Database Management System

Schema Refinement - Functional Dependancy and Normalization

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CSE2004 Syllabus

Module-3

- Guidelines for Relational Schema.
- Functional dependency
- Normalization (1-NF, 2-NF and 3-NF)
- Boyce Codd Normal Form.
- Multi-valued dependency
- Fourth Normal form (4-NF).
- Join dependency and
- Fifth Normal form (5-NF).

Text Books and References

Text Books

- R. Elmasri & S. B. Navathe, Fundamentals of Database Systems, Addison Wesley, 7 th Edition, 2015
- Raghu Ramakrishnan,Database Management Systems,Mcgraw-Hill,4 th edition,2015

References

- A. Silberschatz, H. F. Korth & S. Sudershan, Database System Concepts, McGraw Hill, 6 th Edition 2010
- Thomas Connolly, Carolyn Begg, Database Systems : A Practical Approach to Design, Implementation and Management,6 th Edition,2012
- Pramod J. Sadalage and Marin Fowler, NoSQL Distilled: A brief guide to merging world of Polyglot persistence, Addison Wesley, 2012.
- Shashank Tiwari, Professional NoSql, Wiley, 2011.

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Introduction to Schema Refinement

- E-R Modeling is used by the designer as a requirement analysis tool
- Database design using E-R diagram is a by-product.
- It may contain the amount of
  1. Inconsistency
  2. Ambiguity (Uncertainty/Unclear)
  3. Redundancy.
- Refinement is required to solve these issues and the process is referred as **Normalization**.

Functional Dependency

- It is a relationship that exists between two attributes.
- It typically exists between the **primary key** and **non-key** attribute within a table.
- **X** $\rightarrow$ **Y** : where 'X' is **Determinent** and 'Y' is **Dependent**.

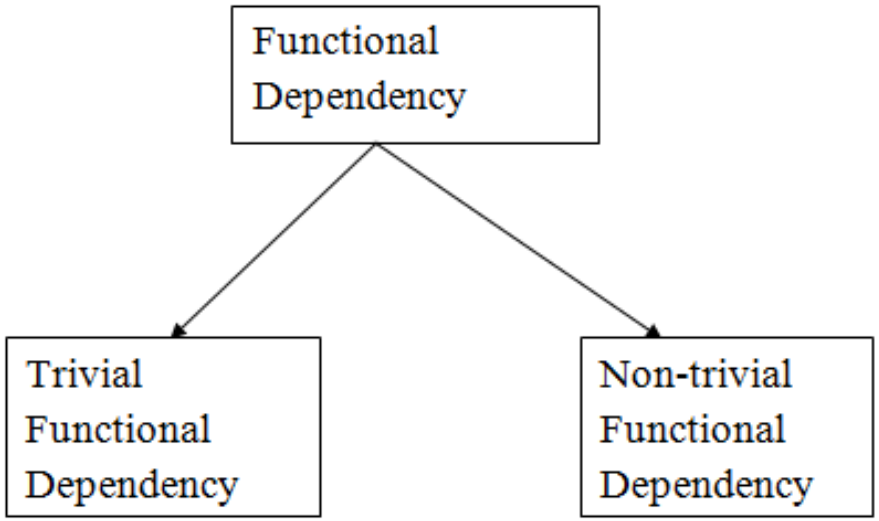
Example :

Consider the Table : **Employee** and attributes - **Emp_Id, Emp_Name, Emp_Address.**

Here Emp_Id attribute can uniquely identify the Emp_Name attribute of Employee table because if we know the Emp_Id, we can tell that employee name associated with it.

Functional dependency can be written as: **Emp_Id** $\rightarrow$ **Emp_Name**
i.e Emp_Name is functionally dependent on Emp_Id.

Functional Dependency's Classification



1. **Trivial FD** :
   - A $\rightarrow$ B has trivial functional dependency if B is a subset of A.
   - The following dependencies are also trivial like: A$\rightarrow$ A, B $\rightarrow$ B
2. **Non-Trivial FD** :
   - A $\rightarrow$ B has a non-trivial functional dependency if B is not a subset of A.
   - When A intersection B is NULL, then A $\rightarrow$ B is called as complete non-trivial.

Examples...!

Consider a table with two columns Employee_Id and Employee_Name.

{Employee_id, Employee_Name} $\rightarrow$ **Employee_Id** is a Trivial Functional Dependency as Employee_Id is a subset of {Employee_Id, Employee_Name}.

Also, **Employee_Id** $\rightarrow$ **Employee_Id** and **Employee_Name** $\rightarrow$ **Employee_Name** are trivial dependencies too.

Employee_Id $\rightarrow$ **Employee_Desig** and **Employee_Id** $\rightarrow$ **Employee_dob** are Non-Trivial Functional Dependency

Building Block of Normalization

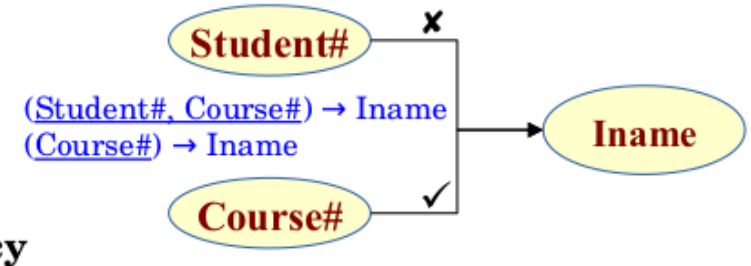
- Determinant : Attribute 'X' can be defined as determinant if it uniquely defines the attribute value 'Y' in given Relation/Entity.
- Attribute 'X' need NOT be a Key attribute.
- It can be represented as X $\rightarrow$ Y (X decides Y or Y is dependent on X)

- In the above Result relation, Grade is dependent on Marks, so Marks(determinant) and Grade(dependent) I.e Marks $\rightarrow$ Grade.
- Here Marks is not a Key attribute.

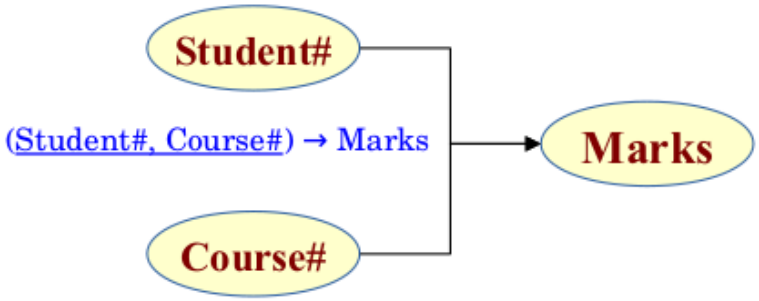
Types of FD's

Types of Functional Dependencies :

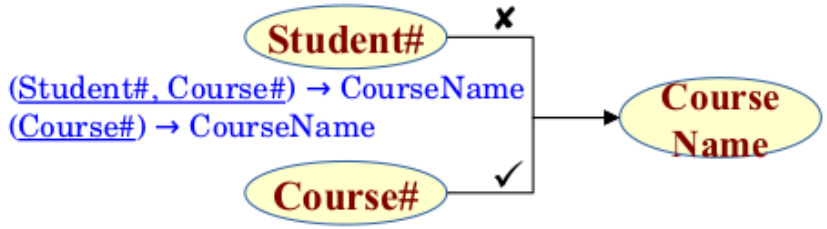
1. **Full Functional Dependency**
2. **Partial Functional Dependency**
3. **Transitive Functional Dependency**



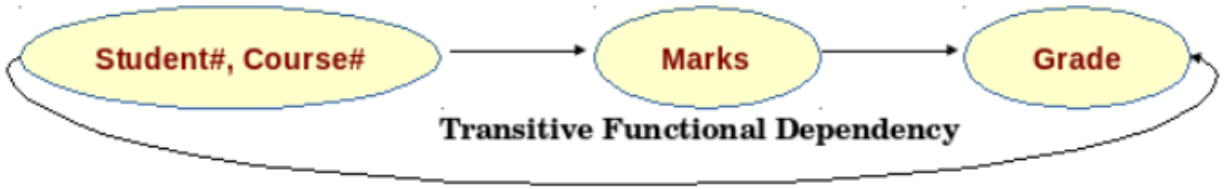
Partial Functional Dependency



Full Functional Dependency



Partial Functional Dependency



(Student#, Course#) → Marks
Marks → Grade
(Student#, Course#) → Grade

DBMS Inference Rules

- The Armstrong's axioms are the basic inference rule.
- Armstrong's axioms are used to conclude functional dependencies on a relational database.
- The inference rule is a type of assertion. It can apply to a set of FD(functional dependency) to derive other FD.
- Using the inference rule, we can derive additional functional dependency from the initial set.

The Functional dependency has 6 types of inference rule:

1. Reflexive Rule
2. Augmentation Rule
3. Transitive Rule
4. Union Rule
5. Decomposition Rule
6. Pseudo Transitive Rule

DBMS Inference Rules

- **Reflexive Rule**(IR-1) : if Y is a subset of X, then X determines Y.
  i.e If $\mathbf{X} \supseteq \mathbf{Y}$ then $X \rightarrow Y$
  Example : X = {a,b,c,d,e} and Y = {a,b,c}

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- **Augmentation Rule** : is also called as a **partial dependency**. In augmentation, if X determines Y, then XZ determines YZ for any Z (i.e if $X \rightarrow Y$ then $XZ \rightarrow YZ$).
  Example : For **R(ABCD)**, if $\mathbf{A \rightarrow B}$ **then** $\mathbf{AC \rightarrow BC}$.

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- **Union Rule** : if X determines Y and X determines Z, then X must also determine Y and Z. (i.e If $X \rightarrow Y$ and $X \rightarrow Z$ then $X \rightarrow YZ$)

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- **Union Rule** : if X determines Y and X determines Z, then X must also determine Y and Z. (i.e If $X \rightarrow Y$ and $X \rightarrow Z$ then $X \rightarrow YZ$)

Proof:

1. $X \rightarrow Y$ (given)
2. $X \rightarrow Z$ (given)
3. $X \rightarrow XY$ (using IR2 on 1 by augmentation with X. Where XX = X)
4. $XY \rightarrow YZ$ (using IR2 on 2 by augmentation with Y)

5. $X \rightarrow YZ$ (using IR3 on 3 and 4)

DBMS Inference Rules

- **Decomposition Rule** : is also known as project rule.
  It is the reverse of union rule.
  i.e if X determines Y and Z, then X determines Y and X determines Z separately. **If X $\rightarrow$ YZ then X $\rightarrow$ Y and X $\rightarrow$ Z.**

  Proof:

  1. X $\rightarrow$ YZ (given)
  2. YZ $\rightarrow$ Y (using IR1 Rule)
  3. X $\rightarrow$ Y (using IR3 on 1 and 2)

DBMS Inference Rules

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  It is the reverse of union rule.
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  Proof:
  1. X $\rightarrow$ YZ (given)
  2. YZ $\rightarrow$ Y (using IR1 Rule)
  3. X $\rightarrow$ Y (using IR3 on 1 and 2)

- **Pseudo transitive Rule** : if X determines Y and YZ determines W, then XZ determines W.
  If **X $\rightarrow$ Y and YZ $\rightarrow$ W then XZ $\rightarrow$ W**

  Proof :
  1. X $\rightarrow$ Y (given)
  2. WY $\rightarrow$ Z (given)
  3. WX $\rightarrow$ WY (using IR2 on 1 by augmenting with W)
  4. WX $\rightarrow$ Z (using IR3 on 3 and 2)

Introduction to Normalization

If a table is not properly normalized and have data redundancy then it will not only eat up **extra memory space** but will also make it difficult to handle and update the database, without facing data loss.

Insertion, Updation and Deletion Anomalies are very frequent if database is not normalized. To understand these anomalies.

Consider the below **Student Table** :

rollno	name	branch	hod	office_tel
401	Akon	CSE	Mr. X	53337
402	Bkon	CSE	Mr. X	53337
403	Ckon	CSE	Mr. X	53337
404	Dkon	CSE	Mr. X	53337

In the table above, we have data of 4 Computer Sci. students. As we can see, data for the fields branch, **hod**(Head of Department) and o**ffice_tel** is repeated for the students who are in the same branch in the college, this is **Data Redundancy**.

Problems without Normalization

Consider the below Student Table :

rollno	name	branch	hod	office_tel
401	Akon	CSE	Mr. X	53337
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404	Dkon	CSE	Mr. X	53337

Insertion Anomaly : Suppose for a new admission, until and unless a student opts for a branch, data of the student cannot be inserted, or else we will have to set the branch information as NULL.

Also, if we have to insert data of 100 students of same branch, then the branch information will be repeated for all those 100 students.

These scenarios are nothing but Insertion anomalies.

Problems without Normalization

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Updation Anomaly

In our Student Table, What if Mr. X leaves the college? or is no longer the HOD of computer science department? In that case all the student records will have to be updated, and if by mistake we miss any record, it will lead to **data inconsistency**.

This is Updation anomaly.

Problems without Normalization

Consider the below Student Table :

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Deletion Anomaly

In our Student table, two different informations are kept together, Student information and Branch information. Hence, at the end of the academic year, if student records are deleted, we will also lose the branch information.

This is Deletion anomaly.

Hence we need to refine our design so that we make an efficient database in terms of storage, space and Inserts, Updates and Deletes Operation.
This is called as **Normalization**.

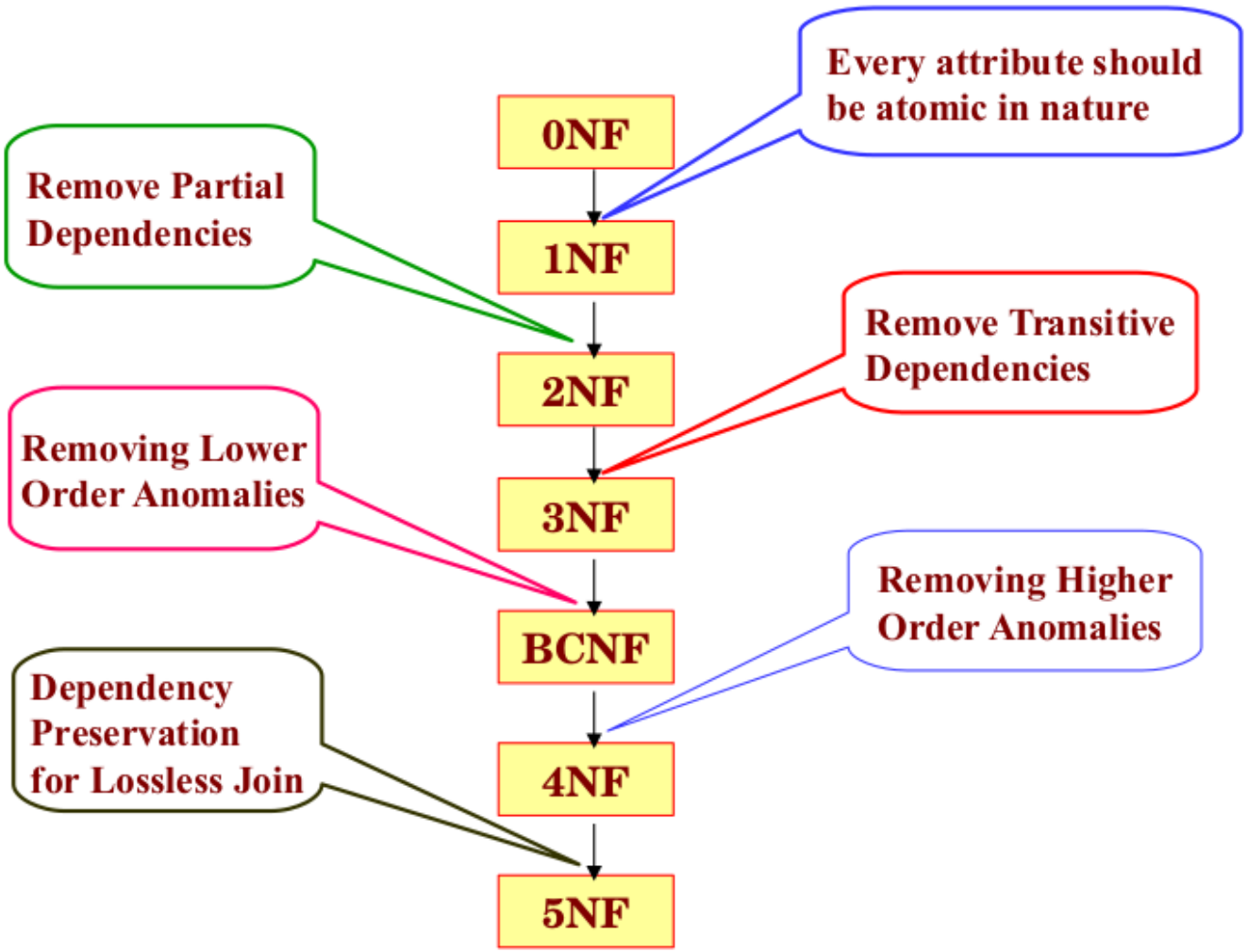
Normalization

- Normalization of Database : is a technique of organizing the data in the database.
- It is a systematic approach of decomposing tables to eliminate data redundancy and undesirable characteristics like Insertion, Update and Deletion Anomalies
- It is a multi-step process that puts data into tabular form by removing duplicated data from the relation tables.
- Normalization is used for mainly two purpose,
  - Eliminating redundant(useless) data.
  - Ensuring data dependencies make sense i.e data is logically stored

Normalization Rules

1NF First Normal Form
2NF Second Normal Form
3NF Third Normal Form
BCNF (Boyce and Codd Normal Form)
4NF and 5NF Fourth and Fifth Normal form

Normalization in NutShel1



1NF - First Normal Form

Important

If tables in a database are not even in the 1st Normal Form, it is considered as **bad database design**

1NF Rules

1. It should only have single(atomic) valued attributes/columns.
2. Values stored in a column should be of the same domain
3. All the columns in a table should have unique names.
4. And the order in which data is stored, does not matter.

Example :
Let us consider the below table:

roll_no	name	subject
101	Akon	OS, CN
103	Ckon	Java
102	Bkon	C, C++

1NF - First Normal Form

Our table already satisfies 3 rules out of the 4 rules, as all our column names are unique, we have stored data in the order we wanted to and we have not inter-mixed different type of data in columns.

But out of the 3 different students in our table, 2 have opted for more than 1 subject. And we have stored the subject names in a single column. But as per the 1st Normal form each column must contain atomic value.

roll_no	name	subject
101	Akon	OS
101	Akon	CN
103	Ckon	Java
102	Bkon	C
102	Bkon	C++

2NF - Second Normal Form

2NF Rules

1. The table should be in the First Normal Form(1NF).
2. There should be no Partial Dependency.

Let's take an example of a **Student table** with columns **student_id**, **name, reg_no**(registration number), **branch** and **address**(student's home address).

student_id	name	reg_no	branch	address
10	Akon	07-WY	CSE	Kerala
11	Akon	08-WY	IT	Gujarat

Here, **student_id** is the primary key and every other column depends on it.

2NF - Second Normal Forrm

Let's create another table for **Subject**, which will have **subject_id** and **subject_name** fields and **subject_id** will be the primary key.

subject_id	subject_name
1	Java
2	C++
3	Php

Let's create another table **Score**, to store the marks obtained by students in the respective subjects along with **teacher**.

score_id	student_id	subject_id	marks	teacher
1	10	1	70	Java Teacher
2	10	2	75	C++ Teacher
3	11	1	80	Java Teacher

Both, {**student_id** + **subject_id**} forms a **Candidate Key** for this table, which can be the **Primary key**.

Where is Partial Dependency?

In the Score table, column **teacher** which is only dependent on the subject, for Java it's Java Teacher and for C++ it's C++ Teacher & so on.

Now as we just discussed that the primary key for this table is a composition of two columns which is **student_id & subject_id** but the teacher's name only depends on subject, hence the subject_id, has nothing to do with student_id.

This is **Partial Dependency**, where an attribute in a table depends on only a part of the primary key and not on the whole key.

How to remove Partial Dependency?

How to Remove Partial Dependency?

The simplest solution is to remove columns **teacher** from **Score** table and add it to the **Subject** table. Hence, the Subject table will become:

subject_id	subject_name	teacher
1	Java	Java Teacher
2	C++	C++ Teacher
3	Php	Php Teacher

And **Score** table is now in the second normal form, with no partial dependency.

score_id	student_id	subject_id	marks
1	10	1	70
2	10	2	75
3	11	1	80

3NF - Third Normal Form

3NF Rules

A table is said to be in the Third Normal Form when,

- It is in the Second Normal form.
- It doesn't have Transitive Dependency.

Student Table

student_id	name	reg_no	branch	address
10	Akon	07-WY	CSE	Kerala
11	Akon	08-WY	IT	Gujarat
12	Bkon	09-WY	IT	Rajasthan

Subject Table

subject_id	subject_name	teacher
1	Java	Java Teacher
2	C++	C++ Teacher
3	Php	Php Teacher

Score Table

score_id	student_id	subject_id	marks
1	10	1	70
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3NF - Third Normal Form

In the Score table, we need to store some more information, which is the **exam_name** and **total_marks**, as below.

score_id	student_id	subject_id	marks	exam_name	total_marks

For Eg: A Mechanical student will have Workshop exam but a computer science student won't. And for some subjects you have Practical exams and for few you don't.

So **exam_name** is dependent on both **student_id** and **subject_id**.

Well, the column **total_marks** depends on **exam_name**. For example, practicals are of less marks while theory exams are of more marks.

But, **exam_name**(not a primary key) is just another column in the score table. and **total_marks** depends on it.

Where a non-prime attribute depends on other non-prime attributes rather than depending upon the prime primary key.

This is **Transitive Dependency**

How to remove Transitive Dependency?

Take out the columns **exam_name** and **total_marks** from Score table and put them in an Exam table and use the **exam_id** wherever required.

score_id	student_id	subject_id	marks	exam_id

The new Exam table

exam_id	exam_name	total_marks
1	Workshop	200
2	Mains	70
3	Practicals	30

Advantage of removing Transitive Dependency is :

- Amount of data duplication is reduced.
- Data integrity achieved.

BCNF : Boyce-Codd Normal Form

Boyce and Codd Normal Form is a higher version of the Third Normal form. This form deals with certain type of anomaly that is not handled by 3NF.

A 3NF table which does not have multiple overlapping candidate keys is said to be in BCNF.

It is also known as 3.5 Normal Form.

For a table to be in BCNF, following conditions must be satisfied:

BCNF Rules

1. R must be in 3^{rd} Normal Form
2. and, for each functional dependency ($X \rightarrow Y$), X should be a super Key.

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2. and, for each functional dependency ($X \rightarrow Y$), X should be a super Key.

The second point sounds a bit tricky, right? In simple words, it means, that for a dependency $A \rightarrow B$, A cannot be a non-prime attribute, if B is a prime attribute.

BCNF Example

Below we have a college enrolment table with columns student_id, subject and professor.

student_id	subject	professor
101	Java	P.Java
101	C++	P.Cpp
102	Java	P.Java2
103	C#	P.Chash
104	Java	P.Java

- One student can enrol for multiple subjects. For example, student with student_id : 101, has opted for subjects - Java & C++
- For each subject, a professor is assigned to the student.
- And, there can be multiple professors teaching one subject like we have for Java.

BCNF Example

What do you think should be the Primary Key?

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Well, in the table above **{student_id, subject}** together form the primary key, because using student_id and subject, we can find all the columns of the table.

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One more important point to note here is, one professor teaches only one subject, but one subject may have two different professors.

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Hence, there is a dependency between subject and professor here, where subject depends on the professor name.

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This table also satisfies the 2nd Normal Form as their is no Partial Dependency.

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And, there is no Transitive Dependency, hence the table also satisfies the 3rd Normal Form.

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But this table is not in Boyce-Codd Normal Form.

BCNF Example

student_id	subject	professor
101	Java	P.Java
101	C++	P.Cpp
102	Java	P.Java2
103	C#	P.Chash
104	Java	P.Java

Why this table is not in BCNF?

BCNF Example

student_id	subject	professor
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101	C++	P.Cpp
102	Java	P.Java2
103	C#	P.Chash
104	Java	P.Java

Why this table is not in BCNF?

{student_id, subject} form primary key, which means subject column is a prime attribute.

BCNF Example

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101	C++	P.Cpp
102	Java	P.Java2
103	C#	P.Chash
104	Java	P.Java

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But, there is one more dependency, **professor** $\rightarrow$ **subject**.

BCNF Example

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101	C++	P.Cpp
102	Java	P.Java2
103	C#	P.Chash
104	Java	P.Java

Why this table is not in BCNF?

{student_id, subject} form primary key, which means subject column is a prime attribute.

But, there is one more dependency, **professor** $\rightarrow$ **subject**.

And while **{subject}** is a prime attribute, professor is a non-prime attribute, which is not allowed by BCNF.

BCNF Example

How to satisfy BCNF?

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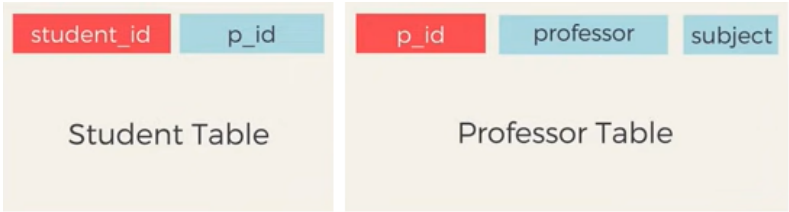
To make this relation(table) satisfy BCNF, we will decompose this table into two tables, student table and professor table.

BCNF Example

How to satisfy BCNF?

To make this relation(table) satisfy BCNF, we will decompose this table into two tables, student table and professor table.

Below we have the structure for both the tables.



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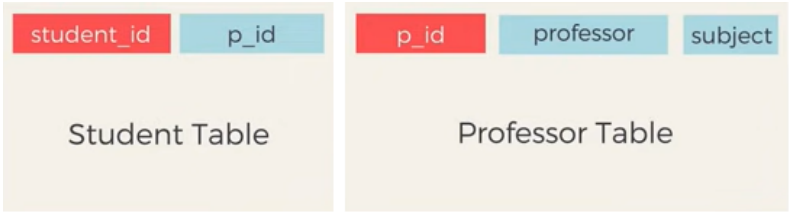


Multivalued Dependencies

- Multivalued dependencies are a consequence of first normal form (1NF) (I.e Doesn't allows an attribute to have a set of values for a tuple, and the accompanying process of converting an UNF into 1NF.
- If we have 2/more multivalued independent attributes in the same relation schema, we get into a problem of having to repeat every value of one of the attributes with every value of the other attribute to keep the relation state consistent and to maintain the independence among the attributes involved. (Redundancy)
- This constraint is specified by a MVD

MVD Example

- For Eg-1 : Consider the relation EMP. A tuple in EMP relation represents the fact that an employee whose name is Ename works on the project whose name is Pname and has a dependent whose name is Dname.
- An employee may work on several projects and may have several dependents, and the employee's projects and dependents are independent of one another.
- To keep the relation state consistent, and to avoid any spurious relationship between the two independent attributes, we must have a separate tuple to represent every combination of an employee's dependent and an employee's project.

EMP

Ename	Pname	Dname
Smith	X	John
Smith	Y	Anna
Smith	X	Anna
Smith	Y	John

The EMP relation with two MVDs:

- Ename $\twoheadrightarrow$ Pname and
- Ename $\twoheadrightarrow$ Dname.

whenever two independent 1:N relationships A → B and A → C are mixed in the same relation R(A,B,C), then MVD may arise.

MVD Example

For Eg-2

Student_Id	Student_Name	Course_Name	Inst_Name
50396	KVP	DBMS	Tulasi
50396	KVP	OS	RK Singh
50396	KVP	CN	Pradeep.K.V
50396	KVP	TOC	Prabhakar Rao
50396	KVP	CN-Lab	Murali

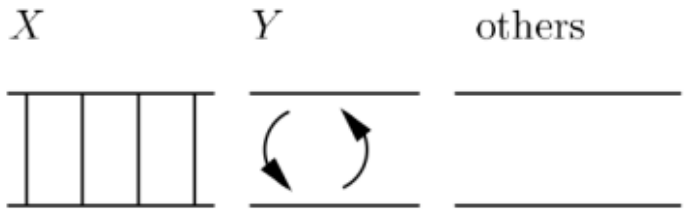
In the above relation with two MVDs:

- Student_ID $\twoheadrightarrow$ Course_name and
- Student_ID $\twoheadrightarrow$ Inst_name.

Formal Definition of Multivalued Dependency

The multivalued dependency X →→ Y holds in a relation R if whenever we have two tuples of R that agree in all the attributes of X , then we can

swap their Y components and get two new tuples that are also in R .



For Eg :

R = Drinkers(name, addr, phones,beerLiked) and with

MVD's : (Name →→ Phones). If Drinkers has 2 Tuples.

Name	Address	Phones	BeerLiked
Sue	Chennai	P1	B1
Sue	Chennai	P2	B2

Name	Address	Phones	BeerLiked
Sue	Chennai	P2	B1
Sue	Chennai	P1	B2

MVD Rules

1. Every FD is an MVD.
   - Because if $X \twoheadrightarrow Y$, then swapping Y 's between tuples that agree on X doesn't create new tuples.
   - Example, in Drinkers : name $\twoheadrightarrow$ addr .

2. Complementation :

   if $X \twoheadrightarrow Y$, then $X \twoheadrightarrow Z$, where Z is all attributes not in X/ Y.
   - Example: since name $\twoheadrightarrow$ phones holds in Drinkers,
   - so does name $\twoheadrightarrow$ (addr,beersLiked) .

Splitting Doesn't Hold

Consider the Relation :

Drinkers(name, areaCode, phones, beersLiked, beerManf)

Name	AreaCode	Phones	BeerLiked	BeerManf
Sue	650	555-1111	Bud	A.B
Sue	650	555-1111	WickedAle	Pete's
Sue	415	555-9999	Bud	A.B
Sue	415	555-9999	WickedAle	Pete's

Name $\rightarrow\rightarrow$ (areaCode,phones) holds, but neither
Name $\rightarrow\rightarrow$ areaCode nor Name $\rightarrow\rightarrow$ phones do

So Decompose the Above Relation into 4NF.

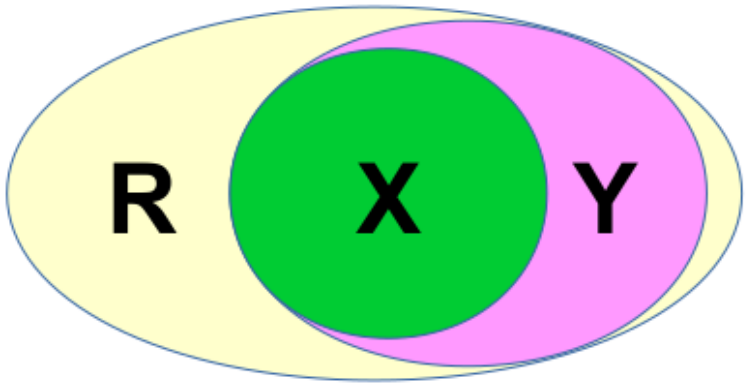
Fourth Normal Form (4NF)

Eliminate redundancy due to multiplicative effect of MVD's.

- Roughly: treat MVD's as FD's for decomposition, but not for finding keys.
- Formally: R is in Fourth Normal Form if whenever MVD exists, I.e $X \rightarrow\rightarrow Y$ is non-trivial (Y is not a subset of X , and $X \cup Y$ is not all attributes), then X is a superkey.

Remember, $X \rightarrow Y$ implies $X \rightarrow\rightarrow Y$, so 4NF is more stringent than BCNF.

Decompose R , using 4NF violation $X \rightarrow\rightarrow Y$, into XY and $X \cup$ (R - Y).



Fourth Normal Form : Example

An MVD X →→ Y in R is called a trivial MVD, if

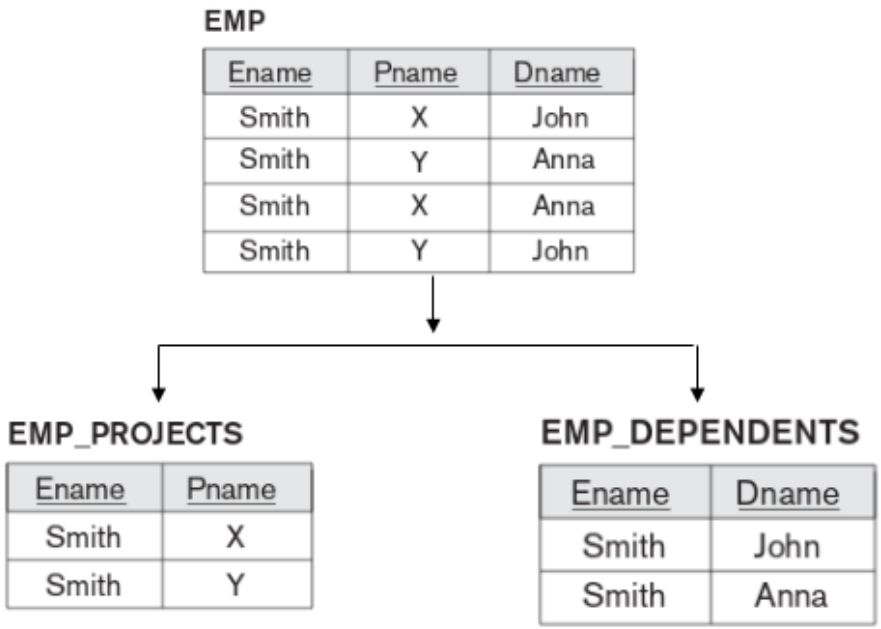
(a) Y is a subset of X, or

(b) X∪Y=R.

For Eg: the relation EMP_PROJECTS has the trivial MVD Ename→→Pname.

An MVD that satisfies neither (a) nor (b) is called anontrivial MVD.

A trivial MVD will hold in any relation state r of R; it is called trivial because it does not specify any significant or meaningful constraint on R.



Fourth Normal Form Definition

A relation 'R' is in fourth normal form iff it is in BCNF and contains no MVD's

Multivalued Dependency: A type of functional dependency where the determinant can determine more than one value. More formally, there are 3 criteria: There must be at least 3 attributes in the relation R(A, B, C)

- Given A, one can determine multiple values of B.
- Given A, one can determine multiple values of C.
- B and C are independent of one another.

Example-1 : Consider the Below Relation 'R'

StudentID	Major	Activities
100	CIS	BaseBall
100	CIS	VolleyBall
100	Accounting	BaseBall
100	Accounting	VolleyBall
200	Marketing	Swimming

FD1: StudentID →→ Major
FD2: StudentID →→ Activities

Fourth Normal Form : Example-2

Example-2 : Consider the Below Relation 'R'

Portfolio ID	Stock Fund	Bond Fund
999	Janus Fund	Municipal Bonds
999	Janus Fund	Dreyfus Short-Intermediate Municipal Bond Fund
999	Scudder Global Fund	Municipal Bonds
999	Scudder Global Fund	Dreyfus Short-Intermediate Municipal Bond Fund
800	Kaufmann Fund	T. Rowe Price Emerging Markets Bond Fund

PortfolioID $\twoheadrightarrow$ Stock Fund
PortfolioID $\twoheadrightarrow$ Bond Fund

R Decomposes into R_1 and R_2

R_1(Portfolio Id, Stock Fund)

Portfolio ID	Stock Fund
999	Janus Fund
999	Scudder Global Fund
888	Kaufmann Fund

R_2 (Portfolio Id, Bond Fund)

Portfolio ID	Bond Fund
999	Municipal Bonds
999	Dreyfus Short-Intermediate Municipal Bond Fund
888	T. Rowe Price Emerging Markets Bond Fund

Lossless Dependency - 5NF (Fifth Normal Form)

It is also Called as "Projection Join" Normal form.

There are certain conditions under which after decomposing a relation 'R', it cannot be reassembled back into its original form I.e Lossless Decomposition is not possible.

A Relation 'R' is said to be in 5NF if it is in 4NF and contains no redundant values/contains no join dependencies.

The process of converting the table into 5NF is as follows:

- Remove the join dependency.
- Break the database table into smaller and smaller tables to remove all data redundancy.

5NF- Join Dependency

Definition :
Let 'R' be a relation, and 'A, B, C, ... Z' be subsets of the attributes of R. Then, We say that R satisfies the Join Dependency – * A, B, C, ... , Z (pronounced as "star A,B,C,....Z") iff, every legal value of 'R' is equal to the join of its projections on A,B,C,..... Z.

Consider for Eg :

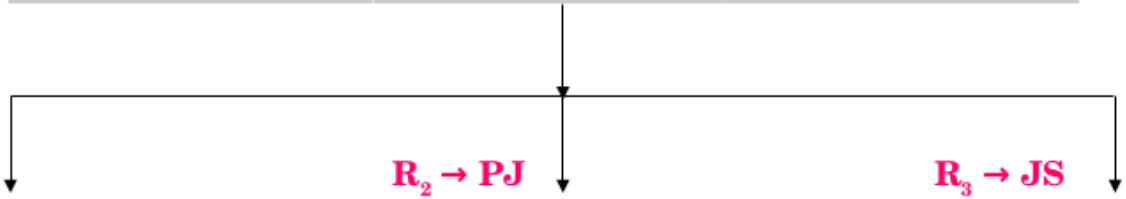
R = SHIPMENTS(Supplier_Name, Part_Number, Project_Number)

SHIPMENTS		
Supplier_Number	**Part_Number**	**Project_Number**
S1	P1	J2
S1	P2	J1
S2	P1	J1
S1	P1	J1

Now R is decomposed into $R_1 \rightarrow SP$, $R_2 \rightarrow PJ$, $R_3 \rightarrow JS$

5NF - Example

SHIPMENTS		
Supplier_Number	**Part_Number**	**Project_Number**
S_1	P_1	J_2
S_1	P_2	J_1
S_2	P_1	J_1
S_1	P_1	J_1



$R_1 \rightarrow SP$

Supplier_ Number	Part_ Number
S1	P1
S1	P2
S2	P1

$R_2 \rightarrow PJ$

Part_ Number	Project_ Number
P1	J2
P2	J1
P1	J1

$R_3 \rightarrow JS$

Project_ Number	Supplier _Number
J2	S1
J1	S1
J1	S2

Now the relations R_1, R_2 and R_3 are in 4NF, because no MVDs.

5NF (Join Dependency) - R1 ⋈ R2

Supplier_ Number	Part_ Number
S1	P1
S1	P2
S2	P1

⋈

Part_ Number	Project_ Number
P1	J2
P2	J1
P1	J1

Joining the Relations R_1 and R_2 over Part_Number

SHIPMENTS		
Supplier_ Number	Part_ Number	Project_ Number
S_1	P_1	J_2
S_1	P_2	J_1
S_2	P_1	J_1
S_1	P_1	J_1
S_2	P_1	J_2

← Spurious Tuple

5NF (Join Dependency) - (R1 ⋈ R2) ⋈ R3

SHIPMENTS		
Supplier_ Number	Part_ Number	Project_ Number
S_1	P_1	J_2
S_1	P_2	J_1
S_2	P_1	J_1
S_1	P_1	J_1
S_2	P_1	J_2

⋈

Project_ Number	Supplier _Number
J2	S1
J1	S1
J1	S2

Joining the Relations R_{12} and R_3 over Part_Number, Supplier_Number

SHIPMENTS		
Supplier_Number	Part_Number	Project_Number
S_1	P_1	J_2
S_1	P_2	J_1
S_2	P_1	J_1
S_1	P_1	J_1

3D Constraint

3D of SHIPMENTS could be more fundamental of Time-independent property. (A property satisfied by all legal values of the relation)

I.e if the relation satisfies a certain time-independent integrity constraint.

The relation SHIPMENTS is equal to the join of its 3 projections SP, PJ and JS is precisely equivalent to the following Statements

If the pair	(s_1, p_1)	appears in SP
And the pair	(p_1, j_1)	appears in PJ
And the pair	(j_1, s_1)	appears in JS
The the triple	(s_1, p_1, j_1)	appears in SHIPMENTS (Join(*SP*,*PJ*,*JS*))

5NF (Join Dependency) - Example

Consider the Relation CTL (Courses_Tutor_Level)

CTL

Course	Tutor	Level
Databases	M. Ursu	Level3
Databases	M. Marman	Level2
Programming	M. Ursu	Level2
Databases	M. Ursu	Level2

CT

Course	Tutor
Databases	M. Ursu
Databases	M. Harman
Programming	M. Ursu

TL

Tutor	Level
M. Ursu	Level3
M. Harman	Level2
M. Ursu	Level2

LC

Course	Level
Databases	Level3
Databases	Level2
Programming	Level2

5NF (Join Dependency) - (CT ⋈ TL)

The Join of CT and TL is as Follows ⋈

join(CT, TL)

Course	Tutor	Level
Databases	M. Ursu	Level3
Databases	M. Ursu	Level2
Databases	M. Marman	Level2
Programming	M. Ursu	Level3
Programming	M. Ursu	Level2

Check 3D Constraint

IF tutor t1 teaches subject s1
AND level l1 studies subject s1
AND tutor t1 teaches level l1
THEN tutor t1 teaches subject s1 for level l1

5NF (Join Dependency) - (CT ⋈ TL) ⋈ LC

Now Join(Join(CT,TL), LC)

join(CT, TL)

Course	Tutor	Level
Databases	M. Ursu	Level3
Databases	M. Ursu	Level2
Databases	M. Marman	Level2
Programming	M. Ursu	Level3
Programming	M. Ursu	Level2

Extra!

⋈

LC

Course	Level
Databases	Level3
Databases	Level2
Programming	Level2

CTL

Course	Tutor	Level
Databases	M. Ursu	Level3
Databases	M. Marman	Level2
Programming	M. Ursu	Level2
Databases	M. Ursu	Level2

Thanks