Normal Forms

We assume that R is a (1NF) relation schema and that F is a set of FDs over R.

⋆ The normal forms we define restrict the *allowable* FDs in F.

1. An FD $X \rightarrow Y$ is **trivial** if Y is a subset of X; otherwise it is **nontrivial**.
2. An FD $X \rightarrow A$ is **canonical** if it is nontrivial and A is a single attribute.

We will assume that all FDs are canonical.

Note that there is no loss of generality in this approach.

Definition. R is in *Boyce-Codd Normal Form* (BCNF) with respect F if for every FD X $\longrightarrow$ A in F, X is a superkey for R with respect F.

BCNF Example 1.

Let schema(R_1) = {STUDENT, POSITION, SUBJECT};

1. S stands for STUDENT,
2. J stands for SUBJECT, and
3. P stands for POSITION.

Let $F_1 = \{\text{SJ} \rightarrow \text{P}, \text{PJ} \rightarrow \text{S}\}$.

1. What are the superkeys of R_1 with respect to F_1 ?
2. Is R_1 in BCNF with respect to F_1 ?

BCNF Example 2.

Let schema(R_2) = {STREET, CITY, POSTCODE};

1. S stands for STREET,
2. C stands for CITY, and
3. P stands for POSTCODE.

Let $F_2 = \{\text{SC} \rightarrow \text{P}, \text{P} \rightarrow \text{C}\}$.

1. What are the superkeys of R_2 with respect to F ?
2. Is R_2 in BCNF with respect to F_2 ?

BCNF Example 3.

Let schema(R_3) = {ENAME, DNAME, MNAME};

1. E stands for ENAME,
2. D stands for DNAME, and
3. M stands for MNAME.

Let $F_3 = \{\text{E} \rightarrow \text{D}, \text{D} \rightarrow \text{M}\}$.

1. What are the superkeys of R_3 with respect to F_3 ?
2. Is R_3 in BCNF with respect to F_3 ?

BCNF Example 4.

Let schema(R_4) = {ENAME, CNAME, SAL};

1. E stands for ENAME,
2. C stands for CNAME, and
3. S stands for SAL.

Let $F_4 = \{E \rightarrow S\}$.

1. What are the superkeys of R_4 with respect to F_4 ?
2. Is R_4 in BCNF with respect to F_4 ?

Recall the concept of a **cover** of a set of FDs.

The following result shows that BCNF is cover insensitive.

Result. R is in *Boyce-Codd Normal Form* (BCNF) with respect to F if and only if R is in BCNF with respect to G, where F is a cover of G.

Assume that we do **not** allow FDs of the form $\emptyset \rightarrow$ Y, i.e. *the left-hand of an FD is assumed to be nonempty.*

What is the meaning of such an FD ?

Result. If schema(R) has two or less attributes, then R is in BCNF with respect to F.

Definition. An attribute A in schema(R) is said to be **prime** with respect to F if A is a member of one of the keys of R with respect to F.

Definition. R is in *Third Normal Form* (3NF) with respect to F if for every FD $X \rightarrow A$ in F either X is a superkey for R with respect to F or A is prime.

Result. 3NF is cover insensitive.

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3NF Example 1.

Let schema(R_1) = {STUDENT, POSITION, SUBJECT};

1. S stands for STUDENT,
2. J stands for SUBJECT, and
3. P stands for POSITION.

Let $F_1 = \{\text{SJ} \rightarrow \text{P}, \text{PJ} \rightarrow \text{S}\}$.

1. What are the superkeys and prime attributes of R_1 with respect to F_1 ?
2. Is R_1 in 3NF F with respect to F_1 ?

3NF Example 2.

Let schema(R_2) = {STREET, CITY, POSTCODE};

1. S stands for STREET,
2. C stands for CITY, and
3. P stands for POSTCODE.

Let $F_2 = \{\text{SC} \rightarrow \text{P}, \text{P} \rightarrow \text{C}\}$.

1. What are the superkeys and prime attributes of R_2 with respect to F ?
2. Is R_2 in 3NF with respect to F_2 ?

3NF Example 3.

Let schema(R_3) = {ENAME, DNAME, MNAME};

1. E stands for ENAME,
2. D stands for DNAME, and
3. M stands for MNAME.

Let $F_3 = \{\mathrm{E} \rightarrow \mathrm{D}, \mathrm{D} \rightarrow \mathrm{M}\}$.

1. What are the superkeys and prime attributes of R_3 with respect to F ?
2. Is R_3 in 3NF with respect to F_3 ?

3NF Example 4.

Let schema(R_4) = {ENAME, CNAME, SAL};

1. E stands for ENAME,
2. C stands for CNAME, and
3. S stands for SAL.

Let $F_4 = \{\mathrm{E} \rightarrow \mathrm{S}\}$.

1. What are the superkeys and prime attributes of R_4 with respect to F ?
2. Is R_4 in 3NF with respect to F_4 ?

Definition. R is in *Second Normal Form* (2NF) with respect to F if for every FD X $\longrightarrow$ A in F either X is not a proper subset of a key for R with respect to F or A is prime.

Result. 2NF is cover insensitive.

2NF Example 1.

Let schema(R_1) = {STUDENT, POSITION, SUBJECT};

1. S stands for STUDENT,
2. J stands for SUBJECT, and
3. P stands for POSITION.

Let $F_1 = \{\text{SJ} \rightarrow \text{P}, \text{PJ} \rightarrow \text{S}\}$.

1. What are the superkeys and prime attributes of R_1 with respect to F_1 ?
2. Is R_1 in 2NF F with respect to F_1 ?

2NF Example 2.

Let schema(R_2) = {STREET, CITY, POSTCODE};

1. S stands for STREET,
2. C stands for CITY, and
3. P stands for POSTCODE.

Let $F_2 = \{\text{SC} \rightarrow \text{P}, \text{P} \rightarrow \text{C}\}$.

1. What are the superkeys and prime attributes of R_2 with respect to F ?
2. Is R_2 in 2NF with respect to F_2 ?

2NF Example 3.

Let schema(R_3) = {ENAME, DNAME, MNAME};

1. E stands for ENAME,
2. D stands for DNAME, and
3. M stands for MNAME.

Let $F_3 = \{\mathrm{E} \rightarrow \mathrm{D},\ \mathrm{D} \rightarrow \mathrm{M}\}$.

1. What are the superkeys and prime attributes of R_3 with respect to F ?
2. Is R_3 in 2NF with respect to F_3 ?

2NF Example 4.

Let schema(R_4) = {ENAME, CNAME, SAL};

1. E stands for ENAME,
2. C stands for CNAM,E and
3. S stands for SAL.

Let $F_4 = \{\text{E} \rightarrow \text{S}\}$.

1. What are the superkeys and prime attributes of R_4 with respect to F ?
2. Is R_4 in 2NF with respect to F_4 ?

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Some fundamental Results.

Result0. R is in BCNF with respect to F if and only if R has no redundancy problems.

Result1. If R is in BCNF with respect to F, then R is in 3NF with respect to F.

Result2. If R is in 3NF with respect to F, then R is in 2NF with respect to F.

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Some interesting results.

Recall A key is **simple** if it consists of a single attribute.

Result1. If R is in 3NF with respect to F and all the keys of R with respect to F are simple, then R is also in BCNF.

Result 2. If R is in 3NF with respect to F and there is a unique key for R with respect to F (i.e. R has only one key with respect to F) then R is in BCNF with respect to F.