IT360: Applied Database Systems

Slide Set: #10

Normalization
(Chapters 3, 4 in Kroenke)

Database Design Process

- Requirements analysis
- Conceptual design → data model
- Logical design
- Schema refinement: Normalization
- Physical tuning

Today's Outline

- Modification Anomalies
- Functional Dependencies
- Normal Forms (1NF, 2NF, 3NF,BCNF, 4NF)
- Normalization

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Premise

- We have one or more tables with data
- The data is to be stored in a new database
- QUESTION: keep or change tables structure?

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Data Redundancy

Number	LastName	FirstName	Email	Company	CompanyOfficer
190	Smith	John	jsmith@usna.edu	12	LT Berge
673	Doe	Jane	jdoe@usna.edu	7	LT Madison
312	Doe	Bob	bred@usna.edu	6	LT Mean
152	Johnson	Matt	mat@usna.edu	7	LT Madison

Rule:

All mids with same Company have the same CompanyOfficer
(Company→ CompanyOfficer)

Problems due to data redundancy?

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Modification Anomalies

- **Deletion Anomaly**: lose more than intended
  - What if we delete all mids in Company 7? (we lose info about CompanyOfficer)
- **Insertion Anomaly**: need to insert more than intended
  - What if we want to record the fact the CompanyOfficer for Company 31 is LT New? (need to have a student in that company)
- **Update Anomaly**: inconsistencies due to updates of some but not all rows
  - What if we change the CompanyOfficer for Company 7 to be LT Derek for only one row?

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Update Anomalies

- The MID table before and after an incorrect update operation on CompanyOfficer for Company = 7

Number	LastName	FirstName	Email	Company	CompanyOfficer
190	Smith	John	jsmith@usna.edu	12	LT Berge
673	Doe	Jane	jdoe@usna.edu	7	LT Madison
312	Doe	Bob	bred@usna.edu	6	LT Mean
152	Johnson	Matt	mat@usna.edu	7	LT Madison

Number	LastName	FirstName	Email	Company	Wing
190	Smith	John	jsmith@usna.edu	12	LT Berge
673	Doe	Jane	jdoe@usna.edu	7	LT Derek
312	Doe	Bob	bred@usna.edu	6	LT Mean
152	Johnson	Matt	mat@usna.edu	7	LT Madison

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Table decomposition

Number	LastName	FirstName	Email	Company	CompanyOfficer
190	Smith	John	jsmith@usna.edu	12	LT Berge
673	Doe	Jane	jdoe@usna.edu	7	LT Madison
312	Doe	Bob	bred@usna.edu	6	LT Mean
152	Johnson	Matt	mat@usna.edu	7	LT Madison

Number	LastName	FirstName	Email	Company
190	Smith	John	jsmith@usna.edu	12
673	Doe	Jane	jdoe@usna.edu	7
312	Doe	Bob	bred@usna.edu	6
152	Johnson	Matt	mat@usna.edu	7

Company	CompanyOfficer
6	LT Mean
7	LT Madison
12	LT Berge

Disadvantage?

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Decisions

- Do we have to decompose / merge?

- How do we identify problems caused by redundancy?
  - Functional dependencies

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Functional Dependency (FD)

- X → Y (X *determines* Y)
  - If same value for X then same value for Y
- Examples:
  - Any primary key determines all the other columns
    - Alpha → (Name, Class, DateOfBirth)
  - EmployeeRating → Wage
  - (NbHours, HourlyPrice)→Charge

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Functional Dependency (FD) Rules (some are Armstrong's Axioms)

Let A, B, C be sets of attributes

- A → (B, C) if and only if A → B and A→ C
- Always, A→A (reflexivity)
- If A →B and B→C, then A→C (transitivity)
- If A →B, and C is a set of attributes, then (A,C)→(B,C) (augmentation)

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FD Facts

- A functional dependency is a statement about *all allowable* instances of a table
- You cannot find the functional dependencies simply by looking at some data:
  - Data set limitations
  - Must be logically a determinant
- Given some data in a table R, we can check if it *violates* some FD, but we cannot tell if the FD *holds* over R!

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Functional Dependencies in the MIDSHIPMAN Table

Assuming data is representative, determine the FD

Alpha	LastName	FirstName	Major	Advisor
111342	Thomas	Sarah	IEA	Lewis
112368	Smith	John	IFP	Jones
116644	Mikalson	Michael	IFA	Skapanski
117862	Doe	Jane	IFA	Skapanski
123116	Doe	Bob	IFP	Lefferton
120908	Johnson	John	IFP	Jones
121198	Thomas	Thomas	IEA	Lewis
129722	Jefferson	Janet	IFP	Lefferton
129832	Thomas	Sarah	IFP	Lefferton

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Functional Dependencies in the MIDSHIPMAN Table

Alpha → (LastName, FirstName, Major, Advisor)

Advisor → Major

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What Makes Determinant Values Unique?

- A determinant is unique in a relation if, and only if, it determines every other column in the relation

- Unique determinants = superkey

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Key

- A set of columns is a key for a relation if :
  1. a) No two distinct rows can have same values in all key columns

     or equivalently

     b) determines all of the other columns in a relation

  2. This is not true for any subset of the key

- Candidate key = key
- Primary key, Alternate key

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Normal Forms

- Relations are categorized as a **normal form** based on which modification anomalies or other problems that they are subject to:

Source of Anomaly	Normal Forms	Design Principles
Functional dependencies	1NF, 2NF, 3NF, BCNF	BCNF: Design tables so that every determinant is a candidate key
Multivalued dependencies	4NF	4NF: Move each multivalued dependency to a table of its own
Data constraints and oddities	5NF, DK/NF	DK/NF: Make every constraint a logical consequence of candidate keys and domains

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Normal Forms

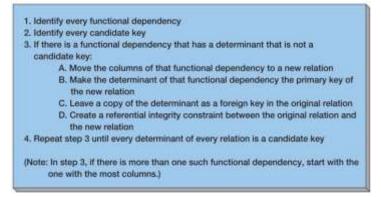| Number	Last Name	First Name	Email	Company	Wing
190	Smith	John	jsmith@usna.edu	12	2
673	Doe	Jane	jdoe@usna.edu	7	4
312	Doe	Bob	bred@usna.edu	6	6
152	Johnson	Matt	mat@usna.edu	7	4

- **1NF:** A table that qualifies as a relation is in 1NF

- **2NF**: 1NF + all non-key attributes depend on <u>all</u> PK

- **3NF**: 2NF + (every determinant is a (super) key or determinee is part of key)

- **Boyce-Codd Normal Form (BCNF)** : A relation is in BCNF if every determinant is a (candidate) key

  "I swear to construct my tables so that all nonkey columns are dependent on the key, the whole key and nothing but the key, so help me Codd."

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Eliminating Modification Anomalies from Functional Dependencies in Relations

- Put all relations into Boyce-Codd Normal Form (BCNF):

1. Identify every functional dependency
2. Identify every candidate key
3. If there is a functional dependency that has a determinant that is not a candidate key:
   - A. Move the columns of that functional dependency to a new relation
   - B. Make the determinant of that functional dependency the primary key of the new relation
   - C. Leave a copy of the determinant as a foreign key in the original relation
   - D. Create a referential integrity constraint between the original relation and the new relation
4. Repeat step 3 until every determinant of every relation is a candidate key

(Note: In step 3, if there is more than one such functional dependency, start with the one with the most columns.)

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Putting a Relation into BCNF: ASSIGNMENT_GRADES

Alpha	Assignment	Points	PointsTotal
129722	QUIZ1	10	10
129722	QUIZ2	2.5	10
129722	QUIZ3	2	20
122422	QUIZ1	6	10
122422	QUIZ2	7	10
122422	QUIZ3	18	20
129936	QUIZ1	6	10
129936	QUIZ2	8	10
129936	QUIZ3	20	20

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Putting a Relation into BCNF: ASSIGNMENT_GRADES

ASSIGNMENT_GRADES (Alpha, Assignment, Points, PointsTotal)

(Alpha, Assignment) → (Points, PointsTotal)
Assignment → (PointsTotal)

ASSIGNMENT (Assignment, PointsTotal)
GRADES (Alpha, Assignment, Points)

Where GRADES.Assignment must exist in ASSIGNMENT.Assignment

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Putting a Relation into BCNF: New Relations

Alpha	Assignment	Points
129722	QUIZ1	10
129722	QUIZ2	2.5
129722	QUIZ3	2
122422	QUIZ1	6
122422	QUIZ2	7
122422	QUIZ3	18
129936	QUIZ1	6
129936	QUIZ2	8
129936	QUIZ3	20

Assignment	PointsTotal
QUIZ1	10
QUIZ2	10
QUIZ3	20

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Redundancy Example

- PartKit →→ Part, PartKit→ Price

PartKit	Part	Price
Bike Repair	Wrench	14.95
Bike Repair	Screwdriver	14.95
Bike Repair	Tube Fix	14.95
Vice	Vice Jaw	125.00
Vice	Handle	125.00
Vice	Extension Screw	125.00
First Aid	Bandaids	24.95
First Aid	Aspirin	24.95
First Aid	Elastic Band	24.95
First Aid	Ibprofin	24.95

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Multivalued Dependencies

Employee →→ Degree

Employee	Degree
Jones	BS
Jones	AA
Greene	PhD
Greene	MS
Greene	BS
Chau	BS

PartKit →→ Part

PartKit	Part
Bike Repair	Wrench
Bike Repair	Screwdriver
Bike Repair	Tube Fix
Vice	Vice Jaw
Vice	Handle
Vice	Extension Screw
First Aid	Bandaids
First Aid	Aspirin
First Aid	Elastic Band
First Aid	Ibprofin

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Eliminating Anomalies from Multivalued Dependencies

- Multivalued dependencies are not a problem if they are in a separate relation, so:
  - Always put multivalued dependencies into their own relation
  - This is known as **Fourth Normal Form (4NF)**

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Normalize or Not?

Customer(CustID, Name, City, State, Zip)

- Assuming that city and state determine zip code, is Customers table in BCNF?
- If Customers table is not in BCNF, would you or would you not normalize it to BCNF? Give one reason for the choice you make

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Class Exercise

- R(A, B, C, D, E, F)
  A→(B,C,D,E,F)
  B→C
  (D,E)→F
- Is A a key? Why?
- Is R in BCNF? Why?
- If R not in BCNF, decompose to BCNF

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Class Exercise

ID	Name	University	MainCampus
1	John Smith	Cornell	Ithaca
2	John Smith	MIT	Boston
3	Matt Johnson	Ithaca College	Ithaca
4	Chris Brown	USNA	Annapolis
5	Jane Doe	Cornell	Ithaca
6	Ric Crabbe	USNA	Annapolis

•Do these FDs hold? Why?
  •ID→University
  •Name→ID
  •University→MainCampus
  •MainCampus→Name

•Example of deletion anomaly?
•Example of insertion anomaly?
•Example of update anomaly?

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Summary

- Modification anomalies
- Functional dependency
  - $X \rightarrow Y$ (X *determines* Y)
  - Unique determinant $\Leftrightarrow$ (candidate) key

- 1NF – A table that qualifies as a relation is in 1NF
- Boyce-Codd Normal Form (BCNF) – A relation is in BCNF if every determinant is a (candidate) key
- 4NF – Multivalued dependencies are in a relation by themselves

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