CS 455 Principles of Database Systems

Homework 5: Normalization

Name:

Instructions: Print this assignment using single-side pages. Fill in your name above, and write in the solutions in the space provided below each question. You are allowed to use the back of each page. If you used any scratch paper to show your work, append those to the end. **Note:** It is important you use this format for gradescope.

Submission: After you've filled in the answers, scan all pages into a PDF, and submit to canvas.

Problems

1. **[Functional Dependencies]** List all *nontrivial* functional dependencies (FDs) satisfied by the following relation instance. (5pts)

Name	Age	City
Bob	25	$Akron$
Bob	25	$Cleveland$
$Barb$	25	$Akron$
$Barb$	25	$Columbus$

2. **[Closure of Attribute Sets]** Consider a relation $R(A, B, C)$ and the following set of functional dependencies:

$$FD(R) = \{A \to B, \\ C \to B\}$$

Consider the following attribute combinations, and find their *attribute closures*. Recall that the closure of a set of attributes α (written $\{\alpha\}^+$) is the set of attributes that can be functionally determined using α with respect to $FD(R)$. Indicate if the set of attributes represents a superkey by **circling them**. **Double-circle** the candidate key(s). I've done the first one for you. (18pts; 3pts each)

(a) $\{A\}^+ = \{A, B\}$ (Not a superkey)

(b) $\{B\}^+ =$

(c) $\{C\}^+ =$

(d) $\{A, B\}^+ =$

(e) $\{A, C\}^+ =$

(f) $\{B, C\}^+ =$

(g) $\{A, B, C\}^+ =$

3. Recall that it is possible to derive new *inference rules* for generating FDs in $FD(R)^+$. For each of the following, show it is either sound through derivation, or unsound by giving a relation instance that satisfies the left-hand side, but contradicts the right-hand side of the implication. You are **required** to use only Armstrong's Axioms for derivation. I'll do the first one for you. (10pts each)

   (a) $\alpha \to \beta \overset{?}{\Longrightarrow} \alpha \cup \gamma \to \beta$

$$\begin{aligned} \alpha \to \beta &\quad \text{1. given} \\ \alpha \cup \gamma \to \beta \cup \gamma &\quad \text{2. augmentation rule: (1) with } \gamma \\ \beta \cup \gamma \to \beta &\quad \text{3. trivial rule} \\ \alpha \cup \gamma \to \beta &\quad \text{4. transitivity rule: (2) and (3)} \\ \therefore \quad \alpha \to \beta \implies \alpha \cup \gamma \to \beta &\quad \text{is sound.} \blacksquare \end{aligned}$$

(b) $\alpha \cup \gamma \to \beta \cup \delta \stackrel{?}{\Longrightarrow} \alpha \to \beta, \gamma \to \delta$

(c) $\alpha \to \beta, \gamma \to \delta \stackrel{?}{\Longrightarrow} \alpha \cup \gamma \to \beta \cup \delta$

4. Consider the relation $R(A, B, C, D, E)$. You are given the following functional dependencies. Find all the keys for the relation. In what normal form is R (choose from 1NF, 2NF, or BCNF)?

$$\begin{aligned} FD(R) = \{ & AD \to E, \\ & BE \to C, \\ & C \to D\} \end{aligned}$$

5. Consider the un-normalized *"University"* relation you were given in a previous assignment. If you need a reminder of the poorly-designed University relation, take a look at the raw data on the **Homework 3** page. When I decompose this relation into a set of relations satisfying BCNF, I obtain:

   - Student(studentID, studentName, class, gpa)
   - Course(courseNum, deptID, courseName, location, meetDay, meetTime)
   - Dept(deptID, name, building)
   - Enroll(courseNum, deptID, studentID, major)

   (a) Verify that you obtain these relations (and their primary keys) after applying the BCNF algorithm. Specifically, identify the set of FDs for the unnormalized relation, as well as its canonical cover FD_c. Then use FD_c for BCNF decomposition. (30pts = 10 for FDs + 10 for cover + 10 for decomposition)

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