Normalization

Database Design

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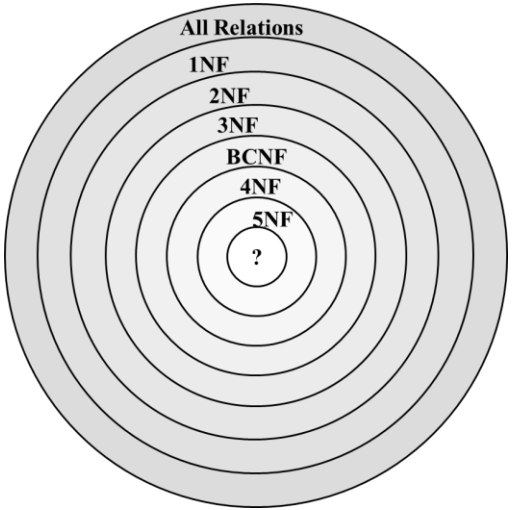
Introduction

- Normalization: systematic validation of participation of attributes in a relation schema from a data redundancy perspective.
- Normal Forms (NFs): stepwise progression towards attaining the goal of a fully normalized relation schema.
- A design that has a lower normal form than another design has more redundancy. Uncontrolled redundancy can lead to data integrity problems.



First Normal Form (1NF)

- No multi-valued attributes or composite attributes.
- By definition, a relation schema is in 1NF.
- Does the below relations satisfy 1NF?

EMPLOYEE

Name	Age	Sex	Emp#
Anderson	21	F	010110
Decker	22	M	010100
Glover	22	M	101000
Jackson	21	F	201100
Moore	19	M	111100
Nakata	20	F	111101

First Normal Form (1NF)

- Does the below relations satisfy 1NF?

EmpNum	EmpPhone	EmpDegrees
123	233-9876	
333	233-1231	BA, BSc, PhD
679	233-1231	BSc, MSc

- Solution to make it 1NF:

Employee

EmpNum	EmpPhone
123	233-9876
333	233-1231
679	233-1231

EmployeeDegree

EmpNum	EmpDegree
333	BA
333	BSc
333	PhD
679	BSc
679	MSc

Note

- A key attribute is any attribute that is part of a key.
- Any attribute that is not a key attribute, is a non-key attribute.

Second Normal Form (2NF)

- At least one of the following conditions applies:
  - Primary key consists of a single attribute
  - No non-key attributes
  - Every non-key attribute depends on all of the primary key (fully functionally dependent)

Second Normal Form (2NF)

- Example

NEW_ALBUM

Album_no	Artist_nm	Price	Stock
BS123	Britney Spears	17.95	1000
JT111	Justin Timberlake	17.95	1200
BTL007	John Lennon	23.95	
BTL007	Paul McCartney	23.95	
BTL007	George Harrison	23.95	
BTL007	Ringo Star	23.95	
MJ100	Michael Jackson	17.95	
JM456	John Mayer	16.95	1000
JM151	John Mayer	16.95	1000
MX789	Madonna	11.95	500
DJM237	John Denver	11.95	2000
DJM237	Michael Jackson	11.95	2000
DJM237	Madonna	11.95	2000
DR711	Diana Ross	12.95	1000
PM137	Paul McCartney	19.95	

candidate key: {Album_no, Artist_nm}

Album_no → Price Album_no → Stock

Modification Anomalies

change the value of price or stock of Album_no BTL007 in NEW_ALBUM

multiple tuples require update and failure to update some can cause an update anomaly

add a new tuple (Album_no: XY11, Price: 17.95 and Stock:100) to NEW_ALBUM

cannot insert without artist name, which is an insertion anomaly

delete Album_no BTL007 from NEW_ALBUM

requires deletion of multiple tuples and failure to delete some can cause a deletion anomaly

Resolution of 2NF Violation

- Pull out the undesirable FD(s) from the target relation schema as a separate relation schema(s)
- Keep the determinant (left side of the FD equation) of the pulled-out relation schema as an attribute(s) in the leftover target relation schema

ALBUM_INFO

Album_no	Price	Stock
BS123	17.95	1000
JT111	17.95	1200
BTL007	23.95	
MJ100	17.95	
JM456	16.95	1000
JM151	16.95	1000
MX789	11.95	500
DJM237	11.95	2000
DR711	12.95	1000
PM137	19.95	

ALBUM_ARTIST

Album_no	Artist_nm
BS123	Britney Spears
JT111	Justin Timberlake
BTL007	John Lennon
BTL007	Paul McCartney
BTL007	George Harrison
BTL007	Ringo Star
MJ100	Michael Jackson
JM456	John Mayer
JM151	John Mayer
MX789	Madonna
DJM237	John Denver
DJM237	Michael Jackson
DJM237	Madonna
DR711	Diana Ross
PM137	Paul McCartney

Second Normal Form (2NF)

- Does the below relation satisfy 2NF?

EMPLOYEE

Name	Age	Sex	Emp#
Anderson	21	F	010110
Decker	22	M	010100
Glover	22	M	101000
Jackson	21	F	201100
Moore	19	M	111100
Nakata	20	F	111101

yes, because the primary key is one attribute

Example

- در حالت کلی، تمام صفات دانشجو، درس و انتخاب در یک رابطه می‌توانند باشند.
- قواعد محیط:

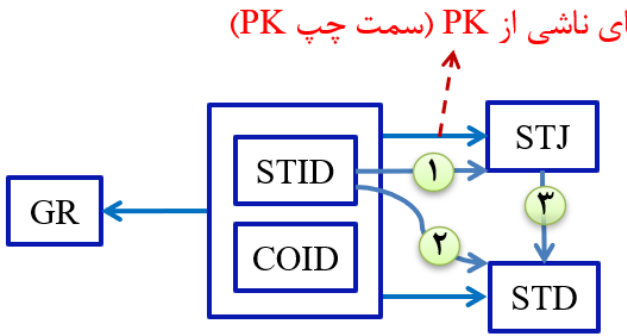
۱- یک دانشجو در یک رشته تحصیل می‌کند.

۲- یک دانشجو در یک دانشکده تحصیل می‌کند.

۳- یک رشته در یک دانشکده ارائه می‌شود.

R (STID, COID,	STJ,	STD,	GR)
777	CO1	Phys	D11	19
777	CO2	Phys	D11	16
777	CO3	Phys	D11	11
888	CO1	Math	D12	16
888	CO2	Math	D12	18
444	CO1	Math	D12	13
555	CO1	Phys	D11	14
555	CO2	Phys	D11	12

$\{(STID, COID) \rightarrow STJ$, $STID \rightarrow STJ\}$ $\{(STID, COID) \rightarrow STD$, $STID \rightarrow STD\}$



Example

$\Pi_{\langle STID,COID,GR\rangle}(R)$

SCG (STID, COID, GR)

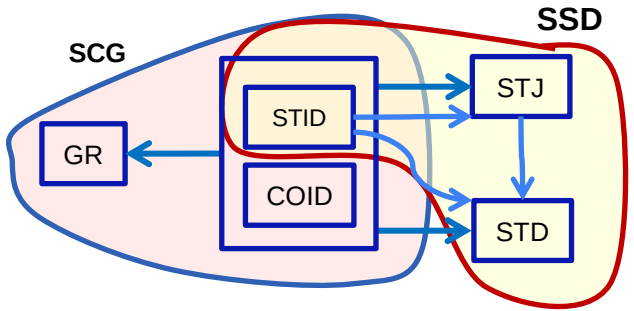
777	CO1	19
777	CO2	16
777	CO3	11
888	CO1	16
888	CO2	18
444	CO1	13
555	CO1	14
555	CO2	12

و

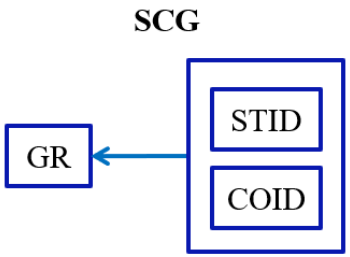
$\Pi_{\langle STID,STJ,STD\rangle}(R)$

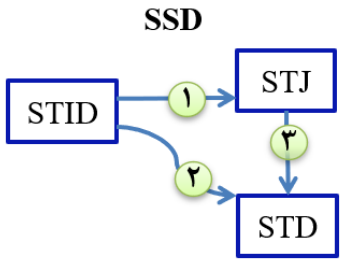
SSD (STID, STJ, STD)

777	Phys	D11
888	Math	D12
444	Math	D12
555	Phys	D11



Example





- رابطه‌های جدید آنومالی‌های R را ندارند:

۱- درج کن: ⟨’666’, ‘Chem’, ‘D16’⟩

بدون مشکل در SSD درج می‌شود.

SSD (STID, STJ, STD)

777	Phys	D11
888	Math	D12
444	Math	D12
555	Phys	D11
666	Chem	D16

۲- حذف کن: ⟨’444’, ‘CO1’, 13⟩

بدون مشکل از SCG حذف می‌شود.

۳- بهنگام‌سازی کن: تغییر رشته دانشجوی 777 را به Chem

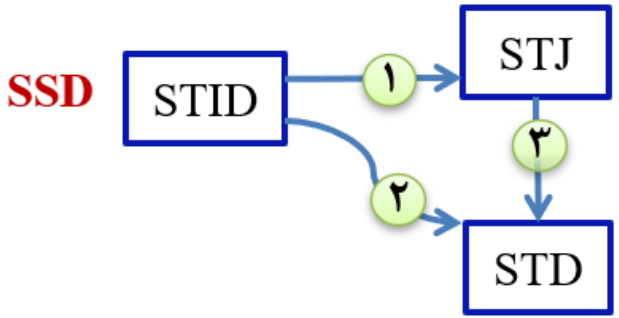
بدون مشکل در SSD بروز می‌شود.

Third Normal Form (3NF)

- A relation is in third normal form if:
  - It is in second normal form
  - It has no transitive dependencies
- **Solution:**
  - Decompose and set up a new relation that includes the nonkey attribute(s) that functionally determine(s) the other nonkey attributes.
  - The common attribute be a CK in at least one of them.
  - All FDs of main relation be in union FD of decomposed relations or can be inferred.

Example

- آیا رابطه‌های جدید (SSD و SCG) آنومالی ندارند؟
- **آنومالی‌های SSD:**

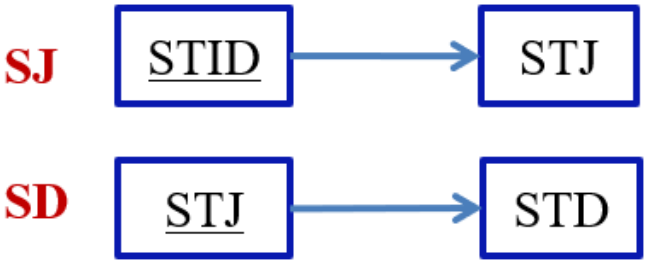


۱- در درج:

اطلاع: «رشته IT در دانشکده D20 ارائه می‌شود.» باشد، اما درج ناممکن است. چون کلید ندارد، باید

۲- در حذف:

حذف کن ⟨'Chem', '666'⟩ و با فرض اینکه تنها حذف انجام می‌شود ولی اطلاع «رشته شیمی در



۳- در بهنگام‌سازی:

«شماره دانشکده رشته فیزیک را عوض کنید». ب

SSD باید نرمال‌تر شود.

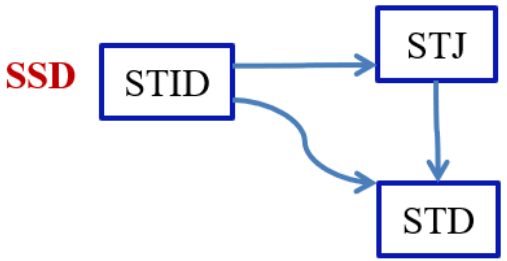
Example

- Which one is a good decomposition?

I SS (STID, STJ) SD (STJ, STD)

II SS (STID, STJ) SD (STID, STD)

III SS(STID, STD) SJ (STJ, STD)



Boyce-Codd Normal Form (BCNF)

- A relation is in BCNF if every determinant of Non-Trivial irreducible FD is a candidate key.

- **Solution:**
  - Decompose and set up a new relation that includes the non-candidate key attribute(s) that functionally determine(s) the other nonkey attributes.

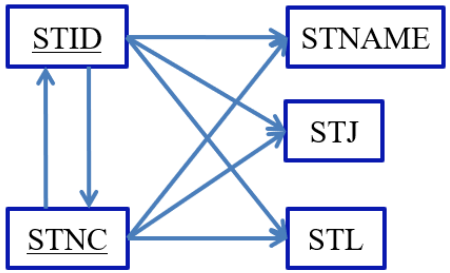
Notes

- **حالت I:** رابطه R فقط یک CK (که همان PK است) داشته باشد. ⇐ اگر R در 3NF باشد، در BCNF هم هست
- **حالت II:** رابطه R بیش از یک CK داشته باشد.
  - **II-1)** CKها مجزا باشند (صفت مشترک نداشته باشند). ⇐ اگر R در 3NF باشد، در BCNF هم هست.

دو دترمینان، هر دو هم CK هستند.

ST (STID, STNAME, STNC, STJ, STL, …)

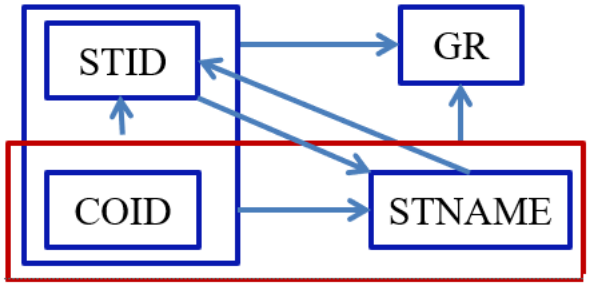
C.K. P.K. C.K.



- **حالت-2)** CKها هم‌پوشا باشند. ⇐ اگر R در 3NF باشد، لزوماً در BCNF نیست.

SCNG (STID, COID, STNAME, GR)

C.K. C.K.



(فرض: هیچ دو دانشجویی نام یکسان ندارند.)

Example

Patient	Hospital	Doctor
Smith	Methodist	D. Cooley
Lee	St. Luke's	Z. Zhang
Marks	Methodist	D. Cooley
Marks	St. Luke's	W. Lowe
Lou	Hermann	R. Duke

Candidate keys:
{Patient , Hospital},
{Patient, Doctor}

{Patient, Hospital} → Doctor

✖ Doctor → Hospital

Example

PAT-DOC (Patient, Doctor)

Patient	Doctor
Smith	D. Cooley
Lee	Z. Zhang
Marks	D. Cooley
Marks	W. Lowe
Lou	R. Duke

DOC-HOS (Doctor, Hospital)

Doctor	Hospital
D. Cooley	Methodist
Z. Zhang	St. Luke's
W. Lowe	St. Luke's
R. Duke	Hermann

Conclusion

Normal Form	Requirements	Decomposition Rules
First	No multi-valued attributes	Form new relations for each multivalued attribute or repeating group
Second	Satisfy at least one of the following three conditions: Primary key consists of a single attribute No non-key attributes No non-key attribute should be functionally dependent on part of the primary key (every non-key attribute should be fully functionally dependent on the primary key)	Decompose and setup a new relation for each partial key with its dependent attribute(s). Make sure to keep a relation with the original primary key and any attributes that are fully functionally dependent on it
Third	No transitive dependencies. Relation should be in second normal form and should not have a non-key attribute functionally determined by another non-key attribute (or a set of non-key attributes)	Decompose and set up a new relation that includes the nonkey attribute(s) that functionally determine(s) the other nonkey attributes
BCNF	Every determinant is a candidate key	Decompose and set up a new relation that includes the non-candidate key attribute(s) that functionally determine(s) the other nonkey attributes.