# Database Management System 17

## Normal Forms

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Normal Forms

1NF(First Normal Form)

Partial FD

2NF(Second Normal Form)

Transitive FD

3NF(Third Normal Form)

BCNF (Boyce-Codd Normal Form)

# Normal Forms

## Normal Forms

- Normal forms provide a stepwise progression towards the construction of normalized relation schemas, which are free from data redundancies
- A relation schema is said to be in a particular normal form if it is satisfying certain defined conditions



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## 1NF(First Normal Form)

A relation is in 1NF iff the values in the relation are atomic and single-valued for every attribute in the relation

Course

| Module | Dept | Lecturer | Text |
|---|---|---|---|
| $M_1$ | $D_1$ | $L_1$ | $T_1, T_2$ |
| $M_2$ | $D_1$ | $L_1$ | $T_1, T_3$ |
| $M_3$ | $D_1$ | $L_2$ | $T_4$ |
| $M_4$ | $D_2$ | $L_3$ | $T_1, T_5$ |
| $M_5$ | $D_2$ | $L_4$ | $T_6$ |

- As the Text column values are not atomic, this relation is not present in 1NF
- To convert this non-1NF relation into a 1NF relation, split up the non-atomic values



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# 1NF(First Normal Form)...

Course1

| Module | Dept | Lecturer | Text |
|---|---|---|---|
| $M_1$ | $D_1$ | $L_1$ | $T_1$ |
| $M_1$ | $D_1$ | $L_1$ | $T_2$ |
| $M_2$ | $D_1$ | $L_1$ | $T_1$ |
| $M_2$ | $D_1$ | $L_1$ | $T_3$ |
| $M_3$ | $D_1$ | $L_2$ | $T_4$ |
| $M_4$ | $D_2$ | $L_3$ | $T_1$ |
| $M_4$ | $D_2$ | $L_3$ | $T_5$ |
| $M_5$ | $D_2$ | $L_4$ | $T_6$ |

Course2

| Module | Dept | Lecturer | $Text_1$ | $Text_2$ |
|---|---|---|---|---|
| $M_1$ | $D_1$ | $L_1$ | $T_1$ | $T_2$ |
| $M_2$ | $D_1$ | $L_1$ | $T_1$ | $T_3$ |
| $M_3$ | $D_1$ | $L_2$ | $T_4$ | |
| $M_4$ | $D_2$ | $L_3$ | $T_1$ | $T_5$ |
| $M_5$ | $D_2$ | $L_4$ | $T_6$ | |

***Corollary: As the relation schema contains no data values, therefore all relation schemas are in 1NF***

Anomalies in 1NF Relations:

- Insertion anomalies
- Updation anomalies
- Deletion anomalies



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# Partial FD

## Partial FD

A FD A $\rightarrow$ B is a partial FD, if some attribute of A can be removed and the FD still holds. That means there is some proper subset of A, C $\subset$ A, such that C $\rightarrow$ B

- **Key attributes**: are the attributes which are part of some candidate key
- **Non-key attributes**: are the attributes which are not part of any candidate key



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# 2NF(Second Normal Form)

## 2NF(Second Normal Form)

A relation is in 2NF iff the following two conditions are met simultaneously:

- It is in 1NF
- No non-key attribute is partially dependent on any key

A non-2NF relation can be decomposed into 2NF relations by:

- Create a new relation by using the attributes from the offending FD as the attributes in the new relation. The determinant of the FD becomes the primary key of the new relation
- The attribute on the RHS of the FD is then eliminated from the original relation
- If more than one FD prevents the relation from being 2NF, repeat steps 1 and 2 for each offending FD
- If the same determinant appears in more than one FD, place all the attributes functionally dependent on this determinant as non-key attributes in the relation having the determinant as the primary key



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# 2NF(Second Normal Form)...

Course

| Module | Dept | Lecturer | Text |
|---|---|---|---|
| $M_1$ | $D_1$ | $L_1$ | $T_1$ |
| $M_1$ | $D_1$ | $L_1$ | $T_2$ |
| $M_2$ | $D_1$ | $L_1$ | $T_1$ |
| $M_2$ | $D_1$ | $L_1$ | $T_3$ |
| $M_3$ | $D_1$ | $L_2$ | $T_4$ |
| $M_4$ | $D_2$ | $L_3$ | $T_1$ |
| $M_4$ | $D_2$ | $L_3$ | $T_5$ |
| $M_5$ | $D_2$ | $L_4$ | $T_6$ |

F={Module$\rightarrow$Dept, Module$\rightarrow$Lecturer, Lecturer$\rightarrow$Dept, {Module, Text}$\rightarrow${Dept, Lecturer}}
Here, Key:{Module, Text}



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# 2NF(Second Normal Form)...

Course1

| Module | Dept | Lecturer |
|---|---|---|
| $M_1$ | $D_1$ | $L_1$ |
| $M_2$ | $D_1$ | $L_1$ |
| $M_3$ | $D_1$ | $L_2$ |
| $M_4$ | $D_2$ | $L_3$ |
| $M_5$ | $D_2$ | $L_4$ |

$F_1$={Module$\rightarrow${Dept, Lecturer}, Lecturer$\rightarrow$Dept}

Course2

| Module | Text |
|---|---|
| $M_1$ | $T_1$ |
| $M_1$ | $T_2$ |
| $M_2$ | $T_1$ |
| $M_2$ | $T_3$ |
| $M_3$ | $T_4$ |
| $M_4$ | $T_1$ |
| $M_4$ | $T_5$ |
| $M_5$ | $T_6$ |

$F_2$={{Module, Text}}$\rightarrow${{Module, Text}}



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# 2NF(Second Normal Form)...

***Corollary: If the primary key has a single attribute, then the relation is in 2NF***

Anomalies in 2NF Relations:

- Insertion anomalies
- Updation anomalies
- Deletion anomalies

Q: R=(A, B, C, D, E), & F={A $\rightarrow$ {B, C, D, E}, {A, B} $\rightarrow$ {C, D, E}, C $\rightarrow$ E, D $\rightarrow$ E}

Q: R=(A, B, C, D, E), & F={{A, B} $\rightarrow$ {C, D, E}, B $\rightarrow$ C, A $\rightarrow$ D}



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# Transitive FD

## Transitive FD

A FD A $\rightarrow$ C is a transitive FD, if there are some set of attributes B such that A $\rightarrow$ B and B $\rightarrow$ C are non-trivial FDs

A $\rightarrow$ B non-trivial means B is not a subset of A



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# 3NF(Third Normal Form)

## 3NF(Third Normal Form)

A relation is in 3NF iff the following two conditions are satisfied simultaneously:

- It is in 2NF
- No non-key attribute is transitively dependent on the key

The process of decomposing the non-3NF relation into 3NF relations is similar to the process of decomposing the non-2NF relation to 2NF relations

Course

| Module | Dept | Lecturer |
|---|---|---|
| $M_1$ | $D_1$ | $L_1$ |
| $M_2$ | $D_1$ | $L_1$ |
| $M_3$ | $D_1$ | $L_2$ |
| $M_4$ | $D_2$ | $L_3$ |
| $M_5$ | $D_2$ | $L_4$ |

F={Module→{Dept, Lecturer}, Lecturer→Dept}

This relation is not present in 3NF because Module → Lecturer and Lecturer → Dept

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# 3NF(Third Normal Form)...

Course1

| Module | Lecturer |
|---|---|
| $M_1$ | $L_1$ |
| $M_2$ | $L_1$ |
| $M_3$ | $L_2$ |
| $M_4$ | $L_3$ |
| $M_5$ | $L_4$ |

$F_1$={Module$\rightarrow$Lecturer}

Course2

| Lecturer | Dept |
|---|---|
| $L_1$ | $D_1$ |
| $L_2$ | $D_1$ |
| $L_3$ | $D_2$ |
| $L_4$ | $D_2$ |

$F_2$={Lecturer$\rightarrow$Dept}

***Corollary: A 2NF relation is in 3NF if no non-key attribute functionally determines any other non-key attribute***



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# 3NF(Third Normal Form)...

The 3NF helped us to get rid of the anomalies caused by dependencies of a non-key attribute on another non-key attribute

However, relations in 3NF are still susceptible to anomalies when the relations have two overlapping candidate keys or when non-key attribute functionally determines a key attribute. Overlapping candidate keys means composite candidate keys with at least one attribute in common among themselves

***Note: A database should normally be in 3NF at least***

Q: Lecturer = (lectid, lectname, courseid, coursename) & F={lectid $\rightarrow$ lectname, lectid $\rightarrow$ courseid, lectid $\rightarrow$ coursename, courseid $\rightarrow$ coursename}

Q: R=(B, C, E), F= {E $\rightarrow$ B, {B,C} $\rightarrow$ E}

Q: Store = (order, product, customer, address, qty, unitprice) & F= {order $\rightarrow$ {customer, address}, customer $\rightarrow$ address, product $\rightarrow$ unitprice, {order, product} $\rightarrow$ qty}



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# BCNF (Boyce-Codd Normal Form)

## BCNF (Boyce-Codd Normal Form)

A relation is in BCNF iff the following two conditions are satisfied simultaneously:

- It is in 3NF
- If for every non-trivial functional dependency, the determinant is a key

The process of decomposing the non-BCNF relation into BCNF relations is a simple process. For each non-trivial FD where the determinant is not the key, construct new relations

Student

| Student | Course | Time |
|---|---|---|
| Rahul | Database | 12 : 00 |
| Pratik | Database | 12 : 00 |
| Praveen | Database | 15 : 00 |
| Praveen | Programming | 10 : 00 |
| Rajib | Programming | 10 : 00 |
| Shivam | Programming | 13 : 00 |

F={{Student, Course} $\rightarrow$ Time, Time $\rightarrow$ Course, {Student, Time} $\rightarrow$ Course}
Key={Student, Course} and {Student, Time}

# BCNF (Boyce-Codd Normal Form)...



## BCNF (Boyce-Codd Normal Form)...

This relation is not present in BCNF as in FD Time $\rightarrow$ Course; the determinant {Time} is not a key

After the conversion of this relation to BCNF, create a new relation $R_1$=(Time, Course) with set of FDs $F_1$={Time $\rightarrow$ Course}

The original relation is changed to R=(Student, Time) as {Student, Time} set is also the key of the relation

Here, we have lost the functional dependency {Student, Course} $\rightarrow$ Time

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# BCNF (Boyce-Codd Normal Form)...

***Corollary: If a relation has only one candidate key, then 3NF and BCNF are same. That means if a relation is in 3NF having only one candidate key, then it is also present in BCNF***

***Note: Normalization to 3NF is always lossless and dependency preserving. But, normalization to BCNF is lossless, but may not preserve all the functional dependencies***

Q: R =(A, B, C, D, E), F={A $\rightarrow$ {B, E}, C $\rightarrow$ D}. Decompose the relation to BCNF

Q: R=(A, B, C, D), F={{A, B} $\rightarrow$ {C, D}, C $\rightarrow$ B}. Decompose the relation into BCNF

Q: R =(A, B, C, D, E, G), F={{A, B} $\rightarrow$ {C, D}, {B, C} $\rightarrow$ {D, A}, C $\rightarrow$ G, B $\rightarrow$ E}. Decompose this relation to BCNF

Q: R =(A, B, C, D) & F= {{A, C} $\rightarrow$ {B, D}, {B, C} $\rightarrow$ {D, A}, A $\rightarrow$ B, B $\rightarrow$ A}. Decompose this relation to BCNF



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