CS 133: Databases

Fall 2019
Lec 21 – 11/21
Database Design
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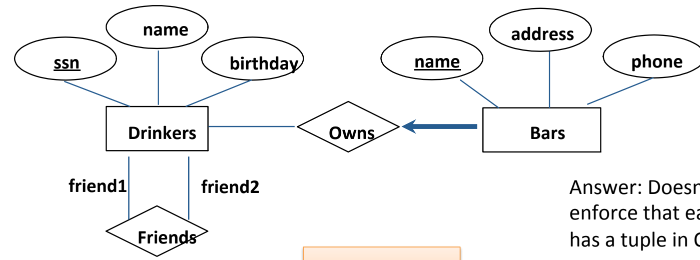
Warm-up Exercise

(See exercise sheet. You can start before class.)



Answer: Doesn't enforce that each Bar has a tuple in Owns.

NOT NULL ?

```
CREATE TABLE Owns
  ( ssn CHAR(11),
    bar_name CHAR(20),
    PRIMARY KEY (bar_name),
    FOREIGN KEY (ssn) REFERENCES Drinkers,
    FOREIGN KEY (bar_name) REFERENCES Bars(name))
```

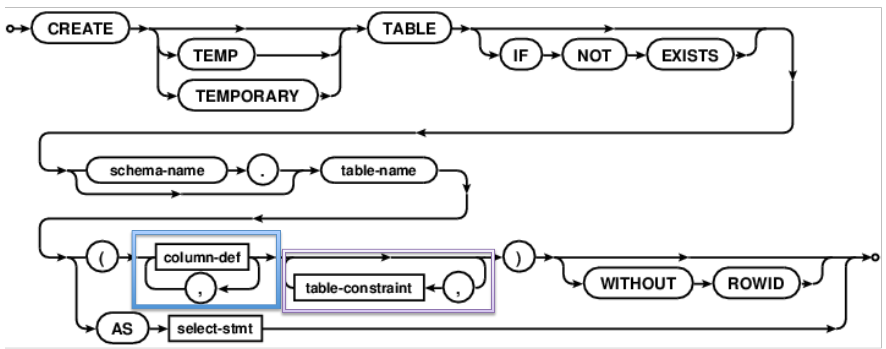
Goals for Today

- Understand the issues that can occur from a poorly designed relational schema
- Learn about the goals and process of *schema refinement*
- Discuss the role of *functional dependencies* in discovering and fixing issues in a design

Review: Database Design

- Requirements Analysis
  - user needs; what must database do?
- Conceptual Design
  - high level description (often done w/ER model)
- Logical Design
  - translate ER into DBMS data model
- Schema Refinement
  - consistency, normalization
- Physical Design - indexes, disk layout
- Security Design - who accesses what

Table and Column constraints (SQLite)

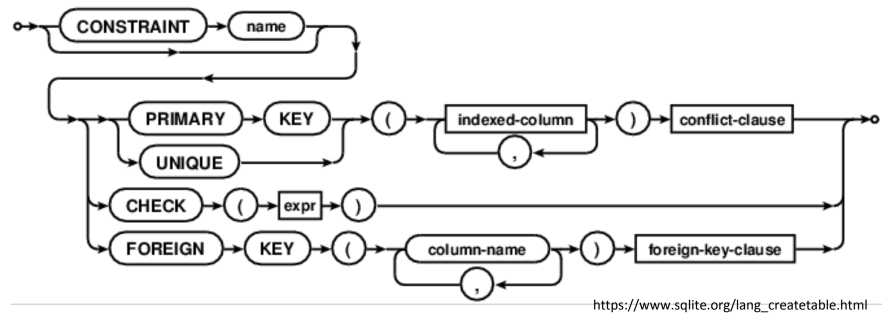


https://www.sqlite.org/lang_createtable.html

Table and Column constraints (SQLite)

- **Column definition**

- **Table constraint**



https://www.sqlite.org/lang_createtable.html

Examples: Create Table

```
CREATE TABLE Friends (
    friend1     VARCHAR(40),
    friend2     VARCHAR(40),
    PRIMARY KEY(friend1,friend2),
    CONSTRAINT notSame CHECK (friend1 <> friend2)
);
CREATE TABLE Bar_Owns(
     name       VARCHAR(40) PRIMARY KEY,
     address    VARCHAR(40) NOT NULL,
     phone      CHAR(12) DEFAULT "555-555-5555",
     owner      CHAR(11) NOT NULL,

    FOREIGN KEY owner REFERENCES Drinkers(ssn)
     ON DELETE NO ACTION
);
```

For cross-relation constraints, need assertion statement!

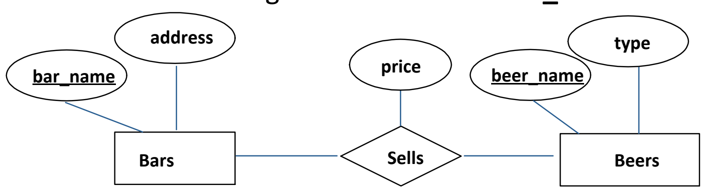
Triggers

- Trigger: procedure that starts automatically if specified changes occur to the DBMS
- Example, SQL:1999 syntax:

```
CREATE TRIGGER youngSailorUpdate
AFTER INSERT ON SAILORS
REFERENCING NEW TABLE NewSailors
FOR EACH STATEMENT
   INSERT
    INTO YoungSailors(sid, name, age, rating)
    SELECT sid, name, age, rating
    FROM NewSailors N
    WHERE N.age <= 18
```

Combos: Entities and Relationships

- For *one-to-many* relationship, **combining entity set and relationship set** into one relation helped us **capture participation constraint**
- What about combining **Bars** and **Sells** as **Bar_Sells**?



Schema Refinement

- Start with initial relational schema, either from scratch or from E/R modeling
- Schema refinement objective: ***could there be issues caused by data redundancy?***
- *Next*: why redundancy is "bad"

Example: Hourly_Emps

- Consider a relation obtained from Hourly_Emps:

Hourly_Emps (*ssn*, *name, lot, rating, wage_per_hr, hrs_per_wk*)

Note on notation: can denote a relation schema by listing its attributes, e.g., **SNLRWH**

→ the ***set*** of attributes {**S,N,L,R,W,H**}

- Assume we know, from application semantics,:
  - *ssn* uniquely identifies an employee (is a key)
  - An employee's ***rating*** determines their ***wage_per_hr***

Redundancy Problems

Hourly_Emps (instance)

S	N	L	R	W	H
123-22-3666	Attishoo	48	8	10	40
231-31-5368	Smiley	22	8	10	30
131-24-3650	Smethurst	35	5	7	30
434-26-3751	Guldu	35	5	7	32
612-67-4134	Madayan	35	8	10	40

Update anomaly: What if we change W in *this tuple only*?

Deletion anomaly: What if we delete all employees with rating 5?

Insertion anomaly: What if we want to insert an employee and don't know the hourly wage their rating? (or we get it wrong?)

Decomposing a Relation

- Redundancy can be removed by “chopping” the relation into pieces.

S	N	L	R	H
123-22-3666	Attishoo	48	8	40
231-31-5368	Smiley	22	8	30
131-24-3650	Smethurst	35	5	30
434-26-3751	Guldu	35	5	32
612-67-4134	Madayan	35	8	40

Hourly_Emps2

R	W
8	10
5	7

Wages

We’ll see how a type of *integrity constraint*, called **functional dependencies**, is used to drive this “chopping” process

Taming Schema Redundancy

- Integrity constraints, in particular ***functional dependencies***, can be used to identify schemas with problems and to **suggest refinements**
- Main refinement technique: *decomposition*
  - E.g., replacing ABCD (via **projection**) with:
    - AB and BCD, or
    - ACD and ABD, or
    - Etc.
- Decomposition should be used judiciously:
  - Is there reason to decompose a relation?
  - What problems (if any) does the decomposition cause?

Keys (Review)

- A set of fields is a candidate key (shortened as just key) for a relation if:
  1. No two distinct tuples can have the same values in *all* candidate key fields, and
  2. This is not true for any subset of the key’s attributes.

Q. Consider relation *R(**a**,**b**,c)*.
For a fixed setting of *a* and *b* values, how many different *c* values could there be?

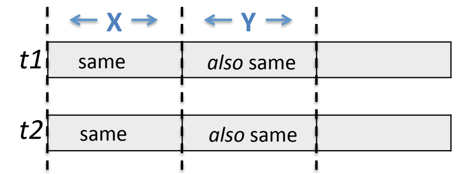
- A candidate key is **minimal**.

  If AB is a candidate key, then neither A nor B is a key on its own.
- A superkey is not necessarily minimal (although it could be)
  - If AB is a candidate key, then ABC, ABD, and even AB are superkeys.

Functional Dependencies

Can read “→” as “determines”

- Let **X** and **Y** be *sets of attributes* in a relation **R**
- A **functional dependency** (FD) has the form X → Y
- If two tuples in R have same values for all attributes in X, then they must **also** have same values for all attributes in Y



- (More formally): A functional dependency **X → Y** *holds* over relation schema R if, for every allowable instance *r* of R:

  $t1 \in r,\ t2 \in r,\ \pi_X(t1) = \pi_X(t2)$ **implies** $\pi_Y(t1) = \pi_Y(t2)$

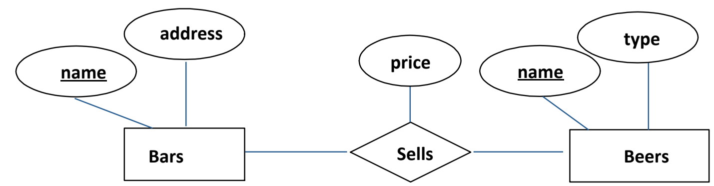
Functional Dependencies (cntd)

- Where do FDs come from?
  – Real-world integrity constraints and semantics

- Keys redefined as FDs with set of attributes K and relation R:
  1. if K → all (other) attributes of R
     K is a "**super key**"
  2. And if no proper subset of K satisfies the above condition, then
     K is **minimal** (and thus a **candidate key**)

Exercise 3: Constructing FDs

- What functional dependencies do you think would make sense for this application?



Bar_name → address
beer_name → type
bar_name, beer_name → price

Reasoning About FDs

- Given some FDs, can usually infer additional FDs that are true
  E.g., *College* use case:

profId → *profName* **and**
profId → *dept*

implies:
profId → *profName, dept*

Union rule
(opposite: *decomposition*)

profId → *dept* **and**
dept → *building*

implies:
profId → *building*

Transitivity rule

- However, *building, roomNum* → *profName*
  does NOT imply *building* → *profName* **or** *roomNum* → *profName*

- A particular FD *f* is *implied by* a set of FDs *F* if *f* holds whenever all FDs in *F* hold

Closure and Rules of Inference

- F^+ = *closure of F* is the set of all FDs that are implied by *F*
  (includes "trivial dependencies": RHS ⊆ LHS)

- Armstrong's Axioms (X, Y, Z are sets of attributes):
  – *Reflexivity*: If Y ⊆ X, then X → Y
  – *Augmentation*: If X → Y, then XZ → YZ for any Z
  – *Transitivity*: If X → Y and Y → Z, then X → Z

- Some additional rules (that follow from AA):
  – *Union*: If X → Y and X → Z, then X → YZ
  – *Decomposition*: If X → YZ, then X → Y and X → Z

Example: Using Inference Rules

- Suppose relation R has three attributes A,B,C and these FDs:
  A → B
  B → C
- Using **reflexivity**
  A → A, AB → A, etc.
- Using **transitivity**
  A → C
- Using **augmentation**
  AC → BC, AB → AC, AB → BC

Repeatedly applying these rules to the set of FDs yields the closure of F, which is **F⁺**

Attribute Closure

- If we just want to check if a particular FD ***X* → *Y*** is in F^+, then:

  1) Compute the *attribute closure* of X (denoted X^+) with respect to *F*
     - X^+ = Set of all attributes A such that X → A is in F^+
       - initialize X^+ := X
       - Repeat until no change to X^+:
         if U → V in *F* such that U is in X^+, then add V to X^+

  2) Check if Y is in X^+

Q. How can attribute closure be used to determine if a set of attributes is a key for a relation?

Exercise 4

Four-way relationship: a *contract* for *parts* between a *supplier* and a *department* for a *project*

- Contracts(*cid*,*sid*,*jid*,*did*,*pid*,*qty*,*value*), and:
  C is the primary key: C → CSJDPQV
  Project purchases each part using single contract: JP → C
  Dept purchases at most 1 part from a supplier: SD → P

- Show that SDJ is a superkey for Contracts
  - JP → C, C → CSJDPQV ***imply*** JP → CSJDPQV
    (by transitivity) (shows that JP is a superkey)
  - SD → P ***implies*** SDJ → JP
    (by augmentation)
  - SDJ → JP, JP → CSJDPQV ***imply*** SDJ → CSJDPQV
    (by transitivity) thus SDJ is a superkey