Database Systems

Relational Model

H. Turgut Uyar Şule Öğüdücü

2002-2015

License

Topics

Relational Model
- Introduction
- Keys
- Referential Integrity
- TutorialD

SQL
- Data Types
- Data Definition
- Data Manipulation
- Referential Integrity

Relational Model

- by Dr. E. F. Codd, 1970
- data is modelled as relations:
  $\alpha \subseteq A \times B \times C \times ...$
- relations are assigned to relation variables (relvar)
- each element of a relation is a tuple
- each piece of data of an element is an attribute
- relations can be represented using tables
- relation $\rightarrow$ table, tuple $\rightarrow$ row, attribute $\rightarrow$ column

Relation Example

MOVIE

TITLE	YEAR	DIRECTOR	SCORE	VOTES
Usual Suspects	1995	Bryan Singer	8.7	3502
Suspiria	1977	Dario Argento	7.1	1004
Being John Malkovich	1999	Spike Jonze	8.3	13809
...	...	...	...	...

- relation variable: `MOVIE`
- tuple: `(Suspiria, 1977, Dario Argento, 7.1, 1004)`
- attribute: `YEAR`

Relation Structure

- relation header: set of attributes of the relation
- affected by data definition language statements
- relation body: set of tuples in the relation
- affected by data manipulation language statements

Relation Predicate

- relation predicate: "meaning" of the relation

example

- "The movie titled `TITLE` was released in `YEAR`.
  It was directed by `DIRECTOR`.
  The average of `VOTES` votes is `SCORE`."

Tuple Values

- each tuple is either *True* or *False* according to the predicate

example: MOVIE relation

- `(Suspiria, 1977, Dario Argento, 1004, 7.1)` is True
- `(Suspiria, 1978, Dario Argento, 1004, 7.1)` is False

Tuple Order

- tuple order is insignificant

example

- these relations are equivalent:

TITLE	...
Usual Suspects	...
Suspiria	...
Being John Malkovich	...

TITLE	...
Suspiria	...
Being John Malkovich	...
Usual Suspects	...

Attribute Order

- attribute order is insignificant

example

- these relations are equivalent:

TITLE	YEAR	...
Usual Suspects	1995	...
Suspiria	1977	...

YEAR	TITLE	...
1995	Usual Suspects	...
1977	Suspiria	...

Duplicate Tuples

- there can not be duplicate tuples in a relation
- each tuple must be uniquely identifiable

example

TITLE	YEAR	DIRECTOR	SCORE	VOTES
Usual Suspects	1995	Bryan Singer	8.7	3502
Suspiria	1977	Dario Argento	7.1	1004
Being John Malkovich	1999	Spike Jonze	8.3	13809
...	...	...	...	...
Suspiria	1977	Dario Argento	7.1	1004
...	...	...	...	...

Domains

- all values for the same attribute should be selected from the same domain
- comparison only makes sense between values chosen from the same domain
- in practice, data types are used instead

Domain Example

- `TITLE` from the titles domain, `YEAR` from the years domain, `DIRECTOR` from the directors domain, ...
- if data types are used:
  `TITLE` string, `YEAR` integer, `DIRECTOR` string, ...
- assigning `"Usual Suspects"` to `DIRECTOR` is valid in terms of data types but it doesn't make sense
- `YEAR` and `VOTES` are integers but it doesn't make sense to compare them

Attribute Values

- attribute values must be scalar
- no arrays, lists, records, ...

example: multiple directors

TITLE	...	DIRECTORS	...
...	...	...	...
The Matrix	...	~~Andy Wachowski, Lana Wachowski~~	...
...	...	...	...

Null Value

- value of attribute not known for tuple

example

- director of movie not known

- tuple does not have a value for attribute

example

- nobody voted for movie, therefore no `SCORE`

Default Value

- a default value can be used instead of null
- it may not be one of the valid values for the attribute

example

- if `SCORE` values are between 1.0 and 10.0, the default value can be chosen as `0.0`

Keys

- let B be the set of all attributes of the relation, and let $A \subseteq B$
- to be a candidate key, A has to be:
- unique: no two tuples have the same values for all attributes in A
- irreducible: no subset of A is unique
- every relation has at least one candidate key

Candidate Key Examples

- `{TITLE}` ?
- `{TITLE, YEAR}` ?
- `{TITLE, DIRECTOR}` ?
- `{TITLE, YEAR, DIRECTOR}` ?

Surrogate Keys

- if a natural key can not be found a surrogate key can be defined
- identity attribute
- its value doesn't matter
- it can be generated by the system

Surrogate Key Example

MOVIE#	TITLE	YEAR	DIRECTOR	SCORE	VOTES
...	...	...	...	...	...
6	Usual Suspects	1995	Bryan Singer	...	...
1512	Suspiria	1977	Dario Argento	...	...
70	Being John Malkovich	1999	Spike Jonze	...	...
...	...	...	...	...	...

- `{MOVIE#}` is a candidate key
- `{MOVIE#, TITLE}` is not a candidate key

Primary Key

- if more than one candidate key, one is selected as the primary key
- others are alternate keys
- names of attributes in the primary key are underlined
- any attribute that is part of the primary key can not be empty in any tuple
- every relation must have a primary key

Primary Key Example

MOVIE#	TITLE	YEAR	DIRECTOR	SCORE	VOTES
...	...	...	...	...	...
6	Usual Suspects	1995	Bryan Singer	...	...
1512	Suspiria	1977	Dario Argento	...	...
70	Being John Malkovich	1999	Spike Jonze	...	...
...	...	...	...	...	...

Scalarity Example

- how to store actor data?

MOVIE

MOVIE#	TITLE	...	ACTORS
6	Usual Suspects	...	Gabriel Byrne
...	...	...	...
70	Being John Malkovich	...	~~Cameron Diaz, John Malkovich~~
...	...	...	...

Scalarity Example

- for scalarity, tuples have to be repeated

MOVIE

MOVIE#	TITLE	...	ACTOR
6	Usual Suspects	...	Gabriel Byrne
...	...	...	...
70	Being John Malkovich	...	Cameron Diaz
70	Being John Malkovich	...	John Malkovich
...	...	...	...

Scalarity Example

MOVIE

MOVIE#	TITLE	...
6	Usual Suspects	...
1512	Suspiria	...
70	Being John Malkovich	...
...	...	...

ACTOR

ACTOR#	NAME
308	Gabriel Byrne
282	Cameron Diaz
503	John Malkovich
...	...

CASTING

MOVIE#	ACTOR#	ORD
6	308	2
70	282	2
70	503	14
...	...	...

Scalarity Example

MOVIE

MOVIE#	TITLE	...	DIRECTOR#
6	Usual Suspects	...	639
1512	Suspiria	...	2259
70	Being John Malkovich	...	1485
...	...	...	...

PERSON

PERSON#	NAME
308	Gabriel Byrne
1485	Spike Jonze
639	Bryan Singer
282	Cameron Diaz
2259	Dario Argento
503	John Malkovich
...	...

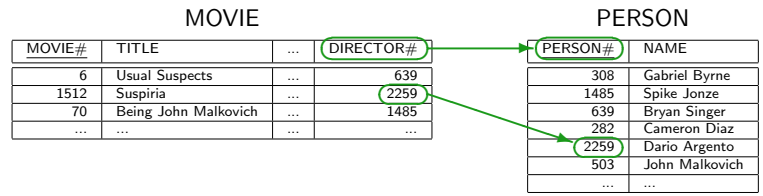
CASTING

MOVIE#	ACTOR#	ORD
6	308	2
70	282	2
70	503	14
...	...	...

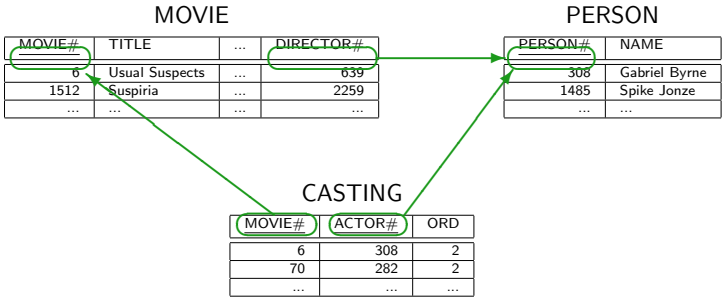
Foreign Keys

- foreign key: an attribute of a relation that is a candidate key of another relation

Foreign Key Example



Foreign Key Examples



Referential Integrity

- referential integrity:
  all values of a foreign key attribute must be present
  among the values of the referenced candidate key attribute
- if a request would break referential integrity:
- don't allow
- reflect the change to affected tuples
- assign null value
- assign default value

Referential Integrity Examples

MOVIE

MOVIE#	TITLE	...	DIRECTOR#
...	...	...	...
1512	Suspiria	...	2259
...	...	...	...

PERSON

PERSON#	NAME
...	...
2259	Dario Argento
...	...

- delete `(2259, Dario Argento)`
- update `(2259, Dario Argento)` as `(2871, Dario Argento)`

Tutorial D Data Types

- `INTEGER`
- `RATIONAL`
- `BOOL`
- `CHAR`

Type Definition

- defining a new type:

```
TYPE type_name POSSREP
  { field_name field_type
    [, ...]
    [ CONSTRAINT condition ] };
```

- deleting a type:

```
DROP TYPE type_name;
```


Type Definition Examples

```
TYPE PERSON# POSSREP
  { VALUE INTEGER };

TYPE MOVIE# POSSREP
  { VALUE INTEGER };

TYPE YEAR POSSREP
  { VALUE INTEGER };

TYPE SCORE POSSREP
  { VALUE RATIONAL
    CONSTRAINT (VALUE >= 1.0)
           AND (VALUE <= 10.0) };
```


Type Operations

- generating a value for a type:

```
type_name(base_value [, ...])
```

example

- generating a SCORE value:

```
SCORE(8.7)
```


Type Operations

- getting the value of a field: THE_ operators

```
THE_field_name(variable_name)
```

example

- getting the VALUE field of a SCORE variable:

```
THE_VALUE(SCORE)
```

Type Operations

- type casting: CAST_AS_ operators

```
CAST_AS_target_type(value)
```

example

- casting an integer VOTES value to a RATIONAL:

```
CAST_AS_RATIONAL(VOTES)
```


Relation Definition

- defining a new relation:

```
RELATION
  { attribute_name attribute_type
    [, ...] }
  KEY { attribute_name [, ...] }
```


Relation Definition Example

```
RELATION
  { MOVIE# MOVIE#,
    TITLE CHAR,
    YEAR YEAR,
    DIRECTOR PERSON#,
    SCORE SCORE,
    VOTES INTEGER }
  KEY { MOVIE# }
```


Relation Variables

- defining a new relation variable

```
VAR relvar_name BASE RELATION
  { ... }
  KEY { ... };
```

- deleting a relation variable:

```
DROP VAR relvar_name;
```

Relation Variable Examples

```
VAR MOVIE BASE RELATION
  { MOVIE# MOVIE#,
    TITLE CHAR,
    YEAR YEAR,
    DIRECTOR PERSON#,
    SCORE SCORE,
    VOTES INTEGER }
  KEY { MOVIE# };
```


Relation Variable Examples

```
VAR PERSON BASE RELATION
  { PERSON# PERSON#,
    NAME CHAR }
  KEY { PERSON# };

VAR CASTING BASE RELATION
  { MOVIE# MOVIE#,
    ACTOR# PERSON#,
    ORD INTEGER }
  KEY { MOVIE#, ACTOR# };
```


Tuple Generation

- generating a tuple:

```
TUPLE
  { attribute_name attribute_value
    [, ...] }
```


Tuple Generation Examples

```
TUPLE
  { MOVIE# MOVIE#(6),
    TITLE "Usual Suspects",
    YEAR YEAR(1995),
    DIRECTOR# PERSON#(639),
    SCORE SCORE(8.7),
    VOTES 35027 }

TUPLE
  { PERSON# PERSON#(639),
    NAME "Bryan Singer" }
```

Relation Generation

- generating a relation:

```
RELATION
  { TUPLE
      { ... }
    [, ...] }
```

- assigning a relation to a relation variable:

```
relvar_name := RELATION { ... };
```


Relation Assignment Example

```
MOVIE := RELATION
  { TUPLE
      { MOVIE# MOVIE#(6),
        TITLE "Usual Suspects",
        YEAR YEAR(1995), DIRECTOR# PERSON#(639),
        SCORE SCORE(8.7), VOTES 35027 },
    TUPLE
      { MOVIE# MOVIE#(70),
        TITLE "Being John Malkovich",
        YEAR YEAR(1999), DIRECTOR# PERSON#(1485),
        SCORE SCORE(8.3), VOTES 13809 } };
```


Tuple Insertion

- inserting tuples:

```
INSERT relvar_name RELATION
  { TUPLE { ... }
    [, ...] };
```


Tuple Insertion Example

```
INSERT MOVIE RELATION
  { TUPLE
    { MOVIE# MOVIE#(6),
      TITLE "Suspiria",
      YEAR YEAR(1977),
      DIRECTOR# PERSON#(2259),
      SCORE SCORE(7.1),
      VOTES 1004 } };
```

Tuple Deletion

- deleting tuples:

```
DELETE relvar_name
  [ WHERE condition ];
```

- if no condition is specified, all tuples will be deleted

Tuple Deletion Example

- delete movies with scores less than 3.0 and votes more than 4

```
DELETE MOVIE
  WHERE ((SCORE < SCORE(3.0))
     AND (VOTES > 4));
```


Tuple Update

- updating tuples:

```
UPDATE relvar_name
  [ WHERE condition ]
  ( attribute_name := attribute_value
    [, ...] );
```

- if no condition is specified, all tuples will be updated

Tuple Update Example

- register a new vote (9) for the movie "Suspiria"

```
UPDATE MOVIE
  WHERE (TITLE = "Suspiria") (
    SCORE := SCORE(
      (THE_VALUE(SCORE)
         * CAST_AS_RATIONAL(VOTES)
         + CAST_AS_RATIONAL(9))
       / CAST_AS_RATIONAL(VOTES + 1)
    ),
    VOTES := VOTES + 1
  );
```

Attribute Renaming

- renaming an attribute:

```
RENAME { attribute_name AS new_name }
```

example

- renaming the DIRECTOR# attribute:

```
RENAME { DIRECTOR# AS PERSON# }
```


Foreign Key Definition

- defining a foreign key:

```
CONSTRAINT constraint_name
  referencing_relvar_name
      { attribute_name }
    <= referenced_relvar_name
       { attribute_name };
```

- attribute names have to match (rename if necessary)

Foreign Key Examples

```
CONSTRAINT MOVIE_FKEY_DIRECTOR
    MOVIE { DIRECTOR# }
        RENAME { DIRECTOR# AS PERSON# }
      <= PERSON { PERSON# };
```


Foreign Key Examples

```
CONSTRAINT CASTING_FKEY_MOVIE
  CASTING { MOVIE# } <= MOVIE { MOVIE# };

CONSTRAINT CASTING_FKEY_ACTOR
  CASTING { ACTOR# }
      RENAME { ACTOR# AS PERSON# }
    <= PERSON { PERSON# };
```

Data Types

- `INTEGER`,
- `SMALLINT`
- `NUMERIC (precision, scale)`
  - `precision`: total number of digits
  - `scale`: number of digits after the decimal point
  - same as: `DECIMAL (precision, scale)`
- `FLOAT (p)`
  - p: lowest acceptable precision
- `BOOLEAN`

String Data Types

- `CHARACTER [ VARYING ] (n)`
- `CHARACTER (n)`: if the string is shorter than n characters it will be padded with spaces
- `CHAR (n)` instead of `CHARACTER (n)`
- `VARCHAR (n)` instead of `CHARACTER VARYING (n)`

Date / Time Data Types

- `DATE`
  - value example: `2005-09-26`
- `TIME`
  - value example: `11:59:22.078717`
- `TIMESTAMP`
  - value example: `2005-09-26 11:59:22.078717`
- `INTERVAL`
  - value example: `3 days`

Large Object Data Types

- arbitrary length objects
- binary: `BINARY LARGE OBJECT (n)`
- `BLOB`
- text: `CHARACTER LARGE OBJECT (n)`
- `CLOB`
- can not be used in queries

Domain Creation

- creating a domain:

```
CREATE DOMAIN domain_name [ AS ] base_type
  [ DEFAULT default_value ]
  [ { CHECK ( condition ) } [, ...] ]
```

- deleting domains:

```
DROP DOMAIN domain_name [, ...]
```


Domain Example

- a domain for valid SCORE values:

```
CREATE DOMAIN SCORES AS FLOAT
  CHECK ((VALUE >= 1.0) AND (VALUE <= 10.0))
```


Table Creation

- creating a table:

```
CREATE TABLE table_name (
  { column_name data_type }
  [, ... ]
)
```

- deleting tables:

```
DROP TABLE table_name [, ... ]
```


Table Creation Example

```
CREATE TABLE MOVIE (
  ID INTEGER,
  TITLE VARCHAR(80),
  YR NUMERIC(4),
  DIRECTORID INTEGER,
  SCORE FLOAT,
  VOTES INTEGER
)
```

- using a domain:

```
CREATE TABLE MOVIE (
  ID INTEGER,
  TITLE VARCHAR(80),
  YR NUMERIC(4),
  DIRECTORID INTEGER,
  SCORE SCORES,
  VOTES INTEGER
)
```

Null and Default Values

- defining nullable columns and default values:

```
CREATE TABLE table_name (
  { column_name data_type
              [ NULL | NOT NULL ]
              [ DEFAULT default_value ] }
  [, ... ]
)
```

- `NULL`: the column is allowed to be empty (default)
- `NOT NULL`: the column is not allowed to be empty

Table Creation Example

```
CREATE TABLE MOVIE (
  ID INTEGER,
  TITLE VARCHAR(80) NOT NULL,
  YR NUMERIC(4),
  DIRECTORID INTEGER,
  SCORE FLOAT,
  VOTES INTEGER DEFAULT 0
)
```


Value Constraints

- defining constraints on values:

```
CREATE TABLE table_name (
  { column_name data_type
              [ NULL | NOT NULL ]
              [ DEFAULT default_value ] }
  [ { CHECK ( condition ) }
    [, ...] ]
)
```


Value Constraint Example

- `SCORE` values must be between `1.0` and `10.0`

```
CREATE TABLE MOVIE (
  ID INTEGER,
  ...,
  SCORE FLOAT,
  VOTES INTEGER DEFAULT 0,
  CHECK ((SCORE >= 1.0) AND (SCORE <= 10.0))
)
```

Primary Keys

- defining primary keys:

```
CREATE TABLE table_name (
  { column_name data_type
              [ NULL | NOT NULL ]
              [ DEFAULT default_value ] }
  [, ... ]
  [ PRIMARY KEY ( column_name [, ...] ) ]
)
```


Primary Key Example

```
CREATE TABLE MOVIE (
  ID INTEGER,
  TITLE VARCHAR(80) NOT NULL,
  YR NUMERIC(4),
  DIRECTORID INTEGER,
  SCORE FLOAT,
  VOTES INTEGER DEFAULT 0,
  PRIMARY KEY (ID)
)
```


Primary Keys

- if the primary key consists of a single column,
  it can be specified in column definition:

  `column_name data_type PRIMARY KEY`

example

```
CREATE TABLE MOVIE (
  ID INTEGER PRIMARY KEY,
  ...
  VOTES INTEGER DEFAULT 0
)
```


Automatically Incremented Values

- no standard on defining automatically incremented values
- PostgreSQL: `SERIAL` data type
  `ID SERIAL PRIMARY KEY`
- MySQL: `AUTO_INCREMENT` property
  `ID INTEGER PRIMARY KEY AUTO_INCREMENT`
- SQLite: `AUTOINCREMENT` property
  `ID INTEGER PRIMARY KEY AUTOINCREMENT`

Uniqueness

- defining unique columns:

```
CREATE TABLE table_name (
  ...
  [ { UNIQUE ( column_name [, ...] ) }
    [, ...] ]
  ...
)
```

- null values are ignored

Uniqueness Example

- titles and (director, year) pairs are unique:

```
CREATE TABLE MOVIE (
  ID SERIAL PRIMARY KEY,
  TITLE VARCHAR(80) NOT NULL,
  YR NUMERIC(4),
  DIRECTORID INTEGER,
  SCORE FLOAT,
  VOTES INTEGER DEFAULT 0,
  UNIQUE (TITLE),
  UNIQUE (DIRECTOR, YR)
)
```


Uniqueness

- if the uniqueness constraint consists of a single column, it can be specified in the column definition:

```
column_name data_type UNIQUE
```

example: person names are unique

```
CREATE TABLE PERSON (
  ID SERIAL PRIMARY KEY,
  NAME VARCHAR(40) UNIQUE NOT NULL
)
```


Indexes

- creating an index

```
CREATE [ UNIQUE ] INDEX index_name
  ON table_name (column_name [, ...])
```

- speeds up queries
- slows down inserts and updates

example: create a year index on movies

```
CREATE INDEX MOVIE_YEAR ON MOVIE (YR)
```

Renaming Tables

- renaming a table:

```
ALTER TABLE table_name
  RENAME TO new_name
```

example

```
ALTER TABLE MOVIE
  RENAME TO FILM
```


Adding Columns

- adding columns to an existing table:

```
ALTER TABLE table_name
  ADD [ COLUMN ] column_name data_type
                 [ NULL | NOT NULL ]
                 [ DEFAULT default_value ]
```

example

```
ALTER TABLE MOVIE
  ADD COLUMN RUNTIME INTEGER
```


Deleting Columns

- deleting columns from a table:

```
ALTER TABLE table_name
  DROP [ COLUMN ] column_name
```

example

```
ALTER TABLE MOVIE
  DROP COLUMN RUNTIME
```


Renaming Columns

- renaming a column:

```
ALTER TABLE table_name
  RENAME [ COLUMN ] column_name TO new_name
```

example

```
ALTER TABLE MOVIE
  RENAME COLUMN TITLE TO NAME
```

Column Defaults

- setting a default value for a column:

```
ALTER TABLE table_name
  ALTER [ COLUMN ] column_name
  SET DEFAULT default_value
```

- removing the default value from a column:

```
ALTER TABLE table_name
  ALTER [ COLUMN ] column_name
  DROP DEFAULT
```


Adding Constraints

- adding a new constraint to a table:

```
ALTER TABLE table_name
  ADD [ CONSTRAINT constraint_name ]
    constraint_definition
```

- removing a constraint from a table:

```
ALTER TABLE table_name
  DROP [ CONSTRAINT ] constraint_name
```

- when adding constraints, what happens with existing tuples?

Constraint Addition Example

- YR values can not be less than 1888

```
ALTER TABLE MOVIE
  ADD CONSTRAINT MINIMUM_YEAR
    CHECK (YR >= 1888)
```

- drop the minimum year constraint

```
ALTER TABLE MOVIE
  DROP CONSTRAINT MINIMUM_YEAR
```


Row Insertion

- inserting a row to a table:

```
INSERT INTO table_name
  [ ( column_name [, ...] ) ]
  VALUES ( column_value [, ...] )
```

- order of values must match order of columns
- if column names are omitted, values must be in order of definition
- omitted columns will take their default values
- automatically generated columns are usually omitted

Row Insertion Example

```
INSERT INTO MOVIE VALUES (
  6,
  'Usual Suspects',
  1995,
  639,
  8.7,
  35027
)
```


Row Insertion Example

```
INSERT INTO MOVIE (YR, TITLE) VALUES (
  1995,
  'Usual Suspects'
)
```

- value for `ID` will be automatically generated

Row Deletion

- deleting rows:

```
DELETE FROM table_name
  [ WHERE condition ]
```

- if no condition is specified, all rows will be deleted

Row Deletion Example

- delete movies with scores less than 3.0 and votes more than 4:

```
DELETE FROM MOVIE
  WHERE ((SCORE < 3.0) AND (VOTES > 4))
```

Row Update

- updating rows:

```
UPDATE table_name
  SET { column_name = column_value } [, ...]
  [ WHERE condition ]
```

- if no condition is specified, all rows will be updated
- order of column assignments is insignificant

Row Update Example

- register a new vote (9) for the movie "Suspiria"

```
UPDATE MOVIE
  SET SCORE = (SCORE * VOTES + 9)
                  / (VOTES + 1),
      VOTES = VOTES + 1
  WHERE (TITLE = 'Suspiria')
```


Foreign Keys

- defining foreign keys:

```
CREATE TABLE table_name (
  ...
  [ { FOREIGN KEY ( column_name [, ...] )
        REFERENCES table_name
          [ ( column_name [, ...] ) ] }
    [, ...] ]
  ...
)
```


Foreign Key Example

```
CREATE TABLE MOVIE (
  ID SERIAL PRIMARY KEY,
  TITLE VARCHAR(80) NOT NULL,
  YR NUMERIC(4),
  SCORE FLOAT,
  VOTES INTEGER DEFAULT 0,
  DIRECTORID INTEGER,
  FOREIGN KEY DIRECTORID REFERENCES PERSON (ID)
)
```

Foreign Keys

- if the foreign key consists of only one column, it can be specified in the column definition:

```
column_name data_type
  REFERENCES table_name [ ( column_name ) ]
```

example

```
CREATE TABLE MOVIE (
  ID SERIAL PRIMARY KEY,
  ...
  VOTES INTEGER DEFAULT 0,
  DIRECTORID INTEGER REFERENCES PERSON (ID)
)
```


Foreign Keys

- if the foreign key refers to the primary key, the referred column can be omitted

example

```
CREATE TABLE MOVIE (
  ID SERIAL PRIMARY KEY,
  ...
  VOTES INTEGER DEFAULT 0,
  DIRECTORID INTEGER REFERENCES PERSON
)
```


Integrity Violation Options

- what to do if referential integrity will be broken?
- don't allow if used: `RESTRICT`, `NO_ACTION`
- reflect the change to affected tuples: `CASCADE`
- assign null value: `SET NULL`
- assign default value: `SET DEFAULT`

Foreign Keys

- integrity violation options:

```
CREATE TABLE table_name (
  ...
  [ { FOREIGN KEY ( column_name [, ...] )
        REFERENCES table_name
          [ ( column_name [, ...] ) ]
        [ ON DELETE option ]
        [ ON UPDATE option ] } [, ...] ]
  ...
)
```

Foreign Key Example

```
CREATE TABLE MOVIE (
  ID SERIAL PRIMARY KEY,
  ...
  DIRECTORID INTEGER,
  FOREIGN KEY DIRECTORID
    REFERENCES PERSON (ID)
    ON DELETE RESTRICT
    ON UPDATE CASCADE
)
```


Referential Integrity Example

MOVIE

ID	TITLE	...	DIRECTORID
6	Usual Suspects	...	639
70	Being John Malkovich	...	1485
107	Batman & Robin	...	105

PERSON

ID	NAME
308	Gabriel Byrne
1485	Spike Jonze

- `MOVIE.DIRECTORID: ON DELETE RESTRICT`
- delete Spike Jonze from PERSON: not allowed
- delete Gabriel Byrne from PERSON: allowed

Referential Integrity Example

MOVIE

ID	TITLE	DIRECTORID
6	Usual Suspects	639
70	Being John Malkovich	1485
107	Batman & Robin	105
112	Three Kings	1070

PERSON

ID	NAME
308	Gabriel Byrne
1485	Spike Jonze

CASTING

MOVIEID	ACTORID	ORD
6	308	2
70	282	2
112	1485	4

- `MOVIE.DIRECTORID: ON DELETE CASCADE`
- `CASTING.MOVIEID: ON DELETE CASCADE`
- `CASTING.ACTORID: ON DELETE CASCADE`
- delete Spike Jonze from PERSON: which rows get deleted?

Referential Integrity Example

MOVIE

ID	TITLE	DIRECTORID
6	Usual Suspects	639
70	Being John Malkovich	1485
107	Batman & Robin	105
112	Three Kings	1070

PERSON

ID	NAME
308	Gabriel Byrne
1485	Spike Jonze

CASTING

MOVIEID	ACTORID	ORD
6	308	2
70	282	2
112	1485	4

- `MOVIE.DIRECTORID: ON DELETE RESTRICT`
- `CASTING.MOVIEID: ON DELETE CASCADE`
- `CASTING.ACTORID: ON DELETE CASCADE`
- delete Spike Jonze from PERSON: which rows get deleted?

Example Database

```
CREATE TABLE MOVIE (
  ID SERIAL PRIMARY KEY,
  TITLE VARCHAR(80) NOT NULL,
  YR NUMERIC(4),
  SCORE FLOAT,
  VOTES INTEGER DEFAULT 0,
  DIRECTORID INTEGER REFERENCES PERSON
)
```


Example Database

```
CREATE TABLE PERSON (
  ID SERIAL PRIMARY KEY,
  NAME VARCHAR(40) UNIQUE NOT NULL
)
```


Example Database

```
CREATE TABLE CASTING (
  MOVIEID INTEGER REFERENCES MOVIE,
  ACTORID INTEGER REFERENCES PERSON,
  ORD INTEGER,
  PRIMARY KEY (MOVIEID, ACTORID)
)
```


References

Required Reading: Date

- Chapter 3: An Introduction to Relational Databases
  - 3.2. An Informal Look at the Relational Model
  - 3.3. Relations and Relvars
- Chapter 6: Relations
- Chapter 9: Integrity
  - 9.10. Keys
  - 9.12. SQL Facilities