Database Management Systems

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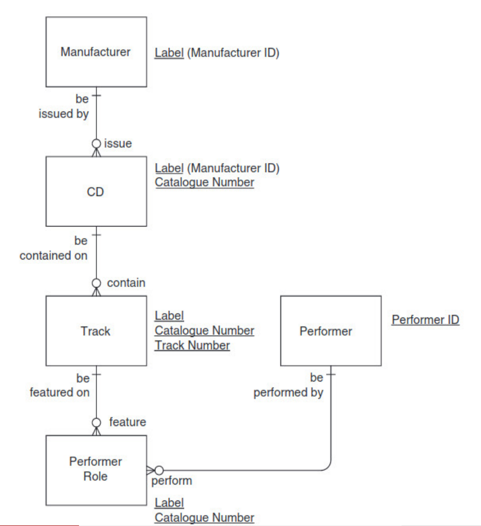
Structured Keys

Keys made up of more than one attribute



Weak Entity Sets - 01

Definition

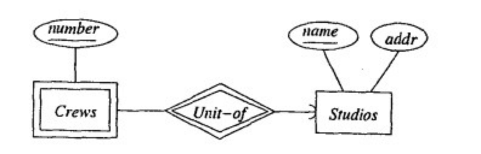
An entity set's key is composed of attributes some or all of which belong to another entity set.

Causes

- When entity sets fall into a hierarchy based on classifications unrelated to the "isa hierarchy"
- Connecting entity sets as a way to eliminate multiway (d-ary) relationships. Entity sets have no attributes of their own

Weak Entity Sets - 02

Example



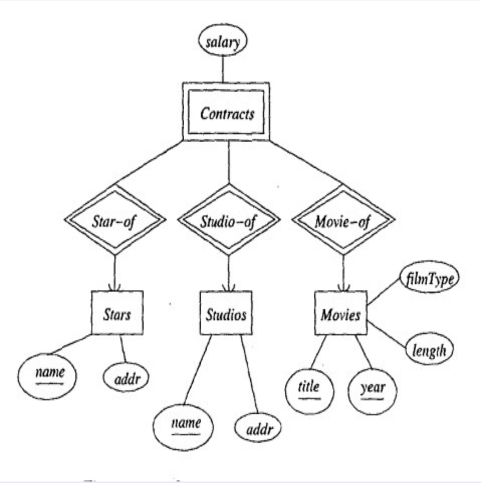
Weak Entity Sets - 03

Example

Studio		Crew
Studio name	Studio address	Number
ABC	123, XYZ1	1
ABC	123, XYZ1	2
ABC	123, XYZ1	3
EFG	124, XYZ2	1
EFG	124, XYZ2	2
EFG	124, XYZ2	3

Weak Entity Sets - 04

Example



Weak Entity Sets - 05

Requirements

- Cannot obtain key attributes for an entity set
- If E is a weak entity set then its key consists of
- Zero or more of its own attributes
- Key attributes from entity sets that are reached by certain many-to-one relationships from E to other entity sets.

Weak Entity Sets - 06

Requirements

- Let $R : E \rightarrow F$
- R must be a binary, many-to-one relationship from E to F
- R must have referential integrity from E to F
- Attributes of F supplies for the key of E must be key attributes of F
- If F itself is weak, then some or all of the key attributes of F supplied to E will be key attributes of one or more entity sets of G to which F is connected

Functional Dependencies

Overview

- Relational designs can be produced in multiple ways
- Regardless of how they are produced, it is possible to improve designs systematically
- Improvements are based on certain types of constraints
- Most important type of constraint is unique-value constraint
- Known as functional dependency (FD)
- Knowledge of this type of constraint is vital for re-design of database schemas
- They eliminate redundancy

Functional Dependencies

Definition - 01

A *functional dependency* (FD) on a relation R is a statement of the form: If two tuples of R agree on attributes $A_1, A_2, \cdots, A_n$ then they must agree on another attribute B

Functional Dependencies

what is agreeing?

Two tuples have same values in their respective components for each of the attributes.

Functional Dependencies

what is agreeing?

- Let t_1 and t_2 be two tuples
- Let $t_1[A_1]$ denote value of attribute A_1 in tuple t_1
- Then the following holds for agreeing $t_1[A_1] = t_2[A_1], t_1[A_2] = t_2[A_2], \cdots, t_1[A_n] = t_2[A_n]$
- This FD is written as: $A_1 A_2 \cdots A_n \rightarrow B$
- Pronounced as $A_1 A_2 \cdots A_n$ functionally determines B

Functional Dependencies

Definition - 02

- Let R be a relational scheme
- Let $X \subseteq R$ and $Y \subseteq R$
- We say relational instance $r(R)$ satisfies *a* functional dependency $X \rightarrow Y$
- If for *every pair* of tuples $t_1 \in r$ and $t_2 \in r$, if $t_1[X] = t_2[X]$ then $t_1[Y] = t_2[Y]$

Legal instance

Definition

An instance r of relational scheme R is a legal instance if it is a true reflection of the mini-world facts it represents.
That is r satisfies all constraints imposed on it in the real world

Valid FD

Definition

- Let R be a relational scheme
- Let $X \subseteq R$ and $Y \subseteq R$
- The FD: $X \rightarrow Y$ is valid if every legal instance $r(R)$ satisfies $X \rightarrow Y$

Armstrong's Axioms - 01

Reflexivity

If $Y \subseteq X$ then, $X \rightarrow Y$.

Armstrong's Axioms - 01

Reflexivity

That is: if $A_1 A_2 \cdots A_n \rightarrow B_1 B_2 \cdots B_m$ then B's are subset of the A's

Armstrong's Axioms - 02

Augmentation

If $X \rightarrow Y$, then $XZ \rightarrow YZ$

Armstrong's Axioms - 03

Transitivity

- If $X \rightarrow Y$ and $Y \rightarrow Z$ then
- $X \rightarrow Z$

Armstrong's Axioms - 04

Additional Rules of Inference - Union

If $X \rightarrow Y$ and $X \rightarrow Z$ then $X \rightarrow YZ$

1. $X \rightarrow Y$ is given

Armstrong's Axioms - 04

Additional Rules of Inference - Union

If $X \rightarrow Y$ and $X \rightarrow Z$ then $X \rightarrow YZ$

1. $X \rightarrow Y$ is given
2. $X \rightarrow Z$ is given

Armstrong's Axioms - 04

Additional Rules of Inference - Union

If $X \rightarrow Y$ and $X \rightarrow Z$ then $X \rightarrow YZ$

1. $X \rightarrow Y$ is given
2. $X \rightarrow Z$ is given
3. $XZ \rightarrow YZ$ (Augment 1 by Z)

Armstrong's Axioms - 04

Additional Rules of Inference - Union

If $X \rightarrow Y$ and $X \rightarrow Z$ then $X \rightarrow YZ$

1. $X \rightarrow Y$ is given
2. $X \rightarrow Z$ is given
3. $XZ \rightarrow YZ$ (Augment 1 by Z)
4. $X \rightarrow XZ$ (Trivial; Augment 2 by X)

Armstrong's Axioms - 04

Additional Rules of Inference - Union

If $X \rightarrow Y$ and $X \rightarrow Z$ then $X \rightarrow YZ$

1. $X \rightarrow Y$ is given
2. $X \rightarrow Z$ is given
3. $XZ \rightarrow YZ$ (Augment 1 by Z)
4. $X \rightarrow XZ$ (Trivial; Augment 2 by X)
5. $X \rightarrow YZ$ (Transitivity using 4 and 3)

Armstrong's Axioms - 05

Additional Rules of Inference - Decomposition

If $X \rightarrow YZ$ then $X \rightarrow Y$ AND $X \rightarrow Z$

1. $X \rightarrow YZ$ is given

Armstrong's Axioms - 05

Additional Rules of Inference - Decomposition

If $X \rightarrow YZ$ then $X \rightarrow Y$ AND $X \rightarrow Z$

1. $X \rightarrow YZ$ is given
2. $YZ \rightarrow Y$ (Reflexivity)

Armstrong's Axioms - 05

Additional Rules of Inference - Decomposition

If $X \rightarrow YZ$ then $X \rightarrow Y$ AND $X \rightarrow Z$

1. $X \rightarrow YZ$ is given
2. $YZ \rightarrow Y$ (Reflexivity)
3. $X \rightarrow Y$ (Transitivity)

Armstrong's Axioms - 05

Additional Rules of Inference - Decomposition

If $X \rightarrow YZ$ then $X \rightarrow Y$ AND $X \rightarrow Z$

1. $X \rightarrow YZ$ is given
2. $YZ \rightarrow Y$ (Reflexivity)
3. $X \rightarrow Y$ (Transitivity)

1. $X \rightarrow YZ$ is given

Armstrong's Axioms - 05

Additional Rules of Inference - Decomposition

If $X \to YZ$ then $X \to Y$ AND $X \to Z$

1. $X \to YZ$ is given
2. $YZ \to Y$ (Reflexivity)
3. $X \to Y$ (Transitivity)

1. $X \to YZ$ is given
2. $YZ \to Z$ (Reflexivity)

Armstrong's Axioms - 05

Additional Rules of Inference - Decomposition

If $X \rightarrow YZ$ then $X \rightarrow Y$ AND $X \rightarrow Z$

1. $X \rightarrow YZ$ is given
2. $YZ \rightarrow Y$ (Reflexivity)
3. $X \rightarrow Y$ (Transitivity)

1. $X \rightarrow YZ$ is given
2. $YZ \rightarrow Z$ (Reflexivity)
3. $X \rightarrow Z$ (Transitivity)

Armstrong's Axioms - 06

Additional Rules of Inference - Composition

If $X \rightarrow Y$ and $A \rightarrow B$ then $XA \rightarrow YB$

1. $X \rightarrow Y$ (given)

Armstrong's Axioms - 06

Additional Rules of Inference - Composition

If $X \rightarrow Y$ and $A \rightarrow B$ then $XA \rightarrow YB$

1. $X \rightarrow Y$ (given)
2. $A \rightarrow B$ (given)

Armstrong's Axioms - 06

Additional Rules of Inference - Composition

If $X \rightarrow Y$ and $A \rightarrow B$ then $XA \rightarrow YB$

1. $X \rightarrow Y$ (given)
2. $A \rightarrow B$ (given)
3. $XA \rightarrow YA$ (Augmentation of 1 with A)

Armstrong's Axioms - 06

Additional Rules of Inference - Composition

If $X \rightarrow Y$ and $A \rightarrow B$ then $XA \rightarrow YB$

1. $X \rightarrow Y$ (given)
2. $A \rightarrow B$ (given)
3. $XA \rightarrow YA$ (Augmentation of 1 with A)
4. $XA \rightarrow Y$ Decomposition of 3 (and $XA \rightarrow A$)

Armstrong's Axioms - 06

Additional Rules of Inference - Composition

If $X \rightarrow Y$ and $A \rightarrow B$ then $XA \rightarrow YB$

1. $X \rightarrow Y$ (given)
2. $A \rightarrow B$ (given)
3. $XA \rightarrow YA$ (Augmentation of 1 with A)
4. $XA \rightarrow Y$ Decomposition of 3 (and $XA \rightarrow A$)
5. $XA \rightarrow XB$ (Augmentation of 2 with X)

Armstrong's Axioms - 06

Additional Rules of Inference - Composition

If $X \rightarrow Y$ and $A \rightarrow B$ then $XA \rightarrow YB$

1. $X \rightarrow Y$ (given)
2. $A \rightarrow B$ (given)
3. $XA \rightarrow YA$ (Augmentation of 1 with A)
4. $XA \rightarrow Y$ Decomposition of 3 (and $XA \rightarrow A$)
5. $XA \rightarrow XB$ (Augmentation of 2 with X)
6. $XA \rightarrow B$ Decomposition 5 (and $XA \rightarrow X$)

Armstrong's Axioms - 06

Additional Rules of Inference - Composition

If $X \rightarrow Y$ and $A \rightarrow B$ then $XA \rightarrow YB$

1. $X \rightarrow Y$ (given)
2. $A \rightarrow B$ (given)
3. $XA \rightarrow YA$ (Augmentation of 1 with A)
4. $XA \rightarrow Y$ Decomposition of 3 (and $XA \rightarrow A$)
5. $XA \rightarrow XB$ (Augmentation of 2 with X)
6. $XA \rightarrow B$ Decomposition 5 (and $XA \rightarrow X$)
7. $XA \rightarrow YB$ (Union 4 and 6)

Armstrong's Axioms - 07

Additional Rules of Inference - Pseudo Transitivity

If $X \rightarrow ZY$ and $Y \rightarrow W$ then $X \rightarrow ZW$

1. $X \rightarrow ZY$ (given)

Armstrong's Axioms - 07

Additional Rules of Inference - Pseudo Transitivity

If $X \rightarrow ZY$ and $Y \rightarrow W$ then $X \rightarrow ZW$

1. $X \rightarrow ZY$ (given)
2. $Y \rightarrow W$ (given)

Armstrong's Axioms - 07

Additional Rules of Inference - Pseudo Transitivity

If $X \rightarrow ZY$ and $Y \rightarrow W$ then $X \rightarrow ZW$

1. $X \rightarrow ZY$ (given)
2. $Y \rightarrow W$ (given)
3. $YZ \rightarrow ZW$ (Augmentation of 2 with Z)

Armstrong's Axioms - 07

Additional Rules of Inference - Pseudo Transitivity

If $X \rightarrow ZY$ and $Y \rightarrow W$ then $X \rightarrow ZW$

1. $X \rightarrow ZY$ (given)
2. $Y \rightarrow W$ (given)
3. $YZ \rightarrow ZW$ (Augmentation of 2 with Z)
4. $X \rightarrow ZW$ (Transitivity of 1 and 3)

Armstrong's Axioms - 08

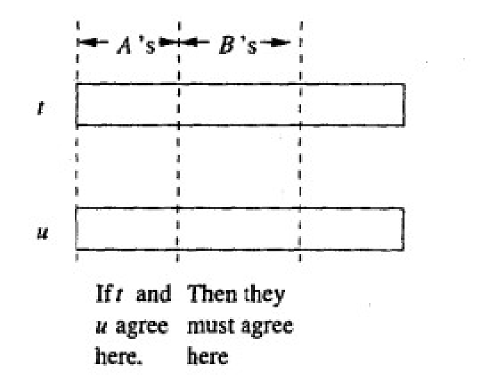
Additional Rules of Inference - Union (Extended)

$$\begin{array}{cccccc} A_1 & A_2 & \cdots & A_n & \rightarrow & B_1 \\ A_1 & A_2 & \cdots & A_n & \rightarrow & B_2 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ A_1 & A_2 & \cdots & A_n & \rightarrow & B_m \end{array}$$

Then we can say: $A_1 A_2 \cdots A_n \rightarrow B_1 B_2 \cdots B_m$

Armstrong's Axioms - 08

Additional Rules of Inference - Union (Extended)



Example - 01

Movies relation

- Let R be: `Movies(title, year, filmType, studioName, startName)`
- Let $r(R)$ be

title	year	length	filmType	studioName	starName
Star wars	1977	124	color	Fox	Carrie Fisher
Star wars	1977	124	color	Fox	Mark Hamill
Star wars	1977	124	color	Fox	Harrison Ford
Mighty Ducks	1991	104	color	Disney	Emilio Estevez
Wayne's world	1992	95	color	Paramount	Data Carvey
Wayne's world	1992	95	color	Paramount	Mike Meyers

Example - 02

Movies relation

The three FDs for the `Movies` relation are

- `title year` → length
- `title year` → filmType
- `title year` → studioName
- These three FDs satisfies every pair of $r(R)$
- `title year` → length filmType studioName

Example - 03

Movies relation

FD that do not satisfy every pair of tuples in $r(R)$ is `title year` $\rightarrow$ startName

Keys of Relations

Properties

Set of one or more attributes $\{A_1, A_2, \cdots, A_n\}$ is a key for relation R if the following holds

1. A_1 to A_n functionally determine all the other attributes of R
2. No proper subset of $\{A_1, A_2, \cdots, A_n\}$ functionally determines all other attributes of R. Satisfying minimal clause

Keys of Relations

Example Movies Relation

(title, year, starName) forms a key

1. Argue for functionally determines all other attributes
   - That is two tuples agrees on (title, year, starName), those tuples agree on (length, fileType, studioName)
   - title year $\rightarrow$ (length,filmType,studioName)

Keys of Relations

Example Movies Relation

(title, year, starName) forms a key

1. Argue for No proper subset ... Point
   - (title, year) do not determine startName
   - (year, starName) is not a key (first point violation)
   - (title, starName) is not a key (first point violation)

Super Keys

Definition

A set of attributes that contains a key is called a super key (super set of a key)

Discussion

- Every key is a super key
- However, some super keys are not (minimal) keys
- That is super key need not satisfy minimality

Discovering Keys for Relations

Thumb Rules

- If entity set is translated to a relation then key attributes of entity set are the key for the relation. Example: students
- (For binary relationships) If R is many-to-many, then keys of both connected entity sets are the key attributes of R. Example: grades(roll_number, cid, grd)
- If R is many-to-one from E_1 to E_2 then key attribute of E_1 are key attributes of R. Example: Employees works for department
- If R is one-to-one then the key attributes for either of the entity are key attributes of R

Rules About FD's - 01

Splitting & Combining

Given an FD of the form: $A_1A_2\cdots A_n \rightarrow B_1B_2\cdots B_m$

- Split the attributes on the right side so that only one attribute appears on right of every FD

$$\begin{array}{cccccc} A_1 & A_2 & \cdots & A_n & \rightarrow & B_1 \\ A_1 & A_2 & \cdots & A_n & \rightarrow & B_2 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ A_1 & A_2 & \cdots & A_n & \rightarrow & B_m \end{array}$$

- Likewise, replace a collection of FD's with common LHS by single FD

Rules About FD's - 02

Splitting & Combining - concise form

Splitting Rule Replace an FD of the form: $A_1A_2\cdots A_n \to B_1B_2\cdots B_m$ by
$A_1A_2\cdots A_n \to B_i$ for $i = 1, 2, \cdots m$

Rules About FD's - 02

Splitting & Combining - concise form

Splitting Rule Replace an FD of the form: $A_1 A_2 \cdots A_n \rightarrow B_1 B_2 \cdots B_m$ by
$A_1 A_2 \cdots A_n \rightarrow B_i$ for $i = 1, 2, \cdots m$

Combining Rule Replace set of FD's of the form $A_1 A_2 \cdots A_n \rightarrow B_i$ for
$i = 1, 2, \cdots m$ by $A_1 A_2 \cdots A_n \rightarrow B_1 B_2 \cdots B_m$

Rules About FD's - 03

Classification

An FD $A_1 A_2 \cdots A_n \rightarrow B_1 B_2 \cdots B_m$ is

Trivial if B's are a subset of A's. title year $\rightarrow$ title

Rules About FD's - 03

Classification

An FD $A_1 A_2 \cdots A_n \rightarrow B_1 B_2 \cdots B_m$ is

Trivial if B's are a subset of A's. title year $\rightarrow$ title

Non-trivial if at least one of the B's is not among the A's. title year $\rightarrow$ year length

Rules About FD's - 03

Classification

An FD $A_1 A_2 \cdots A_n \rightarrow B_1 B_2 \cdots B_m$ is

- **Trivial** if B's are a subset of A's. title year $\rightarrow$ title
- **Non-trivial** if at least one of the B's is not among the A's. title year $\rightarrow$ year length
- **Completely non-trivial** if none of the B's is also one of the A's. title year $\rightarrow$ length

Closure of Attributes

Definition

A general principle from which all rules follow

Closure of Attributes

Definition

- Let $\{A_1, A_2, \cdots, A_n\}$ be set of attributes
- S be a set of FD's
- closure of $\{A_1, A_2, \cdots, A_n\}$ denoted as $\{A_1, A_2, \cdots, A_n\}^+$ under FD's in S is
  - set of attributes B such that
  - every relation that satisfies all the FDs in S also satisfies $A_1 A_2 \cdots A_n \rightarrow B$

Closure of Attributes

Definition

That is $A_1 A_2 \cdots A_n \rightarrow B$ follows from the FDs of S

Closure of Attributes

Computation

Closer of $\{A_1, A_2, \cdots, A_n\}$ w.r.t. set of FD's S

1. Let X be set of attributes that will be become the closure. Initialize $X = \{A_1, A_2, \cdots, A_n\}$
2. Repeatedly search for some FD $B_1 B_2 \cdots B_m \rightarrow C$ such that all of $B_1 B_2 \cdots B_m$ are in X and $C \notin X$. $X = X \cup \{C\}$
3. Repeat step 2 until no more attributes can be added to X
4. The resulting set X is the $\{A_1, A_2, \cdots, A_n\}^+$

Closure of Attributes

Computation

1. Let $R(A, B, C, D, E, F)$ be a relation
2. R satisfies the set of FDs
   $\{\mathrm{AB} \rightarrow \mathrm{C}, \mathrm{BC} \rightarrow \mathrm{AD},$
   $\mathrm{D} \rightarrow \mathrm{E}, \mathrm{CF} \rightarrow \mathrm{B}\}$
3. Compute $\{A, B\}^+$

Closure of Attributes

Computation

1. $X = \{A, B\}$
2. $\{AB \rightarrow C\}$ satisfies step 2
3. Therefore add C to X. That is $X = \{A, B, C\}$
4. $\{BC \rightarrow AD\}$ satisfies step 2
5. Therefore add D to X. $X = \{A, B, C, D\}$ (A is already present in X)
6. $\{D \rightarrow E\}$ satisfies step 2
7. Therefore add E to X. $X = \{A, B, C, D, E\}$
8. $\{CF \rightarrow F\}$ does not satisfies step 2
9. $\{A, B\}^+ = \{A, B, C, D, E\}$