Unit 10: Normalization

When we design the logical database, we want the relation contains minimal redundancy. Redundancies in a table may result in errors or inconsistencies (called anomalies) when users to insert, modify and delete rows in the table. You will find examples of three types of anomalies—insertion, deletion, and modification—in this unit.

Normalization

Normalization is a process of successively reducing relations with anomalies to produce smaller, well-structured relations. This is done by deciding which attributes should be grouped together in a relation. Normalization is based on normal forms and functional dependencies.

In order to design a database that provides efficient and reliable responses to SQL queries, the database should be put into at least the **3rd Normal Form**. While there are higher order normal forms, it is usually only necessary that the database design comply with the 3rd Normal Form. The normal forms for database designs are ***additive*** which means that the 3rd Normal Form assumes that the database is in the 2nd Normal Form and the 2nd Normal Form assumes that the database is in the 1st Normal Form. Thus normalizing a database involves completing 3 sequential steps.

The document shown below explains not only how to put a database into the **3rd Normal Form** but also what it takes to reach the higher normal forms. While reaching the higher normal forms may be desirable in certain situations, reaching the 3rd Normal Form is required for the database to be used effectively.

This class only requires you need to understand and put a database into the 3rd Normal Form.

DataModel.Org

Rules of Data Normalization

1NF Eliminate Repeating Groups - Make a separate table for each set of related attributes, and give each table a primary key.

2NF Eliminate Redundant Data - If an attribute depends on only part of a multi-valued key, remove it to a separate table.

3NF Eliminate Columns Not Dependent On Key - If attributes do not contribute to a description of the key, remove them to a separate table.

BCNF Boyce-Codd Normal Form - If there are non-trivial dependencies between candidate key attributes, separate them out into distinct tables.

4NF Isolate Independent Multiple Relationships - No table may contain two or more 1:n or n:m relationships that are not directly related.

5NF Isolate Semantically Related Multiple Relationships - There may be practical constrains on information that justify separating logically related many-to-many relationships.

ONF Optimal Normal Form - a model limited to only simple (elemental) facts, as expressed in Object Role Model notation.

DKNF Domain-Key Normal Form - a model free from all modification anomalies.

Important Note!
All normal forms are additive, in that if a model is in 3rd normal form, it is by definition also in 2nd and 1st.

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1. Eliminate Repeating Groups

In the original member list, each member name is followed by any databases that the member has experience with. Some might know many, and others might not know any. To answer the question, "Who knows DB2?" we need to perform an awkward scan of the list looking for references to DB2. This is inefficient and an extremely untidy way to store information.

Moving the known databases into a seperate table helps a lot. Separating the repeating groups of databases from the member information results in **first normal form**. The MemberID in the database table matches the primary key in the member table, providing a foreign key for relating the two tables with a join operation. Now we can answer the question by looking in the database table for "DB2" and getting the list of members.

Member List

1	John Smith	Access, DB2, FoxPro
2	Dave Jones	dBASE, Clipper
3	Mike Beach	
4	Jerry Miller	DB2, Oracle
5	Ben Stuart	Oracle, Sybase
6	Fred Flint	Informix
7	Joe Blow	
8	Greg Brown	Access, MSSql Server
9	Doug Hope	

Member Table

MID	Name
1	John Smith
2	Dave Jones
3	Mike Beach
4	Jerry Miller
5	Ben Stuart
6	Fred Flint
7	Joe Blow
8	Greg Brown
9	Doug Hope

Database Table

DID	MID	Database
1	1	Access
2	1	DB2
3	1	FoxPro
4	2	dBASE
5	2	Clipper
6	4	DB2
7	4	Oracle
8	5	Oracle
9	5	Sybase
10	6	Informix
11	8	Access
12	8	MSSql Server

2. Eliminate Redundant Data

In the Database Table, the primary key is made up of the MemberID and the DatabaseID. This makes sense for other attributes like "Where Learned" and "Skill Level" attributes, since they will be different for every member/database combination. But the database name depends only on the DatabaseID. The same database name will appear redundantly every time its associated ID appears in the Database Table.

Suppose you want to reclassify a database - give it a different DatabaseID. The change has to be made for every member that lists that database! If you miss some, you'll have several members with the same database under different IDs. This is an update anomaly.

Or suppose the last member listing a particular database leaves the group. His records will be removed from the system, and the database will not be stored anywhere! This is a delete anomaly. To avoid these problems, we need **second normal form**.

To achieve this, separate the attributes depending on both parts of the key from those depending only on the DatabaseID. This results in two tables: "Database" which gives the name for each DatabaseID, and "MemberDatabase" which lists the databases for each member.

Now we can reclassify a database in a single operation: look up the DatabaseID in the "Database" table and change its name. The result will instantly be available throughout the application.

Database Table

DID	MID	Database
1	1	Access
2	1	DB2
3	1	FoxPro
4	2	dBASE
5	2	Clipper
6	4	DB2
7	4	Oracle
8	5	Oracle
9	5	Sybase
10	6	Informix
11	8	Access
12	8	MSSql Server

Member Table

MID	Name
1	John Smith
2	Dave Jones
3	Mike Beach
4	Jerry Miller
5	Ben Stuart
6	Fred Flint
7	Joe Blow
8	Greg Brown
9	Doug Hope

MbrDB Table

MID	DID
1	1
1	2
1	3
2	4
2	5
4	2
4	6
5	6
5	7
6	8
8	1
8	9

Database Ta

DID	Database
1	Access
2	DB2
3	FoxPro
4	dBASE
5	Clipper
6	Oracle
7	Sybase
8	Informix
9	MSSql Se

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3. Eliminate Columns Not Dependent On Key

The Member table satisfies first normal form - it contains no repeating groups. It satisfies second normal form - since it doesn't have a multivalued key. But the key is MemberID, and the company name and location describe only a company, not a member. To achieve third normal form, they must be moved into a separate table. Since they describe a company, CompanyCode becomes the key of the new "Company" table.

The motivation for this is the same for second normal form: we want to avoid update and delete anomalies. For example, suppose no members from the IBM were currently stored in the database. With the previous design, there would be no record of its existence, even though 20 past members were from IBM!

Member Table

MID	Name	Company	CompLoc
1	John Smith	ABC	Alabama
2	Dave Jones	MCI	Florida
3	Mike Beach	IBM	Delaware
4	Jerry Miller	MCI	Florida
5	Ben Stuart	AIC	Nebraska
6	Fred Flint	ABC	Alabama
7	Joe Blow	RU Nuts	Iowa
8	Greg Brown	XYZ	New York
9	Doug Hope	IBM	Delaware

Member Table

MID	Name	CID
1	John Smith	1
2	Dave Jones	2
3	Mike Beach	3
4	Jerry Miller	2
5	Ben Stuart	4
6	Fred Flint	1
7	Joe Blow	5
8	Greg Brown	6
9	Doug Hope	3

Company Table

CID	Name	Location
1	ABC	Alabama
2	MCI	Florida
3	IBM	Delaware
4	AIC	Nebraska
5	RU Nuts	Iowa
6	XYZ	New York

BCNF. Boyce-Codd Normal Form

Boyce-Codd Normal Form states mathematically that:
A relation R is said to be in BCNF if whenever X -> A holds in R, and A is not in X, then X is a candidate key for R.
BCNF covers very specific situations where 3NF misses inter-dependencies between non-key (but candidate key) attributes. Typically, any relation that is in 3NF is also in BCNF. However, a 3NF relation won't be in BCNF if (a) there are multiple candidate keys, (b) the keys are composed of multiple attributes, and (c) there are common attributes between the keys.

Basically, a humorous way to remember BCNF is that all functional dependencies are:
"The key, the whole key, and nothing but the key, so help me Codd."

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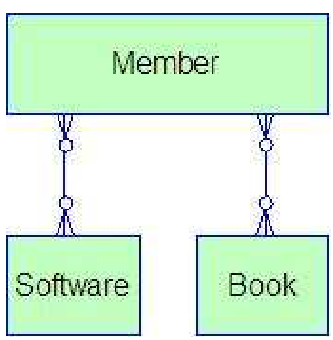
4. Isolate Independent Multiple Relationships

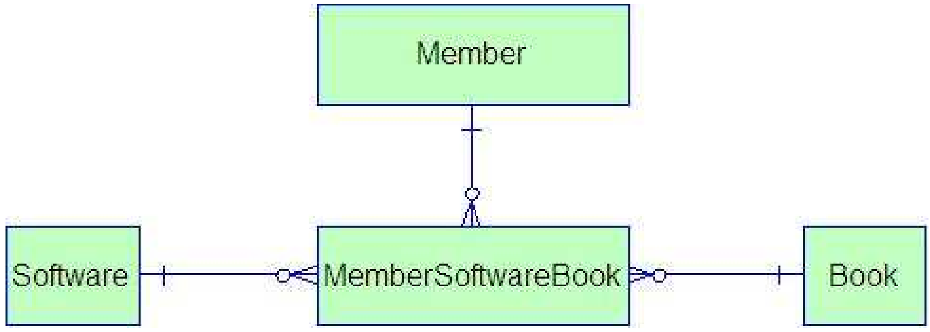
This applies primarily to key-only associative tables, and appears as a ternary relationship, but has incorrectly merged 2 distinct, independent relationships.

The way this situation starts is by a business request list the one shown below. This could be any 2 M:M relationships from a single entity. For instance, a member could know many software tools, and a software tool may be used by many members. Also, a member could have recommended many books, and a book could be recommended by many members.



Initial business request

So, to resolve the two M:M relationships, we know that we should resolve them separately, and that would give us 4th normal form. But, if we were to combine them into a single table, it might look right (it is in 3rd normal form) at first. This is shown below, and violates 4th normal form.



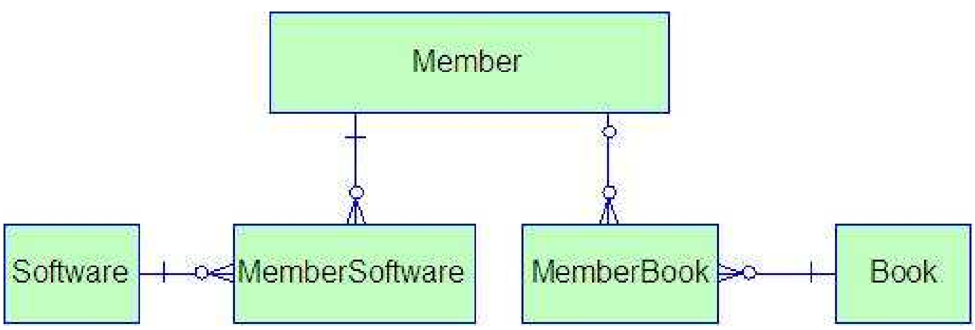
Incorrect solution

To get a picture of what is wrong, look at some sample data, shown below. The first few records look right, where Bill knows ERWin and recommends the ERWin Bible for everyone to read. But something is wrong with Mary and Steve. Mary didn't recommend a book, and Steve Doesn't know any software tools. Our solution has forced us to do strange things like create dummy records in both Book and Software to allow the record in the association, since it is key only table.

MemberSoftwareBook		
MID	**SID**	**BID**
Bill	ERWin	ERWin Bible
John	VB.Net	VB for Dummies
John	Java	Java for Dummies
Mary	ERWin	N/A
Steve	N/A	PowerBuilder Bible

Sample data from incorrect solution

The correct solution, to cause the model to be in 4th normal form, is to ensure that all M:M relationships are resolved independently if they are indeed independent, as shown below.



Correct 4th normal form

NOTE! This is not to say that ALL ternary associations are invalid. The above situation made it obvious that Books and Software were independently linked to Members. If, however, there were distinct links between all three, such that we would be stating that "Bill recommends the ERWin Bible as a reference for ERWin", then separating the relationship into two separate associations would be incorrect. In that case, we would lose the distinct information about the 3-way relationship.

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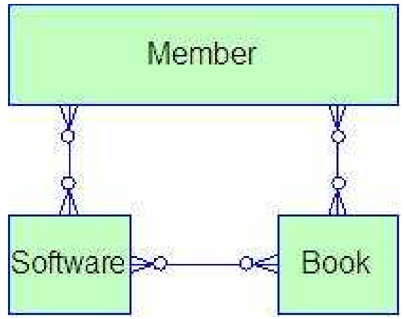
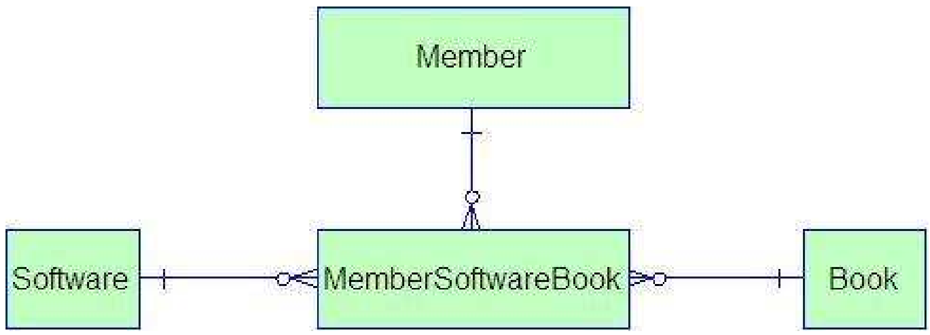
5. Isolate Semantically Related Multiple Relationships

OK, now lets modify the original business diagram and add a link between the books and the software tools, indicating which books deal with which software tools, as shown below.



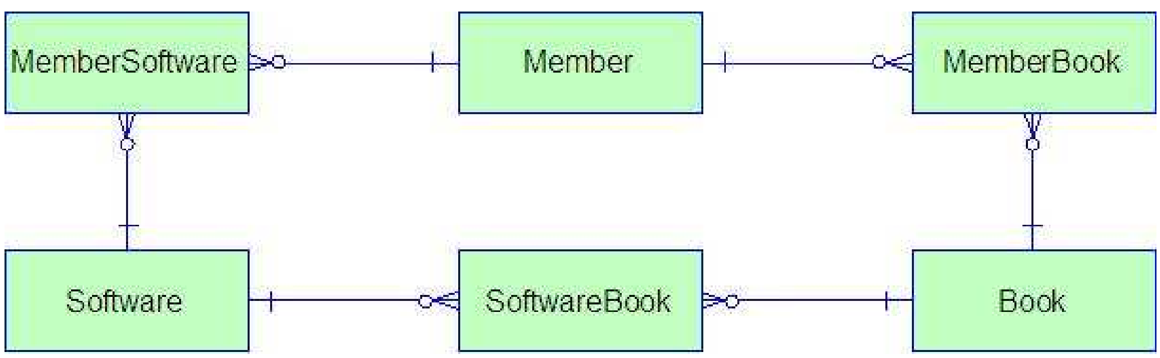
Initial business request

This makes sense after the discussion on Rule 4, and again we may be tempted to resolve the multiple M:M relationships into a single association, which would now violate 5th normal form. The ternary association looks identical to the one shown in the 4th normal form example, and is also going to have trouble displaying the information correctly. This time we would have even more trouble because we can't show the relationships between books and software unless we have a member to link to, or we have to add our favorite dummy member record to allow the record in the association table.



Incorrect solution

The solution, as before, is to ensure that all M:M relationships that are independent are resolved independently, resulting in the model shown below. Now information about members and books, members and software, and books and software are all stored independently, even though they are all very much semantically related. It is very tempting in many situations to combine the multiple M:M relationships because they are so similar. Within complex business discussions, the lines can become blurred and the correct solution not so obvious.



Correct 5th normal form

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6. Optimal Normal Form

At this point, we have done all we can with Entity-Relationship Diagrams (ERD). Most people will stop here because this is usually pretty good. However, another modeling style called Object Role Modeling (ORM) can display relationships that cannot be expressed in ERD. Therefore there are more normal forms beyond 5th. With Optimal Normal Form (OMF)
It is defined as a model limited to only simple (elemental) facts, as expressed in ORM.

7. Domain-Key Normal Form

This level of normalization is simply a model taken to the point where there are no opportunities for modification anomalies.

- "if every constraint on the relation is a logical consequence of the definition of keys and domains"
- Constraint "a rule governing static values of attributes"
- Key "unique identifier of a tuple"
- Domain "description of an attribute’s allowed values"

1. A relation in DK/NF has no modification anomalies, and conversely.
2. DK/NF is the ultimate normal form; there is no higher normal form related to modification anomalies
3. Defn: A relation is in DK/NF if every constraint on the relation is a logical consequence of the definition of keys and domains.
4. Constraint is any rule governing static values of attributes that is precise enough to be ascertained whether or not it is true
5. E.g. edit rules, intra-relation and inter-relation constraints, functional and multi-valued dependencies.
6. Not including constraints on changes in data values or time-dependent constraints.
7. Key - the unique identifier of a tuple.
8. Domain: physical and a logical description of an attributes allowed values.
9. Physical description is the format of an attribute.
10. Logical description is a further restriction of the values the domain is allowed
11. Logical consequence: find a constraint on keys and/or domains which, if it is enforced, means that the desired constraint is also enforced.
12. Bottom line on DK/NF: If every table has a single theme, then all functional dependencies will be logical consequences of keys. All data value constraints can them be expressed as domain constraints.
13. Practical consequence: Since keys are enforced by the DBMS and domains are enforced by edit checks on data input, all modification anomalies can be avoided by just these two simple measures.
