Normal

Databases

Normal Forms for Relational Databases

• criteria for a good database design (i.e., to resolve

update anomalies)

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• formalized b   dependencies

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Normal Forms for Relational Databases(cont)

Normal Forms:

- 1NF, 2NF, 3NF (Codd 1972)

- Boyce-Codd NF (1974)

- Multivalued depen̶d̶e̶n̶c̶i̶e̶s̶ (and Fagin 1977)

- Join dependencies (Rissanen 1977) an̶d̶ (1979)

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First Normal Form (1NF)

This simply means that attribute values are *atomic*, and is part of the definition of the relational model.

Atomic: multivalued attributes, composite attributes, and their combinations are disallowed.

There is currently a lot of interest in ~~non~~ first for databases, particularly those where an attribute value can be a table (nested relations).

Consider the table below, adapted from Desai.

First Normal Form (1NF) <small>(cont)</small>

Fac_Dept	Prof	Course Preferences	
		Course	Course_Dept
Comp Sci	Smith	353	Comp Sci
		379	Comp Sci
		221	Decision Sci
		353	Comp Sci
			Comp Sci
			Comp Sci
			Mathematics
Chemistry	Turner		Comp Sci
			Mathematics
		272	Chemsitry
Mathematics	Jameison	353	Comp Sci
		379	Comp Sci
		221	Decision Sci
		456	Mathematics
		469	Mathematics

This can be transformed into:

First Normal Form (1NF) _(cont)

CRS_PREF			
Prof	Course	Fac_Dept	Crs_Dept
Smith	353	Comp Sci	Comp Sci
Smith	379	Comp Sci	Comp Sci
Smith	221	Comp Sci	Decision Sci
Clark	353	Comp Sci	Comp Sci
Clark			Comp Sci
Clark			Comp Sci
Clark	456		athematics
Turner	353		Comp Sci
Turner	456		athematics
Turner	272	Chemistry	Chemistry
Jamieson	353	Mathematics	Comp Sci
Jamieson	379	Mathematics	Comp Sci
Jamieson	221	Mathematics	Decision Sci
Jamieson	456	Mathematics	Mathematics
Jamieson	469	Mathematics	Mathematics

First Normal Form (1NF) (cont)

The representation in the figure above has the following drawbacks:

• the fact that a given professor is in a given department may be repeated,

• the association between professor and department will not be recorded unless the professor

• the fact that a given course is offe   n department may be repeated,

repeated,

• again, this is not recorded unless someone has a preference for the course.

First Normal Form (1NF) (cont)

Suppose the FD's for these attributes are

$$F = \{Prof \rightarrow Fac\_Dept, Course \rightarrow Crs\_Dept\}.$$

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Notice that a su   utes S such that

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$$S \rightarrow \{Prof \qquad\qquad\qquad\} \in F^+$$

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Thus the only candidate key here is $\{Prof, Course\}$.

First Normal Form (1NF) (cont)

These problems arise because *Fac_Dept* depends only on *Prof* and not on *Course*, and similarly *Crs_Dept* depends only on *Course* and not on *Prof*.

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We can recognize a   functional

dependencies.   https://eduassistpro.github.io/

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Second Normal Form (2NF)

A *prime* attribute is one that is part of a candidate key. Other attributes are *non-prime*.

Definition: In an FD $X \rightarrow Y$, Y is *fully functionally dependent* on X if there is no $Z \subset$ rwise Y is *partially* dependent on X.

Proper Su

Definition (*Second Normal Form*): A relation scheme is in second normal form (2NF) if all non-prime attributes are fully functionally dependent on the candidate keys.

A database scheme is in 2NF if all its relations are in 2NF.

Second Normal Form (2NF) (cont)

Possible 2NF decomposition of the relation above is:

COURSE_PREF	
Prof	Course
Smith	353
Smith	379
Smith	221
Clark	
Clark	
Clark	379
Clark	456
Turner	353
Turner	456
Turner	272
Jamieson	353
Jamieson	379
Jamieson	221
Jamieson	456
Jamieson	469

COURSE	
Course	Dept
353	Comp Sci
379	Comp Sci
221	Decision Sci
	Comp Sci
	Mathematics
	Chemistry
	Mathematics

FACULTY	
Prof	Dept
Smith	Comp Sci
Clark	Comp Sci
Turner	Chemistry
Jamieson	Mathematics

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Second Normal Form (2NF) (cont)

Question: What relational algebra expression recovers *CRS_PREF* from these relations?
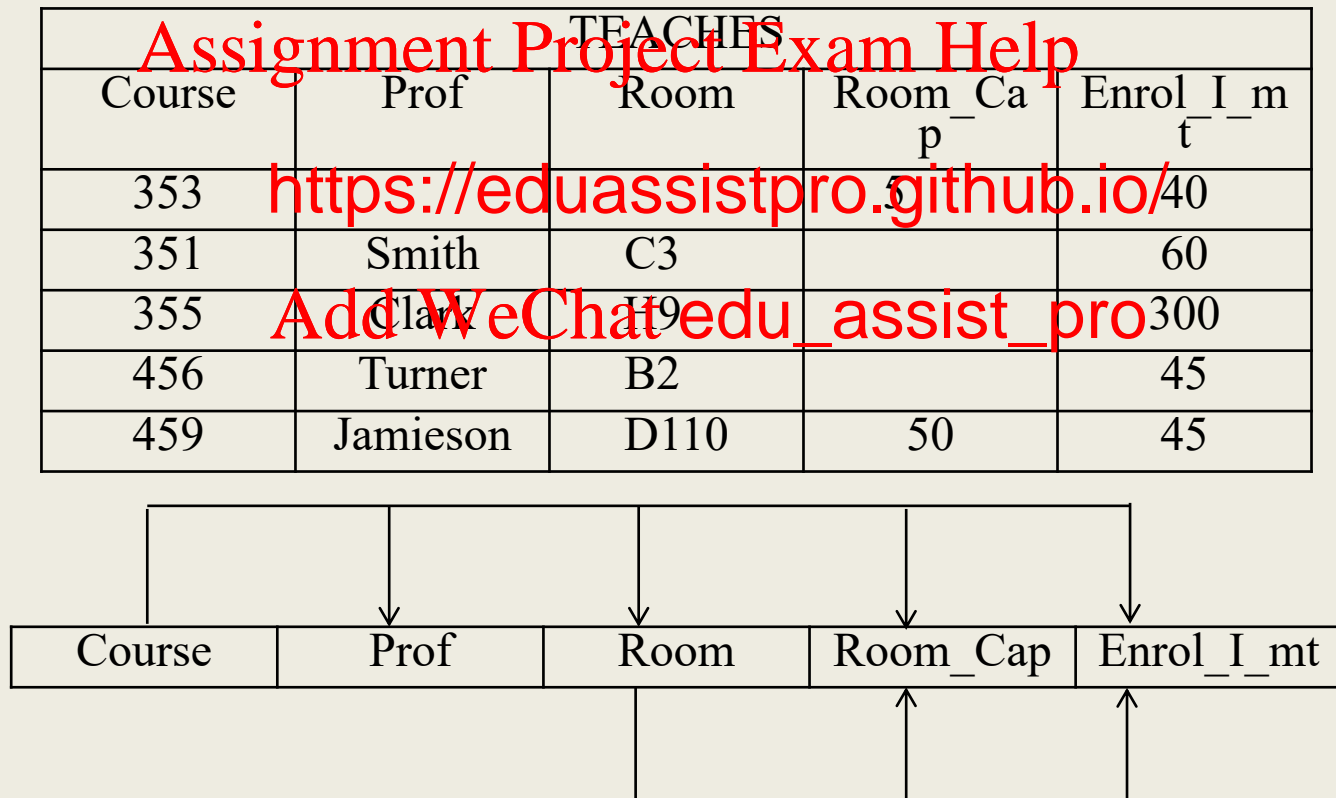
Answer: Join

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Second Normal Form (2NF) (cont)

2NF does not completely eliminate the kind of anomaly we saw before:

		TEACHES		
Course	Prof	Room	Room_Cap	Enrol_I_mt
353				40
351	Smith	C3		60
355	Clark	H9		300
456	Turner	B2		45
459	Jamieson	D110	50	45

Course	Prof	Room	Room_Cap	Enrol_I_mt

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Second Normal Form (2NF) (cont)

This is in 2NF but:

If another course uses say Room A532, then the fact that A532 has *Room_Cap* of 45 and *Enrol_Lmt* of 40 will be stored twice.

If course 355 is ~~940 has~~ *Room_Cap* of 400 and *Enrol_Lmt* of 300 w

This we can also fix by adding further restrictions on functional dependencies.

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Third Normal Form (3NF)

Definition: An FD X→Y is a transitive dependency if there is a Z that is

not a subset of any key, such that $X \rightarrow Z$ and $Z \rightarrow Y$ and $Z \not\rightarrow X$ hold.

The attributes of Y are transitively dependent on X.

e.g. Room_Cap is transitively depende   }, since {*Course*}

→ {*Room*} and {*Room*} → {*Room_Cap*} hold, and {*Room*} is not a

subset of any key.

Third Normal Form (3NF) (cont)

Definition (Third Normal Form): A relation scheme is in *third normal form (3NF)* if for all non-trivial FD's of the form X→A that hold, either X is a superkey or A is a prime attribute.

Note: a FD $X \rightarrow Y$ is ~~Assignment Project Exam Help~~

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Alternative definition: A relation schem~~Add WeChat edu_assist_pro~~ormal form if every non-prime attribute is fully functionally dependent on the keys and not transitively dependent on any key.

A database scheme is in 3NF if all its relations are in 3NF.

Third Normal Form (3NF) (cont)

TEACHES can be decomposed into 3NF:

ROOM_DETAILS		
Room	Room_Cap	Enrol_I_mt
A532	45	40
C320	100	60
B2		45
D1		
H940	400	300

COURSE_		
Course	Prof	Room
353	Smith	A532
351	Smith	C320
456	Turner	B278
459	Jamieson	D110
355	Clark	H940

Third Normal Form (3NF) (cont)

Another example:

LOTS

Property_Id	City	Lot_No	Area	Price	Tax_Rate

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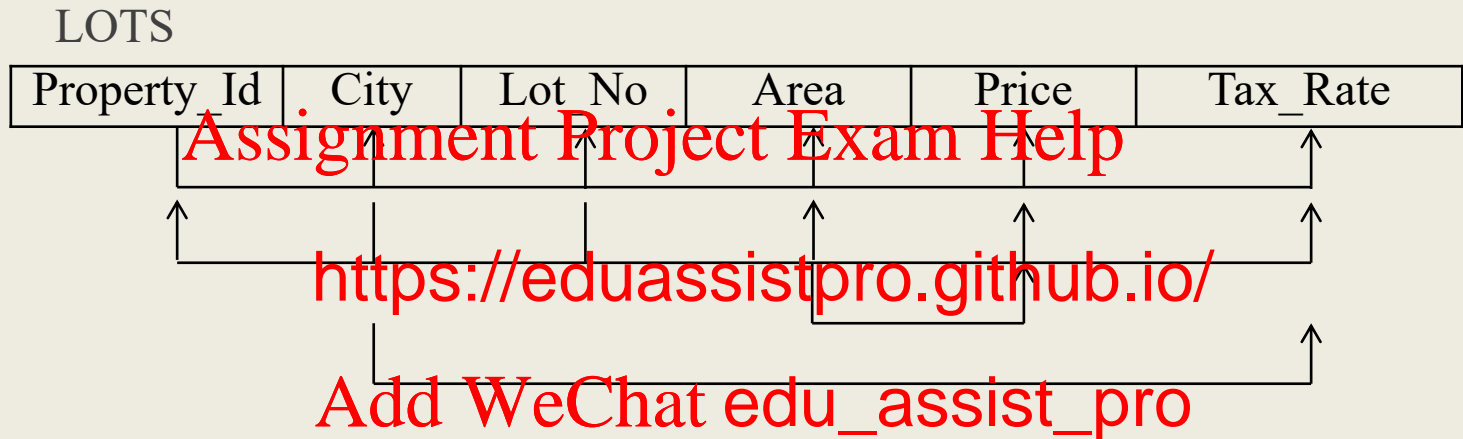
This is not in 2NF since *City→Tax_Rate*, *Tax_Rate* is not prime, and {*City,Lot_No*} is a key, making *Tax_Rate* partially dependent on a key.

We could fix this:
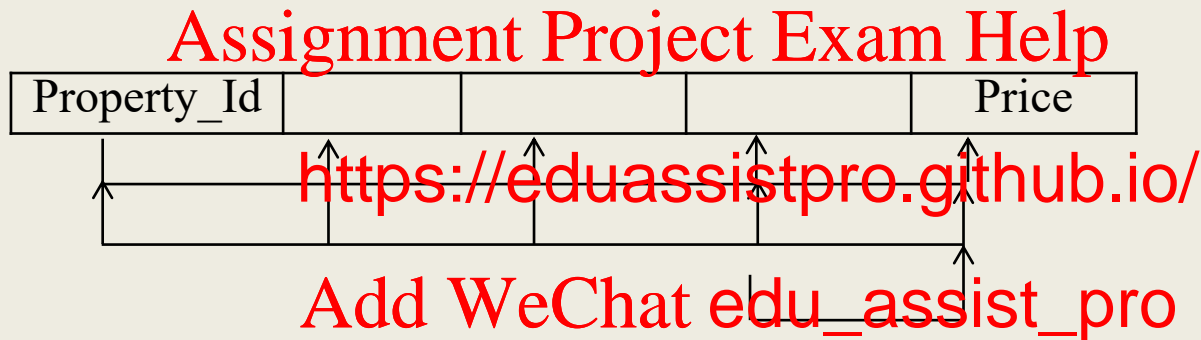
Third Normal Form (3NF) (cont)

LOTS1

City	Tax_Rate

LOTS2

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Property_Id				Price

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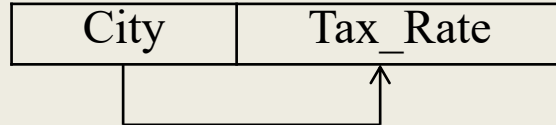
Now we have 2NF but not 3NF, since *Area → Price*, {*Area*} is not a superkey and Price is not prime.

Note: the transitive dependency : *Property_Id→ Area → Price*.
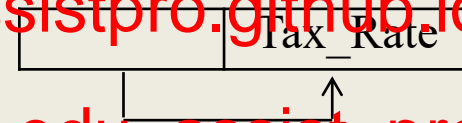
We could fix this too:

Third Normal Form (3NF) (cont)

LOTS1A

Property_Id	City	Lot_No	Area

LOTS1B

LOTS2

Area	P

	Tax_Rate
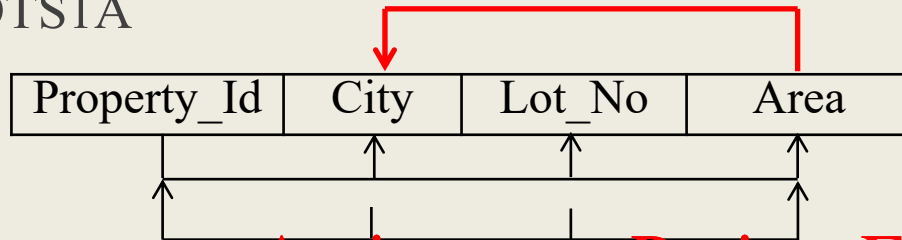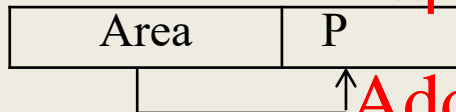
Suppose also that *Area→City*. The relations schemes are still in 3NF since *City* is a prime attribute. However, there can be anomalies, just as before. We need more restrictions still to fix these.

Boyce-Codd Normal Form (BCNF)

Definition (*Boyce-Codd Normal Form*):

A relation scheme is in *Boyce-Codd* Normal Form (BCNF) if whenever

X→A holds and X→A is non-trivial, X is a superkey.

A database scheme i ~~s~~ e in BCNF.

We can make our example into BCNF:

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Boyce-Codd Normal Form (BCNF)(cont)

LOTS1AA

Property_Id	Lot_No	Area

LOTS1AB

Area	City

LOTS1B

Area	Price

ity	Tax_Rate

Boyce-Codd Normal Form (BCNF)(cont)

LOTS1AA

Property_Id	Lot_No	Area

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LOTS1AB

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Area	City	Price			Tax_Rate