L17
Normalization is a Good Idea

Administrivia

Midterms returned today!

Project Part 3 due **next Tuesday** March 29

Part 3 demos: March 28-April 1

Mentor should have contacted you

HW3: Available now; due April 5

Steps for a New Application

Requirements

what are you going to build?

Conceptual Database Design

pen-and-pencil description

Logical Design

formal database schema

Schema Refinement:

fix potential problems, normalization

Normalization

Physical Database Design

use sample of queries to optimize for speed/storage

Information Retrieval

A Relational Model of Data for Large Shared Data Banks

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Future users of large data banks must be protected from having to know how the data is organized in the machine (the internal representation). A prompting service which supplies such information is not a satisfactory solution. Activities of users at terminals and most application programs should remain unaffected when the internal representation of data is changed and even when some aspects of the external representation are changed. Changes in data representation will often be needed as a result of changes in query, update, and report

Redundancy is no good

Update/insert/delete anomalies. Wastes space

<u>sid</u>	name	address	hobby	cost
1	Eugene	amsterdam	trucks	$$
1	Eugene	amsterdam	cheese	$
2	Bob	40th	paint	$$$
3	Bob	40th	cheese	$
4	Shaq	florida	swimming	$

people have names and addrs
hobbies have costs
people many-to-many with hobbies
    What's primary key? sid? sid + hobby?

Anomalies (Inconsistencies)

Update Anomaly

change one address, need to change all

Insert Anomaly

add person without hobby?

not allowed? dummy hobby?

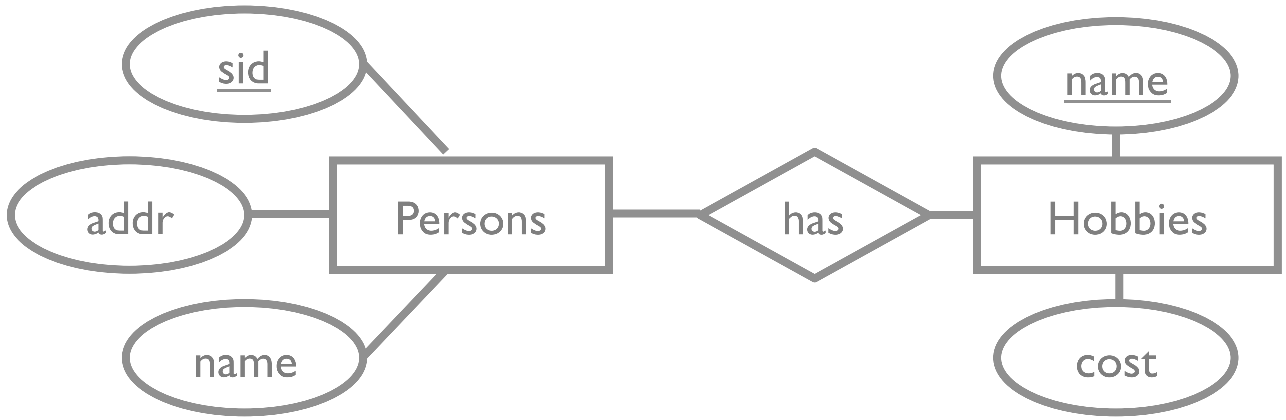
Delete Anomaly

if delete a hobby. Delete the person?

Theory Can Fix This!

A Possible Approach

ER diagram was a heuristic



We have decomposed example table into:

```
person(sid, addr, name)
hobby(name, cost)
personhobby(hobbyname, sid)
```

A Possible Approach

What if decompose into:

```
person(sid, name, address, cost)
personhobby(sid, hobbyname)
```

sid	name	address	cost
1	Eugene	amsterdam	$$
1	Eugene	amsterdam	$
2	Bob	40th	$$$
3	Bob	40th	$
4	Shaq	florida	$

sid	hobby
1	trucks
1	cheese
2	paint
3	cheese
4	swimming

but… which cost goes with which hobby?

lost information: *lossy decomposition*

Decomposition

Replace schema R with 2+ smaller schemas that

1. each contain subset of attrs in R
2. together include all attrs in R

ABCD replaced with AB, BCD or AB, BC, CD

Desirable properties

1. Lossless join: able to recover R from smaller relations
2. Dependency preserving: enforce constraints on by only enforcing constraints on smaller schemas (no joins)

Decomposition is a trade-off

Advantages:

- Eliminates possibility of data getting "out of sync"
- Make changes in one place that apply everywhere
- Access a sub-section of the data for some queries

Disadvantages

- If always need all data together, joins may be slower
- Less flexible because there is no redundancy

How can we systematically decompose relations to remove redundancy?

Functional Dependencies (FD)

sid	name	address	hobby	cost
1	Eugene	amsterdam	trucks	$$
1	Eugene	amsterdam	cheese	$
2	Bob	40th	paint	$$$
3	Bob	40th	cheese	$
4	Shaq	florida	swimming	$

sid sufficient to identify name and addr, but not hobby

e.g., exists a function f(sid) → name, addr

sid → name, addr is a functional dependency

"sid determines name, addr"

"name, addr are functionally dependent on sid"

"if 2 records have the same sid, their name and addr are the same"

Functional Dependencies (FD)

$X \rightarrow Y$

holds on R

if $t_1.X = t_2.X$ then $t_1.Y = t_2.Y$

where X,Y are subsets of attrs in R

Examples of FDs in person-hobbies table

sid → name, address

hobby → cost

sid, hobby → name, address cost

$X \rightarrow Y$ is a functional dependency

$$Y = f(X)$$

Fun Facts

Functional Dependency is an integrity constraint

- statement about all instances of relation
- Generalizes key constraints
  - if K is candidate key of R, then K → R

Given FDs, simple definition of redundancy

- when left side of FD is not table key

Where do FDs come from?

thinking really hard aka application semantics
can't stare at database to derive (like ICs)

Like a Mathematics conjecture:

one counter example can disprove, but examples can't prove there are no example in the universe

Where do FDs come from?

thinking really hard aka application semantics
can’t stare at database to derive (like ICs)

Like a Mathematics conjecture:

Functional Dependency Discovery:
An Experimental Evaluation of Seven Algorithms

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Normal Forms

Criteria met by a relation R wrt functional dependencies

Boyce Codd Normal Form (BCNF)

No redundancy, may lose dependencies

Third Normal Form (3NF)

May have redundancy, no decomposition problems

Redundancy depends on FDs

consider R(ABC)

no FDs: no redundancy

if $A \rightarrow B$: B is duplicated if there are multiple copies of A

BCNF

Relation R in BCNF has *no redundancy* wrt FDs

(only FDs are key constraints)

```
F: set of functional dependencies over relation R
X: Subset of attributes of R
A: One attribute of R
   for (X→A) in F
      A is in X OR
      X is a superkey of R
```

sid, hobby, name, addr, cost

H → C (hobby → cost)

S → NA

What's in BCNF?

<u>S</u>HNAC	NO
<u>S</u>NA, <u>S</u>HC	NO
<u>S</u>NA, <u>H</u>C, <u>S</u>H	YES

```
for (X→A) in F
   A is in X OR
   X is a superkey of R
```

BCNF

Relation R in BCNF has *no redundancy* wrt FDs

(only FDs are key constraints)

```
F: set of functional dependencies over relation R
   for (X→Y) in F
      Y is in X OR
      X is a superkey of R
```

Is this in BCNF?

sid → name

sid	hobby	name
x	y_1	z
x	y_2	?

Let's order pizza

One type of meat, cheese, and vegetable

Pizza	Topping	Type
1	Mozzarella	Cheese
1	Pepperoni	Meat
1	Olives	Vegetable
2	Mozzarella	Cheese
2	Sausage	Meat
2	Peppers	Vegetable

Key?   (Pizza, Type)

Pizza: Dependencies?

Pizza	Topping	Type
1	Mozzarella	Cheese
1	Pepperoni	Meat
1	Olives	Vegetable
2	Mozzarella	Cheese
2	Sausage	Meat
2	Peppers	Vegetable

Topping $\rightarrow$ Type

Pizza, Type $\rightarrow$ Topping

Is this in BCNF?

Pizza BCNF

Topping $\rightarrow$ Type

Pizza, Type $\rightarrow$ Topping

```
for (X→A) in F
   A is in X OR
   X is a superkey of R
```

Pizza BCNF

Topping → Type

Pizza, Type → Topping

```
for (X→A) in F
   A is in X OR
   X is a superkey of R
```

Pizza: Decomposition?

Pizza	Topping
1	Mozzarella
1	Pepperoni
1	Olives
2	Mozzarella
2	Sausage
2	Peppers

Topping	Type
Mozzarella	Cheese
Pepperoni	Meat
Olives	Vegetable
Sausage	Meat
Peppers	Vegetable

Topping $\rightarrow$ Type

Pizza, Type $\rightarrow$ Topping : Lost this dependency!

(In SQL: Can't enforce one topping type)

BCNF in general

Decomposition may not preserve dependencies

In practice: additional checks may be needed

e.g. join to enforce topping type constraint

3rd Normal Form (3NF)

Relax BCNF (e.g., BCNF ⊆ 3NF)

```
F: set of functional dependencies over relation R
     for (X→Y) in F
        Y is in X OR
        X is a superkey of R
```

3rd Normal Form (3NF)

Relax BCNF (e.g., BCNF ⊆ 3NF)

```
F: set of functional dependencies over relation R
      for (X→Y) in F
         Y is in X OR
         X is a superkey of R OR
         Y is part of a key in R
```

Is new condition trivial?   NO! key is minimal

Nice properties

lossless join ^ dependency preserving decomposition to 3NF always possible

Pizza: Dependencies?

Pizza	Topping	Type
1	Mozzarella	Cheese
1	Pepperoni	Meat
1	Olives	Vegetable
2	Mozzarella	Cheese
2	Sausage	Meat
2	Peppers	Vegetable

Topping $\rightarrow$ Type

Pizza, Type $\rightarrow$ Topping

Is this in 3NF?

Pizza: Dependencies?

Topping → Type

Pizza, Type → Topping

```
for (X→Y) in F
    Y is in X OR
    X is a superkey of R OR
    Y is part of a key in R
```

Victory! This is in 3rd Normal Form

(Topping determines part of a key)

Wait, what just happened?

- Redundancy is bad
- Functional dependencies (FD)
  - useful to find duplication
- BCNF: No redundancy permitted!
  - But may not be able to enforce FDs
- 3NF: Permits some duplication
  - Can always decompose into 3NF