TASK

Design and Build a Relational Database

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Introduction

WELCOME TO THE DESIGN AND BUILD A RELATIONAL DATABASE TASK!

In this task, we introduce the relational database. We will also discuss how to evaluate and design good table structures to control data redundancies and avoid data anomalies using the normalisation process.

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WHAT IS A RELATIONAL DATABASE?

A relational database organises data as a set of formally described tables. Data can then be accessed or reassembled from these tables in many different ways without having to reorganise the database tables.

To put it simply, a relational database organises data into tables and links them based on defined relationships. These relationships then enable you to retrieve and combine data from one or more tables with a single query.

Each table in a relational database has a unique name and may relate to one or more other tables in the database through common values. These tables, or relations as they are sometimes called, contain rows (records) and columns (fields). Each row contains a unique instance of data for the categories defined by the columns. For example, a table that describes a customer can have columns for name, address, phone number, and so on. Rows are sometimes referred to as tuples and columns as attributes.

A relationship is a link between two tables. Relationships make it possible to find data in one table that pertains to a specific record in another table.

Tables in a relational database often contain a **primary key**, which is a column or group of columns used as a unique identifier for each row in the table. For example, a Customer table might have a column called CustomerID that is unique for every row. This makes it easy to keep track of a record over time and to associate a record with records in other tables.

Tables may also contain **foreign keys**, which are columns that link to primary key columns in *other* tables, thereby creating a relationship. For example, the Customers table might have a column called SalesRep that links to EmployeeID, which is the primary key in the Employees table. In this case, the SalesRep column is a foreign key. It is being used to show that there is a relationship between a specific customer and a specific sales rep.

A **Relational Database Management System (RDBMS)** is the software used for creating, manipulating, and administering a database. The RDBMS is often referred to as the database. Many commercial RDBMS's use the **Structured Query Language (SQL)**. SQL queries are the standard way to access data from a relational database. SQL queries can be used to create, modify and delete tables, as well as select, insert, and delete data from existing tables.

DATA REDUNDANCY

When talking about databases, it is important to know about the common database or data organisation issues and how to deal with them.

Data redundancy is a condition created within a database or data storage technology in which the same piece of data is held in two separate places. As it is unlikely that data stored in different locations will be always be updated consistently, duplication of data can create 'islands of information' (the term given for the scattered data locations) that can contain different versions of the same data (for example, two different fields within a single database).

Uncontrolled data redundancy can cause issues such as:

- **Data inconsistency:** This exists when different and conflicting versions of the same data appear in different places.
- **Poor data security:** Having multiple copies of data increases the chances of a copy of the data being accessed without authorisation.
- **Data anomalies:** An anomaly is an abnormality. Ideally, a field value change should be made in only a single place. A data anomaly develops when all of the required changes in the redundant data are not made successfully. Data anomalies are defined by Coronel & Morris as:
    - *Update anomalies:* Occurs when the same information is recorded in multiple rows. For example, in an Employee table, if the office number changes, then there are multiple updates that need to be made. If these updates are not successfully completed across all rows, then an inconsistency occurs.

EmployeeID	SalesPerson	SalesOffice	OfficeNumber	Customer1	Customer2	Customer3
1003	Mary Smith	Chicago	312-555-1212	Ford	GM	
1004	John Hunt	New York	212-555-1212	Dell	HP	Apple
1005	Martin Hap	Chicago	312-555-1212	Boeing		

(Sharma & Kaushik, 2015)

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    - *Insertion anomalies:* There is data we cannot record until we know information for the entire row. For example, we cannot record a new sales office until we also know the salesperson because, in order to create the record, we need to provide a primary key. In our case, this is the EmployeeID.

EmployeeID	SalesPerson	SalesOffice	OfficeNumber	Customer1	Customer2	Customer3
1003	Mary Smith	Chicago	312-555-1212	Ford	GM	
1004	John Hunt	New York	212-555-1212	Dell	HP	Apple
1005	Martin Hap	Chicago	312-555-1212	Boeing		
???	???	Atlanta	312-555-1212			

(Sharma & Kaushik, 2015)

- *Deletion anomalies:* Deletion of a row can cause more than one set of facts to be removed. For example, if John Hunt retires, then deleting that row cause us to lose information about the New York office (Coronel & Morris, 2014).

EmployeeID	SalesPerson	SalesOffice	OfficeNumber	Customer1	Customer2	Customer3
1003	Mary Smith	Chicago	312-555-1212	Ford	GM	
~~1004~~	~~John Hunt~~	~~New York~~	~~212-555-1212~~	~~Dell~~	~~HP~~	~~Apple~~
1005	Martin Hap	Chicago	312-555-1212	Boeing		

(Sharma & Kaushik, 2015)

NORMALISATION

Normalisation is a process for evaluating and correcting table structures to minimise data redundancies and therefore reduce the likelihood of data anomalies. In other words, normalisation is a method to remove anomalies and bring the database to a consistent state.

Normalisation works through a series of stages called **normal forms.** The first 3 stages are described as the first normal form (1NF), second normal form (2NF) and third normal form (3NF). 2NF is structurally better than 1NF, and 3NF is structurally better than 2NF. Normally, 3NF is as high as you need to go in the normalisation process for most business database design purposes.

The objective of normalisation, according to Rob, Coronel, & Crockett, is to create tables that have the following characteristics:

- Each table represents a single subject. For example, an employee table will only contain data that directly pertains to employees.

- No data item will be unnecessarily stored in more than one table so that data are only updated in one place.

- All attributes in a table are dependent on the primary key (Rob, Coronel, & Crockett, 2008).

Conversion to First Normal Form

According to Coronel & Morris, the normalisationists with a simple three-step procedure.

- ***Step 1: Eliminate the repeating groups***

  The data must be presented in a tabular format, where each cell has a single value and there are no repeating groups. A repeating group derives its name from the fact that multiple entries of the same type can exist for any single key of an attribute key. These entries, or repeating groups, will have identical structures but may consist of several fields.

PROJ_NUM	PROJ_NAME	EMP_NUM	EMP_NAME	JOB_CLASS	CHG_HOUR	HOURS
15	Evergreen	103	June Arbaugh	Elect. Engineer	$67.55	23
		101	John News	Database Designer	$82.00	19
		105	Alice Johnson	Database Designer	$82.00	35
		106	William Smithfield	Program mer	$26.66	12
		102	David Senior	System Analyst	$76.43	12
18	Amberwave	114	Ann Jones	Applicatio ns Designer	$38.00	24
		118	James Frommer	General Support	$14.50	45
		104	Anne Remoras	System Analyst	$76.43	32
		112	Darlene Smithson	DSS Analyst	$36.30	44

(Coronel & Morris, 2014)

Take a look at the table above. Note that each project number can reference a group of related data entries. The Evergreen project, for example, is associated with five entries, one for each person working on the project. Those entries are related because each of them has a value of 15 for PROJ_NUM. The number of entries in the repeating group grows by one each time a new record is entered for another person who is working on the Evergreen project.

To eliminate repeating groups, you need to eliminate the **null values** (a null value is used in databases to signify a missing or unknown value) by making sure that each repeating group attribute contains an appropriate data value. Doing this converts the table above to 1NF like that below.

PROJ_NUM	PROJ_NAME	EMP_NUM	EMP_NAME	JOB_CLASS	CHG_HOUR	HOURS
15	Evergreen	103	June Arbaugh	Elect. Engineer	$67.55	23
15	Evergreen	101	John News	Database Designer	$82.00	19
15	Evergreen	105	Alice Johnson	Database Designer	$82.00	35
15	Evergreen	106	William Smithfield	Programmer	$26.66	12
15	Evergreen	102	David Senior	System Analyst	$76.43	12
18	Amberwave	114	Ann Jones	Applications Designer	$38.00	24
18	Amberwave	118	James Frommer	General Support	$14.50	45
18	Amberwave	104	Anne Remoras	System Analyst	$76.43	32
18	Amberwave	112	Darlene Smithson	DSS Analyst	$36.30	44

- ***Step 2: Identify the primary key***

  You should note that PROJ_NUM is not an adequate primary key, because it does not *uniquely identify one* row of the table and therefore does not identify all of the remaining entity (row) attributes. To create a primary key that will uniquely identify an attribute value, the new primary key must therefore be composed of a combination of PROJ_NUM and EMP_NUM. So, for example, if you know that PROJ_NUM = 15 and EMP_NUM = 103, the entries for the attributes can only be Evergreen, June Arbaugh, Elect. Engineer, $67.55 and 23.

- ***Step 3: Identify all dependencies***

You have already identified the following dependency by identifying the primary key in step 2:

PROJ_NUM, EMP_NUM -> PROJ_NAME, EMP_NAME, JOB_CLASS, CHG_HOUR, HOURS

This means that PROJ_NAME, EMP_NAME, JOB_CLASS, CHG_HOUR and HOURS are dependent on the combination of PROJ_NUM and EMP_NUM. There are other dependencies, however. For example, the project number determines the project name. You can write this dependency as:

PROJ_NUM -> PROJ_NAME

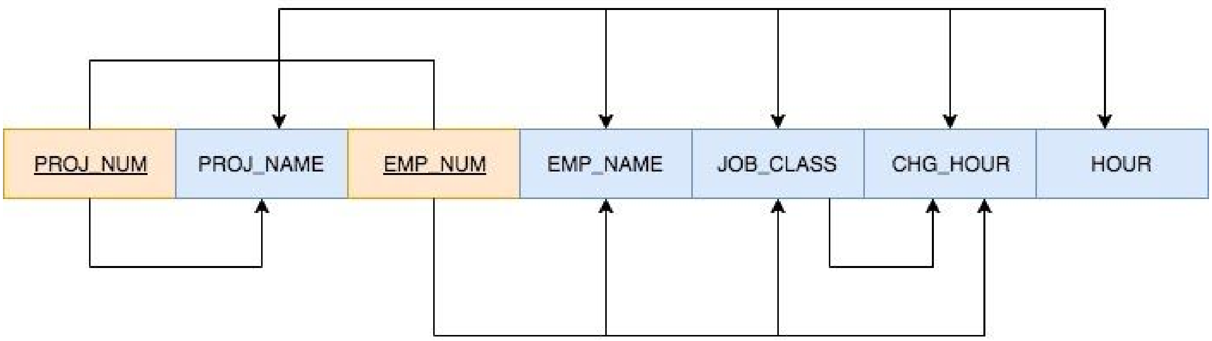
You can also determine an employee's name, job classification and charge per hour if you know an employee number. You can write this dependency as:

EMP_NUM -> EMP_NAME, JOB_CLASS, CHG_HOUR

Lastly, knowing the job classification means knowing the charge per hour for that job classification:

JOB_CLASS -> CHG_HOUR

A dependency diagram can help depict dependencies. They are helpful in getting a birds-eye-view of all the relationships among a table's attributes.



(Coronel & Morris, 2014, pg. 198)

Look at the dependency diagram above:

1. The primary key attributes are underlined and shaded in a different colour.

2. The arrows above the attributes indicate all desirable dependencies. Desirable dependencies are those based on the primary key. Note that the entity's attributes are dependent on the combination of PROJ_NUM and EMP_NUM.

3. The arrows below the diagram indicate less desirable dependencies. There are two types of less desirable dependencies:

    a. Partial dependencies, which are dependencies based on only a part of the composite primary key. For example, you only need to know PROJ_NUM to determine PROJ_NAME.

    b. Transitive dependencies, which are dependencies of one non-prime attribute (an attribute that is not part of a primary key) on another non-prime attribute. For example, CHG_HOUR is dependent on JOB_CLASS (Coronel & Morris, 2014).

A table is in 1NF when:

- All of the key attributes are defined;
- There are no repeating groups in the table;
- All attributes are dependent on the primary key (Coronel & Morris, 2014).

Conversion to Second Normal Form

The relational database design can be improved by converting the database into a format known as the second normal form. According to Coronel & Morris, the following steps are required to convert a database to second normal form:

- ***Step 1: Write each key component on a separate line***

    Write each key component on a separate line, then write the original (composite) key on the last line:

    PROJ_NUM
    EMP_NUM
    PROJ_NUMEMP_NUM

Each component will become the key in a new table. In other words, the original table is now divided into three tables (PROJECT, EMPLOYEE and ASSIGNMENT).

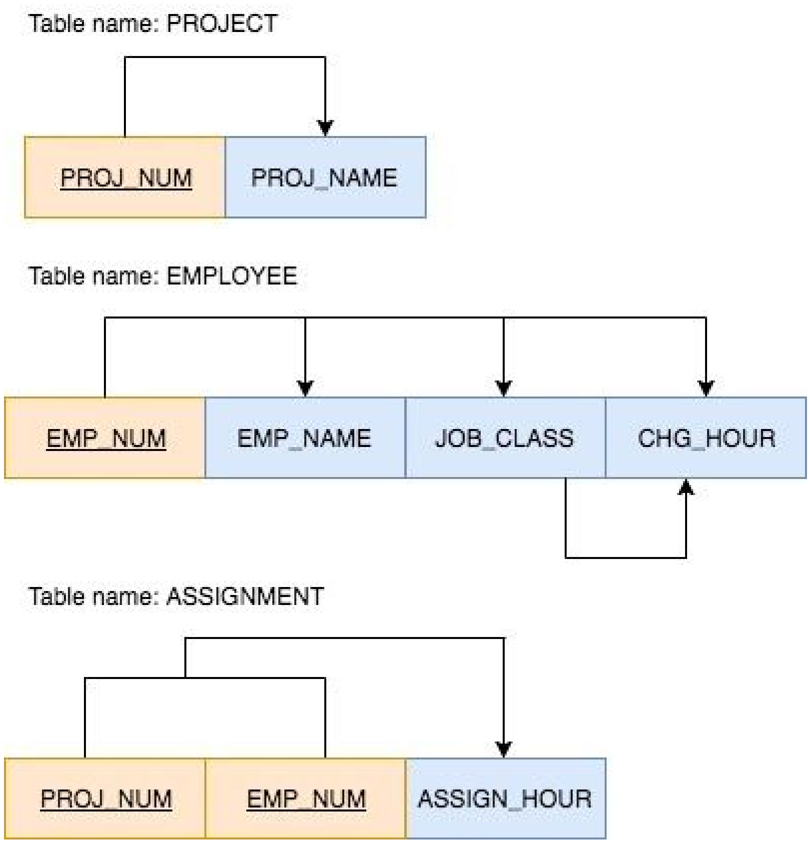
- ***Step 2: Assign corresponding dependent attributes***

  Then use the dependency diagram above to determine those attributes that are dependent on other attributes. The dependencies for the original key components are found by examining the arrows below the dependency diagram. The three new tables are described by the following relational schemas:

  PROJECT (PROJ_NUM, PROJ_NAME)
  EMPLOYEE (EMP_NUM, EMP_NAME, JOB_CLASS, CHG_HOUR)
  ASSIGNMENT (PROJ_NUM, EMP_NUM, ASSIGN_HOURS)

  The number of hours spent on each project by each employee is dependent on both PROJ_NUM and EMP_NUM in the ASSIGNMENT table; you, therefore, place those hours in the ASSIGNMENT table as ASSIGN_HOURS.

  The dependency diagram below shows the result of Steps 1 and 2.



At this point, most of the anomalies discussed earlier have been eliminated. For example, if you now want to add, change or delete a PROJECT record, you need to go only to the PROJECT table and add, change or delete only one row (Coronel & Morris, 2014).

A table is in 2NF when:
- It is in 1NF
- It includes no partial dependencies; that is, no attribute is dependent on only a portion of the primary key.

It is still possible for a table in 2NF to exhibit transitive dependency; that is, one or more attributes may be functionally dependent on non-key attributes (Coronel & Morris, 2014).

Conversion to Third Normal Form

The data anomalies created by the database organisation shown above are easily eliminated by completing the following steps as outlined by Rob, Coronel, & Crockett:

- ***Step 1: Identify each new determinant***

  For every transitive dependency, write its determinant as a PK for a new table. A determinant is any attribute whose value determines other values within a row. You will have three different determinants if you have three different transitive dependencies. The dependency diagram above shows a table that contains only one transitive dependency. Therefore, we write the determinate for this transitive dependency as:

  JOB_CLASS

- ***Step 2: Identify the dependent attributes***

  Identify the attributes that are dependent on each determinant identified in Step 1 and identify the dependency. You write in this case:

  JOB_CLASS -> CHG_HOUR

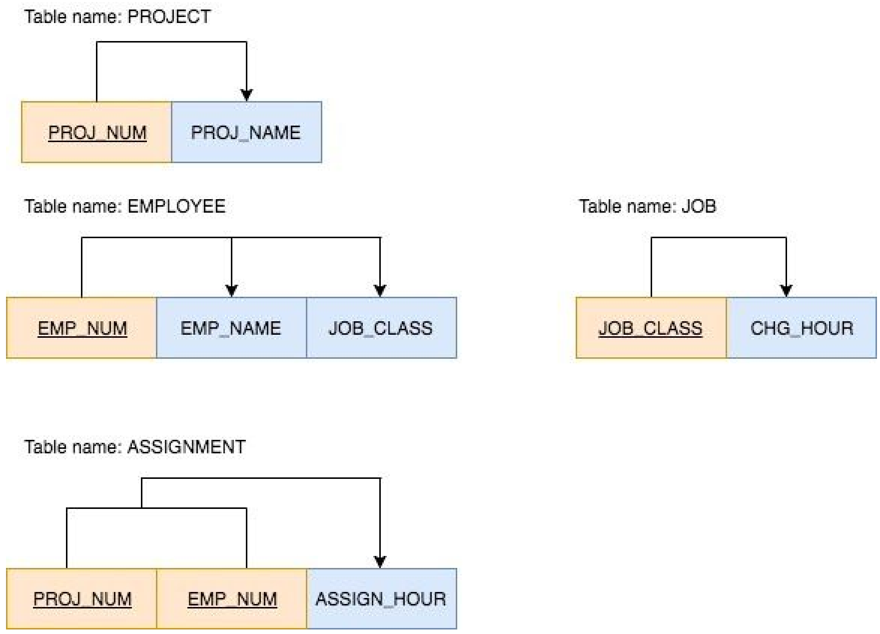
Give the table a name that reflects its contents and function. We shall name this table JOB.

- ***Step 3: Remove the dependent attributes from transitive dependencies***

Eliminate all dependent attributes in the transitive relationship from each of the tables that have such a relationship. In this example, we eliminate CHG_HOUR from the EMPLOYEE table shown in the dependency diagram above to leave the EMPLOYEE table dependency definition as:

EMP_NUM -> EMP_NAME, JOB_CLASS.

Notice that the JOB_CLASS remains in the EMPLOYEE table to serve as the foreign key. You can now draw a new dependency diagram to show all of the tables you have defined in the steps above. Then check the new tables as well as the tables you modified in Step 3 to make sure that each table has a determinant and that no table contains inappropriate dependencies. The new dependency diagram should look as follows:



(Rob, Coronel, & Crockett, 2008, pg. 258)

The dependency diagram created after completing Steps 1-3 can be seen above. After the conversion has been completed, your database should contain four tables:

PROJECT (PROJ_NUM, PROJ_NAME)

EMPLOYEE (EMP_NUM, EMP_NAME, JOB_CLASS)
JOB (JOB_CLASS, CHG_HOUR)
ASSIGNMENT (PROJ_NUM, EMP_NUM, ASSIGN_HOURS)

This conversation has eliminated the original EMPLOYEE table's transitive dependency. The tables are now said to be in third normal form (3NF) (Rob, Coronel, & Crockett, 2008).

A table is said to be in 3NF when:

- It is in 2NF
- It contains no transitive dependencies (Rob, Coronel, & Crockett, 2008).

A note from our coding mentor
Sabir

***Additional reading**: This task merely provides a brief overview of what databases are and how they are used. Database design is a very interesting field that takes a while to learn. If you'd like to know more about database design, we highly recommend reading the book "[Database Design - 2nd Edition](#)" by Adrienne Watt. **Chapters 11 and 12** of this book provide more detail regarding what has been covered in this task.*

Compulsory Task 1

Answer the following questions:

- What is normalization?

- When is a table in 1NF?

- When is a table in 2NF?

- When is a table in 3NF?

- Using the INVOICE table given below, draw its dependency diagram and identify all dependencies (including transitive and partial dependencies). You can assume that the table does not contain any repeating groups and that an invoice number references more than one product. Hint: This table uses a composite primary key.

Attribute Name	Sample Value	Sample Value	Sample Value	Sample Value	Sample Value
INV_NUM	211347	211347	211347	211348	211349
PROD_NUM	AA-E3522QW	QD-300932X	RU-995748G	AA-E3522QW	GH-778345P
SALE_DATE	15-Jan-2018	15-Jan-2018	15-Jan-2018	15-Jan-2018	16-Jan-2018
PROD_LABEL	Rotary sander	0.25-in. Drill bit	Band saw	Rotary sander	Power drill
VEND_CODE	211	211	309	211	157
VEND_NAME	NeverFail, Inc.	NeverFail, Inc.	BeGood, Inc.	NeverFail, Inc.	ToughGo, Inc.
QUANT_SOLD	1	8	1	2	1
PROD_PRICE	$34.46	$2.73	$31.59	$34.46	$69.32

- Using the answer to the above question, remove all partial dependencies and draw the new dependency diagrams. Identify the normal forms for each table structure you created.

- Using the answer to the above question, remove all transitive dependencies and draw the new dependency diagrams. Identify the normal forms for each table structure you created.

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References:

Coronel, C., & Morris, S. (2014). Data Systems: Design, Implementation and Management. London: Cengage Learning.

Rob, P., Coronel, C., & Crockett, K. (2008). Database Systems: Design, Implementation and Management. London: Cengage Learning EMEA, 2008.

Sharma, R., & Kaushik, S. (2015). Database Management System. Horizon Books (A Division of Ignited Minds Edutech P Ltd).