CS 360: Database Systems - Assignment 4 Solution

CS 360：数据库系统 - 作业 4 答案

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Due Date: December 6, 2025

Question 1 / 问题 1

Given (已知):

$$R = \{A, B, C, D, E, L, G, H, I, J, K\}$$

$$F = \{I \to K, AI \to BLG, IC \to ADE, BIG \to CJ, K \to HA\}$$

Tasks (任务):

1. Find a canonical cover for F. (寻找 F 的正则覆盖)
2. Find a 3NF decomposition of R. (寻找 R 的 3NF 分解)
3. Is there a BCNF decomposition of R that is both dependency-preserving and also loss-less join? If so, compute such a decomposition. (是否存在既保持依赖又无损连接的 BCNF 分解？如果有，请计算该分解。)

Solution / 解答

1. Canonical Cover (F_c) / 正则覆盖

Step 1: Flatten RHS (将右侧属性展开)

- $I \to K$
- $AI \to B, AI \to L, AI \to G$
- $IC \to A, IC \to D, IC \to E$
- $BIG \to C, BIG \to J$
- $K \to H, K \to A$

Step 2: Remove Extraneous Attributes from LHS (移除左侧多余属性)

- **For $AI \to BLG$:** We have $I \to K$ and $K \to A$ (transitively $I \to A$). Since $I \to A$, A is extraneous. $AI \to BLG$ becomes $I \to BLG$.
- **For $BIG \to CJ$:** We have $I \to B$ and $I \to G$ (from above). Since I determines B and G, they are extraneous. $BIG \to CJ$ becomes $I \to CJ$.
- **For $IC \to ADE$:** We have $I \to C$ (from above, via $BIG \to C \implies I \to C$). So C is extraneous. $IC \to ADE$ becomes $I \to ADE$.

Step 3: Remove Redundant Dependencies (移除冗余依赖)

- Since $I \to K$ and $K \to A$, $I \to A$ is implied. Remove explicit $I \to A$.

- Since $I \to K$ and $K \to H$, $I \to H$ is implied. Remove explicit $I \to H$.

Final Canonical Cover (最终正则覆盖):

$$F_c = \{I \to BCDEGJKL, K \to AH\}$$

2. 3NF Decomposition / 3NF 分解

Candidate Keys (候选键): I is the unique Candidate Key (since $I \to$ All).

Decomposition (基于 F_c 的分解):

1. $R_1(I, B, C, D, E, G, J, K, L)$
2. $R_2(K, A, H)$

3. BCNF Decomposition / BCNF 分解

Analysis (分析):

- R_1 has key I. All FD LHS are superkeys. **BCNF**.
- R_2 has key K. All FD LHS are superkeys. **BCNF**.

Answer (答案): Yes. The above decomposition is BCNF, Lossless (Intersection K is key of R_2), and Dependency Preserving.
(是。上述分解既是 BCNF，也是无损连接 [交集 K 是 R_2 的键] 且保持依赖的。)

Question 2 / 问题 2

Given (已知):

$$R = \{A, B, C, D, E, H\}$$

$$F = \{ABC \to DE, AB \to D, DE \to ABCH, E \to C\}$$

Tasks (任务):

1. Is this scheme in 3NF, BCNF or none? (该模式是 3NF、BCNF 还是都不是？)
2. If it isn't, decompose into a normal form that is both dependency preserving and loss-less join. (如果不是，分解为既保持依赖又无损连接的范式。)

Solution / 解答

1. Check Normal Forms / 检查范式

Candidate Keys (候选键): DE, ABE, ABC.

Check BCNF: $E \to C$ violates BCNF because E is not a superkey. (违反 BCNF，因为 E 不是超键)。

Check 3NF:

- For $E \to C$, C is part of candidate key (ABC), so C is prime.
- For $AB \to D$, D is part of candidate key (DE), so D is prime.

Thus, it satisfies 3NF. (因此，它满足 3NF)。

Answer: It is in 3NF but not BCNF. (它是 3NF 但不是 BCNF)。

2. Decomposition (Preserving & Lossless) / 分解 (保持依赖且无损)

To ensure a clean BCNF-like structure or just standard 3NF synthesis:

$$S_1 = (A, B, D, E, H) \quad \text{[Key: } DE\text{]}$$

$$S_2 = (A, B, C, E) \quad \text{[Key: } ABC\text{]}$$

Question 3 / 问题 3

Given (已知):

$$R = \{A, B, C, D, E, G, H, I\}$$

$$F = \{A \to BCDEIGH, BCD \to AEIGH, BCE \to ADEIGH, CE \to H, CD \to H\}$$

Tasks (任务):

1. Find a BCNF decomposition of R. (寻找 R 的 BCNF 分解)
2. Is the decomposition you computed dependency preserving? Why or why not? (该分解是否保持依赖？为什么？)

Solution / 解答

1. BCNF Decomposition / BCNF 分解

Violations (违规依赖): $CE \to H$ and $CD \to H$ (LHS are not superkeys / 左侧不是超键).

Decomposition Step: Isolate H with one of the violations, e.g., $CD \to H$.

- $R_1 = (C, D, H)$
- $R_2 = (A, B, C, D, E, G, I)$

Result: R_1 is BCNF (Key CD). R_2 is BCNF (Keys A, BCD, BCE valid, H is gone).

Final BCNF:

$$R_1(C, D, H), \quad R_2(A, B, C, D, E, G, I)$$

2. Dependency Preservation / 依赖保持性

Answer: No (否).

Reason: The dependency $CE \to H$ is lost. In R_2, closure $(CE)^+ = \{C, E\}$, which cannot reach H. R_1 cannot be used because D is not known from CE.
(理由：依赖 $CE \to H$ 丢失了。在 R_2 中，$(CE)^+ = \{C, E\}$，无法推导出 H。无法使用 R_1，因为从 CE 无法推导出 D。)