Database Normalization

The normalization process aims to minimize data duplications, avoid errors during data modifications, and simplify data queries from the database. The three fundamental normalization forms are known as:

- First Normal Form (1NF)
- Second Normal Form (2NF)
- Third Normal Form (3NF)

The following example includes fictitious data required by a **Medical Group Surgery** based in London to generate relevant **reports**. Doctors work in **multiple regions and various councils** in London. And once patients book an appointment, they are given a **slot ID** at their **local surgery**. There might be **multiple surgeries** in the same council but with **different postcodes**, where one or more councils belong to a particular region. For example, East or West London.

Doctor ID	Doctor name	Region	Patient ID	Patient name	Surgery Number	Surgery council	Postcod
D1	Karl	West London	P1 P2 P3	Rami Kim Nora	3	Harrow	HA9SDE
D1	Karl	East London	P4 P5	Kamel Sami	4	Hackney	E1 6AW
D2	Mark	East London	P5 P6	Sami Norma	4	Hackney	E1 6AW
D2	Mark	West London	P7 P1	Rose Rami	5	Harrow	HA862E

The data listed in the table are in an unnormalized form. **Repeating groups of data** appear in many cases, for instance, doctors, regions, and council names. There are also **multiple instances of data** stored in the **same cell**, such as with the patient name and total cost columns. This makes it difficult to update and query data. Moreover, it is not easy to choose a unique key and assign it as a primary key.

First Normal Form

To simplify the data structure of the surgery table, let's apply the first normal form rules to enforce the data **atomicity** rule and eliminate unnecessary **repeating data groups**. The data atomicity rule means you can only have one single instance value of the column attribute in any table cell.

The atomicity problem only exists in the columns of data related to the patients. Therefore, it is important to create a new table for patient data to fix this.

Patient ID	Patient name	Slot ID	Total Cost
P1	Rami	A1	1500
P2	Kim	A2	1200
P3	Nora	A3	1600
P4	Kamel	A1	2500
P5	Sami	A2	1000
P6	Norma	A5	2000
P7	Rose	A6	1000

This table includes one single instance of data in each cell, which makes it much simpler to read and understand. However, the patient table requires two columns, the patient ID and the Slot ID, to identify each record uniquely. This means that you need a composite primary key in this table.

Once you have removed the patient attributes from the main table, you just have the doctor ID, name, region, surgery number, council and postcode columns left in the table.

Doctor ID	Doctor name	Region	Surgery Number	Surgery council	Postcode
D1	Karl	West London	3	Harrow	HA9SDE
D1	Karl	East London	4	Hackney	E1 6AW

D2	Mark	West London	4	Hackney	E1 6AW
D2	Mark	East London	5	Harrow	HA862E

You may have noticed that the table also contains **repeating groups of data** in each column. You can fix this by separating the table into two tables of data: the doctor table and the surgery table, where each table deals with one specific entity.

Doctor ID	**Doctor name**
D1	Karl
D2	Mark

Surgery Number	**Region**	**Surgery council**	**Postcode**
3	West London	Harrow	HA9SDE
4	East London	Hackney	E1 6AW
5	West London	Harrow	HA862E

Second normal form

In the second normal form, you must avoid **partial dependency** relationships between data. Partial dependency refers to tables with a composite primary key. Namely, a key that consists of a combination of two or more columns, where a non-key attribute value depends only on one part of the composite key.

Patient ID	**Patient name**	**Slot ID**	**Total Cost**
P1	Rami	A1	1500
P2	Kim	A2	1200
P3	Nora	A3	1600
P4	Kamel	A1	2500
P5	Sami	A2	1000
P5	Sami	A3	1000
P6	Sami	A4	1500
P7	Norma	A5	2000
P8	Rose	A6	1000
P1	Rami	A7	1500

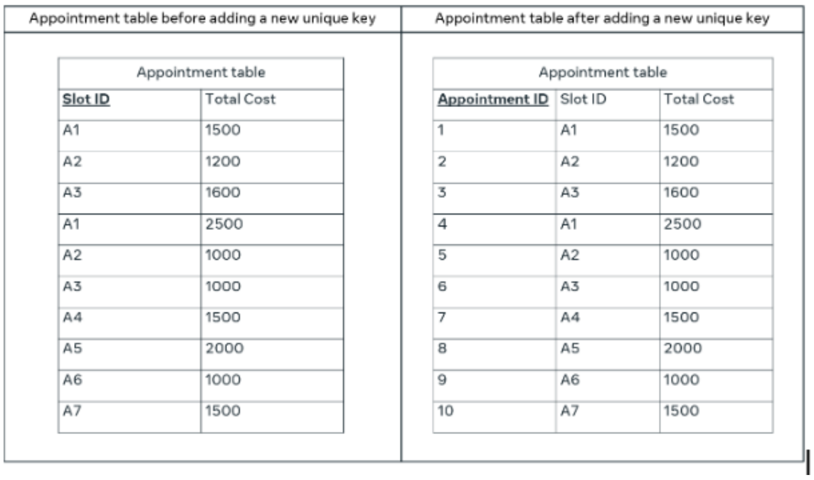
In the patient table, you must check whether any **non-key attributes depend on one part of the composite key**. For example, the patient's name is a non-key attribute, and it can be determined by using the patient ID only.

Similarly, you can determine the total cost by using the Slot ID only. This is called **partial dependency**, which is **not allowed** in the second normal form. This is because all non-key attributes should be determined by using both parts of the composite key, not only one of them.

This can be fixed by splitting the patient table into two tables: patient table and appointment table. In the patient table you can keep the patient ID and the patient's name.

Patient ID	**Patient name**
P1	Rami
P2	Kim
P3	Nora
P4	Kamel
P5	Sami
P7	Norma
P8	Rose

However, in the appointment table, you need to add a unique key to ensure you have a primary key that can identify each unique record in the table. Therefore, the appointment ID attribute can be added to the table with a unique value in each row.



Appointment table before adding a new unique key		Appointment table after adding a new unique key		
Appointment table		Appointment table		
Slot ID	Total Cost	Appointment ID	Slot ID	Total Cost
A1	1500	1	A1	1500
A2	1200	2	A2	1200
A3	1600	3	A3	1600
A1	2500	4	A1	2500
A2	1000	5	A2	1000
A3	1000	6	A3	1000
A4	1500	7	A4	1500
A5	2000	8	A5	2000
A6	1000	9	A6	1000
A7	1500	10	A7	1500

Third Normal Form

For a relation in a database to be in the third normal form, it must **already be in the second normal form (2NF)**. In addition, it must have **no transitive dependency**. This means that any non-key attribute in the surgery table may not be functionally dependent on another non-key attribute in the same table. In the surgery table, the postcode and the council are non-key attributes, and the postcode depends on the council. Therefore, if you change the council value, you must also change the postcode. This is called **transitive dependency**, which is not allowed in the third normal form.

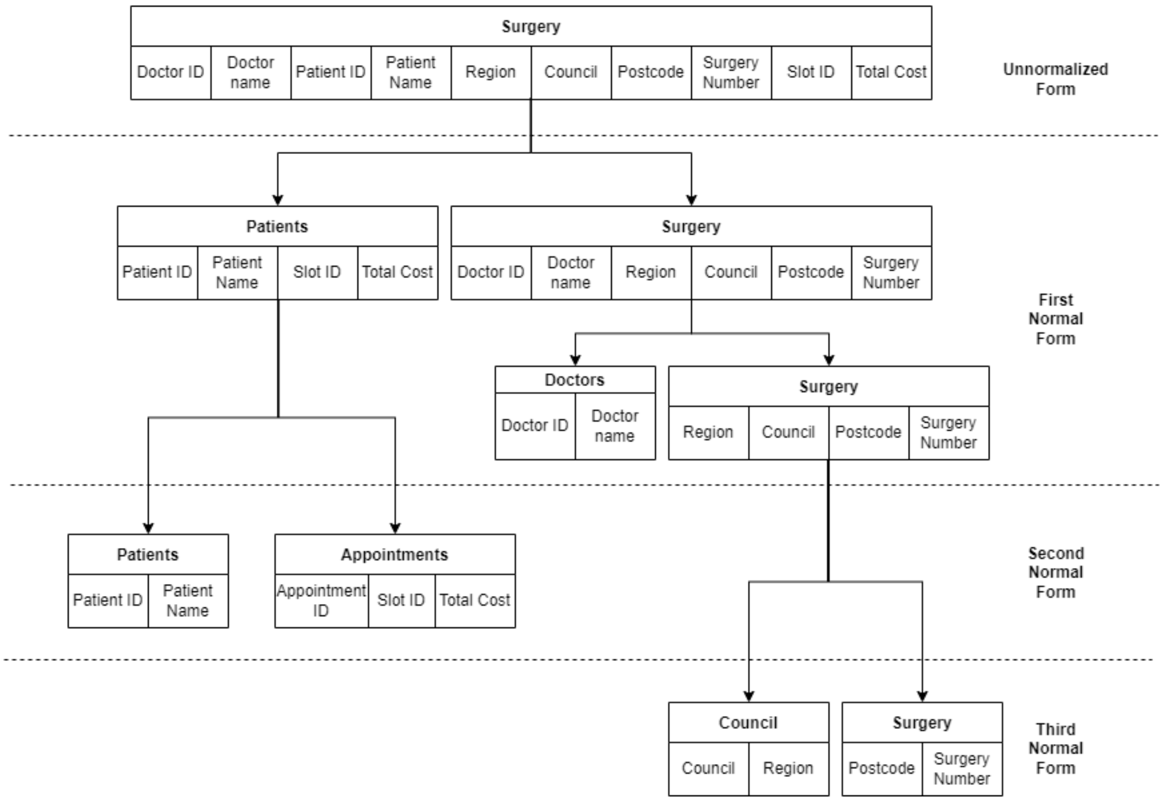
Surgery number	Region	Surgery council	Postcode
3	West London	Harrow	HA9SDE
4	East London	Hackney	E1 6AW
5	West London	Harrow	HA862E

To fix it you can split this table into two tables: one for the region with the city and one for the surgery.

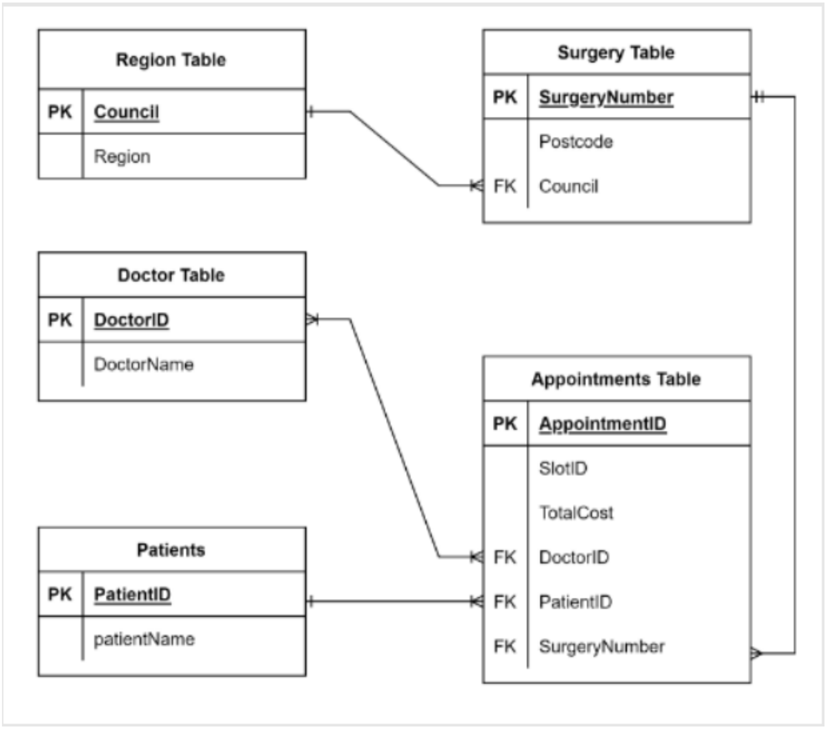
Surgery number	Postcode
3	HA9SDE
4	E1 6AW
5	HA862E

Surgery council	Region
Harrow	West London
Hackney	East London

This ensures the database conforms to first, second, and third normal forms. The following diagram illustrates the stages through which the data moves from the unnormalized form to the first normal form, the second normal form, and finally to the third normal form.



However, it’s important to link all tables together to ensure you have well-organized and related tables in the database. This can be done by defining foreign keys in the tables.



The third normal form is typically good enough to deal with the three anomaly challenges – insertion, update, and deletion anomalies – that the normalization process aims to tackle. Completing the third normal form in a database design helps to develop a database that is easy to access and query, well-structured, well-organized, consistent, and without unnecessary data duplications.