSN integer not NULL,
  Name char(20),
  Dept integer,
  Salary dec(8,2),
  primary key (SSN),
  foreign key (Dept) references DEPT(ID)
    on delete cascade
    on update restrict)
Example (cont.)

db2 => insert into EMP
sql (cont.) => values ( 999, 'DAVE', 2, 50000 )
SQL0530N The insert or update value of FOREIGN KEY "DAVID.EMP.SQL970916001756640" is not equal to any value of the primary key of the parent table. SQLSTATE=23503

db2 => insert into EMP
sql (cont.) => values ( 999, 'DAVE', 1, 50000 )
DB20000I The SQL command completed successfully.
db2 => select * from emp where SSN=999

<table>
<thead>
<tr>
<th>SSN</th>
<th>NAME</th>
<th>DEPT</th>
<th>SALARY</th>
</tr>
</thead>
<tbody>
<tr>
<td>999</td>
<td>DAVE</td>
<td>1</td>
<td>50000.00</td>
</tr>
</tbody>
</table>
Example (cont.)

db2 => delete from DEPT where id=1
DB20000I The SQL command completed successfully.
db2 => select * from emp where SSN=999

<table>
<thead>
<tr>
<th>SSN</th>
<th>NAME</th>
<th>DEPT</th>
<th>SALARY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CHECK constraints

- allow checking for “correct” data:
- syntax:

  CREATE TABLE <name>
  ( ... <attributes>,
    CHECK <condition>
  )

- condition is a *simple* search condition
  ⇒ no subqueries (in DB2)
Example

create table EMP
(  SSN integer not NULL,
  Name char(20),
  Dept integer,
  Salary dec(8,2),
  primary key (SSN),
  foreign key (Dept) references DEPT(ID)
    on delete cascade
    on update restrict,
  check ( salary > 0 )
)  

db2 => insert into emp values (998, 'DAVE', 1, 0 )
SQL0545N The requested operation is not allowed because a row does not satisfy the check constraint "DAVID.EMP.SQL970916000939620". SQLSTATE=23513
Outline

1. ER to Relational Mapping
2. Data Definition in SQL (DDL)
3. Views and View Management
4. Data Security/Control (DCL)
Views

Definition (View)

A view is a relation whose instance is determined by the instances of other relations.

A view has many of the same properties as a table.

- its schema information appears in the database schema
- access controls can be applied to it
- other views can be defined in terms of it
Types of Views

- **Virtual**: Views are used only for querying; they are not stored in the database.
- **Materialized**: The query that makes up the view is executed, the view constructed and stored in the database.
SQL DDL: Views

- General form:

  `CREATE VIEW <name>`
  `[AS] ( <query> )`

- Example

  `create view ManufacturingProjects`
  `
  ( Select projno, projname, firstnme, lastname
  From project, employee
  Where respemp = empno and deptno = 'D21' )`
Accessing a View

Query a view as if it were a base relation.

SELECT projname
FROM manufacturingprojects
Accessing a View

Query a view as if it were a base relation.

```
SELECT projname
FROM manufacturingprojects
```

What happens when you query a virtual view?

- At compile time, the view definition is found
- The query over the view is modified with the query definition
- The resulting query is optimized and executed
Updating Views

- Modifications to a view’s instance must be propagated back to instances of relations in conceptual schema.

What does it mean to insert (Darryl, Hockey)?
What does it mean to delete (Dave, Curling)?
Updating Views

- Modifications to a view’s instance must be propagated back to instances of relations in conceptual schema.
- Some views cannot be updated unambiguously.
Updating Views

- Modifications to a view’s instance must be propagated back to instances of relations in conceptual schema.
- Some views cannot be updated unambiguously.

**Conceptual Schema**

<table>
<thead>
<tr>
<th>Persons</th>
<th>External Schema</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NAME</strong></td>
<td><strong>CITIZENSHIP</strong></td>
</tr>
<tr>
<td>Ed</td>
<td>Canadian</td>
</tr>
<tr>
<td>Dave</td>
<td>Canadian</td>
</tr>
<tr>
<td>Wes</td>
<td>American</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NationalPastimes</th>
<th>PersonalPastimes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CITIZENSHIP</strong></td>
<td><strong>PASTIME</strong></td>
</tr>
<tr>
<td>Canadian</td>
<td>Hockey</td>
</tr>
<tr>
<td>Canadian</td>
<td>Curling</td>
</tr>
<tr>
<td>American</td>
<td>Hockey</td>
</tr>
<tr>
<td>American</td>
<td>Baseball</td>
</tr>
</tbody>
</table>

What does it mean to insert (Darryl, Hockey)?
What does it mean to delete (Dave, Curling)?
Updating Views

- Modifications to a view’s instance must be propagated back to instances of relations in conceptual schema.
- Some views cannot be updated unambiguously.

Conceptual Schema

<table>
<thead>
<tr>
<th>Persons</th>
<th>External Schema</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAME</td>
<td>CITIZENSHIP</td>
</tr>
<tr>
<td>Ed</td>
<td>Canadian</td>
</tr>
<tr>
<td>Dave</td>
<td>Canadian</td>
</tr>
<tr>
<td>Wes</td>
<td>American</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>NationalPastimes</td>
<td>PersonalPastimes</td>
</tr>
<tr>
<td>CITIZENSHIP</td>
<td>PASTIME</td>
</tr>
<tr>
<td>Canadian</td>
<td>Hockey</td>
</tr>
<tr>
<td>Canadian</td>
<td>Curling</td>
</tr>
<tr>
<td>American</td>
<td>Hockey</td>
</tr>
<tr>
<td>American</td>
<td>Baseball</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. What does it mean to insert (Darryl, Hockey)?
Updating Views

- Modifications to a view’s instance must be propagated back to instances of relations in conceptual schema.
- Some views cannot be updated unambiguously.

### Conceptual Schema

<table>
<thead>
<tr>
<th>Persons</th>
<th>External Schema</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NAME</strong></td>
<td><strong>NAME</strong></td>
</tr>
<tr>
<td>Ed</td>
<td>Ed</td>
</tr>
<tr>
<td>Dave</td>
<td>Ed</td>
</tr>
<tr>
<td>Wes</td>
<td>Dave</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>CITIZENSHIP</strong></th>
<th><strong>PASTIME</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Canadian</td>
<td>Hockey</td>
</tr>
<tr>
<td>Canadian</td>
<td>Curling</td>
</tr>
<tr>
<td>American</td>
<td>Hockey</td>
</tr>
<tr>
<td>American</td>
<td>Baseball</td>
</tr>
</tbody>
</table>

### PersonalPastimes

<table>
<thead>
<tr>
<th><strong>NAME</strong></th>
<th><strong>PASTIME</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ed</td>
<td>Hockey</td>
</tr>
<tr>
<td>Ed</td>
<td>Curling</td>
</tr>
<tr>
<td>Dave</td>
<td>Hockey</td>
</tr>
<tr>
<td>Dave</td>
<td>Curling</td>
</tr>
<tr>
<td>Wes</td>
<td>Hockey</td>
</tr>
<tr>
<td>Wes</td>
<td>Baseball</td>
</tr>
</tbody>
</table>

**1.** What does it mean to insert (Darryl, Hockey)?

**2.** What does it mean to delete (Dave, Curling)?
View Updates in SQL

According to SQL-92, a view is updatable only if its definition satisfies a variety of conditions:

- The query references exactly one table
- The query only outputs simple attributes (no expressions)
- There is no grouping/aggregation/DISTINCT
- There are no nested queries
- There are no set operations

These rules are more restrictive than necessary.
Materialized Views

**Problem**

When a base table changes, the materialized view may also change.
Materialized Views

Problem
When a base table changes, the materialized view may also change.

Solution?
- Periodically reconstruct the materialized view.
- Incrementally update the materialized view.
Materialized Views

Problem

When a base table changes, the materialized view may also change.

Solution?

- Periodically reconstruct the materialized view.
- Incrementally update the materialized view.

Example: Data warehouses
Outline

1. ER to Relational Mapping
2. Data Definition in SQL (DDL)
3. Views and View Management
4. Data Security/Control (DCL)
Data Control Language

assigns *access rights* to database objects

- **Syntax:**
  
  GRANT <what> ON <object> TO <user(s)>
  
  REVOKE <what> ON <object> FROM <user(s)>

- <what> ON <object> can be
  
  DATABASE: BINDADD, CONNECT, CREATETAB
  
  CREATE_NOT_FENCED, DBADM
  
  INDEX: CONTROL
  
  PACKAGE: BIND, CONTROL, EXECUTE
  
  TABLE/VIEW: ALTER, CONTROL, INDEX, REFERENCES
  
  SELECT, INSERT, DELETE, UPDATE

- <user(s)> is a list of
  
  (i) USER <name>  
  
  (ii) GROUP <name> 
  
  (iii) PUBLIC
Summary

Schema design summary:

1. Create an ER diagram
   ⇒ visualization of the design goals
2. Translate ER-to-Relational
3. Determine FD, MVD, JD, . . .
   ⇒ detect anomalies and decompose
   ⇒ find keys
4. Determine inter-relational constraints
   ⇒ INDs and foreign key constraints
5. Enforce rest of constraints
   ⇒ CHECK declarations
   ⇒ ECA rules (only as the last resort!)