CSE 344: Section 8
Design Theory

Aug 2nd, 2018

Big Idea "Measure Twice, Cut Once"

E/R is mostly a visualization technique

Poor schemas can lead to inconsistency and performance inefficiencies

Updating a schema is expensive

Identify functional dependencies and normalize to **make well-behaved and fast databases the first time**

Motivating Example

We want to store information about **people**
(Name, SSN, PhoneNumber, City)

Known properties:
- Each person may have multiple phones
- Each person lives in only one city

Motivating Example

Is this a good representation of **people**?

Name	SSN	PhoneNumber	City
Fred	123-45-6789	206-123-4567	Seattle
Fred	123-45-6789	206-890-1234	Seattle
Joe	987-65-4321	626-246-8024	Los Angeles

Motivating Example

Why is this a poor representation of **people**?

Name	SSN	PhoneNumber	City
Fred	123-45-6789	206-123-4567	Seattle
Fred	123-45-6789	206-890-1234	Seattle
Joe	987-65-4321	626-246-8024	Los Angeles

Anomalies:

- Redundancy (data for Fred is duplicated)
- Slow Updates (what if Fred moved to Oahu?)
- Zealous Deletion (what if Joe got rid of his phone?)

Motivating Example

Normalization!

Name	**SSN**	**PhoneNumber**	**City**
Fred	123-45-6789	206-123-4567	Seattle
Fred	123-45-6789	206-890-1234	Seattle
Joe	987-65-4321	626-246-8024	Los Angeles

Name	**SSN**	**City**
Fred	123-45-6789	Seattle
Joe	987-65-4321	Los Angeles

SSN	**PhoneNumber**
123-45-6789	206-123-4567
123-45-6789	206-890-1234
987-65-4321	626-246-8024

Motivating Example

Name	SSN	City
Fred	123-45-6789	Seattle
Joe	987-65-4321	Los Angeles

SSN	PhoneNumber
123-45-6789	206-123-4567
123-45-6789	206-890-1234
987-65-4321	626-246-8024

Anomalies are gone!

- Minimal Redundancy
- Fast Updates
- Precise Deletion

Functional Dependencies (FD)

https://courses.cs.washington.edu/courses/cse344/17au/lectures/6-conceptual-design.pdf

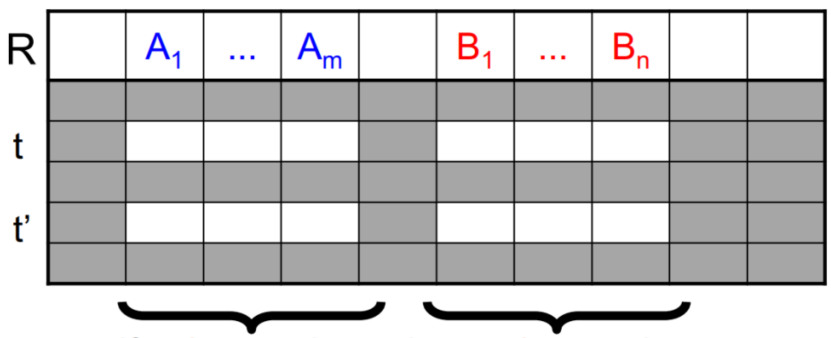
What is a Functional Dependency?

Formally:

Definition $A_1, \ldots, A_m \rightarrow B_1, \ldots, B_n$ **holds** in R if:

$\forall t, t' \in R,$

$(t.A_1 = t'.A_1 \wedge \ldots \wedge t.A_m = t'.A_m \rightarrow t.B_1 = t'.B_1 \wedge \ldots \wedge t.B_n = t'.B_n)$



if t, t' agree here then t, t' agree here

What is a Functional Dependency?

Informally:

An FD holds when some attributes imply other attributes

What is a Functional Dependency?

SSN -> Name ?

SSN -> Name, City ?

SSN -> Name, City, PhoneNumber ?

Name	<u>SSN</u>	<u>PhoneNumber</u>	City
Fred	123-45-6789	206-123-4567	Seattle
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What is a Functional Dependency?

SSN -> Name ?
Yes

SSN -> Name, City ?

SSN -> Name, City, PhoneNumber ?

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What is a Functional Dependency?

SSN -> Name ?
Yes

SSN -> Name, City ?
Yes

SSN -> Name, City, PhoneNumber ?
No

Name	SSN	PhoneNumber	City
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Finding FDs

Could be mapped from data… But usually, FDs should be established from prior knowledge about the data.

SSN -> Name

Name -> SSN

Name	<u>SSN</u>	<u>PhoneNumber</u>	City
Fred	123-45-6789	206-123-4567	Seattle
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Finding FDs

Could be mapped from data… But usually, FDs should be established from prior knowledge about the data.

SSN -> Name ✔

Name -> SSN true for now…

Name	SSN	PhoneNumber	City
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Fred	123-45-6789	206-890-1234	Seattle
Joe	987-65-4321	626-246-8024	Los Angeles

Closure Algorithm

Repeat until X doesn't change **do**:
  if $B_1, \ldots, B_n \rightarrow C$ is a FD **and**
    $B_1, \ldots, B_n$ are all in X
  then add C to X.

Goal: We want everything that an attribute/set of attributes determine

Observation:

If we have A -> B and B -> C, then A -> C

Closure Algorithm

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So really, A -> B and C

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Formal notation is $\{A\}^+ = \{A, B, C\}$

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Formal notation is $\{A\}^+ = \{A, B, C\}$

Since the closure of A is all attributes, A is a superkey

Keys

We call an attribute that determines all other attributes in a schema to be a **superkey**.

If it is the smallest set of attributes (in terms of cardinality) that does this we call that set a **minimal key** or just **key**

Anomalies

X -> Y in your table schema implies an anomaly UNLESS X is a (super)key

We deal with this by normalizing the schema (i.e. ripping apart tables until these anomalies are gone)

Boyce-Codd Normal Form (BCNF)

What is a “Normal Form”?

Goal of normal forms is to promote consistency, speed, ease of use, etc.

1st Normal Form: Tables are flat

2nd Normal Form: Obsolete

3rd Normal Form: See textbook for more details

BCNF (3.5 Normal Form): No bad FDs

What is BCNF?

Definition. A relation R is in BCNF if:

Whenever $X \rightarrow B$ is a non-trivial dependency, then X is a superkey.

=

Definition. A relation R is in BCNF if:

$\forall$ X, either $X^+ = X$ or $X^+ =$ [all attributes]

Example

Relation R : [Property_id (key), Country_name, Lot (key), Area]

Dependency: Property_id → {Country_name, Lot, Area}

{Country_name, Lot} → {Property_id, Area}

Area → Country_name

- R → BCNF?

Example

Relation R : [Property_id (key), Country_name, Lot (key), Area]

Dependency: Property_id → {Country_name, Lot, Area}

{Country_name, Lot} → {Property_id, Area}

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- R → BCNF? No.
- How to normalize?

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Dependency: Property_id → {Country_name, Lot, Area}

{Country_name, Lot} → {Property_id, Area}

Area → Country_name

- R → BCNF? No.
- How to normalize?

  [Property_id (key), Area, Lot (key)]

  [Area (key), country_name]

Practical Tips

Normalization is great for promoting consistency about current states

Fully normalized data can be hindering (think about joins). Denormalizing can bring back redundancy but improve performance in some cases.