Database Systems

Database Design

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Topics

Functional Dependency

Definition

- let Z be the set of all attributes of relation R, and $A, B \subseteq Z$
- A functionally determines B: $A \rightarrow B$
  for every A value there is only one B value
- every functional dependency is an integrity constraint

Functional Dependency Examples

Example

Table: R

MOVIEID	TITLE	COU	LANG	ACTORID	NAME	ORD
6	Usual Suspects	UK	EN	308	Gabriel Byrne	2
228	Ed Wood	US	EN	26	Johnny Depp	1
70	Being John Malkovich	US	EN	282	Cameron Diaz	2
1512	Suspiria	IT	IT	745	Udo Kier	9
70	Being John Malkovich	US	EN	503	John Malkovich	14

- assumption: the language of the movie is the language of the country where it was made

Functional Dependency Examples

Example

- MOVIEID → COUNTRY
- ACTORID → NAME
- MOVIEID → {TITLE, COUNTRY, LANGUAGE}
- {MOVIEID, ACTORID} → COUNTRY
- {MOVIEID, ACTORID} → MOVIEID
- {MOVIEID, ACTORID} → ORD
- {MOVIEID, ACTORID} → {COUNTRY, ORD}
- COUNTRY → LANGUAGE

Irreducible Set

- S: the set of all FDs of the relation
- $T \subseteq S$, such that
  - T contains as few elements as possible
  - every FD in S can be derived by the FDs in T
- let there be only one attribute on the right hand side of FDs

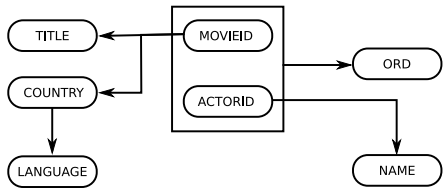
Irreducible Set Example

Example

- MOVIEID → TITLE
- MOVIEID → COUNTRY
- COUNTRY → LANGUAGE
- ACTORID → NAME
- {MOVIEID, ACTORID} → ORD

Dependence Diagram

Example



Normal Forms

- 1NF, 2NF, 3NF, BCNF, 4NF, 5NF
- every form narrows down the scope of the previous form
  - every relation in 2NF is also in 1NF
  - every relation in 3NF is also in 2NF, ...
- 1NF: attribute values are atomic

Normalization

Definition

normalization:
transition from one form to the next, narrower form

- transition between normal forms must be lossless

Theorem (Heath)

- *Z: R the set of all attributes of the relation*
- *$A, B, C \subseteq Z$*
- *if $A \rightarrow B$, then R can be obtained by joining the relations $\{A, B\}$ and $\{A, C\}$*

Lossless Transition Example

Example

Table: R1

MOVIEID	TITLE	COU	LANG
6	Usual Suspects	UK	EN
228	Ed Wood	US	EN
70	Being John Malkovich	US	EN
1512	Suspiria	IT	IT

Table: R2

MOVIEID	ACTORID	NAME	ORD
6	308	Gabriel Byrne	2
228	26	Johnny Depp	1
70	282	Cameron Diaz	2
1512	745	Udo Kier	9
70	503	John Malkovich	14

- $R = natjoin\ (R1)\ (R2)$

Lossy Transition Example

Example

Table: R1

MOVIEID	TITLE	COU	LANG
6	Usual Suspects	UK	EN
228	Ed Wood	US	EN
70	Being John Malkovich	US	EN
1512	Suspiria	IT	IT

Table: R2

COU	ACTORID	NAME	ORD
UK	308	Gabriel Byrne	2
US	26	Johnny Depp	1
US	282	Cameron Diaz	2
IT	745	Udo Kier	9
US	503	John Malkovich	14

- $R \neq natjoin\ (R1)\ (R2)$
- {MOVIEID, ACTORID} → ORD

Anomalies

- *insert*
  - data is known but can not be inserted due to constraints
- *delete*
  - deleting some data causes some other data to be lost
- *update*
  - updating some data requires modifications in multiple tuples

Anomaly Examples

Example

- The country of the movie Gattaca is US but this data can not be added because no actor is known for the movie.
- Deleting the data that Gabriel Byrne is in the movie Usual Suspects causes the data that the country of the movie is UK to be deleted.
- Changing the country of the movie Being John Malkovich as UK requires two tuples to be modified.

2nd Normal Form

Definition

2NF: every non-key attribute depends on the primary key

transition from 1NF to 2NF

- in an R relation that conforms to 1NF:
  - $R(A, B, C, D)$, primary key: $\{A, B\}$
  - $A \rightarrow D$
- for it to be 2NF:
  - $R1(A, D)$, primary key: A
  - $R2(A, B, C)$, primary key: $\{A, B\}$
    A is a foreign key referencing $R1$

1NF-2NF Transition Example

Example

- among the non-key attributes, only ORD depends on the primary key
  - A: MOVIEID
  - B: ACTORID
  - C: {NAME,ORD}
  - D: {TITLE,COUNTRY,LANGUAGE}

1NF-2NF Transition Example

Example

- R1(MOVIEID,TITLE,COUNTRY,LANGUAGE)
  primary key: MOVIEID
- R2(MOVIEID,ACTORID,NAME,ORD)
  primary key: {MOVIEID,ACTORID}
  MOVIEID is a foreign key referencing R1

1NF-2NF Transition Example

Example

- R2 still not 2NF: ACTORID → NAME
  - *A*: ACTORID
  - *B*: MOVIEID
  - *C*: ORD
  - *D*: NAME
- R3(ACTORID,NAME)
  primary key: ACTORID
- R4(MOVIEID,ACTORID,ORD)
  primary key: {MOVIEID,ACTORID}
  ACTORID is a foreign key referencing R3

2NF Relation Examples

Example

Table: R1

MOVIEID	TITLE	COU	LANG
6	Usual Suspects	UK	EN
228	Ed Wood	US	EN
70	Being John Malkovich	US	EN
1512	Suspiria	IT	IT

Table: R3

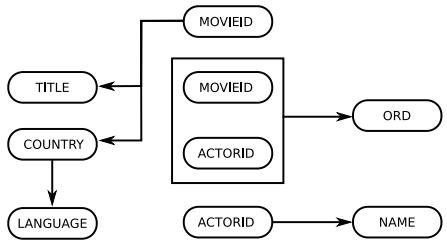
ACTORID	NAME
308	Gabriel Byrne
26	Johnny Depp
282	Cameron Diaz
745	Udo Kier
503	John Malkovich

Table: R4

MOVIEID	ACTORID	ORD
6	308	2
228	26	1
70	282	2
1512	745	9
70	503	14

Dependency Diagram Example

Example



2NF Corrected Anomalies

Example

- If the country of the movie Gattaca is US, this data can be inserted to $R1$.
- If Gabriel Byrne is deleted from the cast list of the movie Usual Suspects, the fact that the country of the movie is UK is preserved in $R1$.
- Changing the country of the movie Being John Malkovich requires updating only one tuple in $R1$.

2NF Remaining Anomalies

Example

- It is known that movies made Brasil are in Portuguese, but this data can not be inserted because there is no known movie made in Brasil.
- Deleting the movie Suspiria causes the data that movies made in Italy are in Italian to be lost.
- If the language of the movies made in the US is to be changed as American English, two tuples need to be updated.

3rd Normal Form

Definition

3NF: non-key attributes are not dependent on any attribute or attribute group other than the primary key

transition from 2NF to 3NF

- in an R relation that conforms to 2NF:
  - $R(A, B, C, D)$, primary key: A
  - $C \rightarrow D$
- for it to be 3NF:
  - $R1(C, D)$, primary key: C
  - $R2(A, B, C)$, primary key: A
    C is a foreign key referencing $R1$

2NF-3NF Transition Example

Example

- R1: COUNTRY → LANGUAGE
  - *A*: MOVIEID
  - *B*: TITLE
  - *C*: COUNTRY
  - *D*: LANGUAGE
- R5(COUNTRY, LANGUAGE)
  primary key: COUNTRY
- R6(MOVIEID, TITLE, COUNTRY)
  primary key: MOVIEID
  COUNTRY is a foreign key referencing R5

3NF Relation Examples

Example

Table: R6

MOVIEID	TITLE	COU
6	Usual Suspects	UK
228	Ed Wood	US
70	Being John Malkovich	US
1512	Suspiria	IT

Table: R5

COU	LANG
UK	EN
US	EN
IT	IT

Table: R3

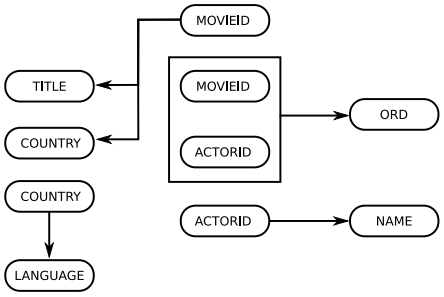
ACTORID	NAME
308	Gabriel Byrne
26	Johnny Depp
282	Cameron Diaz
745	Udo Kier
503	John Malkovich

Table: R4

MOVIEID	ACTORID	ORD
6	308	2
228	26	1
70	282	2
1512	745	9
70	503	14

Dependency Diagram Example

Example



3NF Corrected Anomalies

Example

- If it is known that movies made in Brasil are in Portuguese, this data can be added to *R*5.
- If the movie Suspiria is deleted, the data that movies made in Italy are in Italian is preserved in *R*5.
- If the language of the movies made in the US has to be updated as American English, only one tuple in *R*5 has to be modified.

Boyce-Codd Normal Form

Definition

BCNF: all functional dependencies must be on candidate keys

BCNF Example

Example (let movie titles be unique)

- candidate keys:
  - {MOVIEID,ACTORID}
  - {TITLE,ACTORID}
- non-conforming functional dependencies:
  - MOVIEID → TITLE
  - TITLE → MOVIEID

References

Required text: Date

- Chapter 11: Functional Dependencies
- Chapter 12: Further Normalization I: 1NF, 2NF, 3NF, BCNF

Entity/Relationship Model

- modelling approach
  - Chen 1976
- components
  - entities
  - properties
  - relationships

Entities

Definition
entity:
set of "things" with the same attributes

- elements of the set are *instances* of the entity
- *strong*: can exist by itself
- *weak*: existence depends on another entity

Entity Examples

Example

- entity: movie, director, actor
- instance: Johnny Depp
- strong entity: director
- weak entity: movie

Properties

Definition
property:
data describing entities or relationships

- simple / composite
- key
- single / multiple valued
- empty
- base / derived

Property Examples

Example

- property: title, country, language
- simple: first name, last name
- composite: full name
- base: date of birth
- derived: age

Relationships

Definition
relationship:
connections between entities

- *participant*: entities in the relationship
- *degree*: number of participants
- *total* / *partial*: all instances of the entity do / don't participate in the relationship

Relationship Types

- *one-to-one*
- *one-to-many* or *many-to-one*
- *many-to-many*

Relationship Examples

Example (one-to-one)

- marriage

Example (one-to-many)

- director-movie

Example (many-to-many)

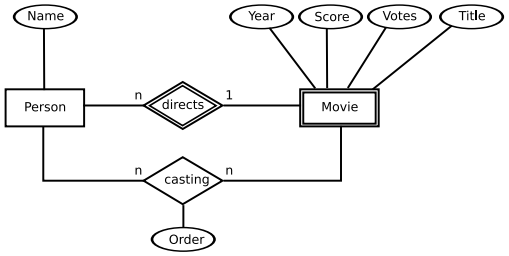
- actor-movie

Entity/Relationship Diagrams

- entity: rectangle
  - weak: double lines
- property: ellipsis
  - derived: dashed lines
  - multi-valued: double lines
  - composite: sub-ellipses
- relationship: diamond
  - between weak and strong: double lines
  - total: connection double lines
  - 1 or n depending on the type of the relationship

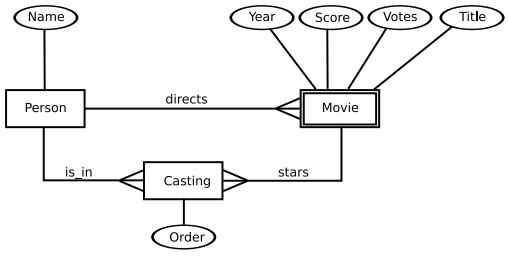
Entity/Relationship Diagram Example

Example



Entity/Relationship Diagram Example

Example



Applying to Design

- every entity a relation
- every property an attribute
- every many-to-many relationship a relation
  - foreign keys to participating entities
- for every many-to-one relationship a foreign from the "many" side to the "one" side

References

Required text: Date

- Chapter 14: Semantic Modeling