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Chapter 3 Design Theory for Relational Databases

Objectives

Understand concepts of:

- Functional Dependencies
- Normalization
- Decomposition
- Multi-valued Dependencies

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Contents

- Functional Dependencies
- Rules about FDs
- Key & Super-Key
- Normal forms

Functional dependency

- A **functional dependency:** constraint between two sets of attributes in a relation
- A set of attributes X (include $A_1A_2\ldots A_n$) in R **functionally determine** another attribute Y (include $B_1B_2\ldots B_m$), also in R, (written $X \rightarrow Y$) if and only if each X value is associated with precisely one Y value
- A functional dependency $A_1A_2\ldots A_n \rightarrow B_1B_2\ldots B_m$ holds on relation R *if two tuples of R agree on all of the attributes* $A_1, A_2, \ldots, A_n$ *then they must also agree on all of the attributes* $B_1, B_2, \ldots, B_m$

Functional dependency

title	*year*	*length*	*genre*	*studioName*	*starName*
Star Wars	1977	124	SciFi	Fox	Carrie Fisher
Star Wars	1977	124	SciFi	Fox	Mark Hamill
Star Wars	1977	124	SciFi	Fox	Harrison Ford
Gone With the Wind	1939	231	drama	MGM	Vivien Leigh
Wayne's World	1992	95	comedy	Paramount	Dana Carvey
Wayne's World	1992	95	comedy	Paramount	Mike Meyers

Easy to see that: the following FD is true

- title,year $\rightarrow$ length, genre, studioName

Exercise: How about the FD

- title,year $\rightarrow$ starName

title, year → startName does not hold in Movies1 relation

Functional dependency

- Review key of relation, candidate keys(alternate keys), primary key
- Super-key
  - A set of attributes that contains a key is called a *super-key*
  - Every super-key satisfies the first condition of a key: it functionally determines all other attributes of the relation
  - If K is a key, L is a super key, then: $K \subseteq L$
  - A key is also a super key

Functional dependency

- **Armstrong's Axioms**
  - Fundamental Rules: Let X, Y, Z are sets of attributes
    - Reflexivity:

      If X is a subset of Y, then Y→X
    - Augmentation

      If X→Y, then XZ→YZ for any Z
    - Transitivity

    If X→Y and Y→Z, then X→Z
  - Additional rules: Let X, Y, Z, W are sets of attributes
    - Union/Combining: if X→Y AND X→Z then X→YZ
    - Decomposition/Splitting: if X→YZ, then X→Y and X→Z
    - Pseudotransitivity: If X → Y and WY → Z then WX →Z
- Trivial FDs: right side is a subset of left side
  - Ex: FLD →FD

Functional dependency

- A set of FD's *S* **follows** from a set of FD's *T* if every relation instance that satisfies all the FD's in *T* also satisfies all the FD's in *S*
- Two sets of FD's *S* and *T* are **equivalent** if and only if *S* **follows** from *T*, and *T* **follows** *S*

The Closure of Attributes

- The closure of a set of attributes $\{A_1, A_2, \ldots, A_n\}$ under FD's in S *(denoted* $\{A_1, A_2, \ldots, A_n\}^+$*)* is the set of attributes B such that every relation that satisfies all the FD's in set S also satisfies $A_1A_2\ldots A_n \rightarrow B$
- That is, $A_1A_2\ldots A_n \rightarrow B$ follows from the FD's of S
- $A_1, A_2, \ldots, A_n \in \{A_1, A_2, \ldots, A_n\}+$, because $A_1A_2\ldots A_n \rightarrow A_i$ is trivial

The Closure of Attributes

Algorithm 3.7: Closure of a set of attributes

- Input: A set of attributes $\{A_1,A_2,\ldots,A_n\}$ and a set of FD's S
- Output: The closure $\{A_1,A_2,\ldots,A_n\}^+$
  1. If necessary, split the FD's of S, so each FD in S have singleton right side
  2. Let X be a set of attributes that will become the closure. Initialize X to be $\{A_1,A_2,\ldots,A_n\}$
  3. Repeatedly search for some FD: $B_1B_2\ldots B_m \rightarrow C$, such that $B_1, B_2, \ldots, B_m$ are in X, but C is not
     a) If such C is found, add to X, and repeat the search
     b) If such C is not found, no more attributes can be added to X
  4. The set X is the correct value of $\{A_1, A_2, \ldots, A_n\}+$

The Closure of Attributes

R(A, B, C, D)

S={A→B, B→C, C→D, D→A}

Compute $\{A\}^+$? $\{B\}^+$?

What are some the keys of R?

Closing Sets of Functional Dependencies

Suppose a set of FD's *S*, any set of FD's T equivalent to *S* is said to be a ***basis*** for *S*.
Then we say T is a ***basis*** for *S*

Just work with only FD's that have *singleton right sides*

A ***minimal basis*** for FD's *S* is a ***basis B*** that satisfies three conditions:

- All the FD's in *B* have singleton right sides
- If any FD is removed from *B*, the result is no longer a basis
- If for any FD in *B* we remove one or more attributes from the left side, the result is no longer a basis

Closing Sets of Functional Dependencies

Example

- R(A,B,C)
- S={A$\rightarrow$ B, A $\rightarrow$ C, B $\rightarrow$ A, B $\rightarrow$ C, C $\rightarrow$ A, C $\rightarrow$ B, AB $\rightarrow$ C, BC $\rightarrow$ A, AC $\rightarrow$ B, A $\rightarrow$ BC, B $\rightarrow$ AC, C $\rightarrow$ AB}
- R and its FD's have several minimal basis
  - {A $\rightarrow$ B, B $\rightarrow$ A, B $\rightarrow$ C, C $\rightarrow$ B}, or
  - {A $\rightarrow$ B, B $\rightarrow$ C, C $\rightarrow$ A}

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What happens to …

… a set of FD's *S* of *R* when we project *R* on some attributes?

That is, suppose a relation *R* with set of FD's *S*, and $R_1 = \pi_L(R)$. What FD's hold in R_1?

Projecting Functional Dependencies

To find a functional dependencies of projection, we

- Follow from *S*, and
- Involve only attributes of R_1

Projecting Functional Dependencies

Algorithm 3.12: Projecting a Set of FD's

- Input: R, $R_1=\pi_L(R)$, *S* a set of FD's that hold in R
- Output: the set of FD's that hold in R_1
- Method:
  - T is the set of FD's that hold in R_1. Initially, T is empty
  - For each set of attributes X of R_1, compute *X*+. Add to *T* all non-trivial FD's $X \rightarrow A$ such that *A* is both in *X*+ and an attribute of R_1
  - Construct a minimal basis from *T*

Projecting Functional Dependencies

Algorithm 3.12: Projecting a Set of FD's (cont)

- Compute a minimal basis from *T*
  - If there is an FD *F* in *T* that follows from other FD's in *T*, then remove *F* from *T*
  - Let Y → B is a FD in *T* , with at least two attributes in *Y*, and let *Z* is *Y* with one of its attributes removed:
    - If *Z* → *B* follows from the other FD's in T (including *Y* → *B*), then replace *Y* → *B* by *Z* → *B*
  - Repeat the above steps in all possible ways until no more changes to *T* can be made

Projecting Functional Dependencies

Two notations

- (1) Closing the empty set and the set of all attributes cannot yield a nontrivial FD
- (2) If we have already knew that the closure of some set *X* is all attributes, then we cannot discover any new FD's by closing supersets of *X*

Projecting Functional Dependencies

Example: Suppose R(A,B,C,D) has FD's A→B, B→C, and C→D. R1=$\pi_{A,C,D}$(R). Find the FD's of R1?

- Compute the closure of the singleton set
  - {A}+={A,B,C,D}, and B is not in R1, then new FD's A→C, A→D
  - {C}+={C,D}, then new FD's C→D
  - {D}+={D}, no new FD's
- Compute the closure of the doubleton set
  - Since {A}+ include all attributes, no care any more for supersets of {A}
  - {C,D}+={C,D}, no new FD's holds in R1
- Finally, there are three FD's A→C, A→D, C→D hold in R1
- A→D is transitive from A→C, and C→D
- So, minimal basis is {A→C, C→D}

Anomalies introduction

Careless selection of a relational database schema can lead to redundancy and related anomalies

So, in this session we shall tackle the problems of relational database designing

Problems such as redundancy that occur when we try to cram too much into a single relation are called *anomalies*

Anomalies

title	*year*	*length*	*genre*	*studioName*	*starName*
Star Wars	1977	124	SciFi	Fox	Carrie Fisher
Star Wars	1977	124	SciFi	Fox	Mark Hamill
Star Wars	1977	124	SciFi	Fox	Harrison Ford
Gone With The Wind	1939	231	drama	MGM	Vivien Leigh
Wayne's World	1992	95	comedy	Paramount	Dana Carvey
Wayne's World	1992	95	comedy	Paramount	Mike Meyers

The principal kinds of anomalies that we encounter are:

Redundancy: information maybe repeated unnecessarily in several tuples (**exp**: the length and genre)

Update Anomalies: We may change information in one tuple but leave the same information unchanged in another (**exp**: if we found that *Star Wars* is 125 minutes long, we may change the length in the first tuple but not in the second and third tuples)

Deletion Anomalies: If a set of values becomes empty, we may lose other information as a side effect (**exp**: if we delete “Fox” from the set of studios, then we have no more studios for the movie “Star Wars”

Decomposition

The accepted way to eliminate anomalies is the *decomposition* of relations

Decomposition of a relation R involves splitting the attributes of R to make the schemas of 2 new relations

Definition: Given a relation $R(A_1,..,A_n)$, we say R is decomposed into $S(B_1,..,B_m)$ and $T(C_1,..,C_k)$ if:

+ $\{A_1,..,A_n\} = \{B_1,..,B_m\} \cup \{C_1,..,C_k\}$
+ $S = \prod_{B1,..Bm}(R)$
+ $T = \prod_{C1,..,Ck}(R)$

Example: Decomposition

title	*year*	*length*	*genre*	*studioName*	*starName*
Star Wars	1977	124	SciFi	Fox	Carrie Fisher
Star Wars	1977	124	SciFi	Fox	Mark Hamill
Star Wars	1977	124	SciFi	Fox	Harrison Ford
Gone With The Wind	1939	231	drama	MGM	Vivien Leigh
Wayne's World	1992	95	comedy	Paramount	Dana Carvey
Wayne's World	1992	95	comedy	Paramount	Mike Meyers

title	*year*	*length*	*genre*	*studioName*
Star Wars	1977	124	SciFi	Fox
Gone With The Wind	1939	231	drama	MGM
Wayne's World	1992	95	comedy	Paramount

title	*year*	*starName*
Star Wars	1977	Carrie Fisher
Star Wars	1977	Mark Hamill
Star Wars	1977	Harrison Ford
Gone With	1939	Vivien Leigh
Wayne's W	1992	Dana Carvey
Wayne's W	1992	Mike Meyers

Discuss

title	*year*	*length*	*genre*	*studioName*
Star Wars	1977	124	SciFi	Fox
Gone With The Wind	1939	231	drama	MGM
Wayne's World	1992	95	comedy	Paramount

title	*year*	*starName*
Star Wars	1977	Carrie Fisher
Star Wars	1977	Mark Hamill
Star Wars	1977	Harrison Ford
Gone With	1939	Vivien Leigh
Wayne's W	1992	Dana Carvey
Wayne's W	1992	Mike Meyers

The redundancy is eliminated (the length of each film appears only once)

The risk of an update anomaly is gone (we only have to change the length of *Star Wars* in one tuple)

The risk of a deletion anomaly is gone (if we delete all the stars for *Gone with the wind,* that deletion makes the movie disappear from the right but still be found in the left)

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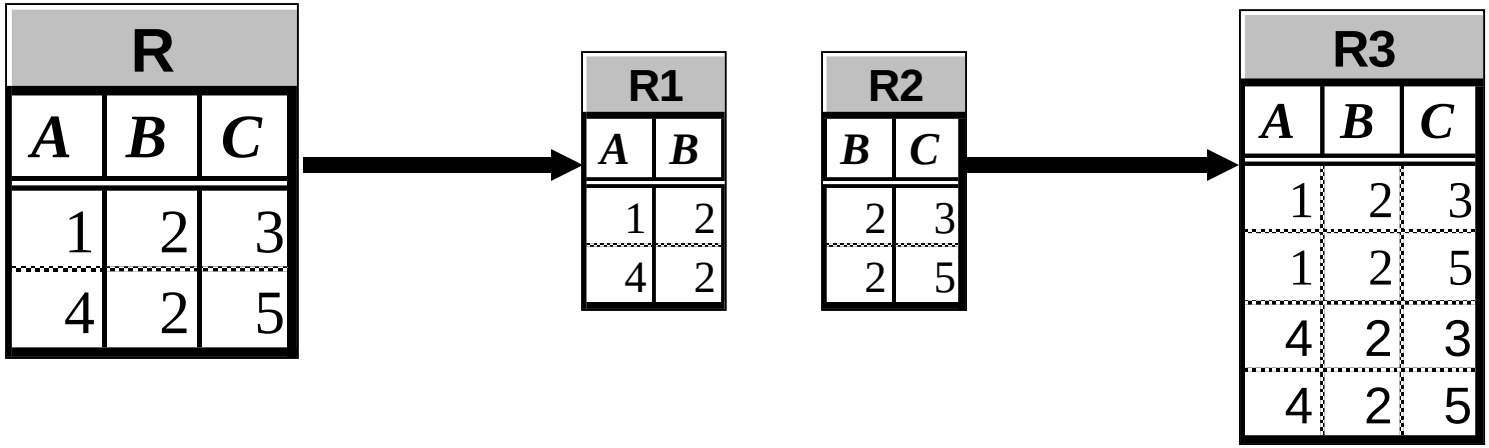
Decomposition: The Good, Bad and Ugly

We observed that before we decompose a relation schema into BCNF, it can exhibit anomalies; That's the "Good"

However, decomposition can also have some bad:

- Maybe we can't recovery the original information; OR
- After reconstruction, the FDs maybe not hold

Example: Loss of information after decomposition



Suppose we have R(A,B,C) but neither of the FD's B->A nor B->C holds.

R is decomposed into R1 and R2 as above

When we try to re-construct R by Natural Join of R1 and R2, we have: R3 = R1 X R2 (but R3 <> R1 => We lost information)

Example: Dependency Loss

If we check the projected FD's in the relations of the decomposition, can we can be sure that when we reconstruct the original relation from the decomposition by joining, the result will satisfy the original FD's?

Normal Forms

- First Normal Form
- Second Normal Form
- Third Normal Form
- Boyce-Codd Normal Form
- Fourth Normal Form
- Fifth Normal Form
- Domain-Key Normal Form

Dependencies: Definitions

- ***Multivalued Attributes*** (or ***repeating groups***): non-key attributes or groups of non-key attributes the values of which are not uniquely identified by (directly or indirectly) (not functionally dependent on) the value of the Primary Key (or its part).

- ***Partial Dependency*** – when a non-key attribute is determined by a part, but not the whole, of a **COMPOSITE** primary key.

- ***Transitive Dependency*** – when a non-key attribute determines another non-key attribute.

1NF

1NF A relation R is in first normal form (1NF) if and only if all underlying domains contain atomic values only

Take the following table.

StudentID is the primary key.

StudentID	StudentName	Address	HouseName	HouseColor	Subject	SubjectCost	Grade
19594332X	Mary Watson	10 Charles Street	Bob	Red	English Maths Info Tech	$50 $50 $100	B A B+

Is it 1NF?

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No. There are repeating groups (subject, subjectcost, grade)

StudentID	StudentName	Address	HouseName	HouseColor	Subject	SubjectCost	Grade
19594332X	Mary Watson	10 Charles Street	Bob	Red	English Maths Info Tech	$50 $50 $100	B A B+

How can you make it 1NF?

Create new rows so each cell contains only one value

StudentID	StudentName	Address	HouseName	HouseColor	Subject	SubjectCost	Grade
19594332X	Mary Watson	10 Charles Street	Bob	Red	English Maths Info Tech	$50 $50 $100	B A B+

StudentID	StudentName	Address	HouseName	HouseColor	Subject	SubjectCost	Grade
19594332X	Mary Watson	10 Charles Street	Bob	Red	English	$50	B
19594332X	Mary Watson	10 Charles Street	Bob	Red	Maths	$50	A
19594332X	Mary Watson	10 Charles Street	Bob	Red	Info Tech	$100	B+

But now look – is the *studentID* primary key still valid?

No – the studentID no longer uniquely identifies each row

StudentID	StudentName	Address	HouseName	HouseColor	Subject	SubjectCost	Grade
19594332X	Mary Watson	10 Charles Street	Bob	Red	English	$50	B
19594332X	Mary Watson	10 Charles Street	Bob	Red	Maths	$50	A
19594332X	Mary Watson	10 Charles Street	Bob	Red	Info Tech	$100	B+

You now need to declare *studentID* and *subject* together to uniquely identify each row.

So the new key is StudentID *and* Subject.

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So. We now have 1NF.

StudentID	StudentName	Address	HouseName	HouseColor	Subject	SubjectCost	Grade
19594332X	Mary Watson	10 Charles Street	Bob	Red	English	$50	B
19594332X	Mary Watson	10 Charles Street	Bob	Red	Maths	$50	A
19594332X	Mary Watson	10 Charles Street	Bob	Red	Info Tech	$100	B+

Is it 2NF?

2NF

A relation R is in second normal form (2NF) if and only if it is in 1NF and every non-key attribute is fully dependent on the primary key

StudentName & Address are dependent on studentID (which is part of the key)

StudentID	StudentName	Address	HouseName	HouseColor	Subject	SubjectCost	Grade
19594332X	Mary Watson	10 Charles Street	Bob	Red	English	$50	B
19594332X	Mary Watson	10 Charles Street	Bob	Red	Maths	$50	A
19594332X	Mary Watson	10 Charles Street	Bob	Red	Info Tech	$100	B+

But they are not dependent on *Subject* (the *other* part of the key)

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And 2NF requires…

StudentID	StudentName	Address	HouseName	HouseColor	Subject	SubjectCost	Grade
19594332X	Mary Watson	10 Charles Street	Bob	Red	English	$50	B
19594332X	Mary Watson	10 Charles Street	Bob	Red	Maths	$50	A
19594332X	Mary Watson	10 Charles Street	Bob	Red	Info Tech	$100	B+

All non-key fields are dependent on the ENTIRE key (studentID + subject)

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So it's not 2NF

StudentID	StudentName	Address	HouseName	HouseColor	Subject	SubjectCost	Grade
19594332X	Mary Watson	10 Charles Street	Bob	Red	English	$50	B
19594332X	Mary Watson	10 Charles Street	Bob	Red	Maths	$50	A
19594332X	Mary Watson	10 Charles Street	Bob	Red	Info Tech	$100	B+

How can we fix it?

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Make new tables

Make a new table for each primary key field

Give each new table its own primary key

Move columns from the original table to the new table that matches their primary key…

Step 1

StudentID	StudentName	Address	HouseName	HouseColor	Subject	SubjectCost	Grade
19594332X	Mary Watson	10 Charles Street	Bob	Red	English	$50	B
19594332X	Mary Watson	10 Charles Street	Bob	Red	Maths	$50	A
19594332X	Mary Watson	10 Charles Street	Bob	Red	Info Tech	$100	B+

STUDENT TABLE (key = StudentID)

Step 2

StudentID	StudentName	Address	HouseName	HouseColor	Subject	SubjectCost	Grade
19594332X	Mary Watson	10 Charles Street	Bob	Red	English	$50	B
19594332X	Mary Watson	10 Charles Street	Bob	Red	Maths	$50	A
19594332X	Mary Watson	10 Charles Street	Bob	Red	Info Tech	$100	B+

STUDENT TABLE (key = StudentID)

StudentID	StudentName	Address	HouseName	HouseColor
19594332X	Mary Watson	10 Charles Street	Bob	Red

SUBJECTS TABLE (key = Subject)

Step 3

StudentID	StudentName	Address	HouseName	HouseColor	Subject	SubjectCost	Grade
19594332X	Mary Watson	10 Charles Street	Bob	Red	English	$50	B
19594332X	Mary Watson	10 Charles Street	Bob	Red	Maths	$50	A
19594332X	Mary Watson	10 Charles Street	Bob	Red	Info Tech	$100	B+

STUDENT TABLE (key = StudentID)

StudentID	StudentName	Address	HouseName	HouseColor
19594332X	Mary Watson	10 Charles Street	Bob	Red

SUBJECTS TABLE (key = Subject)

Subject	SubjectCost
English	$50
Maths	$50
Info Tech	$100

RESULTS TABLE (key = StudentID+Subject)

Step 3

StudentID	StudentName	Address	HouseName	HouseColor	Subject	SubjectCost	Grade
19594332X	Mary Watson	10 Charles Street	Bob	Red	English	$50	B
19594332X	Mary Watson	10 Charles Street	Bob	Red	Maths	$50	A
19594332X	Mary Watson	10 Charles Street	Bob	Red	Info Tech	$100	B+

STUDENT TABLE (key = StudentID)

StudentID	StudentName	Address	HouseName	HouseColor
19594332X	Mary Watson	10 Charles Street	Bob	Red

SUBJECTS TABLE (key = Subject)

Subject	SubjectCost
English	$50
Maths	$50
Info Tech	$100

RESULTS TABLE (key = StudentID+Subject)

StudentID	Subject	Grade
19594332X	English	B
19594332X	Maths	A
19594332X	Info Tech	B+

Step 4 - relationships

STUDENT TABLE (key = StudentID)

StudentID	StudentName	Address	HouseName	HouseColor
19594332X	Mary Watson	10 Charles Street	Bob	Red

SUBJECTS TABLE (key = Subject)

Subject	SubjectCost
English	$50
Maths	$50
Info Tech	$100

StudentID	Subject	Grade
19594332X	English	B
19594332X	Maths	A
19594332X	Info Tech	B+

RESULTS TABLE (key = StudentID+Subject)

Step 4 - cardinality

STUDENT TABLE (key = StudentID)

StudentID	StudentName	Address	HouseName	HouseColor
19594332X	Mary Watson	10 Charles Street	Bob	Red

1

Each student can only appear ONCE in the student table

SUBJECTS TABLE (key = Subject)

Subject	SubjectCost
English	$50
Maths	$50
Info Tech	$100

StudentID	Subject	Grade
19594332X	English	B
19594332X	Maths	A
19594332X	Info Tech	B+

RESULTS TABLE (key = StudentID+Subject)

Step 4 - cardinality

STUDENT TABLE (key = StudentID)

StudentID	StudentName	Address	HouseName	HouseColor
19594332X	Mary Watson	10 Charles Street	Bob	Red

1

SUBJECTS TABLE (key = Subject)

1

Subject	SubjectCost
English	$50
Maths	$50
Info Tech	$100

Each subject can only appear ONCE in the subjects table

StudentID	Subject	Grade
19594332X	English	B
19594332X	Maths	A
19594332X	Info Tech	B+

RESULTS TABLE (key = StudentID+Subject)

Step 4 - cardinality

STUDENT TABLE (key = StudentID)

StudentID	StudentName	Address	HouseName	HouseColor
19594332X	Mary Watson	10 Charles Street	Bob	Red

1

SUBJECTS TABLE (key = Subject)

1

Subject	SubjectCost
English	$50
Maths	$50
Info Tech	$100

A subject can be listed MANY times in the results table (for different students)

∞

StudentID	Subject	Grade
19594332X	English	B
19594332X	Maths	A
19594332X	Info Tech	B+

RESULTS TABLE (key = StudentID+Subject)

Step 4 - cardinality

STUDENT TABLE (key = StudentID)

StudentID	StudentName	Address	HouseName	HouseColor
19594332X	Mary Watson	10 Charles Street	Bob	Red

1

∞

A student can be listed MANY times in the results table (for different subjects)

SUBJECTS TABLE (key = Subject)

1

Subject	SubjectCost
English	$50
Maths	$50
Info Tech	$100

∞

StudentID	Subject	Grade
19594332X	English	B
19594332X	Maths	A
19594332X	Info Tech	B+

RESULTS TABLE (key = StudentID+Subject)

A 2NF check

STUDENT TABLE (key = StudentID)

StudentID	StudentName	Address	HouseName	HouseColor
19594332X	Mary Watson	10 Charles Street	Bob	Red

1

∞

SUBJECTS TABLE (key = Subject)

1

Subject	SubjectCost
English	$50
Maths	$50
Info Tech	$100

∞

StudentID	Subject	Grade
19594332X	English	B
19594332X	Maths	A
19594332X	Info Tech	B+

RESULTS TABLE (key = StudentID+Subject)

SubjectCost is only dependent on the primary key, *Subject*

A 2NF check

STUDENT TABLE (key = StudentID)

StudentID	StudentName	Address	HouseName	HouseColor
19594332X	Mary Watson	10 Charles Street	Bob	Red

1

∞

SUBJECTS TABLE (key = Subject)

1

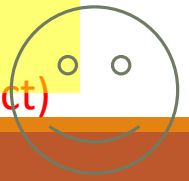
Subject	SubjectCost
English	$50
Maths	$50
Info Tech	$100

∞

StudentID	Subject	Grade
19594332X	English	B
19594332X	Maths	A
19594332X	Info Tech	B+

RESULTS TABLE (key = StudentID+Subject)

Grade is only dependent on the primary key (*studentID + subject*)



A 2NF check

STUDENT TABLE (key = StudentID)

StudentID	StudentName	Address	HouseName	HouseColor
19594332X	Mary Watson	10 Charles Street	Bob	Red

1

∞

Name, Address are only dependent on the primary key (*StudentID*)

SUBJECTS TABLE (key = Subject)

1

Subject	SubjectCost
English	$50
Maths	$50
Info Tech	$100

∞

StudentID	Subject	Grade
19594332X	English	B
19594332X	Maths	A
19594332X	Info Tech	B+

RESULTS TABLE (key = StudentID+Subject)

STUDENT TABLE (key = StudentID)

StudentID	StudentName	Address	HouseName	HouseColor
19594332X	Mary Watson	10 Charles Street	Bob	Red

1

∞

So it is 2NF!

SUBJECTS TABLE (key = Subject)

Subject	SubjectCost
English	$50
Maths	$50
Info Tech	$100

1

∞

StudentID	Subject	Grade
19594332X	English	B
19594332X	Maths	A
19594332X	Info Tech	B+

RESULTS TABLE (key = StudentID+Subject)

But is it 3NF?

3NF

A relation R is in third normal form (3NF) if and only if it is in 2NF and every non-key attribute is non-transitively dependent on the primary key.

An attribute C is transitively dependent on attribute A if there exists an attribute B such that: A->B and B->C

Note that 3NF is concerned with transitive dependencies which do not involve candidate keys. A relation with more than one candidate key will clearly have transitive dependencies of the form: primary_key -> other_candidate_key -> any_non-key_column

A 3NF check

STUDENT TABLE (key = StudentID)

StudentID	StudentName	Address	HouseName	HouseColor
19594332X	Mary Watson	10 Charles Street	Bob	Red

1

∞

Oh oh...

What?

SUBJECTS TABLE (key = Subject)

Subject	SubjectCost
English	$50
Maths	$50
Info Tech	$100

1

∞

StudentID	Subject	Grade
19594332X	English	B
19594332X	Maths	A
19594332X	Info Tech	B+

RESULTS TABLE (key = StudentID+Subject)

A 3NF check

STUDENT TABLE (key = StudentID)

StudentID	StudentName	Address	HouseName	HouseColor
19594332X	Mary Watson	10 Charles Street	Bob	Red

1

HouseName is dependent on both *StudentID + HouseColour*

SUBJECTS TABLE (key = Subject)

Subject	SubjectCost
English	$50
Maths	$50
Info Tech	$100

1

∞

∞

StudentID	Subject	Grade
19594332X	English	B
19594332X	Maths	A
19594332X	Info Tech	B+

RESULTS TABLE (key = StudentID+Subject)

A 3NF check

STUDENT TABLE (key = StudentID)

StudentID	StudentName	Address	HouseName	HouseColor
19594332X	Mary Watson	10 Charles Street	Bob	Red

1

Or HouseColour is dependent on both StudentID + HouseName

SUBJECTS TABLE (key = Subject)

Subject	SubjectCost
English	$50
Maths	$50
Info Tech	$100

1

∞

∞

StudentID	Subject	Grade
19594332X	English	B
19594332X	Maths	A
19594332X	Info Tech	B+

RESULTS TABLE (key = StudentID+Subject)

A 3NF check

STUDENT TABLE (key = StudentID)

StudentID	StudentName	Address	HouseName	HouseColor
19594332X	Mary Watson	10 Charles Street	Bob	Red

1

But either way, non-key fields are dependent on MORE THAN THE PRIMARY KEY (studentID)

SUBJECTS TABLE (key = Subject)

1

Subject	SubjectCost
English	$50
Maths	$50
Info Tech	$100

∞

∞

StudentID	Subject	Grade
19594332X	English	B
19594332X	Maths	A
19594332X	Info Tech	B+

RESULTS TABLE (key = StudentID+Subject)

A 3NF check

STUDENT TABLE (key = StudentID)

StudentID	StudentName	Address	HouseName	HouseColor
19594332X	Mary Watson	10 Charles Street	Bob	Red

1

And 3NF says that non-key fields must depend on nothing but the key

SUBJECTS TABLE (key = Subject)

1

Subject	SubjectCost
English	$50
Maths	$50
Info Tech	$100

∞

∞

StudentID	Subject	Grade
19594332X	English	B
19594332X	Maths	A
19594332X	Info Tech	B+

RESULTS TABLE (key = StudentID+Subject)

A 3NF check

STUDENT TABLE (key = StudentID)

StudentID	StudentName	Address	HouseName	HouseColor
19594332X	Mary Watson	10 Charles Street	Bob	Red

1

∞

WHAT DO WE DO?

SUBJECTS TABLE (key = Subject)

1

Subject	SubjectCost
English	$50
Maths	$50
Info Tech	$100

∞

StudentID	Subject	Grade
19594332X	English	B
19594332X	Maths	A
19594332X	Info Tech	B+

RESULTS TABLE (key = StudentID+Subject)

Again, carve off the offending fields

StudentTable

StudentID	StudentName	Address	HouseName
19594332X	Mary Watson	10 Charles Street	Bob

Primary key: StudentID

1

∞

∞

StudentID	Subject	Grade
19594332X	English	B
19594332X	Maths	A
19594332X	Info Tech	B+

RESULTS TABLE (key = StudentID+Subject)

1

SUBJECTS TABLE (key = Subject)

Subject	SubjectCost
English	$50
Maths	$50
Info Tech	$100

A 3NF fix

StudentTable

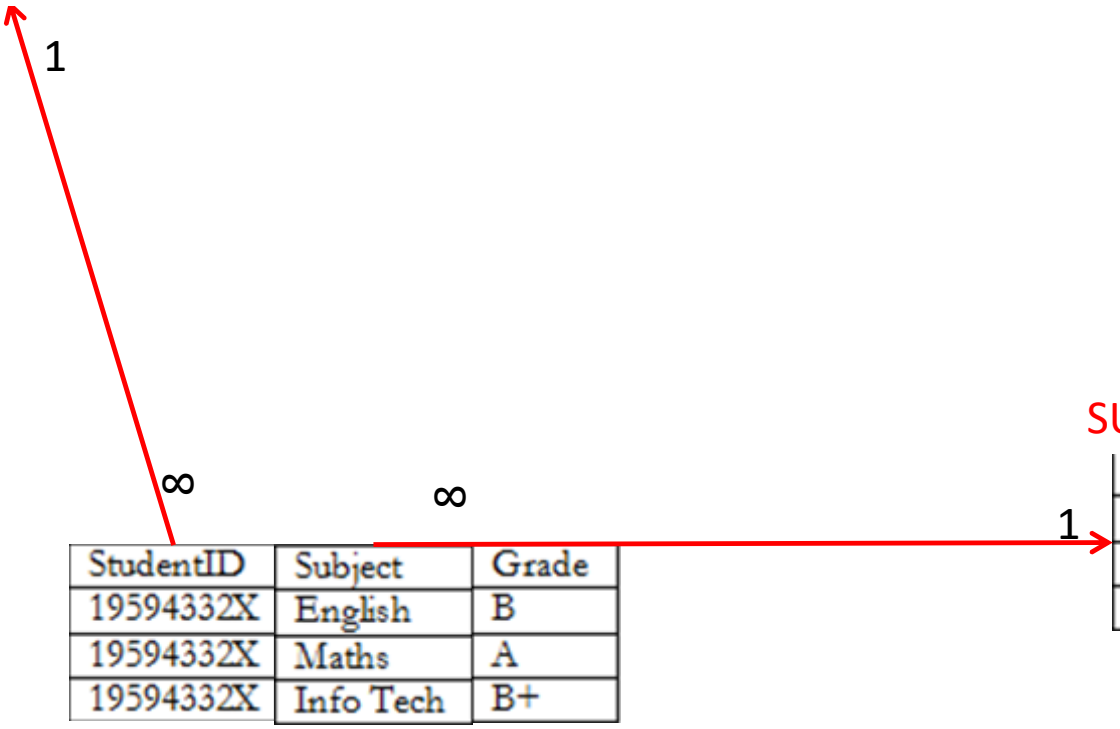
StudentID	StudentName	Address
19594332X	Mary Watson	10 Charles Street

Primary key: StudentID

HouseTable

HouseName	HouseColor
Bob	Red

Primary key: HouseName



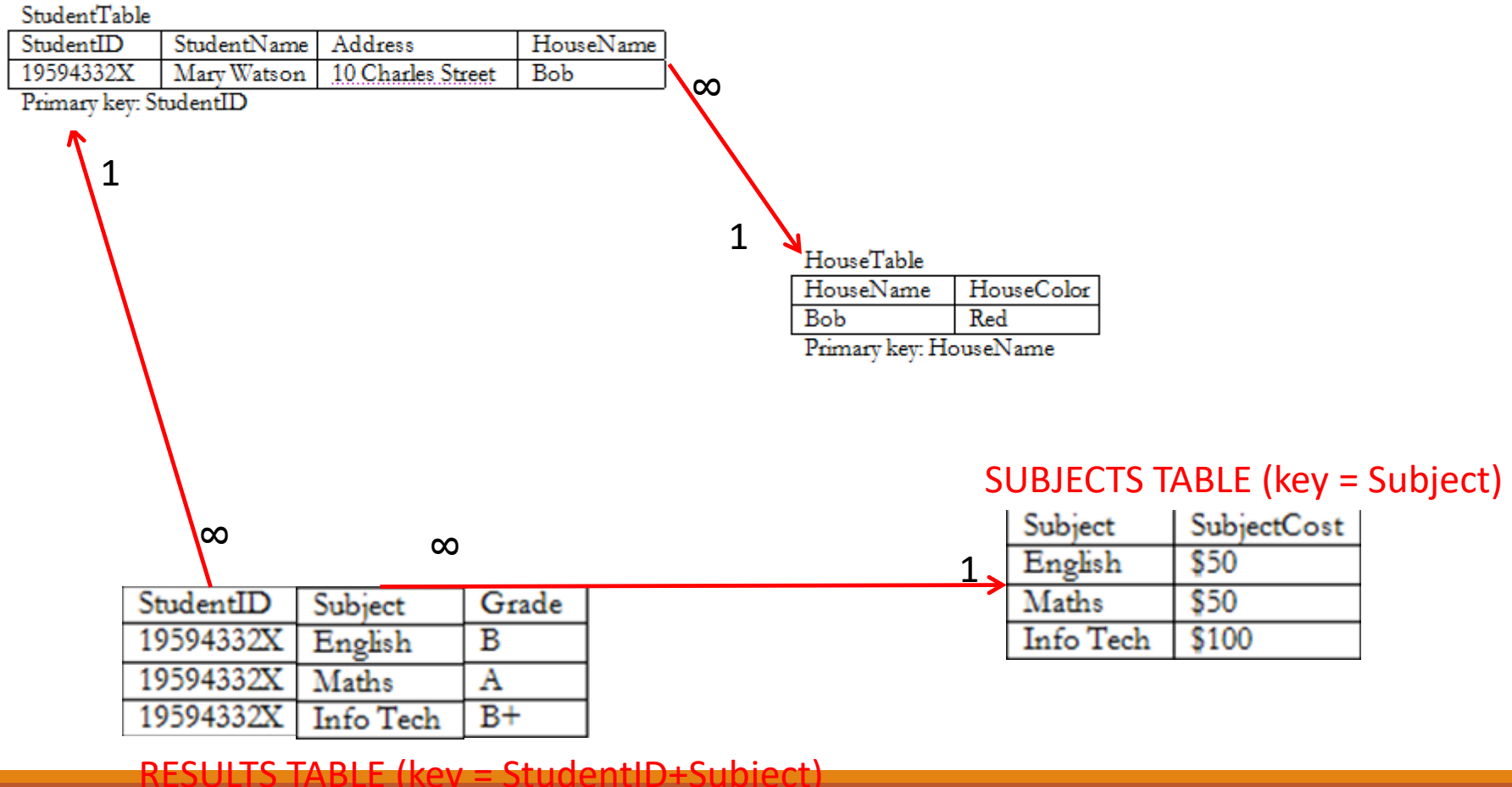
StudentID	Subject	Grade
19594332X	English	B
19594332X	Maths	A
19594332X	Info Tech	B+

RESULTS TABLE (key = StudentID+Subject)

SUBJECTS TABLE (key = Subject)

Subject	SubjectCost
English	$50
Maths	$50
Info Tech	$100

A 3NF fix


StudentTable
StudentID | StudentName | Address | HouseName
19594332X | Mary Watson | 10 Charles Street | Bob
Primary key: StudentID
∞
1
1
HouseTable
HouseName | HouseColor
Bob | Red
Primary key: HouseName
∞
∞
1
SUBJECTS TABLE (key = Subject)
Subject | SubjectCost
English | $50
Maths | $50
Info Tech | $100
StudentID | Subject | Grade
19594332X | English | B
19594332X | Maths | A
19594332X | Info Tech | B+
RESULTS TABLE (key = StudentID+Subject)

A 3NF win!

StudentTable

StudentID	StudentName	Address	HouseName
19594332X	Mary Watson	10 Charles Street	Bob

Primary key: StudentID

HouseTable

HouseName	HouseColor
Bob	Red

Primary key: HouseName

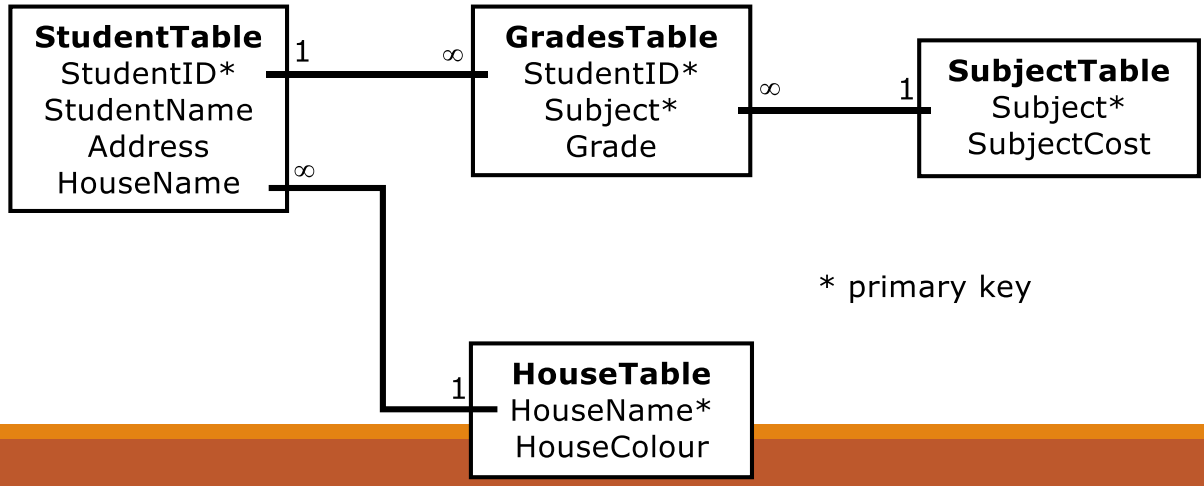
StudentID	Subject	Grade
19594332X	English	B
19594332X	Maths	A
19594332X	Info Tech	B+

RESULTS TABLE (key = StudentID+Subject)

Subject	SubjectCost
English	$50
Maths	$50
Info Tech	$100

SUBJECTS TABLE (key = Subject)

Or...

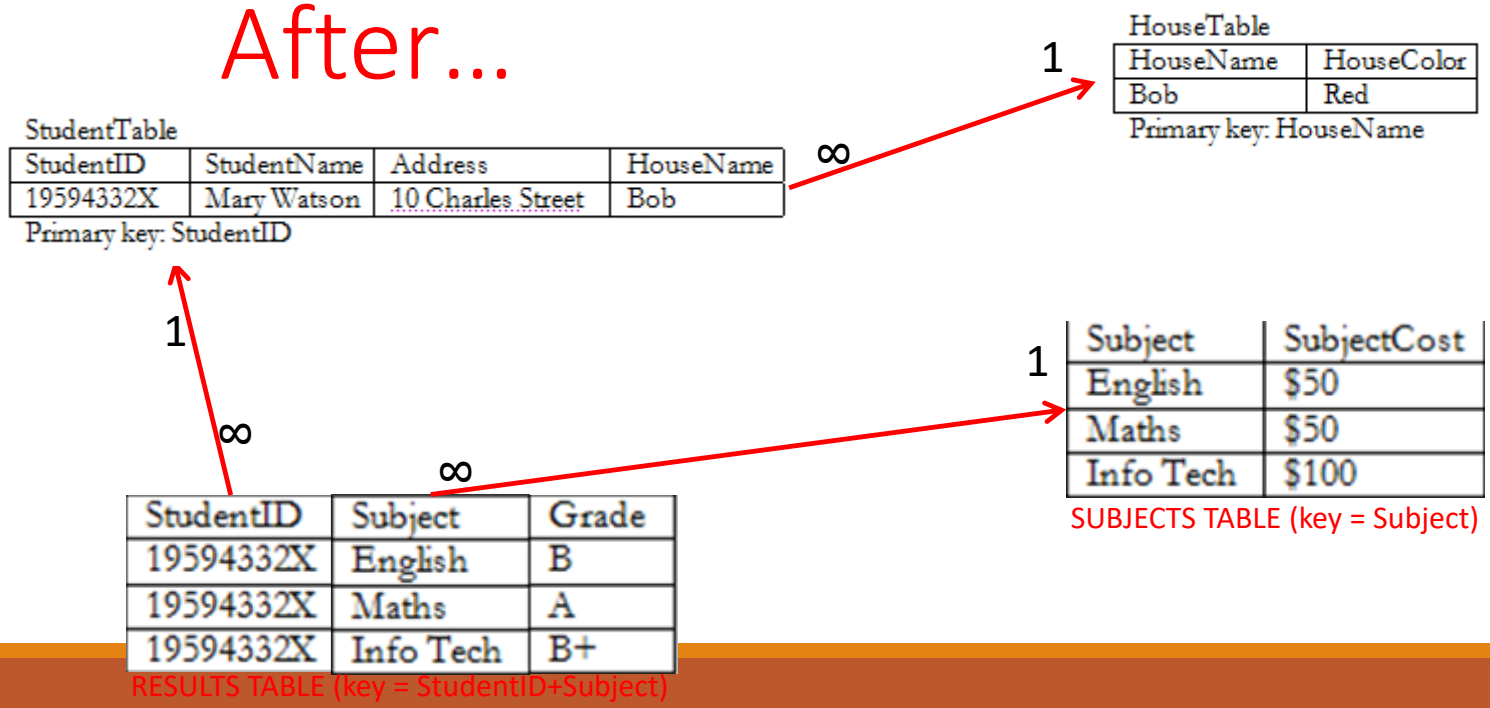


The Reveal

Before…

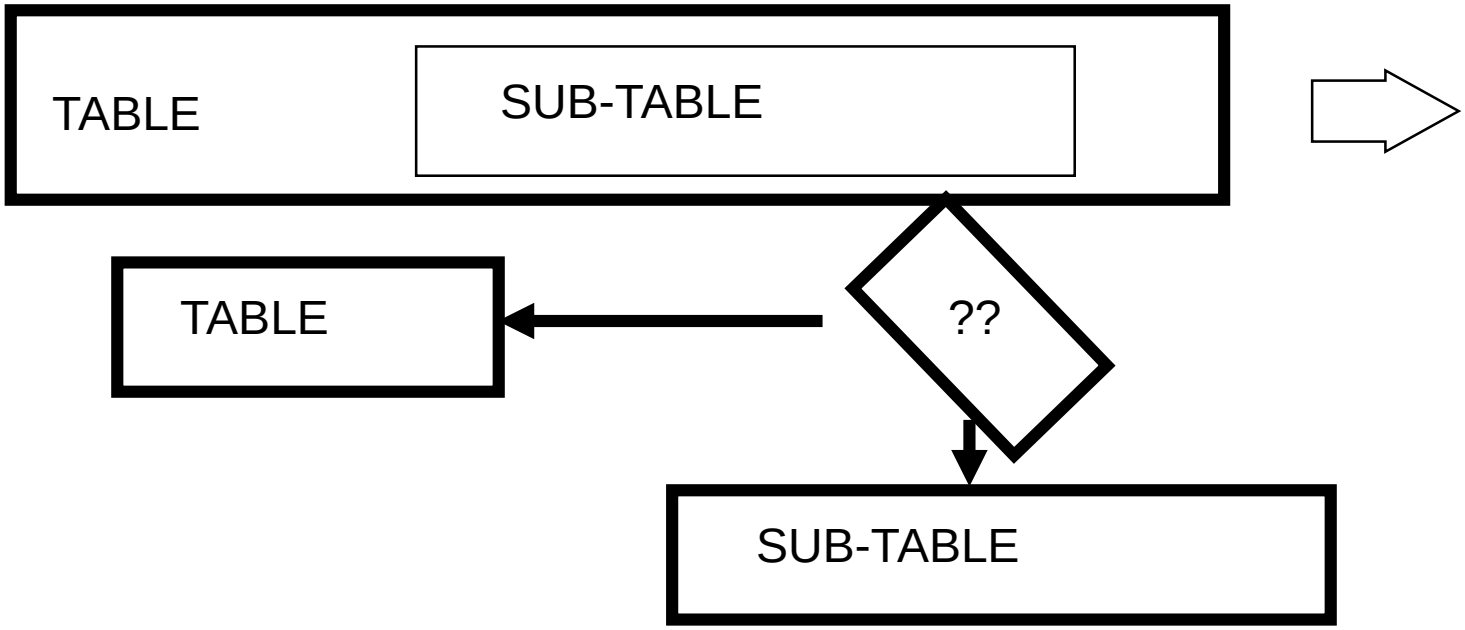
StudentID	StudentName	Address	HouseName	HouseColor	Subject	SubjectCost	Grade
19594332X	Mary Watson	10 Charles Street	Bob	Red	English	$50	B
					Maths	$50	A
					Info Tech	$100	B+

After…



3NF
No transitive dependencies

Table contains data from an embedded entity with non-key attributes.



BCNF is the same, but the embedded table may involve key attributes.

BCNF

A relation R is in BCNF if and only if: **Whenever there is a Non-Trivial FD**
$A_1A_2..A_n$ -> $B_1B_2..B_m$ for R, it is the case that:
$\{A_1,..,A_n\}$ is a super-key for R

That is: the left side of every Non-Trivial FD must be a super-key

Example: BCNF or not

title	*year*	*length*	*genre*	*studioName*	*starName*
Star Wars	1977	124	SciFi	Fox	Carrie Fisher
Star Wars	1977	124	SciFi	Fox	Mark Hamill
Star Wars	1977	124	SciFi	Fox	Harrison Ford
Gone With The Wind	1939	231	drama	MGM	Vivien Leigh
Wayne's World	1992	95	comedy	Paramount	Dana Carvey
Wayne's World	1992	95	comedy	Paramount	Mike Meyers

The above relation is not in BCNF because:
Consider the FD:
{title,year} -> {length, genre, studioName}
We know that {title, year} is not a super-key

Example: BCNF or not

title	*year*	*length*	*genre*	*studioName*
Star Wars	1977	124	SciFi	Fox
Gone With The Wind	1939	231	drama	MGM
Wayne's World	1992	95	comedy	Paramount

The above relation is in BCNF because:
{title,year} -> {length, genre, studioName}

And: neither title nor year by itself functionally determines any of the other attributes

Example: BCNF or not

title	*year*	*starName*
Star Wars	1977	Carrie Fisher
Star Wars	1977	Mark Hamill
Star Wars	1977	Harrison Ford
Gone With	1939	Vivien Leigh
Wayne's W	1992	Dana Carvey
Wayne's W	1992	Mike Meyers

The above relation is in BCNF because: it has no Non-Trivial FD

Differences between BCNF and 3NF

3NF	Boyce-Codd
a *nontrivial* functional dependency: *X* => *A* holds in *R*, either (a) *X* is a superkey of *R*, or (b) (b) *A* is a prime attribute of *R*.	a *nontrivial* functional dependency *X* => *A* holds in *R*, then: a) *X* is a superkey of *R*
Note:A functional dependency *X* => *Y* is a **full functional dependency** if removal of any attribute *A* from *X* means that the dependency does not hold any more; A **partial functional dependency** is not a **full functional dependency**	

BCNF decomposition algorithm (self studying)

Input: A relation R with a set of FD's F

Output: A BCNF decomposition of R with lossless join
Method:

- At each step compute the key for the sub-relation R
- if not in BCNF, pick any FD X->Y which violates
- break the relation into 2 sub-relations
  - R1(XY)
  - R2(S - Y)
  - this has a lossless join
  - project FD's onto each sub-relation
- continue until no more offending FD's

3NF decomposition algorithm – self studying

Input: A relation R with a set of FD's F

Output: A decomposition of R into a collection of relations, all of which are in 3NF. This decomposition has a lossless join and dependency-preservation.

Method:

- Find minimal basic for F, say G.
- ∀ X-A ∈ G, use XA as the schema of one relations in the decomposition.
- If none of the sets of relations from Step 2 is a super key for R, add another relation whose schema is a key for R.

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Summary 1

Decompose a relation into BCNF is a solution for eliminating anomalies

But BCNF can cause information loss and dependency loss

3NF is a relax solution of BCNF that keep loss-less join and dependency-preservation properties

Summary 2:

2NF	3NF	Boyce-Codd
every nonprime attribute *A* in *R* is not partially dependent on *any* key of R	a *nontrivial* functional dependency: *X* => *A* holds in *R*, either (a) *X* is a superkey of *R*, or (b) (b) *A* is a prime attribute of *R.*	a *nontrivial* functional dependency *X* => *A* holds in *R*, then: a) *X* is a superkey of *R*

Note:A functional dependency *X* => *Y* is a **full functional dependency** if removal of any attribute *A* from *X* means that the dependency does not hold any more; A **partial functional dependency** is not a **full functional dependency**