

BI Notes

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2018-03-23

Contents

Preface	5
1 Querying Data with Transact-SQL	7
1.1 Introduction to Transact-SQL	7
1.2 Querying Tables with SELECT	13
1.3 Querying Tables with Joins	21
1.4 Using Set Operators	31
1.5 Using Functions and Aggregating Data	37
1.6 Sub-queries and Apply	51
1.7 Using Table Expressions	57
1.8 Grouping Sets and Pivoting Data	65
1.9 Modifying Data	70
1.10 Programming with Transact-SQL	75
1.11 Error Handling and Transactions	79
1.12 Final Assessment	85
2 Supervised Learning In R Classification	93
2.1 k-Nearest Neighbors (kNN)	93
2.2 Naive Bayes	97
2.3 Logistic regression - binary predictions with regression	100
2.4 Classification Trees	110

Preface

The following notes were taken by me for educational, non-commercial, purposes. If you find the information useful, buy the material/take the course.

Chapter 1

Querying Data with Transact-SQL

Notes taken during/inspired by the edX course ‘Querying Data with Transact-SQL - Microsoft: DAT201x’ by Graeme Malcolm and Geoff Allix.

Course Handouts

- Course Syllabus
 - Getting Started Guide Including Install
 - Adventure Works Entity Relationship Diagram
 - Adventure Works db install script
- NOTE: Remember to ensure read only access for everyone to the folder containing the .SQL and other files
- GitHub Repo for course including course materials, slides, labs etc
 - A copy of the above materials should they be changed or removed

Other useful links * Transact-SQL Reference

```
library(DBI)
```

```
## Loading required package: methods
```

```
# creates a connection to the SQL database
```

```
# note that "con" will be used later in each connection to the database
```

```
con <- DBI::dbConnect(odbc::odbc(),  
                      Driver = "SQL Server",  
                      Server = "localhost\\SQLEXPRESS",  
                      Database = "AdventureWorksLT",  
                      Trusted_Connection = "True")
```

```
# Sets knitr to use this connection as the default so we don't need to specify it for every chunk  
knitr::opts_chunk$set(connection = "con")
```

1.1 Introduction to Transact-SQL

SQL or Structured Query Language was first developed in the 1970s by IBM as a way of interacting with databases. Other vendors have specific versions of SQL for instance Oracle is PL/SQL, Microsoft's implementation is TSQL or Transact SQL. Both SQL Server (on prem) and Azure SQL Databases (cloud) use the same query language, however Azure is a subset of full TSQL since it some commands relate to local files and

data functions within .NET that relate only to SQL Server. However, as new features are added to Azure, some new commands are being added to Azure.

SQL is a declarative language - you express what it is that you want, the results - rather than specifying the steps taken to achieve that - it is not procedural like other programming languages, it is set theory based. It is possible to write procedural elements or steps within TSQL, however if this is occurring a lot, it is perhaps better done in another language, which may also perform or run better.

In databases, we typically talk about entities - one type of thing - which is contained in each table.

* Entities are represented as relations (tables) * And entity attributes as domains (columns)

Most relationships are normalized, with relationships between primary and foreign keys. This helps to reduce duplication, however there are instances where de-normalised data is desired.

Schemas are namespaces for database objects - it shows a logical layout for all or part of a relational database, *“As part of a data dictionary, a database schema indicates how the entities that make up the database relate to one another, including tables, views, stored procedures, and more.”*(see Lucid Chart on Database Schemas). The process of creating a database schema is called data modelling.

When referring to objects in a database, we could use a fully qualified name, such as:

- [server_name.][database_name.][schema_name.]object_name

This is only really relevant for SQL Server, since Azure will only work with one database at a time. Most of the time we typically just use

- schema_name.object_name

The schema name sometimes be discarded, but it is considered best practice to include this, since there is sometimes some ambiguity about tables e.g. if we have two tables - Product.Order and Customer.Order - which order table is being referred to, that in the customer or product schema?

SQL has a number of SQL Statement Types:

- DML or Data Manipulation Language - SELECT, INSERT, UPDATE, DELETE
- DDL or Data Definition Language - CREATE, ALTER, DROP
- DCL or Data Control Language - GRANT, REVOKE, DENY

The course focuses on DML which is typically for working with data.

SELECT statement has a number of possible sub-components:

- FROM [table]
- WHERE [condition for filtering rows]
- GROUP BY [arranges rows by groups]
- HAVING [condition for filtering groups]
- ORDER BY [sorts the output]

Whilst a SQL statement can look like English, it doesn't necessarily run from top to bottom in terms of the sequence of elements that are run in a query. For instance, the FROM is the first thing that will be run, then the WHERE filter will be run, then we GROUP BY, then SELECT the columns we are interested in and finally ORDER the results. This can be important when running some queries, which will be explored later in the course. When we run a query, it is not an actual table in a database that is returned but a set of rows or record set or subset.

1.1.1 Data Types

There are a number of different data types in T-SQL as shown below, which are grouped into a number of different types.

Exact Numeric	Approximate Numeric	Character
tinyint	float	char
smallint	real	varchar
int		text
bigint		nchar
bit		nvarchar
decimal/numeric		ntext
numeric		
money		
smallmoney		

(#fig:Data Types) Figure 1.1: Transact-SQL Data Types

This is more relevant when designing a database, however it is useful to know when querying what data type you have in a broad sense - numeric, data, string and so on - as the types will determine what type of combinations can be combined together in expressions e.g. you can concatenate strings or add numbers together, but you can't concatenate a string and a number together.

Sometimes it is necessary to convert data from one type to another, there are two ways this could happen

- Implicit conversion - compatible data types are automatically converted
- Explicit conversion - requires an explicit function e.g. CAST / TRY_CAST, STR, PARSE ? TRY_PARSE, CONVERT / TRY_CONVERT

The TRY options will attempt a conversion and if it does not work, a NULL will be returned rather than an error in the non-TRY version.

1.1.2 Working with NULLs

There are recognised standards for treating NULL values - ANSI - which says that anything involving a NULL should return a NULL. There are functions that help us handle NULL values:

- ISNULL(column/variable, value) - Returns *value* (which you can specify) if the column or variable is NULL
- NULLIF(column/variable, value) - Returns NULL if the column or variable is a value - we are almost recoding a non-null to a null
- COALESCE (column/variable1, column/variable2, ...) - Returns the value of the first non-NULL column or variable in the list - for instance if contact details, someone might not have an email, so we might want a telephone number, if they don't have that, return an address etc

NULL is used to indicate an unknown or missing value. NULL is **not** equivalent to zero or an empty string.

ISNULL can be used like an IF function in excel, for instance:

```
SELECT name, ISNULL(TRY_CAST(size AS Integer), 0) AS NumericSize
FROM SalesLT.Product;
```

In this instance, if there is a value that will be returned, if not, the NULL value will be returned as a 0.

We can also use a CASE statement to return a value whilst integrating NULL in to our query, e.g.

```
SELECT name,
       CASE size
         WHEN 'S' THEN 'SMALL'
         WHEN 'M' THEN 'MEDIUM'
         WHEN 'L' THEN 'LARGE'
         WHEN 'XL' THEN 'EXTRA LARGE'
         ELSE ISNULL(Size, 'N/A')
       END AS PRODUCT
FROM SalesLT.Product;
```

1.1.3 Lab Exercises

AdventureWorks Cycles is a company that sells directly to retailers, who then sell products to consumers. Each retailer that is an AdventureWorks customer has provided a named contact for all communication from AdventureWorks.

The sales manager at AdventureWorks has asked you to generate some reports containing details of the company's customers to support a direct sales campaign. Let's start with some basic exploration.

First we display the sales person, the customer's title, surname and telephone number

Table 1.1: Displaying records 1 - 10

name	PRODUCT
HL Road Frame - Black, 58	58
HL Road Frame - Red, 58	58
Sport-100 Helmet, Red	N/A
Sport-100 Helmet, Black	N/A
Mountain Bike Socks, M	MEDIUM
Mountain Bike Socks, L	LARGE
Sport-100 Helmet, Blue	N/A
AWC Logo Cap	N/A
Long-Sleeve Logo Jersey, S	SMALL
Long-Sleeve Logo Jersey, M	MEDIUM

Table 1.2: Displaying records 1 - 10

SalesPerson	CustomerName	Phone
adventure-works\pamela0	Mr. Gee	245-555-0173
adventure-works\david8	Mr. Harris	170-555-0127
adventure-works\jillian0	Ms. Carreras	279-555-0130
adventure-works\jillian0	Ms. Gates	710-555-0173
adventure-works\shu0	Mr. Harrington	828-555-0186
adventure-works\linda3	Ms. Carroll	244-555-0112
adventure-works\shu0	Mr. Gash	192-555-0173
adventure-works\josé1	Ms. Garza	150-555-0127
adventure-works\josé1	Ms. Harding	926-555-0159
adventure-works\garrett1	Mr. Caprio	112-555-0191

```
SELECT SalesPerson, Title + ' ' + LastName AS CustomerName, Phone
FROM SalesLT.Customer;
```

Next we cast the CustomerID column to a VARCHAR and concatenate with the CompanyName column

```
SELECT CAST(CustomerID AS VARCHAR) + ': ' + CompanyName AS CustomerCompany
FROM SalesLT.Customer;
```

The SalesLT.SalesOrderHeader table contains records of sales orders. You have been asked to retrieve data for a report that shows:

The sales order number and revision number in the format () (e.g. SO71774 (2)). The order date converted to ANSI standard format yyyy.mm.dd (e.g. 2015.01.31).

```
SELECT SalesOrderNumber + ' (' + STR(RevisionNumber, 1) + ')' AS OrderRevision,
       CONVERT(NVARCHAR(30), OrderDate, 102) AS OrderDate
FROM SalesLT.SalesOrderHeader;
```

Next we write a query that returns a list of customer names. We use ISNULL to check for middle names and concatenate with FirstName and LastName.

```
SELECT FirstName + ' ' + ISNULL(MiddleName + ' ', '') + LastName
AS CustomerName
FROM SalesLT.Customer;
```

Next, we will imagine that some data has been deleted - customer email addresses - then we try to find

Table 1.3: Displaying records 1 - 10

CustomerCompany
1: A Bike Store
2: Progressive Sports
3: Advanced Bike Components
4: Modular Cycle Systems
5: Metropolitan Sports Supply
6: Aerobic Exercise Company
7: Associated Bikes
10: Rural Cycle Emporium
11: Sharp Bikes
12: Bikes and Motorbikes

Table 1.4: Displaying records 1 - 10

OrderRevision	OrderDate
SO71774 (2)	2008.06.01
SO71776 (2)	2008.06.01
SO71780 (2)	2008.06.01
SO71782 (2)	2008.06.01
SO71783 (2)	2008.06.01
SO71784 (2)	2008.06.01
SO71796 (2)	2008.06.01
SO71797 (2)	2008.06.01
SO71815 (2)	2008.06.01
SO71816 (2)	2008.06.01

Table 1.5: Displaying records 1 - 10

CustomerName
Orlando N. Gee
Keith Harris
Donna F. Carreras
Janet M. Gates
Lucy Harrington
Rosmarie J. Carroll
Dominic P. Gash
Kathleen M. Garza
Katherine Harding
Johnny A. Caprio

Table 1.6: Displaying records 1 - 10

CustomerID	PrimaryContact
1	245-555-0173
2	keith0@adventure-works.com
3	donna0@adventure-works.com
4	janet1@adventure-works.com
5	lucy0@adventure-works.com
6	rosmarie0@adventure-works.com
7	dominic0@adventure-works.com
10	kathleen0@adventure-works.com
11	katherine0@adventure-works.com
12	johnny0@adventure-works.com

contact details in sequence.

```
UPDATE SalesLT.Customer
SET EmailAddress = NULL
WHERE CustomerID % 7 = 1;
```

Next we write a query that returns a list of customer IDs in one column, and a second column named PrimaryContact that contains the email address if known, and otherwise the phone number.

```
SELECT CustomerID, COALESCE(EmailAddress, Phone) AS PrimaryContact
FROM SalesLT.Customer;
```

You have been asked to create a query that returns a list of sales order IDs and order dates with a column named ShippingStatus that contains the text “Shipped” for orders with a known ship date, and “Awaiting Shipment” for orders with no ship date.

Again, we imagine that some data is missing by deleting some first.

```
UPDATE SalesLT.SalesOrderHeader
SET ShipDate = NULL
WHERE SalesOrderID > 71899;
```

```
SELECT SalesOrderID, OrderDate,
CASE
    WHEN ShipDate IS NULL THEN 'Awaiting Shipment'
    ELSE 'Shipped'
END AS ShippingStatus
FROM SalesLT.SalesOrderHeader;
```

1.2 Querying Tables with SELECT

1.2.1 Removing Duplicates

If we wanted to know what colours our products are, we would run something like the following.

```
SELECT Color
FROM SalesLT.Product;
```

Here each product has a row and corresponding colour. However, if we just want colour, we are typically interested in removing duplicates to just show what colours we are actually producing. This is achieved using

Table 1.7: Displaying records 1 - 10

SalesOrderID	OrderDate	ShippingStatus
71774	2008-06-01	Shipped
71776	2008-06-01	Shipped
71780	2008-06-01	Shipped
71782	2008-06-01	Shipped
71783	2008-06-01	Shipped
71784	2008-06-01	Shipped
71796	2008-06-01	Shipped
71797	2008-06-01	Shipped
71815	2008-06-01	Shipped
71816	2008-06-01	Shipped

Table 1.8: Displaying records 1 - 10

Color
Black
Red
Red
Black
White
White
Blue
Multi
Multi
Multi

Table 1.9: Displaying records 1 - 10

Color
NA
Black
Blue
Grey
Multi
Red
Silver
Silver/Black
White
Yellow

Table 1.10: Displaying records 1 - 10

Color	Size
NA	NA
Black	NA
Black	38
Black	40
Black	42
Black	44
Black	46
Black	48
Black	52
Black	58

the DISTINCT keyword

```
SELECT DISTINCT Color
FROM SalesLT.Product;
```

These results are DISTINCT at the row level, so if we have two combinations of columns - say size and colour - then it would be DISTINCT colour and size combinations that appear in the database.

```
SELECT DISTINCT Color, Size
FROM SalesLT.Product;
```

Here is just the size - here IS NULL will return a 'None' if the Size is missing (NA).

```
SELECT DISTINCT ISNULL(Size, 'None') AS Size
FROM SalesLT.Product;
```

1.2.2 Sorting Results

ORDER BY is how we sort the results. Any aliased fields used in the SELECT element are visible by ORDER BY. You can order the results using columns that are not selected in the SELECT clause. You can also ORDER BY multiple columns, either ascending or descending.

We can also just show the top 10 products, e.g. the top 10 most expensive. This is done using the keyword TOP

Table 1.11: Displaying records 1 - 10

Size
38
40
42
44
46
48
50
52
54
56

Table 1.12: Displaying records 1 - 10

Category	Name	ListPrice
6	Road-150 Red, 62	3578.27
6	Road-150 Red, 44	3578.27
6	Road-150 Red, 48	3578.27
6	Road-150 Red, 52	3578.27
6	Road-150 Red, 56	3578.27
5	Mountain-100 Silver, 38	3399.99
5	Mountain-100 Silver, 42	3399.99
5	Mountain-100 Silver, 44	3399.99
5	Mountain-100 Silver, 48	3399.99
5	Mountain-100 Black, 38	3374.99

```
SELECT TOP (10) ProductCategoryID AS Category, Name, ListPrice
FROM SalesLT.Product
ORDER BY ListPrice DESC, Category;
```

We can also use TOP (N) Percent or TOP (N) WITH TIES. If we say wanted the bottom 10 items - say those with the lowest price - there is no 'BOTTOM' Keyword, instead we would sort our data so that they are now in the the order we want - with those we are interested at the top - the use TOP again.

1.2.3 Paging through results

This is achieved through using the OFFSET-FETCH which is an extension of ORDER BY. This might be useful if you have a set of web page results and you want to see certain ones.

You first say how many rows you want to skip using e.g. OFFSET 10 ROWS, then use specify how many rows you are interested in retrieving from the database e.g. FETCH NEXT 10 ROWS ONLY.

1.2.4 Filtering and Using Predicates

We can use the WHERE clause with a number of conditions or predicates. For instance = (equals) <> (not equals), IN, BETWEEN (is an inclusive statement e.g. BETWEEN 100 AND 200 includes 100 and 200), LIKE, AND, OR and NOT. IN can be more efficient in coding terms when testing multiple attributes, as you just say color IN (red, blue) rather than colour = 'red' OR colour = 'blue'. This becomes more useful

Table 1.13: Displaying records 1 - 10

Name	Color	Size	ProductNumber
HL Road Frame - Black, 58	Black	58	FR-R92B-58
HL Road Frame - Red, 58	Red	58	FR-R92R-58
HL Road Frame - Red, 62	Red	62	FR-R92R-62
HL Road Frame - Red, 44	Red	44	FR-R92R-44
HL Road Frame - Red, 48	Red	48	FR-R92R-48
HL Road Frame - Red, 52	Red	52	FR-R92R-52
HL Road Frame - Red, 56	Red	56	FR-R92R-56
LL Road Frame - Black, 58	Black	58	FR-R38B-58
LL Road Frame - Black, 60	Black	60	FR-R38B-60
LL Road Frame - Black, 62	Black	62	FR-R38B-62

Table 1.14: Displaying records 1 - 10

Name	Color	Size	ProductNumber
HL Road Frame - Black, 58	Black	58	FR-R92B-58
HL Road Frame - Red, 58	Red	58	FR-R92R-58
LL Road Frame - Black, 58	Black	58	FR-R38B-58
LL Road Frame - Red, 58	Red	58	FR-R38R-58
ML Road Frame - Red, 58	Red	58	FR-R72R-58
Road-450 Red, 58	Red	58	BK-R68R-58
Road-650 Red, 58	Red	58	BK-R50R-58
Road-650 Black, 58	Black	58	BK-R50B-58
Road-250 Red, 58	Red	58	BK-R89R-58
Road-250 Black, 58	Black	58	BK-R89B-58

when testing multiple conditions e.g. IN (red, blue) AND size = large - this would have more typing with explicit code for each combination.

Like mathematics, SQL works on PEMDAS sequencing - parenthesis, exponents, multiplication, division, addition, subtraction.

Some examples.

First look for products that start with an FR:

```
SELECT Name, Color, Size, ProductNumber
FROM SalesLT.Product
WHERE ProductNumber LIKE 'FR%';
```

Or we can look for products that end in a 58:

```
SELECT Name, Color, Size, ProductNumber
FROM SalesLT.Product
WHERE ProductNumber LIKE '%58';
```

Or we can use underscores to specify a number of characters e.g. one `_` is one missing character. A wildcard (`%`) would match any number of chars. The figures in brackets then are like regex, so if we want a numeric value between 0 and 9 we use `[0-9]`. Equally we could use a similar query to find things like email addresses in a string, or email addresses that end in a `.co.uk`.

```
SELECT Name, Color, Size, ProductNumber
FROM SalesLT.Product
```

Table 1.15: Displaying records 1 - 10

Name	Color	Size	ProductNumber
Road-150 Red, 62	Red	62	BK-R93R-62
Road-150 Red, 44	Red	44	BK-R93R-44
Road-150 Red, 48	Red	48	BK-R93R-48
Road-150 Red, 52	Red	52	BK-R93R-52
Road-150 Red, 56	Red	56	BK-R93R-56
Road-450 Red, 58	Red	58	BK-R68R-58
Road-450 Red, 60	Red	60	BK-R68R-60
Road-450 Red, 44	Red	44	BK-R68R-44
Road-450 Red, 48	Red	48	BK-R68R-48
Road-450 Red, 52	Red	52	BK-R68R-52

Table 1.16: Displaying records 1 - 10

Name
Mountain Bike Socks, M
Mountain Bike Socks, L
ML Road Frame - Red, 44
ML Road Frame - Red, 48
ML Road Frame - Red, 52
ML Road Frame - Red, 58
ML Road Frame - Red, 60
HL Mountain Frame - Silver, 44
HL Mountain Frame - Silver, 48
HL Mountain Frame - Black, 44

```
WHERE ProductNumber LIKE 'BK-[0-9][0-9]_[0-9][0-9]';
```

We can use the BETWEEN clause on things like dates to select all products that were removed from sale in 2016:

```
SELECT Name
FROM SalesLT.Product
WHERE SellEndDate BETWEEN '2006/1/1' AND '2006/12/31';
```

Note that it is often useful to order results in the order you want, even if it currently appears it the correct order. Sometimes these queries may change as data or the database does, so it is best to be explicit and use an ORDER BY.

1.2.5 Lab Exercises

You are being told that transportation costs are increasing and you need to identify the heaviest products.

```
-- select the top 10 percent from the Name column
SELECT TOP (10) Percent Name, Weight
FROM SalesLT.Product
-- order by the weight in descending order
ORDER BY Weight DESC;
```

Next, we want to ignore the first 10 records - to page through using offset

Table 1.17: Displaying records 1 - 10

Name	Weight
Touring-3000 Blue, 62	13607.70
Touring-3000 Yellow, 62	13607.70
Touring-3000 Blue, 58	13562.34
Touring-3000 Yellow, 58	13512.45
Touring-3000 Blue, 54	13462.55
Touring-3000 Yellow, 54	13344.62
Touring-3000 Yellow, 50	13213.08
Touring-3000 Blue, 50	13213.08
Touring-3000 Blue, 44	13049.78
Touring-3000 Yellow, 44	13049.78

Table 1.18: Displaying records 1 - 10

Name
Mountain-500 Silver, 52
Mountain-500 Black, 52
Mountain-500 Black, 48
Mountain-500 Silver, 48
Mountain-500 Silver, 44
Mountain-500 Black, 44
Touring-2000 Blue, 60
Mountain-500 Black, 42
Mountain-500 Silver, 42
Touring-2000 Blue, 54

```

SELECT Name
FROM SalesLT.Product
ORDER BY Weight DESC
-- offset 10 rows and get the next 100
OFFSET 10 ROWS FETCH NEXT 100 ROWS ONLY;

```

Next we create a query to find the names, colors, and sizes of the products with a product model ID of 1.

```

-- select the Name, Color, and Size columns
SELECT Name, Color, Size
FROM SalesLT.Product
-- check ProductModelID is 1
WHERE ProductModelID = 1;

```

Now we would like more information on products of certain colors and sizes. We retrieve the product number and name of the products that have a Color of 'Black', 'Red', or 'White' and a Size of 'S' or 'M'.

Table 1.19: 3 records

Name	Color	Size
Classic Vest, S	Blue	S
Classic Vest, M	Blue	M
Classic Vest, L	Blue	L

Table 1.20: Displaying records 1 - 10

ProductNumber	Name
SO-B909-M	Mountain Bike Socks, M
SH-M897-S	Men's Sports Shorts, S
SH-M897-M	Men's Sports Shorts, M
TG-W091-S	Women's Tights, S
TG-W091-M	Women's Tights, M
GL-H102-S	Half-Finger Gloves, S
GL-H102-M	Half-Finger Gloves, M
GL-F110-S	Full-Finger Gloves, S
GL-F110-M	Full-Finger Gloves, M
SH-W890-S	Women's Mountain Shorts, S

Table 1.21: Displaying records 1 - 10

ProductNumber	Name	ListPrice
BK-R93R-62	Road-150 Red, 62	3578.27
BK-R93R-44	Road-150 Red, 44	3578.27
BK-R93R-48	Road-150 Red, 48	3578.27
BK-R93R-52	Road-150 Red, 52	3578.27
BK-R93R-56	Road-150 Red, 56	3578.27
BK-R68R-58	Road-450 Red, 58	1457.99
BK-R68R-60	Road-450 Red, 60	1457.99
BK-R68R-44	Road-450 Red, 44	1457.99
BK-R68R-48	Road-450 Red, 48	1457.99
BK-R68R-52	Road-450 Red, 52	1457.99

```
-- select the ProductNumber and Name columns
SELECT ProductNumber, Name
FROM SalesLT.Product
-- check that Color is one of 'Black', 'Red' or 'White'
-- check that Size is one of 'S' or 'M'
WHERE Color IN ('Black', 'Red', 'White') AND Size IN ('S', 'M');
```

Next you have been asked to retrieve the product number, name, and list price of products that have a product number beginning with 'BK-'.

```
-- select the ProductNumber, Name, and ListPrice columns
SELECT ProductNumber, Name, ListPrice
FROM SalesLT.Product
-- filter for product numbers beginning with BK- using LIKE
WHERE ProductNumber LIKE 'BK-%';
```

Finally, the product manager is interested in a slight variation of the last request regarding product numbers with a particular prefix.

We are interested in products with product number beginning with 'BK-' followed by any character other than 'R', and ending with a '-' followed by any two numerals. Not an R is [^R].

```
-- select the ProductNumber, Name, and ListPrice columns
SELECT ProductNumber, Name, ListPrice
FROM SalesLT.Product
```

Table 1.22: Displaying records 1 - 10

ProductNumber	Name	ListPrice
BK-M82S-38	Mountain-100 Silver, 38	3399.99
BK-M82S-42	Mountain-100 Silver, 42	3399.99
BK-M82S-44	Mountain-100 Silver, 44	3399.99
BK-M82S-48	Mountain-100 Silver, 48	3399.99
BK-M82B-38	Mountain-100 Black, 38	3374.99
BK-M82B-42	Mountain-100 Black, 42	3374.99
BK-M82B-44	Mountain-100 Black, 44	3374.99
BK-M82B-48	Mountain-100 Black, 48	3374.99
BK-M68S-38	Mountain-200 Silver, 38	2319.99
BK-M68S-42	Mountain-200 Silver, 42	2319.99

```
-- filter for ProductNumbers
WHERE ProductNumber LIKE 'BK-[^R]%-[0-9][0-9]';
```

1.3 Querying Tables with Joins

We usually join tables based on primary key - foreign key relationships. We don't run two queries then join, but match at the time of the query. When we are talking about joins, we typically represent them as Venn diagrams.

The convention (ANSI SQL-92) is to specify the JOIN operator in the FROM clause:

```
SELECT ... FROM Table1 JOIN Table 2 ON ;
```

There is an older standard (ANSI SQL-89) where the tables are joined using commas in the FROM clause and using a WHERE operator, but this can lead to accidental cartesian (aka cross) products.

1.3.1 INNER Joins

INNER Joins are typically the most common join type. It involves a join only where a match is found in both input tables. You can add multiple joins after each other.

Some examples - first a basic inner join where the schema, table and column are explicitly stated.

```
SELECT SalesLT.Product.Name AS ProductName, SalesLT.ProductCategory.Name AS Category
FROM SalesLT.Product
INNER JOIN SalesLT.ProductCategory
ON SalesLT.Product.ProductCategoryID = SalesLT.ProductCategory.ProductCategoryID;
```

Next, we can do the same query but make this less cumbersome by using table aliases.

```
SELECT p.Name AS ProductName, c.Name AS Category
FROM SalesLT.Product AS p
INNER JOIN SalesLT.ProductCategory AS c
on p.ProductCategoryID = c.ProductCategoryID;
```

Next, we look at joining multiple tables, where we want the sales, including order level details, the products in the order and the product details. If we don't specify the join type, the assumption is it is a INNER join, as shown below.

Table 1.23: Displaying records 1 - 10

ProductName	Category
Mountain-100 Silver, 38	Mountain Bikes
Mountain-100 Silver, 42	Mountain Bikes
Mountain-100 Silver, 44	Mountain Bikes
Mountain-100 Silver, 48	Mountain Bikes
Mountain-100 Black, 38	Mountain Bikes
Mountain-100 Black, 42	Mountain Bikes
Mountain-100 Black, 44	Mountain Bikes
Mountain-100 Black, 48	Mountain Bikes
Mountain-200 Silver, 38	Mountain Bikes
Mountain-200 Silver, 42	Mountain Bikes

Table 1.24: Displaying records 1 - 10

ProductName	Category
Mountain-100 Silver, 38	Mountain Bikes
Mountain-100 Silver, 42	Mountain Bikes
Mountain-100 Silver, 44	Mountain Bikes
Mountain-100 Silver, 48	Mountain Bikes
Mountain-100 Black, 38	Mountain Bikes
Mountain-100 Black, 42	Mountain Bikes
Mountain-100 Black, 44	Mountain Bikes
Mountain-100 Black, 48	Mountain Bikes
Mountain-200 Silver, 38	Mountain Bikes
Mountain-200 Silver, 42	Mountain Bikes

Table 1.25: Displaying records 1 - 10

OrderDate	SalesOrderNumber	ProductName	OrderQty	UnitPrice	LineTotal
2008-06-01	SO71774	ML Road Frame-W - Yellow, 48	1	356.898	356.8980
2008-06-01	SO71774	ML Road Frame-W - Yellow, 38	1	356.898	356.8980
2008-06-01	SO71776	Rear Brakes	1	63.900	63.9000
2008-06-01	SO71780	ML Mountain Frame-W - Silver, 42	4	218.454	873.8160
2008-06-01	SO71780	Mountain-400-W Silver, 46	2	461.694	923.3880
2008-06-01	SO71780	Mountain-500 Silver, 52	6	112.998	406.7928
2008-06-01	SO71780	HL Mountain Frame - Silver, 38	2	818.700	1637.4000
2008-06-01	SO71780	Mountain-500 Black, 42	1	323.994	323.9940
2008-06-01	SO71780	LL Mountain Frame - Black, 48	1	149.874	149.8740
2008-06-01	SO71780	HL Mountain Frame - Black, 42	1	809.760	809.7600

Table 1.26: Displaying records 1 - 10

OrderDate	SalesOrderNumber	ProductName	OrderQty	UnitPrice	LineTotal
2008-06-01	SO71774	ML Road Frame-W - Yellow, 48	1	356.898	356.8980
2008-06-01	SO71774	ML Road Frame-W - Yellow, 38	1	356.898	356.8980
2008-06-01	SO71776	Rear Brakes	1	63.900	63.9000
2008-06-01	SO71780	ML Mountain Frame-W - Silver, 42	4	218.454	873.8160
2008-06-01	SO71780	Mountain-400-W Silver, 46	2	461.694	923.3880
2008-06-01	SO71780	Mountain-500 Silver, 52	6	112.998	406.7928
2008-06-01	SO71780	HL Mountain Frame - Silver, 38	2	818.700	1637.4000
2008-06-01	SO71780	Mountain-500 Black, 42	1	323.994	323.9940
2008-06-01	SO71780	LL Mountain Frame - Black, 48	1	149.874	149.8740
2008-06-01	SO71780	HL Mountain Frame - Black, 42	1	809.760	809.7600

```

SELECT oh.OrderDate, oh.SalesOrderNumber, p.Name As ProductName, od.OrderQty, od.UnitPrice, od.LineTotal
FROM SalesLT.SalesOrderHeader AS oh
JOIN SalesLT.SalesOrderDetail AS od
ON od.SalesOrderID = oh.SalesOrderID
JOIN SalesLT.Product AS p
ON od.ProductID = p.ProductID
ORDER BY oh.OrderDate, oh.SalesOrderID, od.SalesOrderDetailID;

```

It is possible to do joins based on more than one criteria, e.g. we could join based on the productID and where the ListPrice is less than the unitprice i.e. there has been a discount.

```

-- Multiple join predicates
SELECT oh.OrderDate, oh.SalesOrderNumber, p.Name As ProductName, od.OrderQty, od.UnitPrice, od.LineTotal
FROM SalesLT.SalesOrderHeader AS oh
JOIN SalesLT.SalesOrderDetail AS od
ON od.SalesOrderID = oh.SalesOrderID
JOIN SalesLT.Product AS p
ON od.ProductID = p.ProductID AND od.UnitPrice < p.ListPrice --Note multiple predicates
ORDER BY oh.OrderDate, oh.SalesOrderID, od.SalesOrderDetailID;

```

Table 1.27: Displaying records 1 - 10

FirstName	LastName	SalesOrderNumber
Orlando	Gee	NA
Keith	Harris	NA
Donna	Carreras	NA
Janet	Gates	NA
Lucy	Harrington	NA
Rosmarie	Carroll	NA
Dominic	Gash	NA
Kathleen	Garza	NA
Katherine	Harding	NA
Johnny	Caprio	NA

1.3.2 OUTER Joins

In an outer join we return all the rows from one table, and any matching rows from the second table. The records in the 'outer' table are preserved, typically we use language such as LEFT, RIGHT and FULL keywords. We are pulling in records from that OUTER table. FULL keeps records from both tables, but are typically not seen in practice. OUTER is OPTIONAL e.g. LEFT JOIN is the same as LEFT OUTER JOIN.

Now some examples. First, we bring up a list of customers, with any matching sales records i.e. we have a list of customers who HAVE bought something and those WHO HAVE NOT.

```
--Get all customers, with sales orders for those who've bought anything
SELECT c.FirstName, c.LastName, oh.SalesOrderNumber
FROM SalesLT.Customer AS c
LEFT OUTER JOIN SalesLT.SalesOrderHeader AS oh
ON c.CustomerID = oh.CustomerID
ORDER BY c.CustomerID;
```

Next we can look just for those customers who have not purchased anything using IS NULL.

```
--Return only customers who haven't purchased anything
SELECT c.FirstName, c.LastName, oh.SalesOrderNumber
FROM SalesLT.Customer AS c
LEFT OUTER JOIN SalesLT.SalesOrderHeader AS oh
ON c.CustomerID = oh.CustomerID
WHERE oh.SalesOrderNumber IS NULL
ORDER BY c.CustomerID;
```

Next we add records from multiple tables. If we add tables on to the chain of tables, having first declared a left or right join, you have to keep using LEFT joins. You could use an INNER Join but you would lose some records e.g. if you used an INNER join on the second table below, you would lose those records (products) that had never been sold.

Sometimes it is necessary to go through one table to get to another e.g. to Products -> Orders requires going through order details first. Even if, we are not bringing back any tables from the intermediary table.

```
--More than 2 tables
SELECT p.Name AS ProductName, oh.SalesOrderNumber
FROM SalesLT.Product AS p
LEFT JOIN SalesLT.SalesOrderDetail AS od
ON p.ProductID = od.ProductID
LEFT JOIN SalesLT.SalesOrderHeader AS oh --Additional tables added to the right must also use a left jo
```


Table 1.28: Displaying records 1 - 10

FirstName	LastName	SalesOrderNumber
Orlando	Gee	NA
Keith	Harris	NA
Donna	Carreras	NA
Janet	Gates	NA
Lucy	Harrington	NA
Rosmarie	Carroll	NA
Dominic	Gash	NA
Kathleen	Garza	NA
Katherine	Harding	NA
Johnny	Caprio	NA

Table 1.29: Displaying records 1 - 10

ProductName	SalesOrderNumber
HL Road Frame - Black, 58	NA
HL Road Frame - Red, 58	NA
Sport-100 Helmet, Red	SO71782
Sport-100 Helmet, Red	SO71783
Sport-100 Helmet, Red	SO71784
Sport-100 Helmet, Red	SO71797
Sport-100 Helmet, Red	SO71902
Sport-100 Helmet, Red	SO71936
Sport-100 Helmet, Red	SO71938
Sport-100 Helmet, Black	SO71782

```
ON od.SalesOrderID = oh.SalesOrderID
ORDER BY p.ProductID;
```

Next another example with multiple tables, but this time the order of the tables is different. We SELECT from the product table, then we LEFT Join the Order details so we can identify products that have never sold, then we LEFT JOIN to the order header table so we can get the order number where we use a left outer join as we are left joining those records to our original table. Then we INNER Join product category, because we are joining product category back to the first table - Products. The final table joins back to our original table, before the outer joins. So whether you need to use an OUTER or INNER join depends on where you wish to place the records based on the current list of tables, however you could reorder the tables to do it differently e.g. do the INNER JOIN first, then then LEFT JOINS.

```
SELECT p.Name AS ProductName, c.Name AS Category, oh.SalesOrderNumber
FROM SalesLT.Product AS p
LEFT OUTER JOIN SalesLT.SalesOrderDetail AS od
ON p.ProductID = od.ProductID
LEFT OUTER JOIN SalesLT.SalesOrderHeader AS oh
ON od.SalesOrderID = oh.SalesOrderID
INNER JOIN SalesLT.ProductCategory AS c --Added to the left, so can use inner join
ON p.ProductCategoryID = c.ProductCategoryID
ORDER BY p.ProductID;
```

**** Key Points****

- Use a Left Outer Join to include all rows from the first table and values from matched rows in the

Table 1.30: Displaying records 1 - 10

ProductName	Category	SalesOrderNumber
HL Road Frame - Black, 58	Road Frames	NA
HL Road Frame - Red, 58	Road Frames	NA
Sport-100 Helmet, Red	Helmets	SO71782
Sport-100 Helmet, Red	Helmets	SO71783
Sport-100 Helmet, Red	Helmets	SO71784
Sport-100 Helmet, Red	Helmets	SO71797
Sport-100 Helmet, Red	Helmets	SO71902
Sport-100 Helmet, Red	Helmets	SO71936
Sport-100 Helmet, Red	Helmets	SO71938
Sport-100 Helmet, Black	Helmets	SO71782

second table. Columns in the second table for which no matching rows exist are populated with NULLs.

- Use a Right Outer Join to include all rows from the second table and values from matched rows in the first table. Columns in the first table for which no matching rows exist are populated with NULLs.
- Use a Full Outer Join to include all rows from the first and second tables. Columns in the either table for which no matching rows exist are populated with NULLs.

1.3.3 Cross Joins

Cross Joins create caretesian products - they combine each row from the first table with each row from the second table - to give all possible combinations of products.

One example of it being used would be if we have a list of staff with their attributes, we might want to compare them to the attributes required for all jobs to see which they match, perhaps as an internal job search. Another example is if we have two list of addresses and we calculate the edit distance between the two addresses from the different sources, to try and match those addresses. We would rank the addresses based on their edit distance, with those scoring highest the closest and most likely to be the same address. It can be used to generate test data also.

An example

```
--Call each customer once per product - perhaps not the most realistic example!
SELECT p.Name, c.FirstName, c.LastName, c.Phone
FROM SalesLT.Product as p
CROSS JOIN SalesLT.Customer as c;
```

1.3.4 Self Joins

You might want to join data on to itself but in a different sequence. For instance, we might want to join a person's manager on to their employee(s), but managers are also employees, so this would be a self join. We would use aliases for the table names as we have the same table twice. So when defining a self-join, you must specify an alias for at least one instance of the table being joined.

So our original table looks like this:

```
SELECT *
FROM SalesLT.Employee;
```

Table 1.31: Displaying records 1 - 10

Name	FirstName	LastName	Phone
All-Purpose Bike Stand	Orlando	Gee	245-555-0173
All-Purpose Bike Stand	Keith	Harris	170-555-0127
All-Purpose Bike Stand	Donna	Carreras	279-555-0130
All-Purpose Bike Stand	Janet	Gates	710-555-0173
All-Purpose Bike Stand	Lucy	Harrington	828-555-0186
All-Purpose Bike Stand	Rosmarie	Carroll	244-555-0112
All-Purpose Bike Stand	Dominic	Gash	192-555-0173
All-Purpose Bike Stand	Kathleen	Garza	150-555-0127
All-Purpose Bike Stand	Katherine	Harding	926-555-0159
All-Purpose Bike Stand	Johnny	Caprio	112-555-0191

Table 1.32: 9 records

EmployeeID	EmployeeName	ManagerID
1	adventure-works\david8	8
2	adventure-works\garrett1	1
3	adventure-works\jae0	NA
4	adventure-works\jillian0	3
5	adventure-works\josé1	1
6	adventure-works\linda3	3
7	adventure-works\michael9	9
8	adventure-works\pamela0	3
9	adventure-works\shu0	3

Table 1.33: 9 records

EmployeeName	ManagerName
adventure-works\jae0	NA
adventure-works\garrett1	adventure-works\david8
adventure-works\josé1	adventure-works\david8
adventure-works\linda3	adventure-works\jae0
adventure-works\pamela0	adventure-works\jae0
adventure-works\shu0	adventure-works\jae0
adventure-works\jillian0	adventure-works\jae0
adventure-works\david8	adventure-works\pamela0
adventure-works\michael9	adventure-works\shu0

Table 1.34: Displaying records 1 - 10

CompanyName	SalesOrderId	TotalDue
Professional Sales and Service	71782	43962.7901
Remarkable Bike Store	71935	7330.8972
Bulk Discount Store	71938	98138.2131
Coalition Bike Company	71899	2669.3183
Futuristic Bikes	71895	272.6468
Channel Outlet	71885	608.1766
Aerobic Exercise Company	71915	2361.6403
Vigorous Sports Store	71867	1170.5376
Thrilling Bike Tours	71858	15275.1977
Extreme Riding Supplies	71796	63686.2708

Then the actual self join query - we use a left join as some people i.e. the CEO, will not have a manager.

```
SELECT e.EmployeeName, m.EmployeeName AS ManagerName
FROM SalesLT.Employee AS e
LEFT JOIN SalesLT.Employee AS m
ON e.ManagerID = m.EmployeeID
ORDER BY e.ManagerID;
```

1.3.5 Lab Exercises

Write a query that returns the company name from the SalesLT.Customer table, the sales order ID and total due from the SalesLT.SalesOrderHeader table.

```
-- select the CompanyName, SalesOrderId, and TotalDue columns from the appropriate tables
SELECT c.CompanyName, oh.SalesOrderId, oh.TotalDue
FROM SalesLT.Customer AS c
JOIN SalesLT.SalesOrderHeader AS oh
-- join tables based on CustomerID
ON c.CustomerID = oh.CustomerID;
```

In order to send out invoices to the customers, we need their addresses. Extend your customer orders query to include the main office address for each customer, including the full street address, city, state or province, postal code, and country or region.

Table 1.35: Displaying records 1 - 10

CompanyName	AddressLine1	AddressLine2	City	StateProvince	PostalCode
Good Toys	99700 Bell Road		Auburn	California	95603
West Side Mart	251 The Metro Center		Wokingham	England	RG41 1QV
Nearby Cycle Shop	Burgess Hill	Edward Way	West Sussex	England	RH15 9UD
Professional Sales and Service	57251 Serene Blvd		Van Nuys	California	91411
Eastside Department Store	9992 Whipple Rd		Union City	California	94587
Action Bicycle Specialists	Warrington Ldc Unit 25/2		Woolston	England	WA1 4SY
Extreme Riding Supplies	Riverside		Sherman Oaks	California	91403
Riding Cycles	Galashiels		Liverpool	England	L4 4HB
Thrifty Parts and Sales	Oxnard Outlet		Oxnard	California	93030
Engineered Bike Systems	123 Camelia Avenue		Oxnard	California	93030

```

SELECT c.CompanyName, a.AddressLine1, ISNULL(a.AddressLine2, '') AS AddressLine2, a.City, a.StateProvince
FROM SalesLT.Customer AS c
-- join the SalesOrderHeader table
JOIN SalesLT.SalesOrderHeader AS oh
ON oh.CustomerID = c.CustomerID
-- join the CustomerAddress table
JOIN SalesLT.CustomerAddress AS ca
-- filter for where the AddressType is 'Main Office'
ON c.CustomerID = ca.CustomerID AND AddressType = 'Main Office'
JOIN SalesLT.Address AS a
ON ca.AddressID = a.AddressID;

```

The sales manager wants a list of all customer companies and their contacts (first name and last name), showing the sales order ID and total due for each order they have placed. Customers who have not placed any orders should be included at the bottom of the list with NULL values for the order ID and total due.

```

-- select the CompanyName, FirstName, LastName, SalesOrderID and TotalDue columns
-- from the appropriate tables
SELECT c.CompanyName, c.FirstName, c.LastName, oh.SalesOrderID, oh.TotalDue
FROM SalesLT.Customer AS c
LEFT JOIN SalesLT.SalesOrderHeader AS oh
-- join based on CustomerID
ON oh.CustomerID = c.CustomerID
-- order the SalesOrderIDs from highest to lowest
ORDER BY oh.SalesOrderID DESC;

```

A sales employee has noticed that AdventureWorks does not have address information for all customers. Write a query that returns a list of customer IDs, company names, contact names (first name and last name), and phone numbers for customers with no address stored in the database.

```

SELECT c.CompanyName, c.FirstName, c.LastName, c.Phone
FROM SalesLT.Customer AS c
LEFT JOIN SalesLT.CustomerAddress AS ca
-- join based on CustomerID
ON c.CustomerID = ca.CustomerID
-- filter for when the AddressID doesn't exist
WHERE ca.AddressID IS NULL;

```

Some customers have never placed orders, and some products have never been ordered.

Table 1.36: Displaying records 1 - 10

CompanyName	FirstName	LastName	SalesOrderID	TotalDue
Central Bicycle Specialists	Janeth	Esteves	71946	43.0437
Bulk Discount Store	Christopher	Beck	71938	98138.2131
Metropolitan Bicycle Supply	Krishna	Sunkammurali	71936	108597.9536
Remarkable Bike Store	Cory	Booth	71935	7330.8972
The Bicycle Accessories Company	Guy	Gilbert	71923	117.7276
Discount Tours	Melissa	Marple	71920	3293.7761
Essential Bike Works	Linda	Mitchell	71917	45.1995
Aerobic Exercise Company	Rosmarie	Carroll	71915	2361.6403
Many Bikes Store	Jeffrey	Kurtz	71902	81834.9826
Coalition Bike Company	Donald	Blanton	71899	2669.3183

Table 1.37: Displaying records 1 - 10

CompanyName	FirstName	LastName	Phone
A Bike Store	Orlando	Gee	245-555-0173
Progressive Sports	Keith	Harris	170-555-0127
Advanced Bike Components	Donna	Carreras	279-555-0130
Modular Cycle Systems	Janet	Gates	710-555-0173
Metropolitan Sports Supply	Lucy	Harrington	828-555-0186
Aerobic Exercise Company	Rosmarie	Carroll	244-555-0112
Associated Bikes	Dominic	Gash	192-555-0173
Rural Cycle Emporium	Kathleen	Garza	150-555-0127
Sharp Bikes	Katherine	Harding	926-555-0159
Bikes and Motorbikes	Johnny	Caprio	112-555-0191

Table 1.38: Displaying records 1 - 10

CustomerID	ProductID
1	NA
2	NA
3	NA
4	NA
5	NA
6	NA
7	NA
10	NA
11	NA
12	NA

Write a query that returns a column of customer IDs for customers who have never placed an order, and a column of product IDs for products that have never been ordered.

Each row with a customer ID should have a NULL product ID (because the customer has never ordered a product) and each row with a product ID should have a NULL customer ID (because the product has never been ordered by a customer).

```
SELECT c.CustomerID, p.ProductID
FROM SalesLT.Customer AS c
FULL JOIN SalesLT.SalesOrderHeader AS oh
ON c.CustomerID = oh.CustomerID
FULL JOIN SalesLT.SalesOrderDetail AS od
-- join based on the SalesOrderID
ON od.SalesOrderID = oh.SalesOrderID
FULL JOIN SalesLT.Product AS p
-- join based on the ProductID
ON p.ProductID = od.ProductID
-- filter for nonexistent SalesOrderIDs
WHERE oh.SalesOrderID IS NULL
ORDER BY ProductID, CustomerID;
```

1.4 Using Set Operators

A union query is unlike a join, where as a join adds more columns, a union typically adds more rows. You put all records from one query on to the records at the end of another query. NOTE that it is a list of distinct (non duplicate) records - this will be checked every single row in one table and then checks if that record exists across every single row in the other table. Obviously as more tables are added, checking this can become more time consuming and affects performance.

UNION ALL will not undertake this checking, leading to more performance, but some duplicates. John Smith may appear in the employees table but he may also appear in the customers table. Sometimes this is the desired result. In such an instance it makes sense to add a new field using an alias at the time of the query, such as record type, so we know where this record occurs.

When using Union:

- It is a good idea to use column aliases, so we know which table the column occurs in. However, only aliases in the first query are recognised, so any aliases should be set against the first table

Table 1.39: Displaying records 1 - 10

FirstName	LastName
Catherine	Abel
Kim	Abercrombie
Frances	Adams
Jay	Adams
Samuel	Agcaoili
Robert	Ahlering
Stanley	Alan
Amy	Alberts
Paul	Alcorn
Gregory	Alderson

Table 1.40: Displaying records 1 - 10

FirstName	LastName
Catherine	Abel
Kim	Abercrombie
Frances	Adams
Jay	Adams
Samuel	Agcaoili
Robert	Ahlering
Stanley	Alan
Amy	Alberts
Paul	Alcorn
Gregory	Alderson

- The number of columns must be the same across tables, you can add an additional column but this must be given a specific value or a NULL
- The data types must be approximately similar i.e. we can do an implicit or explicit conversion so they match.

The following example joins the Employees to the customer using Union i.e. removing duplicates.

NOTE: In the following example, views were created (using code provided in the course), before running the queries on the database. Therefore to reproduce these results, it is necessary to run that same code (Module 4, Union sql file, in the CourseFiles zip) before the following queries will run on the AdventureWorksLT db.

```
SELECT FirstName, LastName
FROM SalesLT.Employees
UNION
SELECT FirstName, LastName
FROM SalesLT.Customers
ORDER BY LastName;
```

This gives 440 rows, if however we use UNION ALL

```
SELECT FirstName, LastName
FROM SalesLT.Employees
UNION ALL
SELECT FirstName, LastName
FROM SalesLT.Customers
ORDER BY LastName;
```


Table 1.41: 5 records

FirstName	LastName	Type
Andy	Carothers	Employee
Donna	Carreras	Customer
Donna	Carreras	Employee
Rosmarie	Carroll	Employee
Joseph	Castellucio	Employee

Table 1.42: 1 records

FirstName	LastName
Donna	Carreras

This results in 441 rows, so there is 1 row which occurs in both - a Donna Carreras appears both in the customer and employee table. This could be the same person or indeed just someone with the same name.

It might be useful to know which table the record occurs in, which is where we can introduce a Type column. Not that after the first alias AS Type, subsequent fields e.g. 'Customer' as shown below do not need to be explicitly aliased, however it can make it easier to understand if we do include the AS Type.

```
SELECT FirstName, LastName, 'Employee' AS Type
FROM SalesLT.Employees
UNION
SELECT FirstName, LastName, 'Customer' AS Type
FROM SalesLT.Customers
ORDER BY LastName
OFFSET 100 ROWS FETCH NEXT 5 ROWS ONLY;
```

Note that even though we have used UNION rather than UNION ALL, this would result in the same number of rows as UNION ALL (441), because the presence of the type column means this is no longer the same person - it is not a duplicate record but a unique one. However, it is worth using UNION ALL to limit the number of records that have to be checked for duplicates, so improving performance.

By default, UNION eliminates duplicate rows. Specify the ALL option to include duplicates (or to avoid the overhead of checking for duplicates when you know in advance that there are none).

1.4.1 INTERSECT and EXCEPT Queries

In INTERSECT we look at only rows that appear in each set - we are looking for the duplicates. Whereas using a JOIN would append columns to the source table, in set theory, we are looking for rows, so in an INTERSECT we are looking for those rows that appear in both datasets.

IN EXCEPT we are looking for records that appear in one source but not the other. In such a scenario, the order of the tables matters.

If we now try and identify the person who appears in both our datasets, we can identify the person directly.

```
SELECT FirstName, LastName
FROM SalesLT.Customers
INTERSECT
SELECT FirstName, LastName
FROM SalesLT.Employees;
```

Table 1.43: Displaying records 1 - 10

FirstName	LastName
Abraham	Swearengin
Ajay	Manchepalli
Alan	Steiner
Alice	Steiner
Andrea	Thomsen
Ben	Miller
Billy	Trent
Brad	Sutton
Caroline	Vicknair
Cecelia	Marshall

Next we want to find the EXCEPT - so let's find customers who are not employees, so we don't try and sell products to employees. There are 104 customers, so we should get 103 rows, as we remove Donna Carreras.

```
SELECT FirstName, LastName
FROM SalesLT.Customers
EXCEPT
SELECT FirstName, LastName
FROM SalesLT.Employees;
```

1.4.2 Lab Exercises

Customers can have two kinds of address: a main office address and a shipping address. The accounts department wants to ensure that the main office address is always used for billing, and have asked you to write a query that clearly identifies the different types of address for each customer.

```
-- select the CompanyName, AddressLine1 columns
-- alias as per the instructions
SELECT CompanyName, AddressLine1, City, 'Billing' AS AddressType
FROM SalesLT.Customer AS c
JOIN SalesLT.CustomerAddress AS ca
-- join based on CustomerID
ON c.CustomerID = ca.CustomerID
-- join another table
JOIN SalesLT.Address AS a
-- join based on AddressID
ON ca.AddressID = a.AddressID
-- filter for where the correct AddressType
WHERE ca.AddressType = 'Main Office';
```

Adapt the query to retrieve the company name, first line of the street address, city, and a column named AddressType with the value 'Shipping' for customers where the address type in the SalesLT.CustomerAddress table is 'Shipping'.

```
SELECT c.CompanyName, a.AddressLine1, a.City, 'Shipping' AS AddressType
FROM SalesLT.Customer AS c
JOIN SalesLT.CustomerAddress AS ca
ON c.CustomerID = ca.CustomerID
JOIN SalesLT.Address AS a
ON ca.AddressID = a.AddressID
```

Table 1.44: Displaying records 1 - 10

CompanyName	AddressLine1	City	AddressType
Professional Sales and Service	57251 Serene Blvd	Van Nuys	Billing
Riders Company	Tanger Factory	Branch	Billing
Area Bike Accessories	6900 Sisk Road	Modesto	Billing
Bicycle Accessories and Kits	Lewiston Mall	Lewiston	Billing
Valley Bicycle Specialists	Blue Ridge Mall	Kansas City	Billing
Vinyl and Plastic Goods Corporation	No. 25800-130 King Street West	Toronto	Billing
Fun Toys and Bikes	6500 East Grant Road	Tucson	Billing
Great Bikes	Eastridge Mall	Casper	Billing
Valley Toy Store	252851 Rowan Place	Richmond	Billing
Major Sport Suppliers	White Mountain Mall	Rock Springs	Billing

Table 1.45: Displaying records 1 - 10

CompanyName	AddressLine1	City	AddressType
Family's Favorite Bike Shop	26910 Indela Road	Montreal	Shipping
Center Cycle Shop	1318 Lasalle Street	Bothell	Shipping
Safe Cycles Shop	2681 Eagle Peak	Bellevue	Shipping
Modular Cycle Systems	165 North Main	Austin	Shipping
Progressive Sports	7943 Walnut Ave	Renton	Shipping
Hardware Components	99 Front Street	Minneapolis	Shipping
Sample Bike Store	2000 300th Street	Denver	Shipping
Racing Toys	9228 Via Del Sol	Phoenix	Shipping
Elite Bikes	9178 Jumping St.	Dallas	Shipping
All Cycle Shop	8713 Yosemite Ct.	Bothell	Shipping

```
WHERE ca.AddressType = 'Shipping';
```

Next we can union all these records together to create a list of shipping and billing addresses, using UNION ALL.

```
SELECT c.CompanyName, a.AddressLine1, a.City, 'Billing' AS AddressType
FROM SalesLT.Customer AS c
JOIN SalesLT.CustomerAddress AS ca
ON c.CustomerID = ca.CustomerID
JOIN SalesLT.Address AS a
ON ca.AddressID = a.AddressID
WHERE ca.AddressType = 'Main Office'
-- UNION
UNION ALL
SELECT c.CompanyName, a.AddressLine1, a.City, 'Shipping' AS AddressType
FROM SalesLT.Customer AS c
JOIN SalesLT.CustomerAddress AS ca
ON c.CustomerID = ca.CustomerID
JOIN SalesLT.Address AS a
ON ca.AddressID = a.AddressID
WHERE ca.AddressType = 'Shipping'
ORDER BY c.CompanyName
OFFSET 10 ROWS;
```

Table 1.46: Displaying records 1 - 10

CompanyName	AddressLine1	City	AddressType
All Cycle Shop	8713 Yosemite Ct.	Bothell	Shipping
All Cycle Shop	25111 228th St Sw	Bothell	Billing
All Seasons Sports Supply	Ohms Road	Houston	Billing
Alpine Ski House	7505 Laguna Boulevard	Elk Grove	Billing
Alternative Vehicles	3307 Evergreen Blvd	Washougal	Billing
Another Bicycle Company	567 Sw McLoughlin Blvd	Milwaukie	Billing
Area Bike Accessories	6900 Sisk Road	Modesto	Billing
Area Sheet Metal Supply	399 Clearing Green	London	Billing
Associated Bikes	5420 West 22500 South	Salt Lake City	Billing
Authentic Sales and Service	99 Dean Street, Soho	London	Billing

Table 1.47: Displaying records 1 - 10

CompanyName
A Bike Store
A Great Bicycle Company
A Typical Bike Shop
Acceptable Sales & Service
Action Bicycle Specialists
Active Life Toys
Active Systems
Advanced Bike Components
Aerobic Exercise Company
Affordable Sports Equipment

You have created a master list of all customer addresses, but now you have been asked to create filtered lists that show which customers have only a main office address, and which customers have both a main office and a shipping address.

```

SELECT c.CompanyName
FROM SalesLT.Customer AS c
INNER JOIN SalesLT.CustomerAddress AS ca
ON c.CustomerID = ca.CustomerID
INNER JOIN SalesLT.Address AS a
ON a.AddressID = ca.AddressID
WHERE ca.AddressType = 'Main Office' --Filters out shipping addresses. This is a table of all Billing
EXCEPT
SELECT c.CompanyName
FROM SalesLT.Customer AS c
INNER JOIN SalesLT.CustomerAddress AS ca
ON c.CustomerID = ca.CustomerID
INNER JOIN SalesLT.Address AS a
ON a.AddressID = ca.AddressID
WHERE ca.AddressType = 'Shipping'
ORDER BY c.CompanyName;

```

Or the INTERSECT version to identify the company name of each company that appears in a table of customers with a 'Main Office' address, and also in a table of customers with a 'Shipping' address.

Table 1.48: Displaying records 1 - 10

CompanyName
All Cycle Shop
Center Cycle Shop
Elite Bikes
Family's Favorite Bike Shop
Hardware Components
Modular Cycle Systems
Progressive Sports
Racing Toys
Safe Cycles Shop
Sample Bike Store

```

SELECT c.CompanyName
FROM SalesLT.Customer AS c
INNER JOIN SalesLT.CustomerAddress AS ca
ON c.CustomerID = ca.CustomerID
INNER JOIN SalesLT.Address AS a
ON a.AddressID = ca.AddressID
WHERE ca.AddressType = 'Main Office' --Filters out shipping addresses. This is a table of all Billing
INTERSECT
SELECT c.CompanyName
FROM SalesLT.Customer AS c
INNER JOIN SalesLT.CustomerAddress AS ca
ON c.CustomerID = ca.CustomerID
INNER JOIN SalesLT.Address AS a
ON a.AddressID = ca.AddressID
WHERE ca.AddressType = 'Shipping'
ORDER BY c.CompanyName;

```

1.5 Using Functions and Aggregating Data

Now we are looking to not just bring back individual rows but perform calculations, such as aggregations, on those results.

The functions we will look at are shown below.

1.5.1 Scalar Functions

A scalar function returns a single value, not a row or column or table. In database design things can be deterministic or non-deterministic

- Deterministic - we know what the result will be, assuming the data hasn't changed. The data going in and coming out will be the same
- Non-deterministic - we cannot guarantee what the result will be. For instance if we tested if today's date was less than a value in a table, it would depend on the time and day that the query was run. We can't say what the result will be, based on the data going in/from the db.

A scalar function can be either deterministic or non-deterministic. Scalar is a set of functions, and can do multiple things - date and times, text and image, mathematical, system and system statistical, metadata

Function Category	Description
Scalar	Operate on a single row,
Logical	Scalar functions that com single output
Aggregate	Take one or more input v value
Window	Operate on a window (se
Rowset	Return a virtual table tha Transact-SQL statement

Figure 1.2: Transact-SQL Functions

Table 1.49: Displaying records 1 - 10

SellStartYear	ProductID	Name
2002	680	HL Road Frame - Black, 58
2002	706	HL Road Frame - Red, 58
2005	707	Sport-100 Helmet, Red
2005	708	Sport-100 Helmet, Black
2005	709	Mountain Bike Socks, M
2005	710	Mountain Bike Socks, L
2005	711	Sport-100 Helmet, Blue
2005	712	AWC Logo Cap
2005	713	Long-Sleeve Logo Jersey, S
2005	714	Long-Sleeve Logo Jersey, M

Table 1.50: Displaying records 1 - 10

SellStartYear	SellStartMonth	SellStartDay	SellStartWeekday	ProductID	Name
2002	June	1	Saturday	680	HL Road Frame - Black, 58
2002	June	1	Saturday	706	HL Road Frame - Red, 58
2005	July	1	Friday	707	Sport-100 Helmet, Red
2005	July	1	Friday	708	Sport-100 Helmet, Black
2005	July	1	Friday	709	Mountain Bike Socks, M
2005	July	1	Friday	710	Mountain Bike Socks, L
2005	July	1	Friday	711	Sport-100 Helmet, Blue
2005	July	1	Friday	712	AWC Logo Cap
2005	July	1	Friday	713	Long-Sleeve Logo Jersey, S
2005	July	1	Friday	714	Long-Sleeve Logo Jersey, M

and so on.

We might want to extract the year from a date, for instance to determine when a product was first sold.

```
SELECT YEAR(SellStartDate) SellStartYear, ProductID, Name
FROM SalesLT.Product
ORDER BY SellStartYear;
```

Other examples might include being able to extract certain parts of the date, like the month or day of the week, this can be achieved with the DATENAME function

```
SELECT YEAR(SellStartDate) SellStartYear, DATENAME(mm,SellStartDate) SellStartMonth,
       DAY(SellStartDate) SellStartDay, DATENAME(dw, SellStartDate) SellStartWeekday,
       ProductID, Name
FROM SalesLT.Product
ORDER BY SellStartYear;
```

Or we might want to calculate how long a product has been sold, we can use the DATEDIFF function to work this out.

```
SELECT DATEDIFF(yy,SellStartDate, GETDATE()) YearsSold,
       DATEDIFF(mm,SellStartDate, GETDATE()) MonthsSold,
       ProductID, Name
FROM SalesLT.Product
ORDER BY ProductID;
```

Another common example might be to convert text to upper case.

Table 1.51: Displaying records 1 - 10

YearsSold	MonthsSold	ProductID	Name
16	189	680	HL Road Frame - Black, 58
16	189	706	HL Road Frame - Red, 58
13	152	707	Sport-100 Helmet, Red
13	152	708	Sport-100 Helmet, Black
13	152	709	Mountain Bike Socks, M
13	152	710	Mountain Bike Socks, L
13	152	711	Sport-100 Helmet, Blue
13	152	712	AWC Logo Cap
13	152	713	Long-Sleeve Logo Jersey, S
13	152	714	Long-Sleeve Logo Jersey, M

Table 1.52: Displaying records 1 - 10

ProductName
ALL-PURPOSE BIKE STAND
AWC LOGO CAP
BIKE WASH - DISSOLVER
CABLE LOCK
CHAIN
CLASSIC VEST, L
CLASSIC VEST, M
CLASSIC VEST, S
FENDER SET - MOUNTAIN
FRONT BRAKES

```
SELECT UPPER(Name) AS ProductName
FROM SalesLT.Product;
```

We might want to add two strings together but with a space or other text, so we could use the CONCAT function to achieve this.

```
SELECT CONCAT(FirstName + ' ', LastName) AS FullName,
       FirstName, LastName
FROM SalesLT.Customer;
```

Or we might want to return just a specific number of characters from a string, perhaps there is a structure in the sequence - like the first two chars relate to a product type - so we want to just extract these first two.

```
SELECT Name, ProductNumber, LEFT(ProductNumber, 2) AS ProductType
FROM SalesLT.Product;
```

Or we might have something more complex, where we want to find certain elements of text, we can use CHARINDEX to identify where a char occurs, then combine it with SUBSTRING to extract just a portion of the full string which is n chars before or after a particular character.

```
SELECT Name, ProductNumber, LEFT(ProductNumber, 2) AS ProductType,
       SUBSTRING(ProductNumber, CHARINDEX('-', ProductNumber) + 1, 4) AS ModelCode,
       SUBSTRING(ProductNumber, LEN(ProductNumber) - CHARINDEX('-', ProductNumber), 4) AS Size
FROM SalesLT.Product;
```


Table 1.53: Displaying records 1 - 10

FullName	FirstName	LastName
Orlando Gee	Orlando	Gee
Keith Harris	Keith	Harris
Donna Carreras	Donna	Carreras
Janet Gates	Janet	Gates
Lucy Harrington	Lucy	Harrington
Rosmarie Carroll	Rosmarie	Carroll
Dominic Gash	Dominic	Gash
Kathleen Garza	Kathleen	Garza
Katherine Harding	Katherine	Harding
Johnny Caprio	Johnny	Caprio

Table 1.54: Displaying records 1 - 10

Name	ProductNumber	ProductType
HL Road Frame - Black, 58	FR-R92B-58	FR
HL Road Frame - Red, 58	FR-R92R-58	FR
Sport-100 Helmet, Red	HL-U509-R	HL
Sport-100 Helmet, Black	HL-U509	HL
Mountain Bike Socks, M	SO-B909-M	SO
Mountain Bike Socks, L	SO-B909-L	SO
Sport-100 Helmet, Blue	HL-U509-B	HL
AWC Logo Cap	CA-1098	CA
Long-Sleeve Logo Jersey, S	LJ-0192-S	LJ
Long-Sleeve Logo Jersey, M	LJ-0192-M	LJ

Table 1.55: Displaying records 1 - 10

Name	ProductNumber	ProductType	ModelCode	SizeCode
HL Road Frame - Black, 58	FR-R92B-58	FR	R92B	58
HL Road Frame - Red, 58	FR-R92R-58	FR	R92R	58
Sport-100 Helmet, Red	HL-U509-R	HL	U509	R
Sport-100 Helmet, Black	HL-U509	HL	U509	
Mountain Bike Socks, M	SO-B909-M	SO	B909	M
Mountain Bike Socks, L	SO-B909-L	SO	B909	L
Sport-100 Helmet, Blue	HL-U509-B	HL	U509	B
AWC Logo Cap	CA-1098	CA	1098	
Long-Sleeve Logo Jersey, S	LJ-0192-S	LJ	0192	S
Long-Sleeve Logo Jersey, M	LJ-0192-M	LJ	0192	M

Table 1.56: Displaying records 1 - 10

Name	Size
HL Road Frame - Black, 58	58
HL Road Frame - Red, 58	58
Sport-100 Helmet, Red	NA
Sport-100 Helmet, Black	NA
Mountain Bike Socks, M	M
Mountain Bike Socks, L	L
Sport-100 Helmet, Blue	NA
AWC Logo Cap	NA
Long-Sleeve Logo Jersey, S	S
Long-Sleeve Logo Jersey, M	M

Table 1.57: Displaying records 1 - 10

Name	NumericSize
HL Road Frame - Black, 58	58
HL Road Frame - Red, 58	58
HL Road Frame - Red, 62	62
HL Road Frame - Red, 44	44
HL Road Frame - Red, 48	48
HL Road Frame - Red, 52	52
HL Road Frame - Red, 56	56
LL Road Frame - Black, 58	58
LL Road Frame - Black, 60	60
LL Road Frame - Black, 62	62

1.5.2 Logical Functions

Logical functions test if something is true or not i.e. traditional boolean. But we can use logical functions as filters by using CHOOSE for example, you could use IIF which is also a logical, or we could use CASE to achieve the same result.

An example might be if we want to return some numeric sizes, for instance if we have a table of data with different size formats:

```
SELECT Name, Size
FROM SalesLT.Product;
```

We might only be interested in those that have a numeric type, even though the data is in a char data string, 1 in this instance means true:

```
SELECT Name, Size AS NumericSize
FROM SalesLT.Product
WHERE ISNUMERIC(Size) = 1;
```

Or we might want to assign a value to something, like a product type of bike to certain values and other to everything else.

```
SELECT Name, IIF(ProductCategoryID IN (5,6,7), 'Bike', 'Other') AS ProductType
FROM SalesLT.Product;
```

Or a more complicated query where we assign multiple product types.

Table 1.58: Displaying records 1 - 10

Name	ProductType
HL Road Frame - Black, 58	Other
HL Road Frame - Red, 58	Other
Sport-100 Helmet, Red	Other
Sport-100 Helmet, Black	Other
Mountain Bike Socks, M	Other
Mountain Bike Socks, L	Other
Sport-100 Helmet, Blue	Other
AWC Logo Cap	Other
Long-Sleeve Logo Jersey, S	Other
Long-Sleeve Logo Jersey, M	Other

Table 1.59: Displaying records 1 - 10

ProductName	Category	ProductType
Mountain-100 Silver, 38	Mountain Bikes	Bikes
Mountain-100 Silver, 42	Mountain Bikes	Bikes
Mountain-100 Silver, 44	Mountain Bikes	Bikes
Mountain-100 Silver, 48	Mountain Bikes	Bikes
Mountain-100 Black, 38	Mountain Bikes	Bikes
Mountain-100 Black, 42	Mountain Bikes	Bikes
Mountain-100 Black, 44	Mountain Bikes	Bikes
Mountain-100 Black, 48	Mountain Bikes	Bikes
Mountain-200 Silver, 38	Mountain Bikes	Bikes
Mountain-200 Silver, 42	Mountain Bikes	Bikes

```

SELECT prd.Name AS ProductName, cat.Name AS Category,
       CHOOSE (cat.ParentProductCategoryID, 'Bikes', 'Components', 'Clothing', 'Accessories') AS ProductType
FROM SalesLT.Product AS prd
JOIN SalesLT.ProductCategory AS cat
ON prd.ProductCategoryID = cat.ProductCategoryID;

```

1.5.3 Window Functions

A window in this context is a set of rows - a window in to the database or table. For instance, we might want to RANK a set (or window) of data. The query below will pull out the top 100 more expensive products (ordered by list price) then creates a ranking based on this list price, then orders the results by this ranking.

```

SELECT TOP(100) ProductID, Name, ListPrice,
       RANK() OVER(ORDER BY ListPrice DESC) AS RankByPrice
FROM SalesLT.Product AS p
ORDER BY RankByPrice;

```

Or we might want to partition the results by product category, similar to grouping by product category. This will result in a ranking for each product category. The results might look a little odd at first glance.

```

SELECT c.Name AS Category, p.Name AS Product, ListPrice,
       RANK() OVER(PARTITION BY c.Name ORDER BY ListPrice DESC) AS RankByPrice
FROM SalesLT.Product AS p

```

Table 1.60: Displaying records 1 - 10

ProductID	Name	ListPrice	RankByPrice
749	Road-150 Red, 62	3578.27	1
750	Road-150 Red, 44	3578.27	1
751	Road-150 Red, 48	3578.27	1
752	Road-150 Red, 52	3578.27	1
753	Road-150 Red, 56	3578.27	1
771	Mountain-100 Silver, 38	3399.99	6
772	Mountain-100 Silver, 42	3399.99	6
773	Mountain-100 Silver, 44	3399.99	6
774	Mountain-100 Silver, 48	3399.99	6
775	Mountain-100 Black, 38	3374.99	10

Table 1.61: Displaying records 1 - 10

Category	Product	ListPrice	RankByPrice
Bib-Shorts	Men's Bib-Shorts, S	89.99	1
Bib-Shorts	Men's Bib-Shorts, M	89.99	1
Bib-Shorts	Men's Bib-Shorts, L	89.99	1
Bike Racks	Hitch Rack - 4-Bike	120.00	1
Bike Stands	All-Purpose Bike Stand	159.00	1
Bottles and Cages	Mountain Bottle Cage	9.99	1
Bottles and Cages	Road Bottle Cage	8.99	2
Bottles and Cages	Water Bottle - 30 oz.	4.99	3
Bottom Brackets	HL Bottom Bracket	121.49	1
Bottom Brackets	ML Bottom Bracket	101.24	2

```
JOIN SalesLT.ProductCategory AS c
ON p.ProductCategoryID = c.ProductcategoryID
ORDER BY Category, RankByPrice;
```

1.5.4 Aggregate Functions

There are a lot of aggregate functions including some statistical functions like s.d. as well as some more standard things like MIN, MAX, SUM etc over a set of data. We can use GROUP BY.

First we can get some headline stats of what is in the table.

```
SELECT COUNT(*) AS Products, COUNT(DISTINCT ProductCategoryID) AS Categories, AVG(ListPrice) AS AveragePrice
FROM SalesLT.Product;
```

Or we might be interested in summary figures for just one product type, like bikes. Note that we use COUNT then the specific item, since using COUNT(*) would return the number of rows, which may include duplicates.

Table 1.62: 1 records

Products	Categories	AveragePrice
296	37	742.1235

Table 1.63: 1 records

BikeModels	AveragePrice
97	1586.737

Table 1.64: 3 records

Salesperson	SalesRevenue
adventure-works\jae0	518096.4
adventure-works\linda3	209219.8
adventure-works\shu0	138116.9

```
SELECT COUNT(p.ProductID) BikeModels, AVG(p.ListPrice) AveragePrice
FROM SalesLT.Product AS p
JOIN SalesLT.ProductCategory AS c
ON p.ProductCategoryID = c.ProductCategoryID
WHERE c.Name LIKE '%Bikes';
```

However, our aggregate functions are currently returnign totals. In practice, we may want to return figures by groups, so we need to use GROUP BY in our queries. When we use a GROUP BY which groups up the results, we have to group up everything in the select row that isn't being aggregated. You can't have something in the SELECT which is neither being aggregated nor being grouped. As we are grouping the results, we don't see individual rows of data anymore.

The following example calculates the sales revenue for each sales person.

```
SELECT c.Salesperson, SUM(oh.SubTotal) SalesRevenue
FROM SalesLT.Customer c
JOIN SalesLT.SalesOrderHeader oh
ON c.CustomerID = oh.CustomerID
GROUP BY c.Salesperson
ORDER BY SalesRevenue DESC;
```

Could it be that some sales people have no sales? If so, we need to return values where the total is NULL, by assigning NULL a value of zero. WE also use the LEFT JOIN rather than the INNER JOIN previously, we get sales people included who haven't sold anything.

```
SELECT c.Salesperson, ISNULL(SUM(oh.SubTotal), 0.00) SalesRevenue
FROM SalesLT.Customer c
LEFT JOIN SalesLT.SalesOrderHeader oh
ON c.CustomerID = oh.CustomerID
GROUP BY c.Salesperson
ORDER BY SalesRevenue DESC;
```

Or we might want to know the number of customers each sales person has.

```
SELECT Salesperson, COUNT(CustomerID) Customers
FROM SalesLT.Customer
GROUP BY Salesperson
ORDER BY Salesperson;
```

We might also want to know the sales Revenue by sales person and customer. Note that we now includer the customer details, we cannot use the CUSTOMER alias from the SELECT query in the GROUP BY, as the SELECT query is run after the GROUP BY.

Table 1.65: 9 records

Salesperson	SalesRevenue
adventure-works\jae0	518096.4
adventure-works\linda3	209219.8
adventure-works\shu0	138116.9
adventure-works\michael9	0.0
adventure-works\pamela0	0.0
adventure-works\jillian0	0.0
adventure-works\josé1	0.0
adventure-works\david8	0.0
adventure-works\garrett1	0.0

Table 1.66: 9 records

Salesperson	Customers
adventure-works\david8	73
adventure-works\garrett1	78
adventure-works\jae0	78
adventure-works\jillian0	148
adventure-works\josé1	142
adventure-works\linda3	71
adventure-works\michael9	32
adventure-works\pamela0	74
adventure-works\shu0	151

```

SELECT c.Salesperson, CONCAT(c.FirstName + ' ', c.LastName) AS Customer, ISNULL(SUM(oh.SubTotal), 0.00)
FROM SalesLT.Customer c
LEFT JOIN SalesLT.SalesOrderHeader oh
ON c.CustomerID = oh.CustomerID
GROUP BY c.Salesperson, CONCAT(c.FirstName + ' ', c.LastName)
ORDER BY SalesRevenue DESC, Customer;

```

Or the number of products in each category.

```

SELECT c.Name AS Category, COUNT(p.ProductID) AS Products
FROM SalesLT.Product AS p
JOIN SalesLT.ProductCategory AS c
ON p.ProductCategoryID = c.ProductCategoryID
GROUP BY c.Name
ORDER BY Category;

```

1.5.5 Filtering Groups

If we want to filter, we can use the WHERE clause as we have seen in some previous examples. However, most of the time we filter with the HAVING clause. **HAVING will filter the results RATHER than the input.**

Having clause provides a search condition that each group must satisfy, for instance where the number of orders by a customer is greater than 10.

In the example below, we are interested in finding out which sales people have more than 100 customers.

Table 1.67: Displaying records 1 - 10

Salesperson	Customer	SalesRevenue
adventure-works\jae0	Terry Eminhizer	108561.83
adventure-works\jae0	Krishna Sunkammurali	98278.69
adventure-works\jae0	Christopher Beck	88812.86
adventure-works\linda3	Kevin Liu	83858.43
adventure-works\jae0	Jon Grande	78029.69
adventure-works\shu0	Jeffrey Kurtz	74058.81
adventure-works\jae0	Rebecca Laszlo	63980.99
adventure-works\linda3	Anthony Chor	57634.63
adventure-works\shu0	Frank Campbell	41622.05
adventure-works\linda3	Catherine Abel	39785.33

Table 1.68: Displaying records 1 - 10

Category	Products
Bib-Shorts	3
Bike Racks	1
Bike Stands	1
Bottles and Cages	3
Bottom Brackets	3
Brakes	2
Caps	1
Chains	1
Cleaners	1
Cranksets	3

Table 1.69: 3 records

Salesperson	Customers
adventure-works\jillian0	148
adventure-works\josé1	142
adventure-works\shu0	151

Table 1.70: Displaying records 1 - 10

ProductID	ProductName	ApproxWeight
680	HL ROAD FRAME - BLACK, 58	1016
706	HL ROAD FRAME - RED, 58	1016
707	SPORT-100 HELMET, RED	NA
708	SPORT-100 HELMET, BLACK	NA
709	MOUNTAIN BIKE SOCKS, M	NA
710	MOUNTAIN BIKE SOCKS, L	NA
711	SPORT-100 HELMET, BLUE	NA
712	AWC LOGO CAP	NA
713	LONG-SLEEVE LOGO JERSEY, S	NA
714	LONG-SLEEVE LOGO JERSEY, M	NA

```
SELECT Salesperson, COUNT(CustomerID) Customers
FROM SalesLT.Customer
GROUP BY Salesperson
HAVING COUNT(CustomerID) > 100
ORDER BY Salesperson;
```

** Key Points **

- You can use GROUP BY with aggregate functions to return aggregations grouped by one or more columns or expressions.
- All columns in the SELECT clause that are not aggregate function expressions must be included in a GROUP BY clause.
- The order in which columns or expressions are listed in the GROUP BY clause determines the grouping hierarchy.
- You can filter the groups that are included in the query results by specifying a HAVING clause.

1.5.6 Lab Exercises

Write a query to return the product ID of each product, together with the product name formatted as upper case and a column named ApproxWeight with the weight of each product rounded to the nearest whole unit.

```
SELECT ProductID, UPPER(Name) AS ProductName, ROUND(WEIGHT, 0) AS ApproxWeight
FROM SalesLT.Product;
```

Extend your query to include columns named SellStartYear and SellStartMonth containing the year and month in which AdventureWorks started selling each product. The month should be displayed as the month name (e.g. 'January').

Table 1.71: Displaying records 1 - 10

ProductID	ProductName	ApproxWeight	SellStartYear	SellStartMonth
680	HL ROAD FRAME - BLACK, 58	1016	2002	June
706	HL ROAD FRAME - RED, 58	1016	2002	June
707	SPORT-100 HELMET, RED	NA	2005	July
708	SPORT-100 HELMET, BLACK	NA	2005	July
709	MOUNTAIN BIKE SOCKS, M	NA	2005	July
710	MOUNTAIN BIKE SOCKS, L	NA	2005	July
711	SPORT-100 HELMET, BLUE	NA	2005	July
712	AWC LOGO CAP	NA	2005	July
713	LONG-SLEEVE LOGO JERSEY, S	NA	2005	July
714	LONG-SLEEVE LOGO JERSEY, M	NA	2005	July

Table 1.72: Displaying records 1 - 10

ProductID	ProductName	ApproxWeight	SellStartYear	SellStartMonth	ProductType
680	HL ROAD FRAME - BLACK, 58	1016	2002	June	FR
706	HL ROAD FRAME - RED, 58	1016	2002	June	FR
707	SPORT-100 HELMET, RED	NA	2005	July	HL
708	SPORT-100 HELMET, BLACK	NA	2005	July	HL
709	MOUNTAIN BIKE SOCKS, M	NA	2005	July	SO
710	MOUNTAIN BIKE SOCKS, L	NA	2005	July	SO
711	SPORT-100 HELMET, BLUE	NA	2005	July	HL
712	AWC LOGO CAP	NA	2005	July	CA
713	LONG-SLEEVE LOGO JERSEY, S	NA	2005	July	LJ
714	LONG-SLEEVE LOGO JERSEY, M	NA	2005	July	LJ

```
SELECT ProductID, UPPER(Name) AS ProductName, ROUND(Weight, 0) AS ApproxWeight,
       YEAR(SellStartDate) as SellStartYear,
       DATENAME(m, SellStartDate) as SellStartMonth
FROM SalesLT.Product;
```

Extend your query to include a column named ProductType that contains the leftmost two characters from the product number.

```
SELECT ProductID, UPPER(Name) AS ProductName, ROUND(Weight, 0) AS ApproxWeight,
       YEAR(SellStartDate) as SellStartYear,
       DATENAME(m, SellStartDate) as SellStartMonth,
       LEFT(ProductNumber, 2) AS ProductType
FROM SalesLT.Product;
```

Extend your query to filter the product returned so that only products with a numeric size are included.

```
SELECT ProductID, UPPER(Name) AS ProductName, ROUND(Weight, 0) AS ApproxWeight,
       YEAR(SellStartDate) as SellStartYear,
       DATENAME(m, SellStartDate) as SellStartMonth,
       LEFT(ProductNumber, 2) AS ProductType
FROM SalesLT.Product
WHERE ISNUMERIC(SIZE) = 1;
```

Write a query that returns a list of company names with a ranking of their place in a list of highest TotalDue values from the SalesOrderHeader table.

Table 1.73: Displaying records 1 - 10

ProductID	ProductName	ApproxWeight	SellStartYear	SellStartMonth	ProductType
680	HL ROAD FRAME - BLACK, 58	1016	2002	June	FR
706	HL ROAD FRAME - RED, 58	1016	2002	June	FR
717	HL ROAD FRAME - RED, 62	1043	2005	July	FR
718	HL ROAD FRAME - RED, 44	962	2005	July	FR
719	HL ROAD FRAME - RED, 48	980	2005	July	FR
720	HL ROAD FRAME - RED, 52	998	2005	July	FR
721	HL ROAD FRAME - RED, 56	1016	2005	July	FR
722	LL ROAD FRAME - BLACK, 58	1116	2005	July	FR
723	LL ROAD FRAME - BLACK, 60	1125	2005	July	FR
724	LL ROAD FRAME - BLACK, 62	1134	2005	July	FR

Table 1.74: Displaying records 1 - 10

CompanyName	Revenue	RankByRevenue
Action Bicycle Specialists	119960.82	1
Metropolitan Bicycle Supply	108597.95	2
Bulk Discount Store	98138.21	3
Eastside Department Store	92663.56	4
Riding Cycles	86222.81	5
Many Bikes Store	81834.98	6
Instruments and Parts Company	70698.99	7
Extreme Riding Supplies	63686.27	8
Trailblazing Sports	45992.37	9
Professional Sales and Service	43962.79	10

```

SELECT CompanyName, TotalDue AS Revenue,
       RANK() OVER (ORDER BY TotalDue DESC) AS RankByRevenue
FROM SalesLT.SalesOrderHeader AS SOH
LEFT JOIN SalesLT.Customer AS C
ON SOH.CustomerID = C.CustomerID;

```

Write a query to retrieve a list of the product names and the total revenue calculated as the sum of the LineTotal from the SalesLT.SalesOrderDetail table, with the results sorted in descending order of total revenue.

```

SELECT Name, SUM(LineTotal) AS TotalRevenue
FROM SalesLT.SalesOrderDetail AS SOD
LEFT JOIN SalesLT.Product AS P
ON SOD.ProductID = p.ProductID
GROUP BY P.Name
ORDER BY TotalRevenue DESC;

```

Modify the previous query to include sales totals for products that have a list price of more than 1000.

```

SELECT Name, SUM(LineTotal) AS TotalRevenue
FROM SalesLT.SalesOrderDetail AS SOD
JOIN SalesLT.Product AS P
ON SOD.ProductID = P.ProductID
WHERE ListPrice > 1000
GROUP BY P.Name

```

Table 1.75: Displaying records 1 - 10

Name	TotalRevenue
Touring-1000 Blue, 60	37191.49
Mountain-200 Black, 42	37178.84
Road-350-W Yellow, 48	36486.24
Mountain-200 Black, 38	35801.84
Touring-1000 Yellow, 60	23413.47
Touring-1000 Blue, 50	22887.07
Mountain-200 Silver, 42	20879.91
Road-350-W Yellow, 40	20411.88
Mountain-200 Black, 46	19277.92
Road-350-W Yellow, 42	18692.52

Table 1.76: Displaying records 1 - 10

Name	TotalRevenue
Touring-1000 Blue, 60	37191.49
Mountain-200 Black, 42	37178.84
Road-350-W Yellow, 48	36486.24
Mountain-200 Black, 38	35801.84
Touring-1000 Yellow, 60	23413.47
Touring-1000 Blue, 50	22887.07
Mountain-200 Silver, 42	20879.91
Road-350-W Yellow, 40	20411.88
Mountain-200 Black, 46	19277.92
Road-350-W Yellow, 42	18692.52

```
ORDER BY TotalRevenue DESC;
```

Modify the previous query to only include products with total sales greater than 20000.

```
SELECT Name, SUM(LineTotal) AS TotalRevenue
FROM SalesLT.SalesOrderDetail AS SOD
JOIN SalesLT.Product AS P
ON SOD.ProductID = P.ProductID
WHERE P.ListPrice > 1000
GROUP BY P.Name
-- add having clause as per instructions
HAVING SUM(LineTotal) > 20000
ORDER BY TotalRevenue DESC;
```

1.6 Sub-queries and Apply

Subqueries are queries within queries (nested). The results of the inner or nested query are pasted to the outer query and behave much like an expression.

Our subquery might be scalar, for instance we might have a single value which is passed to the outer query. So we might be interested in the last order (the maximum id) and the details from that order, where the information is held in two different tables.

Table 1.77: 8 records

Name	TotalRevenue
Touring-1000 Blue, 60	37191.49
Mountain-200 Black, 42	37178.84
Road-350-W Yellow, 48	36486.24
Mountain-200 Black, 38	35801.84
Touring-1000 Yellow, 60	23413.47
Touring-1000 Blue, 50	22887.07
Mountain-200 Silver, 42	20879.91
Road-350-W Yellow, 40	20411.88

Table 1.78: 1 records

salesorderid	productid	unitprice	orderqty
71946	916	31.584	1

```
SELECT salesorderid, productid, unitprice, orderqty
FROM SalesLT.SalesOrderDetail
WHERE salesorderid =
    (SELECT MAX(salesorderid) AS lastorder
     FROM SalesLT.SalesOrderHeader);
```

The subquery is in brackets, and the system will treat whatever is in brackets as an individual unit.

In a multi-valued query, mutiple values are returned but as a single column set to the outer query. So we might be interested in every customer in Mexico. One will get returned from the subquery is a one dimensional array - a vector.

1.6.1 Self Contained or Correlated Query

Queries we have looked at so far are self contained queries. The sub-query parts works, then it supplies its value to the outer query. Correlated sub-queries refer to elements of tables used in the outer query. Because the sub-query is searching for values in the outer query, this can be resource intensive. We might, for instance, make a reference to an employee number in the subquery, but that number is dependent on the result of the outer query, so the subqueriy works with the outer query.

As with sub-queries generally, it is best to build the query up iteratively, so you can a) check the query is working and b) check your final sub-query results with those of the individual components to make sure it is doing what it should be. However, this is more difficult when using a correlated query, since there is a dependency.

So our goal is for each customer list all sales on the last day that they made a sale.

So first, lets get a list of customers with their orders and dates.

```
SELECT CustomerID, SalesOrderID, OrderDate
FROM SalesLT.SalesOrderHeader AS SO1
ORDER BY CustomerID,OrderDate
```

Then let's say we want just the latest (max) order date in the db, for each customer ID we have, so we have their individual last order details.

Table 1.79: Displaying records 1 - 10

CustomerID	SalesOrderID	OrderDate
29485	71782	2008-06-01
29531	71935	2008-06-01
29546	71938	2008-06-01
29568	71899	2008-06-01
29584	71895	2008-06-01
29612	71885	2008-06-01
29638	71915	2008-06-01
29644	71867	2008-06-01
29653	71858	2008-06-01
29660	71796	2008-06-01

Table 1.80: Displaying records 1 - 10

CustomerID	SalesOrderID	OrderDate
29485	71782	2008-06-01
29531	71935	2008-06-01
29546	71938	2008-06-01
29568	71899	2008-06-01
29584	71895	2008-06-01
29612	71885	2008-06-01
29638	71915	2008-06-01
29644	71867	2008-06-01
29653	71858	2008-06-01
29660	71796	2008-06-01

```

SELECT CustomerID, SalesOrderID, OrderDate
FROM SalesLT.SalesOrderHeader AS S01
WHERE orderdate =
    (SELECT MAX(orderdate)
     FROM SalesLT.SalesOrderHeader AS S02
     WHERE S02.CustomerID = S01.CustomerID)
ORDER BY CustomerID;

```

1.6.2 The Apply Operator

Using an apply operator and a table function can achieve something similar to a correlated query, but in less complicated code. A CROSS APPLY applies the right table expression to each row in the left table, a bit like the correlated sub-query, with CROSS APPLY being similar to a CROSS JOIN.

Similarly OUTER APPLY adds rows for those with NULL in columns for the right table, similar to LEFT OUTER JOIN. In these instances, the right table is the table returned by the APPLY function.

The first thing we need to do is to create a function. Notice we are passing the function the SalesOrderID, and the most expensive item in the order gets passed back.

```

-- Setup
CREATE FUNCTION SalesLT.udfMaxUnitPrice (@SalesOrderID int)
RETURNS TABLE
AS

```

Table 1.81: 1 records

Text
– Setup CREATE FUNCTION SalesLT.udfMaxUnitPrice (@SalesOrderID int) RETURNS TABLE AS RETURN SELEC

Table 1.82: Displaying records 1 - 10

SalesOrderID	MaxUnitPrice
71774	356.898
71774	356.898
71776	63.900
71780	1391.994
71780	1391.994
71780	1391.994
71780	1391.994
71780	1391.994
71780	1391.994
71780	1391.994
71780	1391.994

```

RETURN
SELECT SalesOrderID,Max(UnitPrice) as MaxUnitPrice FROM
SalesLT.SalesOrderDetail
WHERE SalesOrderID=@SalesOrderID
GROUP BY SalesOrderID;

```

To see what code created a function, to help understand what it does at a later time or if created by someone else, we can use the `sp_helptext` command.

```
sp_helptext 'saleslt.udfmaxunitprice'
```

Then we can use that query to get the results. Note this could have been achieved with a correlated sub-query, but this is perhaps a little easier to interpret.

```

SELECT SOH.SalesOrderID, MUP.MaxUnitPrice
FROM SalesLT.SalesOrderDetail AS SOH
CROSS APPLY SalesLT.udfMaxUnitPrice(SOH.SalesOrderID) AS MUP
ORDER BY SOH.SalesOrderID;

```

**** Key Points ****

- The APPLY operator enables you to execute a table-valued function for each row in a rowset returned by a SELECT statement. Conceptually, this approach is similar to a correlated subquery.
- CROSS APPLY returns matching rows, similar to an inner join. OUTER APPLY returns all rows in the original SELECT query results with NULL values for rows where no match was found.

1.6.3 Lab Exercises

AdventureWorks products each have a standard cost that indicates the cost of manufacturing the product, and a list price that indicates the recommended selling price for the product. This data is stored in the SalesLT.Product table.

Whenever a product is ordered, the actual unit price at which it was sold is also recorded in the SalesLT.SalesOrderDetail table.

Table 1.83: Displaying records 1 - 10

ProductID	Name	ListPrice
680	HL Road Frame - Black, 58	1431.50
706	HL Road Frame - Red, 58	1431.50
717	HL Road Frame - Red, 62	1431.50
718	HL Road Frame - Red, 44	1431.50
719	HL Road Frame - Red, 48	1431.50
720	HL Road Frame - Red, 52	1431.50
721	HL Road Frame - Red, 56	1431.50
731	ML Road Frame - Red, 44	594.83
732	ML Road Frame - Red, 48	594.83
733	ML Road Frame - Red, 52	594.83

Table 1.84: 7 records

ProductID	Name	ListPrice
810	HL Mountain Handlebars	120.27
813	HL Road Handlebars	120.27
876	Hitch Rack - 4-Bike	120.00
894	Rear Derailleur	121.46
907	Rear Brakes	106.50
948	Front Brakes	106.50
996	HL Bottom Bracket	121.49

Use subqueries to compare the cost and list prices for each product with the unit prices charged in each sale.

```
SELECT ProductID, Name, ListPrice
FROM SalesLT.Product
WHERE ListPrice >
    (SELECT AVG(UnitPrice) FROM SalesLT.SalesOrderDetail)
ORDER BY ProductID;
```

AdventureWorks is interested in finding out which products are being sold at a loss. Retrieve the product ID, name, and list price for each product where the list price is 100 or more, and the product has been sold for (strictly) less than 100.

```
SELECT ProductID, Name, ListPrice
FROM SalesLT.Product
WHERE ProductID IN
    (SELECT ProductID FROM SalesLT.SalesOrderDetail
     WHERE UnitPrice < 100)
AND ListPrice >= 100
ORDER BY ProductID;
```

In order to get an idea of how many products are selling above or below list price, you want to gather some aggregate product data. Retrieve the product ID, name, cost, and list price for each product along with the average unit price for which that product has been sold.

```
SELECT ProductID, Name, StandardCost, ListPrice,
    (SELECT AVG(UnitPrice)
     FROM SalesLT.SalesOrderDetail AS SOD
     WHERE P.ProductID = SOD.ProductID) AS AvgSellingPrice
FROM SalesLT.Product AS P
```

Table 1.85: Displaying records 1 - 10

ProductID	Name	StandardCost	ListPrice	AvgSellingPrice
680	HL Road Frame - Black, 58	1059.3100	1431.50	NA
706	HL Road Frame - Red, 58	1059.3100	1431.50	NA
707	Sport-100 Helmet, Red	13.0863	34.99	20.9940
708	Sport-100 Helmet, Black	13.0863	34.99	20.6441
709	Mountain Bike Socks, M	3.3963	9.50	NA
710	Mountain Bike Socks, L	3.3963	9.50	NA
711	Sport-100 Helmet, Blue	13.0863	34.99	20.7440
712	AWC Logo Cap	6.9223	8.99	5.3740
713	Long-Sleeve Logo Jersey, S	38.4923	49.99	NA
714	Long-Sleeve Logo Jersey, M	38.4923	49.99	29.9940

Table 1.86: Displaying records 1 - 10

ProductID	Name	StandardCost	ListPrice	AvgSellingPrice
712	AWC Logo Cap	6.9223	8.99	5.374
714	Long-Sleeve Logo Jersey, M	38.4923	49.99	29.994
715	Long-Sleeve Logo Jersey, L	38.4923	49.99	29.744
716	Long-Sleeve Logo Jersey, XL	38.4923	49.99	29.994
717	HL Road Frame - Red, 62	868.6342	1431.50	858.900
718	HL Road Frame - Red, 44	868.6342	1431.50	858.900
722	LL Road Frame - Black, 58	204.6251	337.22	202.332
738	LL Road Frame - Black, 52	204.6251	337.22	202.332
792	Road-250 Red, 58	1554.9479	2443.35	1466.010
793	Road-250 Black, 44	1554.9479	2443.35	1466.010

```
ORDER BY P.ProductID;
```

AdventureWorks is interested in finding out which products are costing more than they're being sold for, on average. Filter the query for the previous exercise to include only products where the cost is higher than the average selling price.

```
SELECT ProductID, Name, StandardCost, ListPrice,
  (SELECT AVG(UnitPrice)
   FROM SalesLT.SalesOrderDetail AS SOD
   WHERE P.ProductID = SOD.ProductID) AS AvgSellingPrice
FROM SalesLT.Product AS P
WHERE StandardCost >
  (SELECT AVG(UnitPrice)
   FROM SalesLT.SalesOrderDetail AS SOD
   WHERE P.ProductID = SOD.ProductID)
ORDER BY P.ProductID;
```

The AdventureWorksLT database includes a table-valued user-defined function named `dbo.ufnGetCustomerInformation`. Use this function to retrieve details of customers based on customer ID values retrieved from tables in the database.

Retrieve the sales order ID, customer ID, first name, last name, and total due for all sales orders from the `SalesLT.SalesOrderHeader` table and the `dbo.ufnGetCustomerInformation` function.

Table 1.87: Displaying records 1 - 10

SalesOrderID	CustomerID	FirstName	LastName	TotalDue
71774	29847	David	Hodgson	972.7850
71776	30072	Andrea	Thomsen	87.0851
71780	30113	Raja	Venugopal	42452.6519
71782	29485	Catherine	Abel	43962.7901
71783	29957	Kevin	Liu	92663.5609
71784	29736	Terry	Eminhizer	119960.8240
71796	29660	Anthony	Chor	63686.2708
71797	29796	Jon	Grande	86222.8072
71815	30089	Michael John	Troyer	1261.4440
71816	30027	Joseph	Mitzner	3754.9733

Table 1.88: Displaying records 1 - 10

CustomerID	FirstName	LastName	AddressLine1	City
29485	Catherine	Abel	57251 Serene Blvd	Van Nuys
29486	Kim	Abercrombie	Tanger Factory	Branch
29489	Frances	Adams	6900 Sisk Road	Modesto
29490	Margaret	Smith	Lewiston Mall	Lewiston
29492	Jay	Adams	Blue Ridge Mall	Kansas City
29494	Samuel	Agcaoili	No. 25800-130 King Street West	Toronto
29496	Robert	Ahlering	6500 East Grant Road	Tucson
29497	François	Ferrier	Eastridge Mall	Casper
29499	Amy	Alberts	252851 Rowan Place	Richmond
29502	Paul	Alcorn	White Mountain Mall	Rock Springs

```
SELECT SOH.SalesOrderID, SOH.CustomerID, CI.FirstName, CI.LastName, SOH.TotalDue
FROM SalesLT.SalesOrderHeader AS SOH
CROSS APPLY dbo.ufnGetCustomerInformation(SOH.CustomerID) AS CI
ORDER BY SOH.SalesOrderID;
```

Use the table-valued user-defined function `dbo.ufnGetCustomerInformation` again to retrieve details of customers based on customer ID values retrieved from tables in the database. Retrieve the customer ID, first name, last name, address line 1 and city for all customers from the `SalesLT.Address` and `SalesLT.CustomerAddress` tables, using the `dbo.ufnGetCustomerInformation` function.

```
SELECT CA.CustomerID, CI.FirstName, CI.LastName, A.AddressLine1, A.City
FROM SalesLT.Address AS A
JOIN SalesLT.CustomerAddress AS CA
ON A.AddressID = CA.AddressID
CROSS APPLY dbo.ufnGetCustomerInformation(CA.CustomerID) AS CI
ORDER BY CA.CustomerID;
```

1.7 Using Table Expressions

We can create tables in a number of ways that can then be re-used, rather than being a one-off query.

Table 1.89: Displaying records 1 - 10

CustomerID	City
29698	Burnaby
29997	Seattle
29854	Joliet
30027	Oxnard
30023	Peoria
29637	Irving
29545	Bothell
29890	Port Orchard
29772	Austin
29883	Denver

1.7.1 Views

One way we can do this is using a view. Rather than repeatedly joining and selected fields from two tables, we can create a view that contains the join syntax then just select the view. This view can be used and queried as if it were a table. The data is still in the underlying tables, but it is a view or presentation on top of the tables. It's like a named query, which can make this simpler, plus we can add data at the view level, so they can view rights for the view table, but not the underlying data. Note that whilst you are able to use insert to add new rows, you can only do this to one of the underlying tables.

First we create a view

```
-- Create a view
CREATE VIEW SalesLT.vCustomerAddress
AS
SELECT C.CustomerID, FirstName, LastName, AddressLine1, City, StateProvince
FROM
SalesLT.Customer C JOIN SalesLT.CustomerAddress CA
ON C.CustomerID=CA.CustomerID
JOIN SalesLT.Address A
ON CA.AddressID=A.AddressID
```

Then we can query the view.

```
SELECT CustomerID, City
FROM SalesLT.vCustomerAddress
```

And we can join data to that view.

```
SELECT c.StateProvince, c.City, ISNULL(SUM(s.TotalDue), 0.00) AS Revenue
FROM SalesLT.vCustomerAddress AS c
LEFT JOIN SalesLT.SalesOrderHeader AS s
ON s.CustomerID = c.CustomerID
GROUP BY c.StateProvince, c.City
ORDER BY c.StateProvince, Revenue DESC;
```

1.7.2 Using Temporary Tables and Table Variables

Views are persistent database objects, however we might want a temporary table. We prefix the object with a # symbol and they are created in a separate temporary database called tempdb, rather than the db you

Table 1.90: Displaying records 1 - 10

StateProvince	City	Revenue
Alberta	Calgary	0
Alberta	Edmonton	0
Arizona	Chandler	0
Arizona	Gilbert	0
Arizona	Mesa	0
Arizona	Phoenix	0
Arizona	Scottsdale	0
Arizona	Surprise	0
Arizona	Tucson	0
British Columbia	Vancouver	0

are working in. Typically using a single `#` will mean the table exists for the current user session. If you wanted it to be persistent over multiple sessions, use the `##` prefix.

An alternative approach is to use table variables, which were introduced to cause performance problems if used again, as the table has to be re-created each user session, which can become a problem if there are many tables. If we want to use one we prefix it with an `@` sign to signify it is a variable e.g. `@table` so we define the variable as a table. This is connected to the batch rather than the session, so as long as we are in the block of code. It only works well on small databases or queries. They are for temporary situations or a temporary holding space.

In the next block of code we show how we create a temporary table then update and query it.

```
CREATE TABLE #Colors
(Color varchar(15));

INSERT INTO #Colors
SELECT DISTINCT Color FROM SalesLT.Product;

SELECT * FROM #Colors;
```

A table variable is similar, with some syntax differences, but this works on the code set (batch of commands ran at the same time) rather than being for the entire session.

```
DECLARE @Colors AS TABLE (Color varchar(15));

INSERT INTO @Colors
SELECT DISTINCT Color FROM SalesLT.Product;

SELECT * FROM @Colors;
```

**** Key Points ****

- Temporary tables are prefixed with a `#` symbol (You can also create global temporary tables that can be accessed by other processes by prefixing the name with `##`)
- Local temporary tables are automatically deleted when the session in which they were created ends. Global temporary tables are deleted when the last user sessions referencing them is closed.
- Table variables are prefixed with a `@` symbol.
- Table variables are scoped to the batch in which they are created.

Table 1.91: 2 records

CustomerID	FirstName	LastName	AddressLine1	City	StateProvince
29559	Robert	Bernacchi	2681 Eagle Peak	Bellevue	Washington
29559	Robert	Bernacchi	25915 140th Ave Ne	Bellevue	Washington

1.7.3 Table Value Functions (TVF)

This is a specific type of function which returns a table. It is a permanently define database object. Unlike views, we can pass values in to a TVF.

So first we create a TVF.

```
CREATE FUNCTION SalesLT.udfCustomersByCity
(@City AS VARCHAR(20))
RETURNS TABLE
AS
RETURN
(SELECT C.CustomerID, FirstName, LastName, AddressLine1, City, StateProvince
FROM SalesLT.Customer C JOIN SalesLT.CustomerAddress CA
ON C.CustomerID=CA.CustomerID
JOIN SalesLT.Address A ON CA.AddressID=A.AddressID
WHERE City=@City);
```

Then we can call the TVF passing a parameter - in this instance we provide a city name of Bellevue - which will then return the results of the SELECT statement which is a list of customers in that city.

```
SELECT * FROM SalesLT.udfCustomersByCity('Bellevue')
```

1.7.4 Derived Tables

These are derived tables that return a multi column table. They are a virtual table to simplify a query. The table only exists within that SELECT query. It is a programming construct within a SELECT statement, it is used for programming purposes. They can use internal (aka inline) within the derived table element, or external aliases for columns - outside the () of the derived table.

In the example derived table below, the alias ProdCats is provided external to the query (outside the parentheses). Other elements such as Category as defined as internal aliases.

```
SELECT Category, COUNT(ProductID) AS Products
FROM
  (SELECT p.ProductID, p.Name AS Product, c.Name AS Category
   FROM SalesLT.Product AS p
   JOIN SalesLT.ProductCategory AS c
   ON p.ProductCategoryID = c.ProductCategoryID) AS ProdCats
GROUP BY Category
ORDER BY Category;
```

1.7.5 Using Common Table Expressions (CTEs)

Similar to a TVF before we are defining a temporary table object which is used within the scope of the query. But this time around we define the CTE first, then make calls to that CTE afterwards. Unlike a derived query however, you can refer to the CTE multiple times within the same query/code batch, but it won't live

Table 1.92: Displaying records 1 - 10

Category	Products
Bib-Shorts	3
Bike Racks	1
Bike Stands	1
Bottles and Cages	3
Bottom Brackets	3
Brakes	2
Caps	1
Chains	1
Cleaners	1
Cranksets	3

Table 1.93: Displaying records 1 - 10

Category	Products
Bib-Shorts	3
Bike Racks	1
Bike Stands	1
Bottles and Cages	3
Bottom Brackets	3
Brakes	2
Caps	1
Chains	1
Cleaners	1
Cranksets	3

on like a view. We can also use a CTE for recursive elements like loops, so you might want to get everyone within a management tier, then say you want to go through that process three times for the top 3 levels, using the `OPTION(MAXRECURSION 3)`.

So in the following example, we first define the CTE, then we make reference to it. The result here is the same as our derived query previously, but perhaps a little easier to understand.

```
WITH ProductsByCategory (ProductID, ProductName, Category)
AS
(
    SELECT p.ProductID, p.Name, c.Name AS Category
    FROM SalesLT.Product AS p
    JOIN SalesLT.ProductCategory AS c
    ON p.ProductCategoryID = c.ProductCategoryID
)

SELECT Category, COUNT(ProductID) AS Products
FROM ProductsByCategory
GROUP BY Category
ORDER BY Category;
```

Next we will look at the our organisation chart example as previously mentioned. First let's look at our employee table.

Table 1.94: 9 records

EmployeeID	EmployeeName	ManagerID
1	adventure-works\david8	8
2	adventure-works\garrett1	1
3	adventure-works\jae0	NA
4	adventure-works\jillian0	3
5	adventure-works\josé1	1
6	adventure-works\linda3	3
7	adventure-works\michael9	9
8	adventure-works\pamela0	3
9	adventure-works\shu0	3

Table 1.95: 9 records

ManagerID	EmployeeID	EmployeeName	Level
NA	3	adventure-works\jae0	0
3	4	adventure-works\jillian0	1
3	6	adventure-works\linda3	1
3	8	adventure-works\pamela0	1
3	9	adventure-works\shu0	1
9	7	adventure-works\michael9	2
8	1	adventure-works\david8	2
1	2	adventure-works\garrett1	3
1	5	adventure-works\josé1	3

```
SELECT * FROM SalesLT.Employee
```

We can see that each employee has a manager ID apart from Employee 3 who is the CEO/MD. So we have a hierarchy of employees. We will go 3 levels deep this time (three recursions).

```
WITH OrgReport (ManagerID, EmployeeID, EmployeeName, Level)
AS
(
    -- Anchor query
    SELECT e.ManagerID, e.EmployeeID, EmployeeName, 0
    FROM SalesLT.Employee AS e
    WHERE ManagerID IS NULL

    UNION ALL

    -- Recursive query
    SELECT e.ManagerID, e.EmployeeID, e.EmployeeName, Level + 1
    FROM SalesLT.Employee AS e
    INNER JOIN OrgReport AS o ON e.ManagerID = o.EmployeeID
)

SELECT * FROM OrgReport
OPTION (MAXRECURSION 3);
```

**** Key Points ****

- A derived table is a subquery that generates a multicolumn rowset. You must use the AS clause to

Table 1.96: Displaying records 1 - 10

ProductID	ProductName	ProductModel	Summary
749	Road-150 Red, 62	Road-150	This bike is ridden by race winners. Developed with the Adventure Wo
750	Road-150 Red, 44	Road-150	This bike is ridden by race winners. Developed with the Adventure Wo
751	Road-150 Red, 48	Road-150	This bike is ridden by race winners. Developed with the Adventure Wo
752	Road-150 Red, 52	Road-150	This bike is ridden by race winners. Developed with the Adventure Wo
753	Road-150 Red, 56	Road-150	This bike is ridden by race winners. Developed with the Adventure Wo
754	Road-450 Red, 58	Road-450	A true multi-sport bike that offers streamlined riding and a revolutiona
755	Road-450 Red, 60	Road-450	A true multi-sport bike that offers streamlined riding and a revolutiona
756	Road-450 Red, 44	Road-450	A true multi-sport bike that offers streamlined riding and a revolutiona
757	Road-450 Red, 48	Road-450	A true multi-sport bike that offers streamlined riding and a revolutiona
758	Road-450 Red, 52	Road-450	A true multi-sport bike that offers streamlined riding and a revolutiona

define an alias for a derived query.

- Common Table Expressions (CTEs) provide a more intuitive syntax or defining rowsets than derived tables, and can be used multiple times in the same query.
- You can use CTEs to define recursive queries.

1.7.6 Lab Exercises

AdventureWorks sells many products that are variants of the same product model. You must write queries that retrieve information about these products. Retrieve the product ID, product name, product model name, and product model summary for each product from the SalesLT.Product table and the SalesLT.vProductModelCatalogDescription view.

```
SELECT P.ProductID, P.Name AS ProductName, PM.Name AS ProductModel, PM.Summary
FROM SalesLT.Product AS P
JOIN SalesLT.vProductModelCatalogDescription AS PM
ON P.ProductModelID = PM.ProductModelID
ORDER BY ProductID;
```

You are only interested in products which have a listed color in the database. Create a table variable and populate it with a list of distinct colors from the SalesLT.Product table. Then use the table variable to filter a query that returns the product ID, name, and color from the SalesLT.Product table so that only products with a color listed in the table variable are returned.

```
DECLARE @Colors AS TABLE (Color NVARCHAR(15));

INSERT INTO @Colors
SELECT DISTINCT Color FROM SalesLT.Product;

SELECT ProductID, Name, Color
FROM SalesLT.Product
WHERE Color IN (SELECT Color FROM @Colors);
```

The AdventureWorksLT database includes a table-valued function named `dbo.ufnGetAllCategories`, which returns a table of product categories (e.g. 'Road Bikes') and parent categories (for example 'Bikes'). Write a query that uses this function to return a list of all products including their parent category and their own category.

Table 1.97: Displaying records 1 - 10

ParentCategory	Category	ProductID	ProductName
Accessories	Bike Racks	876	Hitch Rack - 4-Bike
Accessories	Bike Stands	879	All-Purpose Bike Stand
Accessories	Bottles and Cages	871	Mountain Bottle Cage
Accessories	Bottles and Cages	872	Road Bottle Cage
Accessories	Bottles and Cages	870	Water Bottle - 30 oz.
Accessories	Cleaners	877	Bike Wash - Dissolver
Accessories	Fenders	878	Fender Set - Mountain
Accessories	Helmets	708	Sport-100 Helmet, Black
Accessories	Helmets	711	Sport-100 Helmet, Blue
Accessories	Helmets	707	Sport-100 Helmet, Red

Table 1.98: Displaying records 1 - 10

CompanyContact	Revenue
Action Bicycle Specialists (Terry Eminhizer)	119960.8240
Aerobic Exercise Company (Rosmarie Carroll)	2361.6403
Bulk Discount Store (Christopher Beck)	98138.2131
Central Bicycle Specialists (Janeth Esteves)	43.0437
Channel Outlet (Richard Byham)	608.1766
Closest Bicycle Store (Pamala Kotc)	39531.6085
Coalition Bike Company (Donald Blanton)	2669.3183
Discount Tours (Melissa Marple)	3293.7761
Eastside Department Store (Kevin Liu)	92663.5609
Engineered Bike Systems (Joseph Mitzner)	3754.9733

```

SELECT C.ParentProductCategoryName AS ParentCategory,
       C.ProductCategoryName AS Category,
       P.ProductID, P.Name AS ProductName
FROM SalesLT.Product AS P
JOIN dbo.ufnGetAllCategories() AS C
ON P.ProductCategoryID = C.ProductCategoryID
ORDER BY ParentCategory, Category, ProductName;

```

Each AdventureWorks customer is a retail company with a named contact. You must create queries that return the total revenue for each customer, including the company and customer contact names. Retrieve a list of customers in the format Company (Contact Name) together with the total revenue for each customer. Use a derived table or a common table expression to retrieve the details for each sales order, and then query the derived table or CTE to aggregate and group the data.

```

SELECT CompanyContact, SUM(SalesAmount) AS Revenue
FROM
    (SELECT CONCAT(c.CompanyName, CONCAT(' (' + c.FirstName + ', c.LastName + ')')), SOH.TotalDue
     FROM SalesLT.SalesOrderHeader AS SOH
     JOIN SalesLT.Customer AS c
     ON SOH.CustomerID = c.CustomerID) AS CustomerSales(CompanyContact, SalesAmount)
GROUP BY CompanyContact
ORDER BY CompanyContact;

```


Table 1.99: Displaying records 1 - 10

ParentProductCategoryName	ProductCategoryName	Products
Accessories	Bike Racks	1
Accessories	Bike Stands	1
Accessories	Bottles and Cages	3
Accessories	Cleaners	1
Accessories	Fenders	1
Accessories	Helmets	3
Accessories	Hydration Packs	1
Accessories	Lights	4
Accessories	Locks	1
Accessories	Panniers	1

1.8 Grouping Sets and Pivoting Data

These are both ways of summarising data - grouping data includes cubing the data.

Grouping sets allows you to define multiple groupings within the same query. So you may have a number of subtotals for different product types, then a total of all the subtotals combined.

So you would have something like

```
SELECT FROM
GROUP BY GROUPING SETS (
,
() – empty parentheses if aggregating all rows )
```

A result line will appear with NULLs in all column(s) which is the grand total.

There are other ways to aggregate the data such as ROLLUP and CUBE. ROLLUP is useful if you have a hierarchy - people in households, towns in regions. Cube will show every possible aggregation, rather than specifying each aggregation.

Both are specified in the GROUP BY X () where x is either ROLLUP or CUBE. You can add in GROUPING_ID

AS fields to make the interpretation easier when using multiple grouping columns. You can then see the grand total more easily, since it will have a 1 in each groupingid column.

So a usual group by might look something like this - with a high level Parent Category followed by a Product Category and a count of items.

```
SELECT cat.ParentProductCategoryName, cat.ProductCategoryName, count(prd.ProductID) AS Products
FROM SalesLT.vGetAllCategories as cat
LEFT JOIN SalesLT.Product AS prd
ON prd.ProductCategoryID = cat.ProductCategoryID
GROUP BY cat.ParentProductCategoryName, cat.ProductCategoryName
ORDER BY cat.ParentProductCategoryName, cat.ProductCategoryName;
```

Here there are no grand total by parent categories. Also, there might be certain items appear in more than one category without totals e.g. bike racks might be in multiple parent categories.

Alternatively, we might create GROUPING SETS which also allows us to create totals.

Table 1.100: Displaying records 1 - 10

ParentProductCategoryName	ProductCategoryName	Products
NA	NA	296
NA	Bib-Shorts	3
NA	Bike Racks	1
NA	Bike Stands	1
NA	Bottles and Cages	3
NA	Bottom Brackets	3
NA	Brakes	2
NA	Caps	1
NA	Chains	1
NA	Cleaners	1

Table 1.101: Displaying records 1 - 10

ParentProductCategoryName	ProductCategoryName	Products
NA	NA	296
Accessories	NA	30
Accessories	Bike Racks	1
Accessories	Bike Stands	1
Accessories	Bottles and Cages	3
Accessories	Cleaners	1
Accessories	Fenders	1
Accessories	Helmets	3
Accessories	Hydration Packs	1
Accessories	Lights	4

```
SELECT cat.ParentProductCategoryName, cat.ProductCategoryName, count(prd.ProductID) AS Products
FROM SalesLT.vGetAllCategories as cat
LEFT JOIN SalesLT.Product AS prd
ON prd.ProductCategoryID = cat.ProductcategoryID
GROUP BY GROUPING SETS(cat.ParentProductCategoryName, cat.ProductCategoryName, ())
ORDER BY cat.ParentProductCategoryName, cat.ProductCategoryName;
```

We now start getting totals, we can see there is a total of 295 products, followed by 3 bib-shorts (irrespective of parent), and later in the table we get the totals by parent categories. But we have no loss some of the relationships with parent categories with this query. It is possible to write a query where these things might appear, GROUPING SETS is the most flexible of the grouping commands, but it might be easier to use one of the other grouping options as required, next shows the the ROLLUP command.

```
SELECT cat.ParentProductCategoryName, cat.ProductCategoryName, count(prd.ProductID) AS Products
FROM SalesLT.vGetAllCategories as cat
LEFT JOIN SalesLT.Product AS prd
ON prd.ProductCategoryID = cat.ProductcategoryID
GROUP BY ROLLUP (cat.ParentProductCategoryName, cat.ProductCategoryName)
ORDER BY cat.ParentProductCategoryName, cat.ProductCategoryName;
```

It is now giving us totals for parents and products. However, we are now missing situations where items might appear in more than one parent category e.g. bottles and cages that are in a category other than accessories. So we can use CUBE to get these other aggregation options, which will give us all possible aggregations.

Table 1.102: Displaying records 1 - 10

ParentProductCategoryName	ProductCategoryName	Products
NA	NA	296
NA	Bib-Shorts	3
NA	Bike Racks	1
NA	Bike Stands	1
NA	Bottles and Cages	3
NA	Bottom Brackets	3
NA	Brakes	2
NA	Caps	1
NA	Chains	1
NA	Cleaners	1

```
SELECT cat.ParentProductCategoryName, cat.ProductCategoryName, count(prd.ProductID) AS Products
FROM SalesLT.vGetAllCategories as cat
LEFT JOIN SalesLT.Product AS prd
ON prd.ProductCategoryID = cat.ProductcategoryID
GROUP BY CUBE (cat.ParentProductCategoryName, cat.ProductCategoryName)
ORDER BY cat.ParentProductCategoryName, cat.ProductCategoryName;
```

**** Key Points ****

- * Use GROUPING SETS to define custom groupings.
- * Use ROLLUP to include subtotals and a grand total for hierarchical groupings.
- * Use CUBE to include all possible groupings.

1.8.1 Pivoting Data

Pivoting is another form of summarising data. We take row based items and pivot them in to single, summarised, columns in a new table. We simply use the PIVOT command. It is possible to undue this using UNPIVOT however this may loose some of the detail that existed in the original data. For instance line level data, such as which particular clothing items were purchased and at which value, is now lost as we just get a clothing total, but re-orientated to match the original data format.

We might want to be able to see the totals by colour in our data and by cateory. You have to know which columns you wish to create using the PIVOT table, for instance in the code below we are listing the actual colours our in the PIVOT command. If one colour was missed, the query would work, but you obviously wouldn't get that colour returned or included in totals.

```
SELECT * FROM
    (SELECT P.ProductID, PC.Name, ISNULL(P.Color, 'Uncolored') AS Color
     FROM saleslt.productcategory AS PC
     JOIN SalesLT.Product AS P
     ON PC.ProductCategoryID=P.ProductCategoryID
    ) AS PPC
PIVOT(COUNT(ProductID) FOR Color IN([Red],[Blue],[Black],[Silver],[Yellow],[Grey],[Multi],[Uncolored])
ORDER BY Name;
```

If we wanted to, we could copy/archive this in to a new table, which can be re-used again or compared and retrieved in the future.

```
CREATE TABLE #ProductColorPivot
(Name varchar(50), Red int, Blue int, Black int, Silver int, Yellow int, Grey int, multi int, uncolored
```

Table 1.103: Displaying records 1 - 10

Name	Red	Blue	Black	Silver	Yellow	Grey	Multi	Uncolored
Bib-Shorts	0	0	0	0	0	0	3	0
Bike Racks	0	0	0	0	0	0	0	1
Bike Stands	0	0	0	0	0	0	0	1
Bottles and Cages	0	0	0	0	0	0	0	3
Bottom Brackets	0	0	0	0	0	0	0	3
Brakes	0	0	0	2	0	0	0	0
Caps	0	0	0	0	0	0	1	0
Chains	0	0	0	1	0	0	0	0
Cleaners	0	0	0	0	0	0	0	1
Cranksets	0	0	3	0	0	0	0	0

```

INSERT INTO #ProductColorPivot
SELECT * FROM
(SELECT P.ProductID, PC.Name, ISNULL(P.Color, 'Uncolored') AS Color
FROM saleslt.productcategory AS PC
JOIN SalesLT.Product AS P
ON PC.ProductCategoryID=P.ProductCategoryID
) AS PPC
PIVOT(COUNT(ProductID) FOR Color IN([Red],[Blue],[Black],[Silver],[Yellow],[Grey],[Multi],[Uncolored])
ORDER BY Name;

```

If we then wanted to unpivot the data we would do so as follows.

```

SELECT Name, Color, ProductCount
FROM
(SELECT Name,
[Red],[Blue],[Black],[Silver],[Yellow],[Grey],[Multi],[Uncolored]
FROM #ProductColorPivot) pcp
UNPIVOT
(ProductCount FOR Color IN ([Red],[Blue],[Black],[Silver],[Yellow],[Grey],[Multi],[Uncolored])
) AS ProductCounts

```

**** Key Points **** * Use PIVOT to re-orient a rowset by generating multiple columns from values in a single column.

* Use UNPIVOT to re-orient multiple columns in an existing rowset into a single column.

1.8.2 Lab Exercises

AdventureWorks sells products to customers in multiple country/regions around the world.

An existing report uses the query provided in the editor to return total sales revenue grouped by country/region and state/province. Modify the query so that the results include a grand total for all sales revenue and a subtotal for each country/region in addition to the state/province subtotals that are already returned.

```

SELECT a.CountryRegion, a.StateProvince, SUM(soh.TotalDue) AS Revenue
FROM SalesLT.Address AS a
JOIN SalesLT.CustomerAddress AS ca
ON a.AddressID = ca.AddressID
JOIN SalesLT.Customer AS c

```

Table 1.104: 9 records

CountryRegion	StateProvince	Revenue
NA	NA	956303.5949
United Kingdom	NA	572496.5594
United Kingdom	England	572496.5594
United States	NA	383807.0355
United States	California	346517.6072
United States	Colorado	14017.9083
United States	Nevada	7330.8972
United States	New Mexico	15275.1977
United States	Utah	665.4251

Table 1.105: 9 records

CountryRegion	StateProvince	Level	Revenue
NA	NA	Total	956303.5949
United Kingdom	NA	United Kingdom Subtotal	572496.5594
United Kingdom	England	England Subtotal	572496.5594
United States	NA	United States Subtotal	383807.0355
United States	California	California Subtotal	346517.6072
United States	Colorado	Colorado Subtotal	14017.9083
United States	Nevada	Nevada Subtotal	7330.8972
United States	New Mexico	New Mexico Subtotal	15275.1977
United States	Utah	Utah Subtotal	665.4251

```

ON ca.CustomerID = c.CustomerID
JOIN SalesLT.SalesOrderHeader as soh
ON c.CustomerID = soh.CustomerID
GROUP BY ROLLUP (a.CountryRegion, a.StateProvince)
ORDER BY a.CountryRegion, a.StateProvince;

```

Modify your query to include a column named Level that indicates at which level in the total, country/region, and state/province hierarchy the revenue figure in the row is aggregated.

```

SELECT a.CountryRegion, a.StateProvince,
       IIF(GROUPING_ID(a.CountryRegion) = 1 AND GROUPING_ID(a.StateProvince) = 1, 'Total', IIF(GROUPING_ID
SUM(soh.TotalDue) AS Revenue
FROM SalesLT.Address AS a
JOIN SalesLT.CustomerAddress AS ca
ON a.AddressID = ca.AddressID
JOIN SalesLT.Customer AS c
ON ca.CustomerID = c.CustomerID
JOIN SalesLT.SalesOrderHeader as soh
ON c.CustomerID = soh.CustomerID
GROUP BY ROLLUP(a.CountryRegion, a.StateProvince)
ORDER BY a.CountryRegion, a.StateProvince;

```

Or to extend your query to include a grouping for individual cities.

```

SELECT a.CountryRegion, a.StateProvince, a.City,
CHOOSE (1 + GROUPING_ID(a.CountryRegion) + GROUPING_ID(a.StateProvince) + GROUPING_ID(a.City),
       a.City + ' Subtotal', a.StateProvince + ' Subtotal',

```

Table 1.106: Displaying records 1 - 10

CountryRegion	StateProvince	City	Level	Revenue
NA	NA	NA	Total	956303.5949
United Kingdom	NA	NA	United Kingdom Subtotal	572496.5594
United Kingdom	England	NA	England Subtotal	572496.5594
United Kingdom	England	Abingdon	Abingdon Subtotal	45.1995
United Kingdom	England	Cambridge	Cambridge Subtotal	2711.4098
United Kingdom	England	Gloucestershire	Gloucestershire Subtotal	70698.9922
United Kingdom	England	High Wycombe	High Wycombe Subtotal	608.1766
United Kingdom	England	Liverpool	Liverpool Subtotal	86222.8072
United Kingdom	England	London	London Subtotal	206736.1667
United Kingdom	England	Maidenhead	Maidenhead Subtotal	43.0437

```

        a.CountryRegion + ' Subtotal', 'Total') AS Level,
SUM(soh.TotalDue) AS Revenue
FROM SalesLT.Address AS a
JOIN SalesLT.CustomerAddress AS ca
ON a.AddressID = ca.AddressID
JOIN SalesLT.Customer AS c
ON ca.CustomerID = c.CustomerID
JOIN SalesLT.SalesOrderHeader as soh
ON c.CustomerID = soh.CustomerID
GROUP BY ROLLUP(a.CountryRegion, a.StateProvince, a.City)
ORDER BY a.CountryRegion, a.StateProvince, a.City;

```

AdventureWorks products are grouped into categories, which in turn have parent categories (defined in the SalesLT.vGetAllCategories view).

AdventureWorks customers are retail companies, and they may place orders for products of any category. The revenue for each product in an order is recorded as the LineTotal value in the SalesLT.SalesOrderDetail table.

Retrieve a list of customer company names together with their total revenue for each parent category in Accessories, Bikes, Clothing, and Components. Make sure to use the aliases provided, and default column names elsewhere.

```

SELECT * FROM
(SELECT cat.ParentProductCategoryName, cust.CompanyName, sod.LineTotal
FROM SalesLT.SalesOrderDetail AS sod
JOIN SalesLT.SalesOrderHeader AS soh ON sod.SalesOrderID = soh.SalesOrderID
JOIN SalesLT.Customer AS cust ON soh.CustomerID = cust.CustomerID
JOIN SalesLT.Product AS prod ON sod.ProductID = prod.ProductID
JOIN SalesLT.vGetAllCategories AS cat ON prod.ProductcategoryID = cat.ProductCategoryID) AS catsales
PIVOT (SUM(LineTotal) FOR ParentProductCategoryName
IN ([Accessories], [Bikes], [Clothing], [Components])) AS pivotedsales
ORDER BY CompanyName;

```

1.9 Modifying Data

This section isn't about querying data, but adding, deleting and updating data in our database.

Table 1.107: Displaying records 1 - 10

CompanyName	Accessories	Bikes	Clothing	Components
Action Bicycle Specialists	1299.885	76613.6518	2461.6573	9494.082
Aerobic Exercise Company	NA	NA	NA	1732.890
Bulk Discount Store	730.464	70597.2840	851.5620	1980.918
Central Bicycle Specialists	NA	NA	NA	31.584
Channel Outlet	216.000	NA	308.6640	NA
Closest Bicycle Store	NA	20389.6680	559.1641	8001.846
Coalition Bike Company	NA	529.4928	124.7760	1201.938
Discount Tours	72.000	2041.1880	341.0580	72.882
Eastside Department Store	1220.236	51096.0548	2772.2296	10594.848
Engineered Bike Systems	NA	2604.7620	178.7460	63.900

To add data we use the `INSERT ... VALUES` command, where you can leave blank columns that allow NULLs and cols with default constraints. You can also leave identify/primary key fields blank since they will be generated automatically, depending on what seed and increment values were specified when the table was set up, however it is possible to override these values if you wish. You can add a NULL value to a column if you wish.

You can also insert the results of another query in to an existing table using `INSERT ... SELECT` or `INSERT ... EXEC` where `EXEC` is the execution of a stored query.

Another option is `SELECT ... INTO` will explicitly create a new table, inserting data based on query. However this newly created table will not have constraints, defaults, indexes or primary keys, just a set of columns with the results of the query. This is currently not supported in Azure, however you could create the table first with the items needed such as columns and pk, then use the `INSERT INTO` for Azure.

Our Identity property of a column generates sequential numbers for insertations of new data into a database and we can set the parameters of this identity column. If you insert a new item (row) in to a table, you might want to then get back this identity column for this new item e.g. you automatically generate a new sales ID but a new order, however you might want to then present this back to the customer, this is achieved using `@?`, but this returns the last identity referenced, so if you are adding the sales order first then the individual items in a separate table, it will retrieve the identity column from the sales order details rather than sales order header. This command therefore returns the last identity from the current connected session.

An alternative is to use `SELECT SCOPE_IDENTITY() AS ORDERID` which will bring back the last identity column for the specified table in the current session, but again this can be problematic. The alternative is to use `IDENT_CURRENT('')` which passes the last identity inserted into a particular table, however this is across all sessions, so if others are inserting the table this can be problematic. So generally the best option is to use `SCOPE_IDENTITY` and present that, before then going on to do other things.

If you perhaps wanted to have two different tables for two different order types - say in store purchases and online purchases as two distinct tables - but to both use the same sequential list for order ID, you could do this using sequences. They exist independently of tables so can be referenced by multiple tables, the query will ask the server what the next id is in the sequence and be provided with that. It is like a central store that issues new numbers on request.

So to create a new table for customer call logs we do the following:

```
CREATE TABLE SalesLT.CallLog
(
```

```
    CallID int IDENTITY PRIMARY KEY NOT NULL, -- no seed or increment set, so will start at 1 then add
    CallTime datetime NOT NULL DEFAULT GETDATE(), -- if not date and time set, it will get the current
    SalesPerson nvarchar(256) NOT NULL,
    CustomerID int NOT NULL REFERENCES SalesLT.Customer(CustomerID), -- references a foreign key from t
```

```

    PhoneNumber nvarchar(25) NOT NULL,
    Notes nvarchar(max) NULL -- the only column which is allowed to be NULL, since perhaps the customer
);
GO

```

If we then wanted to explicitly add or insert a row in to the database we do the following - note the CallID does not need to be given since this is automatically created :

– INT is optional, we state values as we are explicitly stating the values

```

INSERT INTO SalesLT.CallLog
VALUES
('2015-01-01T12:30:00', 'adventure-works\pamela0', 1, '245-555-0173', 'Returning call re: enquiry about

```

If we wanted to accept the default options, we can do that by using DEFAULT (e.g. for data/time) and if there are no notes we can use NULL.

```

INSERT INTO SalesLT.CallLog
VALUES
(DEFAULT, 'adventure-works\david8', 2, '170-555-0127', NULL);

```

Perhaps we need to re-order our fields rather than accepting the default sequence, perhaps it is a modified table or a table from another source. To do this, we explicitly state the columns.

```

INSERT INTO SalesLT.CallLog (SalesPerson, CustomerID, PhoneNumber)
VALUES
('adventure-works\jillian0', 3, '279-555-0130');

```

If we wanted to add two records, we can do this at the same time, and even use some different options for the different rows.

```

INSERT INTO SalesLT.CallLog
VALUES
(DATEADD(mi,-2, GETDATE()), 'adventure-works\jillian0', 4, '710-555-0173', NULL),
(DEFAULT, 'adventure-works\shu0', 5, '828-555-0186', 'Called to arrange deliver of order 10987');

```

There are more examples with adding query results into tables and getting identity values in the demo files.

**** Key Points **** * Use the INSERT statement to insert one or more rows into a table.

* When inserting explicit values, you can omit identity columns, columns that allow NULLs, and columns on which a default constraint is defined.

* Identity columns generate a unique integer identifier for each row. You can also use a sequence to generate unique values that can be used in multiple tables.

1.9.1 Updating and Deleting Data

The UPDATE command will update all the rows in a table or view and can be filtered using WHERE and the columns can be selected using FROM. It is more likely we will want to select a particular set of rows, so we will be using the WHERE clause in most instances. We use the SET clause in the UPDATE statement to assign a value and we can use a calculation and we can specify multiple columns e.g. SET unitprice = (unitprice * 1.04), notes = 'price increase by 4% due to inflation'. You can also update values in a table based on the results of a query. Only columns in the set clause are affected. There are a number of examples in the MSDN TSQL pages Transact-SQL Reference.

A common challenge in data warehousing is what is sometimes referred to as 'upserting' - we are updating records that already exist AND we insert new records if they do not. To do this, we use the MERGE command, which modifies data based on a condition. We look at situations of when the source data matches the target data. So we might check if the ProductID already exists, and where it does we use an UPDATE.

But if there is a record in the source table but on the target table (db) we will INSERT a new product. The code below is an example

```
MERGE INTO Production.Products as P
    USING Production.ProductsStaging as S
    ON P.ProductID=S.ProductID
WHEN MATCHED THEN
    UPDATE SET
        P.UnitPrice = S.UnitPrice, P.Discontinued=S.Discontinued
WHEN NOT MATCHED THEN
    INSERT (ProductName, CategoryID, UnitPrice, Discontinued)
    VALUES (S.ProductName, S.CategoryID, S.UnitPrice, S.Discontinued);
```

We can delete data from a table, however we need to be careful, if we don't specify a WHERE clause we may delete a lot of data!

```
DELETE FROM Sales.OrderDetails
WHERE orderid = 10248;
```

There is an overhead with this approach, since SQL Server will record this transaction. If we are deleting a whole table and wish to deallocate the entire table space, we are based to use TRUNCATE. TRUNCATE TABLE Will fail if the table is referenced by a foreign key constraint in another table, the same will happen with the DELETE command. The table definition remains, but all the data is removed and the space reallocated. This is often used in staging tables, so we might load new data in to a staging table, then use the MERGE command for your target table, then empty the staging table but keep the structure, so we use TRUNCATE.

So if we wanted to add a value to where a value is currently NULL, for instance to state that no notes were recorded, we can do this as:

```
UPDATE SalesLT.CallLog
SET Notes = 'No notes'
WHERE Notes IS NULL;
```

Or we can update multiple columns, in the following example we set two empty strings using '' - note this does it for the ENTIRE table, as there is no WHERE clause.

```
UPDATE SalesLT.CallLog
SET SalesPerson = '', PhoneNumber = '';
```

Now we want to re-add the data just deleted, using a query, getting Sales Person and Phone Number from the customer table, where the CustomerID matches.

```
UPDATE SalesLT.CallLog
SET SalesPerson = c.SalesPerson, PhoneNumber = c.Phone
FROM SalesLT.Customer AS c
WHERE c.CustomerID = SalesLT.CallLog.CustomerID;
```

We might want to archive off then delete anything older than this week. This can be achieved by using DELETE and WHERE.

```
DELETE FROM SalesLT.CallLog
WHERE CallTime < DATEADD(dd, -7, GETDATE());
```

Or if we want to completely wipe the call log table we use TRUNCATE.

```
TRUNCATE TABLE SalesLT.CallLog;
```

**** Key Points **** * Use the UPDATE statement to modify the values of one or more columns in specified rows of a table.

* Use the DELETE statement to delete specified rows in a table.

* Use the MERGE statement to insert, update, and delete rows in a target table based on data in a source table.

1.9.2 Lab Exercises

AdventureWorks has started selling the new product - LED Lights. Insert it into the SalesLT.Product table, using default or NULL values for unspecified columns. Once you've inserted the product, run SELECT SCOPE_IDENTITY(); to get the last identity value that was inserted. Add a query to view the row for the product in the SalesLT.Product table.

```
INSERT INTO SalesLT.Product (Name, ProductNumber, StandardCost, ListPrice, ProductCategoryID, SellStart)
VALUES
('LED Lights', 'LT-L123', 2.56, 12.99, 37, GETDATE());

SELECT SCOPE_IDENTITY();

SELECT * FROM SalesLT.Product
WHERE ProductID = SCOPE_IDENTITY();
```

Insert the two new products with the appropriate ProductCategoryID value, based on the product details above.

Finish the query to join the SalesLT.Product and SalesLT.ProductCategory tables. That way, you can verify that the data has been inserted. Make sure to use the aliases provided, and default column names elsewhere.

```
INSERT INTO SalesLT.ProductCategory (ParentProductCategoryID, Name)
VALUES
(4, 'Bells and Horns');

INSERT INTO SalesLT.Product (Name, ProductNumber, StandardCost, ListPrice, ProductCategoryID, SellStart)
VALUES
('Bicycle Bell', 'BB-RING', 2.47, 4.99, IDENT_CURRENT('SalesLT.ProductCategory'), GETDATE()),
('Bicycle Horn', 'BB-PARP', 1.29, 3.75, IDENT_CURRENT('SalesLT.ProductCategory'), GETDATE());

SELECT c.Name AS Category, p.Name AS Product
FROM SalesLT.Product AS p
JOIN SalesLT.ProductCategory AS c ON p.ProductCategoryID = c.ProductCategoryID
WHERE p.ProductCategoryID = IDENT_CURRENT('SalesLT.ProductCategory');
```

You must now update the records you have previously inserted to reflect the correct pricing. The sales manager at AdventureWorks has mandated a 10% price increase for all products in the Bells and Horns category. Update the rows in the SalesLT.Product table for these products to increase their price by 10%.

```
UPDATE SalesLT.Product
SET ListPrice = ListPrice * 1.1
WHERE ProductCategoryID =
(SELECT ProductCategoryID FROM SalesLT.ProductCategory WHERE Name = 'Bells and Horns');
```

The new LED lights you inserted in the previous challenge are to replace all previous light products. Update the SalesLT.Product table to set the DiscontinuedDate to today's date for all products in the Lights category (ProductCategoryID 37) other than the LED Lights product you inserted previously. So we delete records from the SalesLT.Product table first then delete records from the SalesLT.ProductCategory table.

```
DELETE FROM SalesLT.Product
WHERE ProductCategoryID =
```

```

    (SELECT ProductCategoryID FROM SalesLT.ProductCategory WHERE Name = 'Bells and Horns');

DELETE FROM SalesLT.ProductCategory
WHERE ProductCategoryID =
    (SELECT ProductCategoryID FROM SalesLT.ProductCategory WHERE Name = 'Bells and Horns');

UPDATE SalesLT.Product
SET DiscontinuedDate = GETDATE()
WHERE ProductCategoryID = 37 AND ProductNumber <> 'LT-L123';

```

The Bells and Horns category has not been successful and it must be deleted from the database. Delete the records for the Bells and Horns category and its products. You must ensure that you delete the records from the tables in the correct order to avoid a foreign-key constraint violation.

1.10 Programming with Transact-SQL

We will start looking at procedural logic in this section.

1.10.1 Batches

Batches are sets of commands to SQL Server as a unit. We can separate out elements using the GO command, which will send that batch. GO is not a T-SQL command, it is an interpreter which uses the GO command to send that batch.

1.10.2 Comments

We can add a code block using `/* Comment */` for multiple lines or a comment block, this can come in useful to explain what the code is for or why you are doing something a certain way.

1.10.3 Variables

Variables - usually single scalar values - can be used for many things. We declare the variable, give it a data type, then initialise it with a value if you like, or assign a value later. They are declared using DECLARE ? nvarchar(15)

```
DECLARE @City VARCHAR(20)='Toronto';
```

But rather than declaring a variable's value, we can have a variable which receives something e.g. the results of a select query.

```

DECLARE @Result money
SELECT @Result=MAX(TotalDue)
FROM SalesLT.SalesOrderHeader

PRINT @Result

```

**** Key Points **** A batch defines a group of Transact-SQL commands submitted by a client application for execution. Some commands can only be executed at the start of a new batch, and variable values cannot span batches.

* Use comments to document your Transact-SQL code. Inline comments are prefixed by `--`, and multi-line comment blocks are enclosed in `/*` and `*/`.

Declare variables by using the DECLARE keyword, specifying a name (prefixed with @) and a data type. You can optionally assign an initial value.

* Assign values to variables by using the SET keyword or in a SELECT statement.

1.10.4 Conditional Branching

An IF statement is one such an example, do one thing or something else or indeed nothing. We can go further using IF and ELSE. We can also use this for providing messages, as shown below where we print a message if the row is <1 i.e. it is not found.

It is not necessary to add a BEGIN and END in all cases, but it can be easier to read and helps when possibly expanding the IF list later.

```
UPDATE SalesLT.Product
SET DiscontinuedDate=getdate()
WHERE ProductID=1;

IF @@ROWCOUNT<1
BEGIN
    PRINT 'Product was not found'
END
ELSE
BEGIN
    PRINT 'Product Updated'
END
```

**** Key Points **** * Use the IF keyword to execute a task based on the results of a conditional test.

* Use an ELSE clause if you need to execute an alternative task if the conditional test returns false.

* Enclose multiple statements in an IF or ELSE clause between BEGIN and END keywords.

1.10.5 Looping

Typically in SQL Server we don't want to loop through our data, we work on sets of data, as looping can be slow, so the ideal is to work with sets. A loop will end where a condition (predicate) evaluates to FALSE or unknown. Either we have a BREAK which stops everything or continue, which will move on to the next set of code. So in the example below 5 rows will be affected, as we set the counter as <= 5, adding a row. Looping is best used when you might need to check for something, where we don't know how many times we might need to do something, a situation which is not that common in SQL Server.

```
DECLARE @Counter int=1

WHILE @Counter <=5

BEGIN
    INSERT SalesLT.DemoTable(Description)
    VALUES ('ROW '+CONVERT(varchar(5),@Counter))
    SET @Counter=@Counter+1
END

SELECT Description FROM SalesLT.DemoTable
```

**** Key Points ****

- Use a WHILE loop if you need to repeat one or more statements until a specified condition is true.

- Use BREAK and CONTINUE to exit or restart the loop.
- Avoid using loops to iteratively update or retrieve single records - in most cases, you should use set-based operations to retrieve and modify data.

1.10.6 Stored Procedures

This is encapsulated a block of code in to a named block. They are setup to take parameters as inputs and can use conditional branching (IF ELSE) and other such items. Sounds an awful lot like a function in R. In the example below, if we don't specify a value (the ?) then we run a query which will select all the products (the IF element). If I do specify a category, then return the products in the category (ELSE).

```
CREATE PROCEDURE SalesLT.GetProductsByCategory (@CategoryID INT = NULL)
AS
IF @CategoryID IS NULL
    SELECT ProductID, Name, Color, Size, ListPrice
    FROM SalesLT.Product
ELSE
    SELECT ProductID, Name, Color, Size, ListPrice
    FROM SalesLT.Product
    WHERE ProductCategoryID = @CategoryID;
```

The first time around, the object - the stored procedure - will be created. To use it, we must use an EXEC or EXECUTE (UTE is optional) statement.

```
EXEC SalesLT.GetProductsByCategory
```

If we want to pass a parameter e.g. category 6, we do a similar exercise.

```
EXEC SalesLT.GetProductsByCategory 6
```

**** Key Points **** * Use stored procedures to encapsulate Transact-SQL code in a reusable database objects.
 * You can define parameters for a stored procedure, and use them as variables in the Transact-SQL code it contains.
 * Stored procedures can return rowsets (usually the results of a SELECT statement). They can also return output parameters, and they always return a return value, which is used to indicate status.

1.10.7 Lab Exercises

You want to create reusable scripts that make it easy to insert sales orders. You plan to create a script to insert the order header record, and a separate script to insert order detail records for a specified order header.

Both scripts will make use of variables to make them easy to reuse. Your script to insert an order header must enable users to specify values for the order date, due date, and customer ID.

```
DECLARE @OrderDate datetime = GETDATE();
DECLARE @DueDate datetime = DATEADD(dd, 7, GETDATE());
DECLARE @CustomerID int = 1;

INSERT INTO SalesLT.SalesOrderHeader (OrderDate, DueDate, CustomerID, ShipMethod)
VALUES (@OrderDate, @DueDate, @CustomerID, 'CARGO TRANSPORT 5');

PRINT SCOPE_IDENTITY();
```

As a next step, you want to insert an order detail. The script for this must enable users to specify a sales order ID, a product ID, a quantity, and a unit price.

The script should check if the specified sales order ID exists in the SalesLT.SalesOrderHeader table. This can be done with the EXISTS predicate.

If it does, the code should insert the order details into the SalesLT.SalesOrderDetail table (using default values or NULL for unspecified columns).

If the sales order ID does not exist in the SalesLT.SalesOrderHeader table, the code should print the message ‘The order does not exist’.

```
-- Code from previous exercise
DECLARE @OrderDate datetime = GETDATE();
DECLARE @DueDate datetime = DATEADD(dd, 7, GETDATE());
DECLARE @CustomerID int = 1;
INSERT INTO SalesLT.SalesOrderHeader (OrderDate, DueDate, CustomerID, ShipMethod)
VALUES (@OrderDate, @DueDate, @CustomerID, 'CARGO TRANSPORT 5');
DECLARE @OrderID int = SCOPE_IDENTITY();

-- Additional script to complete
DECLARE @ProductID int = 760;
DECLARE @Quantity int = 1;
DECLARE @UnitPrice money = 782.99;

IF EXISTS (SELECT * FROM SalesLT.SalesOrderDetail WHERE SalesOrderID = @OrderID)
BEGIN
    INSERT INTO SalesLT.SalesOrderDetail (SalesOrderID, OrderQty, ProductID, UnitPrice)
    VALUES (@OrderID, @Quantity, @ProductID, @UnitPrice)
END
ELSE
BEGIN
    PRINT 'The order does not exist'
END
```

Adventure Works has determined that the market average price for a bike is \$2,000, and consumer research has indicated that the maximum price any customer would be likely to pay for a bike is \$5,000.

You must write some Transact-SQL logic that incrementally increases the list price for all bike products by 10% until the average list price for a bike is at least the same as the market average, or until the most expensive bike is priced above the acceptable maximum indicated by the consumer research.

The product categories in the Bikes parent category can be determined from the SalesLT.vGetAllCategories view.

**** Key Points ****

- The loop should execute only if the average list price of a product in the ‘Bikes’ parent category is less than the market average.
- Update all products that are in the ‘Bikes’ parent category, increasing the list price by 10%.
- Determine the new average and maximum selling price for products that are in the ‘Bikes’ parent category.
- If the new maximum price is greater than or equal to the maximum acceptable price, exit the loop; otherwise continue.

```

DECLARE @MarketAverage money = 2000;
DECLARE @MarketMax money = 5000;
DECLARE @AWMax money;
DECLARE @AWAverage money;

SELECT @AWAverage = AVG(ListPrice), @AWMax = MAX(ListPrice)
FROM SalesLT.Product
WHERE ProductCategoryID IN
    (SELECT DISTINCT ProductCategoryID
     FROM SalesLT.vGetAllCategories
     WHERE ParentProductCategoryName = 'Bikes');

WHILE @AWAverage < @MarketAverage
BEGIN
    UPDATE SalesLT.Product
    SET ListPrice = ListPrice * 1.1
    WHERE ProductCategoryID IN
        (SELECT DISTINCT ProductCategoryID
         FROM SalesLT.vGetAllCategories
         WHERE ParentProductCategoryName = 'Bikes');

    SELECT @AWAverage = AVG(ListPrice), @AWMax = MAX(ListPrice)
    FROM SalesLT.Product
    WHERE ProductCategoryID IN
        (SELECT DISTINCT ProductCategoryID
         FROM SalesLT.vGetAllCategories
         WHERE ParentProductCategoryName = 'Bikes');

    IF @AWMax >= @MarketMax
        END
    ELSE
        CONTINUE
END

PRINT 'New average bike price:' + CONVERT(VARCHAR, @AWAverage);
PRINT 'New maximum bike price:' + CONVERT(VARCHAR, @AWMax);

```

1.11 Error Handling and Transactions

You can raise errors yourself because of a condition, and not just some system error. For instance you can introduce business logic, so whilst a transaction in to the database might in principle be ok, you might not see that some business rules are valide i.e. too high of a discount price for instance. You can also pass error mesages back to client applications.

The errors have different levels of severity from 1 to 25 and includes the line number which caused the error. A line with proceedure will state which procedure or sub-proceedure caused the problem. If the error message is particularly high, SQL Server will also udnertake some certain actions to mitigte some of these problems like disconnect from the server if the disk is corrupt. A state is also given, which can be useful when seeking assistance for troubleshooting. Within the database error messages are stored in the sys.messages table in the database and you can add custom messages using sp_addmessage to this table (note this is for SQL Server and not Azure). It is better and more ‘current’ to throw custom error messages within your code, rather than in the db table, and this approach will work with SQL on Azure.

1.11.1 Raising or Throwing Errors

if you wish to raise an error you can do so using the RAISERROR command - this works in both SQL Server and Azure. You can specify the severity and state when doing so.

Another way of raising errors which is newer syntax, it will in time replace RAISERROR, which is THROW. Such user defined errors can only be generated for lower levels of severity, so higher level problems don't cause SQL Server to take mitigating actions like disconnecting the server. The customer error message must be above 50000.

In the following example, the SQL query would run, but we introduce a rule based on business logic which will return an error if no rows are affected by the query. Nothing has failed, but nothing actually happened.

```
UPDATE SalesLT.Product
SET DiscontinuedDate = GETDATE()
WHERE ProductID = 0;

IF @@ROWCOUNT < 1
    RAISERROR('The product was not found - no products have been updated', 16, 0);
```

Or we can use the newer THROW command.

```
UPDATE SalesLT.Product
SET DiscontinuedDate = GETDATE()
WHERE ProductID = 0;

IF @@ROWCOUNT < 1
    THROW 50001, 'The product was not found - no products have been updated', 0;
```

**** Key Points **** System errors have pre-defined numbers, messages, severity levels, and other characteristics that you can use to troubleshoot issues.

* You can use RAISERROR and THROW to raise custom errors.

1.11.2 Catching and Handling Errors

This is sometimes called structured exception handling, where we have a TRY block of code which is something we want to run, then we have a CATCH block of code so that if the TRY code fails we catch and handle that error. We either deal with the error and fix it or throw an error to the compiler. If the TRY block code works, no error will be thrown. There are a number of system global variables we can call for errors depending on what we are trying to catch. We can throw the original message, or we can throw a custom error.

In the first example below, we update the product table using the ProductNumber as ProductID divided by the weight. If the weight is missing, we add 0 in to the divide, which is likely to cause problems since this divides by infinity. If something does go wrong, we will print an error message of what occurred. No red error text will occur, since the application is correctly running - the error is captured by the code.

```
BEGIN TRY
    UPDATE SalesLT.Product
    SET ProductNumber = ProductID / ISNULL(Weight, 0);
END TRY
BEGIN CATCH
    PRINT 'The following error occurred: ';
    PRINT ERROR_MESSAGE();
END CATCH;
```


Table 1.108: Displaying records 1 - 10

ErrorLogID	ErrorTime	UserName	ErrorNumber	ErrorSeverity	ErrorState	ErrorProcedure	ErrorLin
1	2018-03-14 12:16:08	dbo	8134	16	1	NA	
2	2018-03-16 13:25:48	dbo	8134	16	1	NA	
3	2018-03-16 13:27:24	dbo	8134	16	1	NA	
4	2018-03-16 13:27:33	dbo	8134	16	1	NA	
5	2018-03-16 13:27:50	dbo	8134	16	1	NA	
6	2018-03-23 04:03:28	dbo	8134	16	1	NA	
7	2018-03-23 04:08:49	dbo	8134	16	1	NA	
8	2018-03-23 04:20:56	dbo	8134	16	1	NA	
9	2018-03-23 04:21:37	dbo	8134	16	1	NA	
10	2018-03-23 04:22:19	dbo	8134	16	1	NA	

Another approach is to return the error to the application, so that it can do its own error handling. Here we re THROW the error back to the client application. This time the error will be returned in red as an error.

```
BEGIN TRY
    UPDATE SalesLT.Product
    SET ProductNumber = ProductID / ISNULL(Weight, 0);
END TRY
BEGIN CATCH
    PRINT 'The following error occurred: ';
    PRINT ERROR_MESSAGE();
    THROW;
END CATCH;
```

Anotehr more advanced way would be to create some variables in the CATCH block and use a stored procedure in the database. This stored procedure will store the error in to an error log table and throws that error back to the stored procedure. This means you can transport the stored procedure across different databases without having to re-write code and still have a consistent way to handle errors.

```
BEGIN TRY
    UPDATE SalesLT.Product
    SET ProductNumber = ProductID / ISNULL(Weight, 0);
END TRY
BEGIN CATCH
    DECLARE @ErrorLogID as int, @ErrorMsg AS varchar(250);
    EXECUTE dbo.uspLogError @ErrorLogID OUTPUT;
    SET @ErrorMsg = 'The update failed because of an error. View error #'
        + CAST(@ErrorLogID AS varchar)
        + ' in the error log for details.';
    THROW 50001, @ErrorMsg, 0;
END CATCH;
```

Then we can view the error log if we want.

```
SELECT * FROM dbo.ErrorLog;
```

**** Key Points **** Use TRY...CATCH blocks in your Transact-SQL code to catch and handle exceptions.
 * A common exception handling pattern is to log the error, and then if the operation cannot be completed successfully, throw it (or a new custom error) to the calling application.

1.11.3 Transactions

We are concerned about protecting the integrity of the database. A transaction is a group of tasks, possibly inserting in to multiple tables. A transaction can be ACID

- Atomic - one unit of work that everythign contributes towards, you can split it up in to sepearte parts
- Consistent - when the transaction is finished, there won't be any orphaned records or rows
- Isolated - whilst that transaction is happening, other transactions or queries are not effected, they won't get to see the in flight data
- Durable - one finished the data will be stored in the database unless we explicity DELETE it

A transaction must either fully succeed or wholly fail, we cannot have a partial succeed. So for instance if we add a new order, we might add summary info in to a order header table then all the prodcuts into the order detail table. We don't want half of this to work - just inserts in to one table - the whole thing, the transaction, must take place for it to be successful. If for some reason it something doesn't work, perhaps as a consequence for a system fail or network issue, we want the operation to fail not partially succeed or complete. SQL Server will handle this by itself, you don't need to add any transaction error codes or error handling, it will lock or isolate the data as required.

However, if there are multiple statements that you want to execute, it is best done as an encapsulated transaction explicitly. This is done by BEGIN TRANSACTION then COMMIT TRANSACTION if there is an error will can throw an error and use ROLLBACK TRANSACTION. These can be nexted TRANSAC-TIONS which can get complicated. If you ROLLBACK it will ROLLBACK right back to the beggining - so it is Atomic and Consistent. Rather than use ROLLBACK you can use XACT_ABORT which will rollback all transactions if an error is encountered.

So if we had some code as shown below, this would lead to a record being adding to the order header, but no details being added to the product table, since the product we are trying to add (ProductID 9999) does not exist. This would lead to an orphaned sales order header.

```
BEGIN TRY
    INSERT INTO SalesLT.SalesOrderHeader (DueDate, CustomerID, ShipMethod)
    VALUES
    (DATEADD(dd, 7, GETDATE()), 1, 'STD DELIVERY');

    DECLARE @SalesOrderID int = SCOPE_IDENTITY();

    INSERT INTO SalesLT.SalesOrderDetail (SalesOrderID, OrderQty, ProductID, UnitPrice, UnitPriceDiscount)
    VALUES
    (@SalesOrderID, 1, 99999, 1431.50, 0.00);
END TRY
BEGIN CATCH
    PRINT ERROR_MESSAGE();
END CATCH;
```

So we want to add this code within a single transaction, so if one part fails the whole thing will. In this instance it wil try to do both parts individually, but the whole thing will fail as the second part - adding in an invalid productID - fails. So in effect it will undo the transaction - the first part which succeeds adding the order header. If you have many rows, this can therefore be time consuming as it might try to add 10,000 rows, then fails at a later stage, then has to go back and undo all those 10,000 rows. So you may want to add some logic at the beggining of the transaction, before this addition and error followed by rollback occurs.

```
BEGIN TRY
    BEGIN TRANSACTION
    INSERT INTO SalesLT.SalesOrderHeader (DueDate, CustomerID, ShipMethod)
```

```

VALUES
  (DATEADD(dd, 7, GETDATE()), 1, 'STD DELIVERY');

DECLARE @SalesOrderID int = SCOPE_IDENTITY();

INSERT INTO SalesLT.SalesOrderDetail (SalesOrderID, OrderQty, ProductID, UnitPrice, UnitPriceDiscount)
VALUES
  (@SalesOrderID, 1, 99999, 1431.50, 0.00);
COMMIT TRANSACTION
END TRY
BEGIN CATCH
  IF @@TRANCOUNT > 0
  BEGIN
    PRINT XACT_STATE();
    ROLLBACK TRANSACTION;
  END
  PRINT ERROR_MESSAGE();
  THROW 50001, 'An insert failed. The transaction was cancelled.', 0;
END CATCH;

```

As previously discussed, we can use XACT_ABORT rather than ROLLBACK. Again we might want to add some logic at the beginning to check for validity before adding and undoing multiple

```

SET XACT_ABORT ON;
BEGIN TRY
  BEGIN TRANSACTION
    INSERT INTO SalesLT.SalesOrderHeader (DueDate, CustomerID, ShipMethod)
    VALUES
      (DATEADD(dd, 7, GETDATE()), 1, 'STD DELIVERY');

    DECLARE @SalesOrderID int = SCOPE_IDENTITY();

    INSERT INTO SalesLT.SalesOrderDetail (SalesOrderID, OrderQty, ProductID, UnitPrice, UnitPriceDiscount)
    VALUES
      (@SalesOrderID, 1, 99999, 1431.50, 0.00);
  COMMIT TRANSACTION
END TRY
BEGIN CATCH
  PRINT ERROR_MESSAGE();
  THROW 50001, 'An insert failed. The transaction was cancelled.', 0;
END CATCH;
SET XACT_ABORT OFF;

```

- ** Key Points ****
- * Transactions are used to protect data integrity by ensuring that all data changes within a transaction succeed or fail as a unit.
 - * Individual Transact-SQL statements are inherently treated as transactions, and you can define explicit transactions that encompass multiple statements.
 - * Use the BEGIN TRANSACTION, COMMIT TRANSACTION, and ROLLBACK TRANSACTION statements to manage transactions.
 - * Enable the XACT_ABORT option to automatically rollback all transactions if an exception occurs.
 - * Use the @@ system variable and XACT_STATE system function to determine transaction status.

1.11.4 Lab Exercises

You are implementing a Transact-SQL script to delete orders, and you want to handle any errors that occur during the deletion process.

```
DECLARE @OrderID int = 0

-- Declare a custom error if the specified order doesn't exist
DECLARE @error VARCHAR(25) = 'Order #' + cast(@OrderID as VARCHAR) + ' does not exist';

IF NOT NULL (SELECT * FROM SalesLT.SalesOrderHeader WHERE SalesOrderID = @OrderID)
BEGIN
    THROW 50001, @error, 0;
END
ELSE
BEGIN
    SELECT FROM SalesLT.SalesOrderDetail WHERE SalesOrderID = @OrderID;
    DELETE FROM SalesLT.SalesOrderHeader WHERE SalesOrderID = @OrderID;
END
```

Now your code now throws an error if the specified order does not exist. Refine your code to catch this (or any other) error and print the error message to the user interface using the PRINT command. You can use BEGIN TRY, END TRY, BEGIN CATCH and END CATCH for this.

```
DECLARE @OrderID int = 71774
DECLARE @error VARCHAR(25) = 'Order #' + cast(@OrderID as VARCHAR) + ' does not exist';

-- Wrap IF ELSE in a TRY block
TRY CATCH
    IF NOT EXISTS (SELECT * FROM SalesLT.SalesOrderHeader WHERE SalesOrderID = @OrderID)
    BEGIN
        THROW 50001, @error, 0
    END
    ELSE
    BEGIN
        DELETE FROM SalesLT.SalesOrderDetail WHERE SalesOrderID = @OrderID;
        DELETE FROM SalesLT.SalesOrderHeader WHERE SalesOrderID = @OrderID;
    END
END CATCH
-- Add a CATCH block to print out the error
BEGIN CATCH
    PRINT ERROR_MESSAGE();
END CATCH
```

You have implemented error handling logic in some Transact-SQL code that deletes order details and order headers. However, you are concerned that a failure partway through the process will result in data inconsistency in the form of undeleted order headers for which the order details have been deleted.

Your task is to enhance the code you created in the previous challenge so that the two DELETE statements are treated as a single transactional unit of work.

```
DECLARE @OrderID int = 0
DECLARE @error VARCHAR(25) = 'Order #' + cast(@OrderID as VARCHAR) + ' does not exist';

BEGIN TRY
    IF NOT EXISTS (SELECT * FROM SalesLT.SalesOrderHeader WHERE SalesOrderID = @OrderID)
    BEGIN
```

```

        THROW 50001, @error, 0
    END
    ELSE
    BEGIN
        BEGIN TRANSACTION
        DELETE FROM SalesLT.SalesOrderDetail
        WHERE SalesOrderID = @OrderID;
        DELETE FROM SalesLT.SalesOrderHeader
        WHERE SalesOrderID = @OrderID;
        END TRANSACTION
    END
END TRY
BEGIN CATCH
    IF @@TRANCOUNT > 0
    BEGIN
        ROLLBACK TRANSACTION;
    END
    ELSE
    BEGIN
        PRINT ERROR_MESSAGE();
    END
END CATCH

```

1.12 Final Assessment

1.12.1 Section 1

Select the quantity per unit for all products in the Products table.

```

SELECT QuantityPerUnit
FROM Products;

```

Select the unique category IDs from the Products table.

```

SELECT DISTINCT CategoryID
FROM Products;

```

Select the names of products from the Products table which have more than 20 units left in stock.

```

SELECT ProductName
FROM Products
WHERE UnitsInStock > 20;

```

Select the product ID, product name, and unit price of the 10 most expensive products from the Products table.

```

SELECT TOP (10) ProductID, ProductName, UnitPrice
FROM Products
ORDER BY UnitPrice DESC;

```

Select the product ID, product name, and quantity per unit for all products in the Products table. Sort your results alphabetically by product name.

```

SELECT ProductID, ProductName, QuantityPerUnit
FROM Products

```

```
ORDER BY ProductName;
```

Select the product ID, product name, and unit price of all products in the Products table. Sort your results by number of units in stock, from greatest to least.

Skip the first 10 results and get the next 5 after that.

```
SELECT ProductID, ProductName, UnitPrice
FROM Products
ORDER BY UnitsInStock DESC
OFFSET 10 ROWS FETCH NEXT 5 ROWS ONLY;
```

Use STR, CONVERT, and NVARCHAR(30) where appropriate to display the first name, employee ID and birthdate (as Unicode in ISO 8601 format) for each employee in the Employees table.

```
SELECT FirstName + ' has an EmployeeID of ' + STR(EmployeeID, 1) + ' and was born ' +
       CONVERT(NVARCHAR(30), BirthDate, 126)
FROM Employees;
```

Select from the Orders table.

The first column of your result should be a single string in exactly the following format:

<> is from <>

If there is no ShipCity, then you should select ShipRegion, and if there is no ShipRegion you should select ShipCountry.

```
SELECT ShipName + ' is from ' +
       CASE
         WHEN ShipCity IS NULL THEN 'ShipRegion'
         ELSE ShipCity
       END
FROM Orders;
```

The above works, but doesn't properly handle ShipCountry, a better option is to use the COALESCE which returns the first non-null value. The AS destination is optional, if not specified the column will not have a title.

```
SELECT
ShipName + ' is from ' +
       COALESCE(ShipCity, ShipRegion, ShipCountry) AS destination
FROM Orders;
```

Select the ship name and ship postal code from the Orders table. If the postal code is missing, display 'unknown'. The following answer may be different for other dbs or flavours of SQL.

```
SELECT ShipName, ISNULL(ShipPostalCode, 'unknown')
FROM Orders;
```

Using the Suppliers table, select the company name, and use a simple CASE expression to display 'outdated' if the company has a fax number, or 'modern' if it doesn't.

```
SELECT CompanyName,
       CASE
         WHEN Fax IS NOT NULL THEN 'outdated'
         ELSE 'modern'
       END AS Status
FROM Suppliers;
```

1.12.2 Section 2

Get the order ID and unit price for each order by joining the Orders table and the Order Details table. Note that you need to use [Order Details] since the table name contains whitespace.

```
SELECT o.OrderID, od.UnitPrice
FROM Orders AS o
INNER JOIN [Order Details] AS od
ON o.OrderID = od.OrderID;
```

Get the order ID and first name of the associated employee by joining the Orders and Employees tables.

```
SELECT o.OrderID, e.FirstName
FROM Orders AS o
INNER JOIN Employees as e
ON o.EmployeeID = e.EmployeeID;
```

Get the employee ID and related territory description for each territory an employee is in, by joining the Employees, EmployeeTerritories and Territories tables.

```
SELECT e.EmployeeID, t.TerritoryDescription
FROM Employees AS e
INNER JOIN EmployeeTerritories AS et
ON e.EmployeeID = et.EmployeeID
INNER JOIN Territories AS t
ON et.TerritoryID = t.TerritoryID;
```

Select all the different countries from the Customers table and the Suppliers table using UNION.

```
SELECT Country
FROM Customers
UNION
SELECT Country
FROM Suppliers
ORDER BY Country;
```

Select all the countries, including duplicates, from the Customers table and the Suppliers table using UNION ALL.

```
SELECT Country
FROM Customers
UNION ALL
SELECT Country
FROM Suppliers
ORDER BY Country;
```

Using the Products table, get the unit price of each product, rounded to the nearest dollar.

```
SELECT ROUND(UnitPrice, 0)
FROM Products;
```

Using the Products table, get the total number of units in stock across all products.

```
SELECT SUM(UnitsInStock)
FROM Products;
```

Using the Orders table, get the order ID and year of the order by using YEAR(). Alias the year as OrderYear.

```
SELECT OrderID, YEAR(OrderDate) AS OrderYear
FROM Orders;
```

Using the Orders table, get the order ID and month of the order by using DATENAME(). Alias the month as OrderMonth.

```
SELECT OrderID, DATENAME(mm, OrderDate) AS OrderMonth
FROM Orders;
```

Use LEFT() to get the first two letters of each region description from the Region table.

```
SELECT LEFT(RegionDescription, 2)
FROM Region;
```

Using the Suppliers table, select the city and postal code for each supplier, using WHERE and ISNUMERIC() to select only those postal codes which have no letters in them.

```
SELECT City, PostalCode
FROM Suppliers
WHERE ISNUMERIC(PostalCode) = 1;
```

Use LEFT() and UPPER() to get the first letter (capitalized) of each region description from the Region table.

```
SELECT UPPER(LEFT(RegionDescription, 1))
FROM Region;
```

1.12.3 Section 3

Use a subquery to get the product name and unit price of products from the Products table which have a unit price greater than the average unit price from the Order Details table.

Note that you need to use [Order Details] since the table name contains whitespace.

```
SELECT ProductName, UnitPrice
FROM Products
WHERE UnitPrice >
  (SELECT AVG(UnitPrice)
   FROM [Order Details]);
```

Select from the Employees and Orders tables. Use a subquery to get the first name and employee ID for employees who were associated with orders which shipped from the USA.

```
SELECT FirstName, EmployeeID
FROM Employees
WHERE EmployeeID IN
  (SELECT DISTINCT(EmployeeID)
   FROM Orders
   WHERE ShipCountry = 'USA');
```

Create a new temporary table called ProductNames which has one field called ProductName (a VARCHAR of max length 40). Insert into this table the names of every product from the Products table. Select all columns from the ProductNames table you created.

```
CREATE TABLE #ProductNames
(ProductName VARCHAR(40))

INSERT INTO #ProductNames
SELECT ProductName
FROM Products
```



```
SELECT *
FROM #ProductNames;
```

1.12.4 Section 4

Use CHOOSE() and MONTH() to get the season in which each order was shipped from the Orders table. You should select the order ID, shipped date, and then the season aliased as ShippedSeason. Be careful to filter out any NULL shipped dates.

```
SELECT OrderID, ShippedDate,
       CHOOSE (MONTH(ShippedDate), 'Winter', 'Winter', 'Spring', 'Spring', 'Spring', 'Summer', 'Summer', 'Summer', 'Summer') AS ShippedSeason
FROM Orders
WHERE ShippedDate IS NOT NULL;
```

Using the Suppliers table, select the company name and use a simple IIF expression to display ‘outdated’ if a company has a fax number, or ‘modern’ if it doesn’t. Alias the result of the IIF expression to Status.

```
SELECT CompanyName,
       IIF(FAX IS NOT NULL, 'outdated', 'modern') AS Status
FROM Suppliers;
```

Select from the Customers, Orders, and Order Details tables. Note that you need to use [Order Details] since the table name contains whitespace.

Use GROUP BY and ROLLUP() to get the total quantity ordered by all countries, while maintaining the total per country in your result set.

Your first column should be the country, and the second column the total quantity ordered by that country, aliased as TotalQuantity.

```
SELECT c.Country, SUM(od.Quantity) AS TotalQuantity
FROM Customers AS c
JOIN Orders AS o
ON c.CustomerID = o.CustomerID
JOIN [Order Details] AS od
ON o.OrderID = od.OrderID
GROUP BY ROLLUP (c.Country);
```

From the Customers table, use GROUP BY to select the country, contact title, and count of that contact title aliased as Count, grouped by country and contact title (in that order).

Then use CASE WHEN, GROUPING_ID(), and ROLLUP() to add a column called Legend, which shows one of two things:

When the GROUPING_ID is 0, show ‘’ (i.e., nothing) When the GROUPING_ID is 1, show Subtotal for << Country >>’

```
SELECT Country, ContactTitle, COUNT(ContactTitle) AS Count,
       CASE
         WHEN GROUPING_ID(Country, ContactTitle) = 0 THEN ''
         WHEN GROUPING_ID(Country, ContactTitle) = 1 THEN 'Subtotal for ' + Country
       END AS Legend
FROM Customers
GROUP BY ROLLUP (Country, ContactTitle);
```

Convert the following query to be pivoted, using PIVOT().

```
SELECT CategoryID, AVG(UnitPrice) FROM Products GROUP BY CategoryID;
```

Note the first part of the answer defines the item that appears in the row, the second ‘Per Category’ is the table title.

```
SELECT 'Average Unit Price' AS 'Per Category',
[1], [2], [3], [4], [5], [6], [7], [8]
FROM
(
    SELECT CategoryID, UnitPrice
    FROM Products)
    AS SourceTable
PIVOT
(
    AVG(UnitPrice)
    FOR CategoryID IN ([1], [2], [3], [4], [5], [6], [7], [8]))
    AS PivotTable;
```

So we go from long to wide format as illustrated below.

Insert into the Region table the region ID 5 and the description ‘Space’.

Then, in a second query, select the newly inserted data from the table using a WHERE clause.

```
INSERT INTO Region
VALUES
(5, 'Space');

SELECT *
FROM Region
WHERE RegionID = 5;
```

Update the region descriptions in the Region table to be all uppercase, using SET and UPPER().

Next, select all data from the table to view your updates.

```
UPDATE Region
SET RegionDescription = UPPER(RegionDescription);

SELECT *
FROM Region;
```

Declare a custom region ? called ‘Space’, of type NVARCHAR(25).

Use IF NOT EXISTS, ELSE, and BEGIN..END to throw an error message ‘Error!’ if ? is not in the Region table. Do this check using SELECT *.

If the specified description does exist, you should select all columns for that region from the Region table.

```
DECLARE @region AS NVARCHAR(25) = 'Space';

TRY CATCH
IF NOT EXISTS (SELECT * FROM Region WHERE RegionDescription = @region)
    BEGIN
        PRINT 'Error!'
    END
ELSE
    BEGIN
        SELECT * FROM Region;
    END
END CATCH;
```

```
SELECT CategoryID, AVG(UnitPrice) AS AvgUnitPrice
FROM Products
GROUP BY CategoryID;
```

CategoryID	AvgUnitPrice
1	37.98
2	23.06
3	25.16
4	28.73
5	20.25
6	54.01
7	32.37
8	20.68



```
SELECT 'Average Unit Price' AS 'Per Category',
[1], [2], [3], [4], [5], [6], [7], [8]
FROM
(
    SELECT CategoryID, UnitPrice
    FROM Products)
AS SourceTable
PIVOT
(
    AVG(UnitPrice)
    FOR CategoryID IN ([1], [2], [3], [4], [5], [6], [7], [8]))
AS PivotTable;
```

Per Category	1	2	3	4	5
Average Unit Price	37.98	23.06	25.16	28.73	20.25

Figure 1.3: Pivot Answer Section 4 Question 5

(#fig:Pivot Answer)

Chapter 2

Supervised Learning In R Classification

Notes taken during/inspired by the DataCamp course ‘Supervised Learning In R Classification’ by Brett Lantz.

Course Handouts

- Part 1 - k-Nearest Neighbors (kNN)
- Part 2 - Naive Bayes
- Part 3 - Logistic Regression
- Part 4 - Classification Trees

Other useful links * Introduction to Tree Based Methods from ISL

2.1 k-Nearest Neighbors (kNN)

Machine Learning uses computers to turn data in to insight and action. This course looks at supervised learning, where we train the machine to learn from prior examples. When the concept to be learned is a set of categories, the objective is classification. In autonomous driving, we may want our car to undertake some action, like brake, when certain roads signs are observed. After a period of time observing a drivers behaviour, the computer will build a database of signs and appropriate responses. Some if one stop sign is observed, it will try and place where this sign is in relation to other signs it has seen before, then determine what type or class the sign is and do the appropriate action.

To do this, it calculates the distance between the new sign and past signs, using co-ordinates in feature space. For instance, signs could be classified in three dimensions using RGB, then signs of a similar colour will be located together. Distance is then measured based on the signs location in the co-ordinate space. We could for instance measure Euclidean distance, which is used by many NN algorithms, and can be done in R using the knn function.

First let us load the data.

```
# Load the signs data
traffic_signs <- read.csv("../files/SLinRClassification/knn_traffic_signs.csv", stringsAsFactors = FALSE)
signs <- subset(traffic_signs, sample == "train")
signs$id <- NULL
signs$sample <- NULL
```

```

signs_test <- subset(traffic_signs, sample == "test")
signs_test$id <- NULL
signs_test$sample <- NULL

library(class)
next_sign <- signs[146,]
signs      <- signs[1:145,]
sign_types <- signs$sign_type
signs_actual <- signs_test$sign_type
rm(traffic_signs)

#Load the locations and where9am data
locations <- read.csv("./files/SLinRClassification/locations.csv", stringsAsFactors = FALSE)
where9am <- subset(locations, hour == 9)

```

After several trips with a human behind the wheel, it is time for the self-driving car to attempt the test course alone.

As it begins to drive away, its camera captures an image. Let's write some code so that a kNN classifier helps the car recognize the sign.

```

# Load the 'class' package
library(class)

# Create a vector of labels
sign_types <- signs$sign_type

# Classify the next sign observed - the first column of the signs dataset is removed as the class is sp
knn(train = signs[-1], test = next_sign, cl = sign_types)

```

Each previously observed street sign was divided into a 4x4 grid, and the red, green, and blue level for each of the 16 center pixels is recorded. The result is a dataset that records the sign_type as well as $16 \times 3 = 48$ color properties of each sign.

```

# Examine the structure of the signs dataset
str(signs)

```

```

## 'data.frame':   145 obs. of  49 variables:
## $ sign_type: chr  "pedestrian" "pedestrian" "pedestrian" "pedestrian" ...
## $ r1      : int   155 142 57 22 169 75 136 149 13 123 ...
## $ g1      : int   228 217 54 35 179 67 149 225 34 124 ...
## $ b1      : int   251 242 50 41 170 60 157 241 28 107 ...
## $ r2      : int   135 166 187 171 231 131 200 34 5 83 ...
## $ g2      : int   188 204 201 178 254 89 203 45 21 61 ...
## $ b2      : int   101 44 68 26 27 53 107 1 11 26 ...
## $ r3      : int   156 142 51 19 97 214 150 155 123 116 ...
## $ g3      : int   227 217 51 27 107 144 167 226 154 124 ...
## $ b3      : int   245 242 45 29 99 75 134 238 140 115 ...
## $ r4      : int   145 147 59 19 123 156 171 147 21 67 ...
## $ g4      : int   211 219 62 27 147 169 218 222 46 67 ...
## $ b4      : int   228 242 65 29 152 190 252 242 41 52 ...
## $ r5      : int   166 164 156 42 221 67 171 170 36 70 ...
## $ g5      : int   233 228 171 37 236 50 158 191 60 53 ...
## $ b5      : int   245 229 50 3 117 36 108 113 26 26 ...
## $ r6      : int   212 84 254 217 205 37 157 26 75 26 ...
## $ g6      : int   254 116 255 228 225 36 186 37 108 26 ...

```

```
## $ b6      : int  52 17 36 19 80 42 11 12 44 21 ...
## $ r7      : int  212 217 211 221 235 44 26 34 13 52 ...
## $ g7      : int  254 254 226 235 254 42 35 45 27 45 ...
## $ b7      : int  11 26 70 20 60 44 10 19 25 27 ...
## $ r8      : int  188 155 78 181 90 192 180 221 133 117 ...
## $ g8      : int  229 203 73 183 110 131 211 249 163 109 ...
## $ b8      : int  117 128 64 73 9 73 236 184 126 83 ...
## $ r9      : int  170 213 220 237 216 123 129 226 83 110 ...
## $ g9      : int  216 253 234 234 236 74 109 246 125 74 ...
## $ b9      : int  120 51 59 44 66 22 73 59 19 12 ...
## $ r10     : int  211 217 254 251 229 36 161 30 13 98 ...
## $ g10     : int  254 255 255 254 255 34 190 40 27 70 ...
## $ b10     : int  3 21 51 2 12 37 10 34 25 26 ...
## $ r11     : int  212 217 253 235 235 44 161 34 9 20 ...
## $ g11     : int  254 255 255 243 254 42 190 44 23 21 ...
## $ b11     : int  19 21 44 12 60 44 6 35 18 20 ...
## $ r12     : int  172 158 66 19 163 197 187 241 85 113 ...
## $ g12     : int  235 225 68 27 168 114 215 255 128 76 ...
## $ b12     : int  244 237 68 29 152 21 236 54 21 14 ...
## $ r13     : int  172 164 69 20 124 171 141 205 83 106 ...
## $ g13     : int  235 227 65 29 117 102 142 229 125 69 ...
## $ b13     : int  244 237 59 34 91 26 140 46 19 9 ...
## $ r14     : int  172 182 76 64 188 197 189 226 85 102 ...
## $ g14     : int  228 228 84 61 205 114 171 246 128 67 ...
## $ b14     : int  235 143 22 4 78 21 140 59 21 6 ...
## $ r15     : int  177 171 82 211 125 123 214 235 85 106 ...
## $ g15     : int  235 228 93 222 147 74 221 252 128 69 ...
## $ b15     : int  244 196 17 78 20 22 201 67 21 9 ...
## $ r16     : int  22 164 58 19 160 180 188 237 83 43 ...
## $ g16     : int  52 227 60 27 183 107 211 254 125 29 ...
## $ b16     : int  53 237 60 29 187 26 227 53 19 11 ...
```

```
# Count the number of signs of each type
```

```
table(signs$sign_type)
```

```
##
## pedestrian      speed      stop
##           46           49           50
```

```
# Check r10's average red level by sign type
```

```
aggregate(r10 ~ sign_type, data = signs, mean)
```

```
##   sign_type      r10
## 1 pedestrian 113.71739
## 2    speed   80.63265
## 3    stop   131.98000
```

Next we want to try and see how well the predict signs match the actual signs classified by a human. We will also create a confusion matrix to see where it worked and a accuracy measure.

```
# Use kNN to identify the test road signs
```

```
sign_types <- signs$sign_type
```

```
signs_pred <- knn(train = signs[-1], test = test_signs[-1], cl = sign_types)
```

```
# Create a confusion matrix of the actual versus predicted values
```

```
signs_actual <- test_signs$sign_type
```

```
table(signs_pred, signs_actual)

# Compute the accuracy
mean(signs_pred == signs_actual)
```

When we use kNN, the K signifies the number of neighbours to consider when making the classification. Unless specified, R will use $k = 1$ i.e. it will only consider the nearest neighbour. However, as other elements, such as road sign background and lighting, might cause an incorrect road sign to be the nearest based on such factors, this can cause problems. If we use a greater value for K, there is in effect a vote from the nearest neighbours (k) on which sign is the most likely. In the case of a tie, the winner is typically set by random. Setting a high value for K isn't always the best approach, as it can introduce noise in to a pattern. Setting a low value for k might enable it to identify more subtle patterns, but may lead to overfitting and errors.

*** Some people suggest setting K to the square root of the number of observations in the training data *** So if we observed 100 road signs, we would set k to 10. A better approach would be to set k to multiple values, then run the model against some unseen (test) data and see how it performs.

In the following example we set $k = 1$ (default), 7 then 15 and compare the levels of accuracy.

```
# Compute the accuracy of the baseline model (default k = 1)
k_1 <- knn(train = signs[, -1], test = signs_test[, -1], cl = signs[, 1])
mean(k_1 == signs_actual)

# Modify the above to set k = 7
k_7 <- knn(train = signs[, -1], test = signs_test[, -1], cl = signs[, 1], k = 7)
mean(k_7 == signs_actual)

# Set k = 15 and compare to the above
k_15 <- knn(train = signs[, -1], test = signs_test[, -1], cl = signs[, 1], k = 15)
mean(k_15 == signs_actual)
```

$K = 7$ gives the highest level of accuracy.

When multiple nearest neighbors hold a vote, it can sometimes be useful to examine whether the voters were unanimous or widely separated. There is an option we can set using `prob = TRUE` parameter to compute the vote proportions for a kNN model.

```
# Use the prob parameter to get the proportion of votes for the winning class
sign_pred <- knn(train = signs[, -1], test = signs_test[, -1], cl = signs[, 1], k = 7, prob = TRUE)

# Get the "prob" attribute from the predicted classes
sign_prob <- attr(sign_pred, "prob")

# Examine the first several predictions
head(sign_pred)

# Examine the proportion of votes for the winning class
head(sign_prob)
```

kNN models calculate distance, therefore kNN assumes the data is in numeric format e.g. we don't have yellow we have RGB values. If something cannot be easily converted to a numeric, we can create dummy variables e.g. to indicate the shape such as `triangle = 1`, `square = 0`, `circle = 0` might be for one particular sign. This dummy set of vars can then be used in distance calculations.

When we then introduce another variable - the original RGB 0-255 and shape 0-1 - we can have problems as they are on different scales. The variables with a larger scale can have a disproportionate effect on the

calculation of distance, therefore we need to normalise the data. So we change our RGB vlues to go in to the range of 0 to 1. To do this you could create a function yourself, or use one which is included in some packages like caret.

2.2 Naive Bayes

Bayes proposed rules for estimating probabilities in light of historic data. This section will look at applying these methods to phone data to help forecast action. We take the number of times and event happened / all possible events (how many times it could of occurred). But we should also incorporate other variables, like time of day, to give a single probability estimate. This therefore becomes the joint probability $P(A \text{ and } B)$ e.g. $P(\text{work and evening}) = 1\%$, $P(\text{work and afternoon}) = 20\%$.

We also have the conditional probability $P(A|B) = P(A \text{ and } B) / P(B) = P(\text{work} | \text{evening}) = 1/25 = 4\%$ or $P(\text{work} | \text{afternoon}) = 20/25 = 80\%$. WE can do these calculations using the the naive Bayes package in R.

The where9am data frame contains 91 days (thirteen weeks) worth of data in which Brett recorded his location at 9am each day as well as whether the daytype was a weekend or weekday.

```
# Compute P(A)
p_A <- nrow(subset(where9am, location == 'office')) / nrow(where9am)

# Compute P(B)
p_B <- nrow(subset(where9am, daytype == 'weekday')) / nrow(where9am)

# Compute the observed P(A and B)
p_AB <- nrow(subset(where9am, location == 'office' & daytype == 'weekday')) / nrow(where9am)

# Compute then print P(A | B)
p_A_given_B <- p_AB / p_B
p_A_given_B
```

```
## [1] 0.6
```

Next we can use th naive bayes model to predict Brett's location and two different times and days - 9am on a Thursday and 9 am on a Saturday.

```
# Setup our variables for prediction
days <- data.frame(daytype = factor(c("weekday","weekend")))
thursday9am <- subset(days, daytype == 'weekday')
saturday9am <- subset(days, daytype == 'weekend')

# Load the naive Bayes package
library(naive Bayes)
```

```
## Warning: package 'naive Bayes' was built under R version 3.4.3
```

```
# Build the location prediction model
locmodel <- naive_bayes(location ~ daytype, data = where9am)

# Predict Thursday's 9am location
predict(locmodel, thursday9am)
```

```
## [1] office
## Levels: appointment campus home office
```

```
# Predict Saturdays's 9am location
predict(locmodel, saturday9am)
```

```
## [1] home
## Levels: appointment campus home office
```

Brett is most likely at the office at 9am on a Thursday, but at home at the same time on a Saturday. Note that the structure of the variables and their levels matter, for instance if we had a factor variable with just one level and not all possible levels e.g. saturday9am with a daytype of weekend but a factor variable with only the level observed (weekend) and not including the other possibility of weekday in the factor levels, we would get a different result - a result of office. So data structure is important.

We can examine the *a priori* (overall) probabilities just by examining the model and some of its sub-components.

```
locmodel$tables$daytype
```

```
##
## daytype  appointment      campus      home      office
## weekday    1.0000000  1.0000000  0.3658537  1.0000000
## weekend      0.0000000  0.0000000  0.6341463  0.0000000
```

```
locmodel$prior
```

```
##
## appointment      campus      home      office
## 0.01098901  0.10989011  0.45054945  0.42857143
```

We can then compare these probabilities to those we obtain when using a model.

```
# Obtain the predicted probabilities for Thursday at 9am
predict(locmodel, thursday9am, type = "prob")
```

```
##      appointment      campus      home office
## [1,] 0.01538462 0.1538462 0.2307692    0.6
```

```
# Obtain the predicted probabilities for Saturday at 9am
predict(locmodel, saturday9am, type = "prob")
```

```
##      appointment campus home office
## [1,]          0      0      1      0
```

So on a Saturday there is 0% chance Brett is at the office and a 100% chance he is at home.

In Bayesian statistics, we say that independent events occur when knowing the outcome of one event does not help predict the other. For example, knowing if it's raining in London doesn't help you predict the weather in Manchester. The weather events in the two cities are independent of each other.

2.2.1 Putting the Naivety in Naive Bayes

With simple conditions where we have one predictor, daytime of the week, the conditional probability is based on the overlap between the two events. As we add more events, the degree of overlap illustrated through Venn diagrams can become complex and messy. The computer will find it inefficient to calculate the overlap, so the computer uses a shortcut to calculate the conditional probability we hope to compute.

Instead of looking for the intersection between all possible events, the computer will make a naive assumption about the data, it assumes that the events are independent. When this occurs, the joint probability can be calculated by multiplying the individual probabilities. So simpler calculations can be performed based on limited intersections multiplied together.

One of the problems with this approach is that when an event has not been previously observed - such as going to work on a weekend - we immediately get calculation problems, since this individual probability is zero, so the results become zero despite how many other conditions in the calculation may be likely. The solution is to add a small amount, such as 1%, to all the individual components - we call this the Laplace correction. So there will be at least some predicted probability, even if it has never been seen before.

Next we will build a more complicated model using the locations data, which is similar to the where9am data but contains 24hours of data recorded at hourly intervals over 13 weeks and also contains other variables such as hour type.

```
head(locations, n = 10)
```

```
##      month day  weekday daytype hour hourtype location
## 1      1    4 wednesday weekday   0    night    home
## 2      1    4 wednesday weekday   1    night    home
## 3      1    4 wednesday weekday   2    night    home
## 4      1    4 wednesday weekday   3    night    home
## 5      1    4 wednesday weekday   4    night    home
## 6      1    4 wednesday weekday   5    night    home
## 7      1    4 wednesday weekday   6 morning    home
## 8      1    4 wednesday weekday   7 morning    home
## 9      1    4 wednesday weekday   8 morning    home
## 10     1    4 wednesday weekday   9 morning  office
```

Then we setup our variables to be predicted

```
weekday_afternoon <- locations[13,c(4,6,7)]
weekday_evening <- locations[19,c(4,6,7)]
weekend_afternoon <- locations[85,c(4,6,7)]
```

Then we build our mutiple variable model and predict

```
# Build a NB model of location
locmodel <- naive_bayes(location ~ daytype + hourtype, data = locations)

# Predict Brett's location on a weekday afternoon
predict(locmodel, weekday_afternoon)
```

```
## [1] office
## Levels: appointment campus home office restaurant store theater

# Predict Brett's location on a weekday evening
predict(locmodel, weekday_evening)
```

```
## [1] home
## Levels: appointment campus home office restaurant store theater
```

Or with probabilities

```
# Predict Brett's location on a weekday afternoon
predict(locmodel, weekday_afternoon, type = "prob")

##      appointment      campus      home      office restaurant      store
## [1,] 0.004300045 0.08385089 0.2482618 0.5848062 0.07304769 0.005733394
##      theater
## [1,]      0

# Predict Brett's location on a weekday evening
predict(locmodel, weekday_evening, type = "prob")
```

```
##      appointment      campus      home      office restaurant      store
## [1,] 0.004283788 0.004283788 0.7903588 0.05997303 0.04400138 0.09709919
##      theater
## [1,]      0
```

Next we will try to predict where Brett would be on a weekend afternoon. Since there are some locations he has never been to before at this time of day e.g. the campus, office or theatre, we will predict probabilities both with and without the Laplace correction. Adding the Laplace correction allows for the small chance that Brett might go to the office on the weekend in the future. Without the Laplace correction, some potential outcomes may be predicted to be impossible.

```
# Observe the predicted probabilities for a weekend afternoon
predict(locmodel, weekend_afternoon, type = "prob")
```

```
##      appointment campus      home office restaurant      store theater
## [1,] 0.02472535      0 0.8472217      0 0.1115693 0.01648357      0
```

```
# Build a new model using the Laplace correction
```

```
locmodel2 <- naive_bayes(location ~ daytype + hourtype, laplace = 1, data = locations)
```

```
# Observe the new predicted probabilities for a weekend afternoon
predict(locmodel2, weekend_afternoon, type = "prob")
```

```
##      appointment      campus      home      office restaurant      store
## [1,] 0.01107985 0.005752078 0.8527053 0.008023444 0.1032598 0.01608175
##      theater
## [1,] 0.003097769
```

2.2.2 Applying Naive Bayes (NB) to other problems

NB is useful when attributes from multiple factors need to be considered at the same time, then evaluated as a whole, a bit like a Doctor looking at a patient then making a recommendation. There are some considerations to be aware of when apply NB to other scenarios.

Bayes works by calculating conditional probabilities, it builds frequency tables of the number of times a particular condition overlaps with our condition of interest, then the probabilities are multiplied Naively in a chain of events. Each predictor typically comprises a set of categories, numeric data like time of day or age, are difficult without modification. Unstructured text data also causes problems.

We can bin numeric data - like age bands - to make Bayes handle the data better. Or use quintiles. Text data is best adjusted using the bag of words approach. This in effect creates a table, where each sentence or document becomes a row, and the columns become some numeric value for the presence of words, usually dummy vars. NB trained with the bag of words approach can be very effective text classifiers.

2.3 Logistic regression - binary predictions with regression

Regression models are one of the commonest forms of machine learning. If we have a binary outcome (1 or 0), using a standard regression may result in results either above or below this range. With logistic regression, we create a curve, a logistic function (s curve). Our result therefore becomes a probability between 0 and 1. We can calculate this using a glm model, setting the family to binomial, which we can then use in the predict model. If we use the type = "response" argument with predict, we get the predicted probabilities rather than the default log-odds. We then use these probabilities and set some parameters using an ifelse statement e.g. if the predicted probability is greater than 50%, then we might say that is a 1 e.g. `pred <- ifelse(prob > 0.5, 1, 0)`.

The donors dataset contains 93,462 examples of people mailed in a fundraising solicitation for paralyzed military veterans. The donated column is 1 if the person made a donation in response to the mailing and 0 otherwise. The remaining columns are features of the prospective donors that may influence their donation behavior - the independent variables.

```
# Load the data
donors <- read.csv("../files/SLinRClassification/donors.csv", stringsAsFactors = TRUE)

# Examine the dataset to identify potential independent variables
str(donors)

## 'data.frame': 93462 obs. of 13 variables:
## $ donated : int 0 0 0 0 0 0 0 0 0 0 ...
## $ veteran : int 0 0 0 0 0 0 0 0 0 0 ...
## $ bad_address : int 0 0 0 0 0 0 0 0 0 0 ...
## $ age : int 60 46 NA 70 78 NA 38 NA NA 65 ...
## $ has_children : int 0 1 0 0 1 0 1 0 0 0 ...
## $ wealth_rating : int 0 3 1 2 1 0 2 3 1 0 ...
## $ interest_veterans: int 0 0 0 0 0 0 0 0 0 0 ...
## $ interest_religion: int 0 0 0 0 1 0 0 0 0 0 ...
## $ pet_owner : int 0 0 0 0 0 0 0 1 0 0 0 ...
## $ catalog_shopper : int 0 0 0 0 1 0 0 0 0 0 ...
## $ recency : Factor w/ 2 levels "CURRENT","LAPSED": 1 1 1 1 1 1 1 1 1 1 ...
## $ frequency : Factor w/ 2 levels "FREQUENT","INFREQUENT": 1 1 1 1 1 2 2 1 2 2 ...
## $ money : Factor w/ 2 levels "HIGH","MEDIUM": 2 1 2 2 2 2 2 2 2 2 ...

# Explore the dependent variable
table(donors$donated)

##
## 0 1
## 88751 4711

# Build the donation model
donation_model <- glm(donated ~ bad_address + interest_religion + interest_veterans,
  data = donors, family = "binomial")

# Summarize the model results
summary(donation_model)

##
## Call:
## glm(formula = donated ~ bad_address + interest_religion + interest_veterans,
## family = "binomial", data = donors)
##
## Deviance Residuals:
## Min 1Q Median 3Q Max
## -0.3480 -0.3192 -0.3192 -0.3192 2.5678
##
## Coefficients:
## Estimate Std. Error z value Pr(>|z|)
## (Intercept) -2.95139 0.01652 -178.664 <2e-16 ***
## bad_address -0.30780 0.14348 -2.145 0.0319 *
## interest_religion 0.06724 0.05069 1.327 0.1847
## interest_veterans 0.11009 0.04676 2.354 0.0186 *
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
## (Dispersion parameter for binomial family taken to be 1)
##
##      Null deviance: 37330   on 93461   degrees of freedom
## Residual deviance: 37316   on 93458   degrees of freedom
## AIC: 37324
##
## Number of Fisher Scoring iterations: 5
```

We can now apply this model. Remember that the default output is the log-odds of an outcome, so we need to use `type = "response"` to convert this to a probability.

```
# Estimate the donation probability
donors$donation_prob <- predict(donation_model, type = "response")

# Find the donation probability of the average prospect
mean(donors$donated)
```

```
## [1] 0.05040551
```

```
# Predict a donation if probability of donation is greater than average (0.0504)
donors$donation_pred <- ifelse(donors$donation_prob > 0.0504, 1, 0)

# Calculate the model's accuracy
mean(donors$donation_pred == donors$donated)
```

```
## [1] 0.794815
```

So the model appears to be accurate - circa 80%. But, the outcome of interest is quite rare (the second element above, the mean) is only around 5%, so had the model predicted not donated for every person, it would have been accurate 95% of the time.

To visualise this trade off between positive and negative predictions we can use an ROC curve. With an ROC curve we want to be away from the diagonal (an Area Under the Curve or AUC of 0.5) and towards the top left hand corner (top left would be an AUC of 1.0). But as curves of different shapes/gradients can have the same AUC, we should also look at the curve as well as the AUC value.

Next we can plot an ROC and calculate the AUC for our model.

```
# Load the pROC package
library(pROC)
```

```
## Warning: package 'pROC' was built under R version 3.4.4
```

```
## Type 'citation("pROC")' for a citation.
```

```
##
```

```
## Attaching package: 'pROC'
```

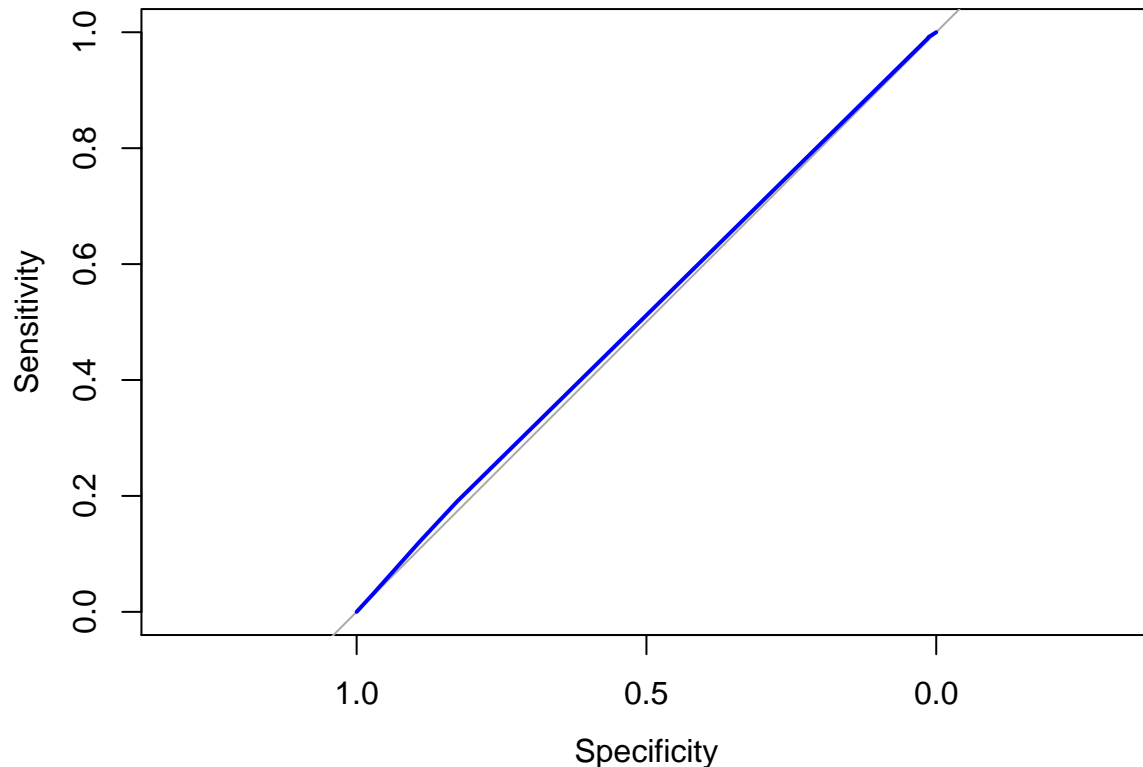
```
## The following objects are masked from 'package:stats':
```

```
##
```

```
##      cov, smooth, var
```

```
# Create a ROC curve
ROC <- roc(donors$donated, donors$donation_prob)
```

```
# Plot the ROC curve
plot(ROC, col = "blue")
```



```
# Calculate the area under the curve (AUC)
auc(ROC)
```

```
## Area under the curve: 0.5102
```

With the line almost on the diagonal and an AUC of just over 0.5 our model isn't doing much better than making predictions at random.

2.3.1 Dummy variables, missing data, and interactions

All of the variables in a regression analysis must be numeric e.g. all categorical data must be represented as a number. With missing data, we can no longer use this information to make predictions.

We use dummy variables - also sometimes called one hot encoding - for logistic regression. The GLM function will automatically convert factor type variables into dummy vars used in the model. We just use the factor function to the data first, if the data/variable is not already a factor.

If we have missing data, our model will automatically exclude these cases (rows) in the model. You can create a categorical variable option (a factor level) for missing e.g. low, medium, high and missing. However for numerical data we have more options, perhaps we might use the mean or median, or build a more complex model if we like to impute this missing variable. Either way, it is a good idea to add a column/variable to indicate if a variable was imputed. Sometimes, this `missing_var` (1 = yes) can become an important predictor in a model.

An interaction effect considers that certain variables, when combined, may have more of an influence together than the sum of their individual components. The combination may strengthen, weaken or completely eliminate the strength of the individual predictors. In the model function, we can use the multiplication symbol (*) to indicate an interaction. The result will include individual components as well as combined effects.

In the next example, we classify a variable as a factor (wealth_rating), then set the reference category for the variable to Medium and finally build a model with this variable.

```
# Convert the wealth rating to a factor
donors$wealth_rating <- factor(donors$wealth_rating, levels = c(0,1,2,3), labels = c("Unknown", "Low", "Medium", "High"))

# Use relevel() to change reference category
donors$wealth_rating <- relevel(donors$wealth_rating, ref = "Medium")

# See how our factor coding impacts the model
summary(glm(donated ~ wealth_rating, data = donors, family = "binomial"))

##
## Call:
## glm(formula = donated ~ wealth_rating, family = "binomial", data = donors)
##
## Deviance Residuals:
##      Min       1Q   Median       3Q      Max
## -0.3320  -0.3243  -0.3175  -0.3175   2.4582
##
## Coefficients:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept)    -2.91894    0.03614  -80.772  <2e-16 ***
## wealth_ratingUnknown -0.04373    0.04243   -1.031    0.303
## wealth_ratingLow    -0.05245    0.05332   -0.984    0.325
## wealth_ratingHigh     0.04804    0.04768    1.008    0.314
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##      Null deviance: 37330  on 93461  degrees of freedom
## Residual deviance: 37323  on 93458  degrees of freedom
## AIC: 37331
##
## Number of Fisher Scoring iterations: 5
```

As mentioned before, in cases where a variable is NA, R will exclude these cases when building a model. Therefore we should try and attempt to handle such cases, one option is imputation as shown below. We also create a new variable to indicate whether the age value was imputed, as a missing value can be an indicator of something more meaningful going on, it could be related to the outcome.

```
# Find the average age among non-missing values
summary(donors$age)

##      Min. 1st Qu.  Median    Mean 3rd Qu.    Max.   NA's
##      1.00  48.00   62.00   61.65   75.00   98.00  22546

# Impute missing age values with mean(age)
donors$imputed_age <- ifelse(is.na(donors$age), round(mean(donors$age, na.rm = TRUE),2), donors$age)

# Create missing value indicator for age
donors$missing_age <- ifelse(is.na(donors$age),1,0)
```

Donors that haven't given both recently and frequently may be especially likely to give again; in other words, the combined impact of recency and frequency may be greater than the sum of the separate effects. In Marketing terms this is known as the RFM Model (recency, frequency and money).

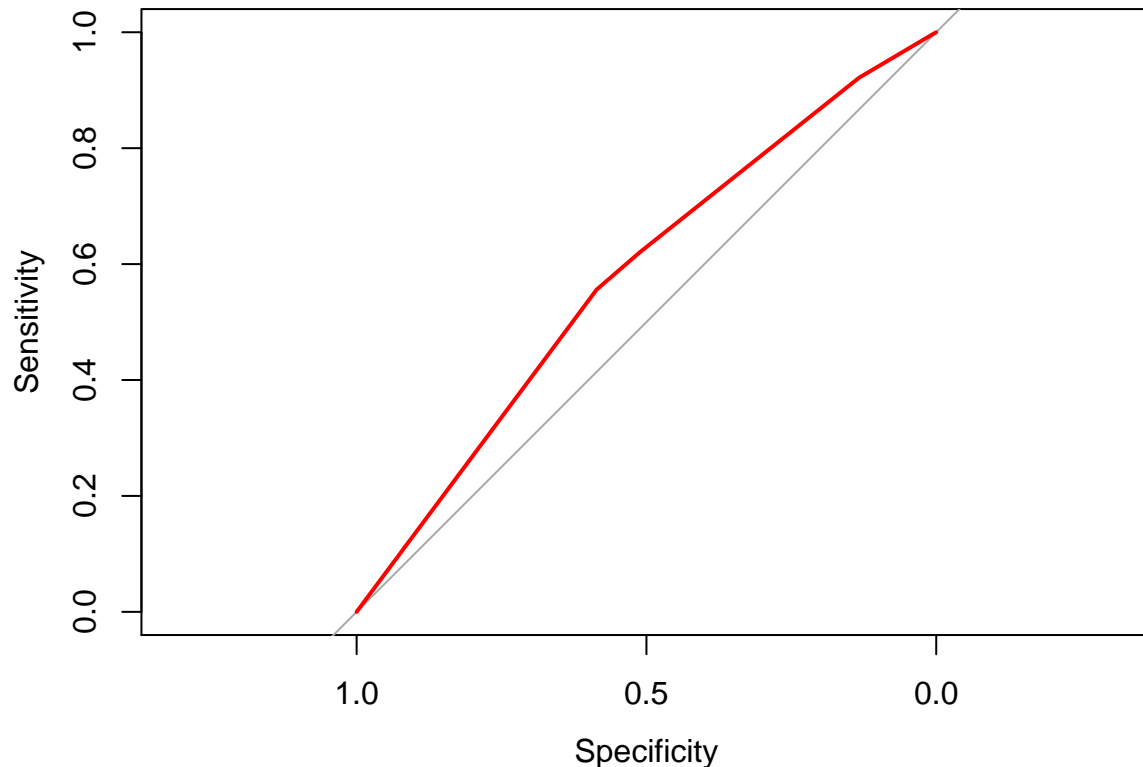
Because these predictors together have a greater impact on the dependent variable, their joint effect must be modeled as an interaction.

```
# Build a recency, frequency, and money (RFM) model
rfm_model <- glm(donated ~ money + recency * frequency, data = donors, family = "binomial")

# Summarize the RFM model to see how the parameters were coded
summary(rfm_model)
```

```
##
## Call:
## glm(formula = donated ~ money + recency * frequency, family = "binomial",
##      data = donors)
##
## Deviance Residuals:
##      Min       1Q   Median       3Q      Max
## -0.3696  -0.3696  -0.2895  -0.2895   2.7924
##
## Coefficients:
##                                Estimate Std. Error z value Pr(>|z|)
## (Intercept)                   -3.01142     0.04279  -70.375  <2e-16 ***
## moneyMEDIUM                    0.36186     0.04300   8.415  <2e-16 ***
## recencyLAPSED                  -0.86677     0.41434  -2.092   0.0364 *
## frequencyINFREQUENT           -0.50148     0.03107 -16.143  <2e-16 ***
## recencyLAPSED:frequencyINFREQUENT 1.01787     0.51713   1.968   0.0490 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##      Null deviance: 37330  on 93461  degrees of freedom
## Residual deviance: 36938  on 93457  degrees of freedom
## AIC: 36948
##
## Number of Fisher Scoring iterations: 6
# Compute predicted probabilities for the RFM model
rfm_prob <- predict(rfm_model, type = "response")

# Plot the ROC curve and find AUC for the new model
library(pROC)
ROC <- roc(donors$donated, rfm_prob)
plot(ROC, col = "red")
```



```
auc(ROC)
```

```
## Area under the curve: 0.5785
```

2.3.2 Automatic feature selection

So far we have been selecting which variables to put in our model manually ourselves. We've had to logically build our model using some fundraising knowledge, thinking about what variables may influence donations. There is a process to speed this up using automatic feature selection called stepwise feature selection.

Stepwise feature selection builds a model each variable at a time and sees which predictor adds value to the final model. Backward deletion begins with a model containing all the features, then variables are deleted as long as the removal of a variable does not negatively impact the models overall ability to predict the outcome. At each step, the predictor that impacts the model the least is removed.

Forward stepwise selection does this in reverse, starting with no predictors, then adding in each predictor by first assessing each predictor to determine which has the greatest ability to predict the outcome at each step and adding that predictor, then re-assessing all remaining predictors.

The results of a forward and backward stepwise process can result in different results AND neither may be the best possible model. This process could be accused as being akin to p-hacking and violates some of our science principles, namely to generate then test a hypothesis - it is atheoretical as there is no theory about how things work. But if the goal is prediction, this might not be such a great concern. But it might be best to consider stepwise regression as a tool to start from.

To run stepwise, we set our null model, then our full model, then use step to iterate either forward or backward between these models.

```

# Specify a null model with no predictors
null_model <- glm(donated ~ 1, data = donors, family = "binomial")

# Specify the full model using all of the potential predictors
full_model <- glm(donated ~ ., data = donors, family = "binomial")

# Use a forward stepwise algorithm to build a parsimonious model
step_model <- step(null_model, scope = list(lower = null_model, upper = full_model), direction = "forward")

## Start:  AIC=37332.13
## donated ~ 1

## Warning in add1.glm(fit, scope$add, scale = scale, trace = trace, k = k, :
## using the 70916/93462 rows from a combined fit

##           Df Deviance   AIC
## + frequency      1   28502 37122
## + money           1   28621 37241
## + has_children    1   28705 37326
## + age             1   28707 37328
## + imputed_age     1   28707 37328
## + wealth_rating   3   28704 37328
## + interest_veterans 1   28709 37330
## + donation_prob   1   28710 37330
## + donation_pred   1   28710 37330
## + catalog_shopper 1   28710 37330
## + pet_owner       1   28711 37331
## <none>           28714 37332
## + interest_religion 1   28712 37333
## + recency         1   28713 37333
## + bad_address     1   28714 37334
## + veteran         1   28714 37334
##
## Step:  AIC=37024.77
## donated ~ frequency

## Warning in add1.glm(fit, scope$add, scale = scale, trace = trace, k = k, :
## using the 70916/93462 rows from a combined fit

##           Df Deviance   AIC
## + money           1   28441 36966
## + wealth_rating   3   28490 37019
## + has_children    1   28494 37019
## + donation_prob   1   28498 37023
## + interest_veterans 1   28498 37023
## + catalog_shopper 1   28499 37024
## + donation_pred   1   28499 37024
## + age             1   28499 37024
## + imputed_age     1   28499 37024
## + pet_owner       1   28499 37024
## <none>           28502 37025
## + interest_religion 1   28501 37026
## + recency         1   28501 37026
## + bad_address     1   28502 37026
## + veteran         1   28502 37027
##

```

```
## Step: AIC=36949.71
## donated ~ frequency + money

## Warning in add1.glm(fit, scope$add, scale = scale, trace = trace, k = k, :
## using the 70916/93462 rows from a combined fit

##           Df Deviance   AIC
## + wealth_rating      3   28427 36942
## + has_children       1   28432 36943
## + interest_veterans  1   28438 36948
## + donation_prob      1   28438 36949
## + catalog_shopper    1   28438 36949
## + donation_pred      1   28439 36949
## + age                1   28439 36949
## + imputed_age        1   28439 36949
## + pet_owner          1   28439 36949
## <none>                1   28441 36950
## + interest_religion  1   28440 36951
## + recency            1   28441 36951
## + bad_address        1   28441 36951
## + veteran            1   28441 36952
##
## Step: AIC=36945.48
## donated ~ frequency + money + wealth_rating

## Warning in add1.glm(fit, scope$add, scale = scale, trace = trace, k = k, :
## using the 70916/93462 rows from a combined fit

##           Df Deviance   AIC
## + has_children       1   28416 36937
## + age                1   28424 36944
## + imputed_age        1   28424 36944
## + interest_veterans  1   28424 36945
## + donation_prob      1   28424 36945
## + catalog_shopper    1   28425 36945
## + donation_pred      1   28425 36945
## <none>                1   28427 36945
## + pet_owner          1   28425 36946
## + interest_religion  1   28426 36947
## + recency            1   28427 36947
## + bad_address        1   28427 36947
## + veteran            1   28427 36947
##
## Step: AIC=36938.4
## donated ~ frequency + money + wealth_rating + has_children

## Warning in add1.glm(fit, scope$add, scale = scale, trace = trace, k = k, :
## using the 70916/93462 rows from a combined fit

##           Df Deviance   AIC
## + pet_owner          1   28413 36937
## + donation_prob      1   28413 36937
## + catalog_shopper    1   28413 36937
## + interest_veterans  1   28413 36937
## + donation_pred      1   28414 36938
## <none>                1   28416 36938
## + interest_religion  1   28415 36939
```

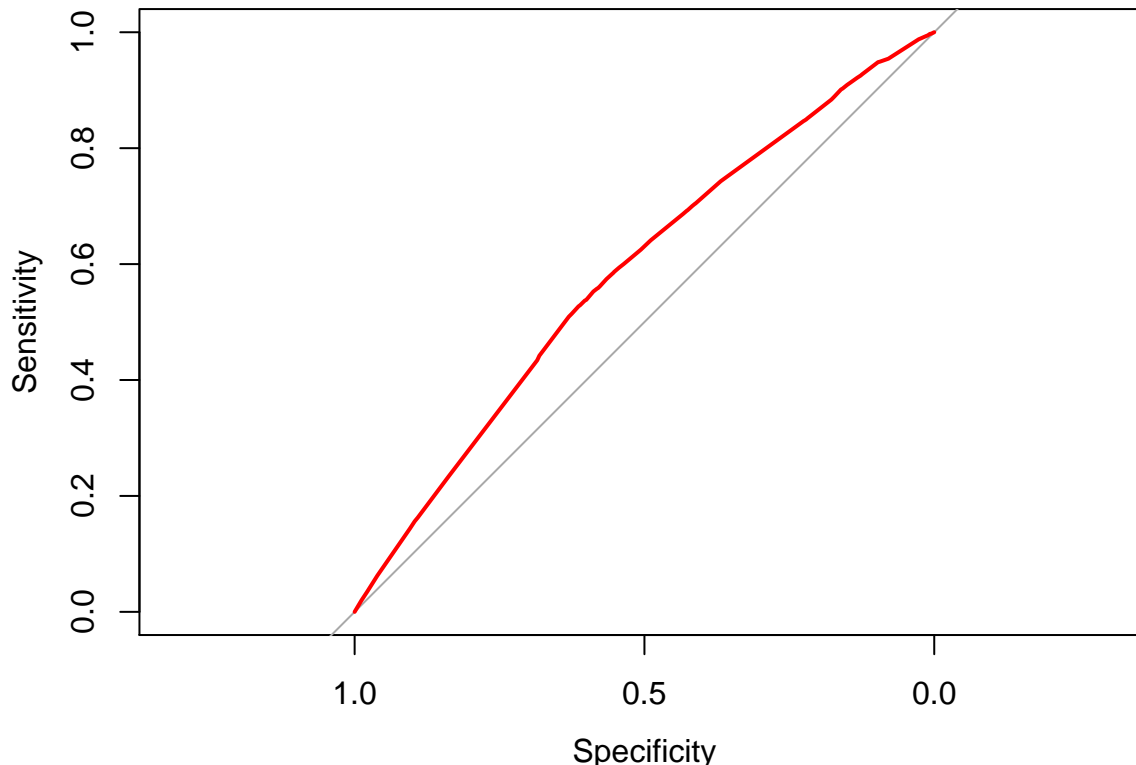
```
## + age          1    28416 36940
## + imputed_age  1    28416 36940
## + recency      1    28416 36940
## + bad_address  1    28416 36940
## + veteran      1    28416 36940
##
## Step:  AIC=36932.25
## donated ~ frequency + money + wealth_rating + has_children +
##      pet_owner
```

```
## Warning in add1.glm(fit, scope$add, scale = scale, trace = trace, k = k, :
## using the 70916/93462 rows from a combined fit
```

```
##           Df Deviance   AIC
## <none>           28413 36932
## + donation_prob  1    28411 36932
## + interest_veterans 1    28411 36932
## + catalog_shopper 1    28412 36933
## + donation_pred   1    28412 36933
## + age             1    28412 36933
## + imputed_age     1    28412 36933
## + recency         1    28413 36934
## + interest_religion 1    28413 36934
## + bad_address     1    28413 36934
## + veteran         1    28413 36934
```

```
# Estimate the stepwise donation probability
step_prob <- predict(step_model, type = "response")

# Plot the ROC of the stepwise model
library(pROC)
ROC <- roc(donors$donated, step_prob)
plot(ROC, col = "red")
```



```
auc(ROC)
```

```
## Area under the curve: 0.5849
```

It is perhaps useful when we lack subject matter expertise and wish to try and find the or some of the most important features which help to predict the outcome of interest.

2.4 Classification Trees

Also known as decisions trees break down data in to a serious of steps or questions (if else) then help to define action. The goal is to model predictors against an outcome of interest. If someone is applying for a loan, we can use past data to determine and build a tree that helps to determine how probable it is that new applicant will repay the debt.

One of those most common R packages is rpart where the part stands for recursive partitioning. There is a good description of how this works in practice in the Introduction to Tree Based Methods from ISL.

The loans dataset contains 11,312 randomly-selected people who were applied for and later received loans from Lending Club, a US-based peer-to-peer lending company.

You will use a decision tree to try to learn patterns in the outcome of these loans (either repaid or default) based on the requested loan amount and credit score at the time of application.

First let's prepare the data.

```
#Load the loans data and subset to just those randomly selected rows
loans_full <- read.csv("./files/SLinRClassification/loans.csv", stringsAsFactors = TRUE)
loans <- subset(loans_full, keep == 1)
```

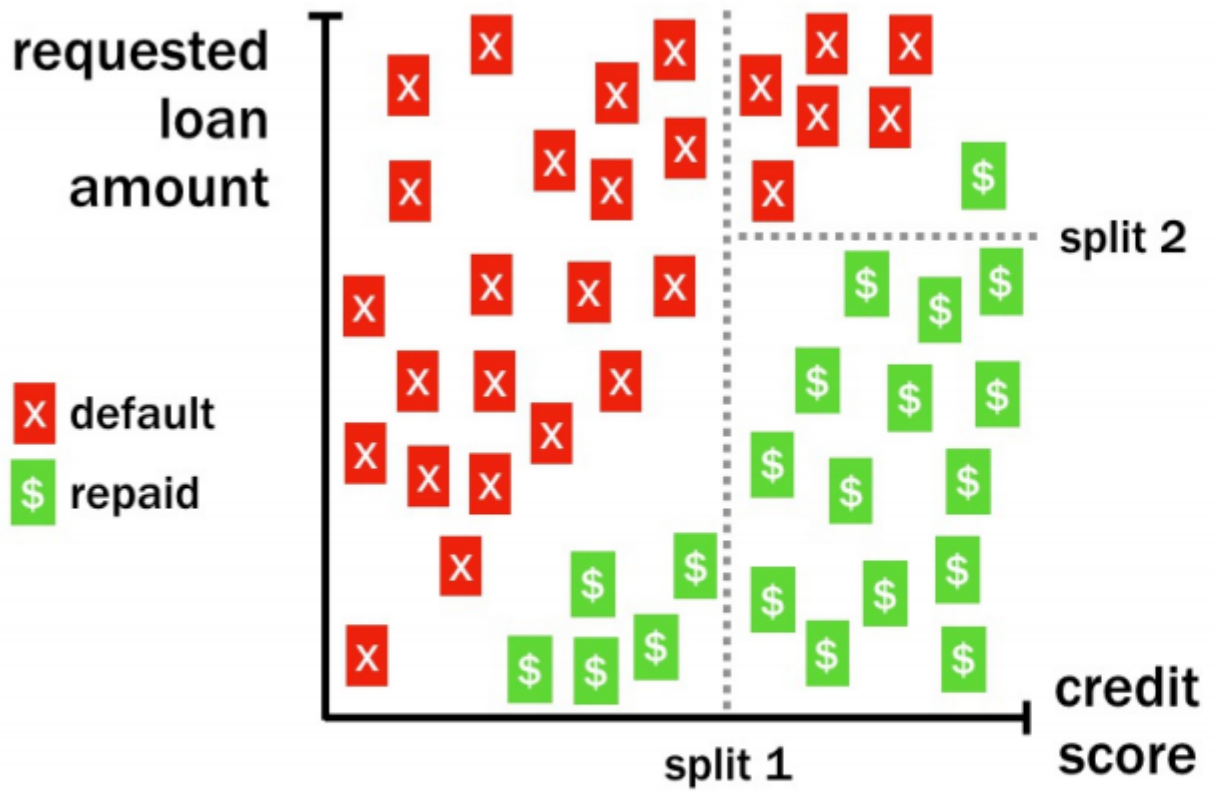


Figure 2.1: Decision Tree

```
# Record default to our variable of interest outcome
loans$outcome[loans$default=="0"] <- "2"
loans$outcome[loans$default=="1"] <- "1"

# Convert the column to a factor and provide names for the levels
loans$outcome <- factor(loans$outcome)
levels(loans$outcome) <- c("default", "repaid")

# Remove the unnecessary columns
loans <- loans[-c(1:3)]
```

Next we do the modelling.

```
# Load the rpart package
library(rpart)

# Build a lending model predicting loan outcome versus loan amount and credit score
loan_model <- rpart(outcome ~ loan_amount + credit_score, data = loans, method = "class", control = rpa

# Make a prediction for someone with good credit
# predict(loan_model, good_credit, type = "class")

# Make a prediction for someone with bad credit
# predict(loan_model, bad_credit, type = "class")
```

The structure of classification trees can be depicted visually, which helps to understand how the tree makes its decisions. This might be useful for Transparency reasons.

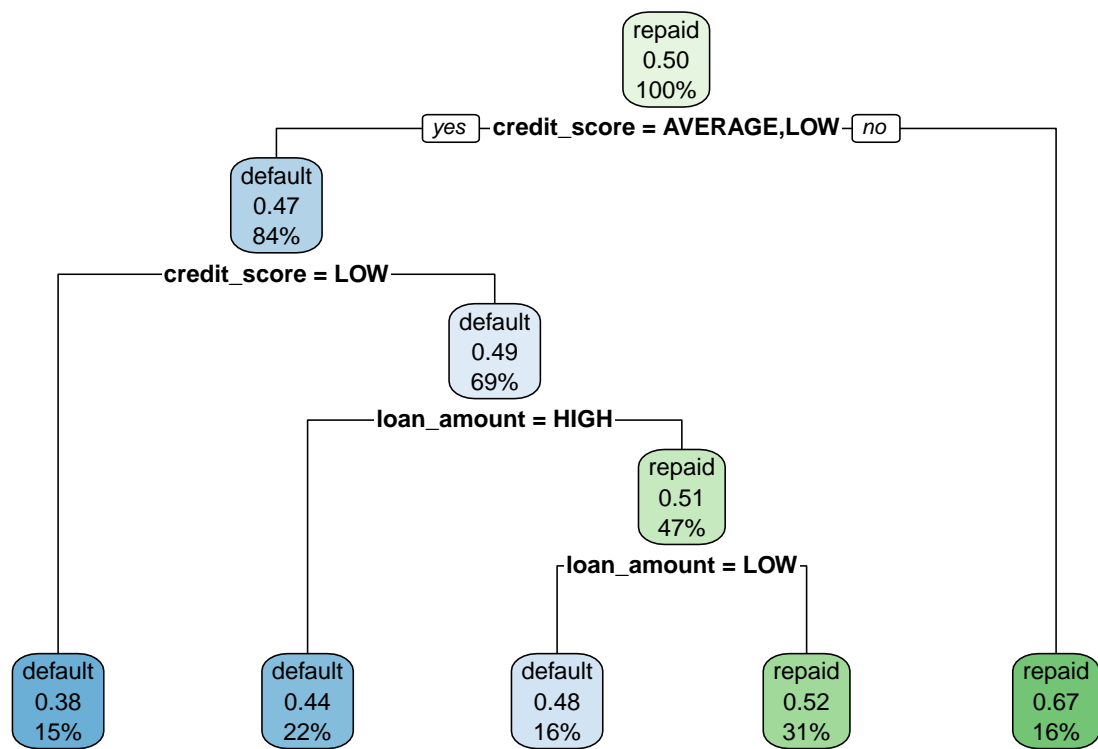
```
# Examine the loan_model object
loan_model

## n= 11312
##
## node), split, n, loss, yval, (yprob)
##      * denotes terminal node
##
##  1) root 11312 5654 repaid (0.4998232 0.5001768)
##    2) credit_score=AVERAGE,LOW 9490 4437 default (0.5324552 0.4675448)
##      4) credit_score=LOW 1667  631 default (0.6214757 0.3785243) *
##      5) credit_score=AVERAGE 7823 3806 default (0.5134859 0.4865141)
##        10) loan_amount=HIGH 2472 1079 default (0.5635113 0.4364887) *
##        11) loan_amount=LOW,MEDIUM 5351 2624 repaid (0.4903756 0.5096244)
##          22) loan_amount=LOW 1810  874 default (0.5171271 0.4828729) *
##          23) loan_amount=MEDIUM 3541 1688 repaid (0.4767015 0.5232985) *
##    3) credit_score=HIGH 1822  601 repaid (0.3298573 0.6701427) *

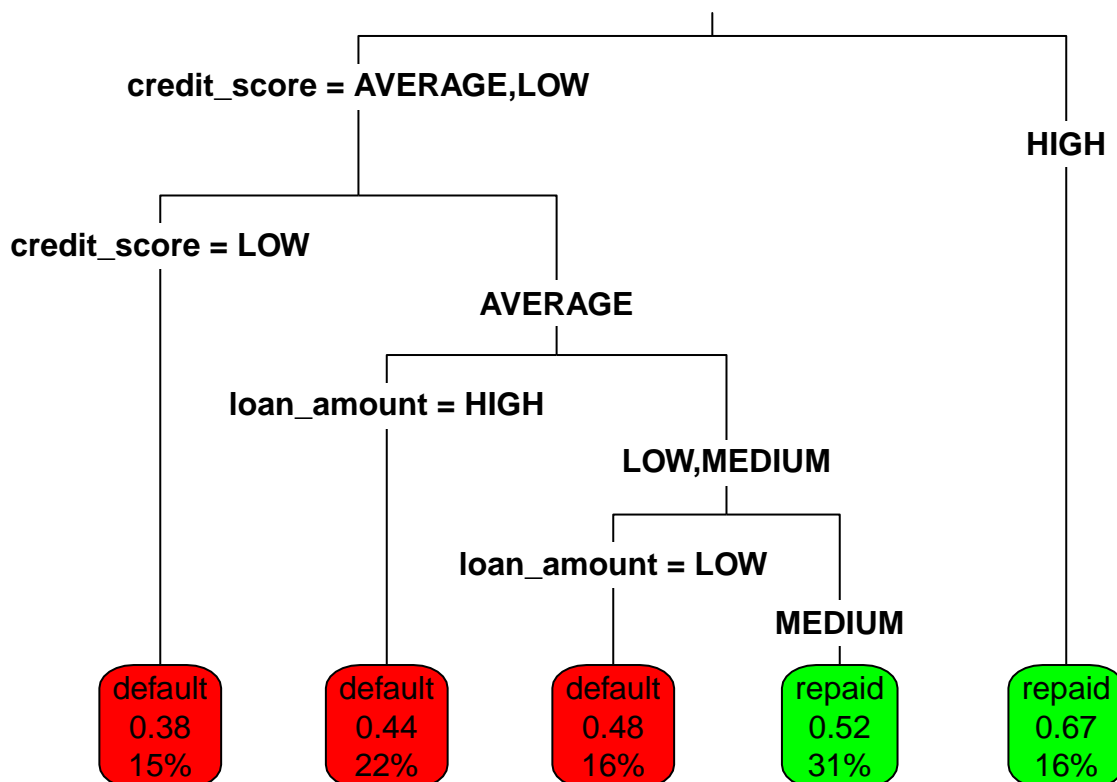
# Load the rpart.plot package
library(rpart.plot)

## Warning: package 'rpart.plot' was built under R version 3.4.4

# Plot the loan_model with default settings
rpart.plot(loan_model)
```

```
# Plot the loan_model with customized settings
rpart.plot(loan_model, type = 3, box.palette = c("red", "green"), fallen.leaves = TRUE)
```



When choosing between different split options - for instance choosing whether to split on loan amount or credit score - the decision tree will provide a split for both, then look and how homogenous the resulting options are. In the diagram below, even though split B (based on loan amount) produces a very similar group for one partition (14/15 defaulted) it is much more mixed for the other partition (19/32 defaulted). In comparison, split A is more pure, so will be chosen first. It will then proceed to look at the next split which results in the most homogenous/similar partition.

As the tree begins to grow, it results in smaller and more homogeneous partitions (below left). An easy option would be to draw a diagonal line (below right) however these requires, in this example, consideration of two different variables, which is not possible with the 'divide and conquer' process. A decision tree creates what are called axis parallel splits, which can mean for some patterns in data they can become overly complex.

Decision trees can divide and conquer until it either runs out of features or cases to classify, which can result in large trees which are over-fitted. So we can split out a test set for evaluation - we create a hold out group or set. The `sample()` function can be used to generate a random sample of rows to include in the training set. Simply supply it the total number of observations and the number needed for training. We use the resulting vector of row IDs to subset the loans into training and testing datasets.

```

# Determine the number of rows for training
train <- nrow(loans) * .75

# Create a random sample of row IDs
sample_rows <- sample(nrow(loans), train)

# Create the training dataset
loans_train <- loans[sample_rows,]

# Create the test dataset

```

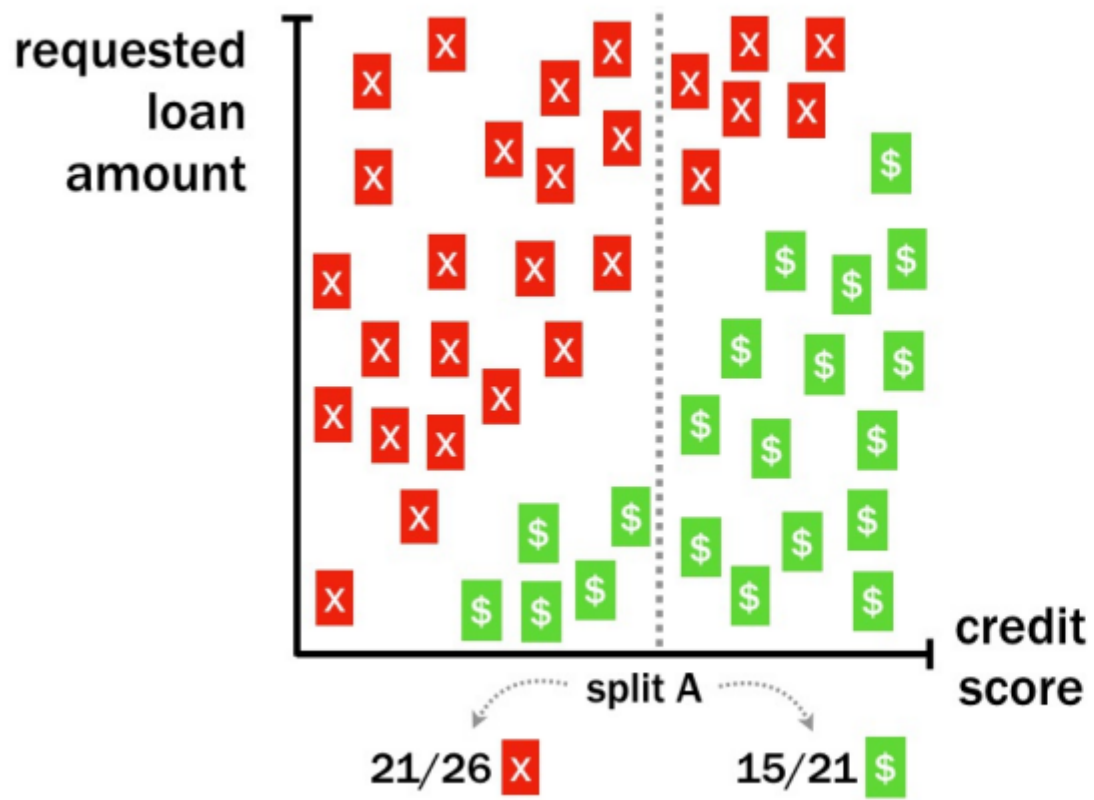


Figure 2.2: Tree Split Choice

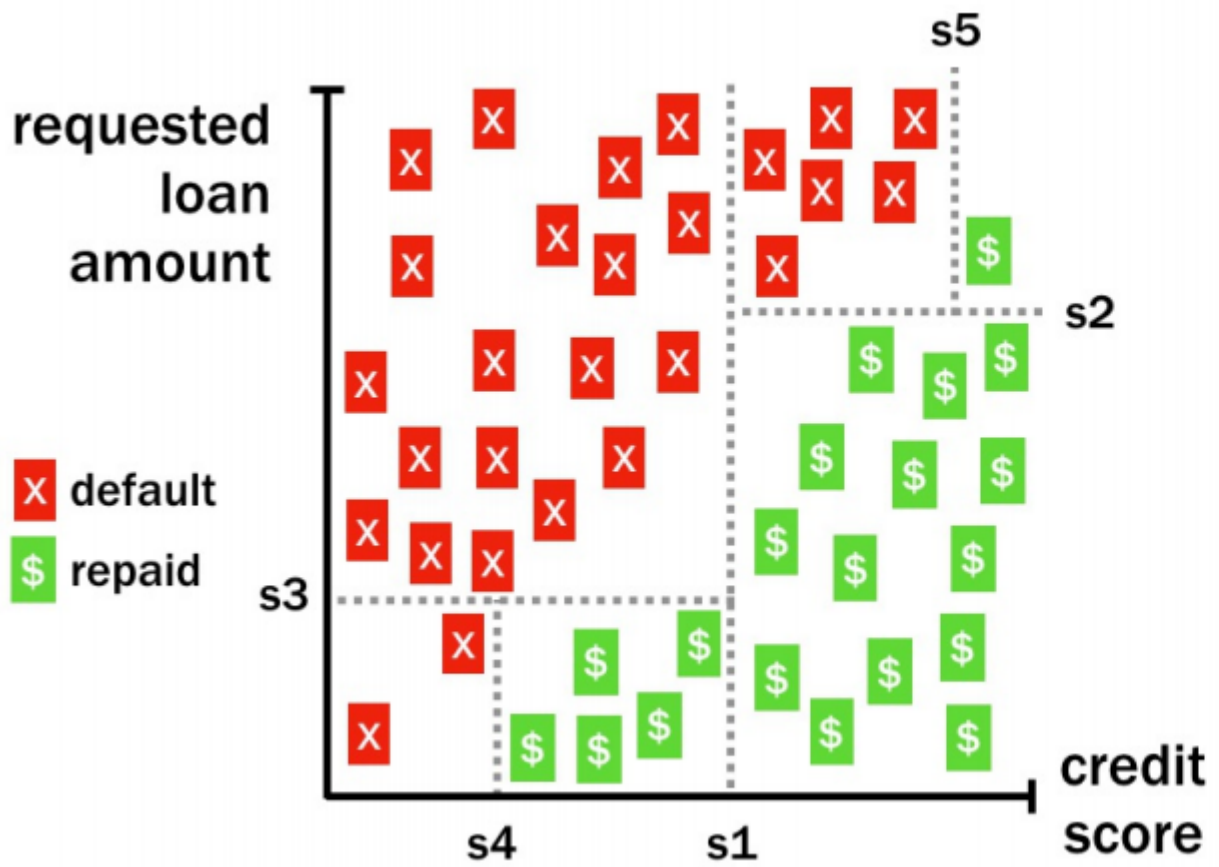


Figure 2.3: Axis parallel split

(#fig:Axis Splits)

```
loans_test <- loans[-sample_rows,]
```

So far we have only built our model based on a couple of the available variables. Next we can use all of the available applicant data to build a more sophisticated lending model using the random training dataset created previously. Then, we use this model to make predictions on the testing dataset to estimate the performance of the model on future loan applications.

```
# Grow a tree using all of the available applicant data
loan_model <- rpart(outcome ~ ., data = loans_train, method = "class", control = rpart.control(cp = 0))

# Make predictions on the test dataset
loans_test$pred <- predict(loan_model, loans_test, type = "class")

# Examine the confusion matrix
table(loans_test$pred, loans_test$outcome)

##
##           default repaid
## default      794    672
## repaid       584    778

# Compute the accuracy on the test dataset
mean(loans_test$pred == loans_test$outcome)

## [1] 0.5558699
```

2.4.1 Tending to classification trees

As classification trees can overfit, we may need to prune the trees. One method of achieving this is stopping the growing method early by limiting the tree depth and is known as pre-pruning. e.g. we have a max tree depth of 7 levels or branches. Another option is to set the minimum number of observations that can occur in any one branch, perhaps the tree is stopped if there are few than 10 observations on any one branch. However, trees stopped early may miss some patterns that might have been discovered later.

An alternative is to post-pruning where a complex, over-fitted tree is built first, then pruned back to reduce the size. After the tree is built we remove nodes or branches that have little impact on the overall accuracy. To do this we can plot the degree of error reduction on the vertical axis against the tree depth (aka complexity) as shown below and look for a ‘dog leg’ or kink in the curve. As the tree grows, each successive branch or node improves the accuracy quite a lot, however later branches or nodes only improve the accuracy by a smaller amount. So we can try and find the point at which the curve flattens.

The rpart package provides this chart and options for pre and post pruning. The pre-pruning is done using the rpart.control function which is then passed to the model as the control. For post pruning, we create the model then use the plotcp(model) to identify the error rate to tree depth trade off, then use the prune(model, cp = n) function to prune the tree, when cp is the complexity parameter.

In the example below, we apply pre-pruning to our applicant data, first by setting the max tree depth to 6, then by setting the min. number of observations at a node to 500.

```
# Grow a tree with maxdepth of 6
loan_model <- rpart(outcome ~ ., data = loans_train, method = "class", control = rpart.control(maxdepth = 6))

# Compute the accuracy of the simpler tree
loans_test$pred <- predict(loan_model, loans_test, type = "class")
mean(loans_test$pred == loans_test$outcome)

## [1] 0.5693069
```

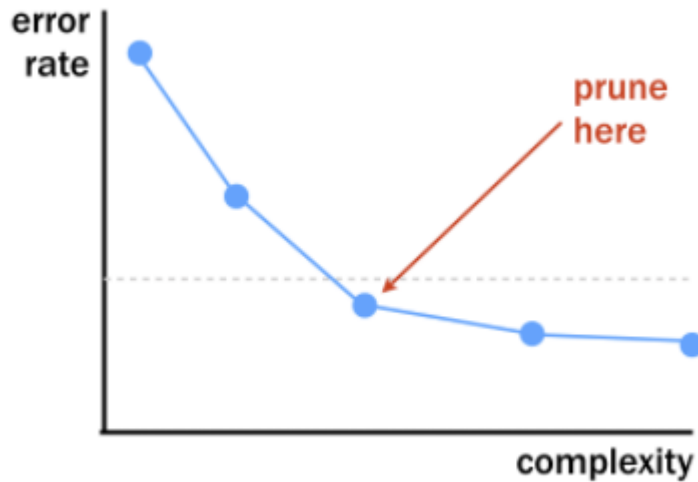


Figure 2.4: Dog Leg

(#fig:Dog Leg)

```
# Grow a tree with minsplitt of 500
loan_model2 <- rpart(outcome ~ ., data = loans_train, method = "class", control = rpart.control(minspli

# Compute the accuracy of the simpler tree
loans_test$pred2 <- predict(loan_model2, loans_test, type = "class")
mean(loans_test$pred2 == loans_test$outcome)

## [1] 0.5813296
```

In both these cases, we see the mean accuracy on the test data, despite fitting a simpler tree, is actually higher than the unpruned tree.

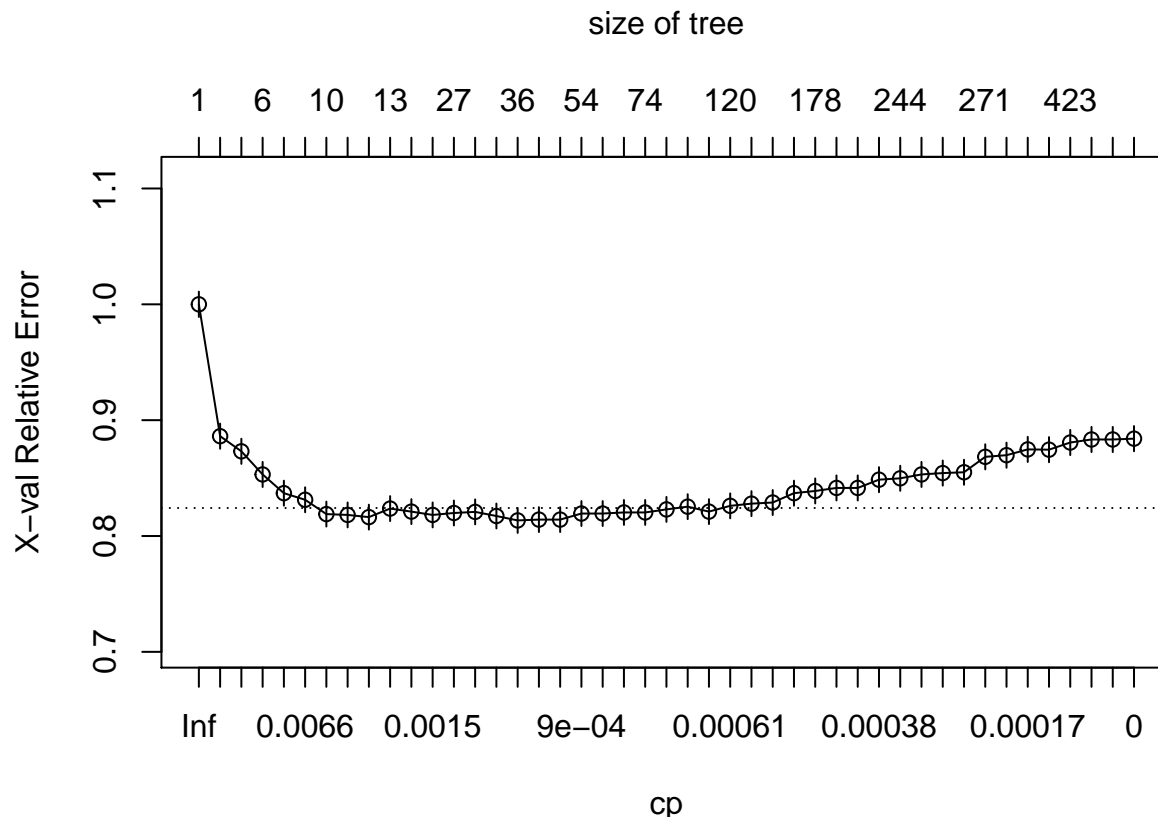
Next we use post-pruning and see that this too improves the predictive accuracy on the test data, despite being a simpler tree.

```
# Grow an overly complex tree
loan_model <- rpart(outcome ~ ., data = loans_train, method = "class", control = rpart.control(cp = 0))

# Compute the accuracy of the unpruned tree
loans_test$pred1 <- predict(loan_model, loans_test, type = "class")
mean(loans_test$pred1 == loans_test$outcome)

## [1] 0.5558699

# Examine the complexity plot
plotcp(loan_model)
```



```
# Prune the tree
loan_model_pruned <- prune(loan_model, cp = 0.0014)

# Compute the accuracy of the pruned tree
loans_test$pred <- predict(loan_model_pruned, loans_test, type = "class")
mean(loans_test$pred == loans_test$outcome)
```

```
## [1] 0.5891089
```

A number of classification trees can be combined together to create a forest of classification trees. Each of the trees is diverse but simple and by combining them together we can help to understand the complexity in the underlying data. But growing different trees requires differing conditions for each tree, otherwise growing 100 trees on the same data would result in 100 identical trees. To do this, we allocate each tree a random subset of data, we do this using the random forest approach. So each tree is given a small random sample which grows a simple tree, and is then combined. This can seem counter intuitive, since we might think having a single complex tree is more accurate. A bit like an effective team, it is better to have specialised skills. Combining multiple learners together is known as ensemble models, where each tree or model is given a vote on a particular observation. The teamwork-based approach of the random forest may help it find important trends a single tree may miss.

We use the randomForest package in R and specify the ntree parameter for the size of the forest and mtry is the number of features selected at random for each tree. We can typically use the default number of features which is \sqrt{p} where p is the total number of parameters.

```
# Load the randomForest package
library(randomForest)
```

```
## randomForest 4.6-12
```

```
## Type rfNews() to see new features/changes/bug fixes.
```

```
# Build a random forest model, first with default values and second with 500 trees and each tree with s  
loan_model_rf <- randomForest(outcome ~ ., data = loans_train)  
loan_model_rf2 <- randomForest(outcome ~ ., data = loans, ntree = 500, mtry = round(sqrt(ncol(loans)-1))
```

```
# Compute the accuracy of the random forest
```

```
loans_test$pred <- predict(loan_model_rf, loans_test, type = "class")  
loans_test$pred2 <- predict(loan_model_rf2, loans_test, type = "class")  
mean(loans_test$pred == loans_test$outcome)
```

```
## [1] 0.594413
```

```
mean(loans_test$pred2 == loans_test$outcome)
```

```
## [1] 0.9062942
```


Bibliography