Assignment Project Exam Help

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Functional Dependency

A “good” database schema should not lead to *update anomalies*.

- update anomalies,
- functional dependencies,
- Armstrong Axioms,
- closures.

Update Anomalies

Redundancy in a database means storing a piece of data more than once.

Redundancy is often useful for efficiency and semantic reasons, but creates the potential for consistency problems.

A poor *redundancy* ... alies.

Consider the example relation below ... “An Introduction to Database Systems” by Desai):

STUDENTS					
Name	Course	Phone_no	Major	Prof	Grade
Jones	353	237-4539	Comp Sci	Smith	A
Ng	329	427-7390	Chemistry	Turner	B
Jones	328	237-4539	Comp Sci	Clark	B
Martin	456	388-5183	Physics	James	A
Dulles	293	371-6259	Decision Sci	Cook	C
Duke	491			Lamb	B
Duke	356			Bond	UN
Jones	492	237-4539		Cross	UN
~~Baxter~~	~~379~~	~~839-0827~~		~~Broes~~	~~C~~

Modification anomalies: e.g. Jones's phone number appears 3 times. When a phone number is changed, it must be changed in all 3 places, or the data will be inconsistent.

Update Anomalies

Insertion anomalies:

- If Jones enrolls in another course, and a different phone number is entered, again the data will be inconsistent.

- Also, if the n between course and professor is stored in this relation, we the association when someone enrolls in the course.

Deletion anomalies: If the last student in a course is deleted, the association between professor and course is lost.

Functional dependencies

A function *f* from S_1 to S_2 has the property

$$if\ x, y \in S_1 \text{ and } x = y, \text{then } f(x) = f(y)\,.$$

A generalization of keys to avoid design flaws violating the above rule.

Let X and Y be sets o

X (*functionally*) determines *Y*, $X \rightarrow Y$, iff plies $t_1[Y] = t_2[Y]$.

i.e., f (t(X)) = t [Y]

We also say $X \rightarrow Y$ is a *functional* dependency, and that Y is *functionally* dependent on X.

X is called the *left side*, Y the *right side* of the dependency.

Examples

- For every Name, there is a unique Phone_no and Major, assume Name is unique;
- For every Course, there is a unique Prof;
- For every Name and Course, there is a unique

Grade.

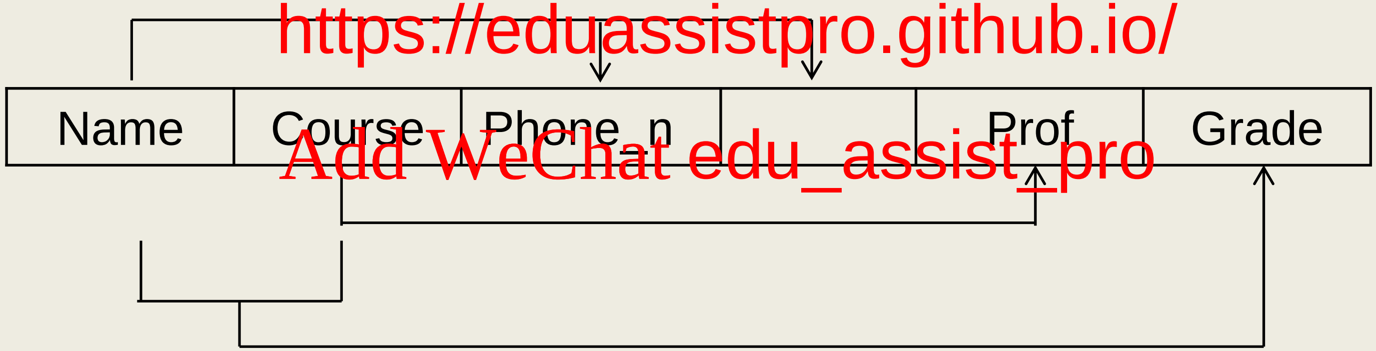
In this example:

$$\{Name\} \rightarrow \{Phone\_no\ ,\ Major\}$$

$$\{Course\} \rightarrow \{Prof\}$$

$$\{Name\ ,\ Course\} \rightarrow \{Grade\}$$

We can also show these in a diagram like this one:



Notice that other FD's follow from these:

$$\{Name\} \rightarrow \{Major\}$$

$$\{Course\ ,\ Grade\} \rightarrow \{Prof\ ,\ Grade\}$$

Functional dependencies

Let F be a set of FD's.

Definition 1: $X \to Y$ is inferred from F (or that F infers $X \to Y$), written in

$$F \models X \to Y$$

if any relation inst sfy $X \to Y$

Impossible to list every relation to ver inferred from F.

A set ρ of derivation rules are required, such that:

a $X \to Y$ is inferred from F according to Definition 1 iff it can be derived using ρ.

Armstrong's axioms (1974)

Notation: If X and Y are sets of attributes, we write XY for their union.

e.g. X = {A, B}, Y = {B, C}, XY = {A, B, C}

F1 (Reflexivity) If $X \supseteq Y$ then $X \rightarrow Y$.

F2 (Augmentation

F3 (Transitivity) $\{X \rightarrow Y, Y \rightarrow Z\} \models$

F4 (Additivity) $\{X \rightarrow Y, X \rightarrow Z\} \models X \rightarrow YZ$.

F5 (Projectivity) $\{X \rightarrow YZ\} \models X \rightarrow Y$.

F6 (Pseudotransitivity) $\{X \rightarrow Y, YZ \rightarrow W\} \models XZ \rightarrow W$.

Example: Given F = $\{A \rightarrow B, A \rightarrow C, BC \rightarrow D\}$, derive $A \rightarrow D$:

1. $A \rightarrow B$ (given)

2. $A \rightarrow C$ (given)

3. $A \rightarrow BC$ (by F4, from 1 and 2)

4. B

5. $A \rightarrow D$ (by F3, from

F4 (Additivity) $\{X \rightarrow Y, X \rightarrow Z\} \models X \rightarrow YZ$.

F5 (Projectivity) $\{X \rightarrow YZ\} \models X \rightarrow Y$.

F6 (Pseudotransitivity) $\{X \rightarrow Y, YZ \rightarrow W\} \models XZ \rightarrow W$.

In fact, F4, F5, and F6 can be derived from F1-F3.

Example: Prove $\{X$

1) $X \rightarrow Y$ is given.

2) $XX \rightarrow XY$ (by F2); that is, $X \rightarrow XY$

3) $X \rightarrow Z$ is given.

4) $XY \rightarrow YZ$ (by F2)

5) $X \rightarrow YZ$ (by F3, 2) and 4))

Armstrong's axioms

We can prove that Armstrong's axioms are sound and complete:

Sound: if F derives $A \rightarrow B$ by using Armstrong's axioms, then F |= $A \rightarrow$ B by Definition 1..

Complete: if F |= derives $M \rightarrow N$ by

using Armstrong'

Algorithm to Check a FD

Given F, how do we check if $X \rightarrow Y$ is in F^+?

F^+ denotes the smallest set of FD's that

- contains F,

- is *closed* un

F^+ is the *closure* of F.

$F = \{ A \rightarrow B, B \rightarrow C, A \rightarrow C \}$

$F^+ = \{AB \text{ -> } A, AB \text{ -> } B, AB \text{ -> } C, AC \text{ -> } A, AC \text{ -> } B,$
$AC \text{ -> } C, ABC \text{ -> } A, ABC \text{ -> } B, ABC \text{ -> } C, AB \text{ -> } AB,$
$AB \text{ -> } BC, AB \text{ -> } AC, \ldots\ldots\}$

F^+ always has an |F|.

Too expensive to compute F^+ to verify a membership.

Instead we can compute the *closure* X^+ of X under F, X^+ is the largest set of attributes functionally determined by X.

It can be proven (using

S1:

S2: $\boxed{X \rightarrow Y \in F^+ \text{ iff (if and only if) } Y \subseteq X^+.}$

Example:

$F = \{ A \rightarrow B, BC \rightarrow D, A \rightarrow C \}$, compute $\{A\}^+$

1st scan of F:

$X^+ := \{A\}$

$X^+ := \{A, B\}$

$X^+ := \{A, B, C\}$

2nd scan of F:

$X^+ := \{A, B, C,$

3rd scan of F: no change, therefore t rminates.

$\{A\}^+ := \{A, B, C, D \}$

Algorithm to compute X^+

$X^+ := X$;

change := true;

while change do

  begin

  change := false;

  for each F

    b

    if ($W \subseteq X^+$) and ($Z \not\subseteq$

      begin

      $X^+ := X^+ \cup Z$;

      change := true;

      end

    end

  end

Algorithm to Compute a Candidate Key

Given a relational schema R and a set F of functional dependencies on R.

A key X of R must have the property that $X^+ = R$.

Algorithm to compute a candidate key

Step 1: Assign

Step 2: Iteratively remove attributes retaining the property $X^+ =$ R till no reduction on X.

The remaining X is a key.

Example:

R = {A, B, C, D} and F = { A → B, BC → D, A → C }

X = {A, B, C} if the left hand side of F is a super key.

A cannot be removed because $\{BC\}^+ = \{B, C, D\} \neq R$

B can be remo B, C, D} = R

→ X = { A, C}

C can be further removed because $\{A\}^+ = \{A, B, C, D\}$

→ X = {A}